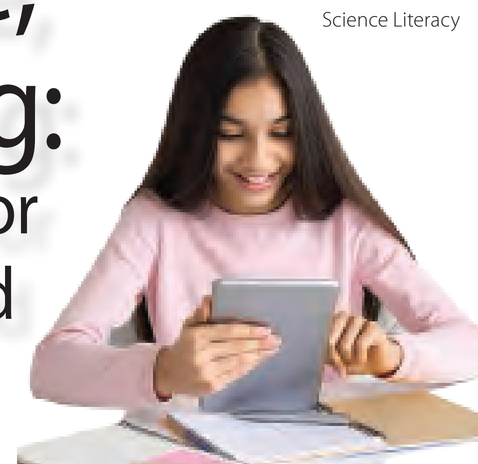
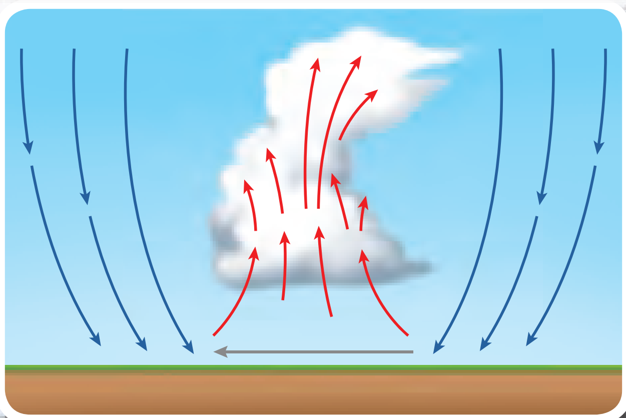
Science Literacy



Weather, Climate, and Water Cycling:

Why does a lot of hail, rain, or snow fall at some times and not others?

Teacher Guide



Atmospheric circulation

Weather and climate

Core Knowledge Science®

GRADE 6

Core Knowledge®

This unit is a modified version of a unit that has earned the NGSS Design Badge. The sole instructional modification is the addition of Core Knowledge Science Literacy content. The modification has not been reviewed.

Weather, Climate, and Water Cycling:

Why does a lot of hail, rain, or snow fall at some times and not others?

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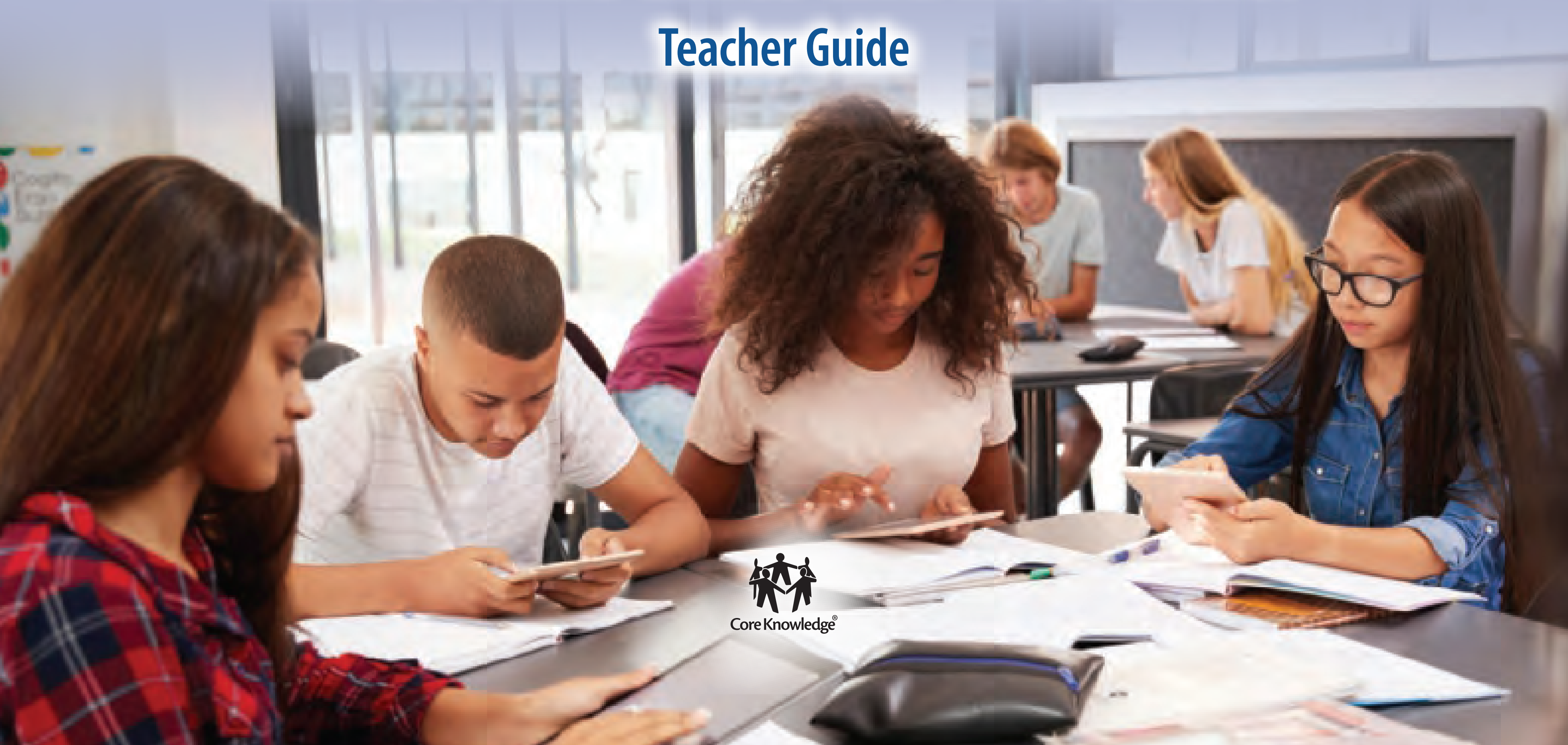

Core Knowledge®

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Weather, Climate, and Water Cycling:

Why does a lot of hail, rain, or snow fall at some times and not others?

Table of Contents

BEFORE YOU BEGIN

Before introducing the unit, please become fully acquainted with the program instructional model and classroom routines by reading the online resource **Teacher Handbook: Overview of the Core Knowledge Middle School Science Program**.

Online Resources

Use this link to download the **CKSci Online Resources Guide** for this unit, which includes specific links to:

- the unit's comprehensive materials list
- a full unit pacing snapshot
- lesson guidance slides
- all other recommended resources.

www.coreknowledge.org/cksci-online-resources

Student Work Pages

All student handouts and exercise pages are included in the consumable Student Work Pages book so that there is no need to print copies of these resources.

Student Books

All student handouts and exercise pages are included in the consumable Student Work Pages book so that there is no need to print copies of these resources. Students also will use the Student Procedure Guide and the Science Literacy Student Reader throughout the unit.

UNIT OVERVIEW

Why does a lot of hail, rain, or snow fall at some times and not others?

This unit on weather, climate, and water cycling is broken into four separate lesson sets. In the first two lesson sets, students explain small-scale storms. In the third and fourth lesson sets, students explain mesoscale weather systems and climate-level patterns of precipitation. Each of these two parts of the unit is grounded in a different anchoring phenomenon.

The unit starts out with anchoring students in the exploration of a series of videos of hailstorms from different locations across the country at different times of the year. The videos show that pieces of ice of different sizes (some very large) are falling out of the sky, sometimes accompanied by rain and wind gusts, all on days when the temperature of the air outside remained above freezing for the entire day. These cases spark questions and ideas for investigations, such as investigating how ice can be falling from the sky on a warm day, how clouds form, why some clouds produce storms with large amounts of precipitation and others don't, and how all that water gets into the air in the first place.

In this first half of the unit, students investigate weather data specific to these events and the temperature profile of the atmosphere above the Earth's surface. They conduct investigations into how sunlight affects the temperature of different surfaces and the air above them, and how this contributes to cloud formation and growth. They work with manipulatives, simulations, and labs to figure out how molecules in different phases change states under different conditions and they conduct investigations into why air moves the way it does as it is heated and cooled. The second half of the unit is anchored in the exploration of a weather report of a winter storm that affected large portions of the midwestern United States. The maps, transcripts, and video that students analyze show them that the storm was forecasted to produce large amounts of snow and ice accumulation in large portions of the northeastern part of the country within the next day. This case sparks questions and ideas for investigations around trying to figure out what could be causing such a large-scale storm and why it would end up affecting a different part of the country a day later.

In the second half of the unit, students also investigate changes in weather conditions over the entire country over multiple days, as well as forecasts of three other storms that are forecasted to affect other parts of the country. They explore how the interactions of air masses, prevailing winds, proximity to the ocean, ocean currents, and surface elevation profiles work together to influence how much precipitation different regions receive. At the end of the second half of the unit, they apply their understandings to develop an explanation for why South America has a tropical rainforest in one part of the continent and temperate rainforest in another part of the continent, despite having some of the driest places on Earth relatively close by both.

Focal Disciplinary Core Ideas (DCIs): ESS2.C, ESS2.D, PS1.A, PS3.A

Focal Science and Engineering Practices (SEPs): Developing and Using Models; Planning and Carrying Out Investigations; Analyzing and Interpreting Data

Focal Crosscutting Concepts (CCCs): Patterns; Cause and Effect; Systems and System Models; Matter and Energy

Building Toward NGSS Performance Expectations

MS-PS1-4: Develop a model that predicts and describes changes in particle motion, temperature, and state of a pure substance when thermal energy is added or removed.

MS-ESS2-4: Develop a model to describe the cycling of water through Earth's systems driven by energy from the sun and the force of gravity.

MS-ESS2-5: Collect data to provide evidence for how the motions and complex interactions of air masses results in changes in weather conditions.

MS-ESS2-6: Develop and use a model to describe how unequal heating and rotation of the Earth cause patterns of atmospheric and oceanic circulation that determine regional climates.

UNIT STORYLINE

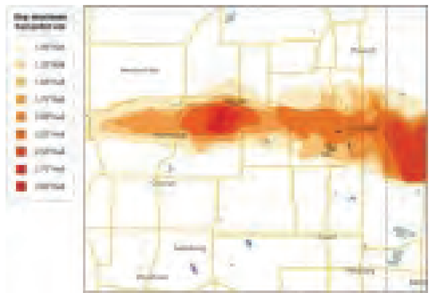
How students will engage with each of the phenomena

HANDS-ON/ LAB ACTIVITIES	VIDEOS OR IMAGES	DATA SETS	READINGS	COMPUTER INTERACTIVES

Why does a lot of hail, rain, or snow fall at some times and not others?

Lesson Question	Phenomena or Design Problem	What we do and figure out	How we represent it
LESSON 1 **3 days** **What causes this kind of precipitation event to occur?** Anchoring Phenomenon	 *Large, frozen pieces of water fall from the sky during storms at different locations on what appear to be relatively warm days. In one case, clouds can be seen moving into and out of the area where it happens.*	We observe three video clips of hail falling in different areas of the United States on different days. We develop a model to try to explain what causes this to occur. We develop questions for our Driving Question Board (DQB) about the mechanisms that cause different kinds of precipitation events. We brainstorm investigations we could do and sources of data that could help us figure out answers to our questions. We figure out these things: • Rain and wind accompany some hail events. • Some of the water that reaches the ground reached a low enough temperature to freeze, at some point, before it fell. • Clouds can be seen moving into and out of the area where it hailed. • Cloud movement in the sky, moving air (wind) at Earth's surface, and temperature may be related to why, where, and when different forms of precipitation fall.	

⇩ **Navigation to Next Lesson:** Many of our questions were about hail. Explaining how it forms could also help explain other precipitation events. It looked like the hail fell in places where green stuff was growing, and we weren't sure how the water got cold enough to freeze and form hail. We wanted to know more about what the air was like on these days (and others) when it hailed. We also thought it would be useful to look at hail more closely, as it may provide some clues about how it formed.

<table>
<tr><th>Lesson Question</th><th>Phenomena or Design Problem</th><th>What we do and figure out</th><th>How we represent it</th></tr>
<tr><td>LESSON 2
1.5 days
What are the conditions like on days when it hails?
Investigation</td><td>
Images of hailstones show that they come in different shapes and sizes. Maps and weather condition data show that hailstorms occur in many places and on relatively warm days.</td><td>We examine photos of hailstones and analyze and interpret data from cases of hail events at different locations and times of year to notice patterns and identify relevant factors that might explain the formation of hail. We figure out these things:
• Hailstones are made of ice, often in layers.
• Hailstorms are more common in the central United States, with fewer events in the west.
• The days that have hail also have relatively warm air temperatures (mostly in the 50–90°F range, which is above the melting/freezing point of water) and relative humidity in the range of 37–96 percent. There are changes in the wind when it hails.
• Hailstorms happen later in the day in the spring, summer, and fall. They impact a small area (20–60 square miles).</td><td></td></tr>
<tr><td colspan="4">⇩ Navigation to Next Lesson: We saw that the temperature near the ground was well above freezing all day on days when it hailed. This makes us wonder how it is possible for frozen water (hail) to fall from the sky in those conditions.</td></tr>
<tr><td>LESSON 3
1.5 days
How does the air higher up compare to the air near the ground?
Investigation</td><td>
Weather balloon data from four sites at four different times during the year show that the temperature of the air closer to the ground is warmer than the temperature of the air higher up in the atmosphere.</td><td>We analyze and interpret temperature profiles of the atmosphere collected from weather balloons at various altitudes at different locations during different times of the year. We develop a consensus model for representing the motion of the molecules that make up air at different temperatures. We figure out these things:
• Regardless of the season, the temperature of the air always decreases as you move away from Earth's surface and higher into the atmosphere.
• The air temperature at very high altitudes (approx. 40,000 ft) is coldest in winter.
• When the temperature of the air increases, the speed of the molecules that make up air increases, and when the temperature of the air decreases, the speed of the molecules that make up air decreases.</td><td>
</td></tr>
<tr><td colspan="4">⇩ Navigation to Next Lesson: In this lesson, we figured out that the air higher up in the atmosphere is colder than the air near the ground. This causes the molecules that make up air to move much more slowly and move closer together high up in the atmosphere, where it is cold, than they do near the ground, where it is warmer. Next we will investigate how the air right above the ground compares to the air a few feet above the ground and determine the mechanisms that play a role in heating and cooling air.</td></tr>
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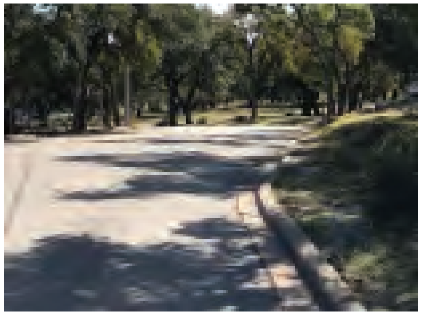
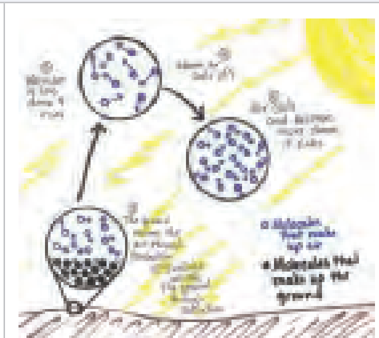
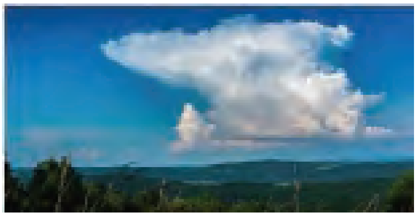
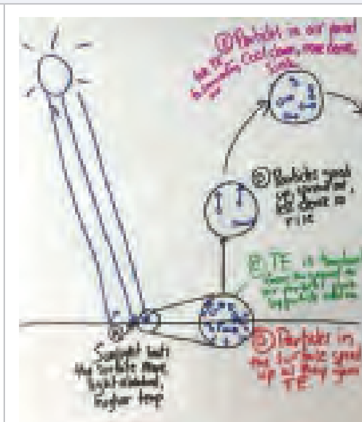
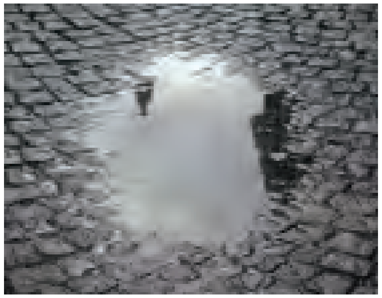
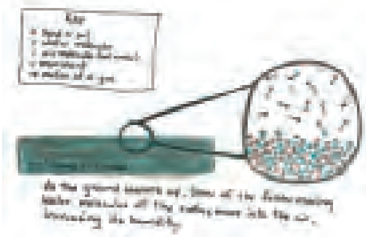
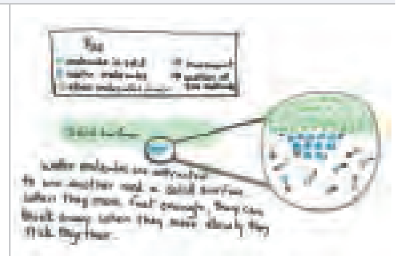
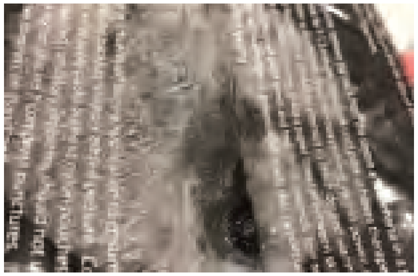
Lesson Question	Phenomena or Design Problem	What we do and figure out	How we represent it
LESSON 4 **2.5 days** **Why is the air near the ground warmer than the air higher up?** Investigation	 *Surfaces on Earth absorb and reflect light differently.*	We plan and carry out an investigation to figure out what causes the air above different ground surfaces to be warmer than the air higher in the atmosphere. We measure the temperature of the air at different ground surfaces, the air temperature above those surfaces, and the amount of sunlight reaching and reflecting off those surfaces. We figure out these things: • Energy from the Sun is absorbed by the ground, which then increases the kinetic energy (and therefore temperature) of the particles in the ground. • Different surfaces heat up differently depending on how much energy from the Sun is absorbed. • As particles in the air come into contact with the ground, energy is transferred to those particles through conduction. • On a sunny day, air temperatures above the ground are cooler than the ground itself.	

⇩ **Navigation to Next Lesson:** We know that the ground absorbs energy from sunlight and transfers that energy to the air through conduction. We are wondering what happens to that air after it warms up.

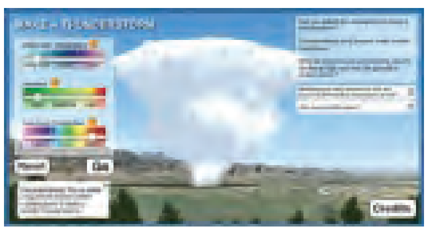
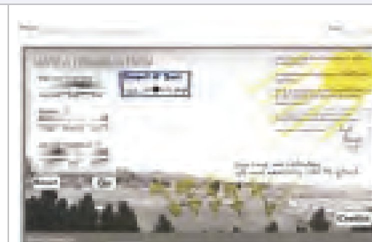
Lesson Question	Phenomena or Design Problem	What we do and figure out	How we represent it
LESSON 5 **2.5 days** **What happens to the air near the ground when it is warmed up?** Investigation	 *Warming and cooling air in a bottle with a soap bubble film over the opening causes the bubble to inflate and deflate. Warming a helium-filled Mylar balloon causes it to increase in volume and rise upward; it decreases in volume and sinks as it cools.*	We conduct an investigation to figure out how transferring thermal energy into and out of a parcel of air in a closed system (a bottle of air with a soap bubble film over the top) affects that air's volume and behavior. We conduct a second investigation to observe how density changes in a parcel of air (in a balloon) cause it to float or sink in the surrounding air. For each investigation, we develop a model to represent how the speed, spacing, and density of the molecules that make up air are affected by temperature changes. We figure out these things: • Changing the temperature of a parcel of air causes changes in the air's density due to changes in the kinetic energy (speed) and spacing of the molecules that make up the air. • Parcels of air that are less dense than the surrounding air rise. Parcels of air that are more dense than the surrounding air sink.	

Lesson Question	Phenomena or Design Problem	What we do and figure out	How we represent it
		• As they rise, parcels of warm, less dense air eventually cool off, transferring thermal energy to the surrounding air.	
⇩ **Navigation to Next Lesson:** We figured out that air near the ground becomes less dense and rises after it is warmed up by the ground through conduction. We will continue to examine the mechanisms that contribute to the formation of hailstorms by investigating the movement of air in a hailstorm cloud.			
LESSON 6 **2 days** **How can we explain the movement of air in a hail cloud?** Putting Pieces Together	 *A time-lapse video shows vertical cloud growth on a sunny day in the type of cloud that tends to form hail.*	We examine photos and a video of clouds that produce hail to look for patterns in the motion of air. We construct an explanation using evidence for the path of air movement below, within, and at the top of a cloud that tends to form hail. We figure out: • Air near the surface of the ground is warmed from thermal energy transfer from the ground through conduction. • The warm air near the ground becomes less dense than the surrounding air and rises. • Eventually, the warm air transfers its energy to the surrounding air, becoming just as cold and dense as the air around it, and it stops rising. • If that air becomes even cooler than the surrounding air, it sinks. • This type of air movement happens more on sunny days because the air right above the ground gets warmed up more by light from the Sun on those days. • Air is a mixture of different types of substances in the gas state including water vapor, which is measured as humidity.	
⇩ **Navigation to Next Lesson:** We know how air below and through a hail cloud is moving and we know that air has water in it, but we still have questions about how all that water got into the air.			

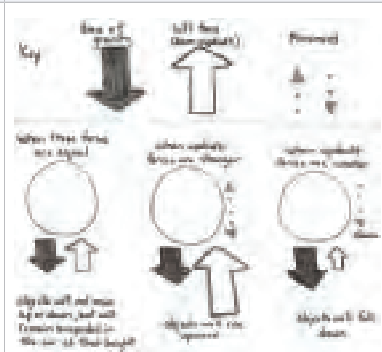
Lesson Question	Phenomena or Design Problem	What we do and figure out	How we represent it
LESSON 7 **2 days** **Where did all that water in the air come from, and how did it get into the air?** Investigation	 *Models of different Earth environments show an increase in relative humidity when thermal energy (heat) is added to the system.*	We plan and carry out an investigation to determine where the water in the air comes from by measuring the humidity in the air over samples of different Earth surfaces. We figure out these things: • Water can go into the air (increasing its humidity) from many different types of surfaces with water in or on them. • When individual water molecules on the surface of a liquid gain enough motion energy (kinetic energy), they leave the liquid to become a gas; this process is called evaporation.	
⇩ **Navigation to Next Lesson:** We know how water gets into the air, but what happens to that water vapor as it rises and cools?			
LESSON 8 **2 days** **What happens to water vapor in the air if we cool the air down, and why?** Investigation	 *Water droplets appear and grow on a cool surface when humid air comes in contact with them. When two water droplets touch, they move toward each other to become one. The motion and interactions between magnetic marbles in a collision change depending on how fast they are moving.*	We carry out investigations to explore what happens when air containing water vapor is cooled and what happens when water droplets make contact with each other. We use magnetic marbles to develop a model for how mutual attraction between water molecules and changes in their speed cause water to change from gas to liquid when it cools below a certain temperature. • Water molecules are attracted to each other. When they are moving fast enough, they can break away from each other and bounce off each other. When they are moving slow enough, they clump and stick together. • Water droplets can grow over time as they run into other water droplets or as more molecules of water vapor condense and stick to them. • When water is below a certain temperature (its condensation/boiling point), the molecules are moving slow enough to remain in liquid form; when water is above that temperature, the molecules are moving fast enough to remain in gas form; they change state when cooled below or heated above that temperature.	
⇩ **Navigation to Next Lesson:** We know water droplets can form in air that is cooled that has water vapor in it. So why aren't water droplets always forming in the air above us outside? What is going on with water in the clouds above us on any given day?			

Lesson Question	Phenomena or Design Problem	What we do and figure out	How we represent it
LESSON 9 **1 day** **Why don't we see clouds everywhere in the air, and what is a cloud made of?** Investigation	 *Informational text describes what clouds are made of, why we can see them, the role of cloud condensation nuclei, and methods of cloud seeding. Ice crystals appear and then grow larger on the surface of a cold gel pack over a container with humid air in it.*	We read about what clouds are made of, why we can see them, the role of cloud condensation nuclei, and methods of cloud seeding. We argue that what happens in clouds is similar to what we see happen on the surface of a cold gel pack over humid air in our 2-L bottles. We figure out these things: • Clouds are made of water droplets and/or ice crystals and molecules of gas (including water vapor). • We see clouds because the water droplets or crystals in them reflect and scatter or absorb a noticeable amount of light. • For molecules of water vapor in the air to start the condensation or deposition process, the air has to reach 100% humidity and then be cooled. The water vapor also needs a solid surface to stick to. In the air, these surfaces are cloud condensation nuclei (small, solid particles).	

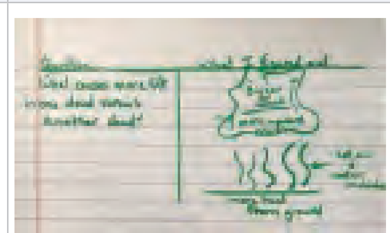
⇩ **Navigation to Next Lesson:** We figured out a lot about what happens to water in the air in clouds as they form. We want to see if we can apply these ideas to explain why clouds might not form all the time in the air above us.

Lesson Question	Phenomena or Design Problem	What we do and figure out	How we represent it
LESSON 10 **2 days** **Why do clouds or storms form at some times but not others?** Investigation	 University Corporation for Atmospheric Research (UCAR) *Changing temperature and humidity inputs changes the size of the thunderstorm developed in a computer simulation.*	We use our *Gotta-Have-It Checklist* to test and revise a thunderstorm simulation to produce larger and smaller storms. We focus on temperature and humidity conditions that are likely to produce storms. We think about what additional features we would like to include in the simulation and we design interfaces for those features. We figure out these things: • A greater difference between near-ground and atmospheric temperatures is correlated with larger storm development. • Higher humidity is correlated with stronger storms. • Simulations are models that can represent only parts of a system, which limits their use.	 University Corporation for Atmospheric Research (UCAR)

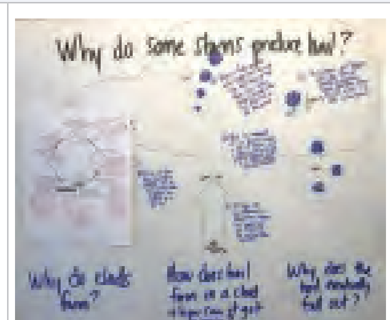
⇩ **Navigation to Next Lesson:** We noticed stronger storms have taller clouds form, and we know hail comes from stronger storms. We are wondering if the tall clouds have something to do with hail formation.

Lesson Question	Phenomena or Design Problem	What we do and figure out	How we represent it
LESSON 11 **2 days** **Why don't water droplets or ice crystals fall from the clouds all the time?** Investigation	 *Tissue paper and a Ping-Pong ball can be suspended in the air by blowing air on them from below. Air blown downward onto a scale or away from it affects the amount of force registered on the scale. A pointer taped to a balloon stretched over the mouth of a jar moves upward when additional force is applied downward on the balloon.*	We try to lift or suspend different objects with air blown upward, and we record the weight of different objects and the amount of force registered when air is blown toward or away from a digital scale. We develop a model to show how objects might be lifted, fall, or remain suspended in the air depending on the relative strength of two different forces acting on them. We record the air pressure using a homemade barometer and record the cloud cover and precipitation outside. We figure out these things: • The more mass something has, the greater the force of gravity pulling down on it (which can be measured as its weight on a scale). • Moving air (wind) pushes (exerts a force on) matter in its path. • Air moving upward (updrafts) can keep an object suspended or floating in the air when the force from the molecules in that air colliding with that object counterbalances the downward force from gravity. When those forces are no longer balanced, the object that was suspended will start moving upward or downward. • A barometer can detect changes in the density of the air outside of it.	

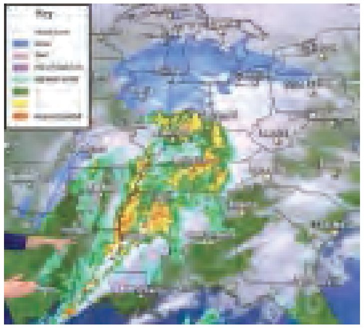
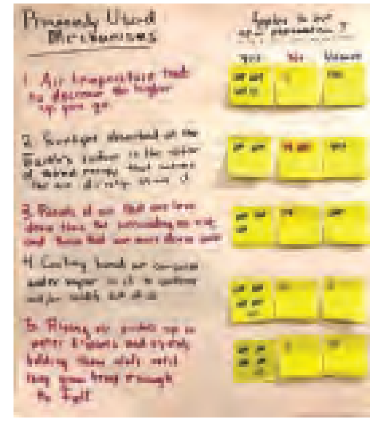
Navigation to Next Lesson: We have ideas for what might cause an updraft to be stronger in one cloud versus another, and we want to investigate those further. We also started taking measurements with a barometer to see if our predictions about whether changes in the pressure of the air outside correspond to changes in cloudiness and/or precipitation, and we want to keep collecting that data over future lessons.

Lesson Question	Phenomena or Design Problem	What we do and figure out	How we represent it
LESSON 12 **2 days** **What causes more lift in one cloud versus another?** Investigation	 *Dye added to water in a tub rises and moves differently when different amounts of thermal energy are added to the system.*	We plan and carry out an investigation to determine what variables affect the amount of lift produced in a fluid. We explain how the results of our investigation help us understand how differences between air and ground temperatures can cause different amounts of lift and movement of air. We figure out these things: • When one spot in a fluid heats up, it becomes less dense, which causes it to rise. When it cools down, it becomes more dense and sinks. This leads to circular motion in fluids, called convection. • The greater the thermal energy input into the fluid, the stronger the lift or convection currents. The more of Earth's surface that is in contact with the air above it, the more thermal energy it can transfer to that air. • Some winds are the result of this convection. Air at the surface moves toward an area where warmed air rose, filling in the space left behind.	

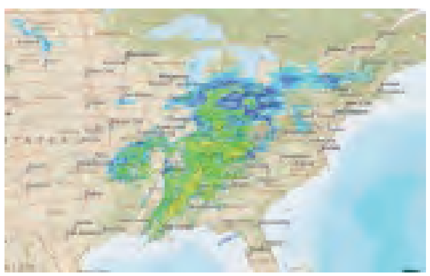
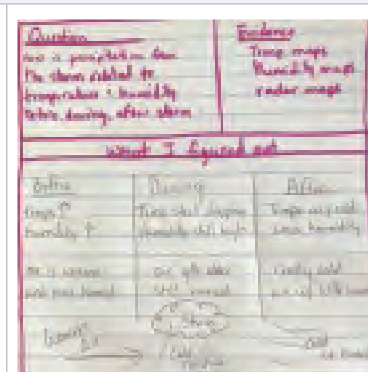
⇩ **Navigation to Next Lesson:** We have figured out what causes air to lift, move around, and sink. We are ready to see if this can help us explain how a hailstorm forms.

Lesson Question	Phenomena or Design Problem	What we do and figure out	How we represent it
LESSON 13 **3 days** **Why do some storms produce (really big) hail and others don't?** Putting Pieces Together	 *Different storms produce different types of precipitation (snow, rain, hail). Storms that produce larger hail also produce stronger updrafts.*	We add to our Gotta-Have-It Checklist and develop a final model to explain why some storms produce hail. We revisit the DQB and discuss the questions that we have now answered. We apply our understanding to a new phenomenon (hurricanes) and individually take an assessment.	

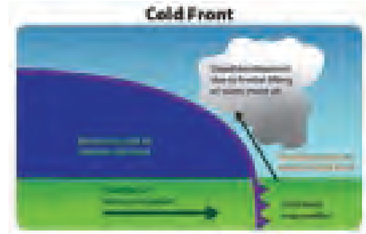
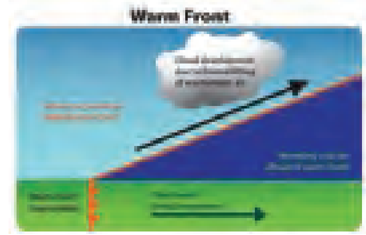
⇩ **Navigation to Next Lesson:** We can now answer many of the questions from our DQB, but there are still some long-term weather events from our related phenomena list that we have questions about.

Lesson Question	Phenomena or Design Problem	What we do and figure out	How we represent it
LESSON 14 **2 days** **What causes a large-scale precipitation event like this to occur?** Anchoring Phenomenon	 *Different forms of precipitation were falling over the midwestern United States on the morning of Saturday, Jan. 19, 2019. A forecast predicts that this storm will produce heavy snowfall and ice accumulation in the northeastern United States by the end of the weekend.*	We explore video and maps from three parts of a weather report and forecast from Jan. 19, 2019. We develop a model to explain how what was happening in one part of the country at one point in time can be connected to what is predicted to happen in another part of the country over a day later. We develop questions for our Driving Question Board (DQB). We brainstorm ways we could investigate these questions. We will figure out these ideas: • Some storms are very large (hundreds of miles across) and can last for many days. • These large-scale storms can produce different types and amounts of precipitation over different areas. • Many of the mechanisms we used to explain small-scale precipitation events seem like they could be relevant to explaining large-scale storms too. • Large-scale storms also may have something to do with large areas of cold air and warm air moving over great distances.	

Navigation to Next Lesson: We have ideas for what might be causing this large-scale rain, ice, and snowstorm. One set of ideas was that it was related to how a large amount of relatively cold and warm air was moving over the country. We want to see if the data support that idea.

Lesson Question	Phenomena or Design Problem	What we do and figure out	How we represent it
LESSON 15 **2 days** **What happens with temperature and humidity of air in large storms?** Investigation	 *Students analyze temperature, humidity, and radar data to track the progression of the storm and precipitation along the front line.*	In this lesson we use temperature, humidity, and radar data across eight-hour increments during the timeline of the storm to track the movement of air and precipitation. We consider how air moves horizontally in large parcels, called air masses, and we also notice that precipitation and storms develop where air masses of different characteristics meet. As a class, we develop different ways of representing what is happening with warm air and cold air across the land. We figure out these ideas: • Air masses are large parcels of air (hundreds of miles wide) with similar characteristics (e.g., temperature, humidity). • Air masses move horizontally, such as from west to east across the United States. • Storms and precipitation can develop where two air masses with different characteristics meet; this boundary is called a *front.*	

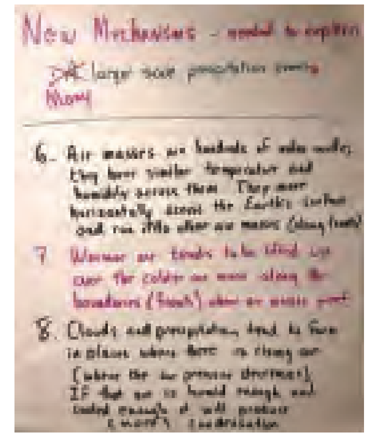
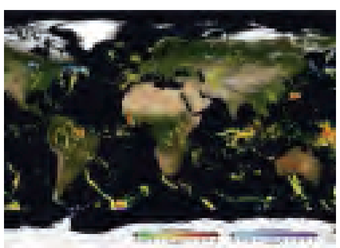
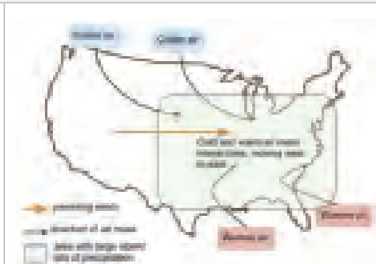
Navigation to Next Lesson: We wonder what happens when two very different air masses interact and if this is why storms develop along these boundaries.

Lesson Question	Phenomena or Design Problem	What we do and figure out	How we represent it
LESSON 16 **2 days** **How do warm air masses and cold air masses interact along the boundaries between them?** Investigation	 *When warm water and cold water interact, cold water sinks, pushing warm water upward. This serves as a model for the interactions that occur between warm and cold air masses in the atmosphere.*	We carry out an investigation to explore what happens along a frontal boundary where warm air and cold air meet. We develop models to describe interactions between warm and cold air masses and use patterns in data to explain changes in precipitation that can occur when air masses collide. We figure out: • When a warm air mass moves toward a cold air mass, the warm air slides over the cold air. When a cold air mass moves toward a warm air mass, the cold air pushes into and below the warm air, pushing it up and over. Both interactions cause predictable changes in weather. • The maximum amount of water vapor that air at a given temperature can hold is referred to as 100% relative humidity. • The maximum amount of water vapor that can be in the air changes based on the temperature of the air; warmer air can hold more water vapor than colder air. • Cooling air at 100% relative humidity will cause water vapor to condense out of the air; the greater the decrease in air temperature, the greater the amount of water vapor that will condense out of it.	 

⇩ **Navigation to Next Lesson:** In this lesson, we figured out what happens when warm air masses and cold air masses interact and why it happens. What we don't yet know is how scientists know when this is going to happen. In the next lesson we will explore how scientists use tools to predict the movement of warm and cold fronts and the accompanying changes in weather.

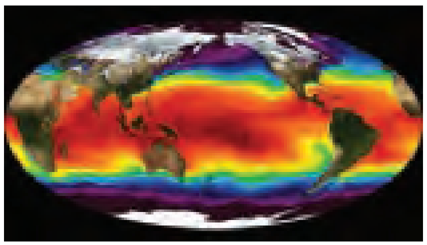
Lesson Question	Phenomena or Design Problem	What we do and figure out	How we represent it
LESSON 17 **1 day** **Is there a relationship between where the air is rising and where precipitation falls?** Investigation	 *Pressure maps for the United States show different amounts of air pressure in different places at different times.*	We analyze national pressure maps from around the time of the original forecast. We construct an explanation of the patterns we notice among (1) the area of lowest air pressure, (2) the locations of the fronts, and (3) where precipitation would fall. We apply scientific ideas to explain what is causing these three things to be connected to one another. We will figure out these ideas: • When the air pressure outside decreases, it tends to correspond with the appearance of cloudier skies and in some cases precipitation. • Large-scale, low-pressure air masses can move and their movement can be predicted.	

<table>
<tr><th>Lesson Question</th><th>Phenomena or Design Problem</th><th>What we do and figure out</th><th>How we represent it</th></tr>
<tr><td></td><td>A homemade barometer detects changes in the density of the air outside of it.</td><td>The movement and location of warm and cold fronts appear to be connected to this low-pressure center.
Precipitation tends to fall along the line of the cold front and warm front and behind the low-pressure center.</td><td></td></tr>
<tr><td colspan="4">⇩ Navigation to Next Lesson: We've developed individual explanations for what caused the patterns we saw in the weather associated with the Jan. 19, 2019 storm. We argued we will have to work together next time to come to agreement on the mechanisms that are the causes that led to this.</td></tr>
<tr><td>LESSON 18
2 days
How can we explain what is happening across this storm (and other large-scale storms)?
Putting Pieces Together, Problematizing</td><td>

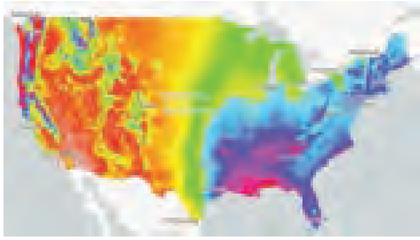
A weather forecast shows that three different storm systems were predicted to affect different parts of the United States from the morning of Nov. 22, 2019 into Nov. 27, 2019.</td><td>We explore video and maps from three parts of a weather report and forecast from Jan. 19, 2019. We develop a model to explain how what was happening in one part of the country at one point in time can be connected to what is predicted to happen in another part of the country over a day later. We develop new questions for our Driving Question Board (DQB) and brainstorm ways we could investigate these questions. We will figure out these things:
Many storms are due to the path that air masses follow as they are moving, other air masses they interact with along their boundaries (fronts), and how much lift occurs in the air mass or along those fronts.
We have new questions about whether certain weather patterns are typical for different places in our country and what causes any differences in those from one place to another over longer periods of time.</td><td></td></tr>
<tr><td colspan="4">⇩ Navigation to Next Lesson: The new questions that emerged from considering whether the patterns we see in storm tracks, precipitation amounts, and types of precipitation are typical for different areas of our country are ones we want to investigate further in future lessons.</td></tr>
<tr><td>LESSON 19
1 day
Are there patterns to how air masses move that can help predict where large storms will form?
Investigation</td><td>
Visualized precipitation data reveal predictable patterns in the movement and direction of air masses.</td><td>In this lesson, we observe a visualization showing precipitation movement across the United States in a predictable pattern from west to east in most locations. These predictable air movements seem to bring colder air from the north and warmer air from the south. We zoom out to a global view and notice the U.S. pattern is the same as other places in the northern hemisphere and a mirror image of the southern hemisphere. We figure out these things:
There are patterns in the direction that air and precipitation move over a region.</td><td></td></tr>
</table>

Lesson Question	Phenomena or Design Problem	What we do and figure out	How we represent it
		• Patterns in air movement are caused by prevailing winds and the prevailing winds in the northern hemisphere mirror the southern hemisphere. • These patterns help us predict where air and precipitation come from (colder from the north and warmer from the south). • Climate is the long-term average of weather in an area, typically averaged over 30 years.	

⇩ **Navigation to Next Lesson:** We figure out that air mostly moves in the same pattern across most of the United States, from west to east, bringing colder air from the north and warmer air from the south. We notice precipitation is more common over or near the ocean and wonder how the ocean changes air masses and precipitation patterns.

Lesson Question	Phenomena or Design Problem	What we do and figure out	How we represent it
LESSON 20 **2 days** **How do oceans affect whether a place gets a lot or a little precipitation?** Investigation	 *Ocean temperatures and currents affect evaporation rates and therefore the temperature and humidity of different air masses.*	In this lesson, we come to agreement about the temperature of air masses and the direction of their movement. We gather additional information about the role of the ocean by observing a visualization of ocean temperatures, reading about ocean currents, and interpreting precipitation data for coastal cities. We revise a model for air mass interactions that explain (1) the places where certain kinds of air masses form, and (2) their predictable movements over time. We figure out: • The ocean is warmer near the equator and cooler near the poles. • Ocean currents can bring warmer waters toward the poles and cooler waters toward the equator. • More evaporation occurs over warmer ocean waters. • The temperature of the ocean affects the humidity of the air moving over it.	

⇩ **Navigation to Next Lesson:** We figure out that the ocean affects the humidity of air masses. We are curious as to why the moisture from the Atlantic Ocean and Gulf of Mexico can travel so far inland compared to the moisture from the Pacific Ocean.

Lesson Question	Phenomena or Design Problem	What we do and figure out	How we represent it
LESSON 21 **2 days** **Why is there less precipitation further inland in the Pacific Northwest than further inland from the Gulf Coast?** Investigation	 *Data from five locations along prevailing wind pathways in the Pacific Northwest and Gulf Coast show that changes in elevation are associated with changes in air temperature and precipitation.*	We analyze precipitation, temperature, and elevation data at five locations along two different prevailing wind pathways to explore why there is less precipitation further inland in the Pacific Northwest than there is further inland from the Gulf Coast. We model what happens as an air mass moves from above the ocean to locations over mountains and relatively flat landforms. We develop a list of key ideas and data we need to explain climate patterns in places outside of the United States. We figure out: • Changes in elevation affect the flow of air over the land. • As elevation increases, the air flowing over the land is forced upward; as elevation decreases the air flowing over the land can fall back downward. • Air that is forced upward cools as it rises and tends to lose much of the water vapor in it through condensation and precipitation.	
⇩ **Navigation to Next Lesson:** We have a list of key ideas and data needed that we're ready to use to explain climate patterns outside of the United States.			
LESSON 22 **1 day** **How can we explain differences in climate in different parts of the world?** Putting Pieces Together	 *South America has both temperate and tropical rainforests, which have high precipitation rates but different average temperatures.*	We use our key ideas list from Lesson 21 to explain why the rainforests are located where they are and why they have different climates. We revisit the Driving Question Board and discuss all of our questions that we have now answered.	
LESSONS 1–22 42 days total			

Lab Safety Requirements for Science Investigations

It is important to adopt and follow appropriate safety practices within the context of hands-on investigations and demonstration, whether this is in a traditional science laboratory or in the field. In this way, teachers need to be aware of any school or district safety policies, legal safety standards, and better professional practices that are applicable to hands-on science activities being undertaken.

Science safety practices in laboratories or classrooms require engineering controls and personal protective equipment (e.g., safety goggles, non-latex aprons and gloves, eyewash/shower station, fume hood, and fire extinguishers). Science investigations should always be directly supervised by qualified adults, and safety procedures should be reviewed annually prior to initiating any hands-on activities or demonstration. Prior to each investigation, students should also be reminded specifically of the safety procedures that need to be followed. Each of the lessons within the units includes teacher guidelines for applicable safety procedures for setting up and running an investigation, as well as taking down, disposing of, and storing materials.

Prior to the first science investigation of the year, a safety acknowledgement form for students and parents or guardians should be provided and signed. You can access a model safety acknowledgement form for middle school activities. (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)

Disclaimer: The safety precautions of each activity are based in part on use of the specifically recommended materials and instructions, legal safety standards, and better professional safety practices. Be aware that the selection of alternative materials or procedures for these activities may jeopardize the level of safety and therefore is at the user's own risk.

Please follow these lab safety recommendations for any lesson with an investigation:

1. Wear safety goggles (specifically, indirectly vented chemical splash goggles), a non-latex apron, and non-latex gloves during the setup, hand-on investigation, and take down segments of the activity.
2. Immediately wipe up any spilled water and/or granules on the floor, as this is a slip and fall hazard.
3. Follow your *Teacher Guide* for instructions on disposing of waste materials and/or storage of materials.
4. Secure loose clothing, remove loose jewelry, wear closed-toe shoes, and tie back long hair.
5. Wash your hands with soap and water immediately after completing this activity.
6. Never eat any food items used in a lab activity.
7. Never taste any substance or chemical in the lab.

Specific safety precautions are called out within the lesson using this icon and a callout box.

What are the Disciplinary Core Ideas (DCIs) used in the context of the phenomena for this unit?

Disciplinary Core Ideas are reproduced verbatim from *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas*. National Research Council; Division of Behavioral and Social Sciences and Education; Board on Science Education; Committee on a Conceptual Framework for New K-12 Science Education Standards. National Academies Press, Washington, DC.

The unit expands students' understanding of weather and climate and the role of water in Earth's surface processes which include these grades 6–8 elements of the Disciplinary Core Ideas (DCIs). It addresses all but the crossed out sections of the ones shown below.

ESS2.C: The Roles of Water in Earth's Surface Processes

- Global movements of water and its changes in form are propelled by sunlight and gravity.
- The complex patterns of the changes and the movement of water in the atmosphere, determined by winds, landforms, and ocean temperatures and currents, are major determinants of local weather patterns.
- Variations in density due to variations in temperature ~~and salinity~~ drive a global pattern of interconnected ocean currents.

- Water continually cycles among land, ocean, and atmosphere via ~~transpiration~~, evaporation, condensation and crystallization, and precipitation, ~~as well as downhill flows on land~~.

ESS2.D: Weather and Climate

- Weather and climate are influenced by interactions involving sunlight, the ocean, the atmosphere, ice, landforms, ~~and living things~~. These interactions vary with latitude, altitude, and local and regional geography, all of which can affect oceanic and atmospheric flow patterns.
- Because these patterns are so complex, weather can only be predicted ~~probabilistically~~.
- The ocean exerts a major influence on weather and climate by absorbing energy from the sun, releasing it over time, and globally redistributing it through ocean currents.

The Unit 7.4 (a 7th grade unit) on Matter Cycling will make reference to transpiration in Lesson 4, when students are investigating if water comes out of plants leaves.

This unit builds on DCI elements that students should have developed in the prior unit 6.2. These ideas are elicited and are used in new contexts (primarily different because of time and temporal scale). In many cases, the unit helps students extend these DCIs. The plain text beneath each of the DCI elements below describes how the ideas are used and where they are extended.

- **PS1.A: Structure and Properties of Matter:** Gases and liquids are made of molecules or inert atoms that are moving about relative to each other. In a liquid, the molecules are constantly in contact with others; in a gas, they are widely spaced except when they happen to collide. In a solid, atoms are closely spaced and may vibrate in position but do not change relative locations.
  - This particle model is reused and extended in Lessons 3–11, 13–14, and 17–18. It is used to model (1) how energy is transferred from the ground to the air (through conduction), (2) why air changes its density (due to changes in the speed of air particles), (3) why density would affect the amount of air pressure detected by a barometer (due to differences in the amount of force applied to the barometer from changes in the weight of a column of air particles overhead), and (4) how the cooling of water vapor in the air can cause the molecules in it to slow down enough that they stick to, rather than bounce off of, neighboring particles in collisions, thereby causing the particles to condense or solidify out of the air.
- **PS3.A: Definitions of Thermal Energy:** The temperature of a system is proportional to the average internal kinetic energy and potential energy per molecule (whichever is the appropriate building block for the system's material). When the kinetic energy of an object changes, there is inevitably some other change in energy at the same time.
  - The idea that thermal energy transfer can occur through conduction is used to explain how the air above the ground is heated by it, and how warm rising air cools off as it moves higher up, This idea is reused in Lessons 5–8, 10, 12, 13, 14, 17, 18, 20, and 22.
- **PS4.B: Electromagnetic Radiation** When light shines on an object, it is reflected, absorbed, or transmitted through the object, depending on the object's material and the frequency (color) of the light.
  - The idea that light is absorbed by the ground and converted to thermal energy is an idea that is reused in Lessons 3, 6–8, 10, 14, 17, 18, 20, and 22 in this unit.

This also unit builds on the following DCI elements from the K–2 grade band:	This also unit builds on the following DCI elements from the 3–5 grade band:
ESS2.C: The Roles of Water in Earth's Surface Processes • Water is found in the ocean, rivers, lakes, and ponds. Water exists as solid ice and in liquid form. **ESS2.D: Weather and Climate** • Sunlight warms Earth's surface. • Weather is the combination of sunlight, wind, snow or rain, and temperature in a particular region at a particular time. People measure these conditions to describe and record the weather and to notice patterns over time.	**ESS2.C: The Roles of Water in Earth's Surface Processes** • Nearly all of Earth's available water is in the ocean. Most freshwater is in glaciers or underground; only a tiny fraction is in streams, lakes, wetlands, and the atmosphere. **ESS2.D: Weather and Climate** • Scientists record patterns of the weather across different times and areas so that they can make predictions about what kind of weather might happen next. • Climate describes a range of an area's typical weather conditions and the extent to which those conditions vary over the years

What should my students know from earlier grades or units?

While this unit engages students in multiple SEPs across the lesson-level performance expectations for all of the lessons in the unit, there are three focal practices that this unit targets to support students' development of the SEPs for the 6th grade year. These are:

1. Developing and Using Models
2. Planning and Carrying Out Investigations
3. Analyzing and Interpreting Data

The sections below describe the development of the SEPs leading to and continuing through this unit for each of these practices.

1) Supporting the practice of Developing and Using Models

This unit assumes students have had experience with the following elements of this practice from the 3–5 grade band:	By the end of units 6.1 and 6.2, students will have experience with the following middle school elements of this practice:
• Identify limitations of models. • Collaboratively develop and/or revise a model based on evidence that shows the relationships among variables for frequent and regular occurring events. • Develop a model using an analogy, example, or abstract representation to describe a scientific principle or design solution. • Develop and/or use models to describe and/or predict phenomena. • Develop a diagram or simple physical prototype to convey a proposed object, tool, or process. • Use a model to test cause and effect relationships or interactions concerning the functioning of a natural or designed system.	• Develop or modify a model—based on evidence—to match what happens if a variable or component of a system is changed. • Develop and/or revise a model to show the relationships among variables, including those that are not observable but predict observable phenomena. • Develop and/or use a model to predict and/or describe phenomena. • Develop a model to describe unobservable mechanisms.

In this unit, students build on their prior experiences with models by engaging in all of the above listed middle school elements again, by using the elements of the SEPs to model systems that are much more complex. The major shift in their engagement in the modeling practice includes:

- **Systems at a much larger spatial scale.** Earlier units had students model systems that were no bigger than a room. Now they will be modeling systems that range in size from miles (in the first half of this unit) to hundreds of miles (in the second half of the unit).
- **Non-visible system boundaries.** Earlier units used boundaries between solids and liquids as the system boundaries that were being modeled. The boundary between the liquid inside the system and the solid that contains the liquid is a simpler modeling situation than those in this unit. This unit introduces invisible boundaries around gases—including air parcels and air masses.
- **Systems over longer time scales.** Phenomena that students modeled in prior units occurred almost instantly (reflections) or within minutes (cooling liquids in a cup). Phenomena that students model in this unit occur over days (mesoscale storms) or many years (climate patterns).
- **Modeling space in three dimensions.** Students develop models from multiple points of view in more than one dimension in this unit. This is the first unit in which students develop both a profile view of the system and a bird's eye view of the system. This occurs in the second half of the unit. This is a major shift towards a three-dimensional visualization of a system, which sets important groundwork for what students will need to do in the next unit (unit 6.4). Students will need to model the surface of the Earth and what is below the surface from both of these perspectives in that unit.

2) Supporting the practice of Planning and Carrying Out Investigations

This unit assumes students have had experience with the following elements of this practice from the 3–5 grade band:	By the end of units 6.1 and 6.2, students will have experience with the the following middle school elements of this practice:
• Plan and conduct an investigation collaboratively to produce data to serve as the basis for evidence, using fair tests in which variables are controlled and the number of trials considered. • Evaluate appropriate methods and/or tools for collecting data.	• Plan an investigation individually and collaboratively, and in the design: identify independent and dependent variables and controls, what tools are needed to do the gathering, how measurements will be recorded, and how many data are needed to support a claim.

This unit assumes students have had experience with the following elements of this practice from the 3–5 grade band:	By the end of units 6.1 and 6.2, students will have experience with the the following middle school elements of this practice:
• Make observations and/or measurements to produce data to serve as the basis for evidence for an explanation of a phenomenon or test a design solution. • Make predictions about what would happen if a variable changes. • Test two different models of the same proposed object, tool, or process to determine which better meets criteria for success.	• Evaluate the accuracy of various methods for collecting data. • Collect data to produce data to serve as the basis for evidence to answer scientific questions or test design solutions under a range of conditions. • Collect data about the performance of a proposed object, tool, process, or system under a range of conditions.

In this unit, students build on their prior experiences with planning and carrying out investigations by engaging in these elements again, but also engage in a new element in lesson 8 and 13:

- Conduct an investigation and/or evaluate and/or revise the experimental design to produce data to serve as the basis for evidence that meet the goals of the investigation.

And they engage in more co-construction of the data collection protocol related to this element in lesson 3, particularly related to how measurements will be gathered and recorded:

- Plan an investigation individually and collaboratively, and in the design: identify independent and dependent variables and controls, what tools are needed to do the gathering, how measurements will be recorded, and how many data are needed to support a claim.

These lessons mark a shift toward engaging students in more revision, evaluation, and modification of experimental designs than in prior units.

3) Supporting the practice of Analyzing and Interpreting Data.

This unit assumes students have had experience with the following elements of this practice from the 3–5 grade band:	By the end of units 6.1 and 6.2, students will have experience with the following middle school elements of this practice:
• Represent data in tables and/or various graphical displays (bar graphs, pictographs and/or pie charts) to reveal patterns that indicate relationships. • Analyze and interpret data to make sense of phenomena, using logical reasoning, mathematics, and/or computation. • Compare and contrast data collected by different groups in order to discuss similarities and differences in their findings. • Analyze data to refine a problem statement or the design of a proposed object, tool, or process. • Use data to evaluate and refine design solutions.	• Apply concepts of statistics and probability (including mean, median, mode, and variability) to analyze and characterize data, using digital tools when feasible. • Consider limitations of data analysis (e.g., measurement error), and/or seek to improve precision and accuracy of data with better technological tools and methods (e.g., multiple trials). • Analyze and interpret data to provide evidence for phenomena. • Analyze and interpret data to determine similarities and differences in findings. • Use graphical displays (e.g., maps, charts, graphs, and/or tables) of large data sets to identify temporal and spatial relationships.

In this unit, students again engage in two elements listed in the right-hand column of the table above. They consider limitations of data analysis (e.g., measurement error), and/or seek to improve precision and accuracy of data with better technological tools and methods (e.g., multiple trials), and they analyze and interpret data to provide evidence for phenomena. The last bulleted element in the right-hand column, using graphical displays (e.g., maps, charts, graphs, and/or tables) of large data sets to identify temporal and spatial relationships, is one that students engage with in new ways and to much greater depth than they did before. In the prior unit (6.2), only one lesson targeted this element in a lesson level expectation (LLPE). In this unit, students engage with data on maps at different scales (e.g. across a few miles vs. hundreds of miles and across a few days vs. years) to identify temporal and spatial relationships in Lessons 2, 7, 13, 14, 15, 17, 18, 19, 20, 21, and 22.

What are the Focal Crosscutting Concepts (CCCs) for this unit?

While this unit engages students in multiple CCCs across the lesson level performance expectations for all the lessons in the unit, there are four focal practices that this unit targets to help support students' development of CCCs across the 6th grade year in CCCs. These are:

1. Patterns
2. Cause & Effect
3. Systems and System Models
4. Matter & Energy

The sections below describe the development of these CCCs leading to this unit and through this unit.

1) Using Patterns:

This unit assumes students have had experience with the following elements of this CCC from the 3–5 grade band:	By the end of units 6.1 and unit 6.2, students will have experience with the following middle school elements of this CCC:
• Similarities and differences in patterns can be used to sort, classify, communicate, and analyze simple rates of change for natural phenomena and designed products. • Patterns of change can be used to make predictions. • Patterns can be used as evidence to support an explanation.	• Macroscopic patterns are related to the nature of microscopic and atomic-level structure. • Patterns in rates of change and other numerical relationships can provide information about natural and human designed systems. • Patterns can be used to identify cause and effect relationships. • Graphs, charts, and images can be used to identify patterns in data.

In this unit, students again engage in the middle school level elements listed above. However the last bulleted element, involving use of visualizations to uncover patterns, is one of the focal CCCs in this unit. Students engage in this CCC element to a much greater extent and in new ways than they did previously. In this unit, students work with data represented on maps at multiple scales (e.g., across a few miles vs. hundreds of miles and across a few days vs. years) to identify temporal and spatial relationships in Lessons 2, 6, 13, 14, 15, 17, 18, 19, 20, 21, and 22 of this unit. The structure of this data grows in complexity from Lesson 2 onward. For example, in Lesson 2, students look at hail accumulation maps from multiple cities and in Lesson 6 they look at two parallel sets of global maps (one showing net radiation and one showing land surface temperature) from two different times of year. In Lesson 14, they look at a time series set of national weather maps showing multiple layers of data overlaid on them, including precipitation amounts and types, cloud cover, low pressure air mass centers, and fronts.

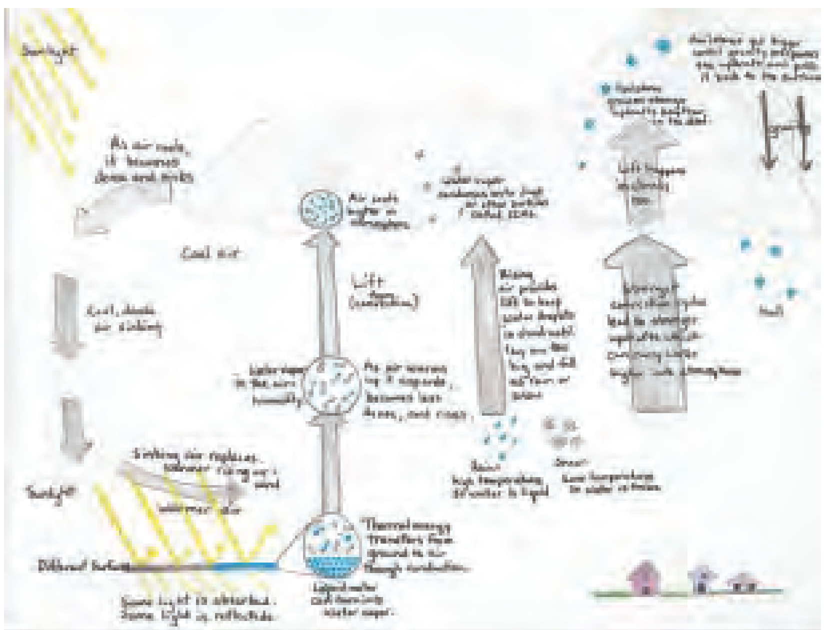
Students' engagement in finding and making sense of patterns will generally be more complex in this unit than in prior units. In prior units, students looked for patterns in data tables, but this work was limited to collecting and analyzing light and temperature data from their own in-class investigations. The complexity of those data tables is extended in this unit. In Lesson 2, students work with weather condition data that were taken across different times of day at different locations and are represented in multiple data tables. They also work with air temperature data from multiple locations and multiple times of year in Lessons 3 and 6, again represented in multiple data tables. These data include negative values for temperature, which is a concept connected to a new 6th grade Common Core math standard (CCSS.MATH.CONTENT.6.NS.C.5). In Lesson 16, students also use graphs to look for patterns in ways they haven't before. They examine the x-values and y-values of two points on a coordinate graph to find differences in the amount of water vapor in the air and differences in air temperature. This also is a connection to a new 6th grade Common Core math standard (CSS.MATH.CONTENT.6.NS.C.8).

2) Using Cause and Effect:

This unit assumes students have had experience with the following elements of this CCC from the 3–5 grade band:	By the end of units 6.1 and 6.2, students will have experience with the following middle school elements of this CCC:
• Cause and effect relationships are routinely identified, tested, and used to explain change. • Events that occur together with regularity might or might not be a cause and effect relationship.	• Relationships can be classified as causal or correlational, and correlation does not necessarily imply causation. • Cause and effect relationships may be used to predict phenomena in natural or designed systems.

This unit assumes students have had experience with the following elements of this CCC from the 3–5 grade band:	By the end of units 6.1 and 6.2, students will have experience with the following middle school elements of this CCC:
	• Phenomena may have more than one cause, and some cause and effect relationships in systems can only be described using probability.

In this unit, students again engage in the three middle school level elements listed above in the right-hand column. However, they develop much longer chains of cause and effect than in previous units. Students used a single mechanism to explain phenomena in the previous units (e.g., reflection vs. transmission of light in Unit 6.1, and conduction in Unit 6.2). In contrast, students construct a much longer and more complex chain of cause and effect to explain the anchoring phenomena in this unit. This chain of cause and effect includes (1) light's interaction with matter, (2) conduction, (3) density changes in air, (4) convections, (5) evaporation, (6) condensation, and (7) opposing forces on suspended water particles in the air. The system model students develop in Lesson 13, shown here, reflects this increased complexity in cause and effect thinking.



3) Using Systems and System Models:

This unit assumes students have had experience with the following elements of this CCC from the 3–5 grade band:	By the end of units 6.1 and unit 6.2, students will have experience with the following middle school elements of this CCC:
• A system is a group of related parts that make up a whole and can carry out functions its individual parts cannot. • A system can be described in terms of its components and their interactions.	• Systems may interact with other systems; they may have sub-systems and be a part of larger complex systems. • Models can be used to represent systems and their interactions—such as inputs, processes and outputs—and energy, matter, and information flows within systems.

In this unit, students again engage in the middle school level elements listed in the right-hand column above. As described in the SEP Developing and Using Models section above, they also develop system models for much more complex systems. In this unit, the major shifts in thinking about the nature of this more complex system include:

- **systems at a much larger spatial scale**
- **non-visible system boundaries**
- **systems over longer time scales**
- **modeling space with a three-dimensional perspectives**

Student also engage in a new element of this CCC in Lesson 10:

- Models are limited in that they only represent certain aspects of the system under study.

They do this when evaluating the limitations of the thunderstorm simulation, identifying which aspects of the system are represented in the model and which additional aspects could be added to account for thunderstorm develop and then propose modifications to that simulation, to better represent particle level mechanisms and energy flow through the system.

4) Using Matter & Energy:

This unit assumes students have had experience with the following elements of this CCC from the 3–5 grade band:	By the end of units 6.1 and 6.2, students will have experience with the following middle school elements of this CCC:
• Matter is made of particles. • Matter flows and cycles can be tracked in terms of the weight of the substances before and after a process occurs. The total weight of the substances does not change. This is what is meant by conservation of matter. Matter is transported into, out of, and within systems. • Energy can be transferred in various ways and between objects.	• Matter is conserved because atoms are conserved in physical and chemical processes. • Within a natural or designed system, the transfer of energy drives the motion and/or cycling of matter. • Energy may take different forms (e.g. energy in fields, thermal energy, energy of motion). • The transfer of energy can be tracked as energy flows through a designed or natural system.

In the unit 6.1, students tracked matter in and out of an open system and argued for mass conservation in closed system processes. In this unit, students track the flow of matter and energy across systems at a scale that is much larger and includes non-visible system boundaries, across longer time scales, and in three dimensional perspectives (see section 3 above). Thus, they use their ideas about matter and energy flow to address a completely new range of phenomena that occur across dramatically different scales of time and space. In addition, they use three different energy transfer processes to do this—radiation, conduction, and convection (see section 2 above).

Four focal CCCs may seem like a lot for a single unit. However, this is an 8-week unit, which is one of two units (out of twenty-four) that are the longest in the entire middle school scope and sequence. Our more typical 5 to 6 week units tend to have two to three focal CCCs.

In many ways, one can think of this unit as two units in one—where lesson sets 1 and 2 are anchored around a small-scale weather phenomenon, and lessons sets 3 and 4 are anchored around large-scale weather phenomenon and long-term patterns (climate level). Patterns is a focal CCC in the second half of the unit, whereas the Matter & Energy CCC is a focal CCC in the first half. The CCCs of Cause & Effect and Systems & System Models cut across all lesson sets. Analyzing and Interpreting Data is a focal SEP in the second half of the unit, whereas Planning and Carrying out Investigations is a focal SEP in the first half. The chart below summarizes this pattern.

X = a focal SEP or CCC in this lesson set	*Lesson set 1*	*Lesson set 2*	*Lesson set 3*	*Lesson set 4*
SEP: Developing and Using Models	X	X	X	X
SEP: Planning & Carrying Out Investigations	X	X		
SEP: Analyzing and Interpreting Data			X	X
CCC: Patterns			X	X
CCC: Cause & Effect	X	X	X	X
CCC: System & System Models	X	X	X	X
CCC: Matter and Energy	X	X		

What are some common ideas that students might have?

It is valuable to think of the *relevant ideas* listed below not as misconceptions that need to be erased but as productive ideas that we can use to build understanding. Not only does this help some students feel more comfortable talking about science and build a scientific identity, it improves science learning across the board. Having a set of competing ideas to compare, evaluate, and resolve is what drives the focus of many of the lesson questions and related investigations of the unit. Students will make incremental progress on revising these ideas over multiple lessons. The list below also indicates where students will first encounter a line of evidence that they can use to start to refute these ideas.

Some *relevant ideas* about **what causes differences in air temperature** that students may come into the unit with include:

- *Air should get warmer higher up because it is closer to the sun.*
    - In lesson 3, students will encounter evidence that this does not happen in the lower atmosphere, when they determine the temperature profile of the air from balloon sounding data.

- *Light warms the air above the Earth's surface by absorbing the light that reaches it, rather than being mostly heated by indirect heating from conduction between the air and the surface it is in contact with.*
  - In lesson 4, students gather firsthand evidence that light from the sun directly heats the earth's surface when it is absorbed by those surfaces.

Some *relevant ideas* about the **composition of air and clouds** that students may come into the unit with include:

- *The humidity of air is the same everywhere on Earth and does not change.*
  - In lesson 7, students will encounter a reading about relative humidity and how it changes. They will also carry out an investigation to directly measure change in the relative humidity of the air.
- *A cloud is all gas, rather than a combination of gas and water droplets or ice crystals.*
- *Water vapor is in the air outside of a cloud but not in the air inside of a cloud.*
- *A cloud is something similar to a sponge—a solid that can absorb only so much water before it becomes saturated and starts overflowing with water, leading to precipitation.*
  - In lesson 9, students' ideas about clouds will be addressed in a reading that describes the composition of clouds.

Some *relevant ideas* about **what causes precipitation** that students may come into the unit with include:

- *Precipitation occurs as a result of clouds running into other clouds.*
- *Precipitation occurs as a result of strong winds blowing into or on clouds.*
  - In lesson 8, students will develop a model that explains how intermolecular attraction in combination with changes in the average speed of molecules can explain why water vapor condenses into a liquid below a certain temperature. In lesson 9, they will determine the role of CCN in initiating this process.
- *Precipitation is independent of temperature changes in the air.*
  - In lesson 16, students will address this idea when they calculate how much water vapor condenses out of the air and how much the relative humidity of the air changes when the temperature of the air drops a certain amount.

Some relevant ideas about **ocean temperatures and ocean currents** that students may come into the unit with include:

- *The temperature of the ocean is much colder than the land.*
- *The temperature of the ocean is the same everywhere.*
  - In lesson 13, students will encounter a transfer task about hurricanes that describes how warm the surface of the ocean gets in parts of the world where hurricanes form during a particular time of year. In lesson 20, students will analyze maps showing the average surface temperature of the oceans across the entire Earth.
- *Ocean currents only occur near the shore.*
  - In lesson 20, students will address this idea when they work with a reading and a map that shows how ocean currents move water great distances and that some ocean currents move warm water away from the equator toward the poles and other ocean currents bring colder water from the poles toward the equator.

What modifications will I need to make if this unit is taught out of sequence?

This is the third unit in 6th grade in the Scope and Sequence. Given this placement, several modifications would need to be made if teaching this unit earlier or later in the middle school curriculum. These include the following adjustments:

- If taught before Unit 6.2, supplemental teaching of the following would be required:
  - Gases and liquids are made of molecules or inert atoms that are moving about relative to each other. In a liquid, the molecules are constantly in contact with others; in a gas, they are widely spaced except when they happen to collide. In a solid, atoms are closely spaced and may vibrate in position but do not change relative locations.
  - The temperature of a sample of matter is proportional to the average internal kinetic energy per molecule in that sample.
  - When the kinetic energy of a particle object changes, there is inevitably some other change in energy at the same time; kinetic energy can be transferred from one particle to another through particle collision. This form of energy transfer (conduction) can occur between solid, liquids and gases when they make contact with each other.
  - When light shines on an object, it is reflected, absorbed, or transmitted through the object, depending on the object's material and the color of the light. Energy from the light that is absorbed by a sample of matter is converted to increased particle motion energy in that sample of matter.
  - The total kinetic energy of particles in a sample of matter is also referred to as the thermal energy of that matter.

    - Identifying independent and dependent variables and controlling for other variables can help you conduct fair tests, which is a necessary condition for producing data that can serve as the basis for evidence in supporting or refuting a potential cause and effect relationship in a system.
- If taught before Unit 6.1 (or at the start of the school year), supplemental teaching of classroom norms, setting up the Driving Question Board, and asking open-ended and testable questions would need to be added. Experience with using light sensors and reading and interpreting their output would need to be added.

What are prerequisite math concepts necessary for the unit?

In this unit, students will need to have prior experiences in working with the ideas in the **bolded** sections of the related Common Core Math Standards listed below.

CCSS.MATH.CONTENT.6.NS.C.5: **Understand that positive and negative numbers are used together to describe quantities having opposite directions or values** (**e.g., temperature above/below zero,** elevation above/below sea level, credits/debits, positive/negative electric charge); **use positive and negative numbers to represent quantities in real-world contexts, explaining the meaning of 0 in each situation.**

CSS.MATH.CONTENT.6.NS.C.8: Solve real-world and mathematical problems by graphing points in all four quadrants of the coordinate plane. Include use of coordinates and absolute value to **find distances between points with the same first coordinate or the same second coordinate.**

CCSS.MATH.CONTENT.6.RP.A.2: **Understand the concept of a unit rate a/b associated with a ratio a:b with b ≠ 0,** and use rate language in the context of a ratio relationship.

CCSS.MATH.CONTENT.6.RP.A.3: **Use ratio and rate reasoning to solve real-world and mathematical problems,** e.g., by reasoning about tables of equivalent ratios, tape diagrams, double number line diagrams, or equations.

Additionally, when students generate and interpret the tables of data in Lessons 2, 4, and 11, they will draw on what they have learned across a number of Represent and Interpret data standards for grades 1–5, within the domain of Measurement and Data in the Common Core Mathematics Standards.

TEACHING SCIENCE LITERACY

How does the Core Knowledge Science Literacy routine integrate with the unit investigations?

The Core Knowledge Science Literacy Student Reader and the weekly Science Literacy routine layer varied reading opportunities into the science unit. In their lives after graduating from high school, most students will not become scientists. They will no longer routinely participate in guided investigations to figure out how phenomena work. They will, however, read text about science and scientific claims, day in and day out. The ability to learn and think about science through reading is a skill unto itself and is important in tandem with investigative learning. It is natural to primarily associate emerging literacy with reading and writing instruction at the elementary level, but middle school is an important time to hone literacy skills—specifically in science in the era of politicization of science topics, polarization among adults, and proliferation of misinformation on social media. Detection and construction of well-reasoned explanations are important not just in science, but throughout everyday life. Using claims and evidence in reasoning is the way that thoughtful people think about things, and writing is thinking in print. Students become voters as they emerge from high school, so it is important that they acquire skills for detection of faulty information and practice legitimate communication about scientific issues in the years leading up to that civic benchmark.

Throughout the course of the unit's investigative lessons, students write in their science notebooks in some fashion almost daily, and significant emphasis is placed on the speaking and listening communication threads of the CCSS. The instructional design of the investigations is deliberately light on having students access disciplinary core content through text. NGSS emphasis is on students investigating phenomena along the storyline, so students' interaction with text within lessons is minimal and in service to the unit's storyline. The Science Literacy routine is integrated to exercise students' ability to interact with text about science topics. The routine presents students with short reading selections in a variety of styles, all related to the unit in which students are engaged. Each reading selection is accompanied by a brief but thoughtful writing exercise.

The subject matter of the reading selections ties back to the unit, but the timing for the assigned readings is such that students do not read about specific facets of the subject before they have completed the lessons to investigate that content. In other words, the reading enhances and reinforces the knowledge that students have built in previous lessons; the reading does not reveal beforehand the key takeaways that students are intended to learn through lesson interactions.

When is it done within a unit?

The Core Knowledge Science Literacy Student Reader includes one reading collection per week for every week of the unit. A week's reading collection relates to the lessons completed in the previous week. The reading is assigned at the beginning of the week with the accompanying writing exercise due at the end of the week.

The reading and writing exercises are designed to be completed by students independently, with brief, supporting, teacher-facilitated discussions at the beginning, midpoint, and end of the week.

How do students typically represent their thinking as part of the routine?

Students generate a written product associated with each reading selection. The products are varied in form, and include graphic organizers, concept maps, cartoons, memes, infographics, storyboards, outlines, and paragraphs. The complexity of the products increases from week to week, with the final product for the unit being a single, thoughtfully reasoned, and well-constructed paragraph.

SCIENCE LITERACY: PREFACE

Put Yourself in This Scene

Literacy Objective

✓ Initiate thinking about the need to evaluate information in text and images.

Literacy Activity

- Read a brief scenario to pique interest, launch discussion, and begin to frame expectations.

Instructional Resource

Student Reader

Preface

Science Literacy Student Reader, Preface
"Put Yourself in This Scene"

No Prerequisite Investigations

The reading of the Preface is appropriate during the first week of unit instruction. The reading does not preemptively tell students facts about the topic that they are intended to learn throughout the course of their investigations.

Standards and Dimensions

NGSS

Disciplinary Core Idea ESS2.D: Weather and Climate:
Because these patterns are so complex, weather can only be predicted probabilistically. (MS-ESS2-5)

Science and Engineering Practices:
Using Mathematics and Computational Thinking Apply mathematical concepts and/or processes (such as ratio, rate, percent, basic operations, and simple algebra) to scientific and engineering questions and problems.;
Asking Questions and Defining Problems
Ask questions that challenge the premise(s) of an argument or the interpretation of a data set.

CCSS

English Language Arts
RST.6-8.2: Determine the central ideas or conclusions of a text; provide an accurate summary of the text distinct from prior knowledge or opinions.

RST.6-8.10: By the end of grade 8, read and comprehend science/technical texts in the grades 6–8 text complexity band independently and proficiently.

Math
CONTENT.6.RPA.3.C: Find a percent of a quantity as a rate per 100 (e.g., 30% of a quantity means 30/100 times the quantity); solve problems involving finding the whole, given a part and the percent.

MP.2: Reason abstractly and quantitatively.

Core Vocabulary

Core Vocabulary: Core Vocabulary terms are those that students should learn to use accurately in discussion and in written responses. During facilitation of learning, expose students repeatedly to these terms. No Core Vocabulary terms are highlighted in the Preface.

Language of Instruction: The Language of Instruction consists of additional terms, not considered a part of Core Vocabulary, that you should use when talking about any concepts in this exercise. Students will benefit from your modeling the use of these words without the expectation that students will use or explain the words themselves.

probability **science literacy**

A Glossary at the end of the Science Literacy Student Reader lists definitions for Core Vocabulary and selected Language of Instruction.

1. Plan ahead.

Determine your pacing to introduce the reading selections, check in with students on their progress, and discuss the reading content and writing exercise. If you are performing Science Literacy as a structured, weekly routine, you might implement a schedule like this:

- Monday: Designate a ten-minute period at the beginning of the week to introduce students to the Science Literacy Student Reader.
- Friday: Set aside time at the end of the week to facilitate a brief discussion about the reading.

2. Preview the assignment and set expectations. (Monday)

- Let students know that for the Science Literacy routine, they will read independently and then complete short writing assignments. The reading selections relate to topics they will be exploring in their Weather, Climate, and Water Cycling unit science investigations.
- The reading and writing will typically be completed outside of class (unless you have available class time to allocate).
- The first week's reading is a short introductory segment in the book, and there is no accompanying writing exercise as the unit is getting started.
- The class will discuss the reading together at the end of the week.

SUPPORT—The Preface about the weather app scenario is written at approximately Lexile 900–1050, which leans toward the middle of the expected text complexity band for middle school. You may wish to introduce a word identification and comprehension convention into your routine to support struggling readers. Hang an envelope near the door with the label, "When we talk about the next reading selection, I could use a little more help understanding the word(s). . . " Encourage students, as they are reading, to jot words, phrases, or sentences that they are unclear about onto small scraps of paper and tuck them into the envelope at any time preceding the discussion of the reading. Whenever you facilitate class discussion about a reading selection, check the envelope first, and layer in added examples and repeat definitions to help students build comprehension and fluency for terms or complex sentences about which they have revealed they are uncertain.

3. Facilitate discussion.

(FRIDAY)

Facilitate a brief class discussion about the Science Literacy Student Reader Preface, entitled "Put Yourself in This Scene."

Student Reader

Preface

SUPPORT—If you are using the recommended word envelope convention, check the envelope to see if it contains any words, phrases, or sentences that students need help understanding. Read key sentences aloud, and provide concise explanation.

Pages 2–3 **Suggested prompts**	**Sample student responses**
How would you summarize the "scene" referred to in the title?	*It's a story about some friends who like to meet at a local park or playground but who disagree on when to meet based on their different interpretations of the information on a weather app.*
When have you been in a situation in which you had to decide on doing an activity or not based on the weather forecast?	*deciding on which day to go to the beach, a bike ride, or a picnic* *deciding when to water outdoor plants* *deciding when to go to a storm shelter*
What questions should you ask Thea about her reasoning not to go to a basketball game?	*What is the probability of rain that would have made you comfortable to play basketball? Does it have to be 0%?* *Would you have been willing to come play at 6 p.m.?* *How accurate do you think your weather app is?* *What other factors than getting wet playing basketball affected your decision not to come?*
What does the percentage in each row in the image show?	*It tells you the chance of rain falling during that hour of the day.*

Pages 2–3 **Suggested prompts**	**Sample student responses**
If you want to learn more about how to interpret data from weather apps, what reliable sources could you use?	*Ask an Earth science teacher.* *Read articles in science magazines or newspapers.* *Ask a reference librarian for sources.* *Read the information about the app from the app company that made it.*
What if your parent or grandparent asked your advice about which weather app to use? How would you answer them?	*that I would read online reviews written by experts* *that I could make a chart with the pros and cons of each app* *that they could download free versions of a few apps and try each one out*
If you flip a coin, what is the chance you will get heads each time, expressed as a percentage?	*50%*
If the weather app says the chance of rain is 50%, is it going to rain?	*You don't know. You only know that it's about as likely not to rain as to rain.*
How useful is thinking about math to scientifically literate people? Why?	*very useful because much of the data from science is in the form of numbers*

KEY IDEA—Point out that predicting the weather is complex because of all the variables involved. Meteorologists collect data using satellites, radar, measurement instruments dropped from planes, ground weather stations, ocean buoys, ships, and aircraft. The huge amount of data collected is processed using powerful computers, called supercomputers. This allows weather apps to display and constantly update forecasts by the minute, by the hour, and up to two weeks in advance. Understanding how weather forecasting is done allows people to interpret and use the information presented on weather apps. Both the investigations and the reading selections in the unit ahead will help students advance to a place where they have more knowledge to apply to the scenario, and they will circle back to the topic of what weather apps can and cannot tell them at the end of the unit.

LESSON 1

What causes this kind of precipitation event to occur?

Previous Lesson *There is no previous lesson.*

This Lesson

Anchoring Phenomenon

3 DAYS

We observe three video clips of hail falling in different areas of the United States on different days. We develop a model to try to explain what causes this to occur. We develop questions for our Driving Question Board (DQB) about the mechanisms that cause different kinds of precipitation events. We brainstorm investigations we could do and sources of data that could help us figure out answers to our questions.

Next Lesson *We will analyze data from hail-related weather events, including hailstone images, hail maps, and weather data.*

Building Toward NGSS

MS-PS1-4, MS-ESS2-4, MS-ESS2-5, MS-ESS2-6

What Students Will Do

Develop an initial model to describe changes and mechanisms at both the observable and the particle level that cause hail to fall during a brief time period.

Ask questions that arise from careful observation of phenomena and gaps in our current models to clarify and seek additional information about how changes to the flow of matter and energy in the air above and around a location on Earth's surface could cause short-duration precipitation events and longer-duration precipitation events (scale).

What Students Will Figure Out

- Rain and wind accompany some hail events.
- Some of the water that reaches the ground reached a low enough temperature to freeze, at some point, before it fell.
- Clouds can be seen moving into and out of the area where it hailed.
- Cloud movement in the sky, moving air (wind) at Earth's surface, and temperature may be related to why, where, and when different forms of precipitation fall.

Lesson 1 • Learning Plan Snapshot

Part	Duration	Summary	Slide	Materials
1	22 min	**EXPLORE SOME STORM-RELATED PHENOMENA** Record and share noticings and wonderings from three video clips of hailstorms. Make predictions about what we might see going on in the sky before, during, and after these events.	A	chart paper, markers, computer and projector, hail videos (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**.)
2	7 min	**CREATE INITIAL MODELS** Create initial models to explain what caused the precipitation events seen in the videos.	B	*Initial Model*
3	8 min	**CONNECT TO PREVIOUS UNIT IDEAS** Review ideas developed in the Cup Design Unit that might be useful for representing particle-level differences in precipitation-related phenomena.	C	posters from the previous Cup Design Unit that summarize ways to represent what was happening to the matter and energy in the cup systems
4	8 min	**DEVELOP INITIAL MODELS** Develop a particle-level representation for three places above the ground and identify places where energy may be getting transferred into, through, or out of the system.	D	*Initial Model*, *Representing Particle-Level Changes in the System*, colored pencil or highlighter
				End of day 1
5	3 min	**TARGET A NORM TO FOCUS ON** Review the classroom norms and pick one norm to focus on for today.	E	classroom norms handout (to tape into new notebooks if needed), classroom norms poster
6	10 min	**COMPARE MODELS** Conduct a gallery walk to compare models.	F	*Initial Model*, *Representing Particle-Level Changes in the System*, Communicating in Scientific Ways poster or handouts
7	20 min	**DEVELOP AN INITIAL CONSENSUS MODEL** Convene a Scientists Circle to develop an initial consensus model.	G	Initial Consensus Model poster, markers, posters from the previous Cup Design Unit that summarize ways to represent what was happening to the matter and energy in the cup system
8	5 min	**DEVELOP INITIAL QUESTIONS** Record initial questions for the DQB and save them for sharing next period.	H	markers, sticky notes

Part	Duration	Summary	Slide	Materials
9	7 min	**IDENTIFY RELATED PHENOMENA AND REFLECT ON NORMS** Recall and record experiences with two different categories of related phenomena. Revisit individual focal norms.	I, J	chart paper, markers, sticky notes
				End of day 2
10	13 min	**SHARE RELATED PHENOMENA AND RECORD ADDITIONAL QUESTIONS** Share experiences with two different types of related phenomena and generate additional questions for the Driving Question Board.	K-M	chart paper, markers, sticky notes, Related Phenomena poster
11	20 min	**BUILD THE DRIVING QUESTION BOARD** Develop the DQB with contributions from all students in the class.	N	chart paper, scissors, markers, DQB
12	12 min	**DEVELOP IDEAS FOR FUTURE INVESTIGATIONS** Develop ideas for future investigations using contributions from all students in the class.	O	Ideas for Future Investigations and Data We Need poster, markers
				End of day 3

Lesson 1 • Materials List

	per student	per group	per class
Lesson materials **Student Procedure Guide** **Student Work Pages**	• science notebook • *Initial Model* • *Representing Particle-Level Changes in the System* • colored pencil or highlighter • classroom norms handout (to tape into new notebooks if needed)		• chart paper • markers • computer and projector • hail videos (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**) • posters from the previous Cup Design Unit that summarize ways to represent what was happening to the matter and energy in the cup systems • classroom norms poster • Communicating in Scientific Ways poster or handouts • Initial Consensus Model poster • sticky notes • Related Phenomena poster • scissors • DQB • Ideas for Future Investigations and Data We Need poster

Materials preparation (30 minutes)

Online Resources

Review teacher guide, slides, and teacher references or keys (if applicable).

Make copies of handouts and ensure sufficient copies of student references, readings, and procedures are available.

If students are working in new notebooks, you will want to provide them a new copy of the classroom norms (built together in previous units) to tape to the inside cover of their notebook.

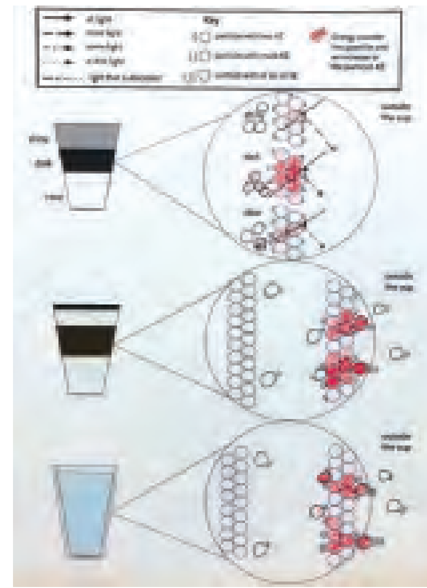
Test the three hail videos ahead of time. (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)

Prepare these posters ahead of time for each class: Related Phenomena, Ideas for Future Investigations and Data We Need, and Initial Consensus Model.

Use three pieces of chart paper to set up the Initial Consensus Model poster. It should have the title **“What causes this kind of precipitation event to occur?”** written above them. Label each piece of chart paper with the time period it represents, as shown in the diagram.

Prepare a driving question banner on a half-piece of poster paper with the driving question written on it, “Why does a lot of hail, rain, or snow fall at some times and not others?” This banner will be added over the DQB after it is completed.

Bring out any posters from the previous Cup Design Unit that summarize ways to represent what was happening to the matter and energy in the cup system. An example is shown here.



If you do not have these records from that unit, develop a diagrammatic representation of the Cup Design Unit’s main ideas for the class to refer to. Use the conventions you developed with your students for representing these ideas.

Download the Communicating in Scientific Ways file from the Online Resources and use it in your classroom as a poster or add it to students’ science notebooks as a handout.

Determine where to set up the DQB and other posters so students can gather around them. Near this space, post the classroom norms you developed with students in previous units.

Lesson 1 • Where We Are Going and NOT Going

Where We Are Going

In the first 13 lessons of this unit, students use ideas about how light interacts with matter to explain why surfaces on Earth warm up over the course of a sunny day. They will develop ideas about how the composition and spacing of molecules in the air change as it warms and cools, which can explain what causes the amount of water vapor in the air to change, what causes water to evaporate or condense to form precipitation, what causes some air to rise or sink, and what causes clouds to form. They will develop ideas to explain how differential heating of gases and liquids results in convection, which can explain what causes some surface winds, why precipitation doesn’t fall from every cloud, and why some storms produce hail and others do not. The need to develop these ideas will be established through the development of students’ questions at the end of this lesson and the investigation of these questions over the next twelve lessons.

In this first lesson, students identify potential causes for why hail forms, which likely include a location in the atmosphere (e.g., higher up) where the air is colder than the air near the ground. They will gather evidence for that idea in Lesson 2.

Students should come to this unit with prior knowledge from the Cup Design Unit related to these two NGSS performance expectations:

- MS-PS1-4: Develop a model that predicts and describes changes in particle motion, temperature, and state of a pure substance when thermal energy is added or removed.
- MS-PS4-2: Develop and use a model to describe that waves are reflected, absorbed, or transmitted through various materials.

Relevant ideas from previous work include these:

- Gases, liquids, and solids are made of particles.
- In a liquid, the particles are constantly in contact with each other; in a gas, they are widely spaced except when they happen to collide. In a solid, the particles are closely spaced and may vibrate in position without changing relative locations.
- Temperature is a measure of the average kinetic energy of particles of matter.
- Thermal energy can be transferred through particle collisions within an object or between two objects in contact with each other (via conduction).

Students may come to this unit with prior knowledge that air tends to be cooler the higher up they travel, based on experiences related to mountains and air travel. Some may think that the air should get warmer higher up because it is closer to the sun.

Students may think that a cloud is all gas, rather than a combination of gas and droplets or crystals. Alternatively, they may think of a cloud as something similar to a sponge—a solid that can absorb only so much water before it becomes saturated and starts overflowing with water, leading to precipitation.

In Lesson 14 students will explore an additional anchor phenomenon, a severe winter storm forecast, to motivate adding new questions to the Driving Question Board. In the lessons that come after this, students will explain why larger-scale and longer-duration precipitation events occur by developing and using a model for how midlatitude, low-pressure weather systems form and produce precipitation, particularly along frontal boundaries.

Where We Are NOT Going

An intentional effort is made in Lesson 1 to not refer to the hail events or related phenomena as “weather events.” This is to avoid having students generate questions about lightning and thunder, which will happen if the related phenomena conversation is framed too broadly. Instead, we use the terms “precipitation” and “other precipitation events” in this first lesson to help students generate relevant phenomena and questions about how precipitation forms, which is the goal of this unit. We anticipate students will generate many questions about how hail and thunderstorms form and a smaller set of questions about blizzards and hurricanes. Please avoid using the word “weather” until Lesson 2.

1. Explore some storm-related phenomena.

22 MIN

Materials: science notebook, chart paper, markers, computer and projector, hail videos (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)

Introduce the phenomenon. Say, *I have some videos that show a kind of perplexing phenomenon occurring outdoors that I want to explore together. Some of you may have experienced this phenomenon before. Let's get ready to explore this phenomenon by preparing our science notebooks.*

Present **slide A**. After preparing space to organize a new section in their notebook for this unit, have students make a two-column chart on the next available page to record their noticings and wonderings from the videos.

Say that the first video clip was recorded on April 7, 2013, in Fort Scott, Kansas. Tell them to make notes on their chart during and/or after you show the video.

Science Notebook

This is the first use of the science notebook for this new unit. You may need time to organize a new section in the notebook. It is recommended to have students do the following:

- Reserve a blank page at the start of the unit, to be titled on day 3 of this lesson when students are given the unit question.
- After the title page, reserve 2 pages (4 pages front-to-back) for the table of contents (unless all tables of contents are at the front of the notebook).
- Reserve 8 pages (16 pages front-to-back) for the Progress Tracker.
- Number the pages so everyone begins the first investigation on the same page number (e.g., page 1 for the first page of the table of contents, page 5 for the first page of the Progress Tracker, and page 21 for the first Notice and Wonder chart they are making now).

Remind students that the notebook is their tool for recording their observations, evidence, and ideas to share with the classroom community. They should see it as a space to brainstorm and record their thinking as well as a place to show how their thinking changes as they learn more.

Show the first hail video. Play the first hail video. (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**). Give students an additional minute to record their notes on their charts. Take about 3 minutes to have a few students share a few of the things they noticed with the class. Start a public record of what they share, using chart paper, the board, or a digital document. Don't worry about generating a comprehensive list when students report out what they noticed, as you can emphasize that you will ask them to report out additional noticings and wonderings again in a few minutes.

Emphasize that this kind of event doesn't occur all that often, but ask for a show of hands of students who have seen something like this before. At this point, it is likely that students will identify this event as hail.

*** Supporting Students in Developing and Using Scale, Proportion, and Quantity**

At this point in the unit, it is important to emphasize the relatively brief duration of a typical hailstorm compared to other precipitation events students may have experienced. Helping students notice this sets the stage for thinking about longer-duration precipitation events later in this lesson and explaining them in the second half of this unit. In Lesson 2, students will see the relatively small area that a hailstorm impacts. In the second half of the unit, they will make explicit comparisons between explanations for small-scale precipitation events (like hailstorms) vs. larger-scale precipitation events (like what is happening along frontal boundaries between mesoscale air masses).

Say, *Share with your partner any experiences you've had with hail and how your experience compared to what you saw in the video.* Give students a couple of minutes to do this.

Bring students back together, emphasizing that you have another video from a different time and place that produced different-sized pieces of hail than this one did. Tell students that this next video clip is of golf ball-sized hail that fell on October 5, 2010, in Phoenix, Arizona. Remind them to record what they notice and wonder about this event during and/or after you show the video.

Show the second hail video. Play the second hail video. (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**). Give students an additional minute to record their notes. Have a few students share these with the class. Add what they share to the public record you started after the first video.

Alternate Activity

To make this type of phenomenon even more locally relevant, you could search the internet for videos of hail in your state or region. It is recommended to only use video that foregrounds the falling of hail rather than the damage or impact after the event. The latter will generate questions that are better raised and addressed in the later Unit 6.5. If you find a video you want to add, show it after the second hail video and then end with the timelapse video. (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**).

Before starting the next video clip, tell students it is a time-lapse video from before, during, and after a hailstorm that produced smaller hail than the other two videos. Explain that this video was recorded on June 10, 2013, in Winnipeg, Manitoba, Canada, and is sped up 60 times, so each second in the video is equal to 1 minute of real time; therefore, though the video is only 99 seconds long, it represents 99 minutes of real time.

Show the third hail video. Play the third hail video. (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**). Give students an additional minute to record what they notice and wonder. Have students share these observations with the class, and add them to your public record.

Don't worry about generating a comprehensive list when students report out what they noticed. Here are some anticipated student observations:

- *It looked like big pieces of ice or snow were falling in all the videos, but the size of them looked different in each of the three cases.*
- *When it hit the ground, it bounced really high in the first and second videos. It made noise when it hit things in those videos.*
- *The plants in the area had green leaves (e.g., grass, flowers, trees).*
- *There was wind at some point in all of them. It was very strong in the second one (Arizona), and there was some in the first one (Kansas).*
- *There was rain at one point along with the hail in the second one (Arizona), and there was rain before the hail in the third one (Canada), and it looked like the ground was wet in the first one—maybe from previous rain.*
- *It seemed windy in the second video. And there was a moment in the third video when the tarp on the ground seemed to flap a lot.*
- *It didn't seem to last very long in all three cases.*

Additional Guidance

You may find that while they share what they noticed, some students will suggest initial explanations for why the hailstorm happened. As they do, say things like, *It sounds like you have some initial ideas about how or why this happened. This is a really interesting and strange phenomenon to try to explain. What you shared is helping me think of new questions. Remember, if something somebody says makes you think of a new question, jot it down in your notebook so you can look back at it later when we start building our DQB.* This helps transition the class back to focusing on what students noticed and the experiences they shared, rather than following up on any initial explanations that arose. It will help generate a sense of wonder and curiosity around what is happening and what might be causing it.

Define *precipitation*. Once students notice that it was both raining and hailing during the second video, introduce the word ***precipitation*** as a way to refer to any liquid or solid forms of water that fall to the ground from above, which can include hail, rain, sleet, or snow. Add the word to your word wall along with those examples.

Additional Guidance

Precipitation is a key reference word that you will use to help students think of certain kinds of related phenomena in later steps. That is why it is introduced here by the teacher, as a word that students "find out" rather than "earn" at this point in the unit.

If students don't bring up what they noticed happening in the sky before and after the hail fell in the third video, use these suggested prompts to help elicit that line of observations.

Suggested prompts	Sample student responses
Did you notice any changes in the sky before the hail fell in the third video?	*It was partly cloudy at first, and then it became completely overcast right before it rained and hailed.*
How were you able to see what was happening in the sky when the camera was pointed toward the front yard?	*You could see the clouds overhead in the reflection on the car windows.*
What patterns could you see in the movement of the clouds?	*It looked like they came in from one direction.*
Was anything happening in the sky after the hail fell?	*It cleared up afterwards (it became sunny).*
	The clouds overhead kept moving in the direction they were moving before the storm.

Students may want to watch the third video again to check observations that they didn't notice but others reported; if so, show the video again.

Additional Guidance

Seeing a reflected image in a window is another strange phenomenon. A window is typically thought of as something you can see through, rather than something that can also act like a mirror under certain conditions. Students investigated this as part of Unit 6.1: *Why do we sometimes see different things when looking at the same object?* (One-way Mirror Unit). If your students have completed this unit, you may want to point out that a part of the phenomenon in the video (the reflection in the car windows) is something they have already investigated and explained. If students have not completed this unit, don't take time to make that connection. **Describe the duration of hail events.** Emphasize that the sky appeared to remain cloud covered the entire length of the first two videos, but each video clip was also really short—the first was under a minute and the second was under 2 minutes. Tell students, *Though most hail events are quite brief and last just 5 to 10 minutes, the first two video clips didn't help us see what was happening before and after the hail fell.*

Emphasize that in the third video, however, we were able to use the reflected image in the car windows to see changes in the sky over a longer time before, during, and after the hail fell (99 minutes total).

2. Create initial models.

7 MIN

Materials: science notebook, *Initial Model*

Cue students to create their initial models. Present **slide B**. Read the directions on the slide aloud. Distribute a copy of *Initial Model* to each student. Ask students to wait before taping it into their notebooks. You will collect their models at the end of this class period for review and return them at the start of the next period, which is when they can add the handout to their notebooks.

Additional Guidance

Students may ask what kind of precipitation the handout is referring to. If they do, reference the definition and examples of precipitation on the word wall, and ask what types they saw in the videos. Emphasize that their model should account for each type they observed. Though hail is the most perplexing part of the precipitation event in the videos, students may have noticed other types of precipitation at the same time, such as rain.

Cue students to create their initial models by first representing what type of changes they saw happening outside before, during, and after the precipitation event.

Emphasize that the handout divides the event into three time points. Say something like, *Use the middle box to show what was happening above and around the place where the precipitation fell, at the time that it started falling. The box on the left is for showing what was happening above and around the place where the precipitation fell, but an hour beforehand. The box to the right is for showing what was happening an hour afterward.*

Provide additional guidance. The handout doesn't provide a scale for distance. Help students include their ideas about the scale in their model through prompts such as, *One thing to consider in your model is how big of a space you are trying to represent. So include labels and notes to show the distance between the place where things in the air are happening and the place where the precipitation fell (How high are the clouds? How high did this precipitation fall from?).**

*** Supporting Students in Developing and Using Scale, Proportion, and Quantity**

In the next few lessons, students will uncover data that will help them determine the relative scale of this weather event. This will include how big an area hail typically falls over, how big the clouds that produce hail grow, and how fast those clouds move over an area. This initial model provides an opportunity to get a sense of students' intuitions about the height of storm clouds. Students are unlikely to indicate that they picture those clouds having started elsewhere and moved from relatively far away (e.g., many miles) over the course of an hour.

Lastly, remind students that even though they are drawing what was happening at different points of time in each box, they can use arrows, symbols, and annotations to connect things between the boxes, to help show how things that happened an hour in the past caused the hail to form and fall when it did.

Emphasize that identifying what is causing the observed changes in their models can be the most challenging part, because we need to consider things that may be happening even though we can't see them. Remind students that a combination of written descriptions, labels, and diagrams helps make their thinking visible, both for themselves and for others. Ask them to write down any questions that come to mind as they work. Encourage students to use different-colored writing implements if it is helpful.

While students construct their models, walk around the room and quietly ask probing questions of students who have no written labels or descriptions on their models, to help them represent their thinking more clearly and elaborate upon their ideas.*

After giving students 8 minutes to do this, ask them to pause their individual work on this part of the model.

3. Connect to previous unit ideas.

8 MIN

Materials: posters from the previous Cup Design Unit that summarize ways to represent what was happening to the matter and energy in the cup systems

Connect to ideas developed in the Cup Design Unit. Say something like, *Today we explored a phenomenon where relatively big pieces of hail somehow formed and ended up falling from the sky. We also saw rain falling during the storm, and other interesting things were happening in the air, including changes in the wind and clouds overhead. So this phenomenon included things happening with both water and air. Those were two important parts of the systems we modeled and explained in our previous Cup Design Unit too. In that unit, we developed some useful ways to represent what was happening to the matter and energy in a system. Let's review those, so we can figure out whether they might be useful in explaining changes that would cause hail to form and fall.*

Additional Guidance

If your students didn't complete the Cup Design Unit but did complete one or more other units of study that covered the particle nature of matter, temperature, thermal energy, conduction, and light's interaction with matter, modify this framing in slide C to reflect those experiences.

Present **slide C**. Give students 3 minutes to discuss these questions with a partner. Then facilitate a short Consensus Discussion around the ideas students developed in that previous unit.*

Key Ideas

Purpose of this discussion:

- Summarize the conventions the class developed for representing the particles that make up different states of matter: in a gas, a liquid, and a solid.

* Supporting Students in Engaging in Developing and Using Models

Here are some additional prompts to help students create their initial models or make their ideas more explicit:

- *What did you draw in the air here? Can you label what that is? Can you explain how it got there?*
- *Where did this water come from? Can you label and explain that?*
- *What do these lines or arrows represent? Can you label them?*
- *It looks like you included the Sun in this box. How is it connected to the changes you're showing?*
- *It looks like you're showing something happening in the clouds. Can you describe what you think is happening to cause that?*
- *How far up do you picture this happening? Can you include a description or a scale to show that?*
- *How far away do you picture this happening an hour beforehand? Can you include a description or a scale to show that?*

- Summarize the different ways that energy can be transferred into and out of a system like a cup with liquid in it, how the class represented this in the past, and what happens to the particles in the system when this occurs.

Listen for these ideas:

- The particles in a gas, like air, are spread far apart, and the particles in a solid and a liquid are packed close together.
- Energy can be transferred through collisions between neighboring particles (conduction).
- Energy can enter a system when matter absorbs light shining on it (radiation).
- The particles of a substance move faster, on average, at higher temperatures and slower, on average, at lower temperatures.

4. Develop initial models. 8 MIN

Materials: science notebook, *Initial Model*, *Representing Particle-Level Changes in the System*, colored pencil or highlighter

Develop a particle-level representation for the initial models. Say something like, *Let's try to use those ideas about particles and energy to represent what we think is happening in the air and water above and around where the precipitation event occurred.*

Present **slide D**. Distribute a copy of *Representing Particle-Level Changes in the System* to each student. Take a minute to review the directions and answer any questions.

Have students complete their models on *Representing Particle-Level Changes in the System* and add annotations to *Initial Model* in a colored pencil or highlighter. During this time, walk around the room and quietly ask probing questions of students who have no written labels or descriptions representing energy on *Initial Model*, to help them make their thinking more visible on their papers.*

Collect students' copies of *Initial Model* and *Representing Particle-Level Changes in the System* to review before the next period.

Assessment Opportunity

This initial model collection will help you (1) get a sense of commonalities and differences across models and (2) plan for the consensus model discussion during day 2 by serving as an individual pre-assessment of student understanding.

End of day 1

5. Target a norm to focus on. 3 MIN

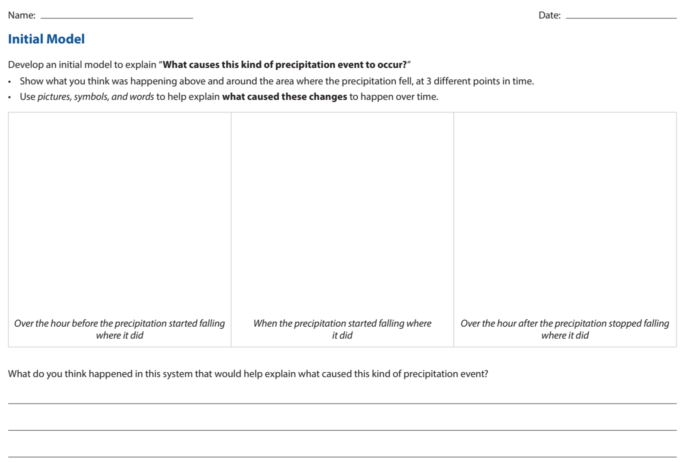
Materials: classroom norms handout (to tape into new notebooks if needed), science notebook, classroom norms poster

Choose a focal norm. Display **slide E**. Direct students to look over the classroom norms once more. If students are working in new science notebooks, provide them with a new copy of the norms to tape to the inside cover. If not, they can refer to the copy already in their notebook from the previous unit and/or the copy posted on the wall. Ask students to choose a norm to practice in class today.

*** Strategies for this Consensus Discussion**

This is considered a Consensus Discussion because the ideas being articulated were already developed in the Cup Design Unit. Since that unit would have been completed recently, reviewing these ideas should be easy. It is useful to have a public record of the ideas students are sharing to refer to throughout this lesson and later lessons. If you have these records from that unit, bring them out now. If not, develop a diagrammatic representation of the Cup Design Unit's main ideas for the class to refer to. A set of sample diagrams from that unit's Teacher Guide is provided here as a reference. Use the conventions you developed with your students for representing ideas in this discussion.

As students are doing this, give back their copies of *Initial Model* and *Representing Particle-Level Changes in the System* that you collected last time.



Name: ______________ Date: ______________

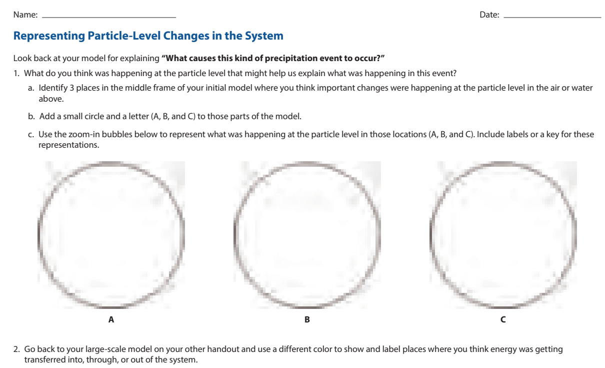
Initial Model

Develop an initial model to explain "**What causes this kind of precipitation event to occur?**"

- Show what you think was happening above and around the area where the precipitation fell, at 3 different points in time.
- Use *pictures, symbols, and words* to help explain **what caused these changes** to happen over time.

Over the hour before the precipitation started falling where it did	*When the precipitation started falling where it did*	*Over the hour after the precipitation stopped falling where it did*

What do you think happened in this system that would help explain what caused this kind of precipitation event?



Name: ______________ Date: ______________

Representing Particle-Level Changes in the System

Look back at your model for explaining "**What causes this kind of precipitation event to occur?**"

1. What do you think was happening at the particle level that might help us explain what was happening in this event?
   a. Identify 3 places in the middle frame of your initial model where you think important changes were happening at the particle level in the air or water above.
   b. Add a small circle and a letter (A, B, and C) to those parts of the model.
   c. Use the zoom-in bubbles below to represent what was happening at the particle level in those locations (A, B, and C). Include labels or a key for these representations.

A B C

2. Go back to your large-scale model on your other handout and use a different color to show and label places where you think energy was getting transferred into, through, or out of the system.

Additional Guidance

Evaluate how well your students did with the classroom norms in the previous unit. If they did well with some norms, celebrate that now. If they need additional work on others, focus their attention to those. As needed, spend additional time discussing the norms again and having students share (1) what a given norm would look like if everyone were following it and (2) what it would sound like.

* Supporting Students in Developing and Using Energy and Matter

Here are some additional prompts to help students develop their initial models or make their ideas about matter and energy more explicit:

- *Are you showing the particles in a gas here or in a solid or a liquid? Or in more than one state of matter? Can you label that?*
- *What do these arrows represent? Can you label them?*
- *Where in your model are you showing energy moving into, through, or out of the system? Can you explain the process or mechanism for how that might be happening?*

6. Compare models. 10 MIN

Materials: science notebook, *Initial Model*, *Representing Particle-Level Changes in the System*, Communicating in Scientific Ways poster or handouts

Prepare for a silent gallery walk. Show **slide F**. Read the slide aloud. Emphasize that everyone should be prepared to compare their own ideas to those they see other people using. Encourage students to linger on the models they see to read the written explanations on them fully. This may mean that each student only gets to a couple of models in the gallery walk, but that is OK.

Ask if there are any questions. Set the timer for 4 minutes and cue students to begin the gallery walk.

Discuss similarities and differences. When the timer goes off, have students pause where they are in the gallery walk. Instruct them to find one or two people nearest them to talk to. Have each student share an interesting similarity and difference they noticed across the models with their new shoulder partners.

7. Develop an initial consensus model.

20 MIN

Materials: science notebook, Initial Consensus Model poster, markers, posters from the previous Cup Design Unit that summarize ways to represent what was happening to the matter and energy in the cup system

Gather in a Scientists Circle. Present **slide G**. Tell students to bring their science notebooks and their handouts with them, along with chairs, to form a Scientists Circle.

Move the posters from the previous Cup Design Unit to be next to the Initial Consensus Model poster.

Scientists Circle

Your students may be familiar with the Scientists Circle from the previous unit. A Scientists Circle includes these important features:

- students sitting so they face one another to build a sense of shared mission and a community of learners working together
- celebrating progress toward answering students' questions and developing more complete explanations of phenomena
- focusing on where students need to go next and how they might go about the next steps in their work

Tell students, *Remember that the goal of this discussion is to figure out areas of agreement and disagreement between our initial models. Knowing where we agree and disagree will help us figure out more about what might be happening in this kind of phenomenon. We also want to use this time to practice using our classroom norms.**

Remind students of the sentence starters. Make certain a *Communicating in Scientific Ways* poster or handout is conveniently located for students to see.

Develop and record the consensus model. It is useful to develop a visual representation of areas of agreement and disagreement at this point. This is what you will capture in the initial consensus model, a public record of the parts or pathways of the system that students are certain about as well as those they are less certain about. A suggested plan for developing this model, along with example images showing its incremental co-construction, is provided below. Ensure that the model you develop with your students represents their shared thinking. Different classes may develop this model in a different order or way.

It will be easiest to start with establishing agreement around what we all saw in the air outside when the precipitation fell as well as what we saw during the hour beforehand and the hour afterward. Almost all student models will include these elements:

- a cloud or clouds moving over the place where the precipitation fell
- rain (liquid water) and hail (solid water) falling from above
- relatively clear skies overhead (and sunlight reaching the ground) before and after the hailstorm (seen in video 3)

*** Attending to Equity**

This is an important opportunity to emphasize that each individual has contributions to make to their community of learners. It is through differences in thinking that the class will grow their knowledge together. Throughout this unit, students will be asked to be open to sharing knowledge products that depict their current thinking and to be open to learning from classmates who share their knowledge too.

*** Strategies for This Consensus Discussion**

There are two goals of this discussion: (1) to continue to help students build the habit of sharing their initial ideas publicly and (2) to generate a variety of initial ideas about what is causing these precipitation events. As such, it is important to accept all student responses and encourage students to share their ideas. Further, it is important to highlight any areas of disagreement and help students clearly explicate their thinking. Be careful not to favorably respond to any one idea over others so as not to "give away" what might be going on.

Since the cloud is now a primary shared feature, focus on what we know about it and where it came from. Record these areas of controversy as they emerge:

- *Though we all showed a cloud, we aren't in agreement about its shape or size.*
- *We aren't in agreement (or aren't sure) about whether precipitation fell out of the cloud at a different location before it started falling over the location we saw in the videos.*
- *Though we know the cloud moved in over the place where it hailed, we don't know how far away it came from, nor whether it was the same shape or size before and after it arrived.*
- *Some of us showed water going into the cloud at some point before it fell out as precipitation. Others didn't. But, we all agree now that all that water must have gotten up into the cloud at some point.*

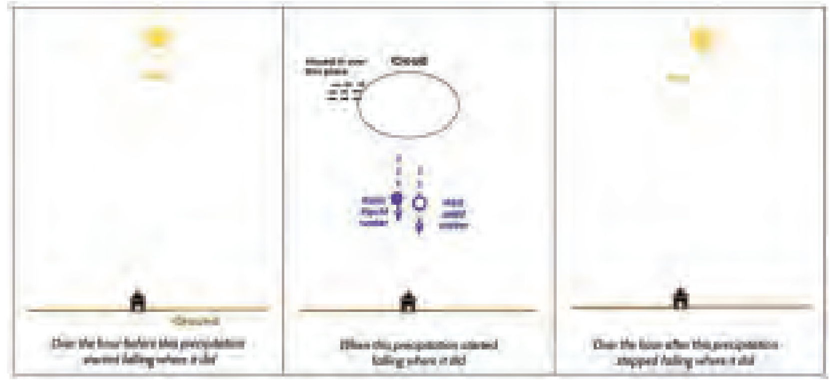
Help the class recognize and record areas of agreement and uncertainty around temperature in the system, including these:

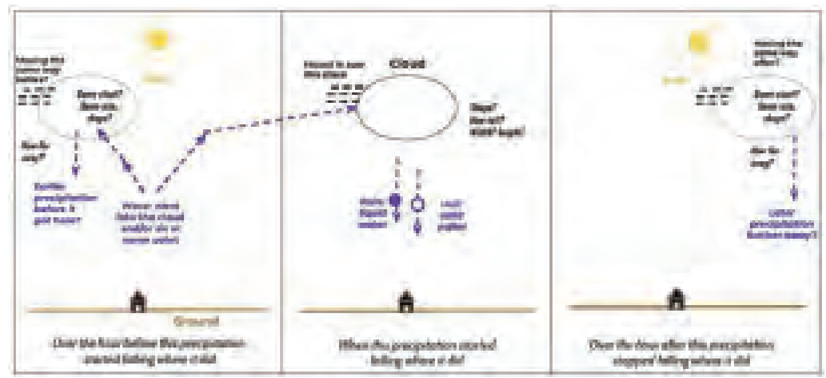
- *The temperature got cold enough somewhere in the system to freeze some of the water that fell.*
- *There must be temperature differences somewhere in the system because some of the water that fell was frozen and some wasn't.*

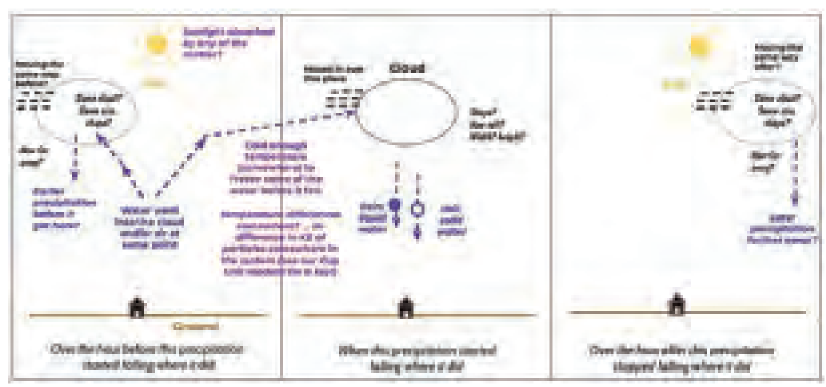
Emphasize that we have a way to represent temperature differences between a gas, liquid, or solid as differences in the average kinetic energy of the particles, based on our work in the Cup Design Unit. Post those representations from that unit next to this consensus model as a reference. They should include ideas identified earlier: the particles in a gas (like air) are spread far apart; the particles in a solid and a liquid are packed close together; and the particles of a substance move faster, on average, at higher temperatures and slower, on average, at lower temperatures.

Ask students about any places in their model where they thought energy might be getting transferred into, through, or out of the system. Remind students that this is what they added in a new color to their original model. Areas of agreement and uncertainty will likely include these:

- *We agree that light can be absorbed by matter (as in some systems in the Cup Design Unit), but we aren't in agreement about whether (or where) that was happening in this system.*
- *We aren't sure (or aren't in agreement) whether there were other ways energy was moving through or out of the system (e.g., conduction, wind, and so forth).*







If students noticed winds at the surface and agree on this, add that too.

Help the class recognize areas of disagreement or controversy around these issues:

- which direction the winds are going and whether that changes over time
- whether there is wind at the height of the clouds (or above them) and whether it is the same as wind at the surface

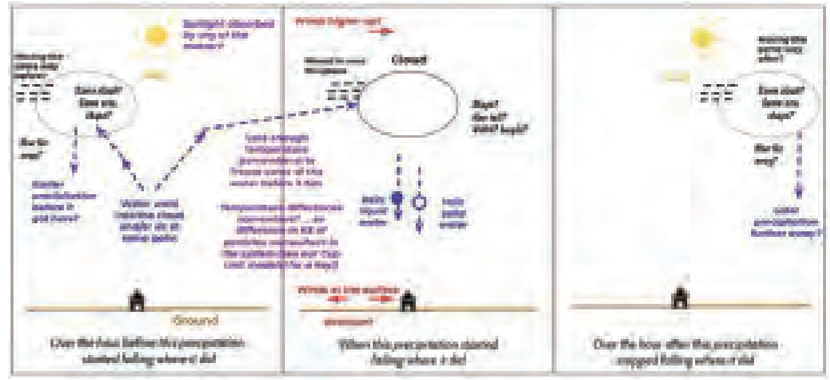
Lastly, emphasize that a cloud seems to be at the center of all the action in this system. Ask about what students showed happening in the cloud at the particle level. It is likely that some models did not show anything happening in the cloud, and there may be different ideas or controversy around models that did. Help the class recognize those areas we didn't all show or didn't all agree on.

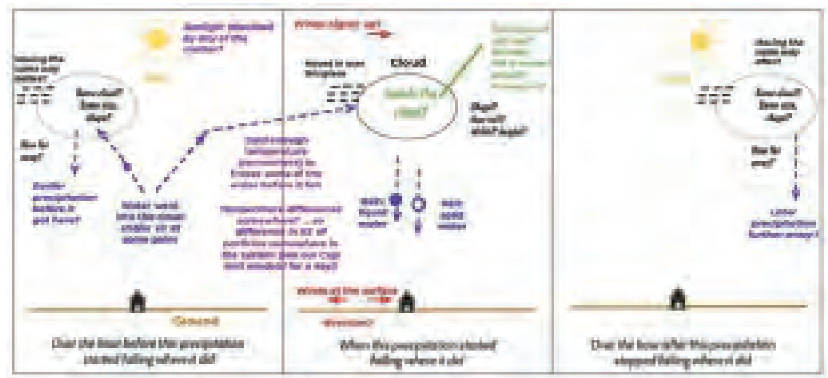
Cloud-related areas of controversy that you may hear students raise at this point will include things like these:

- *Does it fill up with water as it gets darker?*
- *Is there ice or liquid water in it?*
- *Is there water vapor in it?*
- *Does part of the cloud get heavier before the precipitation falls out?*
- *Is part of the cloud held up somehow?*
- *Is there air or wind moving inside the cloud?*

Record these areas of uncertainty as well. Include any additional ideas your class raises or is collectively unsure about, such as ideas related to humidity or pressure.

Save the Initial Consensus Model Poster to use as part of the background for the DQB on day 3.





8. Develop initial questions.

5 MIN

Materials: markers, sticky notes

Record initial questions. Make sure extra markers and sticky notes are provided for this part. Say, *Let's try to capture some of the questions we have about what is happening in this type of phenomenon.*

Present **slide H**. Read the directions on the slide aloud. Give students sticky notes and at least 4 minutes to generate questions. Encourage students to write more than one question, but only one per sticky note. Have students put their initials in pencil on the back of their questions and save them in the back of their science notebooks until next time.

9. Identify related phenomena and reflect on norms. 7 MIN

Materials: science notebook, chart paper, markers, sticky notes

Identify and record related experiences. Present **slide I**. If needed, refer back to the meaning of *precipitation* posted earlier (“liquid or solid forms of water that fall to the ground from above”).

Give students 3 minutes to record their related phenomena in their science notebooks. As students are doing this, prepare a two-sheet Related Phenomena poster, with these titles:

- Times when a lot of precipitation fell **in one place in a relatively short time** (minutes)
- Times when a lot of precipitation fell **continuously in one place over a much longer time**

Check in on the classroom norms. Ask a few students to share how the class did overall on it as a learning community on their norms. If time allows, use **slide J** to prompt collecting their thoughts on how each student feels they did on their chosen focal norm on a sticky note as an exit ticket.

End of day 2

10. Share related phenomena and record additional questions. 13 MIN

Materials: science notebook, chart paper, markers, sticky notes, Related Phenomena poster

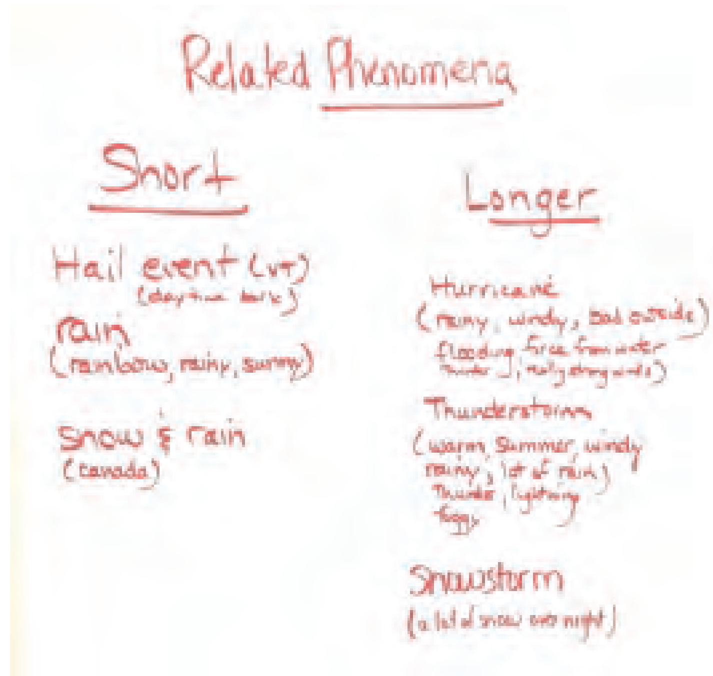
Share and record related experiences. Post the Related Phenomena poster. Present **slide K**. Take 6 minutes to have all students share out related phenomena from their notebooks and assign them to one of the two sheets on the chart.

Start off with the phenomenon everyone experienced—the hail events in the videos—and ask students where it should go. Students should assign it to the first poster (relatively short time). Write “The 3 hail events in the videos” on that poster.

As students share their examples, record them on the corresponding posters according to students’ suggestions. Related phenomena that students will likely share as “short” include severe thunderstorms. Related phenomena that students will share as “longer” include things like multi-hour or -day hurricanes, northeasters, blizzards, and drizzle.

If students aren’t sure where an example goes, you could add it between both posters with a question mark or with arrows pointing to both posters to indicate the uncertainty. Alternatively, you could write it on another sheet of chart paper.

With each example shared, ask for a show of hands of students who described a similar event in their science notebooks. Put tally marks showing the number of students next to that event on the poster, and have students put a check mark next to their own similar event if it gets written up on the poster. This will ensure everyone’s example is



represented on the posters and consolidate the overlapping examples. A sample poster from one class of students is shown here.

Connect mechanisms across related phenomena. Present **slide L**. Give students 3 minutes to discuss the question on this slide with a partner.

Record additional individual questions. Make sure extra markers and sticky notes are provided. Say, *Let's try to capture any additional questions we have about what is happening in these different precipitation events too, before we form our Driving Question Board.*

Present **slide M**. Give students at least 3 minutes to generate their questions on sticky notes. To prompt an array of questions, remind students to think carefully about the hail events in the videos in addition to other related phenomena. Encourage students to write more than one question, but only one question per sticky note, and put their initials in pencil on the back of each.

While students write questions, move the Related Phenomena poster to hang next to the Initial Consensus Model poster where all students can see it from a Scientists Circle. These posters together will serve as the space where students can add their questions to build their DQB, and will be referred to as the DQB in subsequent activities and lessons.

11. Build the Driving Question Board.

20 MIN

Materials: chart paper, scissors, markers, DQB

Gather in a Scientists Circle around the DQB. Present **slide N**. Have students bring their science notebooks and all of their sticky notes questions, including those from the last class period, along with a chair.

Remind students that our goal is to capture all our questions to build a DQB. Say something like, *It looks like you have a lot of really good questions about the hail storms in the videos and about other precipitation-related phenomena. It is important that we hear everybody's questions, and we might find that we have similar questions. To help us group similar questions, let's try to post each question on a spot on the Initial Consensus Model poster or on the Related Phenomena poster, or in between them.*

Review these steps for forming the DQB:

- The first student comes up to the DQB with a sticky note, faces the class, and remains standing.
- The student reads their question off the note and then posts it on the DQB near the section of the consensus model or related phenomena it is most related to.
- The student selects the next student whose hand is raised.
- The next student reads their question and posts it on the DQB. This student also says what other posted questions it relates to and explains why or how it relates.*
- The student then selects the next student whose hand is raised.*
- This process continues until everyone has had a chance to post a question.

*** Supporting Students in Engaging in Asking Questions and Defining Problems**

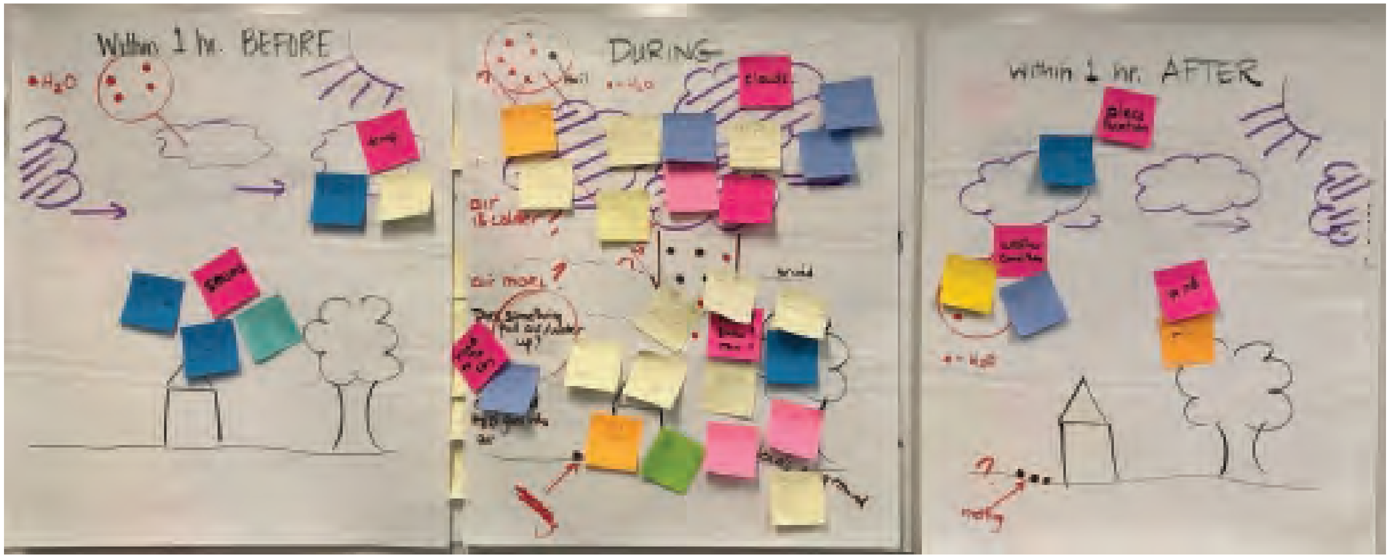
If students forget to explain how or why their questions are linked to someone else's question, press them to try to talk through their own thinking. This is a key way to emphasize the importance of listening to and building off each other's ideas, and to help scaffold student thinking.

Don't worry if some questions raised are not part of topics in this unit. Over time, with practice in this type of activity, students will get better and better at forming testable questions in the scope of the DQB.

- Remind students to keep track of whether their question was already asked, put a checkmark on that sticky note if it was, and then select a different question to share.

As students share, questions will naturally start clustering on certain parts of the DQB.

An example of one such DQB is shown here.



Once students have completed their sharing, ask them to identify the categories of questions, if time permits. Here are some possible examples of categories that are likely to emerge and the kinds of questions you will hear students raise related to each.

- **Hail:** How does hail form, why do different things (hail, snow, or rain) sometimes form in clouds, and what keeps them up there?
- **Wind:** Why is there a lot of wind in some storms?
- **Clouds:** What is going on in the clouds?
- **Snow and blizzards:** Where does the water come from in a blizzard (when it seems to be freezing cold), and how do blizzards form?
- **Hurricanes:** What causes hurricanes?
- **Rain:** Why does it rain heavily sometimes in some places and not in others?
- **Elevation and temperature:** How does the temperature higher up in the air compare to the air closer to the ground?

Point out that many of the questions are connected to how and why different types and amounts of precipitation do or do not occur. Suggest that including these questions under a single driving question could remind us of how the work on any one question is in the service of all our questions. Propose that **“Why does a lot of hail, rain, or snow fall at some times and not others?”** could be a single driving question that most of our questions could fit under.

If students can’t figure out which question to connect theirs to, encourage them to ask the class for help. After an idea is shared, ask the original presenter if there is agreement and why, and then post the question.

If a question is similar to (or the same as) another one, have the student place it on top of that question so other students can visualize how many questions are identical or related. Emphasize that this provides us with evidence of where many people are thinking about similar things.

*** Attending to Equity**

Having the student who volunteered and posted a question pick the next student to share (from those whose hands are raised) is a great way to turn over the pacing and cadence of this group work to the students. Reuse this technique in future Scientists Circles to encourage increased student agency in the classroom learning community. When you do this, take a seat with the students in the circle to position yourself as an equal member of the learning community who is listening, making sense of questions, and trying to figure this out. If you have questions you want to share with the group, raise your hand and wait for someone to call on you.

Once the class agrees to this, write it in large letters on a half-piece of chart paper and hang this banner over the top of the entire DQB. Remind students that we can revise this question as we continue to figure out new things in future lessons.

12. Develop ideas for future investigations.

12 MIN

Materials: Ideas for Future Investigations and Data We Need poster, markers

Brainstorm ideas for future investigations and useful data sets. Present **slide O**. Read the slide aloud. Give students 3 minutes to talk with a shoulder partner to generate ideas. You may want to encourage students to stand or stretch while they talk.

As students are doing this, hang the Ideas for Future Investigations and Data We Need poster right next to the DQB.

In the remaining 9 minutes, have students reconvene standing in a semi-circle around the Ideas for Future Investigations and Data We Need poster so all can see it.

Build the poster with students' ideas. Tell students you want everyone's ideas to be shared and represented on the poster. Say something like, *To make sure we have your ideas up here, I will pass a marker to the first person on the edge of the circle. That student should share one idea. I will write it up and number it. Once I've almost finished writing it, that student should pass the marker to the student next to them. The second student then shares an idea. If that idea is on the poster already, the student should say which idea it is and how it is similar. I will put a tally mark next to it. The marker is then passed and we continue until we have heard once from everyone in the class. If you have additional ideas that don't end up on the poster, feel free to raise your hand after the marker makes it all the way around the circle. If we run out of time, we'll pick up here in the next class. And if you think of new ideas as we go, feel free to jot them down. We should always be thinking of ways we can add to this list.*

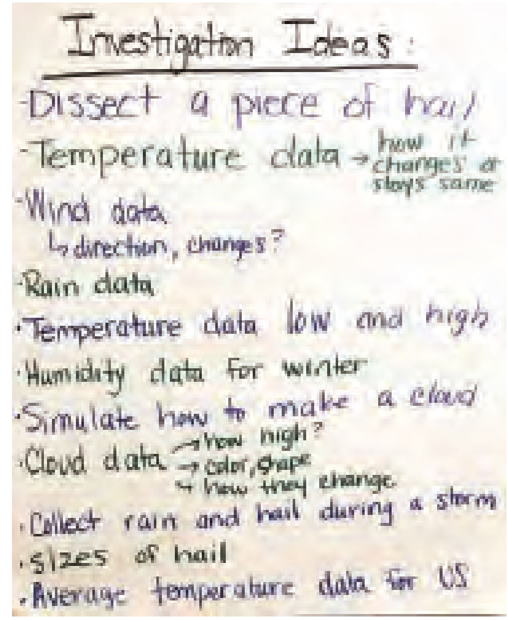
In large classes, you may run out of time before all students share out an idea. If needed, resuming this activity right where you left off is a natural point to launch Lesson 2.

A sample poster from one class of students is shown. Notice that most of the ideas that students suggested map closely to the data presented in Lessons 2 and 3. A few additional ideas are related to cloud data and simulating a cloud, which is more aligned to the investigations in Lesson 6 and beyond. This is the typical pattern we have seen in other classrooms. Though the ideas for the investigations in Lessons 4 and 5 will not be apparent at this point, students will suggest something similar when they start those lessons, during the navigation portion.

Celebrate the formation of a joint enterprise. Once this poster is built, celebrate that they created a joint mission and proposed action plan to guide the work of our learning community for weeks to come. Say something like, *Wow. We have accomplished so much. We now have a mission to accomplish as a class, thanks to all the questions you shared and how you connected them. These questions really represent what we hope to figure out. And we have a lot of ideas for investigations and data sources we can work with. I am very excited for us to start investigating all of these. I have lots of* *additional data and equipment for us to use that are well matched to the things you've said we need. Let's plan to start exploring some of this in our next lesson.*

Prioritize one set of ideas for investigations. If time permits, say something like, *I noticed many of our questions were about how hail formed. Explaining that could help explain other precipitation events too. One thing you all said was weird was that it looked like the hail fell in places where green stuff was growing and it looked warm, so we weren't sure how the water got cold enough to freeze and form hail. We wanted to know more about what it was like outside on these days when it hailed. We also thought it would be useful to look at hail more closely, for clues about how it formed. Let's plan to look at that sort of data next time. Let's start making some predictions beforehand. If you could take observations of both things, what do you expect you might find?* Give students a minute or two to turn and talk with a partner.

Collect students' unposted sticky note questions before they leave.



ADDITIONAL LESSON 1 TEACHER GUIDANCE

Supporting Students in Making Connections in ELA

CCSS.ELA-Literacy.SL.6.1.c: Pose and respond to specific questions with elaboration and detail by making comments that contribute to the topic, text, or issue under discussion.

While the class is building the Driving Question Board, if a student forgets to explain why or how their question is linked to someone else's, press that student to talk through their own thinking. This is a key way to emphasize the importance of listening to and building off one another's ideas, and to help scaffold student thinking. If students can't figure out which question to connect theirs to, encourage them to ask the class for help. After an idea is shared, ask the original presenter if there is agreement and why, and then post the question.

This lesson's activities rely on students communicating and articulating their thinking. One tool that supports classroom discussion is the Communicating in Scientific Ways sentence starters. This 1-page document can be enlarged and printed as a class poster, printed on 8.5-×-11 paper and posted near students' desks, and/or scaled down and taped into students' science notebooks. Reference the sentence starters and encourage students to use them. The sentence starters can be especially useful for helping students engage in scientific talk, particularly students who may feel reluctant to contribute.

LESSON 2

What are the conditions like on days when it hails?

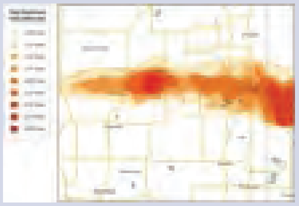
Previous Lesson

We observed three video clips of hail falling in different areas of the United States on different days. We developed a model to try to explain what causes this kind of precipitation event to occur. We developed questions for our Driving Question Board (DQB) and brainstormed ways we could investigate our questions.

This Lesson

Investigation

1.5 DAYS



We examine photos of hailstones and analyze and interpret data from cases of hail events at different locations and times of year to notice patterns and identify relevant factors that might explain the formation of hail.

Next Lesson

We will analyze temperature profile data for different altitudes of the atmosphere at a variety of locations during different times of the year. We will develop a consensus model for representing the motion of the molecules that make up air at different temperatures.

Building Toward NGSS

MS-PS1-4, MS-ESS2-4, MS-ESS2-5, MS-ESS2-6

What Students Will Do

Analyze and interpret data using graphical displays (e.g., maps, charts, graphs, tables) of large data sets to identify temporal and spatial patterns in the range of weather conditions that lead to the formation of precipitation (hail).

What Students Will Figure Out

- Hailstones are made of ice, often in layers.
- Hailstorms are more common in the central United States, with fewer events in the west.
- The days that have hail also have relatively warm air temperatures (mostly in the 50–90°F range, which is above the melting/freezing point of water) and relative humidity in the range of 37–96 percent. There are changes in the wind when it hails.
- Hailstorms happens later in the day in the spring, summer, and fall. They impact a small area (20–60 square miles).

Lesson 2 • Learning Plan Snapshot

Part	Duration	Summary	Slide	Materials
1	3 min	**NAVIGATION** Review ideas for data to collect before, during, and after a hail event.	A	
2	8 min	**OBSERVE HAILSTONES** Observe and identify patterns of hailstones using images.	B-D	*Hailstone Images*, chart paper, markers
3	12 min	**ANALYZE HAIL FREQUENCY MAP DATA** Analyze and interpret a map showing the frequency of occurrences of hail in the United States.	E, F	*Hail Frequency Map*, tape, chart paper, markers, computer and projector, whiteboard (optional)
4	10 min	**ANALYZE AN EXAMPLE HAILSTORM CASE** Students analyze a hailstorm case in preparation for analyzing other cases independently.	G-J	*Weather Data for Fort Scott*, chart paper, markers, computer and projector, whiteboard (optional)
5	14 min	**ANALYZE HAILSTORM CASES IN PARTNERS** Analyze hailstorm case data with a partner, compare with another pair, and complete an exit ticket.	K-M	*Weather Data from Seven Hailstorm Sites*
				End of day 1
6	2 min	**NAVIGATION** Share one pattern students have noticed so far.	N	
7	15 min	**CONDUCT A BUILDING UNDERSTANDINGS DISCUSSION ABOUT IDENTIFYING PATTERNS IN HAILSTORM CASES** Work together to compare hailstorm cases to identify patterns.	O-Q	*Weather Data from Seven Hailstorm Sites*, chart paper, markers
8	5 min	**ADD TO OUR PROGRESS TRACKERS** Record what we have figured out about the conditions on days when it hails in our individual Progress Trackers.	R	
9	2 min	**NAVIGATION (OPTIONAL)** Discuss initial ideas about how hail formed even though the air temperature near the ground was warm.	S	
				End of day 2

Lesson 2 • Materials List

	per student	per group	per class
Lesson materials **Student Procedure Guide** **Student Work Pages**	• science notebook • *Hailstone Images* • *Hail Frequency Map* • tape • *Weather Data for Fort Scott*	• *Weather Data from Seven Hailstorm Sites*	• chart paper • markers • computer and projector • whiteboard (optional)

Materials preparation

Online Resources

Review teacher guide, slides, and teacher references or keys (if applicable).

Make copies of handouts and ensure sufficient copies of student references, readings, and procedures are available.

Make 1 copy of *Hail Frequency Map* for each student.

Make 1 single-sided copy of *Weather Data for Fort Scott* for each student.

Make 1 single-sided copy of *Weather Data from Seven Hailstorm Sites* for every 7 students. For example, if you have a class of 28 students, make 4 copies of this document, thereby producing 4 copies of each hailstorm case (A-G). Each student will get 2 pages for their case.

Lesson 2 • Where We Are Going and NOT Going

Where We Are Going

This lesson introduces weather data. By the end of 5th grade, students should know that weather is the minute-by-minute or day-by-day variation in the atmosphere's condition on a local scale. In this lesson students begin to analyze data for some of the conditions of the atmosphere.

Part of that weather data, temperature, is connected to a molecular model that students will revisit in Lesson 3. Hailstorms tend to form on days when thermal energy transfer from the ground leads to relatively warm air temperature at the surface (i.e., in the 50–80°F range, which is above the freezing/melting point of water), as students see in the weather data. Students will start to develop ideas around the role of thermal energy transfer as a mechanism in hailstorm formation in Lesson 5. The role of temperature and its connection to state changes of water will be developed beginning in Lesson 7.

Students also see that the days that had hail had relative humidity within 53–94 percent around the time of the hail event. Relative humidity and its relationship to the amount of water in the air will be qualitatively introduced in Lesson 6.

Both temperature and humidity data, along with wind data presented in this lesson, lay the groundwork for developing ideas related to air masses and how they move and cause weather, which will be addressed later in the unit.

Hailstones are made of ice, often in layers. Students will explain how these layers form toward the end of the unit.

Hailstorms are relatively short in duration and isolated in impact. The weather data examined in this lesson are gathered from weather stations in the vicinity of the hailstorm. Because of a hailstorm's relatively small area, we are often limited to analyzing data in the vicinity of a hailstorm rather than under the center of it. Analyzing weather changes under the center of much larger-scale weather events (e.g., along fronts for larger air masses with uniform properties) reveals additional changes in weather conditions (e.g., pressure) that help to predict and explain how those types of phenomena occur; this will be addressed in the second half of the unit.

The second part of this lesson engages students in analyzing relatively complex data sets (after they have analyzed hailstone images). Students are given a table of weather data spanning an entire day, along with a map showing the accumulated precipitation over a region on that day. Evaluating both together requires students to look for and interpret temporal and spatial patterns. Additional complexity in this data comes from the presence of multiple variables (columns) in the table as well as the absence of some data (e.g., time of the storm) for some sites. Though students have previously seen such complexity in data tables from Unit 6.2: *How can containers keep stuff from warming up or cooling down?* (Cup Design Unit), this data set includes greater complexity because the weather data for each site do not start at exactly the same time of day, nor are they measured at the same time increments.

This complexity is by design, as a focal practice of this unit is supporting and developing students' literacy in data analysis and interpretation. By the end of the unit, students will need to be able to analyze data sets to find patterns across weather events over bigger areas and longer periods of time. This gradual increase in scale and data complexity will continue into their next unit of study (Unit 6.4: *How and why does Earth's surface change?* [Everest Unit]). But, remember that students have already had numerous experiences in analyzing data tables for patterns in the Cup Design Unit. See this lesson as the next step in a learning progression toward fluency in data analysis, particularly related to these two elements in Appendix F of NGSS:

- Use graphical displays (e.g., maps, charts, graphs, and/or tables) of large data sets to identify temporal and spatial relationships.
- Analyze and interpret data to determine similarities and differences in findings.

Where We Are NOT Going

Though the melting/freezing point of water can vary slightly based on the elevation at which it is measured (due to changes in the pressure of the surrounding atmosphere), a melting/freezing point of 32°F (0°C) is introduced as a relatively fixed and known value for both the temperature at which frozen water starts to melt when thermal energy is added to it and the temperature at which liquid water starts to freeze when thermal energy is removed from it.

LEARNING PLAN FOR LESSON 2

1. Navigation

3 MIN

Materials: None

Review previously generated ideas for next steps. Present **slide A** and remind students, *In the last lesson, we observed and tried to explain a hailstorm and other long-term and short-term precipitation events. We had a lot of questions about what hail is like and what the conditions are like during a hailstorm. We also came up with some ideas for investigating some of those questions.*

Have students turn and talk and then share their ideas. Use the suggested prompts to help students recall their ideas for investigating questions about hail and hailstorms.

Suggested prompt	Sample student responses
If you were at a spot where you knew a hailstorm was going to occur, what are some types of data you would want to collect before, during, and after the event to try to figure out what conditions lead to a hailstorm?	• *We would want to examine hail samples to see what the hail looks like.* • *We would want to know the area that was affected, maybe by looking at maps. Maybe the maps could help us figure out where hail falls so we can see what the conditions are like there.* • *We would want to collect weather data such as temperature and wind speed during the hailstorm.*

Tell students that you have some of this information pooled from several different cases of when hail fell.

2. Observe hailstones.

8 MIN

Materials: science notebook, *Hailstone Images*, chart paper, markers

Introduce the hailstone images. Present **slide B**. Explain that though you don't have a direct source for shipping hailstones to your class, you do have some hailstone images from different hailstorms for students to examine—some showing the outside and some showing hailstones cut in half.

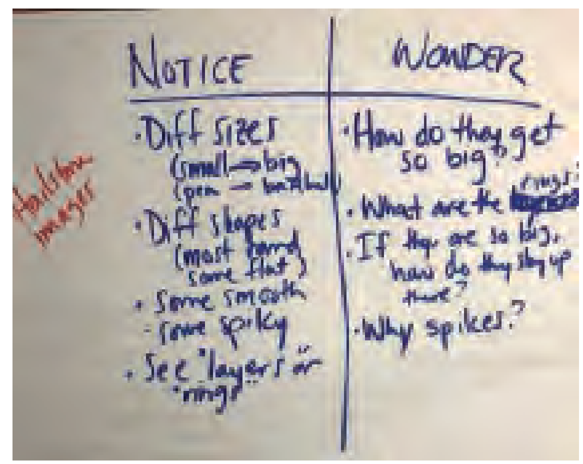
Examine the images and make observations. Have students write the heading "Hailstone Observations" on a new notebook page and create a two-column Notice and Wonder chart below that heading. Present **slide C** and refer students to *Hailstone Images* in the Student Edition. Give students 4 minutes to record their observations.

Make sense of the images. Present **slide D** and lead a whole-class discussion. You may want to go back to **slide C** as you discuss the patterns. Capture any questions on a class questions chart that you can add to as you work through other data sources in this lesson.

Suggested prompts	Sample student responses	Follow-up questions
What are some patterns you noticed as you examined the hailstone images?	• *Some are smooth and some are spiky on the surface.* • *They range in size from the size of peas to the size of baseballs.* • *The larger ones have (3-4) rings and look like solid ice throughout their insides.*	*Where in the images did you see that?* *Can you say more about the ways in which the hailstones looked similar? Different?* *Does anyone agree or disagree? Why?*
What ideas do you have about how hailstones are produced?	• *Maybe they have to be up there longer to get really big?* • *They must freeze up there because they look like ice.* • *Maybe they form in stages, because of the rings.*	*How do these ideas compare to the ideas you shared in Lesson 1?* *Does this provide any evidence to support your earlier ideas?*
What questions does this raise for you?	• *I don't get why some are spiky and some are smooth.* • *Why don't they melt on the way down?* • *How could they be different sizes?*	*What else could we do or look at to figure out more?*

Transition to the other data sources that students suggested using in the navigation section of this lesson.

Say, *OK, so comparing images of different hailstones helped us see specific similarities and differences. This raised more questions. Comparing several cases is a really useful approach when trying to figure out how things work. It can help us see patterns we may not see in a single case. Let's do that again, but for some of the other data you asked for—weather conditions before, after, and during the hailstorm.*



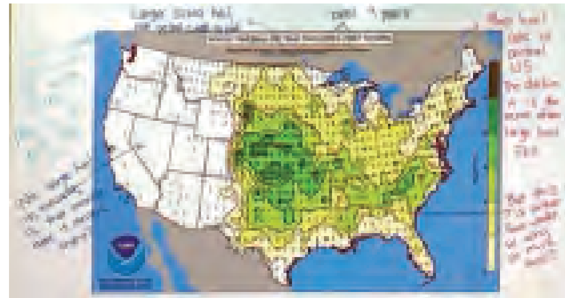
3. Analyze hail frequency map data.

12 MIN

Materials: science notebook, *Hail Frequency Map*, tape, chart paper, markers, computer and projector, whiteboard (optional)

Present the map. Distribute the *Hail Frequency Map* and project **slide E**. Say, *This map might be useful as we try to answer some of our questions.*

Ask students to tape the *Hail Frequency Map* into their notebook and make a two-column chart on the opposite page, with the column headings "Patterns" and "Questions".



Point out the map features.* Project **slide F**. If possible, project it on a whiteboard where you can annotate features of the map that will help students make sense of the data. Use the prompts below and encourage students to annotate their copy of the map.

Suggested prompts	Sample student responses
What is this a map of? What does the title of the map tell us about what it shows?	*Severe hail days per year.*
What does it mean by "severe"?	*It says "inch + hail," so big hail—not pellet-sized.*
What else does the title tell us about these data?	*How many storms per year.*
	It shows hail over 9 years.
What do the little numbers mean?	*They show how many days in a year had severe hail.*
What do you think the darker and lighter parts on the map mean? How do you know?	*Darker means there are more severe hail days in that location. Lighter means there are fewer.*
	The green bar on the side shows us.
As an example, can you point out an area where you think there's a lot of hail?	*Right in the middle, like in Kansas, there is a bunch of dark green.*

Analyze the map and record patterns and questions.* Ask students to spend 3–4 minutes individually analyzing the map, recording any patterns they notice and questions these patterns raise.

Discuss patterns and questions. After students have worked on their own, spend about 5 minutes as a class having them share out patterns they saw in the data. Use the prompts below. As students share, encourage them by saying, *Record questions that come up as we encounter observations we can't fully explain.* One way to share and record ideas during this discussion is to continue projecting the map on a whiteboard and annotating around it.

*** Supporting Students in Engaging in Analyzing and Interpreting Data**
The ways in which data are represented can help students notice patterns. However, students need to understand the data that are represented in the map before they can identify those patterns. Prompting students to explain the map features and annotating them as a class will support their sensemaking and ability to identify patterns in the data.

*** Supporting Students in Developing and Using Patterns**
Noticing patterns can lead to questions about how and why these patterns occur. For example, why do centrally located states have more hail? What are the conditions there or on any day when there is hail? Encourage students to record questions that arise, while you capture those questions on a class chart and/or Driving Question Board.

Suggested prompts	Sample student responses
What are some patterns you noticed as you examined the hail map?	• *There are more days of hail in the middle of the country.* • *There aren't very many days of hail on the west coast, particularly near the ocean.* • *Some places have a lot of hail (more than 13 days).*
What new ideas or questions does this raise about hailstorms?	• *Do places like California have hail? Is it just smaller, so it didn't show up on the map?* • *Why do centrally located states have more hail? Maybe something about the conditions in the middle of the country makes hail more common?* • *What are conditions like on the days when there is hail?*

Transition to the hail weather data. Say, *So, maybe if we zoomed in on some of these locations we could find out more about what is going on when hailstorms happen.*

4. Analyze an example hailstorm case.

10 MIN

Materials: *Weather Data for Fort Scott*, science notebook, chart paper, markers, computer and projector, whiteboard (optional)

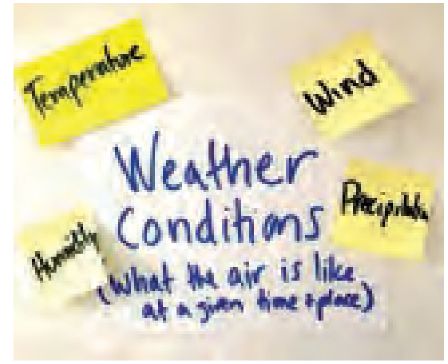
Orient to the weather data. Present **slide G**. Tell students, *We have weather data from eight sites where hail hit, shown in the map on the right. We saw three of these storms in the videos.*

Direct students' attention to the photograph of the weather station on the slide. Explain that near each of the eight sites is a weather station that measures weather conditions. Lead a short discussion, using the prompts below, about what is meant by "weather" and "weather conditions".

Suggested prompts	Sample student responses
How have you heard the word "condition" used before?	*"Condition" is what something is like.*
For example, if we were describing this (textbook, desk, other item), what words would you use to describe its condition?	*We could describe the condition as new, old, scratched, and so forth.*
When weather people talk about weather conditions, they focus on specific measurements about the air. What are some common weather measurements you have heard of that might be measured at this weather station?	*Temperature* *Wind* *Rain (precipitation)*

Say, *All these conditions together make up our weather in a particular place at any given point in time. So, when we talk about weather conditions* ***we mean what the air is like at a given time in terms of things like the temperature, how windy it might be, how humid it is, and other factors***.

Additional Guidance



By the end of 5th grade, students should know that weather is the minute-by-minute or day-by-day variation in the atmosphere's condition on a local scale. In this lesson students begin to analyze data for some of the conditions of the atmosphere. You may want to start a word wall and add examples of data about the atmosphere that are used to describe weather as in this unit.

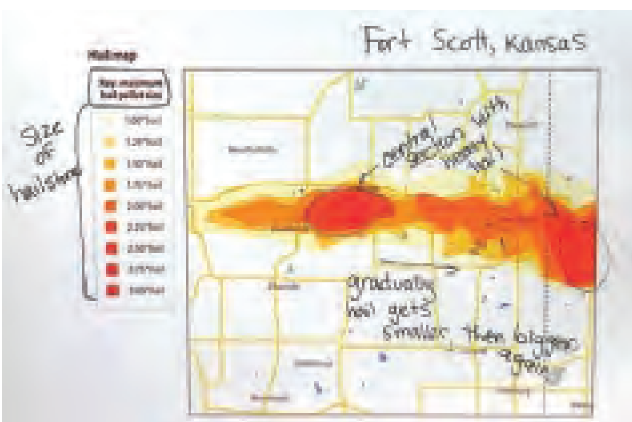
Refer again to the weather station on the slide. Explain that the devices used to measure the air must be suspended in the air. The image shows a typical example of a station with instruments mounted on it to keep them off the ground.

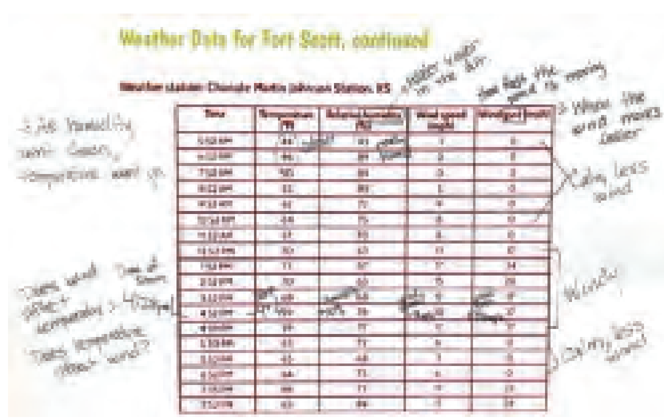
Analyze a hailstorm case together. Project **slide H**. Explain that each of the eight sites has a case file containing four things:

- a map of the United States showing the location of the case (and the other cases)
- a zoomed-in map showing the area impacted by hail
- when the event happened
- the weather data from a weather station at a nearby location

Say, *We will analyze these data to help us identify patterns in the location, timing, and conditions of several hailstorm events*. Ask students to write the question, **"What patterns do we notice in the location, scale, timing, and weather conditions during hailstorms?"** on the next page in their notebooks.

Go through the Fort Scott case together to help students identify the available information, and ask them for possible observations. Record these observations on a chart so groups can later compare their own cases to these initial observations to identify patterns. As previously, it is helpful to project the map on a whiteboard and annotate around it to share and record ideas, as in these examples:





Analyze the zoomed-in map of Fort Scott, KS. Present **slide I**. Say, *Let's look first at one of the cases we saw in the videos*. Distribute the handout *Weather Data for Fort Scott* to each student and project the zoomed-in map of Fort Scott, KS. Help students interpret the representation by posing questions such as, *What do the different colors mean?*

Tell students to individually draw an arrow to something they notice and then write what they notice on their handout, as directed by the slide. Ask for a few responses and record their ideas on chart paper or the whiteboard projection. Listen for student responses such as, *It seems like streaks instead of one big blob. Some parts are darker than other parts*.

Analyze the data table for Fort Scott, KS. Present **slide J**. With the class, model making observations about the weather data for a particular site.

Help students make sense of the weather data in the case file.

- On the data table, ask students to put a mark next to the time the hail event started.
- Examine row 1 of the data table and discuss what each item means. Annotate the projected table as you discuss.

Ask pairs to identify one thing they notice about the time of day or conditions (temperature and humidity) when hail occurred, as directed by the slide. Have pairs share out one or two observations as you record them on the observations chart or whiteboard.

Listen for these student responses:

- *The hail happened in the afternoon.*
- *It was warm that day (above 75°F).*
- *The wind changed. There were big wind gusts around the time of the hail.*
- *Humidity was pretty high.*
- If students don't mention it, ask about when the storm happened: e.g., *It happened in the afternoon. It happened in the spring.*

Additional Guidance

Students may note that these data are from 2012-2013 and be concerned that it is not more current. The years in which the hailstorm data were collected do not impact its relevance to our question of figuring out what conditions are like on a typical day when it hails. Complete and accurate data sets are more important in this case than having more recent data. However, having more recent data might help to validate our models about what conditions are necessary for hail to form.

5. Analyze hailstorm cases in partners. 14 MIN

Materials: *Weather Data from Seven Hailstorm Sites*

Analyze cases in partners. Present **slide K** and have students group in partners. Distribute the case files from *Weather Data from Seven Hailstorm Sites* and have partners identify patterns in their assigned case by marking and writing what they notice on the map and weather data tables. Give students 8–10 minutes for the task.

Share observations with another pair. Project **slide L**. After pairs have had a chance to annotate their data, have them share their observations with another pair. Ask students to listen for similarities and differences between the cases as they share.

Introduce exit ticket. Project **slide M**. Ask students to individually record patterns they are starting to see between the cases: one regarding the location of hailstorms and one regarding the timing or conditions needed for hailstorms to occur. They can record these on a sheet of paper or index card to turn in.

End of day 1

> **Attending to Equity**
> Cases A and G are somewhat more complex because in one case there are two hailstorm events and in one case the time of the hailstorm is unknown. As an opportunity for differentiation, you can provide these cases to students who may benefit from the extra challenge.

6. Navigation

2 MIN

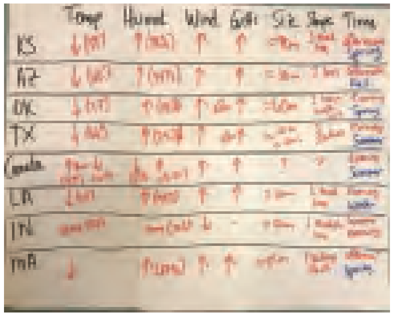
Materials: None

Turn and talk. Show **slide N**. Ask students to discuss with their partner 1 pattern they have noticed so far regarding the location, timing, or conditions of a hailstorm.

7. Conduct a Building Understandings Discussion about identifying patterns in hailstorm cases.

15 MIN

Materials: science notebook, *Weather Data from Seven Hailstorm Sites*, chart paper, markers



Gather in a Scientists Circle. Project **slide O** and have students bring their science notebooks and chairs to the circle.

Compile observations.* Ask the student pairs to share what they noticed in their data. Project **slide P**. Record their data observations for each site on chart paper or a spreadsheet so students can then identify patterns across the large data set. Add columns for anything else that students identify as important in the data.

> *** Supporting Students in Engaging in Analyzing and Interpreting Data**
> Scientists use a range of approaches and tools to derive meaning from data. In this lesson, one approach to making sense of the large amounts of data shown across the eight sites is the use of a summary table that lines up the findings from each site side by side first to compare key categories and changes in values across sites. Such a tool often helps scientists see larger patterns and outliers that would not be apparent by comparing the data from only one case to another.

Supporting Students in Making Connections in Math

Ask students to summarize or describe what a typical (average) humidity or temperature value is when hail occurs, or otherwise ask students to look for centers (averages, typical values) as well as variability within the data. Drawing patterns from typical values supports the practice of using measures of center (even if we're not calculating them) to find patterns within data.

Examine the compiled data. Give students 2 minutes to silently examine the compiled data on the class chart for any patterns they see across the sites.

Discuss patterns. Project **slide Q**. Lead a class discussion using the prompts below. Make another class chart and record patterns students agree on.

Key Ideas

Purpose of the discussion:

- Identify patterns in the location, scale, timing, and weather conditions that can help us determine what most hail events have in common.

Listen for these ideas:

- Location and scale
  - Hailstorms happen more often in the Midwest.
  - Hailstorms appear to happen in “lines”.
  - Hailstorms impact relatively small areas (20-60 square miles).
  - Hailstorms are relatively short (10-30 minutes).
- Timing
  - Hail is less common in the winter months.
  - Hail happens later in the day.
- Weather conditions
  - The temperature is relatively warm (above 50°F) on days when it hails.
  - Humidity is relatively high when it hails.
  - The humidity goes up and the temperature goes down around the time of a hailstorm.
  - There are changes in wind when it hails.

Suggested prompts	Sample student responses	Follow-up questions
What was one pattern you noticed in the location, scale, timing, and weather conditions that lead to the formation of hail?	*They come in a line and don’t cover a very big area.*	*Can you show us where you see that in our data?* *Do others agree?* *Did others say that idea in a different way?*
What about the duration?	*They don’t last that long.*	*Has anyone experienced a storm that is short like that?*
What does the pattern of data lead you to conclude about the timing of hailstorms?	*They happen later in the day—in the afternoon or evening.*	*Can you give us some examples from the data that support that pattern?* *What else can you say about when hailstorms happen?*

Suggested prompts	Sample student responses	Follow-up questions
What patterns do you observe in the data about the weather conditions around the time of a hailstorm?	*It was pretty warm.*	*Do others agree?* *What other patterns did you notice about temperature?*
What other patterns do you observe in the data about the weather conditions?	*The humidity was kind of high.*	*What is humidity?* *What does it feel like when someone says, "It's really humid out?"* *What can we say about the humidity when there is hail?*
Any other patterns?	*The wind increased and there were bigger gusts right around the time of the storm.*	

Supporting Students in Making Connections in Math

It is also helpful to discuss the outliers in the data, an important skill in both math and science. Students develop the concept of outliers and quantitative measures of central tendency for what is typical in a data set in their work in CCS in math in 6th grade. Help students recognize that one way to look for patterns is to start by identifying the "typical" conditions for a phenomenon (e.g., what the weather conditions are like on **most days** when hailstorms occur, how each weather condition changes from before to after the hailstorm in **most cases**). Identifying outliers can be a second useful step in looking for patterns, because they can help us see when a case doesn't match the general patterns—such case(s) are relatively rare. Patterns in weather data can be very complex; most weather phenomena have more than one cause, and identifying outliers can help support this argument. Suggest to students that the general patterns we find in what is typical on most days will help us figure out the primary mechanisms causing the phenomenon in **most** cases.

Problematize the idea that it was warm out but hail is frozen. Say, *These temperature data are really strange and hard to explain. Water freezes from a liquid to a solid when its temperature drops below 32°F (0°C). This is the freezing and melting point of water, because above this temperature, frozen water starts to melt. So, if the temperature near Earth's surface is well above this point all day, how is it possible that frozen water can be falling from the sky?*

Suggested prompts	Sample student responses
What did you notice about where the weather data were collected?	*Air conditions are measured with stations a little above the ground (we had a photo of the weather instrument package that took the measurements).*
Based on the patterns in the data you analyzed about the air at the weather stations, was the air temperature ever that cold when it hailed?	*No, it was usually in the 60s and 70s.*
What new questions does this raise for you?	*What's it like in the air up high to be able to make ice?*

8. Add to our Progress Tracker. 5 MIN

Materials: science notebook

Set up the Progress Tracker. Tell students to take some individual time to capture what we figured out from our analysis of the hailstorm data. Have them turn to the Progress Tracker section in their notebooks. Use **slide R** to guide students in drawing a two-column chart on the first page of this section and completing the two columns.

Give students 3-5 minutes to quietly update their Progress Tracker using words and drawings to show what they've learned so far about the conditions on days when it hails. Ask students to draw a line underneath their responses when done. Prompt students to use patterns from the data they analyzed.

9. Navigation (Optional) 2 MIN

Materials: science notebook

Consider how hail forms when temperatures are warm near the ground. Show **slide S**. Ask students to stop and jot in their notebooks about their ideas for how it is possible for hail to form and fall from the sky when the temperature in the air near the ground outside is not cold enough for water to freeze.

Additional Guidance

If you are continuing to Lesson 3 on the same day as you are ending Lesson 2, you can skip this section, as it is repeated as a turn and talk in Lesson 3.

ADDITIONAL LESSON 2 TEACHER GUIDANCE

Supporting Students in Making Connections in Math

CCSS.MATH.CONTENT.6.SP.A.2 Understand that a set of data collected to answer a statistical question has a distribution which can be described by its center, spread, and overall shape.

This lesson provides an opportunity for students to describe and summarize numerical data sets by summarizing or describing what a typical (average) humidity or temperature value is when hail occurs.

LESSON 3

How does the air higher up compare to the air near the ground?

Previous Lesson *We analyzed data from hail-related weather events, including hailstone images, hail maps, and weather condition data.*

This Lesson

Investigation

1.5 DAYS

We analyze and interpret temperature profiles of the atmosphere collected from weather balloons at various altitudes at different locations during different times of the year. We develop a consensus model for representing the motion of the molecules that make up air at different temperatures.

Next Lesson *We will plan an investigation to figure out what causes the air closer to the ground to be warmer than the air higher in the atmosphere. We will analyze temperature and sunlight data to think about how incoming and reflected sunlight might affect ground and surface air temperatures.*

Building Toward NGSS

MS-PS1-4, MS-ESS2-4, MS-ESS2-5, MS-ESS2-6

What Students Will Do

Analyze and interpret sets of data to identify patterns (similarities across data sets) that provide evidence that air temperature changes based on altitude above Earth's surface independently of geographical location or time of year.

Develop a model to show the relationship between the motion of the molecules that make up air and the energy of those molecules to explain the patterns of change in air temperature at various altitudes.

What Students Will Figure Out

- Regardless of the season, the temperature of the air always decreases as you move away from Earth's surface and higher into the atmosphere.
- The air temperature at very high altitudes (approx. 40,000 ft) is coldest in winter.
- When the temperature of the air increases, the speed of the molecules that make up air increases, and when the temperature of the air decreases, the speed of the molecules that make up air decreases.

Lesson 3 • Learning Plan Snapshot

Part	Duration	Summary	Slide	Materials
1	10 min	**NAVIGATION** Discuss initial ideas about how hail formed when the air temperature near the ground was warm.	A-B	
2	10 min	**INTRODUCE WEATHER BALLOONS** Watch a video about weather balloons and the data they collect. Make predictions about how the temperature of the air higher up in the atmosphere will compare to the temperature of the air closer to the ground.	C-D	computer, projector, weather balloon video (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)
				End of day 1
3	15 min	**ANALYZE AND INTERPRET WEATHER BALLOON DATA** Analyze and interpret weather balloon data to determine how the temperature of the air higher up compares to the temperature of the air closer to the ground.	E-H	*Weather Balloon Data*
4	10 min	**CONDUCT A BUILDING UNDERSTANDINGS DISCUSSION ABOUT THE RELATIONSHIP BETWEEN ALTITUDE AND AIR TEMPERATURE** Convene a Scientists Circle to share observations, claims, and evidence regarding the relationship between air temperature and altitude.		*Weather Balloon Data*, chart paper, markers
5	13 min	**REPRESENT TEMPERATURE DIFFERENCES IN AIR** Develop a consensus model for representing the motion of the molecules that make up air at different temperatures.	I-J	chart paper, markers
6	6 min	**UPDATE PROGRESS TRACKER** Synthesize what we have figured out and add it to our Progress Trackers.	K	
7	3 min	**NAVIGATION** Discuss initial predictions about whether a difference in air temperature would be found in the air a few feet above the ground versus an inch from the ground for different areas of the school grounds and at different times of the day.	L	
				End of day 2
		SCIENCE LITERACY ROUTINE Upon completion of Lesson 3, students are ready to read Student Reader Collection 1 and then respond to the writing exercise.		Student Reader Collection 1: *Weather Concepts*

Lesson 3 • Materials List

	per student	per group	per class
Lesson materials **Student Procedure Guide** **Student Work Pages**	• science notebook • *Weather Balloon Data*		• computer • projector • weather balloon video (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**) • chart paper • markers

Materials preparation (10 minutes)

Online Resources

Review teacher guide, slides, and teacher references or keys (if applicable).

Make copies of handouts and ensure sufficient copies of student references, readings, and procedures are available.

Test weather balloon video (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**) prior to the lesson.

Lesson 3 • Where We Are Going and NOT Going

Where We Are Going

In Lesson 1, students observed videos of hailstorms at different locations and different times of the year. This led them to the unit question, "Why does a lot of hail, rain, or snow fall at some times and not others?" In Lesson 2, students began to investigate this question by exploring what the conditions of the air were like on a day when it hailed. They analyzed weather data from a number of sites on a day when it hailed and examined photos of hailstones. They noticed patterns in the data and pictures; for example, that the air temperature near the ground was mostly in the 50-90°F range, which led them to wonder how hail could form when the air temperature is above water's freezing point. In Lesson 3, students investigate this problem by analyzing weather balloon data to determine whether any part of the air is cold enough for water to freeze. In this lesson, students focus on

- looking for patterns in weather balloon data,
- using patterns as evidence for claims that the air higher in the atmosphere (where clouds form) is colder than the air nearer to the ground, and
- modeling the motion of and distance between the molecules that make up air near the ground and higher up in the atmosphere.

This leads students to wonder why the air nearer to the ground is warmer than the air higher up in the atmosphere, which will be addressed in Lesson 4.

Where We Are NOT Going

The temperature profile of the atmosphere tends to decrease up to around 30,000 feet above sea level. Other layers of the atmosphere higher up have different temperature profiles, but these are not relevant to explaining the phenomena we are exploring in this unit, as nearly all weather conditions occur within the lowest layer of the atmosphere (the troposphere), whose upper boundary can range from 20,000 to 59,000 feet above Earth's surface, depending on location (e.g., at the poles or the equator) and the time of year.

Students will develop explanations for what causes the air closer to the surface to be warmer than the air higher up in later lessons. The following related ideas will also be established in later lessons:

- The Sun heats Earth's surface through radiation.
- The ground heats the air above it through conduction.
- Air parcels at different temperatures have different densities.
- Temperature differences in air lead to the formation of convection currents.

LEARNING PLAN FOR LESSON 3

1. Navigation

10 MIN

Materials: science notebook

Navigate from previous lessons. Tell students, *In Lesson 1, we observed videos of hailstorms. They occurred in various locations and at different times of the year, but we noticed some similarities among the hailstorms. This led us to look at weather data for several sites where hailstorms occurred, and we noticed some patterns in the data. So, think back to the videos we observed in Lesson 1 and the data we analyzed in Lesson 2. What was the air like on a day when it hailed?* Call on a few students to share their thinking.

Show **slide A**.

Additional Guidance

Slide A is identical to the final navigation slide in Lesson 2. If you are continuing from Lesson 2 to Lesson 3 on the same day, skip slide S at the end of Lesson 2 and use slide A at the beginning of Lesson 3.

Say, *This is such a strange phenomenon! How is it possible for hail to form and fall from the sky when the temperature near the surface is not cold enough for water to freeze? Take a few moments to jot down your thinking on a new page in your science notebook*. Give students a few moments to record their thinking, then have a few students share. Possible responses for both questions are below.

Suggested prompts	Sample student responses
What was the air outside like on a day when it hailed?	*It was warm outside.* *The hailstorm happened during either spring, summer, or fall.* *The temperature outside was not at freezing.*
How is it possible for hail to form and fall from the sky when the temperature near the surface is not cold enough for water to freeze?	*It has to be cold somewhere for hail to form, since hail is ice.* *Maybe the air up around the clouds is colder than the air around us near the ground, since hail comes from clouds.*

Identify data we might need. Project **slide B** and ask students to follow along as you read the questions aloud. Give students a few moments to individually think about the questions, then have them turn and talk with a partner. After a few minutes, ask students to share their thinking with the class. Suggested prompts are below.

Suggested prompts	Sample student responses
What data would we need to find out whether the air high up is colder than the air near the ground?	*We would need to measure the temperature of the air near the ground and high up in the atmosphere. Then we could compare the temperatures.* *We might want to measure the air temperature near the ground and high up in the atmosphere at different sites, since we watched hailstorm videos from different sites.* *We might also want to take these measurements at different times during the year, since we know hailstorms occur during different times of the year.*
How high up in the atmosphere do you think we would need to go?	*We need to go at least as high as the clouds form.* *We could look for information about clouds to see how high in the atmosphere they form, then we would know how high we would need to go.*
How could we obtain these data?	*We could send tools up in a plane, then drop them with a parachute. As the tools fall, they can measure the temperature of the air at different heights.* *We could send up tools in a hot air balloon or a balloon filled with helium. That way the tools can measure the air temperature as the balloon rises.*

Motivate the need to use weather balloon data. To help students see the need to look for and analyze air temperature data, say, *We know hailstorms occur on warm or hot days. We also know the air must be cold somewhere* *for hail to form. So we've realized we need to find out if the air near the clouds is colder than the air near the ground. To do this, we need to measure the air temperature in both of those places. We also thought we might want to measure the air temperature at different sites and at different times of the year. But we can't actually go out and take these measurements ourselves. So, we need to know where we can get this kind of information about air temperature.*

2. Introduce weather balloons.

10 MIN

Materials: science notebook, computer, projector, weather balloon video (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)

Introduce weather balloons. Show **slide C**. Tell students, *Your idea about using balloons is exactly what scientists do! To measure a variety of weather conditions at different levels in the atmosphere, scientists use weather balloons to carry tools or instruments high up into the sky. I have a video that shows how weather balloons are used to gather different types of data that help scientists predict weather. As you watch the video, listen for the kinds of things that these instruments measure.*

Show (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**). After the video, ask, *What kinds of things do the instruments on a weather balloon measure?* Allow a few students to share.

Suggested prompt	Sample student response
What kinds of things do the instruments on a weather balloon measure?	*The weather balloon's instruments measure temperature and humidity.*

Say, *The scientist in the video said the instruments attached to the weather balloon measure temperature and humidity. These instruments can also measure wind speed, wind direction, air pressure, altitude, and geographical position. We will learn more about these science terms as we work with them through this lesson.*

Additional Guidance

With the exception of *temperature*, the terms introduced here should not be added to the word wall at this point. Students use these words in the activities in this and subsequent lessons in this unit. As students begin using terms such as *humidity*, *atmosphere*, and *altitude*, ask them to explain what they mean, then consider adding them to the word wall at the end of the lesson as "words we earned".

Make predictions. Show **slide D**. Say, *So we now know weather balloons can measure the temperature of the air high up in the atmosphere. If we look at weather balloon data, how does the air higher up compare to the air near the ground? Do you think there would be places where the air would be cold enough for hail to form, even if the air temperature near the ground is warm?*

Ask students to record the question on the slide in their science notebooks and jot down their predictions. In addition to making predictions about the general trend in the temperature, encourage students to predict what the actual temperatures might be near the ground and higher up in the atmosphere. As students finish writing, ask a few to share their predictions and their reasoning with the class.

Suggested prompt	Sample student responses
How does the air higher up compare to the air near the ground?	*The air up high might be warmer than the air closer to the ground because the air up high is closer to the Sun.* *The air up high is probably colder than the air closer to the ground because the air near the clouds needs to be very cold for hail to form.*

End of day 1

3. Analyze and interpret weather balloon data.

15 MIN

Materials: science notebook, *Weather Balloon Data*

Revisit previous ideas. Ask students, *Where did we leave off at the end of our last class? What were we trying to figure out?* Solicit responses from a few students, then move into today's work.

Suggested prompts	Sample student responses
Where did we leave off at the end of our last class?	*We thought about what the air was like on a day when it hailed.* *Since the air temperature on days when it hails is usually warm, we wondered how it was possible for hail to form when the air temperature near the surface is not cold enough to cause water to freeze.* *This made us wonder if the air higher up in the atmosphere is colder than the air closer to the ground, so we decided we needed some data about air temperature at different levels of the atmosphere.* *We learned scientists use weather balloons to carry measuring tools up high into the atmosphere to measure air temperature.* *So we made predictions about what we would find if we could get data about the air temperature near the ground and higher up in the atmosphere.*
What were we trying to figure out?	*We were trying to figure out how the air higher up compares to the air near the ground.* *This might help us figure out how hail is able to form on days when it is warm outside.*

* Supporting Students in Engaging in Analyzing and Interpreting Data

The weather balloon data include 16 sets of data—four sites, each with temperature data collected on four different dates. Since students may need guidance in analyzing and interpreting all this data, the work is scaffolded to provide support:

- As a class, students are asked to look for patterns in one set of data (Albany, NY, on July 11) and document their observations in their science notebooks. (Slide E)
- Students then work with a partner to analyze four sets of data, each recorded on a different date, for one assigned site. Students document observed patterns in their science notebooks. (Slide F)
- Next, partners work with another pair of students

Share weather balloon data. Say, *So now that we know where we left off, let's move forward with our plan to check air temperature data from weather balloons to see how the air near the ground compares to the air higher up in the atmosphere.* Distribute *Weather Balloon Data* to students. Orient them to the handout by saying, *We have some data from weather balloons, like the one we saw in the video, from four different sites at four different times of the year: January, April, July, and October. Let's look at the data collected from one of these sites in July of 2018.*

Additional Guidance

Using weather balloon data collected at midnight serves the following purposes:

- Students can analyze the data and find patterns supporting the claim that the air higher in the atmosphere is colder than the air near the ground.
- We intentionally have students analyze air temperature data taken at night to keep them focused on looking for patterns in the data at different altitudes rather than considering the Sun's differential heating of the air during the day.
- At the end of the lesson, we explore the role of the Sun by having students analyze weather balloon data collected at noon. This motivates the need to investigate the Sun's role in heating Earth's surface, and how surface heating causes the air close to the ground to heat through conduction.

The weather balloon data do not use metric units, because we are building on students' understanding of measurements in feet and °F. This allows for a more intuitive understanding and comparison of data, as students are likely more familiar with these units of measure than meters and °C.

Project **slide E**. Give students a few moments to look at the data on the slide, then use the following questions to guide a discussion.*

Suggested prompts	Sample student responses
What was the location or site where these data were collected?	*Albany, NY*
When were the data collected?	*At midnight on July 11, 2018.*
What does each column in the data table show?	*The first column tells us the height above the ground and the second column tells us the temperature.*
If we read across the first row of data, what do the numbers in that row mean?	*At 308 feet above the ground, the air temperature was 52.2°F.*
What does the second row of data tell us?	*At 8,816 feet, it was 36.0°F.*

Following this discussion of the data on **slide E**, ask, *What patterns do you notice in this set of weather balloon data? Record your observations in your notebook.*

Give students a minute to jot down their observations, then ask a few to share with the whole group. Students should notice that the air temperature decreases as we move higher up into the atmosphere.

to compare their data and observations. Students look for similarities and differences across the two sites and document their observations. (Slide G)

- Finally, students share their observations with the class, compare data and observations across all four sites, and make a claim based on their discussions and observations. (Slide H)

Focusing students' analysis on looking for patterns in the data helps them find and use evidence to support their claims about air temperature at various altitudes in the atmosphere.

*** Attending to Equity**

It is important to organize activities in ways that create opportunities for students to engage in meaningful, accountable talk by emphasizing socially safe activity structures (e.g., small-group or partner work before a whole-class discussion). This is especially beneficial to multilingual students. For this reason, partner talk or small-group talk should precede whole-class discussion whenever possible to give students an opportunity to share their ideas with one or two peers before "going public."

Analyze site data in pairs. Say, *Now we are ready to analyze more data.* Show **slide F**. Tell students, *Work with a partner to examine data from one of the four sites, which were chosen at random: Salem, Amarillo, Willmington, and Albany. Look for patterns in the four sets of data for your assigned site. Then record your observations in your science notebooks.* Pair students and assign a site to each pair. Give them a few minutes to examine the data for their assigned site and record any patterns they notice within that data for a particular time of the year and across the four times of the year.

Compare data with another pair. Have each pair of students find another pair of students who analyzed data from a different site.

Show **slide G**. Tell students to work together in groups of four (two pairs) to compare observations from different sites. Give groups a couple of minutes to talk and record any patterns they notice across the data from their two sites.*

Make a claim and support with evidence. Show **slide H**. Say, *Now that you have had the chance to look at data from two different sites, write a claim in your notebook that describes any relationships between the temperature of the air and the distance from the ground (altitude). Make sure you support your claim with evidence from your analysis of the data.**

4. Conduct a Building Understandings Discussion about the relationship between altitude and air temperature.

10 MIN

Materials: science notebook, *Weather Balloon Data*, chart paper, markers

Gather in a Scientists Circle. Say, *We need to take some time to share our observations and important ideas from our discussions so we can build our understanding of the phenomenon we are trying to explain. So, please bring your notebooks, work page, and a chair to a Scientists Circle.* Give students a minute or two to get settled.*

Conduct a Building Understandings Discussion. During this discussion, have students share how they analyzed their assigned data. Keep in mind that you want students to share patterns they noticed in data sets for a particular location and across sites (e.g., several dates at a single site or a single date at several sites). Use the following prompts to guide the discussion. Make sure numerous students share their observations.

Suggested prompts	Sample student responses
What did you notice about the air temperature in the data sets you analyzed?	*The temperature decreased as the balloon moved up.* *The air got colder as the balloon moved higher in the atmosphere.*
Was this pattern true for all four sites?	*Yes. The pattern was the same at each site. The air got colder as the balloon moved higher in the atmosphere.*
What did you notice when you compared the data over the four time periods?	*The temperatures in January tended to be much colder at all four sites. This was especially true at higher altitudes (16,000 feet and above).*

*** Supporting Students in Engaging in Constructing Explanations and Designing Solutions**

Some or all of your students may need support writing claims supported by evidence and reasoning. Support can be provided in a number of ways:

- Provide a graphic organizer to help students write their claims, supporting evidence, and reasoning.
- Students can work with their partner or small group to construct a claim supported by evidence.
- Remind students of the question their claim should answer. For example, say, *Remember, your claim should answer the question, "How does the air higher up compare to the air near the ground?" Make sure your claim is supported by evidence from your observations of the weather balloon data.*
- Provide sentence stems (either on a handout or on a sheet of chart paper) to help students write a claim supported by evidence. For example, "The temperature of the air up high is __________ than the air near the ground. I know this because __________."

Document claims and evidence. As the discussion progresses, ask, *What claim(s) can we make based on our findings?* Listen for the following claims to surface, along with supporting evidence from the data sets. Document students' claims and evidence on chart paper.

Key Ideas Purpose:

This discussion gives students the opportunity to share their observations and make claims based on the patterns they find in the data.

Listen for these ideas:

- The temperature of the air always decreases as you move away from Earth's surface and higher into the atmosphere.
- This pattern can be found in the data for all four sites and at the four times of the year that data are collected.
- The air temperature at very high altitudes (approx. 40,000 ft) is coldest in winter.

*** Strategies for This Building Understandings Discussion**
A Building Understandings Discussion is useful following an investigation or activity as an opportunity to have students share, critique, and build on evidence-based claims. Your role is to invite students to share and support their claims using evidence and reasoning. Students can disagree and the class does not need to reach consensus on all ideas shared. Identifying areas of disagreement can motivate future investigations.

5. Represent temperature differences in air. 13 MIN

Materials: science notebook, chart paper, markers

Compare predictions to claims. This is an opportunity to revisit students' responses to the lesson question and assess whether their predictions aligned with the weather balloon data. Say, *Think about the claims we made and the evidence we used to support them. Look back at your previous response to the lesson question. Were your predictions correct? Why or why not?*

Suggested prompts	Sample student responses
What was the lesson question?	*How does the air higher up compare to the air near the ground?*
What claims were we able to make based on the weather balloon data?	*Regardless of the season, the temperature of the air always decreases as you move away from Earth's surface and higher into the atmosphere.* *The air temperature at very high altitudes (approx. 40,000 ft) is coldest in winter.*
Were your predictions correct?	*Yes, some of us predicted the air up high would be colder than the air near the ground.* *No, some of us thought the air up high would be warmer than the air near the ground because it is closer to the Sun.*

Review prior understandings about energy and matter. Say, *So now that we know the air up high in the atmosphere is much colder than the air near the ground, we want to figure out why. To move us toward understanding this phenomenon, we first need to revisit what we already know and understand about energy and matter, and connect that to what might be happening at different altitudes with the molecules that make up air.*

Show **slide I** and say, *Let's take a minute or two to do a "quick write." In the Cup Design Unit, we designed cups to keep liquids cold or hot. In the process, we learned quite a bit about the relationship between the temperature of a substance and the motion and kinetic energy of the particles that make up that substance. On the next page in your notebook, take a few minutes to jot down what you know and understand about temperature and the kinetic energy of particles of matter.*

If students need support, make sure they have access to their Cup Design Unit notebooks so they can revisit their Progress Trackers from that unit. Give students 3-4 minutes to write before asking them to share their thinking with the class. As they share, document their ideas on chart paper. Listen for the following ideas to surface.

Suggested prompt	Sample student responses
What do we know about temperature and the kinetic energy of particles of matter?	*Solids, liquids, and gases are made up of particles. Particles in a gas have a lot of space between them.* *Light that is absorbed by matter transforms into thermal energy.* *The particles of matter move; so, the particles have kinetic energy.* *Temperature is the average kinetic energy of the particles in a substance.* *A particle's speed is related to how much kinetic energy it has.* *The particles in a hot substance have more kinetic energy than the particles in a cold substance.*

Represent temperature differences in air. Tell students, *Now that we have reviewed what we know about temperature and the kinetic energy of particles, let's think about how to represent our ideas about what air at different altitudes is doing at the particle level. Remember, if we can figure out what the air is doing at different altitudes, this will help us move towards understanding why the air higher in the atmosphere is always colder than the air near the ground and help us explain how hailstones form.*

Show **slide J**. Say, *Turn and talk to the person next to you. Using what we know about the relationship between temperature and the motion of particles of matter, how can we represent the temperature differences between the molecules that make up air high up in the atmosphere and those closer to the ground?* Give students a few minutes to talk and document their thinking in their notebooks. As they finish, ask a few to share their thinking and how they represented the molecules that make up air near the ground and high up in the atmosphere. Listen for student thinking and models or representations that include the ideas below.

Suggested prompt	Sample student responses
How can we represent the temperature differences between the molecules that make up air high up in the atmosphere and those closer to the ground?	*The molecules that make up air high in the atmosphere have less kinetic energy, because it is cold. So we should draw those molecules a little closer together and moving more slowly.* *The molecules that make up air near the ground have more kinetic energy, because the temperature is higher. We should draw those molecules a little farther apart and moving more quickly.*

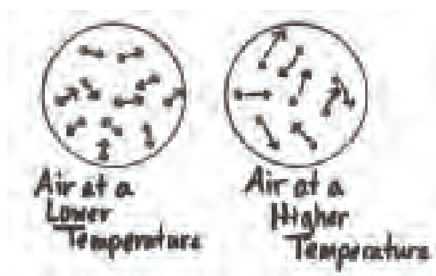
Document a consensus model. Using students' ideas and input, create a consensus model (on chart paper) that represents the particle-level differences in air high up in the atmosphere versus air closer to the ground.

6. Update Progress Tracker.

6 MIN

Materials: science notebook

Update Progress Tracker. Ask students to return to their desks, then show **slide K**. Tell students to turn to the Progress Tracker section in their notebooks and draw a line after the entry for Lesson 2. Then say, *Write the lesson question, "How does the air higher up compare to the air near the ground?" in the left column of your Progress Tracker. Then, use pictures and/or words to document what you have figured out related to the lesson question.* Give students 5 minutes to work. Look for the following ideas in their work.

Question	What I figured out in words and/or pictures	
How does the air higher up compare to the air near the ground?	The temperature of the air decreases as you move away from Earth's surface and higher into the atmosphere. The air temperature at very high altitudes (approx. 40,000 ft) is coldest in winter. When the temperature of the air increases, the speed of the molecules that make up air increases, and when the temperature of the air decreases, the speed of the molecules decreases.	

Assessment Opportunity

Reviewing students' responses in the Progress Tracker provides an opportunity to formatively assess their understanding of the lesson-level performance expectations. Students' responses should not be graded; rather, use what you learn to inform next steps for moving their thinking forward. Examples include

- documenting your feedback in students' notebooks, such as additional probing questions, suggestions for improvement, or a request for additional evidence or reasoning;
- revisiting, reteaching, or reinforcing ideas from the lesson to help students fill in gaps in their learning;
- using examples of actual student work to prompt discussion about what we have and haven't figured out up to this point in the unit; and
- asking additional questions at the beginning of Lesson 4 to probe students' thinking and help students make connections and build understandings.

7. Navigation

3 MIN

Materials: science notebook

Foreshadow the next lesson by making predictions. Show **slide L** and say, *Remember, we are ultimately trying to explain how hailstorms form. We now know the air is colder higher up in the atmosphere than it is near the ground, which helps us understand where it might be cold enough for hailstones to form. Our next step is to figure out* ***why*** *the air up high is colder. Based on what we have figured out from the weather balloon data, if we gathered more data by moving closer to the ground, what do you think we would see in that data? In addition, if we looked at weather balloon data taken at 12:00 noon instead of 12:00 midnight, what do you think we would see in that data? Do you think we would see the same patterns? Why or why not?*

Have students go to the next page in their science notebooks, add the title "Predictions" at the top of the page, then write their responses to the questions on the slide. Tell students they will have a chance to share their predictions and make connections to the learning experiences in the next lesson.

ADDITIONAL LESSON 3 TEACHER GUIDANCE

Supporting Students in Making Connections in ELA

Students engage in discussion when they work together in small groups to compare observations as well as when they work in whole group to share claims and then revise their model.

CCSS.ELA-LITERACY.SL.6.1: Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grade 6 topics, texts, and issues, building on others' ideas and expressing their own clearly.

Additionally, this lesson provides an opportunity for students to write an argument.

CCSS.ELA-LITERACY.W.6.1: Write arguments to support claims with clear reasons and relevant evidence.

- CCSS.ELA-LITERACY.W.6.1.A. Introduce claim(s) and organize the reasons and evidence clearly.
- CCSS.ELA-LITERACY.W.6.1.B. Support claim(s) with clear reasons and relevant evidence, using credible sources and demonstrating an understanding of the topic or text.

SCIENCE LITERACY: READING COLLECTION 1

Weather Concepts

1 **Rain, Snow, and Hail Capitals**

2 **A History of Mapping Weather**

3 **Modern Weather Data Visualizations**

4 **The Atmosphere as a Fluid**

Literacy Objectives

- ✓ Summarize key points related to the work and interests of meteorologists.
- ✓ Distinguish causes and effects related to air and the atmosphere.
- ✓ Organize related details on a poster.

Literacy Activities

- Read varied text selections related to the topics explored in Lessons 1–3.
- Evaluate the reading selections according to provided prompts and criteria.
- Compare and contrast information gained from reading text with information gained from class investigation.
- Prepare a job posting for a meteorologist in response to the reading.

Instructional Resources

Student Reader Collection 1	**Science Literacy Student Reader, Collection 1** "Weather Concepts"
Exercise Page EP 1	**Science Literacy Exercise Page** EP 1

Prerequisite Investigations

Assign the Science Literacy reading and writing exercise *after* class completion of this lesson group:

- Lesson 1: What causes this kind of precipitation event to occur?
- Lesson 2: What are the conditions like on days when it hails?
- Lesson 3: How does the air higher up compare to the air near the ground?

Standards and Dimensions

NGSS

Disciplinary Core Idea ES2.D: Weather and Climate: Because these patterns are so complex, weather can only be predicted probabilistically. (MS-ESS2-5)

Science and Engineering Practice(s): Using Mathematics and Computational Thinking; Obtaining, Evaluating, and Communicating Information

Crosscutting Concepts: System and System Models; Patterns; Cause and Effect

CCSS

English Language Arts

RST.6-8.2: Determine the central ideas or conclusions of a text; provide an accurate summary of the text distinct from prior knowledge or opinions.

RST.6-8.6: Analyze the author's purpose in providing an explanation, describing a procedure, or discussing an experiment in a text.

RST.6-8.10: By the end of grade 8, read and comprehend science/technical texts in the grades 6-8 text complexity band independently and proficiently.

WHST.6-8.10: Write routinely over extended time frames (time for reflection and revision) and shorter time frames (a single sitting or a day or two) for a range of discipline-specific tasks, purposes, and audiences.

Math

6.SP.B.3: Recognize that a measure of center for a numerical data set summarizes all of its values with a single number, while a measure of variation describes how its values vary with a single number.

MP.2: Reason abstractly and quantitatively.

Core Vocabulary

Core Vocabulary: Core Vocabulary terms are those that students should learn to use accurately in discussion and in written responses. During facilitation of learning, expose students repeatedly to these terms. However, these terms are not intended for isolated drill or memorization.

precipitation **probability**

Language of Instruction: The Language of Instruction consists of additional terms, not considered a part of Core Vocabulary, that you should use when talking about any concepts in this exercise. Students will benefit from your modeling the use of these words without the expectation that students will use or explain the words themselves.

accuracy	**atmospheric pressure**
density	**fluid**
latitude	**longitude**
mean	**precision**
prime meridian	**severe weather**

A Glossary at the end of the Science Literacy Student Reader lists definitions for Core Vocabulary and selected Language of Instruction.

1. Plan ahead.

Determine your pacing to introduce the reading selections, check in with students on their progress, and discuss the reading content and writing exercise. If you are performing Science Literacy as a structured, weekly routine, you might implement a schedule like this:

- Monday: Designate a ten-minute period at the beginning of the week to introduce students to the assignment.
- Wednesday: Plan to touch base briefly with students in the middle of the week to answer questions about the reading, to clarify expectations about the writing exercise, and to help students stay on track.
- Friday: Set aside time at the end of the week to facilitate a discussion about the reading and the writing exercise.

2. Preview the assignment and set expectations. (MONDAY)

- Let students know they will read independently and then complete a short writing assignment. The reading selection relates to topics they are presently exploring in their Weather, Climate, and Water Cycling unit science investigations.
- The reading and writing will be completed outside of class (unless you have available class time to allocate).
- Preview the reading. Share a short summary of what students can expect.
  - *First, you will read a photo essay with some fun facts about where to find the most rain, snow, and hail.*
  - *Next, you'll read how changes in the technology of mapping intersect with changes in the accuracy and precision of weather mapping.*
  - *Then, you'll see how essential mathematical ideas such as mean and probability are essential to understanding climate maps.*
  - *Finally, you'll read an article that explains why your ears pop when you fly or take an elevator up to the top of a tall building.*
- Distribute Exercise Page 1. Preview the writing exercise. Share a summary of what students will be expected to deliver. Emphasize that Science Literacy exercises are brief. The focus is on thoughtful quality of a small product, not on the assignment being big and complex.
  - *For this assignment you will be expected to generate a career day poster about what meteorologists do and what kinds of subjects a student should enjoy to become a successful weather scientist.*

Exercise Page

EP 1

- Remind students of helpful strategies they can employ during independent reading. Offer the following advice:
  - *The reading should take approximately 30 minutes to complete.* (Encourage students to break reading into smaller sections over multiple short sittings if their attention wanders.)
  - *A good reading strategy is to scan through the collection first to see the titles, section headers, graphics, and images to see what the selections are going to be about before fully reading.*
  - *Next, "cold read" the selections without yet thinking about the writing assignment that will follow.*
  - *Then, carefully read the Exercise Page to understand the expectations for the writing part of the assignment.*
  - *Revisit the reading selections to complete the writing exercise.*
  - *Jot down any questions for the midweek progress check in class.* (Be sure students know, though, that they are not limited to that time to ask you for clarification or answers to questions.)

3. Touch base to provide clarification and address questions. (Wednesday)

Touch base midweek with students to make sure they are on track while working independently. You may choose to administer a midweek minute-quiz to give students a concrete reason not to postpone completing the reading until the last minute. Ask questions such as these, and have students jot answers on a half sheet of paper:

Suggested prompts	Sample student responses
What are three types of precipitation highlighted with photos in the first reading?	*rain, snow, and hail*
What kinds of data do today's weather maps display in real time?	*maximum temperature, minimum temperature, atmospheric pressure, and precipitation*
What are some forms of severe weather?	*tornadoes, thunderstorms with high winds, and hail*
Why is the mathematical concept of "mean" essential to describing climate data?	*The mean is a single number that is the center of many pieces of weather data collected over up to 30 years. A mean is the average.*

Ask a few brief discussion questions related to the reading that will help students tie the text content to students' classroom investigations.

Suggested prompts	Sample student responses
How did the first selection photos about hail support what you learned from the videos in Lesson 1?	*In the videos, we saw how the hail fell. In the photos in Selection 1, we could see how the hail looked up close and how the storm clouds that make hail look in the distance.*
How was the information in the first selection about "Hail Alley" supported by the Hail Frequency Map you saw in Lesson 2?	*The map also showed that there are a high number of hail days per year in the part of the United States where Wyoming, Colorado, and Nebraska meet.*
Hot-air balloons that tourists get to ride rise to about 3,000 feet. Based on what you learned in Lesson 3 about air temperature and altitude, what can tourists expect to experience as the balloon rises?	*that the air temperature will decrease*

- Refer students to the Exercise Page 1. Provide more specific guidance about expectations for students' deliverables due at the end of the week.
  - *The writing expectation for this assignment is to develop a poster to explain what it takes to be a meteorologist—a weather scientist.*

Exercise Page

EP 1

    - *You don't have to do any additional research because a careful read of Collection 1 will suggest characteristics of people who might enjoy this career.*
    - *After you read each selection, jot down some notes alongside the bulleted list of points on Exercise Page 1.*
    - *The important criteria for your poster are that the points you make are supportable by the readings and that it is appealing enough to capture other students' attention.*
- Explain that a well-developed career day poster should make the career sound appealing or intriguing to other students.
- Answer any questions students may have relative to the reading content or the exercise expectations.

4. Facilitate discussion. (Friday)

Facilitate class discussion about the reading collection and writing exercise. This collection consists of four selections, three of them focusing on visualizing weather data, climate data, and the atmosphere.

Online Resources

Student Reader

Collection 1

Pages 4–11 **Suggested prompts**	**Sample student responses**
What is the general purpose of the first selection, "Rain, Snow, and Hail Capitals"?	*It describes some fun facts about the places in the United States with the most extreme weather.*
Which form of precipitation does not have a United States capital in this reading?	*sleet*
Based on what you learned in Lesson 1, what do you think conditions are like in the storm clouds photo for "Hail Alley"?	*It's windy, and the temperature is below freezing in some places and above freezing in other places.*
What is the general purpose of the second selection, "A History of Mapping Weather"?	*It compares mapmaking years ago to weather mapmaking today.*
Is the equator a line of latitude or longitude?	*latitude*
Take a look at the Dig into Data box. If you travel from Rome (with a longitude of 12 degrees E) to Istanbul (with a longitude of 28 degrees E), are you moving toward the prime meridian or the antimeridian? Explain how you know.	*toward the antimeridian, because you are moving farther east away from the prime meridian but not enough degrees to pass the antimeridian and get closer to the prime meridian*
The world's first weather satellite was launched in 1960. How do you think the data shown on the 1938 map showing a hurricane in the Atlantic Ocean were collected?	*maybe from weather balloons, planes, or ships*
What is the general purpose of the third article, "Modern Weather Data Visualizations"?	*It explains that, in addition to current weather conditions, maps can also be used to display long-term weather data, or climate. Also that climate data can be used to make predictions about the probability of future weather.*

SUPPORT—If you are using the recommended word envelope convention, check the envelope to see if it contains any words, phrases, or sentences that students need help understanding. Read key sentences aloud, and provide concise explanation.

Pages 8–13 Suggested prompts	**Sample student responses**
How would you describe the climate of our community based on the two temperature maps in this reading?	*(Answers will vary depending on the location of your school, but students should be able to estimate numerical mean temperatures for July and January and discuss how broad or narrow the range of temperatures are from summer to winter.)*
How do you think historical probability of severe weather maps might look for other days of the year?	*If tornadoes, thunderstorms with high winds, and hail occur less often in the winter, a winter day map might not show any deep red color at all.*
How could a one-month temperature outlook map be useful to families?	*Families could decide if the coming month is a good time for a trip, to go on a vacation, or to have an outdoor family reunion.*
What is the general purpose of the fourth article, "The Atmosphere as a Fluid"?	*It explains that many characteristics of air and weather can be explained by knowing that the atmosphere acts like a fluid.*
What causes air in the atmosphere to move, and where does it move?	*Heat from Earth warms the air above it, causing the air to become less dense and rise through more dense, cooler air. Then air moves sideways into the space left by the rising air.*
Based on what we figured out in Lesson 3, describe how the particles of air behave as they are warmed by Earth and rise in the atmosphere.	*As the temperature of air rises, the particles spread apart and move faster. Spreading apart makes the air less dense, so the air rises.*

SUPPORT—To find supporting evidence for their answers to the question of how historical probability maps may look for other days of the year, have students use the online interactive map on the NOAA website. Demonstrate how to click "Maps" at the upper right and then "Severe Weather" in the menu below. Next, use the slider below the map to select the days of the year students want to view.

EXTEND—Direct students to an online graph showing how the temperature of the atmosphere changes with altitude above Earth's surface. Have students interpret and describe the changes in temperature above the troposphere—in the stratosphere, mesosphere, and thermosphere.

5. Check for understanding.

Evaluate and Provide Feedback

For Exercise 1, students should develop a career day poster to communicate some of the characteristics useful to become a good meteorologist. Exemplary student posters should address the five points listed on Exercise Page 1, all of which can be inferred by a thoughtful reading of the selections in Collection 1. Look for effort in design as well as the following information points about this career:

- As a meteorologist, a person will be studying the atmosphere near Earth's surface.
- A student should like and be good at Earth science, physical science, and math.
- As a weather scientist, a person will be measuring and analyzing precipitation, temperature, atmospheric pressure, and various forms of severe weather.
- A student should enjoy working with computer programs that make calculations such as mean and that draw maps.
- Since so much weather data are displayed as maps, a person should enjoy making and interpreting maps.

Use the rubric provided on the Exercise Page to supply feedback to each student.

LESSON 4

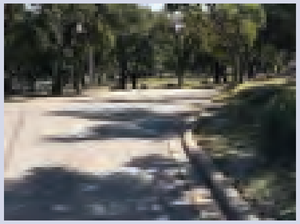
Why is the air near the ground warmer than the air higher up?

Previous Lesson *We analyzed temperature profile data for different altitudes of the atmosphere at a variety of locations during different times of the year. We developed a consensus model for representing the motion of the molecules that make up air at different temperatures.*

This Lesson

Investigation

2.5 DAYS



We plan an investigation to figure out what causes the air above different ground surfaces to be warmer than the air higher in the atmosphere. We measure the temperature of different ground surfaces and the air temperature above them, and also the amount of sunlight reaching and reflecting off them. Both sets of data help us figure out that different amounts of incoming and reflected sunlight are associated with different ground and surface air temperatures, and that ground temperatures are warmer than surface air temperatures.

Next Lesson *We will conduct two investigations to explore how transferring thermal energy into and out of a parcel of air in a closed system can help us explain what is happening to the air near the ground on a day when it hails. For each investigation, we will develop a model to represent how the molecules that make up the air are affected.*

Building Toward NGSS

MS-PS1-4, MS-ESS2-4, MS-ESS2-5, MS-ESS2-6

What Students Will Do

Plan an investigation collaboratively by identifying variables of interest, tools to gather data, methods for obtaining measurements, and how many sites are necessary to determine if a pattern exists between the temperature of the ground and the temperature of the air right above it.

Collect, analyze, and interpret data using graphical displays (tables of data we obtain from our own investigations) to identify ground and surface air temperature patterns as they relate to incoming and reflected solar radiation.

Develop and use a model to describe phenomena and unobservable mechanisms that track the transfer of energy from the Sun to the ground and then to the air at the surface.

What Students Will Figure Out

- Energy from the Sun is absorbed by the ground, which then increases the kinetic energy (and therefore temperature) of the particles in the ground.

- Different ground surfaces heat up differently depending on how much energy from the Sun is absorbed.
- As particles in the air come into contact with the ground, energy is transferred to those particles through conduction.
- On a sunny day, air temperatures above the ground are cooler than the ground itself.

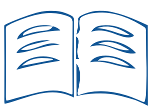
Lesson 4 • Learning Plan Snapshot

Part	Duration	Summary	Slide	Materials
1	10 min	**NAVIGATION** Share predictions of whether the same pattern of air temperatures at different altitudes would hold true if the data were collected in the middle of the day versus the middle of the night.	A	
2	25 min	**PLANNING OUR INVESTIGATION** Consider what data to collect, which tools to use, and how to conduct the measurements.	B-F	Temperature and Sunlight Investigation
3	8 min	**MAKE PREDICTIONS** Predict what we expect to see in the data we plan to collect.	G	Temperature and Sunlight Investigation
4	2 min	**NAVIGATION** Summarize the plan for the investigation and prepare students for the next class period's data collection.	H	
				End of day 1
5	3 min	**NAVIGATION** Prepare for data collection outside.	E, F, H	Temperature and Sunlight Investigation
6	25 min	**CONDUCT THE TEMPERATURE AND SUNLIGHT INVESTIGATION** Collect ground and air temperature and sunlight data.		Temperature and Sunlight Investigation
7	15 min	**REPORT RESULTS AND MAKE SENSE OF DATA** Share and make sense of the data as a class to understand what the patterns mean for ground and air temperatures.	I-K	calculator (optional), computer and projector, chart paper, markers, Temperature and Sunlight Investigation
8	2 min	**NAVIGATION** Summarize how the collected data connect to the lesson question.		
				End of day 2

Part	Duration	Summary	Slide	Materials
9	5 min	**DISCUSS HOW TO REPRESENT OUR IDEAS ABOUT THE EFFECT OF SUNLIGHT ON TEMPERATURE** Discuss ways we represented the interaction of light with matter and energy transfer to matter in contact with other matter from the Cup Design Unit.	L	
10	15 min	**DEVELOP A CONSENSUS MODEL IN A SCIENTISTS CIRCLE AND UPDATE PROGRESS TRACKERS** Share thinking about how sunlight can warm the ground during the day.	M	chart paper, markers
11	3 min	**CONNECT TO THE ANCHORING PHENOMENON** Transition to focusing on how air above ground surfaces is affected by becoming warmer.	N	

End of day 3

Lesson 4 • Materials List

	per student	per group	per class
Temperature and Sunlight Investigation materials	• *Sunlight and Temperature Investigation* • clipboard (optional)	• 2 thermometers • 1 light meter	
Lesson materials **Student Procedure Guide**  **Student Work Pages** 	• science notebook	• calculator (optional)	• computer and projector • chart paper • markers

Materials preparation (15 minutes)

Online Resources

Review teacher guide, slides, and teacher references or keys (if applicable).

Make copies of handouts and ensure sufficient copies of student references, readings, and procedures are available.

Sunlight and Temperature Investigation

- **Group Size**: 4-5 students
- **Setup**: Gather thermometers and light meters for each group of students. Ensure the equipment works, the unit of measure for temperature is set to Fahrenheit, and the unit of measure for light is set to lux. If you have a set of class clipboards, it may be helpful to have students use them for data collection outside.

- **Notes for during the lab:** This lesson includes collection of sunlight and temperature data outside. The data are best collected on a sunny or partly sunny day when ground surfaces are exposed to sunlight. Data collected on very cold or cloudy days often yields results that do not show much of a difference between the ground and the air, as ground surfaces do not absorb as much solar radiation; instead, the energy transfer stabilizes, yielding temperature data that are nearly the same. If the weather is not optimal for data collection, the class can use data from a previous year or use *Sunny Day: Sample Data for Colorado Springs* and *Cloudy Day: Sample Data for Colorado Springs*, both in the Student Edition. These sample data sets highlight temperature differences between days when there is abundant solar radiation versus days when there is not and the ground and air temperatures equalize.
- **Safety**: Direct students to collect data in the safe areas around the school grounds.
- **Storage**: Thermometers and light meters can be stored in a box for use in subsequent classrooms. To prolong the battery life, consider removing batteries from the devices.

Watch the Investigation Set Up video (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**) for guidance on how to use the light meters and thermometers.

Lesson 4 • Where We Are Going and NOT Going

Where We Are Going

In this lesson, students make connections to key physical science ideas about light, thermal energy, and thermal energy transfer. These ideas were developed in the One-way Mirror Unit and Cup Design Unit but are applied in a new context in this lesson.

As part of the lesson, students wrestle with non-intuitive temperature data patterns that emerged with the weather balloon data in Lesson 3. Many students might think the air higher up should be warmer because it is closer to the Sun and the ground is the last thing the sunlight reaches. Students might know different surfaces heat up differently from personal experiences with a hot, sandy beach or a black asphalt parking lot on a warm summer day, but they might not have thought about how different ground surface temperatures might affect the air above those surfaces.

By collecting data about incoming and reflected sunlight, students build a case that the ground absorbs solar radiation, which transfers energy into the ground material, thus changing its temperature. Different ground surfaces have different temperatures because they absorb different amounts of solar radiation, based on the type of material and how long the surface has been exposed to solar radiation (i.e., the longer it has been in the sun, the more energy it has absorbed). This lesson assumes that your students were taught the Cup Design Unit, so that you can leverage the ideas about thermal energy and different materials to support student sensemaking in this lesson. A critical key idea from that unit, that is reused in this lesson and the next lesson is that all matter is made of molecules that are arranged and move differently depending on how much thermal energy is added or removed. Students need to consider the amount of matter in the air versus the ground, and where energy from the Sun is initially absorbed. Air is transparent and contains relatively little matter, so the vast majority of solar radiation is absorbed by the ground, but as molecules in the air come into contact with molecules in the ground, some of this energy is transferred via conduction.

As students collect data on the school grounds, it is important to emphasize two things: (1) Different surfaces absorb energy differently, based on their material and how long they have been in sunlight, and (2) surfaces in the shade are less exposed to sunlight and should yield lower temperatures as a result.

Where We Are NOT Going

This lesson begins to build evidence for how the ground heats the air molecules above it as those molecules collide with the surface. It does not include ideas about convection (i.e., the transfer of heat energy in a fluid, such as air), which is introduced later in the unit.

LEARNING PLAN FOR LESSON 4

1. Navigation

10 MIN

Materials: science notebook

Revisit previous air temperature patterns. Ask students to summarize the pattern we noticed in the weather balloon data for air temperature at different altitudes. They should say the air temperature decreases as you go higher in the atmosphere. Transition them to thinking about air closer to the ground by asking, *Why is the air warmer near the ground?* Use a popcorn-share strategy (random volunteering) around the room to gather student ideas, and accept all these ideas for now.

Revisit previous predictions. Show **slide A**. Remind students of their predictions task from the end of Lesson 3. Ask them to first turn and talk with a partner to share their initial thinking about both questions, then share as a class. Use the prompts below and press students to provide a rationale for their ideas as you record them on the board.

Suggested prompts	Sample student responses
If we gathered data by moving closer to the ground, what do you expect we would see happen to the air temperature?	*I think it would be warmer because that is what the weather balloon data showed.* *It would all be warm because all the air below _____ feet is warmer than the air above it.* *Well, if the ground is warmer than the air above it, I think that if we looked at the air closer to the ground, the temperatures would be warmer than the temperatures way high in the sky.* *I think all the temperatures would be the same because it is all close to the ground.*
If we gathered data at 12:00 noon instead of at midnight, what would the data look like? Would we see the same pattern? Why or why not?	*Maybe not, since the Sun is out during the day, but temperatures high in the sky would be warmer.* *I think all the temperatures would be warmer during the day than at night.*

With the second question, be sure to encourage students to consider the role of the Sun in heating things during the day versus at night. This will help prepare them to consider the heating of surfaces as part of the investigation.

When they have shared their predictions, say, *It seems like we all agree the air is warmer near the ground, but we need to understand why. That is what we are trying to figure out today.*

Introduce the lesson question. This may or may not have already come up while discussing predictions. Ask, *Why is the air near the ground warmer than the air higher up?* Write this question in a public space to refer to it throughout the lesson. Importantly, follow up with, *How could we investigate this question?*

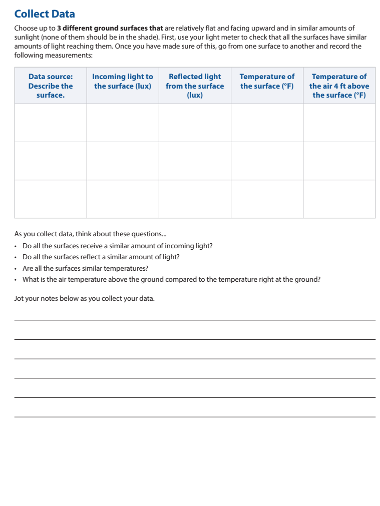
2. Planning Our Investigation

25 MIN

Materials: *Temperature and Sunlight Investigation*, science notebook

Plan the investigation. Show **slide B**. Ask students how we could test our ideas related to the lesson question, "Why is the air near the ground warmer than the air higher up?" Transition them to think about investigating this question by saying, *How could we study air close to the ground to see what is happening?*

Arrange students in groups of 4-5. Distribute *Sunlight and Temperature Investigation* to each student. The handout has a place for the investigation question; a table for identifying data to collect, tools and methods, and collection sites; a place for predictions; a table for the collected light and temperature data; and a place for notes about the data. Each section will be completed separately as students plan and carry out the investigation.*



Collect Data

Choose up to **3 different ground surfaces that** are relatively flat and facing upward and in similar amounts of sunlight (none of them should be in the shade). First, use your light meter to check that all the surfaces have similar amounts of light reaching them. Once you have made sure of this, go from one surface to another and record the following measurements:

Data source: Describe the surface.	Incoming light to the surface (lux)	Reflected light from the surface (lux)	Temperature of the surface (°F)	Temperature of the air 4 ft above the surface (°F)

As you collect data, think about these questions...

- Do all the surfaces receive a similar amount of incoming light?
- Do all the surfaces reflect a similar amount of light?
- Are all the surfaces similar temperatures?
- What is the air temperature above the ground compared to the temperature right at the ground?

Jot your notes below as you collect your data.

Choose data to measure. Ask students to record the investigation question (the lesson question) at the top of their handout. Prompt them to consider possible types of data that would be helpful in answering the question, turn and talk in their groups, and record their responses in the table's first row, "What data should we collect and why?"

*** Supporting Students in Engaging in Planning and Carrying Out Investigations**

This lesson develops this element of Planning and Carrying Out Investigations: Plan an investigation individually and collaboratively, and in the design, identify independent and dependent variables and controls, what tools are needed to gather the data, how measurements will be recorded, and how much data are needed to support a claim. Slides B-F help guide students through this process.

Give students time to share their ideas about what data they want to collect. Students will likely say they could go outside and measure the temperature of the air and the ground. Some may consider collecting sunlight data, especially after previously discussing the difference between weather balloon data from midnight and noon, and some might suggest recording the time of day; if they do not, ask, *Do you think it would matter what time we collect the data? Would it matter if it is cloudy or sunny, or dark or light outside? What if we are in the shade?*

Additional Guidance

The data collected are ground and air temperatures and incoming and reflected sunlight. Students are likely to suggest collecting temperatures outside but may not think of gathering data on incoming and reflected light. If they do not mention light, ask, *What causes the air to warm up anywhere in our atmosphere?* to get them to think about the role of the Sun. Remind them how we collected data on total incoming light in the previous units by using the light meter. It is important for students to make the connection that "sunlight" is energy from the Sun. This idea is critical later in this lesson as they model the transfer of energy in this system.

Discuss measurement tools. Display **slide C**. Based on the data students listed in the first row of the handout's table, ask what tools we could use to collect it (other than our eyes). Prompt them to consider the tools we used in past units to collect temperature and light data (i.e., thermometers and light meters).

Once students identify a tool, challenge them to provide a rationale for how the tool will help us gather the data we need to answer the investigation question.

Establish measurement procedures. As a class, develop procedures to ensure collecting accurate, precise data with the chosen tools. Encourage students to consider how to measure temperature right at the ground versus in the air farther above, as well as how to measure how much light is reaching the surface and how much is being reflected back. Here is an example discussion:

Suggested prompts	Sample student responses	Follow-up questions
So we are interested in the temperature of the ground and the air above it. How might we measure those temperatures?	*We could use a thermometer to get the temperature.*	*And where would we place the thermometer to measure the temperature of the ground?* *What about air farther above the ground? Can we agree on where we might hold the thermometers?*
Would it matter if we are in the wind?	*The wind could make the thermometer read colder than it is.*	*Can we agree to collect sunlight and temperature data in a few places that are protected from the wind?*
What about the shade? How would that affect our recordings?	*The temperature in the shade would be cooler than areas in sunlight.*	*How does being in the shade affect the temperature?*
What about the type of ground surface? Would the color matter? Or would it matter if one surface is really rough and one is really smooth?	*I think really dark surfaces are hotter because when I walk on a black parking lot, it feels really hot.* *It might be hard to hold the thermometer just as close to the rough surface as the smooth surface.*	*OK, so maybe we could test out a few different colored surfaces to see if there is a difference in the data.* *So maybe we should choose surfaces that are about the same roughness so we can collect our data in the exact same way for each one?*

The class should agree to the following procedures and write them in the second row of the table:

- Air temperature right at the ground should be taken by holding the thermometer about ½ inch from the surface.
- Air temperature farther above the ground should be taken by holding the thermometer approximately 4 feet from the surface.
- Block the wind, if necessary, so it doesn't affect the temperature readings.

- Incoming light should be recorded by holding the light meter facing upward and parallel to the surface, either lying flat on the ground or just a few inches off the ground, with no shadows blocking the sensor.
- Reflected light should be recorded by turning the meter to face downward and parallel to the surface, about 6 inches from the ground, with no shadows blocking the sensor.

Additional Guidance

Using the light meter: There will not be time to fully explain lux as the unit for measuring light, but it has been discussed in previous units. What students need to understand is that the light sensor measures the amount of light reaching and reflecting off a surface. To measure incoming light, the photoreceptive dome must be facing up and flat on the surface so it accounts for the angle of the sunlight as well. To measure reflected light, the meter must be turned to face the surface and held slightly off the ground and not in a shadow. Note: Be sure all light meters are set to the same setting if there are options. Be sure to note the scale provided on the meter in case students need to add "0s" to the number.

Using the thermometers: Meat thermometers offer an affordable way to get a quick reading of temperature. Ensure they are set to record temperature in Fahrenheit.

Select sites. Display **slide D**. Ask students how we might select data collection sites, and to identify potential sites on the school grounds. Example criteria include these:

- Sites should have the same Sun exposure (approximately the same incoming light).
- Site surfaces should be similar in how rough or smooth they are.
- Sites should be free of snow, ice, or water, as those would affect the readings.

Ask students why it is important to gather data from several sites. Emphasize that this will allow us to see patterns in the data. Only one or two sites are not enough to generalize from the data to think through what might be happening between the ground and the air.

Give students a moment to think of various sites around the school grounds (see examples below) that will work for data collection. Use **slide E** and **slide F** to provide additional best practices and things to avoid when collecting data.

Blacktop

Dirt

Mulch

Grass or sidewalk

Additional Guidance

For this investigation, students are discouraged from taking readings in the shade or on the grass. While a ground surface is in the shade, incoming energy from the Sun is reduced and its absorption of solar radiation decreases, lowering its temperature. A surface with grass, especially if it has just been watered, can also have a lower temperature even when it is absorbing high amounts of solar energy. It is therefore more difficult to make comparisons between grass's light absorption and corresponding temperature than with light absorption and corresponding temperature of other surfaces, such as concrete sidewalks, parking lots, and similar mineral materials.

3. Make predictions.

8 MIN

Materials: Temperature and Sunlight Investigation, science notebook

Make predictions linked to the data collection procedures. Display **slide G** and ask students to look closely at the photo. Considering the data collection procedures just outlined, have students turn and talk in partners to answer this question, *What might we see if we collect temperature and sunlight data in different parts of this photo? Draw and write about what you think we will see when we collect temperature and sunlight data outside.* Instruct them to focus on what we would expect to see in the bubbles on the photo. After partners have talked, have some students share their thinking with the class.*

*** Supporting Students in Engaging in Planning and Carrying Out Investigations**
An important part of planning and carrying out an investigation is anticipating and/or predicting what the collected data might mean and how they will help to answer the question under study. Students should consider what collected data from different sites (both ground and air) might show based on their prior knowledge from previous units or their experiences touching different surfaces in sunlight.

Assessment Opportunity

Students may struggle to predict what they might see when they collect data outside. Prompt them with: *What do we know about the air? Is it a solid or gas? What about the ground? Which has more matter?* These questions are intended to help students make connections between previous units and this current investigation.

Suggested prompts	Sample student responses
If you could check the air right at the surface of the sidewalk in the photo, would you expect it to be the same temperature above every part of the sidewalk?	*Different parts of it might have slightly different temperatures.* *Maybe it matters if it is in the shade.*
What if you compared a sunny part of the sidewalk with a spot in the shade? Would it be the same temperature?	*Probably not. It probably feels cooler in the shade.*
How do all the places in the sunlight compare?	*A blacktop feels really warm in sunlight compared to grass and maybe the sidewalk.*
Think about the pattern we saw with the weather balloon data. If we zoom into the space right at the ground and also the air about 4 feet above the ground, would we see a similar pattern? Why or why not?	*I don't think the temperatures will be different because they are really close together.* *If the ground is really hot, then maybe the air right at the ground will be really hot too because the air is touching the ground.*

Rehearse the procedures ahead of time. If time allows, students can practice taking readings in the classroom or outside on the school grounds. By working in their groups, everyone can understand the best practices for data collection and how to "calibrate" with one another so readings are consistent across multiple students. This is also a good opportunity to explain the different roles students can take on while working in their groups.

Additional Guidance

Each student in the group can have the role of (1) ground temperature reader, (2) air temperature reader, (3) incoming light reader, and (4) reflected light reader. Students should trade roles when collecting data at different surfaces so they all have the opportunity to use the equipment. And, each reading should be taken and agreed upon by at least two students.

4. Navigation

2 MIN

Materials: None

Summarize the investigation plan. Use **slide H** to remind students of the question we are trying to answer and how this investigation plan will help us answer it.

Prepare students for outside data collection by providing a few logistic reminders:

- *Next class, immediately join your group and get your equipment. You'll need two thermometers, a light meter, clipboards, and something to write with.*
- *Be sure to have your handout ready to record data.*
- If the weather will be cold, remind students to wear appropriate clothes and jackets to collect data outside.

End of day 1

5. Navigation

3 MIN

Materials: Temperature and Sunlight Investigation, science notebook

Reorient to the outside investigation. Use **slides E, F,** and **H** to remind students of best practices for data collection and to emphasize the question we are trying to answer. Have students also look at the plan for the investigation on the first page of *Sunlight and Temperature Investigation*. When everyone has their materials and is ready, take the class outside.

6. Conduct the temperature and sunlight investigation.

25 MIN

Materials: Temperature and Sunlight Investigation, science notebook

Collect data at the first surface as a class. Outside, say, *OK, we have some ideas about what might cause the ground and the air to heat up during the day. We know it has something to do with how sunny it is and also what kind of surface the* *ground is. Remember, our question is "Why is the air near the ground warmer than the air higher up?" So now let's collect data from our first site together.*

Select a sunny surface that all students can gather around. As a class, have each group take ground and air temperature and light readings and record them in the first row of their data table. Then have groups report their readings to the class to see if any are inconsistent with the rest. Slight differences are fine, but significantly outlying readings should be retaken and rerecorded. Make sure students are holding the equipment correctly, at the same height, and readings are similar across groups before the groups begin data collection independently.

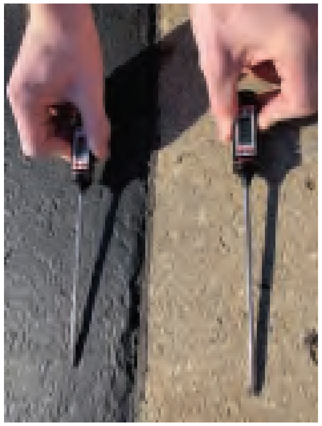
Additional Guidance

Students need to pay close attention to the units of measure for the sunlight data they report. Many readings will be in kilolux (klx), and students must convert the place value of those data sources to lux for recording in the data table.

Collect the remaining data in groups. Give the groups 15 minutes to collect temperature and light data for up to three other surfaces. Remind them that for each selected data source, they should collect the following:

- air temperature right at the ground (holding the thermometer about ½ inch from the surface)
- air temperature farther above the ground (holding the thermometer at approximately 4 feet from the surface; students can use a meter stick or hold their arm at the same angle for each measurement)
- incoming light (holding the light meter with its dome face up, not in a shadow)
- reflected light (holding the light meter with its dome facing the surface, not in its shadow or another shadow)



Additional Guidance

Each group should have two meat thermometers to allow options for data collection. Students can collect the temperature of two different side-by-side surfaces; for example, setting the thermometers on a concrete sidewalk and on pebbles next to it, or on black asphalt and on a concrete sidewalk. This will help them see the different amounts of energy that surfaces absorb from the Sun, as evidenced by varied temperatures. Students can also place the first thermometer on a surface and then hold the second 3-4 feet above the surface. This will allow them to see a slight temperature difference between the air right at the ground and the air farther above, which will help them build an understanding of convection in Lesson 5.

Alternate Activity

The *Temperature and Sunlight Investigation* works best on a day when it is sunny or partly sunny and temperatures are above freezing. Data collection on very cold days or dark, cloudy days will give skewed results. If you are unable to go outside for this lesson, have students work with the reference data sets *Sunny Day: Sample Data for Colorado Springs* and *Cloudy Day: Sample Data for Colorado Springs*. Alternatively, if this unit falls during winter or another time of year that makes data collection difficult, consider having a group of students collect data earlier in the school year so your class can work with local data; or, keep data collected the previous year to use again if needed.

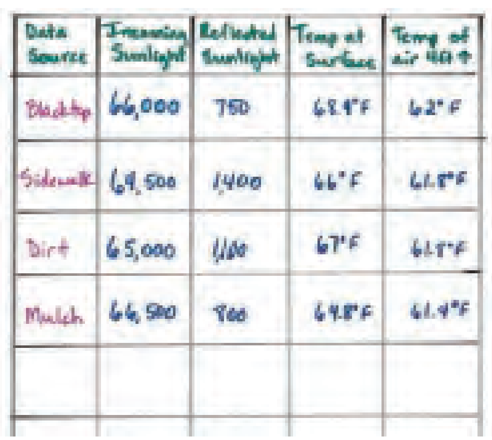
Also, during data collection, have students consider some important questions listed below the data table on *Sunlight and Temperature Investigation*, including which surfaces are warmer and colder, which surfaces reflect more light, and so forth. Aim to wrap up data collection within 25 minutes so there is enough time to report out results and look for some preliminary patterns.

7. Report results and make sense of data. 15 MIN

Materials: Temperature and Sunlight Investigation, science notebook, calculator (optional), computer and projector, chart paper, markers

Compile results. Use **slide I** to develop a representative list of all the groups' data sources and the patterns in those sources. It is best to project the slide onto a whiteboard so you can write into the projected table. Alternatively, create a class data table using two pieces of chart paper.

First, focus on gathering students' temperature and sunlight data from a variety of data sources (e.g., dark surfaces, light surfaces, asphalt, concrete, and so forth). Ask each group to share one source that is different from those of the other groups. Record and display the data for the class.



*** Attending to Equity**
As students report what they notice, be sure to prompt them to make connections to their everyday life: *Have you ever noticed something like this in your life, when some surface was really hot but another wasn't?* Examples include a hot, sandy beach or a sidewalk on a warm summer day, when the grass nearby feels cool to the feet, or walking across a parking lot's dark surface and feeling an increase in temperature.

Make sense of the sunlight data. Give students individual think time to notice any patterns across all the group measurements. Then ask students to focus on the sunlight data specifically. Display **slide J**. Remind them to think about incoming and reflected sunlight, and what that means for how energy from the Sun affects the ground. The difference between the two is a rough estimate of how much light is absorbed by the surface, which is what leads to an increase in temperature (as seen in the next set of columns). Give students time to consider what the different surfaces are like, such as how dark they are; how much light came to them and how much reflected off; and how that might explain how much light was absorbed.*

Push students to make connections to the Cup Design Unit. On day 3 of this lesson, they will draw their ideas about what happens at Earth's surface as energy from the Sun is absorbed into the ground. For now they need to notice patterns in the data that serve as evidence for the absorption of energy.

Suggested prompts	Sample student responses	Follow-up questions
Was there a difference between incoming and reflected light?	*Yes.*	*Can you describe how they were different?*
Where did the other light go?	*It went into the ground.*	*So what does that mean when light is absorbed into the ground? How do you know?*
How did the surfaces differ in the incoming and reflected light?	*Darker surfaces facing the same direction as lighter surfaces had the same amount of light reaching them. However, darker surfaces had a higher temperature than lighter surfaces. Less light reflected off darker surfaces.*	*Why do you think the darker surfaces were warmer than the lighter surfaces?*

Make sense of the temperature data. Transition students to focus on the temperature data specifically.* Display **slide K**. Ask, *What do you notice about the temperature data?*

Suggested prompts	Sample student responses	Follow-up question
Which surfaces were warmer? Which were cooler?	*The darker surfaces were warmer than lighter surfaces.* *The concrete was cooler than the blacktop parking lot.*	*Why do you think the type of surface matters?*
How do the sunlight data relate to the temperature data?	*The surfaces that absorbed more energy from the Sun had higher ground temperatures than the surfaces that absorbed less.*	

*** Supporting Students in Engaging in Analyzing and Interpreting Data**

The difference between the incoming sunlight and the amount reflected off a surface roughly calculates the amount of light being absorbed by the surface. Different surface materials behave differently depending on how much light is absorbed. The more energy from the Sun that is absorbed, the higher the surface's temperature. Solar energy is mostly absorbed by the ground (not the air above it), which is why ground temperatures are consistently higher than air temperatures. This is a critical idea for students to start developing at this juncture. Through analyzing and interpreting data, students can build evidence for this key science idea.

Suggested prompts	Sample student responses	Follow-up questions
Were the ground temperature and the air temperature the same?	*No, the ground was a little bit warmer than the air temperature.*	*Does this match our predictions?* *How does it relate to the weather balloon data?*
What do you think happens at the ground that makes temperatures there hotter than the air above the ground?	*The ground absorbs the energy from the Sun and when it does, the temperature increases.*	*Can air absorb energy from the Sun?*

8. Navigation

2 MIN

Materials: None

Define where we are in the investigation. Remind students that we are collecting and analyzing temperature data near the ground because we noticed a pattern in the previous lesson that air temperatures are warmer near the ground than high in the atmosphere. Say, *We are trying to figure out how a hailstorm can happen on a hot day, so tracking energy from the Sun to Earth's surface could help explain what causes the temperature patterns we are noticing.*

End of day 2

9. Discuss how to represent our ideas about the effect of sunlight on temperature.

5 MIN

Materials: science notebook

Connect the Investigation Findings to Prior Unit Models. Show **slide L**. Remind students that we've determined that energy from the Sun enters Earth's atmosphere and it travels to the surface of Earth where it reaches the ground. Emphasize that we should try to represent our shared thinking about how that is related to the temperature of the ground and the air in contact with the ground, and that thinking about light and how it interacts with solids and how solids interact with gases is something students have done before in the Cup Design unit. Ask students to think back to some of the ways we represented how light interacts with matter, temperature changes, and particle interactions as they discuss the questions on **slide L** with a partner.

Additional Guidance

Listen to students' discussions. These ideas should be coming up in their talk:

- Particles in solids and liquids are closer together than in gases.
- As the speed that particles are vibrating increases, the temperature increases.

- As particles in the ground absorb energy from the Sun, their kinetic energy increases, which increases temperature.
- The absorbed light speeds up the molecules on the surface of the ground, and the more they vibrate, the hotter the temperature will be.

If the students aren't raising these ideas, ask them to talk about what is happening to the particles that make up the ground and the air above it as light shines on the ground.

10. Develop a consensus model in a Scientists Circle and update Progress Trackers.

15 MIN

Materials: science notebook, chart paper, markers

Form a Scientists Circle. Find a good spot for the whole class to develop a consensus model to explain what they think is happening and how we would represent it. Preferably, use a whiteboard so students can edit one another's ideas or draw next to one another, but chart paper can also work.

Display **slide M**. Start by asking for ideas about how to represent the light coming from the sun that reaches the surface of the ground. Ask for student volunteers willing to come up and represent this.

Encourage students to label what they draw in the model, including things like the sun, the light rays, and the ground. Ask if other groups had similar or different ways to represent this. Another group can add to the first group's ideas.

As different groups share, facilitate a Consensus Discussion around the ideas students are representing.*

Transition to asking about what happens to some of the light that reaches the ground and how this affects the motion of the particles in the ground. Again ask for student volunteers to come up and represent this.

Lastly, transition to asking about what happens to the kinetic energy in the particles in the ground when air particles above the ground come into contact with it. Ask for a third set of student volunteers to come up and represent this.

Key Ideas

Purpose of the discussion: To generate a list of ideas related to how energy from the Sun can be absorbed by the ground, increasing its kinetic energy (and therefore temperature), and then how some of that energy transfers to the air above.

Listen for these ideas:

- The light that doesn't end up bouncing off the surface is absorbed.
- The surfaces that absorb more light tend to be warmer (higher temperature).
- Light transmits through air and reaches the ground, where some of it is absorbed and some is reflected.
- When the Sun's energy is absorbed, it causes the particles in the ground to vibrate more, increasing the ground's kinetic energy and temperature.
- Particles in the ground with more kinetic energy transfer energy to the particles in the air through conduction when they collide.

*** Strategies for This Consensus Discussion**

To encourage students to build upon one another's ideas and come to points of agreement, prompt them to say things like, *We agree with that idea but want to add to it*, or *We had a different way of thinking about it*. Ask questions of students (and encourage students to ask them of each other) such as these:

- *Where do we have agreement?*
- *Do we feel like we know where the sunlight that isn't reflected is going?*
- *How does temperature relate to that idea?*

Use the Progress Tracker to come to an agreement. Say, *OK, these representations have helped us articulate some new ideas for how to think about ground and air temperature that are strongly connected to what we figured out about the interaction of light, solids, and gases in contact with solids in the Cup Design unit. So how would you summarize what we can say now about how sunlight affects ground and air temperatures?*

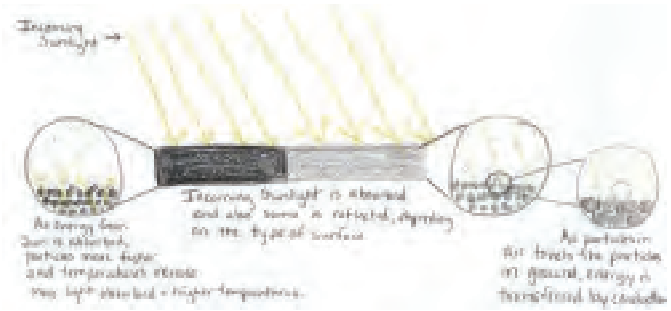
Prompt students to draw a three-box Progress Tracker in their notebook underneath the question we have been trying to answer, "Why is the air near the ground warmer than the air higher up?" Ask what evidence we have been working with to answer this question (e.g., ground and air temperatures, light meter data for incoming and reflected light).

Give students an opportunity to develop a record of the key ideas we developed as a class, in words and/or diagrams in their Progress Tracker.

<table>
<tr><th>Question</th><th>Source of Evidence</th></tr>
<tr><td>Why is the air near the ground warmer than the air higher up?</td><td>Ground and air temperatures
Incoming sunlight and reflected light</td></tr>
<tr><th colspan="2">What we figured out in words and pictures</th></tr>
<tr><td>Incoming sunlight is absorbed by the ground, and this causes the ground to heat up.

Particles in the ground with more kinetic energy transfer energy to the particles in the air through conduction when they collide.

Different surfaces heat up differently depending on how much sunlight they absorb or reflect.

Air temperatures right above the ground, however, are cooler than the ground itself.</td><td>
</td></tr>
</table>

11. Connect to the anchoring phenomenon. **3 MIN**

Materials: science notebook

Summarize for students that we have a partial answer to why it's warmer near Earth's surface: Solid surfaces absorb light (energy from the Sun) and warm up as a result. Some materials absorb more light than others. Some of this energy is then transferred to the air right above the ground. Say, *But how does understanding what is happening when the ground warms up help us explain our hail storm?*

Stop and Jot. Display **slide N**. Give students a few minutes to jot down their thinking in response to the question on the slide. Then say, *Okay, let's keep thinking a bit more about how all of this might be connected to what causes hailstorms before we start further investigations.*

Additional Guidance

The lesson as written assumes that you are starting the next lesson (lesson 5) on the same day that you are finishing this lesson (lesson 4), and that you will have 20 minutes left in the period to make progress on lesson 5.

ADDITIONAL LESSON 4 TEACHER GUIDANCE

Supporting Students in Making Connections in Math

Students collect data in groups and create a shared class data set as part of this lesson. This activity intersects with mathematics in supporting students to understand the characteristics of data sets.

CCSS.MATH.CONTENT.6.SP.B.5: Summarize numerical data sets in relation to their context, such as by:

CCSS.MATH.CONTENT.6.SP.B.5.A: Reporting the number of observations.

CCSS.MATH.CONTENT.6.SP.B.5.B: Describing the nature of the attribute under investigation, including how it was measured and its units of measurement.

LESSON 5

What happens to the air near the ground when it is warmed up?

Previous Lesson

We planned and conducted an investigation to explain why the air closer to the ground is warmer than the air farther above it. We collected and analyzed temperature and sunlight data to figure out how incoming and reflected sunlight affected ground and surface air temperatures. We noticed that some ground surfaces heated up more than others.

This Lesson

Investigation

2.5 DAYS

We conduct an investigation to explore how transferring thermal energy into and out of a parcel of air in a closed system (a bottle of air with a soap bubble film over the top) affects that air's volume and behavior. We conduct a second investigation to explore how density changes in a parcel of air in another closed system (a balloon) cause it to float or sink in the surrounding air. For each investigation, we develop a model to represent how the speed, spacing, and density of molecules that make up air are affected by temperature changes.

Next Lesson

We will examine photos and a video of clouds that tend to produce hail and construct an explanation using evidence for the path of air movement below, within, and at the top of a type of cloud that tends to form hail. We will revise our initial consensus model and return to the Driving Question Board (DQB), leading us to learn more about what makes up the air.

Building Toward NGSS

MS-PS1-4, MS-ESS2-4, MS-ESS2-5, MS-ESS2-6

What Students Will Do

Conduct investigations to collect and use observations and data as evidence to determine the effects of thermal energy transfer to the air in contact with Earth's surface.

Develop and use a model to track and describe how transferring thermal energy to and from a fixed amount of air (matter) in a closed system affects its volume and density due to unobservable mechanisms (causes), including changes in the speed and spacing of the molecules that make up that air.

What Students Will Figure Out

- Changing the temperature of a parcel of air causes changes in the air's density due to changes in the kinetic energy (speed) and spacing of the molecules that make up the air.
- Parcels of air that are less dense than the surrounding air rise. Parcels of air that are more dense than the surrounding air sink.
- As they rise, parcels of warm, less dense air eventually cool off, transferring thermal energy to the surrounding air.

Lesson 5 • Learning Plan Snapshot

Part	Duration	Summary	Slide	Materials
1	5 min	**NAVIGATION** Brainstorm how air getting warmed up near the surface might be related to what causes hail to form on relatively warm days and ways to trap air and warm it.	A-B	
2	5 min	**MAKE PREDICTIONS ABOUT WHAT WILL HAPPEN TO AIR WHEN IT IS HEATED AND COOLED** Make and record predictions about what will happen to air trapped in a closed system when it is heated and when it is cooled.	C-D	Soap Bubble and Bottle Investigation
3	10 min	**CONDUCT THE SOAP BUBBLE AND BOTTLE INVESTIGATION** Observe and describe what happens when the air inside a closed system is heated and cooled.	E-F	Soap Bubble and Bottle Investigation
				End of day 1
4	20 min	**BUILDING UNDERSTANDINGS DISCUSSION ABOUT THE EFFECT OF ADDING THERMAL ENERGY TO AIR IN A CLOSED SYSTEM** Draw and discuss ideas about what is happening to the molecules that make up air when heat is removed or added. As a class, test these ideas to help build understanding.	G-H	*Soap Bubble and Bottle Investigation*, tape, chart paper, markers, 3 bottle models drawn on separate sheets of chart paper (see Advance preparation for Day 1: Soap Bubble and Bottle Investigation)
5	7 min	**CONNECT TO THE ANCHORING PHENOMENON** Review what happened in the *Soap Bubble and Bottle Investigation* and use this information to predict what would happen to air outside near the ground on a day when it hails.	I	*Soap Bubble and Bottle Investigation*

6	18 min	**TRACK THE FLOW OF ENERGY INTO AND OUT OF THE CLOSED BOTTLE SYSTEM** Use sticky notes on the classroom consensus models to document the flow of energy into and out of the closed bottle system as the air is warmed up and cooled down. Summarize the relationship between volume and matter by introducing the concept of density.	J-N	chart paper, markers, 3-x-3 sticky notes
				End of day 2
7	5 min	**MAKE A PREDICTION** Use what we figured out from the *Soap Bubble and Bottle Investigation* to predict what would happen to a closed system of gas in a balloon. Then consider how this might also apply to the air near the ground on a day when it hails.	O-P	
8	10 min	**CONDUCT THE HEATED BALLOON INVESTIGATION** Observe what happens to a partially deflated Mylar balloon when it is warmed up.	Q	Heated Balloon Investigation
9	16 min	**CONDUCT A BUILDING UNDERSTANDINGS DISCUSSION ABOUT THE EFFECT OF ADDING THERMAL ENERGY TO THE BALLOON** Develop an initial model to explain what is happening to the molecules inside the balloon when heat is added. Conduct a Building Understandings Discussion to surface additional ideas about the effects of heating air in a closed system and develop a classroom consensus model.	R-U	*Heated Balloon Investigation*, tape, chart paper, markers, 3-x-3 sticky notes
10	5 min	**MAKE CONNECTIONS TO THE LESSON QUESTION** Use evidence from the investigations to explain what happens to air near the ground when it is warmed up.	V	
11	5 min	**UPDATE PROGRESS TRACKER** Synthesize what we have figured out and add it to our Progress Trackers.	W	
12	4 min	**NAVIGATION** Discuss how the behavior of the air near the ground when it is warmed up helps explain what is happening to the air outside on a day when it hails.	X	
				End of day 3
		SCIENCE LITERACY ROUTINE Upon completion of Lesson 5, students are ready to read Student Reader Collection 2 and then respond to the writing exercise.		Student Reader Collection 2: *Energy and Surfaces*

Lesson 5 • Materials List

	per student	per group	per class
Soap Bubble and Bottle Investigation materials		• plastic bottle • small container with soap bubble solution • 2 6-quart tubs • access to hot and cold water	
Heated Balloon Investigation materials			• partially deflated and counterweighted Mylar helium balloon • heating pad • hair dryer
Lesson materials **Student Procedure Guide** **Student Work Pages**	• science notebook • *Soap Bubble and Bottle Investigation* • *Heated Balloon Investigation*		• tape • chart paper • markers • 3 bottle models drawn on separate sheets of chart paper (see Advance preparation for Day 1: Soap Bubble and Bottle Investigation) • 3-x-3 sticky notes

Materials preparation (40 minutes)

Review teacher guide, slides, and teacher references or keys (if applicable).

Make copies of handouts and ensure sufficient copies of student references, readings, and procedures are available.

Day 1: *Soap Bubble and Bottle Investigation*

- **Group size:** 5 students
- **Advance preparation:**
  - Watch the video for the *Soap Bubble and Bottle Investigation* to preview the materials and procedures. (See the **Online Resources Guide** for a link to relevant items. **www.coreknowledge.org/cksci-online-resources**)
  - Draw the three bottle models shown on **slide G**, each on a separate sheet of chart paper.
- **Setup:**
  - Prepare one empty 2-liter soda bottle (no cap) per group. Save the caps and bottles for reuse in later lessons.

Online Resources

- Prepare soap bubble solution and put it into small plastic bowls, one per group. Liquid dish soap should work, but if the bubbles pop too easily, try a solution of 8 parts water, 4 parts liquid dish soap, and 1 part glycerin.
- Prepare one cold water bath per group: one 6-quart tub with approximately 3 inches of cold tap water. If the water isn't very cold, add ice. These can be prepared ahead of class.
- Have materials ready to prepare one hot water bath per group: one 6-quart tub with approximately 3 inches of hot water. If your school has a hot water tap, this is sufficient. If not, use the electric kettle(s) from the Cup Design Unit to heat the water. Water does not need to be boiling.

- **Safety:** Students will work with hot water. Ensure the water is not boiling before you pour it into their tubs. Also, make sure students allow the hot water to cool down before they empty the tub in the nearest sink.

Day 2: *Heated Balloon Investigation*

- **Group size:** Whole class
- **Advance preparation:** Watch the video for the *Heated Balloon Investigation* to observe how to prepare the balloon. (See the **Online Resources Guide** for a link to relevant items. **www.coreknowledge.org/cksci-online-resources**)
- **Setup:**
    - Use a straw or a chopstick to deflate the helium-filled Mylar balloon to about ⅔ full. (Be careful not to deflate it too much, or it will not have enough helium to rise when warmed up.) Then use paper clips as counterweights so it very slowly descends when released and floats right at ground level.
    - Have a heating pad and a hair dryer (preferably with multiple heat settings) ready to use. The pad is the preferred heating method; the dryer is a backup if the pad doesn't generate enough heat to produce a large enough volume change in the balloon to get it to rise.
    - If your classroom is not carpeted, place a towel, small blanket, or carpet square under the heating pad to reduce heat transfer to the floor.

Lesson 5 • Where We Are Going and NOT Going

Where We Are Going

In the previous lesson, students made connections to key physical science ideas about light, thermal energy, and thermal energy transfer. They collected temperature data from a number of sites and used that data to figure out that the ground warms up the air just above it through conduction. This led students to wonder what happens to the air near the ground after it is warmed up.

In this lesson, students conduct two investigations. In the first, they trap air in a bottle using a soap bubble film, then place the bottle in a cold water tub and a hot water tub. In the second, a heating pad is used to warm a Mylar balloon partially filled with helium. Both investigations are an opportunity to observe the effects of changing the amount of thermal energy in a gas in a closed system.

As students work through these investigations, they document their observations, then represent the effects of heating a gas in a closed system using models. They should notice the following changes to the gas in each closed system.

Soap bubble and bottle system:

- When cooled, the bubble at the top of the bottle sinks into the bottle because the air inside takes up less space.
- When warmed, the bubble at the top of the bottle expands outward because the air inside takes up more space.

Heated balloon system:

- When warmed, the balloon expands because the helium inside takes up more space.
- The balloon also floats upward, then slowly sinks back to the floor.

Students discuss the changes they observe in each system and are guided to think about the changes at the particle level. This again is a connection to key physical science ideas in this lesson. They develop models for each system to show that the molecules that make up the gas move faster and spread out, taking up more space, when thermal energy is added. This changes the density of the gas in each system. As the gas in the balloon becomes less dense, the balloon rises in the surrounding air, which is more dense.

This will lead students to wonder, "How does rising and sinking air help us explain what is happening to the air outside on a day when it hails?"

Where We Are NOT Going

Students will figure out the importance of rising and sinking air in the creation of hailstorms in upcoming lessons. The following related ideas are also established in later lessons:

- Temperature differences in air lead to the creation of convection currents.
- Strong convection currents continually move air and moisture upward, causing hail formation.

1. Navigation

5 MIN

Materials: science notebook

Additional Guidance

The lesson as written assumes that you are starting this lesson on the same day that you are finishing lesson 4, and that you will have 20 minutes left in the period to make progress on lesson 5. If this is not the case, allocate a couple of minutes to have students summarize what we figured out in Lesson 4 that helps us understand how the air above the ground warms up, rather than summarizing it for students as described below, before discussing connections about how this might be causing hail.

Determine next steps. Say, *So if we figured out that Earth's surface is heated when it absorbs light from the Sun and that different surfaces heat up differently depending on how much sunlight they absorb, let's think a bit more about how that might be related to what is causing hail.* Show **slide A**. Give students a minute or two to talk with a partner about the question on the slide, then have them share their ideas with the class.

Suggested prompt	Sample student responses
How could investigating what happens to the air getting warmed up near the ground help us explain some of the mechanisms that lead to hailstorms?	*On days when it hailed, the air was relatively warm near the surface, so we need to trap some air and warm it up to see what happens to it.* *If we can observe what happens to the air after it is warmed, that may help us figure out what is happening to the air outside on a day when it hails.*

Additional Guidance

If students don't recall Lesson 2's connection between hail occurring on days when the air temperature outside (at the surface) was relatively warm, help them by asking what the surface air temperature was on days when it hailed. Then remind students that this pattern led us to wonder how hail formed on warm days, especially since it doesn't always hail on warm days, and the air up high in the atmosphere seems to always get cold enough to freeze water. You can then suggest that figuring out what happens when the warm air above the surface and the colder air higher up in the atmosphere interact might help us explain what happened on the days when it hailed.

Say, *Figuring out what happens to the air near the ground after it gets warmed up might help us explain some of the mechanisms (or processes) that lead to hailstorms. Let's figure out how we might go about doing that.* Show **slide B.** Discuss the second question on the slide as a class.

Suggested prompt	Sample student responses
How could we trap some air in contact with a warm surface to figure out more about what happens to air after it is warmed up?	*We could trap air near the ground in a bag and close the bag with a twist tie.* *We could trap air near the ground in a container with an airtight lid.*

After students share, say, *You certainly have some good ideas. Let's conduct an investigation to try to make progress on our lesson question: "What happens to the air near the ground when it is warmed up?"* Write this lesson question on the board.

2. Make predictions about what will happen to air when it is heated and cooled.

5 MIN

Materials: Soap Bubble and Bottle Investigation, science notebook

Set up science notebooks. Show **slide C** and say, *To do this, we will conduct two investigations. Let's take a few moments to set up our science notebooks for the first investigation. Turn to the next available page in your notebook and write the title "Soap Bubble and Bottle Investigation." Then add the heading "Prediction" below the title.* Give students a few moments to do this.

Preview the investigation process. Show **slide D** and tell students, *We'll use a clear plastic bottle as our container of air and trap air in it by sealing the opening with a thin layer of soap bubble solution. We'll cool down the air by placing the bottle in a tub of cold water, then warm up the air by placing the bottle in a tub of hot water. As we work, we'll document our observations.*

Additional Guidance

We could have chosen to seal the opening of the bottle in several ways. For example, we could use the bottle cap or a sheet of plastic wrap. However, we need a seal that closes the system and is flexible enough to reflect observable changes in the density and volume of the air inside the bottle when it is cooled or warmed.

Demonstrate how to dip the bottle into the soap bubble solution to make a film that seals the bottle. Then say, *Scientists often study things in closed systems to better understand what is happening to some of the matter and energy in a larger open system. With an unbroken soap bubble covering the opening, the bottle is a closed system. That means the number of molecules (or particles) that make up the air in the bottle remains the same, because no air can get in or out. Studying a small amount of air in a closed system will help us better understand what happens to the air outside when it is warmed up.**

Make and record predictions. Refer to **slide D** again and say, *Let's make some predictions:*

- *What do you think will happen to the air in the bottle when it is in contact with the cold water? Why?*
- *What do you think will happen to the air in the bottle when it is in contact with the hot water? Why?*

Think about these questions and jot down your predictions in your notebooks.

*** Supporting Students in Engaging in Developing and Using Models**

When focusing on the crosscutting concept of Systems and System Models, students learn that models, whether built or drawn, are used to represent systems and their interactions, including inputs, processes, and outputs. They also come to understand that energy, matter, and information flow within and through systems.

At this point in the lesson, you may want to spend a little time reminding students that matter cannot enter or leave a closed system. However, energy can enter and leave a closed system. Both of these ideas were developed in the Cup Design Unit.

3. Conduct the soap bubble and bottle investigation. 10 MIN

Materials: Soap Bubble and Bottle Investigation, science notebook

Set up the *Soap Bubble and Bottle Investigation*. Put students in groups of 5. Show **slide E** and give groups a minute or two to get their materials and fill one tub with cold water. When groups are ready, walk to each group and fill their second tub with hot water about 3 inches deep.

Safety Precautions

Remind students to be cautious around the hot water used in this investigation. The following precautions are recommended:

- The water should not be hot enough to burn the skin, but it needs to be warm enough to cause a change in the volume of the air inside the closed bottle system (a bubble should form at the opening of the bottle).
- The teacher should pour the water into each group's hot water tub while it is on the group's table, rather than have students bring a tub to the water and then carry it back to their table.
- After the investigation, students should allow the hot water to cool down before discarding it in a nearby sink.

Conduct the investigation. When everything is set up, show **slide F**. Tell students, *You need to conduct the investigation at least twice. The first time, seal your bottle with the soap bubble solution and closely observe what happens when the bottle is first placed into the cold water tub, then the hot water tub. The second time, use words and/or pictures to record your observations in your notebook. Feel free to try the investigation a third or fourth time if you need to, but make sure you take time to record your observations. In addition, if the bubble pops, seal the bottle again with the soap bubble solution and repeat the process.*

Give students about 5 minutes to conduct the investigation and record their observations. Walk around the room and listen to their observations. Encourage them to explain their observations using what they already know about energy, how it transfers, and its effects on the particles in matter. Use questions like the following to guide their thinking as they make and document observations.

Suggested prompts	Sample student responses	Follow-up questions
What did you notice happening the first time you conducted the investigation?	*The soap bubble film sank into the bottle in the cold water.* *Putting the bottle in the hot water caused a bubble to form at the top of the bottle.*	*What do you think caused the soap bubble film to sink into the bottle?* *What do you think caused the bubble to form?*
Are we adding more air to or taking air out of the bottle?	*We don't think we are adding any air to the bottle.* *Maybe air is sneaking through the soap bubble film.*	*Do you think air can move in and out of the system through the bubble?*

Suggested prompt	Sample student response	Follow-up questions
Think back to the Cup Design Unit. What did we figure out happened between parts of the system at different temperatures?	*Think back to the Cup Design Unit. What did we figure out happened between parts of the system at different temperatures?*	*What do we call this type of energy transfer?* *What happened to the particles when energy was added or removed from them?*

Additional Guidance

If your students have previously completed the Cup Design Unit, encourage them to make connections to those ideas, such as how thermal energy can transfer into or out of a closed system through direct contact with other substances of different temperatures. Students should recall conduction (particle collisions) as a mechanism for how energy transfers into and out of a closed system, like the bottle. However, keep the discussion brief right now; there is time after the investigation to make these connections more fully.

Direct students to clean up their areas and return their materials.

End of day 1

4. Building Understandings Discussion About the Effect of Adding Thermal Energy to Air in a Closed System

20 MIN

Materials: science notebook, *Soap Bubble and Bottle Investigation*, tape, chart paper, markers, 3 bottle models drawn on separate sheets of chart paper (see Advance preparation for Day 1: Soap Bubble and Bottle Investigation)

Connect to the previous investigation. Ask students to summarize what they saw the bubble film do in the previous investigation when they added and when they removed thermal energy from the air trapped in the bottle.

Say, *Let's try to explain these results using a particle model of air and what we know about how particle motion is related to temperature.*

Develop an initial model. Distribute the *Soap Bubble and Bottle Investigation* handout. Show **slide G** and tell students to work with a partner or small group to complete the handout, then tape it into their science notebooks.

Hold a Building Understandings Discussion. After students complete the handout, have them bring their notebook with their handout, along with a chair, to a Scientists Circle for a Building Understandings Discussion.*

* Strategies for This Building Understandings Discussion

The purpose of this discussion is to help students develop and revise their ideas about how air, which is a fluid, behaves when heat is added or removed. This is the first in a series of activities that will help them understand the relationship between matter, energy, volume, and density. Students will ultimately apply those ideas to how water, which is also a fluid, behaves. Later in the unit, both of these applications will help students understand why warm air rises and carries water

Key Ideas

The goal of this discussion is to help students make sense of what happens to air when it is cooled down and warmed up.

During this discussion, students should make connections to a number of ideas from the Cup Design Unit:

- The molecules (or particles) that make up a warmer material have more kinetic energy than the molecules that make up a cooler material.

- Because the molecules in a warmer material have greater kinetic energy than those in a cooler material, they move faster.
- Warmer materials transfer energy to cooler materials through particle collisions. This type of energy transfer is known as *conduction*.
- Energy is constantly transferred from particles with more energy to those with less energy.
- Matter cannot enter or leave a closed system.
- Energy can enter and leave a closed system through conduction and/or radiation.

In addition, the following key ideas should surface:

- The bottle system is a closed system.
- The amount of matter (molecules that make up the air) in the bottle remains the same.
- As the air in the bottle is cooled down, the molecules that make up the air slow down and take up less space. This means the volume of the air decreases.
- As the air in the bottle is warmed up, the molecules that make up the air speed up and spread out. This means the volume of the air increases. Project **slide H** and use the questions (repeated below) to guide the discussion. Keep in mind that you may need to revisit the investigation during this discussion. Therefore, make sure you have the necessary materials to conduct the investigation.

Suggested prompts	Sample student responses
When representing the molecules that made up the air in the closed bottle system after cooling and after warming, how many dots should you draw? Why?	*We should draw the same number of dots (molecules) in each bottle as in the original room-temperature bottle. Since the soap bubble film did not let any air in or out of the bottle, and there were no holes in the bottle, it was a closed system. So the amount of air stayed the same at all times.*
In what ways did changing the temperature of the air in the closed bottle system affect the molecules that made up the air inside?	*The molecules sped up when the temperature increased and slowed down when the temperature decreased.* *When the molecules sped up, they also spread out and took up more room.* *When the molecules slowed down, they took up less room.*
What evidence supports the changes you represented in the molecules that made up the air in the bottle?	*We know the molecules that made up the air in the bottle were moving faster and taking up more space when the temperature increased because the bubble expanded to allow the air (molecules) to take up more room.* *We know the molecules were slowing down and taking up less space when the temperature decreased because the bubble sank into the bottle as the amount of space needed by the air (molecules) decreased.*

vapor higher up in the atmosphere where it is cold enough for hail to form.

The scaffolded questions used in this part of the lesson are designed to help students draw on and build upon ideas from the Cup Design Unit and start thinking about how interactions at the molecular level can help us explain the effects of thermal energy on particle motion, volume, and density of air (and water).

During this discussion, some students might think the soap bubble film sank into the bottle because gravity pulled it down. If so, ask them to explain why that happened in the cold bath but not in the hot bath. If other students think something is happening to the bottle itself to make the soap bubble expand or contract, challenge them to test their ideas. For example, if they think the bottle is expanding and contracting, have them measure the bottle's length and width under both cold and hot conditions.

Build consensus models representing the closed systems. After discussing the questions, post the sheets of chart paper showing the three bottle models side by side so they appear in the same order as on the *Soap Bubble and Bottle Investigation* handout. Tell students, *Let's talk about how you represented what happened to the air in the closed bottle system when it was in the cold water bath and when it was in the hot water bath.*

Have a few students share their models and ask them to support their work with evidence from the investigation. As students share, draw the molecules that make up the air in the bottle in both the second and third models. The models should include the following characteristics:

Characteristic	Original bottle	Bottle in cold water tub	Bottle in hot water tub
# of molecules	30	30	30
Length of arrow for speed of each molecule	Set length	Shorter than the set length	Longer than the set length
Spacing between molecules	Set spacing	Closer together than the set spacing	Farther apart than the set spacing
Temperature of the air in the bottle compared to room temperature air	Same as room temperature	Colder than room temperature	Warmer than room temperature

When the models are completed, summarize the discussion by saying, *We observed that warming up—or adding thermal energy to—air causes the molecules that make up the air to move faster and spread apart. We know this is true because the bubble expanded as the molecules spread out. We also observed that cooling down—or taking thermal energy away from—air caused the molecules to slow down and take up less space. So let's think about how this related to what might be happening outside on a day when it hails.*

5. Connect to the anchoring phenomenon.

7 MIN

Materials: science notebook, *Soap Bubble and Bottle Investigation*

Assign students a new partner to talk with. Assign students in the Scientists Circle a number, so they have a corresponding number on the other end of the circle that matches theirs. For example in a class of 24, count off students up to 12 and then repeat. Project **slide I.** Tell students to stand up and pair up to discuss the two questions on the slide with the person who has the corresponding number.

Additional Guidance

This strategy of "Stand Up, Pair Up" is designed to give students a movement break before returning to the Scientists Circle again.

After 3–4 minutes ask students to bring their science notebooks and gather again in the Scientists Circle to discuss the questions as a whole group.

Suggested prompts	Sample student responses
In what ways are the closed bottle system and the air near the ground similar?	*The air close to the ground is warmed by the ground the same way the air in the closed bottle system was warmed by the hot water in the tub—through conduction.* *When the ground warms the air near it, that air will be affected the same way the air in the bottle was affected—the molecules will move faster and spread out.*
How does investigating the closed bottle system help us investigate our ideas about how a hailstorm forms?	*On days when it hails, the temperature is usually warm, which means the ground is warming the air close to it. So those molecules are moving faster and spreading out to take up more space, like the air in the bottle.* *These similarities will help us determine what to do next to figure out what happens to the air near the ground after it is warmed up.*

6. Track the flow of energy into and out of the closed bottle system. 18 MIN

Materials: science notebook, chart paper, markers, 3-x-3 sticky notes

Additional Guidance

Have the three bottle models from Day 1 available for students to see.

Introduce the idea of tracking the energy flow. Point to the three models of the closed bottle system and say, *Let's think about the investigation we conducted and the models we developed in our last class. We figured out a number of things about the air in the closed bottle system when it was warmed up or cooled down, so we know thermal energy played an important role in what we observed. Tracking energy as it moves into and out of this system was useful for helping us understand phenomena in our Cup Design unit. Let's take that approach again and try and track energy flow through the system to help us understand what might be happening to the air on a day when it hails.*

Show **slide J**, read the questions on the slide aloud, and say, *Let's consider each model of our bottle and think about these questions as we track and document the flow of energy in the system.*

Additional Guidance

The task in this portion of the lesson is for students to work together in a Scientists Circle to document the flow of energy in the three models of the closed bottle system:

- air in the bottle at room temperature

- air in the bottle in contact with cooler water
- air in the bottle in contact with warmer water

Slide K provides questions to be used with each model to help students think about the following ideas:

- where energy is located
- the direction of the flow of energy (from warmer to colder)
- the mechanisms that play a role in the transfer of energy into and out of the closed bottle system

As students share their responses to the questions, document their thinking using sticky notes and arrows on the models to show the transfer and flow of energy.

Track and document the energy flow in each model of the closed systems. Tell students, *We'll place sticky notes on the models to show the location of energy, and we'll indicate where energy transfers using arrows. Let's begin with the closed bottle system prior to cooling or heating, move to the bottle in the cold water tub, and finish with the bottle in the hot water tub.*

Use the questions on **slide J** to guide the discussion. For each model, give students 2 minutes to think about and discuss the questions, then solicit responses and document them on each model. This includes air temperature inside and outside the bottle, location of energy (on sticky notes), and transfer of energy (arrows). Sample responses and models are shown below.

Documenting the Flow of Energy—*Soap Bubble and Bottle Investigation*

Suggested prompts	**Sample student responses**		
	Air in the bottle at room temperature	**Air in the bottle in contact with a cooler surface**	**Air in the bottle in contact with a warmer surface**
1. What do we know about the temperature of the following? a. the air outside the bottle b. the water in the tub c. the air inside the bottle	a. *The air outside the bottle is room temperature.* b. *N/A* c. *The air inside the bottle is room temperature.*	a. *The air outside the bottle is room temperature.* b. *The water in the tub is colder than room temperature.* c. *Initially, the air in the bottle is warmer than the water in the tub. After the bottle is placed in the cold water tub, the air in the bottle cools down.*	a. *The air outside the bottle is room temperature.* b. *The water in the tub is warmer than room temperature.* c. *Initially, the air in the bottle is colder than the water in the tub. After the bottle is placed in the hot water tub, the air in the bottle warms up.*

Documenting the Flow of Energy—*Soap Bubble and Bottle Investigation*			
Suggested prompts	**Sample student responses**		
	Air in the bottle at room temperature	**Air in the bottle in contact with a cooler surface**	**Air in the bottle in contact with a warmer surface**
2. Where can we locate energy in and around the bottle system?	*Energy is in the* • *air outside the bottle* • *air inside the bottle* • *bottle wall*	*Energy is in the* • *air outside the bottle* • *air inside the bottle* • *bottle wall* • *cold water in the tub*	*Energy is in the* • *air outside the bottle* • *air inside the bottle* • *bottle wall* • *hot water in the tub*
3. What energy transfers are causing the changes we observed in each model?	*Energy is moving back and forth between the air inside the bottle, the bottle wall, and the air outside the bottle, because everything is room temperature. The bottle system is stable.*	*Energy is moving from the air inside the bottle to the bottle wall, then to the cold water, because the air in the bottle is warmer than the cold water.*	*Energy is moving from the hot water to the bottle wall, then to the air inside the bottle, because the water is warmer than the air in the bottle.*
4. How might we document and track these transfers of energy?	*We need a sticky note with an **E** to represent energy on* • *the air outside the bottle,* • *the bottle wall, and* • *the air inside the bottle.* *We need arrows showing energy flowing back and forth between the air outside, the bottle wall, and the air inside, because all three are at room temperature.*	*We need a sticky note with an **E** to represent energy on* • *the cold water in the tub,* • *the bottle wall, and* • *the air inside the bottle.* *We need arrows showing energy flowing from the air in the bottle to the bottle wall, and from the bottle wall to the cold water in the tub, because energy moves from the warmer air to the colder water.*	*We need a sticky note with an **E** to represent energy on* • *the hot water in the tub* • *the bottle wall, and* • *the air inside the bottle.* *We need arrows showing energy flowing from the hot water in the tub to the bottle wall, and from the bottle wall to the air in the bottle, because energy moves from the warmer water to the colder air.*
Sample model	See Figure A.	See Figure B.	See Figure C.

Figure A.

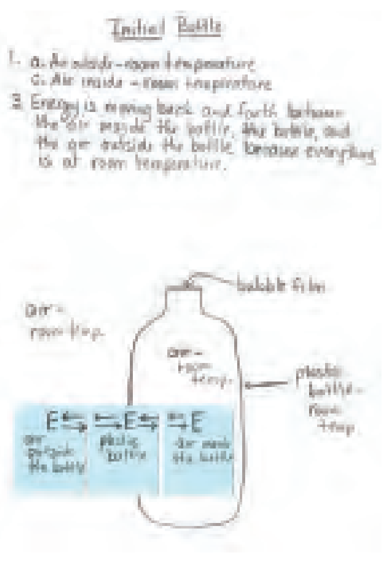


Figure B.

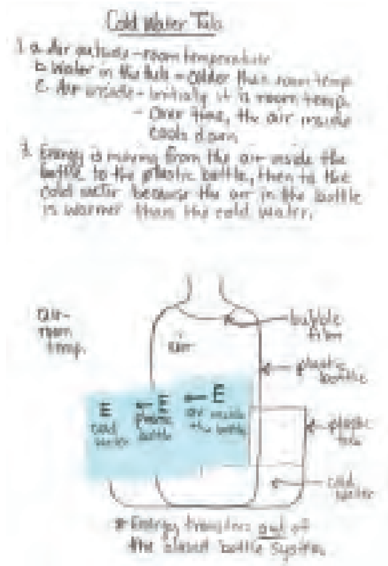
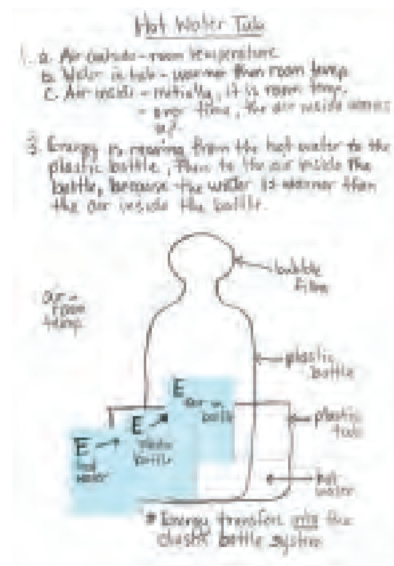


Figure C.



Have students head back to their desks when the class finishes documenting the flow of energy on all three models.

Introduce the concept of density. Before moving on to the second investigation, introduce the concept of density. Show **slide K** and tell students, *The relationship between the amount of matter in a sample and its volume (the amount of space it takes up) is the **density** of that material. Think about the closed bottle system. When we placed the bottle in the cold water, what happened to the air inside the bottle?*

Solicit a few responses, then show **slide L**. Say, *When we cooled down the air inside the closed bottle system, the molecules that made up that parcel of air slowed down and moved closer together. Since the molecules then occupied a smaller amount of space (volume), the air inside the bottle became more dense. This means its molecules were more densely packed together than before.*

Ask, *When we placed the bottle in hot water, what happened to the air inside the bottle?*

Again, solicit a few responses, then show **slide M**. Say, *When we warmed up the air inside the bottle, the same number of molecules moved faster and needed more space. The air inside the bottle became less dense. This means its molecules were less densely packed together than before.*

Suggested prompts	Sample student responses
When we placed the bottle in the cold water, what happened to the air inside the bottle?	*When the air inside the closed bottle system was cooled down, the molecules that made up the air slowed down and took up less space. Since the same number of molecules were still in the bottle, the air became more dense, because the molecules were more densely packed in a smaller space (or volume).*
When we placed the bottle in the hot water, what happened to the air inside the bottle?	*When the air inside the closed bottle system was warmed up, the molecules that made up the air moved faster and took up more space. Since the same number of molecules were still in the bottle, the air became less dense, because the molecules were less densely packed in a larger space (or volume).*

Show **slide N** and say, *Look carefully at the models on the slide. The models show samples of the molecules that make up the air near the ground in a schoolyard. Sample A is in a very shady area, and Sample B is out in direct sunlight. Which sample is less dense? What caused this difference? Work with your partner to make claims and support them with evidence. Be prepared to share your claims with the class.*

Give students a few minutes to talk, then ask a few to share their claims, evidence, and reasoning. Listen for students to make connections between the relative temperature of the air in each sample, the kinetic energy in the molecules that make up the air, and how closely packed the molecules are due to the amount of kinetic energy. Students should figure out that the air in the shade (Sample A) is cooler and more dense because the molecules have less kinetic energy and have moved closer together. Likewise, the air in direct sunlight (Sample B) is warmer and less dense because the molecules have more kinetic energy and have moved farther apart.

End of day 2

7. Make a prediction.

5 MIN

Materials: None

Additional Guidance

Before class starts, plug in the heating pad and hair dryer. Make sure the heating pad is turned on high and is placed on a carpet square or towel if the floor is not carpeted. Make sure the Mylar balloon is partially deflated and is counterweighted with paperclips and extra scraps of paper attached to it so it just barely sinks down (slowly) when released.

Set up science notebooks. Show **slide O** and say, *From our first investigation of warming air and cooling air in a closed bottle system, we figured out some new things that might be happening in the air outside as it warms up or cools down. Let's take a few moments to set up our science notebooks for the second investigation. Turn to the next available page in your notebook and write the title "Heated Balloon Investigation." Then add the heading "Predictions" below the title.* Give students a minute or two to do this.

Make and record predictions. Tell students, *We have learned quite a bit about what happens to air when it is warmed up and cooled down. So now I want you to use what we have figured out to make a prediction.*

Show **slide P** and say, *Take a few moments to read and think about the questions on the slide. Record your predictions in your notebook and be prepared to share your predictions with the class.*

Give students a minute or two to write, then ask a few to share their predictions.

Suggested prompts	Sample student responses
If we could trap a larger amount of air in something like a balloon and add thermal energy to it from a surface it was in contact with, what does our model predict would happen to that air? Why?	*The molecules that make up the air inside the balloon would move faster and spread out.* *The molecules move faster when they have more thermal energy. When molecules move faster, they need more space to move, so the volume (or amount of space they take up) would increase.* *Since the molecules have more energy and are spread farther apart, the air in the balloon would be less dense. (The same amount of air is spread out in a larger space.)* *We would see the same thing happen with the balloon that we saw with the soap bubble and bottle system—the balloon would expand.*
Do you think something similar happens to air near the ground on a day when it hails? Why?	*The air near the ground on a warm day should heat up, just like the air in the bottle when the bottle was placed in the hot water tub.* *The molecules that make up the air near the ground should move faster and spread out to take up more space.* *The air near the ground should be less dense.* *But the air near the ground is not in a closed system, so this might affect what happens to that air.*

Because of the investigation and discussion on day 1, students will likely predict that the balloon will get bigger when it is warmed up; however, they most likely will **not** predict that the balloon will rise and fall when thermal energy is transferred to and from it. This key insight will be added with this demonstration to help them build an understanding of convection.

Tell students, *Let's use a balloon to test our predictions about what happens to air when it is warmed up.*

8. Conduct the heated balloon investigation.

10 MIN

Materials: Heated Balloon Investigation, science notebook

Prepare science notebooks for observations. Show **slide Q** and say, *Before we start, you need to add a section for observations of the balloon in your notebook. As we conduct the investigation, record what you notice happening to the balloon at various points.* Give students a moment to write the heading "Observations", then have them gather around the investigation setup.

Conduct the *Heated Balloon Investigation*. Due to the advance preparation and materials needed, this investigation is done as a demonstration rather than in small groups. Tell students, *I have a Mylar balloon that has some helium in it. What do you notice about the balloon? Document your observations in your notebook*. Students should notice the balloon is a little flat, because some of the helium is missing. They should also notice it is floating right at ground level.

Give students a few moments to document what they notice, then say, *In this investigation, a heating pad represents the ground that has been warmed by the Sun. The helium in the balloon represents a parcel of air. We are going to warm up the gas inside the balloon by placing it on the heating pad. This will help us better understand what happens to air near the ground as it is warmed by the ground. Unlike our balloon, the air outside is not a closed system, but as we've talked about, scientists often study things in closed systems to better understand what happens to a portion of the matter and energy in a larger open system, so we are doing the same.*

Have a student volunteer place the balloon on the heating pad and lightly hold it in direct contact with the source of heat for about a minute. While the balloon is against the heating pad, ask, *What do you notice happening to the balloon? Document what you notice in your notebook*. Give students a few moments to document their observations. They should notice the balloon is expanding as the helium inside is warmed up. They should also hear it crinkling as it expands.

Have the student volunteer release the balloon. Ask, *What do you notice happening to the balloon? Document it in your notebook*. Give students a few moments to document their observations. Students should notice the balloon looks "full" and rises from the ground toward the ceiling.

Within a minute or two, the balloon should begin to fall back toward the ground. As it does, ask, *What do you notice happening to the balloon now? Document what you see*. Students should notice the balloon is slowly falling back to the floor and has visibly shrunk.

Retrieve the balloon and repeat the demonstration, allowing students to record additional observations. Encourage students to talk with a partner to try to make sense of what is happening with the balloon.

Alternate Activity

If the heating pad does not heat up the Mylar balloon enough to cause it to rise, have students watch while you heat the balloon with the hair dryer. For safety reasons, the dryer must be at least 4–5 inches away from both the balloon and your hands so it does not melt the balloon or burn your skin.

Safety Precautions

Hair dryers can burn if held too close to the skin. If you use a hair dryer to warm the Mylar balloon, make sure to keep the end of the dryer far enough away from your skin to prevent this.

It is also possible that the dryer might melt the balloon. Though you want to get the dryer relatively close to the balloon to warm it up, make sure to keep it 4 or more inches away from the balloon to prevent melting.

9. Conduct a Building Understandings Discussion about the effect of adding thermal energy to the balloon.

16 MIN

Materials: science notebook, *Heated Balloon Investigation*, tape, chart paper, markers, 3-x-3 sticky notes

Develop an initial model. Ask students to return to their seats, then distribute *Heated Balloon Investigation*. Show **slide R** and tell students to work with a partner or small group to complete the handout, tape it into their notebook, then bring their notebook and chair to a Scientists Circle.

Lead a Building Understandings Discussion. After students are seated in the Scientists Circle, lead a Building Understandings Discussion. The goal is to help students make sense of what happens to the gas in the balloon when it is warmed up and to make connections to the lesson question: "What happens to the air near the ground when it is warmed up?"

Show **slide S** and tell students to take a few moments to look at the questions on the slide. Use these questions (and others as needed) to guide the discussion. Encourage students to support their thinking with reasoning as they respond to questions and share their ideas.

Suggested prompt	Sample student responses	Follow-up questions
What happened to the balloon when it was held against the heating pad?	*The balloon expanded in size.* *We saw it expand, and we heard it crinkle as it expanded.*	

Suggested prompts	Sample student responses	Follow-up questions
Why?	*The heating pad transferred thermal energy to the balloon, which then transferred thermal energy to the helium in the balloon. As the helium molecules gained energy, they moved faster and farther apart. As they took up more space, the balloon expanded.*	
What happened to the density of the helium in the balloon as it was heated?	*As the helium molecules moved faster and farther apart, the helium took up more space. This means the molecules were less densely packed, so the helium in the warm balloon was now less dense than before.*	*What happened when we let go of the balloon?* *What did you notice about the balloon when it fell back to the ground?*
What happened to the density of the helium inside the balloon as it traveled back down to the floor?	*The helium and balloon started to cool down as it moved through the air.*	
Why?	*When the helium started cooling down, the molecules slowed down and did not take up as much room.* *The helium molecules were more densely packed.* *When the density of the helium was greater than the air around it, it caused the balloon to sink.*	

Build a time series consensus model. As students share their observations and respond to the questions on **slide S**, ask them to show their time series models on *Heated Balloon Investigation* and describe the temperature, volume, and density of the balloon at different points in time. As students share, use chart paper and markers to draw a time series model and document the ideas they agree on.

When drawing the classroom consensus model, follow the directions that guided students as they drew their model on the handout:

1. Draw a time series model that shows the balloon's journey at 3 positions over time:
    a. The balloon was first placed on the heating pad.
    b. The balloon was at its highest point in the air.
    c. The balloon fell back to the ground.

2. At each of these 3 positions (a, b, c), describe the following:
   - temperature changes of the gas in the balloon
   - the temperature of the gas in the balloon compared to the temperature of the air outside the balloon
   - volume changes of the balloon
   - the density of the gas in the balloon compared to the density of the air outside the balloon (less dense, as dense, or more dense)

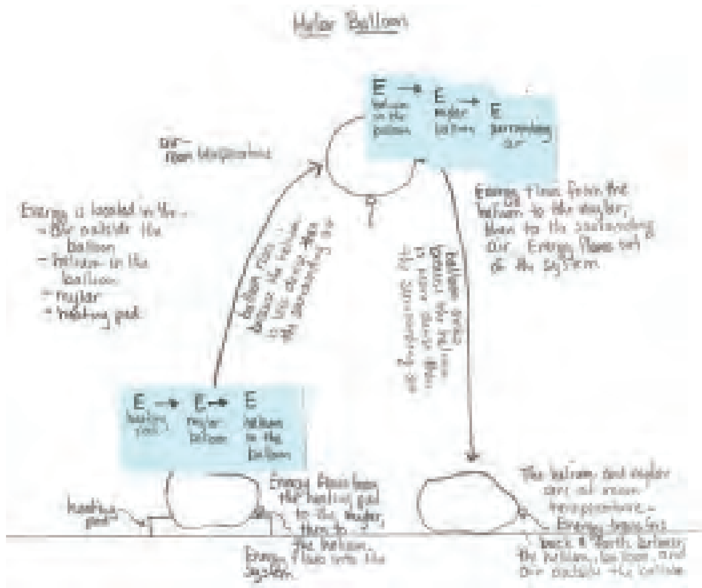
Using these same directions to draw the classroom consensus model will help move students' thinking forward when they are asked to track the flow of energy in and out of the balloon.

Document the flow of energy on the time series consensus model. Once these ideas have been documented on the classroom consensus model, show **slide T** and ask students to think about the flow of energy into and out of the balloon at each of the three points in time. Use the questions on the slide to guide this part of the discussion. Use 3-x-3 sticky notes to document the type(s) and transfers of energy that occur when the balloon is placed on the heating pad. Repeat this for when the balloon is at its highest point and is beginning to float back to the floor.

Suggested prompts	Sample student responses
*If we think about the balloon on the heating pad, **where is energy located?***	*Energy is in the* • *heating pad* • *balloon* • *helium inside the balloon* • *air in the room* *The heating pad has more energy than the balloon and the helium inside the balloon.* *Before we put the balloon on the heating pad, the balloon, helium, and surrounding air were all room temperature.*
*So, based on what we know about the transfer of energy, **where and when does energy transfer** when we place the balloon on the heating pad?*	*Thermal energy always moves from warmer matter to matter that is cooler.* *The thermal energy from the heating pad transfers to the balloon. Then it transfers to the helium inside the balloon, so both the balloon and the helium warm up.*

Suggested prompts	Sample student responses
How do we show the flow of energy?	*We need a sticky note with an E to represent energy on the:* • *heating pad* • *balloon* • *helium inside the balloon* *Next, we need arrows showing energy flowing from the heating pad to the balloon and from the balloon to the helium inside the balloon.* *This shows the energy flow is moving from the heating pad to the balloon to the helium inside the balloon, since the heating pad has more energy than the balloon and helium inside it.*
So, let's think about the balloon as it moves from its highest point back down to the floor. ***Where is energy located?***	*Energy is in the:* • *balloon* • *helium inside the balloon* • *surrounding air in the room*
Where and when does energy transfer *at that point in time?*	*The balloon and the helium are warmer than the surrounding air, so the thermal energy moves out of the balloon system.* *The thermal energy from the warm helium transfers to the balloon. Then it transfers to the air outside the balloon, so both the balloon and the helium cool down.*
How do we show the flow of energy?	*We need a sticky note with an E to represent energy on the:* • *helium inside the balloon* • *balloon* • *air outside the balloon* *Next, we need arrows showing energy flowing from the helium to the balloon and from the balloon to the air outside the balloon.* *This shows the energy flow is moving from the helium to the balloon to the air outside it, since the helium and balloon have a greater amount of energy than the surrounding air in the room.* *This continues to happen until the balloon floats all the way to the floor.*

The classroom consensus model should resemble this:



Draw conclusions using evidence. When the consensus model is complete, take a few minutes to help students draw some conclusions using evidence from the investigation. Say, *Let's think about the behavior of the balloon and how it relates to density.* Show **slide U** and tell students to take a few moments to read and think about the questions on the slide and then turn and talk with a partner. Remind them to be prepared to share their thinking with the class.

After students have had a few minutes to talk, call on a few to share their thinking. Remember, the goal is to help students figure out that changes in the density of the gas in the balloon are causing it to float and sink. If they struggle, use additional questions to help them think about the relationship between the unchanging amount of helium in the closed balloon system, the changes in volume as the balloon warms up and cools down, and the density of the helium.

Suggested prompts	Sample student responses
How does the density of the helium inside the balloon change when thermal energy transfers into the balloon from the heating pad?	*When the helium inside the balloon warms up, the molecules move faster and farther apart. The helium becomes less dense because the molecules are less densely packed in a larger amount of space.*
How does the density of the helium change when thermal energy flows out of the balloon into the surrounding air?	*When the helium inside the balloon cools down, the molecules slow down and do not take up as much space inside the balloon. The helium becomes more dense because the molecules are more densely packed in a smaller amount of space.*
And, how do these changes affect the behavior of the balloon?	*When the helium in the balloon becomes less dense, it floats up into the air.* *When the helium becomes more dense, it sinks to the floor.*

10. Make connections to the lesson question. 5 MIN

Materials: science notebook

Use what we have figured out to answer the lesson question. Show **slide V**. Ask, *Do you think the air close to the ground behaves in the same way as the helium in the balloon when warmed up?* Have students turn and talk to a partner. After a minute or two, solicit a few responses, making sure they support their thinking with evidence from the lesson investigations.

Suggested prompts	Sample student responses
Do you think the air close to the ground will behave in the same way as the helium in the balloon when warmed up?	*When the air near the ground is warmed up, it will become less dense and rise, just like the balloon.* *When the warmed air cools down, it will become more dense and sink, just like the balloon.*
Why or why not?	*Even though we used helium instead of air in the balloon, we know that air behaves like helium because of what we observed in the closed bottle system when placed in the hot water tub. A bubble formed at the top of the bottle because the molecules that made up the air sped up and spread out. Since the molecules were less densely packed, the air in the bottle became less dense, just like the helium in the balloon.* *This makes us think the air near the ground will behave just like the helium in the balloon. It will become less dense and rise when it is warmed up and become more dense and sink when it cools down.*

11. Update Progress Tracker. 5 MIN

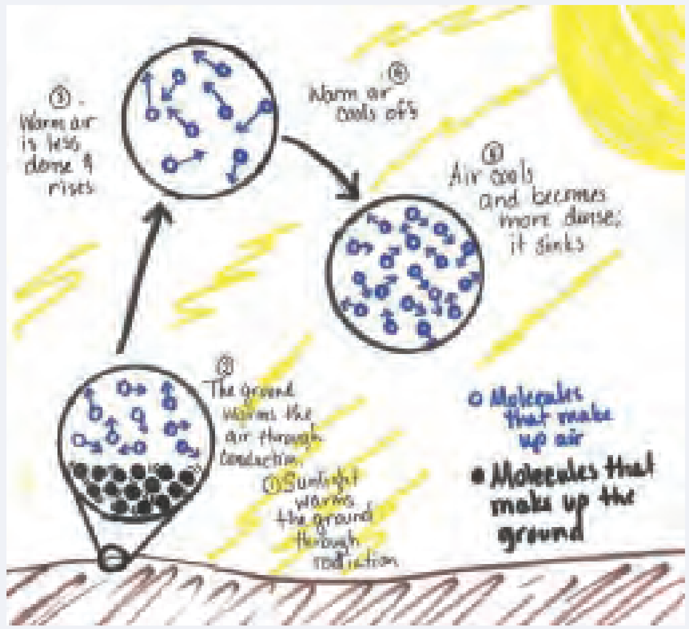
Materials: science notebook

Update Progress Tracker. Ask students to return to their desks, then show **slide W**. Tell students to turn to their Progress Tracker section, draw a two-column chart, and label it like the example on the slide. Then say, *Write the lesson question, "What happens to the air near the ground when it is warmed up?" in the left column of your Progress Tracker. In the right column, use pictures and/or words to document what you have figured out related to the lesson question.* Look for the following ideas in students' work.

<table>
<tr><th>Question</th><th>What I figured out in words/pictures</th></tr>
<tr><td>What happens to the air near the ground when it is warmed up?</td><td>

When the air near the ground is warmed up, the molecules that make up the air speed up and spread out, taking up more space. The air becomes less dense. The warm air rises because it is less dense than the surrounding air.

As the warm air rises, it begins to lose energy and cool down, which causes the molecules to slow down and take up less space. The air then sinks because it is more dense than the surrounding air.



</td></tr>
</table>

Assessment Opportunity

Reviewing students' responses in the two-column Progress Tracker provides an opportunity to formatively assess students' understanding of the lesson-level performance expectations. Responses should not be graded; rather, use what you learn to inform next steps for moving students' thinking forward. Examples of next steps include

- documenting feedback in students' notebooks, such as additional probing questions, suggestions for improvement, or a request for additional evidence or reasoning;
- revisiting, reteaching, or reinforcing ideas from the lesson to help students fill in gaps in their learning;

- using examples of actual student work to prompt discussion about what we have and haven't figured out up to this point in the unit; and
- asking additional questions at the beginning of the next lesson to probe students' thinking and help them make connections and build understanding.

12. Navigation

4 MIN

Materials: None

Navigate to the next lesson. Show **slide X** and say, *Now that we understand what happens to air when it is warmed up, let's think about the anchoring phenomenon. Consider the results of our investigations so far. What new predictions do you now have about what might be happening to the air outside on a day when it hails? Turn and talk again to your partner.*

Give students a minute or two to talk, then solicit a few responses. Tell students we will continue to investigate mechanisms that contribute to the formation of hailstorms in our next lesson.

Suggested prompt	Sample student responses
Consider the results of our investigations so far. What new predictions would you now make about what might be happening to the air outside on a day when it hails?	*Maybe air is rising and sinking outside too, because we know air near the ground would rise when it is warmed up.* *It also might explain how water in the air is carried higher up in the atmosphere where it is cold enough to freeze and form hail.*

SCIENCE LITERACY: READING COLLECTION 2

Energy and Surfaces

1 **Uneven Heating of Earth**
2 **Solar Irradiance**
3 **The Atmosphere and Pressure**
4 **Earth's Diverse Surfaces**

Literacy Objectives

- ✓ Summarize key points related to solar radiation, atmospheric pressure, and Earth's surface.
- ✓ Distinguish cause(s) and effect(s) related to solar energy and the atmosphere.
- ✓ Organize related details about solar radiation, atmospheric pressure, and Earth's surface.
- ✓ Translate text to visual/graphic representation of ideas.

Literacy Activities

- Read varied text selections related to the topics explored in Lessons 4–5.
- Evaluate the reading selections according to provided prompts and criteria.
- Compare and contrast information gained from reading text with information gained from class investigation.
- Prepare a science comic strip in response to the reading.

Instructional Resources

Student Reader Collection 2	**Science Literacy Student Reader, Collection 2** "Energy and Surfaces"
Exercise Page EP 2	**Science Literacy Exercise Page** EP 2

Prerequisite Investigations

Assign the Science Literacy reading and writing exercise *after* class completion of this lesson group:

- Lesson 4: Why is the air near the ground warmer than the air higher up?
- Lesson 5: What happens to the air near the ground when it is warmed up?

Standards and Dimensions

NGSS

Disciplinary Core Idea ESS2.D: Weather and Climate:
Weather and climate are influenced by interactions involving sunlight, the ocean, the atmosphere, ice, landforms, and living things. These interactions vary with latitude, altitude, and local and regional geography, all of which can affect oceanic and atmospheric flow patterns. (MS-ESS2-6)

Science and Engineering Practice:
Obtaining, Evaluating, and Communicating Information

Crosscutting Concepts: Cause and Effect, Energy and Matter

CCSS

English Language Arts

RST.6-8.2: Determine the central ideas or conclusions of a text; provide an accurate summary of the text distinct from prior knowledge or opinions.

RST.6-8.5: Describe how a text presents information (e.g., sequentially, comparatively, causally).

RST.6-8.6: Analyze the author's purpose in providing an explanation, describing a procedure, or discussing an experiment in a text.

RST.6-8.7: Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually (e.g., in a flowchart, diagram, model, graph, or table).

RST.6-8.10: By the end of grade 8, read and comprehend science/technical texts in the grades 6-8 text complexity band independently and proficiently.

WHST.6-8.10: Write routinely over extended time frames (time for reflection and revision) and shorter time frames (a single sitting or a day or two) for a range of discipline-specific tasks, purposes, and audiences.

Core Vocabulary

Core Vocabulary: Core Vocabulary terms are those that students should learn to use accurately in discussion and in written responses. During facilitation of learning, expose students repeatedly to these terms. However, these terms are not intended for isolated drill or memorization.

pressure

Language of Instruction: The Language of Instruction consists of additional terms, not considered a part of Core Vocabulary, that you should use when talking about any concepts in this exercise. Students will benefit from your modeling the use of these words without the expectation that students will use or explain the words themselves.

fluid **glacier** **heat island**

ice sheet **irradiance** **rotation**

transpiration

A Glossary at the end of the Science Literacy Student Reader lists definitions for Core Vocabulary and selected Language of Instruction.

1. Plan ahead.

Determine your pacing to introduce the reading selections, check in with students on their progress, and discuss the reading content and writing exercise. If you are performing Science Literacy as a structured, weekly routine, you might implement a schedule like this:

- Monday: Designate a ten-minute period at the beginning of the week to introduce students to the assignment.
- Wednesday: Plan to touch base briefly with students in the middle of the week to answer questions about the reading, to clarify expectations about the writing exercise, and to help students stay on track.
- Friday: Set aside time at the end of the week to facilitate a discussion about the reading and the writing exercise.

Exercise Page

EP 2

2. Preview the assignment and set expectations. (Monday)

- Let students know they will read independently and then complete a short writing assignment. The reading selection relates to topics they are presently exploring in their Weather, Climate, and Water Cycling unit science investigations.
- The reading and writing will be completed outside of class (unless you have available class time to allocate).
- Preview the reading. Share a short summary of what students can expect.
    - *First, you will read a science comic strip that explains how the angle of sunlight striking Earth affects the amount of energy reaching Earth.*
    - *In the article that follows, you'll learn how the incoming solar energy is measured and compared.*
    - *Then you'll read an article about how pressure changes in the atmosphere cause movement of air and changes in weather.*
    - *Finally, you'll read an article that explains how the varied materials that cover Earth's surface interact with solar energy.*
- Distribute Exercise Page 2. Preview the writing exercise. Share a summary of what students will be expected to deliver. Emphasize that Science Literacy exercises are brief. The focus is on thoughtful quality of a small product, not on the assignment being big and complex.
- *For this assignment you will be expected to generate a science comic strip that will entertain and inform your audience about one interesting or important idea from each of the four reading selections.*
- Remind students of helpful strategies they can employ during independent reading. Offer the following advice:
    - *The reading should take approximately 30 minutes to complete.* (Encourage students to break reading into smaller sections over multiple short sittings if their attention wanders.)
    - *A good reading strategy is to scan through the collection first to see the titles, section headers, graphics, and images to see what the selections are going to be about before fully reading.*
    - *Next, "cold read" the selections without yet thinking about the writing assignment that will follow.*
    - *Then, carefully read the Exercise Page to understand the expectations for the writing part of the assignment.*
    - *Revisit the reading selections to complete the writing exercise.*
    - *Jot down any questions for the midweek progress check in class.* (Be sure students know, though, that they are not limited to that time to ask you for clarification or answers to questions.)

Exercise Page

EP 2

3. Touch base to provide clarification and address questions. (Wednesday)

Touch base midweek with students to make sure they are on track while working independently. You may choose to administer a midweek minute-quiz to give students a concrete reason not to postpone completing the reading until the last minute. Ask questions such as these, and have students jot answers on a half sheet of paper:

SUPPORT—A solid understanding of density will help students discuss these questions more effectively. Revisit the meaning of density, more or less matter per a unit of volume.

Suggested prompts	Sample student responses
At what angle does sunlight striking Earth pass through the least amount of atmospheric gases?	*at nearly 90 degrees*
For all places in the United States, what causes the difference in the amount of solar irradiance between winter and summer?	*the fact that for the Northern Hemisphere Earth's axis is tilted toward the sun in summer and away from the sun in winter*
How is wind related to pressure?	*When high-pressure air tries to spread out, it results in wind.*
What is a heat island?	*Heat islands are areas made of materials that absorb more sunlight and transfer more heat back to the atmosphere than other Earth surfaces. Cities, for example, have a warmer climate than the surrounding region.*

Ask a few brief discussion questions related to the reading that will help students tie the text content to students' classroom investigations.

Suggested prompts	Sample student responses
What likely happens to the temperature of the air over Earth surfaces as Earth rotates?	*As Earth rotates, surfaces that are in sunlight no longer receive sunlight. This would make the air over them cooler.*
In Lesson 4, you measured reflected light from several surfaces. How do you predict the measurements would compare to those for sea ice or a glacier?	*Frozen water probably reflects more sunlight than the blacktop, sidewalk, dirt, and mulch we tested.*
In Lesson 5, how did your model support the idea that the atmosphere is a fluid?	*We warmed up a partially deflated balloon and saw that the pressure of the air inside it increased, changing the shape of the balloon. We also held the balloon, and where we squeezed it, the air seemed to move.*

- Refer students to the Exercise Page 2. Provide more specific guidance about expectations for students' deliverables due at the end of the week.
  - *The writing expectation for this assignment is to draw a comic strip to highlight some important, interesting, or challenging science ideas in Collection 2.*
  - *That means you will have to choose one idea from each reading to talk about.*
  - *You don't have to draw well to make an effective comic.*

Exercise Page

EP 2

- *Use your character or avatar to connect with readers by giving it a personality—funny, bored, enthusiastic. Even if your character is a raindrop or cloud, give it emotions or attitude!*
    - *Connect the panels in your strip with a single theme or storyline.*
    - *Place your text in word balloons or under your drawings.*
    - *The important criteria for your work are that you show your interest or understanding of one science idea from each of the four readings and that you use the comic strip format to engage your readers.*
- Answer any questions students may have relative to the reading content or the exercise expectations.

4. Facilitate discussion.

(FRIDAY)

Facilitate class discussion about the reading collection and writing exercise. Point out that while all four readings are expository in nature, they employ slightly different techniques for delivering the descriptions and explanations. Tell students to be on the lookout for varied types of graphic treatments and at least one description of a hands-on model.

Student Reader

Collection 2

Pages 14–17 **Suggested prompts**	**Sample student responses**
What is the general purpose of the first selection, "Uneven Heating of Earth"?	*It explains how sunlight strikes Earth at different angles, depending on the latitude and the season.*
What happens to solar energy as it interacts with the atmosphere?	*Some of the solar energy is reflected into space, some is absorbed by particles or air, and some strikes the ground.*
How effective are comic strips for communicating science information? Explain your opinion.	*They can be very effective, making it more fun to read about science and breaking the ideas into bite-sized pieces.*
What is the general purpose of the second selection, "Solar Irradiance"?	*It explains how the amount of solar energy reaching Earth's surface is measured and compared.*
How did you decide which science idea in this reading to highlight in your science comic strip?	*I chose the one that I didn't know before.* *I chose the one everyone should learn.* *I chose the one that seems to summarize the reading.*
How does the second selection help you build knowledge on top of what you learned in the first selection?	*The first article reveals that when solar energy strikes Earth at an angle less than 90 degrees, the light has to pass through more atmosphere. The second article details how scientists measure and compare the amount of solar energy striking Earth's surface.*

SUPPORT—If you are using the recommended word envelope convention, check the envelope to see if it contains any words, phrases, or sentences that students need help understanding. Read key sentences aloud, and provide concise explanation.

SUPPORT—To answer the questions about sunlight's interactions with the atmosphere, remind students to draw upon learning from Unit 1, Light and Matter. For example, in Lesson 1, they learned that some materials can be reflective and transmit light at the same time.

Pages 16–23 **Suggested prompts**	**Sample student responses**
Take a look at the Dig into Data box on page 16. How is global horizontal irradiance data useful to people who install solar panels?	*The data show how much solar energy strikes a surface at different angles. That way, the people installing panels can decide where to place the panels and how to tilt them to collect the most energy.*
After looking at all the maps, what can you infer are some places where solar panels will work best?	*in southern California, Arizona, New Mexico, and Florida*
What is the general purpose of the third article, "The Atmosphere and Pressure"?	*It explains that, because the atmosphere is a fluid, it moves in response to changes in density and pressure.*
What was the author's intention in describing a hands-on activity in the first paragraph?	*It was to present information about how fluids of different pressure behave in a way that might be already familiar to most readers.* *It was to suggest that readers try the demonstration to better understand the main idea.*
Take another look at the last paragraph in this selection. What are some other ways you could present this text?	*as a science comic strip, a labeled diagram, a poster, or an infographic*
How does this article answer the Lesson 5 question, "What happens to the air near the ground when it is warmed up?"	*When air near the ground is heated, it becomes less dense and rises, allowing more dense air to rush in to take its place.*
What is the general purpose of the fourth article, "Earth's Diverse Surfaces"?	*It compares several Earth surfaces and how they affect the atmosphere.*
Where does the energy for evaporating liquid water come from?	*It comes from solar energy that is absorbed by soil and water.*
How would the atmosphere be affected if plant transpiration did not take place?	*There would be much less water vapor in the atmosphere and probably fewer clouds and less precipitation.*
How did you decide what idea from this selection to present in your science comic strip?	*I chose the idea that surprised me the most.* *I tried to state a main idea that summarized the entire reading.*

5. Check for understanding.

Evaluate and Provide Feedback

For Exercise 2, students should create a four-panel science comic strip using the template on Exercise Page 2. Students should create one character or avatar to convey a science idea that highlights an interesting or important idea from each of the four readings—one per panel. Look for understanding that the character is the narrator and has a certain point of view and personality that is consistent across all four panels of the comic strip.

Consider displaying students' comic strips around the room and having students take a gallery walk to tour the work. Afterward, debrief in whole-class discussion.

Online Resources

Use the rubric provided on the Exercise Page to supply feedback to each student.

EXTEND—Students may enjoy using online tools or apps to create more polished comic strips, including the option to use photos and audio. Most of these tools allow teachers to leave feedback for students and have tips and samples related to school topics. Before using with students, preview the tool or app to determine that it conforms to your school's internet policies.

LESSON 6

How can we explain the movement of air in a hail cloud?

Previous Lesson *We conducted two investigations to explore how transferring thermal energy into and out of a parcel of air in a closed system affected its volume and density, causing it to float or sink in the surrounding air. For each investigation, we developed a model to represent how the molecules that make up air were affected.*

This Lesson

Putting Pieces Together

2.5 DAYS

We examine photos and a video of clouds that tend to produce hail to look for patterns in the motion of air as clouds form. We construct an explanation using evidence for the path of air movement below, within, and at the top of a type of cloud that tends to form hail. We revise our initial consensus model and return to the Driving Question Board (DQB), which makes us realize we need to know more about what makes up the air.

Next Lesson *We will investigate where the water in the air comes from by measuring the humidity in the air over different Earth surfaces. We will develop a model for how the water got into the air.*

Building Toward NGSS

MS-PS1-4, MS-ESS2-4, MS-ESS2-5, MS-ESS2-6

What Students Will Do

Analyze and interpret data including graphical displays of large data sets to identify cause-and-effect relationships to construct an explanation of how the movement of parcels of air via conduction and convection causes the upward and downward movement of air in clouds.

Develop and use a model to describe how thermal energy from the Sun causes movement of parcels of air via conduction to cause the formation of clouds.

Obtain information by reading scientific texts adapted for classroom use and summarize key ideas to determine that the air is a mixture of different types of gases (matter), including water vapor, and that relative humidity is a measure of a small proportion of molecules of water vapor in the air.

What Students Will Figure Out

- Air near the surface of the ground is warmed from thermal energy transfer from the ground through conduction.
- The warm air near the ground becomes less dense than the surrounding air and rises.
- Eventually, the warm air transfers its energy to the surrounding air, becoming just as cold and dense as the air around it, and it stops rising.
- If that air becomes even cooler than the surrounding air, it sinks.
- This type of air movement happens more on sunny days because the air right above the ground gets warmed up more by light from the Sun on those days.
- Air is a mixture of different types of substances in the gas state including water vapor, which is measured as humidity.

Lesson 6 • Learning Plan Snapshot

Part	Duration	Summary	Slide	Materials
1	3 min	**NAVIGATION** Predict what might happen to the motion of the air in the clouds on a day when it hails.	A	
2	4 min	**OBSERVE STRUCTURE OF HAIL-PRODUCING CLOUDS** Examine photos of clouds that tend to produce hail and compare them to other clouds.	B-D	*Comparing Hail Clouds to Other Clouds*, tape
3	10 min	**OBSERVE VIDEO OF CLOUDS FORMING** Look for patterns in the motion of air in a video of cloud formation.	E	*Tracking Air Movement in Cloud Formation*, tape, computer and projector, cloud formation video (See the **Online Resources Guide** for a link to relevant items. **www.coreknowledge.org/ckscionline-resources**)
4	25 min	**CONSTRUCT A SCIENTIFIC EXPLANATION FOR AIR MOVEMENT IN A HAIL CLOUD—EMBEDDED SUMMATIVE ASSESSMENT** Use data to construct an explanation of the path of air movement below, within, and at the top of a type of cloud that tends to form hail.	F	*Explaining the Movement of Air in a Hailstorm Cloud*
				End of day 1
5	15 min	**REVISE OUR INITIAL CLASS CONSENSUS MODEL** Revise our initial consensus model to account for what we figured out in previous lessons about the mechanisms for movement of parcels of air.	G	initial class consensus model from Lesson 1

Part	Duration	Summary	Slide	Materials
6	12 min	**REVISIT THE DQB** Return to the DQB to determine what questions we have answered or made progress on.	H	DQB, sticky notes
7	5 min	**IDENTIFY NEXT STEPS AND NEW QUESTIONS** Problematize what we don't yet know regarding where all the water that forms hail comes from. Add any new questions to the DQB.	I	
8	15 min	**CONDUCT A CLOSE READING ON COMPOSITION OF AIR AND HUMIDITY** Use the close reading strategy to read about the composition of air, including the amount of water in the air and how it is measured.	J-N	*What Is Air?*

End of day 2

Lesson 6 • Materials List

	per student	per group	per class
Lesson materials **Student Procedure Guide** **Student Work Pages**	• *Comparing Hail Clouds to Other Clouds* • science notebook • tape • *Tracking Air Movement in Cloud Formation* • *Explaining the Movement of Air in a Hailstorm Cloud* • *What Is Air?*		• computer and projector • cloud formation video (See the **Online Resources Guide** for a link to relevant item. **www.coreknowledge.org/cksci-online-resources**) • initial class consensus model from Lesson 1 • DQB • sticky notes

Materials preparation (20 minutes)

Online Resources

Review teacher guide, slides, and teacher references or keys (if applicable).

Make copies of handouts and ensure sufficient copies of student references, readings, and procedures are available.

Check the cloud formation video to make sure it plays. (See the **Online Resources Guide** for a link to relevant item. **www.coreknowledge.org/cksci-online-resources**)

Lesson 6 • Where We Are Going and NOT Going

Where We Are Going

Students use the mechanisms developed in the first five lessons to explain why air in clouds rises and sinks. The particle-based explanation of conduction and convection used in this lesson involves Earth's surface warming the air above it through conduction, as the surface absorbs light energy from the Sun over the course of the day. Changes in the temperature of different air parcels cause changes in the speed and spacing of their particles, leading to changes in the air's density. Parcels of air that are less dense than the surrounding air rise, and parcels of air that are more dense than the surrounding air sink. Parcels of warmed, less dense air eventually cool off (transferring their thermal energy to the surrounding air), thus causing the air to stop rising and begin to sink.

Additionally, students specifically think about hail clouds and why they tend not to form in the winter months. In the winter in the Northern Hemisphere, less light is absorbed (less net radiation) at the surface (lower land surface temperature) than in summer. In the winter, the surface doesn't get as warm as it does at other times of year, and therefore cannot transfer as much thermal energy to the air right above it. Without enough thermal energy, air does not rise high enough to create taller clouds.

Students individually develop an explanation for how air rises and sinks in clouds via conduction. We then use those ideas to update our consensus model and return to our DQB.

Where We Are NOT Going

The many different types of clouds and their names are not the focus of the unit. The reason for introducing one type of cloud (cumulonimbus) is that its shape and height differ from other clouds in the atmosphere, due to vertical growth driven by convection (a term not introduced in this lesson). Hail clouds extend very high into the atmosphere, where it is very cold. The rising air within the cloud is at the heart of why this type of cloud tends to produce hail. Later lessons will address the high updrafts that are central to hail formation.

A more general convection cycle that explains why any fluid (gases and liquids) moves in circular patterns (rising away from sources of thermal energy, spreading out, falling as it cools, and rushing back into the spot away from which the fluid originally lifted) will be more fully developed in later lessons to explain surface winds.

LEARNING PLAN FOR LESSON 6

1. Navigation

3 MIN

Materials: None

Connect back to the motion of the balloon. Project **slide A**. Say, *Let's think about how what we figured out in the last lesson could be applied to explain the weather, and in particular, to explain things that might be happening on days when it hails.*

Have students discuss the slide's questions with a partner:

- Do you think larger parcels of air outside, over the course of a day, also end up doing what the balloon did in our classroom? Why?
- If you could observe the motion of the air in the clouds on a day when it hails, what do you predict you might see happening?

After a couple minutes, have a few students share out their ideas. Then say you have some photos and video showing the type of cloud that tends to form hail, which we can use to test our predictions and evaluate what we've figured out so far.

2. Observe structure of hail-producing clouds.

4 MIN

Materials: *Comparing Hail Clouds to Other Clouds*, science notebook, tape

Introduce the cloud type that tends to form hail. Project **slide B.** Explain that the type of cloud that produces hail tends to develop into a structure similar to the one in the photo (taken from an airplane). This type of cloud is called *cumulonimbus*. Ask students to share what they notice about this cloud. Orient them to the photo by asking where the hail would be falling (way below the cloud line).

Compare hail clouds to other clouds. Say you have some images of hail clouds as well as other clouds. Show **slide C** and distribute *Comparing Hail Clouds to Other Clouds*. Have students take a moment to individually think about the following questions:

- What do you notice about the structure of the hail cloud?
- How does it compare to the other clouds?

Solicit a few noticings from students. Listen for the idea that hail clouds are very tall.

Discuss how air temperature might explain tall hail clouds. Show **slide D.** Lead a discussion that connects the extensive height of the hail clouds to temperature and why that might be important in hail formation.

Suggested prompts	Sample student responses	Follow-up question
What do we know about the temperature of the air at different heights of the cloud?	*It gets colder the higher you go up.* *There are big temperature differences between the ground and high up in the cloud.*	*What evidence do we have for that idea?*
How might the air temperature at different heights be related to the formation of hail?	*Hail is frozen, so maybe it has to go really high where it is really cold to form hail.* *Maybe the difference in temperature matters?*	

3. Observe video of clouds forming. 10 MIN

Materials: *Tracking Air Movement in Cloud Formation*, science notebook, tape, computer and projector, cloud formation video (See the **Online Resources Guide** for a link to relevant items. **www.coreknowledge.org/cksci-online-resources**)

Formation of a cumulonimbus cloud. Project **slide E**. Explain that you have a video that shows the growth of a few different clouds over the course of a day. Toward the end of the video, one of them develops into a cumulonimbus cloud. Distribute *Tracking Air Movement in Cloud Formation*. Say, *Let's watch the video once without recording anything.*

Show the time-lapse video of cloud formation (See the **Online Resources Guide** for a link to relevant items. **www.coreknowledge.org/cksci-online-resources**). Read the directions on the slide (the same as on the handout), emphasizing that students will annotate the hail cloud images at six time points when you pause the video. Then play the video again, pausing it at the following times: 0:20, 0:32, 0:36, 0:41, 0:48, 0:58. At each pause, instruct students to make notes on the hail cloud of where they saw air moving up, where it stopped rising, and where it moved down. Tell them we can use our ideas and evidence from Lessons 1–5 to help explain these patterns.

Alternate Activity

Teachers who have piloted this unit and use Google Classroom to push videos out to their students have reported that students are able to see more detail and pull more patterns out of the video when they can view it and replay it a second or third time themselves. If you have a way to make the video available to students to view on their own devices, that is the preferred method for having students analyze the video a second or third time on their own.

4. Construct a scientific explanation for air movement in a hail cloud—embedded summative assessment.

25 MIN

Materials: science notebook, *Explaining the Movement of Air in a Hailstorm Cloud*

Connect the video to the assessment.* Say, *We can see in the video that the clouds are rising and sinking and, when the hail cloud forms, it rises fast. We are going to use data from one specific instance and then some global data to explain what's going on with the air in hail clouds.* Project **slide F**. Distribute *Explaining the Movement of Air in a Hailstorm Cloud* and have students complete it individually. Tell them they can use their Progress Trackers from previous lessons to help recall what evidence, ideas, and models are useful for answering each question.

Additional Guidance

If students struggle with determining what evidence on the assessment is relevant, encourage them to refer to their science notebook to see what questions we were trying to answer with a particular investigation. Use prompts such as, *What did the temperature data from Lesson 4 help us figure out?*

If students need more support in connecting the evidence to the claim (reasoning), provide sentence starters or fill-in-the-blanks, such as these (possible responses shown in parentheses):

1. The Sun ______(heats up the ground), which causes ______(the air that comes into contact with the ground to heat up through conduction). This makes that air ______(less dense) because ______(the air particles move faster and spread out), therefore ______(the air that is less dense than the surrounding air rises up).
2. The temperature of the air near the ground depends on ______(the temperature of the ground below it). On sunny days ______(the ground can warm up more and can transfer that energy to the air that comes into contact with it).
3. The warm air ______(transfers its energy to the surrounding air), which causes ______(the air to cool down and become the same density as the surrounding air).

End of day 1

*** Attending to Equity**

This assessment encourages students to demonstrate their understanding of key skills and concepts from the unit so far by scaffolding the construction of a written explanation. Some students may benefit from using other modalities, such as drawing, to show their thinking for any or all of the questions on this assessment. Consider allowing some students to present their answers verbally as another student scribes their thinking on paper; this would allow students to also use gestures to help articulate their understanding about how the air behaves and rises in a cloud. Encouraging students to use other modalities to show their thinking creates an equitable pathway for all students to demonstrate proficiency.

5. Revise our initial class consensus model.

15 MIN

Materials: science notebook, initial class consensus model from Lesson 1

Gather in a Scientists Circle. Gather around the initial consensus model or other public records you might have of how the class represented ideas in the previous lessons. Say, *It seems like we have figured out some parts of what happens in the air when a hailstorm forms, and we may have begun to answer some of the questions we had on our initial consensus model. Let's work together to represent our thinking now by revising that model based on what we have figured out so far.*

Present **slide G**. Remind students of the questions they answered on the assessment last time:

- What caused this upward movement of air in the cloud?

*** Strategies for This Consensus Discussion**

Taking stock of our progress of our revised model provides an opportunity for the class to synthesize ideas and motivate next steps of figuring out how the water

- Why does this type of cloud motion tend to happen more on sunny days?
- Why did the rising air in the cloud eventually stop rising (or start falling)?
- Why do hailstorms tend to happen more in the summer than the winter?

gets into the air. It also provides an opportunity to reconsider the ideas that students used in their assessment and to clarify any lingering confusion.

Key Ideas

Purpose of this discussion: Synthesize what we have figured out so far about the unobservable mechanisms behind the movement of parcels of air. Discuss how our revised classroom consensus model can help explain why hail clouds don't commonly form in the winter.

Look for/listen for these ideas:

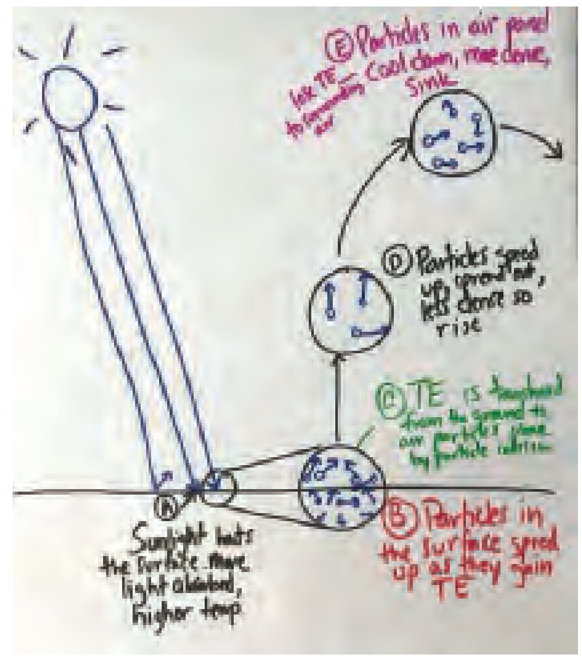
Mechanisms leading to air movement

- Sunlight heats Earth's surface.
- Particles at the surface move faster.
- Thermal energy is transferred from the ground to the air right above it via conduction.
- Heating the air makes the air particles move faster and spread out, making that parcel of air less dense.
- The less dense air parcel rises up.
- As the air parcel loses thermal energy to the surrounding air, it cools, its particles slow down, and it becomes more dense than the surrounding air and sinks.

How our revised model can explain lack of hailstorms in the winter

- The ground has to heat up enough so the parcels of nearby air warm up and rise.
- If the ground does not heat up enough, the parcels of air cannot rise way up high like they do in hail clouds.

Generate the revised model. Ask students to share ideas to include in our revised classroom consensus model. It may be helpful to start by posing the first question on the slide, allowing students to share ideas, and then asking how we could represent them in our model. Then move on to the second and third questions. Remind students to refer to their Progress Trackers and other class artifacts for how we represented ideas earlier. Push students to think about what is happening with the thermal energy in each part of the model. To the right is an example of a model:



Apply the revised model to explain why hailstorms don't happen in the winter.

After the class has represented their thinking for why air parcels rise and sink, help students apply their model to explain why the really tall clouds that produce hail don't form in the winter.

Say, *Our revised model can explain the rising and sinking of air in any cloud. Let's see if we can use it to explain hail clouds.*

Suggested prompts	Sample student responses
How do hail clouds compare to other clouds?	*They are really tall.*
	They go from down low to way up high.
What did our data from Lesson 2 tell us about when hailstorms tend to happen?	*They were in the spring, summer, or fall.*
How can our model explain why hail clouds don't often form in the winter in North America?	*The ground has to get really warm to transfer enough energy to the air so the air can rise.*
	In hail clouds, the air rises really high to where water can freeze.
	In the winter the ground doesn't get warm enough to get the air to rise that high.

6. Revisit the DQB.

12 MIN

Materials: DQB, sticky notes

Gather around the DQB. Stay in the Scientists Circle or gather more closely around the DQB so everyone can see the questions. Project **slide H**.

Additional Guidance

A high-resolution photograph of the DQB or a typed list of the questions from the DQB is a useful supplement to provide to students for this step.

Say, *Let's revisit our DQB and see which questions we have made progress on, and then next time we can see if there are any questions we need to refine or want to pursue in upcoming lessons.*

Note which questions have been answered by marking them with the following symbols:

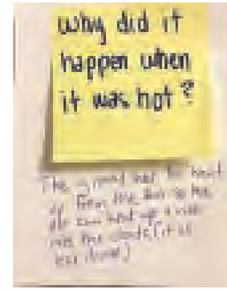
- We did not answer this question or any parts of it yet: **O**
- Our class answered *some parts* of this question, or I think I could answer *some parts* of this question: ✓
- Our class answered this question, or using the ideas we have developed I could now answer this question: ✓+

Additional Guidance

If you have one DQB for all your classes, you can move the questions so they are grouped together based on the degree to which they have been answered, instead of writing directly on them. Keeping the questions on the board (versus removing those we think we have answered) helps keep an important record of our progress. Remind students that even if questions already have check marks indicating that we would like to pursue them further in future lessons, that is OK; it means we have a joint mission to figure out those phenomena together.

Alternate Activity

You may want to have students write answers to questions we have answered, either in pairs or individually. One effective way to do this is to attach the sticky note with the question to a half-sheet of paper and then write the answer below. These can then be placed back up on the DQB. This can be a productive activity when you have extra time before or after the assessment or on days when the teacher may be absent. Time is built in after the assessment on day 2 of this lesson.



7. Identify next steps and new questions. 5 MIN

Materials: None

Problematize and navigate to other parts of our initial model. Say, *So we have arrows going up showing what is happening with the air, and our initial consensus model also had clouds. We even drew dark clouds and had some ideas for what those dark clouds are made of. What's the difference between the air below the cloud and the air in the cloud? Is there a difference?*

Project **slide I**. Have students turn and talk for a minute about how what's **in the air** at the three locations might be similar and different. Then have a couple of students share out. Ideas about similarities might include that the air is made of the same type(s) of particles; differences might be temperature, density, and amount of water.

Emphasize that though we agree about how the speed and spacing of the molecules in the air at different locations below and in the cloud might compare, we have some different ideas about what exactly is in the air (anywhere), and what (if anything) might be similar or different if we sample air from within a cloud or below it.

Say, *I have a short reading that has a mix of text and data that might provide some of the answers we are looking for.*

8. Conduct a close reading on composition of air and humidity. 15 MIN

Materials: *What Is Air?*

Model the close reading strategy. Distribute *What Is Air?* to each student. Project **slide J**. Remind students that close reading requires reading more than once and with different purposes and strategies for interacting with the text. Lead them through the following steps for the reading's first two paragraphs:

1. Project **slide K**. Say, *Let's do one together.* Ask students to identify the main question we are trying to answer in this reading. Tell them to write the question "What is in the air?" at the top of the reading as a key strategy to remind us of our purpose and the type of information we are looking for.
2. Project **slide L**. Give students time to read the first two paragraphs on their own.

3. Project **slide M**. Show students an example of step 3 by reading the first two paragraphs aloud. As you read, pause and share your thinking, highlighting a few ideas that answer our focus question.
4. Project **slide N**. Tell students to try steps 4 and 5 by recording a summary of key ideas and new questions in their notebook. They should write their summary under the heading "What is in the air?" Here is a sample of ideas they might record:
   - Air is a mixture of different types of molecules (substances) in the gas state, which we can't see.
   - There are also some larger particles in the air, which we can sometimes see (pollen, ash, dust).
   - Water vapor in the air, measured as humidity, makes up a relatively small fraction of the molecules in the air.

Navigate to the next lesson. Let students know that in the next lesson we will figure out where all that water in the atmosphere is coming from.

Alternate Activity

One way to help students connect their learning to events in their own lives is to support local outdoor observations of clouds and storms. Consider doing an outdoor cloud observation as a class as well as assigning a project or home learning activity in which students record a time-lapse video of clouds and then make observations from their video. Time-lapse videos are particularly powerful for seeing change over time and can be an engaging project. Use questions like these to guide discussion around their videos and observations:

- *What did you notice happening to the clouds over time?*
- *Did the clouds change shape or color?*
- *Did you notice patterns in clouds at certain times of day?*

Additionally, students can use the GLOBE website (See the **Online Resources Guide** for a link to relevant item. **www.coreknowledge.org/cksci-online-resources**) to collect local cloud observation data, which are then entered at the GLOBE website. Providing students a choice to pursue an area of interest is an important way to differentiate instruction and extend the application of ideas the class figured out together without compromising coherence of the storyline.

ADDITIONAL LESSON 6 TEACHER GUIDANCE

Supporting Students in Making Connections in ELA

CCSS.ELA-LITERACY.W.6.1.B: Support claim(s) with clear reasons and relevant evidence, using credible sources and demonstrating an understanding of the topic or text.

The midpoint assessment provides an opportunity for students to make and support claims with relevant evidence in the form of data provided on the assessment as well as from their investigations.

Supporting Students in Making Connections in ELA

CCSS.ELA-LITERACY.RST.6-8.2: Determine the central ideas or conclusions of a text; provide an accurate summary of the text distinct from prior knowledge or opinions.

What Is Air? and the close reading protocol provide an opportunity for students to summarize the central ideas of the text around the question, *What is air?*

LESSON 7

Where did all that water in the air come from, and how did it get into the air?

Previous Lesson

We examined photos and a video of clouds that tend to produce hail and constructed an explanation using evidence for the path of air movement below, within, and at the top of a type of cloud that tends to form hail. We revised our initial consensus model and returned to the DQB, which led us to learn more about what makes up the air.

This Lesson

Investigation

2 DAYS

We plan and carry out an investigation to determine where the water in the air comes from by measuring the humidity in the air over samples of different Earth surfaces. We develop a model to account for how the water got into the air from these places.

Next Lesson

We will carry out investigations to explore what happens when air containing water vapor is cooled and when water droplets make contact with each other. We will use magnetic marbles to develop a model for how mutual attraction between water molecules and changes in their speed cause water to change from gas to liquid when it cools below a certain temperature.

Building Toward NGSS

MS-PS1-4, MS-ESS2-4, MS-ESS2-5, MS-ESS2-6

What Students Will Do

Plan and conduct an investigation using a model to gather data to serve as evidence to support a claim about where water in the air originates (inputs).

Develop and use a model to predict and describe changes in particle motion and the movement of water molecules from a liquid into the air (via evaporation) when the thermal energy of the water increases (cause).

What Students Will Figure Out

- Water can go into the air (increasing its humidity) from many different types of surfaces with water in or on them.
- When individual water molecules on the surface of a liquid gain enough motion energy (kinetic energy), they leave the liquid to become a gas; this process is called evaporation.

Lesson 7 • Learning Plan Snapshot

Part	Duration	Summary	Slide	Materials
1	5 min	**NAVIGATION** Recall what we figured out about what air is made of, what humidity is, and how humidity can be measured.	A	
2	8 min	**EXPLORE THE USE OF HUMIDITY PROBES** Explore humidity levels in the classroom with humidity probes and compare levels in different places.	B	whiteboard or chart paper, markers, Measuring Humidity Activity
3	5 min	**MAKE PREDICTIONS FOR THE INVESTIGATION** Make predictions for types of Earth surfaces where water might be added to the air.	C, D	tape, Sources of Water in the Air Lab
4	10 min	**PLAN OUR INVESTIGATION** Plan an investigation to figure out where the water in the air comes from.	E, F	whiteboard or chart paper, markers, Sources of Water in the Air Lab
5	18 min	**CONDUCT THE INVESTIGATION** Conduct an investigation simulating environments where water may be coming from and collect data to see whether the humidity levels change. Complete an exit ticket.	G, H	whiteboard or chart paper, markers, Sources of Water in the Air Lab
				End of day 1
6	2 min	**NAVIGATION** Revisit the lesson question and how our investigation can help answer it.	I	
7	10 min	**INTERPRET INVESTIGATION DATA** Interpret the class data and make claims about potential sources of water in the air.	J	class data table, computer, projector, Sources of Water in the Air Lab
8	10 min	**DEVELOP A MODEL TO EXPLAIN CHANGES IN HUMIDITY** Develop a model to explain how some of the water in or on the earth material gets into the air.	K	*Model for How Water Gets into the Air*
9	6 min	**PROVIDE AND RECEIVE FEEDBACK** Provide and receive feedback about individual models.	L	*Peer Feedback Guidelines* (optional), *Model for How Water Gets into the Air*, tape
10	5 min	**RESPOND TO FEEDBACK** Use feedback to make revisions to individual models.	M	*Model for How Water Gets into the Air*, *Self-Assessment* (optional)

Part	Duration	Summary	Slide	Materials
11	12 min	**UPDATE PROGRESS TRACKER** Come to consensus and update Progress Tracker to explain how the water got into the air.		*Model for How Water Gets into the Air*, whiteboard or chart paper, markers
12	3 min	**NAVIGATION** Connect the class model back to the phenomenon we are trying to explain.	O	
				End of day 2

Lesson 7 • Materials List

	per student	per group	per class
Measuring Humidity Activity materials			• humidity probes (including 1 humidity probe secured to a ruler or stick) • hot plate with pot or electric kettle filled halfway with water • hot mitts
Sources of Water in the Air Lab materials	• *Sources of Water in the Air*	• prepared empty 2-L soda bottle with bottom cut off (with cap on) • humidity probe • sticky hoop-and-lock fastener material • reusable plastic bowl • 1 cup earth material • 100-watt incandescent bulb and clamp lamp (1 per every 2 groups)	• 1 liter of each earth material for the investigation: ◦ wet sand ◦ dry sand ◦ crushed ice or snow ◦ sod or a small potted plant ◦ rocks ◦ water ◦ dirt (optional)
Lesson materials **Student Procedure Guide** **Student Work Pages**	• science notebook • *Model for How Water Gets into the Air* • *Peer Feedback Guidelines* (optional) • *Self-Assessment* (optional)		• whiteboard or chart paper • markers • tape • class data table • computer • projector

Online Resources

Materials preparation (30 minutes)

Review teacher guide, slides, and teacher references or keys (if applicable).

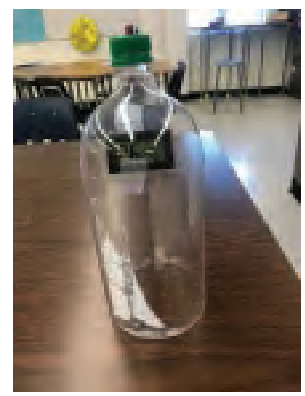
Make copies of handouts and ensure sufficient copies of student references, readings, and procedures are available.

Day 1: ***Measuring Humidity Activity***

- **Group size:** whole class
- **Setup:** Gather a pot and hot plate or an electric kettle and fill it halfway with water for boiling. Gather 1-2 pairs of protective hot mitts. Because the humidity probes are small, you may need to tape a probe to a stick or ruler to safely hold the probe near the steam. Be sure not to cover the vents on the back of the probes.
- **Safety:** Ensure that the student volunteers are wearing hot mitts and that the humidity probe is taped to a stick or ruler when gathering humidity readings near the boiling water.

Day 1: ***Sources of Water in the Air Lab***

- **Group size:** 3-4 students
- **Setup:**
  - Watch the investigation setup video to see how to prepare the bottles for the investigation. (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)
  - Prepare an empty 2-L soda bottle (with cap on) (1 per group) by cutting off the bottom. Use a hacksaw to start the cut and then cut around the bottle with scissors. Attach a humidity probe to the bottle's inside surface using sticky hoop-and-lock fastener material to allow the probe's removal at the end of each class.
  - Gather reusable plastic bowls for holding the earth materials. The flat bottoms must be small enough to fit within the diameter of a 2-L bottle (9.8 centimeters).
  - Gather 1 liter of each earth material for the investigation:
    - wet sand
    - dry sand
    - crushed ice or snow
    - sod or a small potted plant
    - rocks
    - water
    - dirt (optional)
  - Gather 100-watt incandescent bulbs and lamps (e.g., clamp lamp) (1 per every 2 groups).
- **Notes for after the lab:** Air the bottles out and lightly shake them to remove any accumulated water before using in the next class.
- **Safety:** Use caution in cutting the bottles. For safety, start the cut with a hacksaw and then use scissors.



Lesson 7 • Where We Are Going and NOT Going

Where We Are Going

In the previous lesson, students figured out what causes the rising and falling of the air in clouds. We explored the composition of air, including the amount of water in the air and how it is measured. In this lesson, we figure out where all that water in the air comes from. Students conduct an investigation to explore the sources of water in the air, and they develop a model to show how some of the water in or on different earth materials gets into the air. They add ideas to their model of moving air to include water vapor as one type of molecule in the air. They incorporate the idea that when individual water molecules on the surface of a liquid gain enough motion energy (kinetic energy), they leave the liquid to become a gas; this process is called evaporation. Students also add the idea that water can go into the air (increasing its humidity) from many different types of surfaces with water in or on them.

Where We Are NOT Going

In the upcoming lessons, students will figure out what happens to the water vapor in the air as it rises and cools.

Absolute humidity is the measure of the actual water vapor in the air. Relative humidity is the ratio of the absolute humidity to the theoretical maximum for a given temperature and pressure, expressed as a percentage. The amount of water vapor molecules that a sample of air can hold when it reaches 100 percent relative humidity changes based on temperature and pressure. These are not target ideas for this lesson or unit.

Some students may interpret that 100 percent relative humidity means that 100 percent of the air is made of water vapor molecules. The previous lesson's reading *What Is Air?* will help students see that a relative humidity of 100 percent corresponds to an absolute humidity of at most 5 percent.

LEARNING PLAN FOR LESSON 7

1. Navigation

5 MIN

Materials: science notebook

Connect back to the last lesson. Project **slide A**. Remind students that last time, we revised our model to show how and why the air is moving below and within a hail cloud—but we were left wondering what is in that air, and how the air is different at different places in and around the cloud.

Revisit the reading. Cue students to look back at their notes from *What Is Air?*. Then have them turn and talk to a partner about the following questions:

- What did we learn about what air is made of?
- What is humidity, and how can it be measured?

Share ideas. Hear ideas from a few students, listening for these:

- *Air is a mixture of different types of molecules (substances) in the gas state, which we can't see.*
- *Humidity is how much water vapor (water in the gas state) is in the air.*
- *Humidity probes measure relative humidity.*

2. Explore the use of humidity probes. 8 MIN

Materials: Measuring Humidity Activity, whiteboard or chart paper, markers

Discuss the idea of humidity. Tell the class you have humidity probes, which measure the amount of water vapor (molecules of water in gas form) in the air.

Suggested prompts	Sample student responses
Where else have we heard this word "humidity"?	*We saw it in our weather data. On days when it hailed, the humidity was kind of high.*
On a very humid day, what does it feel like?	*sticky, sweaty, wet*

Measure humidity inside. Present **slide B**. Say, *I wonder what the humidity in this room is right now?* Have a student volunteer come up and read the humidity value for inside the classroom. Have a student record this location and the value on the board.

Then ask, *What could we do to make the air near the probe more humid?* Possible responses include these:

- *Put it near the water.*
- *Maybe if we breathed on it?*
- *Maybe we could put it near some steam or boiling water.*
- *Maybe we could spray water near it?*

Gather students around the boiling water in your hot plate and pot or electric kettle. Have a few volunteers measure the humidity right above the boiling water and a couple of distances (e.g., 0.5 meters and 2 meters) away from it, holding the probe at each location for about 30 seconds. Have another student record the measurements on the whiteboard or chart paper.

Safety Precautions

Holding a humidity probe near steam poses a danger of burns. Instruct students to use protective hot mitts. The probes are small, so you may need to tape one to a stick or ruler to safely hold it near the steam. Be sure not to cover the vents on the back of the probe.

Measure humidity outside. Say, *I wonder what the humidity is outside right now?* If your room has a window, tape or mount one of the humidity probes to the outside of the window so the display is readable from within the classroom.

If you don't have a window but do have a weather gauge in the room that is connected to the outside, have a student report the humidity value and add to the list on the board. If you have neither of these, you can go online and pull up a weather site to see the current humidity outside.

Suggested prompt	Sample student responses
How do our humidity readings from the inside, outside, and above the boiling water compare?	*It is lower inside our room.* *It is highest over the boiling water.* *The humidity went down as we moved away from the boiling water.*

Say, *But water isn't boiling outside, and we know from our close reading and our humidity reading for outside that there is water in the air. So where is that water coming from?*

3. Make predictions for the investigation.

5 MIN

Materials: Sources of Water in the Air Lab, science notebook, tape

Discuss where the water in the air could be coming from. Project **slide C**. Ask students to turn and talk about the question, "Where did all that water in the air come from?" After students share a few ideas, tell them to record this question in their science notebook as something to investigate.

Predict which environments might contribute water to the air. Say, *If you could measure how much water went into the air, do you think there are some places where more water goes into the air than in other places?*

Project **slide D**. Distribute *Sources of Water in the Air*. Ask students to tape the handout into their notebook and record their predictions about which places in the world they think water in the air could be coming from.

4. Plan our investigation.

10 MIN

Materials: Sources of Water in the Air Lab, science notebook, whiteboard or chart paper, markers

Brainstorm initial ideas. Project **slide E**. Ask students to turn and talk about these questions:

- What data should we collect? Why?
- How could we use a humidity probe, a lamp, and containers like these to see whether water is going into the air from each of these places?*

Collaboratively design the investigation. Lead a class discussion about how to design the investigation. Record the decisions on a whiteboard or chart paper as you plan together.

While planning, have students decide how often to monitor the results. Pilot classrooms recorded humidity readings every minute or every 2 minutes for 5–8 minutes.

*** Supporting Students in Engaging in Planning and Carrying Out Investigations**
Having students describe the purpose of each of the materials to be used engages them in thinking about what tools are needed to gather the data to answer the question motivating the investigation. As the discussion

Suggested prompts	Sample student responses
What data should we collect?	*We should record the humidity in different environments.*
How will that help us answer our question?	*If the humidity readings go up, then we know water is going into the air.*
How could we use these materials to gather this data?	*We could put the humidity probe inside the bottle.* *We could put the bottle over the materials and see if the humidity changes.* *We could shine a light on it to warm it up like the Sun.*
What can we agree on for how to do the investigation and what data to collect?	*We should all put our bowl of earth material the same distance away from the light.* *We should record the humidity at the start and the end.* *Maybe we should record the humidity every minute.*

continues, push students to think about what data would be most helpful to report on the class data table. In this case, the change in humidity from start to finish rather than (or in addition to) the beginning and ending humidity levels is the most relevant data.

Map the bottle system to the real world. After students have discussed how we could use the materials, project **slide F**. Say, *We can use this bottle system to investigate what happens. However, we need to map the components to the real world so we can apply our results to help explain how the water gets into the air.*

Lead a discussion to map the bottle system to elements in the real world. Listen for the following ideas:

- *The bowl with earth material represents an environment like a desert or a field.*
- *The air in the bottle represents the atmosphere.*
- *The light represents solar energy from the Sun.*
- *The bottle system is similar to the real world because real-world environments have earth materials with air around them and get heated up by the Sun.*
- *The bottle system is different from the real world because the bottle is a closed system but Earth is not.*

5. Conduct the investigation.

18 MIN

Materials: Sources of Water in the Air Lab, science notebook, whiteboard or chart paper, markers

Conduct the investigation. Project **slide G**. Have groups decide which environment they would like to test and how they will simulate that environment with the available materials. Remind them to monitor their setup and collect data according to the schedule decided during planning.

Additional Guidance

For the control, make sure to set it up with no light source on it. This will yield easier to interpret results than having a light on it. Here is why: Having no light source on it should yield relatively little change in its relative humidity, because the temperature of the air inside shouldn't change much. But if you were to put a light source on it, this would heat the air inside a bit, due to a greenhouse effect. This in turn would shift the relative humidity reading on the probe, even though the concentration of water vapor in the air (absolute humidity) would not be changing. The humidity probe would calculate relative humidity based on temperature, based on a mathematical relationship like the one students will explore using graphs they analyze in Lesson 16. At this point in the unit, however, it is counterproductive to have to try to make sense of any shifts in relative humidity, in a system where there is clearly no additional source of water vapor.

Report results. Discuss what data would be most helpful to report out. Tell the groups to each send up a volunteer to post their group's data on a class data table. You can project the data table onto a whiteboard so students can write directly into it. Alternatively, you can create a whole-class data table using chart paper.

Assign and collect exit ticket. Project **slide H**. Before students leave, have them complete an exit ticket answering these questions about the completed investigation:

- How is the model we used to gather data similar to and different from the real world?
- How will the data we collected help us answer our question: "Where did all that water in the air come from?"

Between classes, flip each bottle over to air it out. You may want to lightly shake the bottles a few times before your next class to fill them with fresh classroom air and remove any moisture. Be careful not to shake the humidity probe free.

End of day 1

6. Navigation

2 MIN

Materials: None

Revisit the lesson question. Project **slide I**. Remind students of the investigation question and ask a few students to share ideas for how the data we collected last time will help us answer it.

7. Interpret investigation data.

10 MIN

Materials: Sources of Water in the Air Lab, class data table, computer, projector

Revisit class results. Show **slide J.** Project or display the class data from the investigation.

Make sense of the data. Ask students to work with a partner to analyze the data and answer the "Making-Sense Questions" on *Sources of Water in the Air.*

Discuss claims. Ask pairs to share their claim about the question, "Where did all that water in the air come from?" Lead a brief discussion to see if others agree. Record the claim(s) publicly to be referenced and used at the end of the lesson when students add to their Progress Tracker. Listen for the idea that water can go into the air (increasing its humidity) from many different types of surfaces with water in or on them.

8. Develop a model to explain changes in humidity. 10 MIN

Materials: *Model for How Water Gets into the Air*

Develop models. Project **slide K**. Distribute *Model for How Water Gets into the Air*. Orient students to the zoomed-in circle where they are to show what is happening at the surface of the ground as well as in the air. Let students know they will be sharing their model with a partner, so they should use words and keys with their images to clarify what they mean and help others understand it.

Assessment Opportunity

Students have had several opportunities throughout the unit to develop models that represent unobservable mechanisms, including how thermal energy drives the cycling of matter. This activity provides a great opportunity to formatively assess their ability to represent what is happening at the molecular level as thermal energy is added to the bottle system. If students struggle to show this, ask them to look back in their Progress Trackers for how we have represented these ideas earlier in the unit.

9. Provide and receive feedback. 6 MIN

Materials: *Peer Feedback Guidelines* (optional), *Model for How Water Gets into the Air*, science notebook, tape

Pair up and compare models. Distribute *Peer Feedback Guidelines* if desired. This can be taped into notebooks. Show **slide L**. Explain how students will give each other feedback. Have students find a partner to share with.

Alternate Activity

You can also have students give and get feedback using sticky notes instead of verbal feedback. Prompts for what to write include the following:

- I wonder about ______. I noticed you ______.
- I appreciate how you ______.
- It would be clearer if you added ________.
- I see you're thinking about ________.
- Do you think you should add ________?

10. Respond to feedback.

5 MIN

Materials: *Model for How Water Gets into the Air*, science notebook, *Self-Assessment* (optional)

Reflect on peer feedback. Display **slide M** for reminders about receiving feedback, also listed below. Explain, *We use peer feedback to improve our work, making it more clear, more accurate, and better supported by evidence. When you receive feedback, you should take these steps:*

- *Review your notes about the feedback your partner provided.*
- *Decide if you agree or disagree with the feedback.*
- *Revise your work to address the feedback.*

Give students 4 minutes to make any additions or revisions to their models using the feedback provided.

Assessment Opportunity

At the end of this lesson or for home learning, the *Self-Assessment* handout is a good opportunity for students to self-assess. Helping students reflect on their progress in giving and receiving feedback will help build their skills in this important area.

11. Update Progress Tracker.

12 MIN

Materials: science notebook, *Model for How Water Gets into the Air*, whiteboard or chart paper, markers

Gather in a Scientists Circle and set up Progress Tracker. Have students bring their science notebook, *Model for How Water Gets into the Air*, and a chair to form a Scientists Circle. Project **slide N**. In their notebooks, students should draw a three-column Progress Tracker to help the class come to an agreement about the evidence and what we have figured out in words and pictures. First, have students write down the question we have been trying to answer, “Where did all that water in the air come from, and how did it get into the air?” Next, ask what evidence we have been working with to answer this question (e.g., humidity readings).

Question	Source of Evidence
Where did all that water in the air come from, and how did it get into the air?	Humidity readings from our bottle systems.

Shift to “What we figured out”. Facilitate a discussion for what we have figured out. Start with the first part of the question that the class answered earlier in the lesson, “Where did all that water in the air come from?” Add the idea that water can go into the air (increasing its humidity) from many different sources.

Then lead a discussion to come to consensus on how that water gets into the air. It would be helpful to project *Model for How Water Gets into the Air* or draw the picture from the handout on chart paper as a place to create a class model. This model will be revisited in Lesson 8.

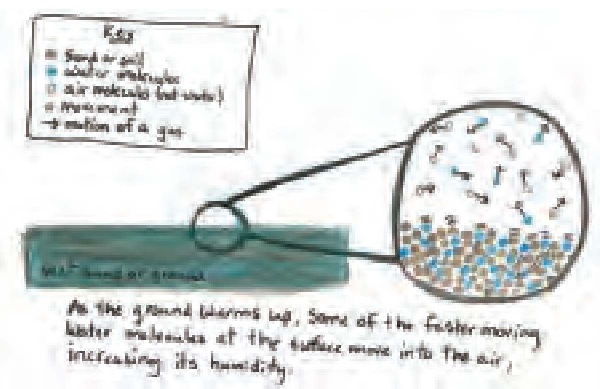
Suggested prompts	Sample student responses	Follow-up questions
What is one important idea that we want to represent to help explain how the water gets into the air?	*We need to show water molecules on the ground and in the air.*	*Did everyone show that?* *How should I draw the particles in the air compared to on the ground?*
What else should we show to help explain how the water gets into the air?	*We have to show the molecules moving faster when they warm up.*	*Do others agree?* *How did you show that?* *Can you say more about why the particles are moving faster?*
Why is it important to represent the molecules moving faster?	*Because the molecules have to heat up and move fast enough to change from a liquid to a gas.*	*So are you saying . . . ?* *Can someone restate what __ just said?*
How does this model explain the increase in humidity that we saw in our investigation?	*When water goes into the air as water vapor, the humidity increases.*	*How does this relate to a hailstorm?*

Finalize the class model. If needed, introduce the term *evaporation* to describe the process in which individual water molecules on the surface of a liquid gain enough motion energy (kinetic energy) to leave the liquid and become a gas. Add this term to the word wall and to the class model. Ask students to draw the model the class agrees upon into their Progress Tracker, using words and pictures. The image below shows an example of the model the class might create.

What we figured out in words and pictures

What we figured out, in words and pictures

- Water can go into the air (increasing its humidity) from many different sources.
- When individual water molecules on the surface of a liquid gain enough motion energy (kinetic energy), they leave the liquid and become a gas; this process is called evaporation.



Alternate Activity

You can also ask for students to project their model using a document camera and then, as a class, annotate or combine ideas from several models.

12. Navigation

3 MIN

Materials: None

Turn and talk. Project **slide O**. Ask students to turn and talk about this question: “How does what we just figured out help us explain what is happening in the clouds?” Listen for ideas about how water gets into the clouds, given that we know hailstorms have rain and frozen water.

ADDITIONAL LESSON 7 TEACHER GUIDANCE

Supporting Students in Making Connections in ELA

Students engage in discussion when they verbally provide and receive feedback on their models and then incorporate that feedback to revise their models.

CCSS.ELA-LITERACY.SL.6.1: Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grade 6 topics, texts, and issues, building on others’ ideas and expressing their own clearly.

LESSON 8

What happens to water vapor in the air if we cool the air down, and why?

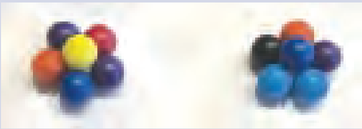
Previous Lesson

We planned and carried out an investigation to test where the water in the air comes from by measuring the humidity in the air over samples of different Earth surfaces. We developed a model to account for how the water got into the air.

This Lesson

Investigation

2 DAYS



We carry out investigations to explore what happens when air containing water vapor is cooled and what happens when water droplets make contact with each other. We use magnetic marbles to develop a model for how mutual attraction between water molecules and changes in their speed cause water to change from gas to liquid when it cools below a certain temperature.

Next Lesson

We will read about what clouds are made of, why we can see them, the role of cloud condensation nuclei, and methods of cloud seeding. We will argue that what happens in clouds is similar to what happens on the surface of cold gel packs over humid air in 2-L bottles.

Building Toward NGSS

MS-PS1-4, MS-ESS2-4, MS-ESS2-5, MS-ESS2-6

What Students Will Do

Carry out an investigation to collect data about the patterns in the appearance and growth of water droplets in humid air that is cooled down and how water droplets interact to serve as evidence to explain the causes of condensation (effect).

Develop and use a model to describe unobservable mechanisms that explain why the mutual attraction between water molecules and a decrease in their speed causes them to condense (effect) when water reaches a low enough temperature (condensation/boiling point).

What Students Will Figure Out

- Water molecules are attracted to each other. When they are moving fast enough, they can break away from each other and bounce off each other. When they are moving slow enough, they clump and stick together.

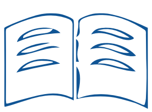
- Water droplets can grow over time as they run into other water droplets or as more molecules of water vapor condense and stick to them.
- When water is below a certain temperature (its condensation/boiling point), the molecules are moving slow enough to remain in liquid form; when water is above that temperature, the molecules are moving fast enough to remain in gas form; they change state when cooled below or heated above that temperature.

Lesson 8 • Learning Plan Snapshot

Part	Duration	Summary	Slide	Materials
1	5 min	**NAVIGATION** Review what is happening to water molecules when they evaporate.	A	
2	7 min	**MAKE PREDICTIONS AND PREPARE TO INVESTIGATE OUR QUESTION** Predict what would happen to the water vapor in humid air if we cooled the air.	B-C	
3	8 min	**CONDUCT INVESTIGATION A** Make observations of a 2-L bottle cover with a bag of ice on top as it is held over warmed water.	D	*Procedures for Investigations A and B* (optional), Investigation A
4	7 min	**MAKE SENSE OF OUR DATA FROM INVESTIGATION A** Share observations of the 2-L bottle cover and share initial explanations for those observations.	E-F	
5	7-8 min	**CONDUCT INVESTIGATION B** Explore what happens when water drops are blown on with a straw and get near each other or touch each other.	G	optional: *Procedures for Investigations A and B*, Investigation B
6	10 min	**MAKE SENSE OF OUR INVESTIGATION RESULTS** Discuss what happened when water drops got near each other or touched each other.	H-I	extra piece of notebook paper
				End of day 1
7	5 min	**NAVIGATION** Share initial ideas of interactions that could be happening between water molecules when they get really close to each other.	J	
8	7 min	**MAP THE ELEMENTS OF OUR MODEL** Brainstorm examples of larger objects that are attracted to each other. Develop an analogy map for how magnetic marbles can be used to represent water molecules.	K	*Elements Map and Results for Investigation C*, tape

Part	Duration	Summary	Slide	Materials
9	15 min	**ORCHESTRATE INVESTIGATIONS WITH MAGNETIC MARBLES** Conduct a series of investigations with magnetic marbles and a plastic storage bin.	L-P	*Elements Map and Results for Investigation C*, optional: *Procedure for Investigation C*, Investigation C
10	5 min	**UPDATE PROGRESS TRACKER** Update the Progress Tracker to reflect new ideas about what happens to water vapor when it is cooled and why this happens.	Q	*Elements Map and Results for Investigation C*
11	10 min	**SHARE FINDINGS AND ADD TO PROGRESS TRACKER** Use discussion protocols to share and connect findings in small groups. Include these additional connections in the Progress Tracker.	R	*Elements Map and Results for Investigation C*, timer (or wall clock)
12	3 min	**NAVIGATION** Raise questions about why we don't see clouds in the air all the time and what a cloud is.	S	*Elements Map and Results for Investigation C*, class consensus model poster(s) from Lesson 7, sticky notes, markers
				End of day 2
		SCIENCE LITERACY ROUTINE Upon completion of Lesson 8, students are ready to read Student Reader Collection 3 and then respond to the writing exercise.		Student Reader Collection 3: *Water in and out of the Air*

Lesson 8 • Materials List

	per student	per group	per class
Investigation A materials		• materials bin for Investigation A	• timer (or wall clock)
Investigation B materials		• materials for Investigation B	
Investigation C materials		• materials bin for Investigation C	• timer (or wall clock)
Lesson materials **Student Procedure Guide**  **Student Work Pages** 	• science notebook • optional: *Procedures for Investigations A and B* • extra piece of notebook paper • *Elements Map and Results for Investigation C* • optional: *Procedure for Investigation C*		• tape • timer (or wall clock) • class consensus model poster(s) from Lesson 7 • sticky notes • markers

Materials preparation (40 minutes)

Online Resources

Review teacher guide, slides, and teacher references or keys (if applicable).

Make copies of handouts and ensure sufficient copies of student references, readings, and procedures are available.

Optional: Make copies of *Procedures for Investigations A and B* and *Procedure for Investigation C* for each student to refer to if you wish. These procedures are also embedded in the slides and the student handbook.

Ensure the class consensus model poster(s) from Lesson 7 is visible for students to refer to when you add annotations or sticky notes to the clouds shown on it toward the end of this lesson.

Day 1: *Investigation A*

- **Group size:** 3
- **Advance preparation:**
  - Watch the investigation setup video to see how to prepare the ice bags and how students will drape them over the top of the bottles. (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)
  - Make one ice bag for each group of 3 students: Place 8–10 ice cubes in a 1 qt ziplock bag, squeeze out the air before sealing, and keep frozen until class. If you have more than one class, make 2 sets of bags so you can rotate a set back to the freezer between classes.
- **Setup:** Place the following in a 6-qt storage bin for each group of students (for easy transportation):
  - 1 sealed ziplock bag of ice (taken from the freezer when ready to use)
  - 1 empty 2-L soda bottle (including cap) with bottom cut off (from Lesson 7)
  - 1 small container or cup of warm tap water
  - 1 magnifying glass
- **Storage/reuse:** Collect the materials bin after students complete the investigation. Place the ice bags in the freezer between classes.

Day 1: *Investigation B*

- **Group size:** 3
- **Advance preparation:**
  - Cut small pieces of wax paper (e.g., 6″ x 6″), 1 per student in every class.
  - Pour out 1 small container or cup of room-temperature water per group of 3 students (you can reuse this from *Investigation A*'s materials bin).
- **Setup:** Provide the following for each group:
  - 3 pieces of wax paper
  - 3 straws
  - 1 pipette
  - 1 small container or cup of room-temperature water

- paper towel(s)

- **Safety and disposal:** Have each student dispose of their own piece of wax paper and straw.

Day 1: ***Investigation C***

- **Group size:** 3
- **Advance preparation:**
  - Watch the Part 2 Investigation Setup video to see examples of the motions you will demonstrate with the magnetic marbles and plastic containers. (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)
  - Have superglue handy to repair any magnetic marbles that break during this activity. Such repairs take only a few seconds.
- **Setup:** Provide the following for each group:
  - 10 magnetic marbles in a 6-qt container with a lid (you can reuse the storage bins from *Investigation A*).
- **Storage/reuse:** All materials can be stored indefinitely and reused.

Lesson 8 • Where We Are Going and NOT Going

Where We Are Going

In 5th grade, students should have developed an initial understanding of the connection between particles and condensation (PS1.A from *NRC Framework*, p. 108):

- "Matter of any type can be subdivided into particles that are too small to see, but even then the matter still exists and can be detected by other means (e.g., by weighing or by its effects on other objects). For example, a model showing that gases are made from matter particles that are too small to see and are moving freely around in space can explain many observations, including . . . the appearance of visible scale water droplets in condensation, fog, and, by extension, also in clouds or the contrails of a jet."

This lesson is designed to build upon those ideas in day 1 to develop two new mechanisms to account for cloud formation and growth of droplets in the air above us over time in day 2. One mechanism is droplet collision and merging. Another is ongoing condensation of water vapor molecules on water droplets.

Students draw on additional disciplinary core ideas (PS1.A and PS3.A), previously developed in the Cup Design Unit, across this lesson and previous lessons in this unit:

- "Gases and liquids are made of molecules or inert atoms that are moving about relative to each other. In a liquid, the molecules are constantly in contact with each other; in a gas, they are widely spaced except when they happen to collide."
- "Temperature is a measure of the average kinetic energy of particles of matter."

Students integrate these ideas to develop a more mechanistic explanation for why water changes state when it reaches a certain temperature. This helps them develop a major part of the MS DCI PS1.A:

- "The changes of state that occur with variations in temperature can be described and predicted using these models of matter."

Magnetic marbles are introduced on day 2 to represent water molecules. As intermolecular attraction is not actually due to magnetism, we help students recognize that magnetism is only a useful analogy, as well as a limitation of their model. Students have used marbles before to represent particles in different states of matter in the Cup Design Unit.

Where We Are NOT Going

The condensation/boiling point of water changes based on local atmospheric pressure. Since increases in elevation correspond to decreased atmospheric pressure, this also results in a decrease in condensation/boiling point of water. Though there is a reference to the role of pressure in state changes in MS DCI PS1.A, students do not need to understand that in this unit. Pressure will be introduced later to predict and explain certain aspects of large-scale air mass interactions.

Developing a model that includes some sort of attraction or stickiness between molecules is useful for explaining why the moving particles in a liquid or solid don't fly apart. What causes intermolecular forces and why they differ for different substances, however, will be addressed in high school.

The idea of a connection that holds particles together when they are close to each other (and at a low enough temperature) is developed in middle school: "The role of forces between particles also begins to be discussed in grade 6—topics include the recognition that particles in a solid are held together by the forces of mutual attraction and repulsion (which act like springs) and that there are forces between particles in a gas that causes them to change their paths when they collide" (*NRC Framework*, p. 237). Attraction between the particles that make up solids will be developed in Lesson 9 (to explain deposition) and developed further in Unit 8.1: *Why do things sometimes get damaged when they hit each other?* (Breaking Stuff Unit).

Don't worry that we aren't yet talking about what else makes up clouds (such as dust and ash). Students will uncover that additional information in the next lesson.

LEARNING PLAN FOR LESSON 8

1. Navigation

5 MIN

Materials: science notebook

Revisit Lesson 7. Show **slide A**. Have a few students summarize some of what we figured out in the previous lesson about what happens at the particle level when water evaporates from an environment. Listen for responses such as these:

- Water can go into the air (increasing its humidity) from many different types of surfaces with water in or on them.
- When individual water molecules on the surface of a liquid gain enough kinetic energy, they leave the liquid to become a gas; this process is called evaporation.

Ask students to recall what we know happens to the temperature of the air the higher it is in the atmosphere.

Suggested prompt	Sample student responses
Yesterday, we trapped air over a water source and added energy to the system, and its humidity went up. We know that warming air makes it less dense, which can cause it to rise. But what else do we know eventually happens to air parcels as they rise?	*They cool down.* *They become more dense.* *They eventually sink.*

Raise the new lesson question. Say something like, *So then what exactly happens to all that water vapor in that air when it cools off as it rises? Let's think about this more.*

2. Make predictions and prepare to investigate our question.

7 MIN

Materials: science notebook

Predict the effect of a temperature decrease on humid air. Show **slide B**. Instruct students to turn and talk with a partner about the questions on the slide. After a couple minutes, have a few students share out what they discussed and ideas about how we might test those predictions.

Suggested prompt	Sample student responses
What do you think would happen to the water vapor molecules in humid air if we cooled the air down? Why?	*It might form droplets.* *It might get foggy.* *It might condense.* *Some of it might turn back into a liquid.*

Additional Guidance

Students who completed the Cup Design Unit are likely to recall related experiences with cooling air and condensation forming on the outside of a cup. If they don't, that is fine. They will redevelop and extend a particle-level model for what is happening in this lesson.

Say something like, *Let's investigate these predictions by collecting data. Our materials from yesterday are available to use again for this investigation. That includes 2-L bottle covers that we can reuse to trap some warm, humid air and cool it down so we can observe what happens to it. But before we do, let's prepare our science notebooks so we can keep track of what we are trying to figure out.*

Introduce the first part of the lesson question. Show **slide C**. Have students write this initial question in their notebook: "What happens to water vapor in the air if we cool the air down?" Tell them to create a table for observations as shown on the slide. They will add the next part of the question—"and why?"—partway through the lesson.

3. Conduct Investigation A. 8 MIN

Materials: Investigation A, science notebook, *Procedures for Investigations A and B* (optional)

Conduct *Investigation A*. Show **slide D**. This slide provides instructions for the investigation. Alternatively, students can look at a copy of these instructions in *Procedures for Investigations A and B* in their student edition or as a handout you provide.

Assign students to groups of 3. Have one student from each group collect their materials bin, including a small container or cup of hot water. Students should conduct this investigation at their tables rather than at lab stations to minimize transition time. Tell students that they only have 7 minutes for this investigation. Guide the pacing by announcing the start time, then 2 minutes in (5 minutes left), and then 5 minutes in (2 minutes left). During the last minute, have students return their bins.

4. Make sense of our data from Investigation A. 7 MIN

Materials: science notebook

Discuss observations and initial explanations. Present **slide E**. Discuss the questions on the slide as a class.

Suggested prompts	Sample student responses
Where in the bottle did you see the strongest evidence of water molecules turning from water vapor back into liquid water?	*At the top of the bottle.*
Why do you think this happened more in this part of the bottle than other parts?	*The bottle was colder near the top.*
What caused the droplets to get larger over time?	*The water collected on the droplets.* *The water vapor came out of the air.* *Droplets stuck to neighboring droplets.*

Expand the lesson question. Say something like, *OK, we agree on what we saw happening as we cooled the air with water vapor in it—liquid water appeared. This phenomenon we observed is referred to as* ***condensation.*** *We can say that dropping the temperature of the air with water vapor in it somehow caused this to happen. Scientists refer to the temperature at which a substance turns from gas into liquid as its "condensation point" when the gas is being cooled down. They also call this temperature the substance's "boiling point", because the liquid turns back into gas at the same temperature when the liquid is being warmed up.*

Add these two words and phrases to the word wall:

- **Condensation** - the process in which water vapor becomes liquid.
- **Condensation/boiling point** - the temperature at which a substance (like water) turns from gas into liquid and vice versa.

Say, *I want to emphasize that these words alone don't yet help us say what is happening at the particle level to explain why lowering the temperature of water vapor in the air* ***causes*** *small droplets of water to appear and then grow over time. Let's try to figure that out. To prepare, let's add to our lesson question so it reflects what we are wondering about.*

Show **slide F**. Have students update the lesson question by adding "and why?" in their notebook.

Motivate a closer inspection of water droplets. Say, *Let's do another investigation to figure out more about what interactions might have been happening between the water molecules and water droplets in the previous phenomenon. In this investigation, we will explore the behavior of water droplets and use our observations to figure out more about how they interact with each other.*

5. Conduct Investigation B. 7-8 MIN

Materials: Investigation B, science notebook, optional: *Procedures for Investigations A and B*

Conduct *Investigation B*. Show **slide G**. This slide provides instructions for the investigation. Alternatively, students can look at a copy of these instructions in *Procedures for Investigations A and B* in their student edition or as a handout you provide.

Assign students to groups of 3. Have one student from each group collect their materials bin for the investigation. Groups should conduct this investigation at their tables rather than at lab stations to minimize transition time. After about 5 minutes, have students return their bins.

Safety Precautions

For health reasons, have each student dispose of their own piece of wax paper and the straw they used.

If you handed out copies of *Procedures for Investigations A and B*, collect these now to reuse for the next class.

6. Make sense of our investigation results. 10 MIN

Materials: science notebook, extra piece of notebook paper

Discuss the behavior of the droplets. Show **slide H**. Ask, *When water droplets got really close or just barely touched each other, what did you see them do?*

Listen for noticings of seeing two water droplets come together, merge, pull together, and so forth when they got really close to or touched each other. As observations are shared, ask other students to comment on whether they saw something similar.

Additional Guidance

If students don't recall seeing something like this or don't describe their observations in this way, suggest looking at one of these events together. Tell them you have a slow-motion video of this phenomenon and then play the Slow-motion Water Droplet Collision video. After the video, ask students again to describe the behavior of the droplets. (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)

Introduce the exit ticket. Show **slide I**. Have students put their name on a blank sheet of notebook paper to use as an exit ticket. Say something like, *I want us to think more about particle interactions, and I want you to tell me what you are thinking about these two questions on an exit ticket that I'll collect before you leave. Think about what you just saw a bunch of water molecules in liquid form do when they got close to another bunch of water molecules in liquid form. First, explain what might have been happening between the water droplets that would make them do this. Then, imagine the same thing happening between any two water molecules when they get close to each other. How could you use these ideas to explain why liquid droplets appeared on the side of the bottle and grew larger as you lowered the temperature of the air with water vapor in it?*

Give students the remaining time to complete their exit ticket. Collect these before they leave.

Assessment Opportunity

Review these responses. See the assessment guidance section for ideas to provide helpful feedback to push students' thinking further during day 2. If you do this, save a copy of the exit tickets before returning them. You can then compare these responses to those in the Progress Tracker at the very end of this lesson.

End of day 1

7. Navigation

5 MIN

Materials: science notebook

Recall the phenomena we explored last time. Ask what investigations we did last time. Listen for these answers:

- We cooled humid air and saw water droplets appear and grow over time in a bottle held over that air.
- We blew on water droplets to make them move and saw them merge with other droplets when they got close to them.

Share initial ideas about how water molecules interact. Show **slide J**. Remind students that they responded to these questions last time in their exit ticket.

Additional Guidance

If you provided written feedback on students' exit tickets, pass them back now.

Tell the class that what they wrote was a great start and very useful as a set of initial explanations, but our goal today is to further develop those explanations. Emphasize that it is important to share these ideas and look for ways to build off each other's ideas to refine our thinking. Tell students that they will have a chance to revise their response to the question in their Progress Tracker at the end of this lesson and that you are looking forward to seeing how their ideas will develop by then.

Ask students to share their ideas for the prompts on **slide J** with the class.

Suggested prompts	Sample student responses
What type of interactions could be happening between water molecules when they get really close to each other that would explain our observations?	*Maybe they are attracted to each other.* *Maybe they attach to each other.* *Maybe they pull in other water molecules.*
How could these ideas help us explain why droplets appeared on the inside of the bottle and grew larger as we cooled the humid air?	*Maybe something like this was happening with neighboring water droplets on the bottle surface.* *Maybe this was how water vapor molecules got pulled into the water droplets.* *Cooler air contains water molecules that are moving slower, so maybe that has something to do with why they formed bigger and bigger droplets over time.*

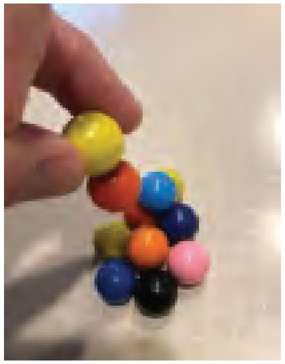
8. Map the elements of our model.

7 MIN

Materials: science notebook, *Elements Map and Results for Investigation C*, tape

Introduce the idea of intermolecular attraction. Say, *Scientists use the interactions between water molecules to explain our observations. They think water molecules are attracted to each other, and that the attraction is particularly strong when the molecules are close to each other.*

Ask students for examples of larger objects that are attracted to other things and seem to pull things toward them when they get close. Accept all responses. Students are likely to suggest magnets as one example.



Introduce magnets as an analogy for water molecule attraction. Say, *One way to think about the attraction between water molecules is to think of a magnet. Magnets can pull certain things toward them when they are close to them. Water molecules are similar in that they are attracted to other water molecules. They aren't exactly like magnets, which are only attracted to certain metals. But even though molecules aren't really tiny magnets, picturing them as attracting each other like magnets may help us explain and predict some of the phenomena we have observed. Let's use magnetic marbles as representations of water molecules, to explore how their behavior changes under different conditions. We will use what we notice to refine our explanation of why water vapor condenses when cooled and why water droplets grow in size.*

Hold out two magnetic marbles to show students, one in each hand. Explain that each marble has a magnet inside. Ask what will happen when the two marbles come near each other. Students will predict that they will stick to each other. Demonstrate this outcome by bringing the marbles together and holding up one of them with the second dangling from it.

Say, *We are using magnetic marbles because water molecules also tend to stick together when they get close to each other. Each marble will represent a single water molecule. Let's keep track using this handout.*

Show **slide K**. Hand out copies of *Elements Map and Results for Investigation C* for students to add to their science notebook. Have students write "a single molecule of water" in the middle column for the first row (corresponding to "each magnetic marble") of the first table on this handout.

Say that each group will share a bin with a lid on it, which they will use to do four explorations (C1-C4) with the marbles—for example, shaking the marbles slowly versus more quickly, or rolling marbles toward each other slowly versus more quickly. Establish agreement that faster movement of molecules would represent an increase in temperature for a solid, liquid, or gas.

Complete the rest of the first table on the handout as a class. The finished table should look similar to this:

This element in our investigation . . .	***is like this feature in the real world . . .***	***because . . .***
each magnetic marble	a single water molecule	water molecules tend to stick together and are attracted to each other
faster vs. slower movement of the marbles	increases vs. decreases in temperature	temperature is a measure of the average speed of the molecules in a solid, liquid, or gas

9. Orchestrate investigations with magnetic marbles.

15 MIN

Materials: Investigation C, *Elements Map and Results for Investigation C*, optional: *Procedure for Investigation C*

Additional Guidance

This series of explorations is designed to alternate quickly between small-group work and individual sense-making. To support making these quick shifts, set a timer to help stick to the tight time limits and end times for each step. Students will find the magnetic marbles very tempting to keep fiddling with, so have them completely close their bins between investigations and bring all eyes and attention to your cues for each new part.

Overview the investigation procedures. Assign students to groups of 3. Present **slide L**. Tell the class that each group will do a series of very short explorations using a bin with 10 magnetic marbles in it. Emphasize that each exploration will be timed and relatively quick, and after each one, the person holding the bin will put it down and everyone will record their observations on *Elements Map and Results for Investigation C*. Everyone in the group will then read aloud the directions for the next investigation together before passing the bin to a new person in their group. Ask students if they have any questions. Have one student from each group collect their materials bin for the investigation to do at their tables rather than at lab stations to minimize transit time.

Coordinate and direct the pacing for *Investigation C1*. Present **slide M**. Optional: you can also provide these directions for students' reference by giving them a copy of *Procedure for Investigation C*.

Have all groups put the lid on their bin and put it in the middle of their table. With the class, read aloud the text in the first cell in row C1 of the second table on *Elements Map and Results for Investigation C*.

Set the timer for 2 minutes. When the timer goes off, signal time and have groups return all marbles to the bins, put the lids on, and place the bins in the middle of the tables. Direct students to the second cell in row C1 on their handout. Have them silently read the question and write a short answer in the third cell. Give 2 minutes for this.

Coordinate and direct the pacing for *Investigation C2*. Present **slide N**. Tell groups to leave the bins untouched as you and the class read aloud the text in the first cell in row C2 of their handout. Demonstrate how to move the container for each step as you saw in the Part 2 Investigation Setup video. Warn students to hold the lid down tightly so the marbles don't end up flying out of the bin. (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)

Set the timer for 1 minute. When the timer goes off, signal time and have groups flip the closed bins upright and place them in the middle of the tables. Direct students to silently read the second cell in row C2 and write a short answer in the third cell. Give 2 minutes for this.

Coordinate and direct the pacing for *Investigation C3*. Present **slide O**. Tell groups to leave the bins untouched as you and the class read aloud the text in the first cell in row C3. Demonstrate how to move the container for each step as you saw in the Part 2 Investigation Setup video. Tell students to hold the lid tightly down again and not shake the container any faster than you do, as the shells of the marbles can break if they shake it too vigorously. (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)

Set the timer for 1 minute. When the timer goes off, signal time and have groups flip the closed bins upright and place them in the middle of the tables. Direct students to silently read the second cell in row C3 and write a short answer in the third cell. Give 2 minutes for this.

Coordinate and direct the pacing for *Investigation C4*. Present **slide P**. Tell groups to leave the bins untouched as you and the class read aloud the text in the first cell in row C4.

Set the timer for 2 minutes. When the timer goes off, signal time and have groups return all marbles to the bins, put the lids on, and place the bins in the middle of the tables. Direct students to silently read the second cell in row C4 and write a short answer in the third cell. Give 2 minutes for this.

10. Update Progress Tracker.

5 MIN

Materials: science notebook, *Elements Map and Results for Investigation C*

Cue students to update their Progress Tracker. Say, *Let's pause our investigations now and take a moment to use what we figured out about particle interactions in this last investigation to help answer our lesson question.*

Show **slide Q**. Give students the remaining time to individually update their Progress Tracker as shown on the slide. Collect the materials bins as students are doing this. Also collect *Procedure for Investigation C* if copies were handed out for reference during the investigation.

11. Share findings and add to Progress Tracker. 10 MIN

Materials: science notebook, *Elements Map and Results for Investigation C*, timer (or wall clock)

Introduce the discussion protocol. Project **slide R**. Tell students they will follow this protocol when they meet in a moment in small groups. Read through the protocol. Say that you want to review their Progress Tracker as a formative assessment after their final individual update. Ask if they have any questions.

Assign students to groups of 3. Say that you will call out 1-minute intervals for the protocol (e.g., by saying "switch"). Start the timer and call out minute intervals.

After 6 minutes, pause the small-group discussion and have students individually add to their Progress Tracker as outlined on the bottom of the slide.

Assessment Opportunity

This is a good formative assessment opportunity. Compare students' responses here to those in the exit tickets. This will provide an opportunity to assess growth in understanding over the lesson. Look for old ideas previously developed in the Cup Design Unit and new ones developed in this lesson:

- Temperature is related to the average speed of the particles or molecules. (old idea)
- When molecules are in a gas state, they are spread far apart and moving relatively fast and bounce off other molecules they collide with. (old idea)
- Liquids are made of molecules that are moving, but in a different pattern than in gas form—they move closer together and slide past each other; they also bump into neighboring molecules. (old idea)
- Water molecules have some sort of attractive property or force between them that pulls them toward each other and keeps them stuck together when they are close enough to each other. (new idea)
- When water is below a certain temperature (its condensation/boiling point), the molecules are moving slow enough that they remain stuck to each other, which keeps them in liquid form. When water is above that temperature, the molecules are moving fast enough that they don't remain stuck together—they fly around and bounce off each other, which keeps them in gas form. (new idea)

See the assessment guidance section for more details.

12. Navigation 3 MIN

Materials: science notebook, *Elements Map and Results for Investigation C*, class consensus model poster(s) from Lesson 7, sticky notes, markers

Connect this lesson to Lesson 7. Say, *Based on what we figured out about cooling air, it seems like condensation must be happening in the air up high where it is cooler. That would mean that this is where water droplets should start forming.*

Mark this location (in the clouds) on the class consensus model poster(s) from Lesson 7. You can do this by adding sticky notes to the poster as temporary annotations, rather than writing directly on the poster.

Raise new questions. Say, *But if we know water droplets can form in air that is cooled that has water vapor in it, then why aren't water droplets always forming in the air above us outside? And if clouds are related to precipitation, then at what point are droplets forming in the clouds? We have some ideas about how droplets might grow bigger, but why isn't precipitation always falling from any clouds that pass over us? What exactly is a cloud, anyway? If we look back at our Driving Question Board, we can see that we had questions about clouds and what is going on inside of them. Let's start talking about these questions, so we have some ideas about what we need to figure out next time.*

Project **slide S**. Have students turn and talk with a partner about these questions.

SCIENCE LITERACY: READING COLLECTION 3

Water in and out of the Air

1. **Lake Mead**
2. **Sticky Water**
3. **Science Fiction, Science Fact**
4. **A Minute to a Million Years**
5. **Heat and Drought**

Literacy Objectives

- ✓ Summarize key points related to water and water vapor in Earth systems.
- ✓ Distinguish cause(s) and effect(s) related to water, weather, and climate.

Literacy Exercises

- Read varied text selections related to the topics explored in Lessons 6–8.
- Evaluate the reading selections according to provided prompts and criteria.
- Compare and contrast information gained from reading text with information gained from class investigation.
- Prepare a cause-and-effect graphic organizer in response to the reading.

Instructional Resources

Student Reader
Collection 3

Science Literacy Student Reader, Collection 3
"Water in and out of the Air"

Exercise Page
EP 3

Science Literacy Exercise Page
EP 3

Prerequisite Investigations

Assign the Science Literacy reading and writing exercise *after* class completion of this lesson group:

- Lesson 6: How can we explain the movement of air in a hail cloud?
- Lesson 7: Where did all that water in the air come from, and how did it get into the air?
- Lesson 8: What happens to water vapor in the air if we cool the air down, and why?

Standards and Dimensions

NGSS

Disciplinary Core Ideas: ESS2.C: The Roles of Water in Earth's Surface Processes: Water continually cycles among land, ocean, and atmosphere via transpiration, evaporation, condensation and crystallization, and precipitation, as well as downhill flows on land. (MS-ESS2-4)

PS1.A: Structure and Properties of Matter
The changes of state that occur with variations in temperature or pressure can be described and predicted using these models of matter. (MS-PS1-4)

Science and Engineering Practices:
Constructing Explanations and Designing Solutions; Obtaining, Evaluating, and Communicating Information

Crosscutting Concept: Cause and Effect

CCSS

English Language Arts

RST.6-8.2: Determine the central ideas or conclusions of a text; provide an accurate summary of the text distinct from prior knowledge or opinions.

RST.6-8.4: Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to grades 6-8 texts and topics.

RST.6-8.6: Analyze the author's purpose in providing an explanation, describing a procedure, or discussing an experiment in a text.

RST.6-8.10: By the end of grade 8, read and comprehend science/technical texts in the grades 6-8 text complexity band independently and proficiently.

WHST.6-8.4: Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience.

Core Vocabulary

Core Vocabulary: Core Vocabulary terms are those that students should learn to use accurately in discussion and in written responses. During facilitation of learning, expose students repeatedly to these terms. However, these terms are not intended for isolated drill or memorization.

drought **humidity**

Language of Instruction: The Language of Instruction consists of additional terms, not considered a part of Core Vocabulary, that you should use when talking about any concepts in this exercise. Students will benefit from your modeling the use of these words without the expectation that students will use or explain the words themselves.

adhesion **cohesion**

evaporation **surface tension**

A Glossary at the end of the Science Literacy Student Reader lists definitions for Core Vocabulary and selected Language of Instruction.

1. Plan ahead.

Determine your pacing to introduce the reading selections, check in with students on their progress, and discuss the reading content and writing exercise. If you are performing Science Literacy as a structured, weekly routine, you might implement a schedule like this:

- Monday: Designate a ten-minute period at the beginning of the week to introduce students to the assignment.
- Wednesday: Plan to touch base briefly with students in the middle of the week to answer questions about the reading, to clarify expectations about the writing exercise, and to help students stay on track.
- Friday: Set aside time at the end of the week to facilitate a discussion about the reading and the writing exercise.

2. Preview the assignment and set expectations. (Monday)

- Let students know they will read independently and then complete a short writing assignment. The reading selection relates to topics they are presently exploring in their Weather, Climate, and Water Cycling unit science investigations.
- The reading and writing will be completed outside of class (unless you have available class time to allocate).
- Preview the reading. Share a short summary of what students can expect.
    - *First, you will read an article about why Lake Mead loses a lot of water to evaporation, including data about how the evaporation rate changes throughout the year.*
    - *Next, you'll learn about some very interesting properties of water that make it bead up on surfaces and even prevent objects from penetrating the water's surface.*

- *Then you'll read about a science fiction novel in which survival on another planet requires capturing tiny amounts of water vapor from the air. You'll learn that a similar technology has been developed for very arid places on Earth.*
- *Next, you'll read about the "residence times" of water in different locations on Earth. As the reading title says, it can be from one minute to a million years!*
- *Finally, you'll compare two maps to see how higher-than-normal heat is related to droughts.*

- Distribute Exercise Page 3. Preview the writing exercise. Share a summary of what students will be expected to deliver. Emphasize that Science Literacy exercises are brief. The focus is on thoughtful quality of a small product, not on the assignment being big and complex.
  - *For this assignment you will be expected to complete a cause-and-effect graphic organizer.*
- Remind students of helpful strategies they can employ during independent reading. Offer the following advice:
  - *The reading should take approximately 30 minutes to complete.* (Encourage students to break reading into smaller sections over multiple short sittings if their attention wanders.)
  - *A good reading strategy is to scan through the collection first to see the titles, section headers, graphics, and images to see what the selections are going to be about before fully reading.*
  - *Next, "cold read" the selections without yet thinking about the writing assignment that will follow.*
  - *Then, carefully read the Exercise Page to understand the expectations for the writing part of the assignment.*
  - *Revisit the reading selections to complete the writing exercise.*
  - *Jot down any questions for the midweek progress check in class.* (Be sure students know, though, that they are not limited to that time to ask you for clarification or answers to questions.)

Exercise Page

EP 3

3. Touch base to provide clarification and address questions. (WEDNESDAY)

Touch base midweek with students to make sure they are on track while working independently. You may choose to administer a midweek minute-quiz to give students a concrete reason not to postpone completing the reading until the last minute. Ask questions such as these, and have students jot answers on a half sheet of paper:

Suggested prompts	Sample student responses
What happens to the water in Lake Mead during a heat wave?	*The water level drops by billions of gallons because of an increase in evaporation.*
What property of water enables insects to walk on the top of the water?	*surface tension or cohesion*
How is the design of a dew collector like a spider web?	*The dew collectors are made of a fine mesh of threads, like a spider web.*
Where on Earth does water "take up residence"?	*in the air, in plants, in rivers and lakes, in the soil, in ice caps, the ocean, and underground*
What is a drought?	*It's a period of low precipitation, leading to a water shortage.*

Ask a few brief discussion questions related to the reading that will help students tie the text content to students' classroom investigations.

Suggested prompts	Sample student responses
The readings focus on the water in air. What else did you learn in Lesson 6 about the composition of air?	*that air is a mixture of gaseous and solid substances* *that water vapor makes up only a small part of the air mixture*
What happens to water at the molecular scale as it evaporates from Lake Mead?	*As sunlight heats the surface of the water, water molecules move faster and change from a liquid in the lake to a gas in the air above the lake.*
Recall that, in Lesson 8, you blew on water drops and saw them merge with other drops. Based on your reading, why does this happen?	*It happens because water molecules are sticky, or strongly attracted to one another. The term for this property is* cohesion.

- Refer students to the Exercise Page 3. Provide more specific guidance about expectations for students' deliverables due at the end of the week.
    - *The writing expectation for this assignment is to complete a cause-and-effect graphic organizer that summarizes a key idea from each of the reading selections.*
    - *For some readings, the cause statements are missing, and for others, the effect statements are missing.*
    - *Don't worry about using all the terms in the boxes—not all of them are needed.*
    - *Often there is more than one effect for a cause, so feel free to write about more than one effect.*
    - *The important criteria for your work are that you show you can distinguish between causes and effects and state the relationships accurately.*
- Answer any questions students may have relative to the reading content or the exercise expectations.

Exercise Page

EP 3

4. Facilitate discussion.

(FRIDAY)

Facilitate class discussion about the reading collection and writing exercise. Students begin by reading about factors affecting the evaporation rate of water—whether the water is in a huge reservoir or in a damp towel.

Student Reader

Collection 3

Pages 24–25 Suggested prompt	Sample student response
What is the general purpose of the first selection, "Lake Mead"?	*It explains why so much of the water held in this reservoir is lost to evaporation.*

Pages 25–31 Suggested prompts	Sample student responses
What is your strategy for reading an article with a graph? Do you read the text first or the graph first? Explain.	*I like to read the text first because it should summarize the main idea of the graph.*
	I like to read the graph first so I can make my own predictions about the main ideas.
The article says that desert air has low humidity. In what kinds of environments would the air have high humidity?	*the ocean, a rainforest, a temperate forest, a wetland*
What did you learn in Lesson 7 about how to increase the humidity of air?	*that adding energy and warming the air will allow the humidity to increase*
What is the general purpose of the second selection, "Sticky Water"?	*It describes two properties of water—cohesion and adhesion—and explains why water tends to form bead shapes and cling to other substances.*
Look at the Connection box on page 27. How can you explain rain in terms of stickiness?	*When cloud water droplets touch, the stickiness of the water makes the droplets connect and form larger drops. Eventually, the drops get so big and heavy that gravity causes them to fall as rain.*
How did you model the stickiness of water in Lesson 8?	*We used magnetic marbles to represent water molecules.*
What is the general purpose of the third article, "Science Fiction, Science Fact"?	*It summarizes a 1965 science fiction novel and compares parts of the story to a new technology for collecting water from air.*
How do the designs of the dew collectors in the two photos differ?	*The one with the single collector is round, while the other photo shows rectangular collectors.*
	The single collector is larger than those that are in a group.
	In the large collector, water is collected in a clear container, while the smaller dew catchers let the liquid water run into the ground to water plants.
How does what you learned about the stickiness of water in the second selection contribute to making the dew collectors work?	*Adhesion makes the water drops stick to the mesh structure, and cohesion keeps the drops together as they flow down the structure to the collector or ground.*
What is the general purpose of the fourth article, "A Minute to a Million Years"?	*It compares the estimated amount of time water is stored in different places on Earth, such as in the atmosphere, in the ocean, and underground.*

SUPPORT—If you are using the recommended word envelope convention, check the envelope to see if it contains any words, phrases, or sentences that students need help understanding. Read key sentences aloud, and provide concise explanation.

Online Resources

SUPPORT—Point out to students that the line in the graph represents estimated mean (averaged) measurements from two years. Explain that the estimates are based on recently collected data and likely account for expected changes in air temperatures.

EXTEND—Have students watch a video explaining how water striders take advantage of surface tension to move across the surface of a pond. Analyze the slow-motion demonstration showing what happens when some milk is dropped into a container of water.

Pages 31–33 **Suggested prompts**	**Sample student responses**
What do you think the graph category called "Biospheric water" means?	*water that is stored inside living things, such as plants and animals*
What data in the graph surprised you?	*I was surprised that water stays underground twice as long as it stays in the ocean.* *I was surprised that water in glaciers, which is solid ice, does not stay there as long as liquid water in the ocean.*
What is the general purpose of the fifth article, "Heat and Drought"?	*It explains that the hotter the weather or climate gets, the more droughts there will be.*
How can you use what you learned in our class discussions about kinetic energy to explain "more warmth often means more evaporation"?	*When water molecules are heated, they gain kinetic energy. This means they move faster. When they move faster, they change from liquid to a gas (evaporate) faster.*
Based on this article, would you classify the relationship between heat and drought as causal or correlational? Why?	*causal, because the article says that the warmer it is, the more water evaporates from Earth's surface* *correlational, because more warmth can contribute to drought but might not* *correlational, because if you compare the maps, places like Maine were warmer in June 2021, but there was no drought forecast for that month*
What part of the article did you need to concentrate on to complete the cause-and-effect statement in the writing exercise?	*the last paragraph about farmland and California's Central Valley*

SUPPORT—Make sure English learners understand the meaning of the term *residence time*. Use a dictionary to find the four meanings of the noun *residence* and have students identify the one that best fits the context of this article ("a duration of abode in a place").

5. Check for understanding.

Evaluate and Provide Feedback

For Exercise 3, students should complete a partially filled-in cause-and-effect graphic organizer that addresses key concepts presented in each of the five reading selections in Collection 3. Look for evidence that they were able to use some of the highlighted terms from the readings appropriately, that they followed the style by writing in complete sentences, and that they were able to distinguish causes from effects.

A sample completed student sheet is shown below.

Cause	Effect
There has been a high rate of evaporation at Lake Mead.	Billions of gallons of water have been lost from the reservoir during the drought.
There is a force between water molecules.	Water molecules form round drops and create surface tension on the tops of bodies of water.
The desert air cools and makes structures in the desert cool, too.	Water vapor condenses on a mesh and can be collected to water plants.
At one time, the ocean level was much higher than it is today.	A whale skeleton is found in a dry desert.
The weather is hotter in a farming region.	There is more evaporation from the soil, and plants dry out.

LESSON 9

Why don't we see clouds everywhere in the air, and what is a cloud made of?

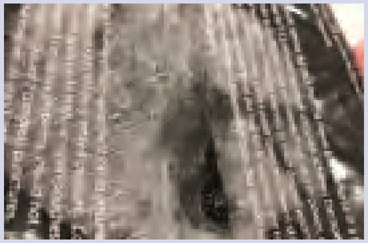
Previous Lesson

We carried out investigations to explore what happens when air containing water vapor is cooled and when water droplets make contact with each other. We used magnetic marbles to develop a model for how mutual attraction between water molecules and changes in their speed cause water to change from gas to liquid when it cools below a certain temperature.

This Lesson

Investigation

1 DAY



We read about what clouds are made of, why we can see them, the role of cloud condensation nuclei, and methods of cloud seeding. We argue that what happens in clouds is similar to what we see happen on the surface of a cold gel pack over humid air in our 2-L bottles.

Next Lesson

We will develop and use our Gotta-Have-It Checklist to test and revise a thunderstorm simulation. We will use these tools to think about how temperature, humidity, and other conditions produce larger and smaller storms.

Building Toward NGSS

MS-PS1-4, MS-ESS2-4, MS-ESS2-5, MS-ESS2-6

What Students Will Do

Obtain and communicate information by reading scientific texts adapted for classroom use to determine key ideas and cause-and-effect relationships related to what clouds are made of, why we can see them, the role of cloud condensation nuclei, and methods of cloud seeding.

Apply scientific ideas and principles to **construct an explanation** and represent interactions between energy and matter that lead to the condensation and crystallization of water in the atmosphere and the formation of clouds.

What Students Will Figure Out

- Clouds are made of water droplets or water crystals (ice) and molecules of gas (including water vapor).
- We see clouds because the water droplets or crystals in them reflect and scatter or absorb a noticeable amount of light.

- For molecules of water vapor in the air to start the condensation or deposition process, the air has to reach 100% humidity and then be cooled. The water vapor also needs a solid surface to stick to. In the air, this surface is cloud condensation nuclei (small, solid particles).

Lesson 9 • Learning Plan Snapshot

Part	Duration	Summary	Slide	Materials
1	5 min	**NAVIGATION** Share ideas about why we don't see clouds everywhere in the air and what a cloud is made of.	A	chart paper, markers, Driving Question Board, initial consensus model
2	25 min	**USE CLOSE READING STRATEGIES TO LEAD INTO THE FROST DEMONSTRATION** Use close reading strategies to gather information and make observations of the side and top of a 2-L bottle held over a small container of water.	B-H	highlighters, tape, *Reading: What Are Clouds?*, chart paper, markers, 6-quart tub, 2-L soda bottle with bottom cut off and part of the top cut off, hot water in small container or cup, paper towels, cold gel pack
3	12 min	**EXPLAIN THE RELATED PHENOMENON OF FROST FORMATION** Make observations of the gel pack and construct an explanation of this phenomenon.	I	*Explaining a Related Phenomenon*, related Frost Demonstration setup
4	3 min	**EXPLAIN THE HOME-LEARNING OPPORTUNITY** Distribute *Reading: Can Other Gases in the Air Turn into Liquids or Solids?* and explain the home-learning close reading assignment.	J	*Reading: Can Other Gases in the Air Turn into Liquids or Solids?*

End of day 1

Lesson 9 • Materials List

	per student	per group	per class
Lesson materials **Student Procedure Guide** **Student Work Pages**	• science notebook • highlighters • tape • *Reading: What Are Clouds?* • *Explaining a Related Phenomenon* • *Reading: Can Other Gases in the Air Turn into Liquids or Solids?*		• chart paper • markers • Driving Question Board • initial consensus model • 6-quart tub • 2-L soda bottle with bottom cut off and part of the top cut off

	per student	per group	per class
			• hot water in small container or cup • paper towels • cold gel pack • related Frost Demonstration setup

Materials preparation (15 minutes)

Online Resources

Review teacher guide, slides, and teacher references or keys (if applicable).

Make copies of handouts and ensure sufficient copies of student references, readings, and procedures are available.

Frost Demonstration

- **Advance preparation:**
  - Watch the investigation setup video to preview the materials and procedures used in this investigation. (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)
  - Put all the gel packs in the freezer the day before the lesson, each inside its own ziplock freezer bag.
- **Setup:**
  - Have hot (100°F –120°F) water ready to pour into a small container or cup. If your school has a hot water tap, this is sufficient. If not, you can use an electric kettle to heat the water.
  - For the class demonstration, put these materials in a 6-qt tub to carry easily to and from your demonstration area:
    - 2-L soda bottle with bottom cut off and part of the top cut off
    - small container or cup for holding hot water
    - paper towels
  - Take a cold gel pack out of the freezer when you are ready to do the demonstration for each class and add it to the tub. Plan to return it to the freezer right after the demonstration, since they take awhile to get cold enough (–8°F) for ice crystals to form on them rather than water droplets.
- **Safety:** You work with hot water in this demonstration. Although students do not directly handle the hot water, they stand (or sit) close enough to the demonstration to observe both the setup and the results. Therefore, you must exercise caution. You only need enough hot water to fill the small container, and you do not need to heat the water to a temperature greater than about 120°F.

Lesson 9 • Where We Are Going and NOT Going

Where We Are Going

In Lesson 8, students investigate how thermal energy affects water and how those changes lead to the formation of clouds. This lesson builds on and extends the ideas developed in that lesson. Students use close reading strategies to obtain key ideas from scientific text to answer the question, "Why don't we see clouds everywhere in the air, and what is a cloud made of?" Key ideas include these:

- Clouds are made of gases and water droplets or ice crystals suspended in those gases.
- The water droplets and ice crystals reflect light, which allows us to see clouds.
- For clouds to form, the air has to be at 100% relative humidity and cooled down enough for water vapor to change state from a gas to a liquid (water) or solid (ice).
- Water vapor also needs a solid surface to stick to in order to form droplets or ice crystals. In the air, there are very small particles, such as dust, ash, pollen, and pollutants, that provide this solid surface for droplet or crystal formation. Scientists call these particles cloud condensation nuclei (CCN).
- Cloud seeding is a process in which CCN are added to the air to increase cloud formation and precipitation.

Students apply these ideas to explain the formation of frost on a cold gel pack in contact with warm, humid air.

Where We Are NOT Going

What students have figured out to this point in the unit lays the foundation for the concepts developed in Lessons 10-12, which includes understanding how convection currents develop in the atmosphere and explaining their role in creating different types of precipitation, including hailstones.

LEARNING PLAN FOR LESSON 9

1. Navigation

5 MIN

Materials: science notebook, chart paper, markers, Driving Question Board, initial consensus model

Share ideas about clouds. Tell students, *We have figured out a lot about how water gets into the air and what happens to water vapor in the air when it cools. But if we look back at our Driving Question Board, we can see that we have been wondering about what is going on in a cloud since we first saw the videos of hailstorms. So, let's try to generate some initial explanations about clouds by sharing some of the ideas you and your partner discussed last time.*

Show **slide A**. Tell students, *Take a few moments to look back at the ideas you wrote down in your science notebook at the end of the last lesson, then look at the questions on the slide. Be prepared to share your thinking with the class.*

Give students a few moments to look back at their ideas, then solicit answers to the slide's questions from those who would like to share. Accept all answers, and foreground any areas of uncertainty that emerge, since this will help further motivate the lesson question we need to investigate.

Suggested prompts	Sample student responses
Why don't we see clouds everywhere in the air, all the time? For example, why are there clouds at B and C, but not at A?	*Maybe clouds can only be in certain places.* *Maybe it has to do with the temperature or humidity levels at that point in the air.*
What are clouds made of?	*Air? Water? Not sure.*
How could what we figured out in the last lesson be used to figure out answers to these questions?	*Condensation or droplets could be related to what happens in clouds. Maybe it is related to when it rains.*

Introduce the lesson question. Write the lesson question on chart paper for students to refer to: "Why don't we see clouds everywhere in the air, and what is a cloud made of?" Say, *The answers to our questions about clouds seem important for revising our consensus model explaining why hail and other forms of precipitation fall when they do. Let's keep these questions at the forefront of our thinking as we figure things out today.*

2. Use close reading strategies to lead into the frost demonstration. 25 MIN

Materials: science notebook, highlighters, tape, *Reading: What Are Clouds?*, chart paper, markers, 6-quart tub, 2-L soda bottle with bottom cut off and part of the top cut off, hot water in small container or cup, paper towels, cold gel pack

Introduce the reading and review the close reading strategies. Tell students, *I have a short reading that might provide some of the answers we are looking for.* Distribute the reading *Reading: What Are Clouds?* to each student. (Note: There is an additional copy in the student edition for reference.)

Show **slide B** and remind students about close reading strategies by saying, *We have used close reading strategies before to help us approach scientific text in a strategic way. Remember, close reading requires us to read more than once with different purposes and strategies for interacting with the text. Take a minute to review the process outlined on the slide.* Give students a minute to skim the steps to use in this close reading.

Show **slide C**. Ask, *What is the main question we are trying to answer using this reading?* Since it was written on chart paper at the beginning of the lesson, students should be able to quickly respond.

Suggested prompt	Sample student response
What is the main question we are trying to answer using this reading?	*Why don't we see clouds everywhere in the air, and what is a cloud made of?*

Say, *Writing the main question at the top of the reading is a key strategy, because it reminds us of our purpose and the type of information we are looking for. So, take a moment to write the question at the top of your handout.*

Show **slide D**, then give students 3-5 minutes to read the text on their own. Next, project **slide E**. Give students an additional 3-5 minutes to highlight key ideas on their own. Remind them to be selective about what they highlight, keeping the main question in mind so they look for information that helps answer that question.

Orient to the *Frost Demonstration*. Show **slide F**, and say, *We'll go back to the reading in just a moment, but I want to pause, so we can set up a demonstration to produce a phenomenon that you will need to explain using ideas from the reading. The demonstration will take a few minutes to produce this interesting outcome, so let's set it up now, return to the reading to summarize the key ideas, then check the setup in a few minutes.*

Set up the demonstration. Have students come up and gather around the demonstration to observe the setup as you talk through it for the next 3–4 minutes.

Say, *The phenomenon we are going to observe is related to what you read about frost forming outside in some places on some mornings. Who has seen frost before?* Take a quick poll (show of hands), then explain the setup as you build it:

- Fill a small container or cup with hot (100°F–120°F) water.
- Show the 2-L bottle that will cover the setup, pointing out that both the top and bottom of the bottle are cut open. Place this cover over the container or cup of hot water.
- Remove the cold gel pack from the ziplock bag.
- Wipe down the gel pack with a paper towel and show students that the gel pack doesn't appear to have any water on its surface.
- Remind students that the gel pack is a closed system. This means no matter can get in or out of it.
- Also mention the freezing point of water is 32°F, while the temperature of the gel in the pack is about -8°F. Write this information under the lesson question on the chart paper. (You can measure the gel pack's temperature by placing a thermometer on its top surface, if you wish.)
- Place the gel pack over the top of the 2-L bottle. A photograph of this setup is shown above.

Animate the text box on the slide and say, *When we finish our reading, we will come back to the setup and lift up the gel pack. Do you think we will see anything on the surface of the gel pack that is facing the water? If so, what? Turn and talk with a partner to share your prediction.*

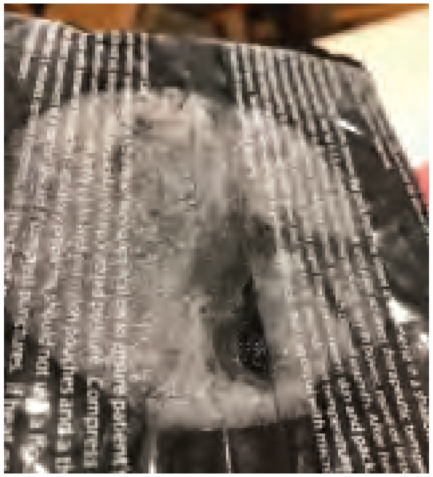
Give partners a few moments to share their predictions, but do not solicit any responses at this time. Instead, ask them to hold their predictions and return to their seats.

Set up science notebooks. After students return to their seats, show **slide G** and say, *Let's quickly set up our science notebooks so we can work with a partner to summarize the reading. Turn to a new page in your notebook, and follow the directions on the slide.* Give students a minute or two to do this.

Summarize the reading's key ideas. Show **slide H** and say, *Now let's return to our reading. Work with a partner to summarize the key ideas from the reading that answer the main question. Write the summary in your own words in your science notebook. Remember, some of these key ideas may be helpful for predicting and explaining what will happen with the system we just set up. You can also jot down any new questions that this reading raises for you. When you finish, tape the reading into your science notebook.* Give students 5–7 minutes to complete this.

3. Explain the related phenomenon of frost formation.

12 MIN



Materials: science notebook, *Explaining a Related Phenomenon*, related Frost Demonstration setup

Revisit the demonstration setup and predictions. As students finish summarizing the key ideas, have them gather around the demonstration setup again. Say, *In the last lesson, we saw droplets form at the top of the 2-L bottle. Today, we read about what is needed for water droplets and ice crystals to form in the clouds. We also read how water vapor can condense out of the air and deposit on surfaces other than cloud condensation nuclei (CCN) when the temperature drops. After we set up this demonstration, I asked you to make a prediction: I asked, "Do you think we will see anything on the surface of the gel pack that is facing the water? And, if so, what?"*

Have a few students share their predictions, then lift up the gel pack and flip it over to show its underside. Ask, *What do you think is on the surface of the gel pack that was facing the water?* Solicit responses from students.

Suggested prompt	Sample student responses
What do you think is on the surface of the gel pack that was facing the water?	*It could be ice.* *Maybe it's ice crystals.* *It looks like frost or snow.*

Say, *Let's put this gel pack back on the bottle and let it sit for another five minutes. What do you think we might see then? Quickly share your ideas with someone next to you.*

Give students a moment to turn and talk, then say, *Before we check the gel pack again, it seems that we can already explain some things about this phenomenon using the ideas we have developed over the last few lessons and what we figured out from our reading today. So, let's head back to our seats.*

Construct an explanation for frost formation. Show **slide I**. Tell students, *Your task is to construct an explanation of the phenomenon you just observed by individually answering the questions on the slide. These questions are also on a handout that I will give you. This is an individual assessment that will allow me to see how well you can apply what we have figured out over the last few lessons. You may use your science notebook to help you, and I will collect this handout before the end of the class period.*

Distribute a copy of the handout *Explaining a Related Phenomenon* to each student, and give students a few minutes to complete it at their seats. Collect these before the end of the period.

Assessment Opportunity

This assessment opportunity gives you a chance to formatively assess students' understanding of the interactions occurring between energy and matter that lead to the formation of clouds. Though the explanation that students are writing in response to each prompt is relatively brief and doesn't focus on citing sources of evidence from previous experiments, it does require them to draw on the scientific principles and models that they constructed from those experiments as well as some of the new ideas introduced in the reading.

Although detailed information is given in the assessment guidance section for this lesson, it is important at this point to remember the following:

- Students need opportunities at strategic points throughout a unit to describe and/or apply what they have figured out.
- Students should be encouraged to use drawings as well as words to explain their thinking.
- Feedback on students' work should be both constructive and meaningful—it should provide guidance to students that can help them increase their scientific understanding and it should be specific to each student's needs.
- Feedback should be timely—within a day or two of the assessment—to give students a chance to make use of teacher feedback to improve.
- Formative assessments should not be graded. Grades are often subjective and do not give students meaningful, constructive feedback on their work.

4. Explain the home-learning opportunity.

3 MIN

Materials: *Reading: Can Other Gases in the Air Turn into Liquids or Solids?*

Introduce the home-learning assignment. If time permits, distribute a copy of the handout *Reading: Can Other Gases in the Air Turn into Liquids or Solids?* to each student. (Note: The student edition contains an additional copy of the reading for reference.) Show **slide J** and introduce the assignment by saying, *I want to give you an opportunity to use the close reading strategies on your own, outside of class. Take a look at the handout Reading: Can Other Gases in the Air Turn into Liquids or Solids?. The question you are trying to answer with this reading is, "Why is water the only gas in the air outside that we see change into a liquid or solid?" Take a moment to circle that question on your handout, then turn to a partner and review the close reading strategies. If you need help, the strategies are on the slide.*

Give partners a minute to review the close reading strategies. If necessary, quickly read the strategies aloud one last time before the end of the class period. Collect the handout *Explaining a Related Phenomenon* before students leave.

Alternate Activity

Since the ideas in this second reading aren't essential to explaining storms and hail, you could save it for a different home-learning assignment or for part of a class assignment when you need a substitute teacher to cover your classes.

ADDITIONAL LESSON 9 TEACHER GUIDANCE

Supporting Students in Making Connections in ELA

CCSS.ELA-LITERACY.RST.6-8.2: Determine the central ideas or conclusions of a text; provide an accurate summary of the text distinct from prior knowledge or opinions.

Reading: What Are Clouds? and the close reading protocol provide support for students to identify and summarize key ideas that answer the question, *Why don't we see clouds everywhere in the air, and what is a cloud made of?*

LESSON 10

Why do clouds or storms form at some times but not others?

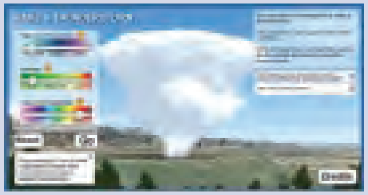
Previous Lesson

We read about what clouds are made of, why we can see them, the role of cloud condensation nuclei, and methods of cloud seeding. We argued that what happens in clouds is similar to what we saw happen on the surface of a cold gel pack over humid air in our 2-L bottles.

This Lesson

Investigation

2 DAYS



University Corporation for Atmospheric Research (UCAR)

We develop and use our Gotta-Have-It Checklist to test and revise a thunderstorm simulation to produce larger and smaller storms. We focus on temperature and humidity conditions that are likely to produce storms. We think about what additional features we would like to include in the simulation, and we design interfaces for those features.

Next Lesson

We will try to lift or suspend different objects with air blown upward. We will develop a model to show how an object might be lifted, fall, or remain suspended in the air depending on the relative strength of two different forces acting on it. We will record the air pressure, using a homemade barometer, and the cloud cover and precipitation outside.

Building Toward NGSS

MS-PS1-4, MS-ESS2-4, MS-ESS2-5, MS-ESS2-6

What Students Will Do

Modify a model—based on evidence—to build a storm system by changing the input variables, such as temperature and humidity, and measuring changes in the output, the size of storm formation.

Evaluate the limitations of the thunderstorm simulation, identifying which aspects of the system are represented in the model and which additional aspects could be added to account for thunderstorm development.

Construct an explanation that includes correlational relationships between temperature and humidity that can be used to predict storm development.

What Students Will Figure Out

- A greater difference between near-ground and atmospheric temperatures is correlated with larger storm development.
- Higher humidity is correlated with stronger storms.
- Simulations are models that can represent only parts of a system, which limits their use.

Lesson 10 • Learning Plan Snapshot

Part	Duration	Summary	Slide	Materials
1	8 min	**NAVIGATION** Review the phenomenon and the question we are trying to answer about it.	A-B	highlighters or colored pencils, chart paper, markers
2	15 min	**CREATE THE GOTTA-HAVE-IT CHECKLIST** Work in partners to review artifacts from Lessons 1-9 and decide what ideas should be included in a new model to answer the lesson question.	C	*Gotta-Have-It Checklist*, tape
3	20 min	**TRY IT OUT: MAKE A THUNDERSTORM** Work in partners and use the *Gotta-Have-It Checklist* to manipulate conditions in a simulation to form a storm. Use this experience to consider revisions to the checklist.	D	*Gotta-Have-It Checklist*, *Data Table for Making a Thunderstorm*, computer, Make a Thunderstorm Simulation (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)
4	2 min	**NAVIGATION** Summarize briefly why we are working with the simulation.	E	
				End of day 1
5	2 min	**NAVIGATION** Consider the question we are trying to answer and where we left off.	F	
6	5 min	**REVISIT THE CHECKLIST** Discuss the simulation's limitations and the ideas from the checklist that were not represented in the simulation.	G	*Gotta-Have-It Checklist*, *Data Table for Making a Thunderstorm*
7	12 min	**REVISE THE SIMULATION** Chunk the checklist's ideas into natural categories and then revise portions of the simulation.	H	*Gotta-Have-It Checklist*, *Blank Simulation to Revise Make a Thunderstorm*, highlighters or colored pencils, markers, tape
8	7 min	**COMPARE REVISIONS IN A GALLERY WALK** View students' revisions to the simulation and think about how representations help us to better understand (or not) the lesson question.	I	
9	10 min	**CONSENSUS DISCUSSION** Build consensus about how certain ideas in the checklist could be modeled in the simulation and why they are important to include.	J	*Gotta-Have-It Checklist*, *Blank Simulation to Revise Make a Thunderstorm*, whiteboard or chart paper, markers

Part	Duration	Summary	Slide	Materials
10	7 min	**CONSTRUCT AN EXPLANATION** Revisit some of the questions on the Driving Question Board to develop answers and ask new questions.	K	*Explaining Relationships in Storm Development*
11	2 min	**PROBLEMATIZE HAIL FORMATION** Share ideas about what makes a hailstorm different from a storm that produces only rain or snow.	L	
				End of day 2

Lesson 10 • Materials List

	per student	per group	per class
Lesson materials **Student Procedure Guide** **Student Work Pages**	• science notebook • highlighters or colored pencils • *Gotta-Have-It Checklist* • *Data Table for Making a Thunderstorm* • *Blank Simulation to Revise Make a Thunderstorm* • *Explaining Relationships in Storm Development*	• computer • Make a Thunderstorm Simulation (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**) • highlighters or colored pencils • markers	• chart paper • markers • tape • whiteboard or chart paper

Materials preparation (15 minutes)

Online Resources

Review teacher guide, slides, and teacher references or keys (if applicable).

Make copies of handouts and ensure sufficient copies of student references, readings, and procedures are available.

Ensure there are enough computers for students in teams of two to use the Make a Thunderstorm simulation. (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)

Lesson 10 • Where We Are Going and NOT Going

Where We Are Going

For large storms to form, there must be a source of water along with an input of thermal energy to begin convection. The combination of hotter air temperatures with higher humidity is correlated with stronger storms. As air warms up near the ground, it forms a convection cell. As that warm, moist air climbs in the atmosphere, it cools and condenses. The more thermal energy added, the stronger the convection cycle. Storms are not likely to form with low humidity or low air temperatures near the ground as there is less thermal energy to cause convection and also less water in the system. Students will likely understand that higher humidity is correlated with a stronger storm because more water is available for precipitation. It might be more difficult for them to explain why the greater temperature difference between the air close to the ground and higher in the atmosphere would cause a stronger storm. This idea relates to how much thermal energy is being added to the system to cause convection, which ultimately carries water molecules into the atmosphere to condense and form clouds and storms.

Where We Are NOT Going

This lesson has students consider how certain variables are correlated with stronger or weaker storm development. Temperature and humidity data (inputs) are often used to predict when storms will happen (outputs), and we want students to notice a correlation between these inputs and outputs. We do not focus on the difference between correlation and causation in this lesson, but rather push students to think about what constitutes a correlation between two variables.

LEARNING PLAN FOR LESSON 10

1. Navigation

8 MIN

Materials: science notebook, highlighters or colored pencils, chart paper, markers

Share new ideas from the home learning assignment. As students come into class, ask them to share any new ideas they gained from their reading for home learning about water and how it behaves.

Assess students' current thinking on hailstorm development. Ask, *What have we been up to?* This navigation is to review aspects of the phenomenon and the science ideas to help explain it. Project **slide A**. Have students think for a moment about what we are trying to figure out related to hailstorms. Quickly review the investigations from Lessons 1–9 and take stock of what we figured out through those investigations. Don't spend too long on this, as students will revisit their Progress Trackers later to create a *Gotta-Have-It Checklist*. Sample prompts are below.

Suggested prompts	Sample student responses
What happens when sunlight hits surfaces on Earth?	*Some of the sunlight is absorbed by the ground and some is reflected.*
Do all surfaces act the same?	*Darker surfaces tend to absorb more sunlight than lighter surfaces.*

Suggested prompts	Sample student responses
What happens to the air right above the surface?	*When the ground is heated by the sunlight, it starts to warm the air above it. There is a transfer of energy between the particles in the ground and the air particles right above it through conduction.*
How can we explain the pattern of warmer air near the surface and cooler air higher up?	*Air near the ground warms through conduction, and those air particles begin to move faster and spread out. Pockets of warm air rise because they are less dense, but as they rise, they begin to cool, slow down, and become more dense and sink.*
What is happening with water molecules near the surface?	*As heat is added, water molecules from a water source and/or moist soil also warm up. As more energy is added, some water molecules turn into a gas and become water vapor.*
What happens to those molecules higher in the atmosphere?	*As water vapor rises in the atmosphere, it cools and turns back into liquid. It condenses on dust particles or other things in the air and begins to form clouds.*

Introduce the lesson question. Have students summarize some of the big questions we've been working on in the previous lessons. Then show **slide B** and introduce the new question, "Why do clouds or storms form at some times but not others?"

Students do not need to write this question yet, but tell them to reflect on their initial model from Lesson 1 and what we have been investigating. Have students open their science notebook to the page with their initial model from Lesson 1. Give them a moment to highlight parts of their initial model that they can now explain.

Establish the class mission. Say, *So we know a lot more about what is happening as the ground and air heat up and how water molecules move around in this system. But we are still trying to figure out what causes clouds or storms to form on some days but not others. That's what we are going to focus on today.*

2. Create the Gotta-Have-It Checklist.

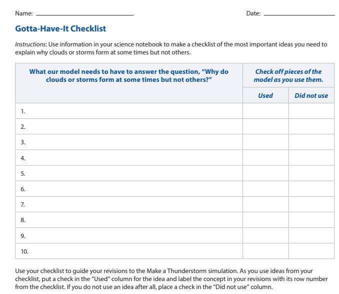
15 MIN

Materials: science notebook, *Gotta-Have-It Checklist*, tape

Preview the checklist's purpose. Tell students they will create a *Gotta-Have-It Checklist* to decide which ideas from their Progress Trackers and investigations are most important for explaining why clouds and storms form on some days but not on others. They will use this checklist with a thunderstorm simulation to manipulate the size of the resulting storm. Direct students to first consult their Progress Trackers. Explain that they have figured out important ideas over the past lessons and that some may be more critical than others for explaining cloud and storm formation.

*** Supporting Students in Engaging in Developing and Using Models**
An alternative to developing the *Gotta-Have-It Checklist* in partners is to construct it as a

Create the checklist. Distribute a copy of *Gotta-Have-It Checklist* to each student. They will tape or glue the handout into their notebook when complete. Use **slide C** to show how to build the checklist. Tell students to complete only the left column right now, leaving the right columns blank.



Name: ______________ Date: ______________

Gotta-Have-It Checklist

Instructions: Use information in your science notebook to make a checklist of the most important ideas you need to explain why clouds or storms form at some times but not others.

What our model needs to have to answer the question, "Why do clouds or storms form at some times but not others?"	*Check off pieces of the model as you use them.*	
	Used	*Did not use*
1.		
2.		
3.		
4.		
5.		
6.		
7.		
8.		
9.		
10.		

Use your checklist to guide your revisions to the Make a Thunderstorm simulation. As you use ideas from your checklist, put a check in the "Used" column for the idea and label the concept in your revisions with its row number from the checklist. If you do not use an idea after all, place a check in the "Did not use" column.

Have students work with a partner to develop their checklist by noting the ideas from their Progress Trackers that may help them explain the lesson question. They do not need to record all the ideas from previous lessons—only the ones they want to include to answer the lesson question. Partners should spend up to 10 minutes working on the checklist.*

Share ideas. Facilitate a brief sharing of ideas from the partner pairs. Do not let this discussion take too long or it will take away from students' time to try out the simulation and revise their checklist. Ask several students to briefly mention an idea they included on the checklist and say why it's important. You can also ask which ideas they did not include and why those are less important. The examples below are not a comprehensive list.

class with a public representation of the agreed-upon ideas for the consensus model. If you make this modification to the current activity, keep in mind the following important components to ensure productivity:

- The process should be collaborative and involve students arguing from evidence for their ideas.
- There should be a public record, or artifact, of the ideas students agree to include in their models.

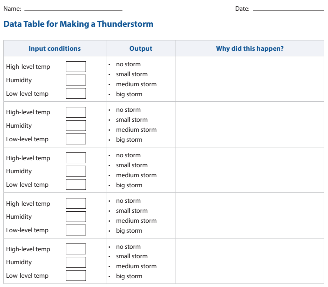
Suggested prompts	Sample student responses
Can someone suggest an idea from a previous lesson that can help explain why clouds or storms form?	*Earth's surface is warmer than the air above it.* *The air near the ground is warmer than air near where clouds form.* *Evaporation of water at the surface is important for clouds or storms.* *Evaporation happens because of heating from sunlight.* *Clouds form when water condenses.* *A source of water is important to get water into the atmosphere for storms.* *Warm air rises and cooler air sinks.* *Warm air holds more water vapor than cool air.*
Can someone suggest an idea we have worked with that will not be helpful for explaining why clouds or storms form?	*Dark surfaces heat up faster than light surfaces because they absorb more sunlight (solar radiation) (Lesson 4).*

3. Try it out: Make a thunderstorm.

Materials: *Gotta-Have-It Checklist*, *Data Table for Making a Thunderstorm*, computer, Make a Thunderstorm Simulation (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)

Set the purpose for using the simulation. Tell students you have a simulation that will let us test our ideas for what causes a storm to form (or not). Show **slide D**. Explain that it is important to test a model to make sure it is useful for figuring out a phenomenon and helpful for making predictions. If we can figure out the best conditions to form clouds or storms, then the model can help us understand why these form at some times and not others.

Introduce the simulation. Present the Make a Thunderstorm simulation at (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**), which allows the user to manipulate the temperature and humidity to see how changing those parts of the model affect storm potential. Emphasize that if one variable in the simulation changes, the outcome changes. Tell students we will need to explain why a strong storm forms and also why weaker storms form based on the changes made to the model. Distribute a copy of *Data Table for Making a Thunderstorm* to each student.


Name: Date:

Data Table for Making a Thunderstorm

Input conditions	Output	Why did this happen?
High-level temp Humidity Low-level temp	• no storm • small storm • medium storm • big storm	
High-level temp Humidity Low-level temp	• no storm • small storm • medium storm • big storm	
High-level temp Humidity Low-level temp	• no storm • small storm • medium storm • big storm	
High-level temp Humidity Low-level temp	• no storm • small storm • medium storm • big storm	
High-level temp Humidity Low-level temp	• no storm • small storm • medium storm • big storm	

Have students work in partners, using the ideas on their *Gotta-Have-It Checklist* to manipulate the simulation conditions to produce different sizes of storms. Encourage students to notice what is happening as the storm is forming, such as how big it gets and what is happening to the clouds, and to record their observations on *Data Table for Making a Thunderstorm*.

Ask follow-up questions. When students have had sufficient time to manipulate the conditions in the simulation, ask which conditions produced stronger or larger storms and which conditions produced smaller storms. Importantly, encourage them to use ideas from their checklist to help explain why a greater temperature difference (between the near-surface air temperatures and those high in the atmosphere) with high levels of humidity would cause the strongest storm.*

Suggested prompts	Sample student responses
Which conditions produced the biggest storms?	*Hot air at the surface and cold air higher in the atmosphere.* *High humidity.*
Is this in line with our checklist?	*Yes, we know we need warmer air temperatures near the surface and higher humidity to form clouds higher up in the air.*
What conditions produced weaker storms or no storms at all?	*Low humidity didn't produce any storms. There has to be medium or high humidity for storms.* *Cold air near the ground didn't produce any storms.*

* Supporting Students in Three-Dimensional Learning

During the simulation activity and the following class discussion, look and listen for student ideas about how they modified the model (changing the inputs for temperature and humidity) to change the size of the storm (the output). Prompt students with specific questions about how changing one input (e.g., warm high-level temperatures, warm low-level temperatures) changed the output.

Assessment Opportunity

Use this activity and discussion as a formative assessment to determine whether students understand how changing the inputs (i.e., temperature and humidity) in a system model (i.e., the Make a Thunderstorm simulation) changed the outputs in the system (i.e., the size of the resulting storm). You can use *Data Table for Making a Thunderstorm* to assess students' understanding of why certain outputs occurred based on the inputs.

4. Navigation

2 MIN

Materials: None

Remind students that we are trying to figure out how hail forms. Project **slide E** and ask, *Did you notice how the storm clouds got really tall in the simulation when we made a big storm? How does that happen? Can we explain how hail forms yet?*

End of day 1

5. Navigation

2 MIN

Materials: None

Revisit the simulation. Show **slide F**. Ask students to think back to what the Make a Thunderstorm simulation was helping them to answer. Explain their new task today is to work with a partner to consider ways to revise the simulation to better represent more ideas from their *Gotta-Have-It Checklist*. Emphasize that they are using the simulation to answer the question, "Why do clouds or storms form at some times but not others?"

6. Revisit the checklist.

5 MIN

Materials: *Gotta-Have-It Checklist*, *Data Table for Making a Thunderstorm*

Revisit the checklist. Show **slide G**. As a class, revisit the *Gotta-Have-It Checklist* with these three questions in mind:

- What does the simulation help us see that we already have in the checklist?
- What does it help us see that we *did not* have in the checklist?
- What is the simulation missing that we wish it had?

As part of this discussion, students should note that the simulation does well to visualize basic patterns in temperature and humidity that cause different levels of storms. The idea about the temperature difference between air near the ground and higher in the atmosphere is a part of the simulation, as well as the humidity level. However, the simulation will likely lead students to notice that their checklist might be lacking ideas about the size of the storm based on these

*** Supporting Students in Developing and Using Systems and System Models**

System models have limitations in that they can only represent certain aspects of a system. This conversation is focused on helping students identify the limitations of the simulation they are working with (which represents conditions, so they might want to add something to this effect. Finally, encourage them to consider how they want to revise or add to the simulation to better represent ideas in their checklist.* This question transitions students to the next activity.

a system) and then identify how the simulation could be changed to represent additional inputs and outputs.

7. Revise the simulation.

12 MIN

Materials: science notebook, *Gotta-Have-It Checklist*, *Blank Simulation to Revise Make a Thunderstorm*, highlighters or colored pencils, markers, tape

Prepare students to modify the simulation. As students have been revising their checklists and discussing what the simulation did well but also what it is missing, there is a natural opportunity to push student thinking about the ideas in the checklist by having them revise the simulation to better represent their thinking.

One way to break up this task is to chunk the *Gotta-Have-It Checklist* into parts and have students work on only a part of the list. For example, students could work in partners on the ideas that

- help explain where the energy came from to impact ground and air temperatures at different altitudes,
- help explain air circulation,
- explain where the water comes from and what happens to it when energy is added or removed, and
- represent what is happening to molecules at different parts of the system.

Show **slide H**. Distribute a copy of *Blank Simulation to Revise Make a Thunderstorm* to each student and tell them to work in partners to creatively revise the simulation to account for more of the ideas on their checklist. Give students the remaining time to work on their revisions by using colored pencils or markers to mark up the blank version of the simulation.

Alternate Activity

If you have access to devices that allow your students to mark up the simulation digitally, this is an alternative to using the handout.

As students work, walk around the room to see where they struggle to represent their ideas and also where they develop creative solutions. Consider using the following prompts to challenge their thinking:

Prompts for eliciting student ideas about the simulation

- *How can we represent the molecules of water as energy is added? Where does that go in the simulation?*
- *How can we show a temperature change between air near the ground and higher in the atmosphere?*
- *How can we represent where the energy is coming from to heat the ground?*

Prompts for proposing modifications or coming to consensus with conflicting ideas

- *How are these representations similar? How are they different?*

- *How could we modify what we have so we account for the ideas in our checklist?*
- *Is there something we need to clarify before we decide to change the simulation? What is that?*

These are examples of student work on revising the simulation:

Once students have completed their revisions to the simulation, have them post their revision in a public place for a gallery walk.

8. Compare revisions in a gallery walk. 7 MIN

Materials: science notebook

Conduct a gallery walk. Show **slide I**. Have students view everyone's work during a gallery walk. Tell them to observe how others represented the same ideas but in different ways, and to consider how different ways of representing ideas from the *Gotta-Have-It Checklist* help answer the lesson question. Instruct them to write in their notebook what about other students' revisions helped to push their thinking forward or clarify an idea.*

Assessment Opportunity

Use the gallery walk to review and formatively assess students' understanding of the limitations of models and how models can be modified to account for new inputs and outputs.

* Supporting Students in Three-Dimensional Learning

Students' revisions to the simulation can serve as evidence of their understanding of how to (1) account for what the model is (and is not) representing in a system (CCC), (2) evaluate the limitations of a model (SEP), and (3) use their knowledge of the DCIs (e.g., how temperature and humidity are related to air movements and storm development) to create a more sophisticated simulation.

9. Consensus Discussion 10 MIN

Materials: science notebook, *Gotta-Have-It Checklist*, *Blank Simulation to Revise Make a Thunderstorm*, whiteboard or chart paper, markers

Facilitate a Consensus Discussion.* After the gallery walk, students will have new and/or revised ideas about their *Gotta-Have-It Checklist* and their proposed revisions for the Make a Thunderstorm simulation. Tell them we will now revisit the checklist as a class and consider together what the simulation does well, where it could be improved, and why it is important to do so.

Remind students of the classroom norms. Emphasize the importance of having a safe space where we can share our ideas and push each other's thinking.

Display **slide J**. To begin the discussion, give the different groups time to offer proposals for what should go in the simulation based on what they saw in the gallery walk, and to support or challenge each proposal based on whether it would improve the simulation or be distracting. During the discussion, ask students how to represent their ideas visually, drawing upon the gallery walk.

Construct a class model. On the whiteboard or poster paper, create a public representation of agreed-upon ideas as the class puts them together. Scaffold this discussion with these three prompts:

- *What does the simulation do well to answer this question?*
- *How would we revise the simulation?*
- *Why would these revisions be important to do?*

If time allows, as students offer suggestions for each prompt, ask them to draw their thinking on the whiteboard or paper. Ask other students: *Can we agree on this idea? Does it help us answer our question? Is there a way to clarify the idea?*

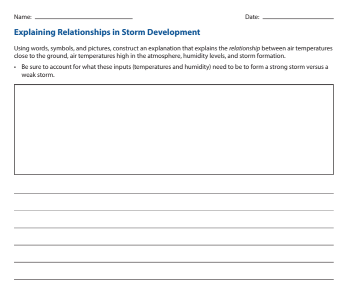
Emphasize that no model or simulation of a system (in this case, storm formation) can represent everything well and that certain features and representations might be more appealing to some users and less appealing to others. The important thing is that the simulation does not include incorrect science ideas.

*** Strategies for This Consensus Discussion**
The purpose of this Consensus Discussion is to build and reinforce a common, class-level model to explain what conditions are necessary for clouds and storms to form. These ideas come from Lessons 1–9. The teacher's role is to prompt students to share what needs to be in the simulation, what evidence they have to support their ideas, and how to represent them. The students' role is to offer ideas to include in the simulation, describe how to represent them, support or challenge proposed ideas from peers, and come to consensus about what should be included (without it becoming too complicated or distracting).

10. Construct an explanation. 7 MIN

Materials: *Explaining Relationships in Storm Development*

Have students construct an explanation. Display **slide K**. For the rest of the class period, have students construct an explanation to explain the relationship between the inputs in the simulation (i.e., temperature, humidity) and the output (storm formation), and why these inputs can only be used to predict when a storm might occur.*


Name: ________ Date: ________

Explaining Relationships in Storm Development

Using words, symbols, and pictures, construct an explanation that explains the *relationship* between air temperatures close to the ground, air temperatures high in the atmosphere, humidity levels, and storm formation.

- Be sure to account for what these inputs (temperatures and humidity) need to be to form a strong storm versus a weak storm.

*** Supporting Students in Developing and Using Cause and Effect**
One of the lesson-level performance expectations for this lesson focuses on students' identifying correlation among variables. While the element for Cause and Effect also asks students to distinguish between correlation and causation, this distinction is not included in this lesson. Instead, the focus of the explanation is to have students think about how the

11. Problematize hail formation.

2 MIN

Materials: science notebook

Problematize hail formation. At this point, students have figured out general conditions for storm formation, but they have not figured out how hail forms. Project **slide L** and ask these questions:

- *Did you notice how the storm clouds got really tall in the simulation when we made a big storm? How does that happen?*
- *Can we explain how hail forms yet?*

Give students a moment to think, and then ask one or two students to share their thinking with the class. There will likely still be some wondering about these questions. Tell students this is where we are going next in the unit.

factors are related to one another (correlation) without identifying that one causes the other to occur. For example, a large difference between air temperatures near the ground and higher up is associated with stronger storm development, but that alone does not cause a storm to occur. It is important at this point for students to identify variables correlated with storm development so they can construct a more complete causal mechanism later in the unit.

ADDITIONAL LESSON 10 TEACHER GUIDANCE

Supporting Students in Making Connections in ELA

In this unit, students frequently engage in speaking, listening, and responding to others as part of their participation in scientific and engineering practices. In this instance, students engage in peer-to-peer discussion to share, express, and refine their thinking. As they do this, they must develop, present, and defend their ideas verbally in a focused, coherent manner with relevant evidence; sound, valid reasoning; and well-chosen details (CCSS.ELA-Literacy.SL.6.1). Using the Communicating in Scientific Ways sentence starters can facilitate the discussion.

As students construct their explanations in this lesson, they are also working toward: CCSS.ELA-LITERACY.W.6.2. Write informative/explanatory texts to examine a topic and convey ideas, concepts, and information through the selection, organization, and analysis of relevant content.

CCSS.ELA-LITERACY.W.6.2.A. Introduce a topic; organize ideas, concepts, and information, using strategies such as definition, classification, comparison/contrast, and cause/effect; include formatting (e.g., headings), graphics (e.g., charts, tables), and multimedia when useful to aiding comprehension.

CCSS.ELA-LITERACY.W.6.2.B. Develop the topic with relevant facts, definitions, concrete details, quotations, or other information and examples.

CCSS.ELA-LITERACY.W.6.2.C. Use appropriate transitions to clarify the relationships among ideas and concepts.

CCSS.ELA-LITERACY.W.6.2.D. Use precise language and domain-specific vocabulary to inform about or explain the topic.

LESSON 11

Why don’t water droplets or ice crystals fall from the clouds all the time?

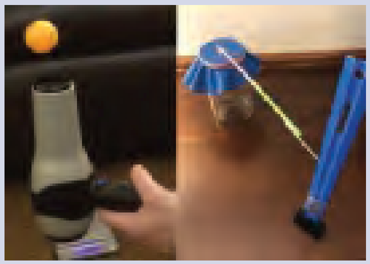
Previous Lesson

We developed and used our Gotta-Have-It Checklist to test and revise a thunderstorm simulation. We used these tools to think about how temperature, humidity, and other conditions produce larger and smaller storms.

This Lesson

Investigation

2 DAYS



We try to lift or suspend different objects with air blown upward, and we record the weight of different objects and the amount of force registered when air is blown toward or away from a digital scale. We develop a model to show how an object might be lifted, fall, or remain suspended in the air depending on the relative strength of two different forces acting on it. We record the air pressure, using a homemade barometer, and the cloud cover and precipitation outside.

Next Lesson

We will plan and carry out an investigation to determine what variables affect the amount of lift produced by transferring thermal energy into a fluid. We will explain how the results of our investigation help us understand how differences between air and ground temperatures can cause different amounts of lift and movement of air.

Building Toward NGSS

MS-PS1-4, MS-ESS2-4, MS-ESS2-5, MS-ESS2-6

What Students Will Do

Use mathematical thinking and construct an explanation to predict patterns in the relationship between the relative strength of two opposing forces on different objects and the resulting change in motion of those objects.

Develop a model to represent balanced and unbalanced forces on an object suspended by an upward current of air, and use the model to predict and explain whether the object would remain suspended (stability) or start moving downward or upward (change) due to the relative strength of the opposing forces.

What Students Will Figure Out

- The more mass something has, the greater the force of gravity pulling down on it (which can be measured as its weight on a scale).

- Moving air (wind) pushes (exerts a force on) matter in its path.
- Air moving upward (updrafts) can keep an object suspended or floating in the air when the force from the molecules in that air colliding with that object counterbalances the downward force from gravity. When those forces are no longer balanced, the object that was suspended in the air will start moving upward or downward.
- A barometer can detect changes in the density of the air outside of it.

Lesson 11 • Learning Plan Snapshot

Part	Duration	Summary	Slide	Materials
1	7 min	**NAVIGATION** Brainstorm ideas about what is holding stuff up in the clouds and examples of when moving air moved something else around or held something aloft.	A, B	20 magnetic marbles
2	7 min	**EXPLORE TISSUE PAPER AND AIR INTERACTIONS** Try to suspend a small piece of tissue paper in the air by blowing at it through a straw.	C	Ping-Pong ball, Straw and Tissue Paper Exploration
3	8 min	**INVESTIGATE WEIGHT** Discuss the relationship between mass and weight. Measure and record the weight of a Ping-Pong ball and pieces of tissue paper.	D	chart paper, marker, Investigation A: Comparing Weights
4	8 min	**INVESTIGATE AIR FORCES** Measure and record the force of air from a straw and a hair dryer on a scale.		Investigation B: Comparing Air Forces
5	8 min	**INVESTIGATE THE BEHAVIOR OF A PING-PONG BALL IN THE AIR FROM A HAIR DRYER** Discuss what the behavior of a Ping-Pong ball when released in the air from a hair dryer tells us about the forces acting on the ball.		Investigation C: Ping-Pong Ball Behavior
6	7 min	**DEVELOP PREDICTIONS AND EXPLANATIONS** Use mathematical thinking to predict how objects of different masses would (or would not) move in response to different lift forces, answer the lesson question, and brainstorm causes for lift forces of different strengths.	E-F	*Predicting and Explaining the Effects of Opposing Forces*

End of day 1

Part	Duration	Summary	Slide	Materials
7	18 min	**UPDATE PROGRESS TRACKER** Develop a model as a class showing two forces at work in the system and use it to explain differences in the movement of a Ping-Pong ball, water droplets, or ice crystals in the air.	G	*Predicting and Explaining the Effects of Opposing Forces*, 3 pieces of chart paper, markers
8	10 min	**BRAINSTORM CAUSES FOR FORCES OF DIFFERENT STRENGTHS** Brainstorm possible factors causing changes in the strength of updrafts and ideas for how to investigate these.	H	20 magnetic marbles, chart paper, markers
9	10 min	**INTRODUCE DEVICES TO MEASURE RISING OR FALLING AIR** Measure changes in forces detected on a digital scale under a stream of upward moving air; discuss how a homemade barometer would respond to changes in the density of the air outside of it.	I-J	chart paper, markers, Investigation D: Detecting Changes in Air Pressure
10	7 min	**PREDICT AND RECORD DATA ON A WEATHER LOG** Make predictions of pressure and cloud and precipitation relationships and record the current conditions on a weather log.	K	*Weather Log*, chart paper, markers, Air Pressure poster and a piece of blank chart paper covering it, tape, Investigation D: Detecting Changes in Air Pressure *End of day 2*
		SCIENCE LITERACY ROUTINE Upon completion of Lesson 11, students are ready to read Student Reader Collection 4 and then respond to the writing exercise.		Student Reader Collection 4: *All About Clouds*

Lesson 11 • Materials List

	per student	per group	per class
Straw and Tissue Paper Exploration materials	• disposable bendy straw • piece of tissue paper		• timer or wall clock
Investigation A: Comparing Weights materials			• Ping-Pong ball • digital scale • plastic cup • scissors • tissue paper • blank pieces of paper or chart paper • marker

	per student	per group	per class
Investigation B: Comparing Air Forces materials			• hair dryer • digital scale • a new straw
Investigation C: Ping-Pong Ball Behavior materials			• hair dryer • Ping-Pong ball • meter stick
Investigation D: Detecting Changes in Air Pressure materials			• box fan • digital scale • homemade barometer
Lesson materials **Student Procedure Guide** **Student Work Pages**	• science notebook • *Predicting and Explaining the Effects of Opposing Forces* • *Weather Log*		• 20 magnetic marbles • Ping-Pong ball • chart paper • marker • 3 pieces of chart paper • markers • Air Pressure poster and a piece of blank chart paper covering it • tape

Materials preparation (45 minutes)

Online Resources

Review teacher guide, slides, and teacher references or keys (if applicable).

Make copies of handouts and ensure sufficient copies of student references, readings, and procedures are available.

Make the Air Pressure poster (next page) on chart paper. Use an orange marker for labeling low-pressure air. Students will similarly use orange-colored pencils for identifying regions of low-pressure air on maps in Lesson 17.

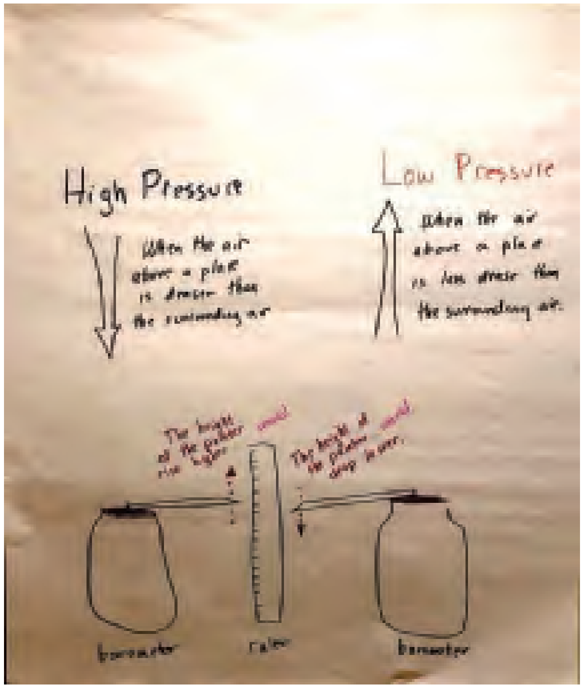
Cover this poster with a piece of blank chart paper. You will remove this toward the end of this lesson and use it to cover up the poster again before your next class.

Day 1: *Straw and Tissue Paper Exploration*

- **Group size:** 1
- **Advance preparation:** Have 1 disposable bendy straw and 1 small piece of tissue paper available per student.
- **Safety:** Make sure students dispose of their straw after using it.

Day 1: ***Investigation A: Comparing Weights***

- **Group size:** Whole class
- **Advance preparation:** Watch the teacher orientation video showing the use of the Ping-Pong ball, hair dryer, and digital scale. (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)
    - Place the following in a materials bin:
        - Ping-Pong ball
        - digital scale (accurate to 0.1 oz)
        - plastic or paper cup
        - scissors
        - 2 pieces of tissue paper per class
        - 1 disposable bendy straw per class



Investigation B: Comparing Air Forces

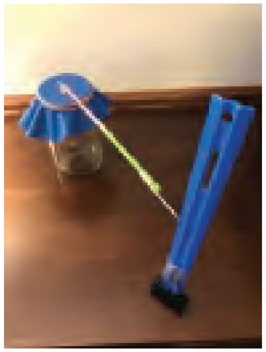
- **Group size:** Whole class
- **Advance preparation:** Set aside a meter stick and a hair dryer to use in the demonstration area.
- **Safety:** Make sure not to block the air intake vent on the hair dryer when you turn it on. Only run the hair dryer with the heat switched off (the heat setting to cool). Dispose of the straw used for this demonstration for each class.
- **Storage:** Except for the straw, all other materials can be stored and reused indefinitely.

Investigation C: Ping-Pong Ball Behavior

- **Group size:** Whole class
- **Advance preparation:** Prepare to reuse the equipment from both *Investigation A* and *Investigation B*.

Investigation D: Detecting Changes in Air Pressure

- **Group size:** Whole class
- **Advance preparation:**
    - Set aside 20 magnetic marbles (from Lesson 8) and a box fan in the demonstration area.
    - Watch the teacher orientation video showing how to use the box fan and build the balloon barometer. (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)
    - Build a balloon barometer.
        - Cut the edges and neck off an unfilled 36" latex balloon.
        - Use one of the two halves of the cut balloon. Wipe off both sides with a wet paper towel and then a dry paper towel to remove remove any dust that would prevent tape from sticking to it or prevent it from making a good seal with the glass jar.



- Stretch this piece of the balloon over the mouth of a large glass jar. Secure it with two rubber bands, doubled up and wrapped around the edge.
- Trim off the bendy ends of two plastic straws or use two non-bendy plastic straws.
- Squeeze and insert the end of one straw into the end of the other and tape them together.
- Tape a toothpick to one end of this extended straw.
- Use a piece of packing tape to secure the other end of the extended straw to the center of the balloon surface that is stretched over the jar.
- Clip a binder clip to the bottom of a plastic ruler. Use tape to further secure the ruler to the metal handles, to prevent it from sliding around in the binder clip.
- The assembled barometer is shown on the previous page.

Lesson 11 • Where We Are Going and NOT Going

Where We Are Going

This lesson introduces new physical science ideas related to the role of opposing forces on changing an object's motion and position. In particular, students consider how opposing forces on water droplets or ice crystals can explain why they don't immediately fall out of clouds when they first start forming and why precipitation occurs when it does. Students develop and use a two-force diagram to represent the gravitational pull downward on an object (whose strength is related to the object's mass) and a lift force upward from updrafts (whose strength is related to the speed that air is moving upward).

Another key physical science idea for students to develop further is that moving air can push on objects. Though students may experience this at a macroscopic level (e.g., wind), you are helping them connect this idea to the idea that molecules in the moving air are actually colliding with and applying a force on the objects they run into.

This lesson introduces students to balanced and unbalanced forces in the context of different objects suspended by an upward current of air. In the case of an object suspended in the air from a hair dryer or a water droplet in a cloud, you are helping students see that these objects have at least two opposing forces acting on them, but they sum to zero net force on the object when it is suspended in the air, which causes it to neither fall nor rise. And in the case of an object that starts falling or rising in a stream of upward-moving air, the forces must not sum to zero, which is an example of when nonzero net forces cause changes in the object's speed or direction of motion.

This lesson introduces the idea of pressure as a measure of force exerted on a surface by the air above it and also links to changes in the density in the air above. It has students make predictions about whether such differences are related to whether the air is rising or falling at a location as well as the level of sunniness or cloudiness (and precipitation) outside. Students will not get confirmation of such a relationship until they collect data on this over subsequent lessons.

Where We Are NOT Going

An example of an object that was not initially moving upward or downward but then starts falling or rising due to net forces on it that do not sum to zero is a special case of how an object's motion can change due to nonzero net forces. This lesson avoids introducing cases in which nonzero net forces cause an already-moving object to slow down, speed up, or change its direction. Those ideas will be explored further in Unit 8.1 *Why do things sometimes get damaged when they hit each other?* (Breaking Stuff Unit). This lesson also avoids introducing cases where opposing forces that yield zero net force causes no change in the movement of an already-moving object by referring to cases in which an object is released in the air and two opposing forces are acting on it, thereby ensuring that we can refer to the object as having no relative motion to start with.

You will reintroduce and build on the idea that matter has mass to develop a new idea: that the more mass an object has, the stronger the force of gravity acting on it. This means it will have a stronger attraction toward Earth, as indicated by its weight on a scale. This is the first introduction of the distinction between mass versus weight in any units. Please do not dwell on this distinction at this time. You are only introducing the idea that a scale can report a measurement of forces (in ounces) or a calculated value of what the mass of the object must be (in grams) if the weight of the object is being measured in a typical classroom setting. Students will develop an understanding of mass and weight in Unit 8.4.

Stick with the idea of air pressure as a way of describing relative changes in the density of air above the barometer. Other ways of thinking about pressure, such as the force applied to a surface from the particles that hit it or the force per unit area, are counterproductive to introduce in this unit and are likely to add barriers to student understanding of the phenomena they are trying to explain.

LEARNING PLAN FOR LESSON 11

1. Navigation

7 MIN

Materials: science notebook, 20 magnetic marbles

Revisit cloud composition. Show **slide A**. Review with students what we now know about the composition of a cloud, emphasizing that what we see when we look at a cloud is light scattering off water droplets or ice crystals made of many millions of water molecules.

Problematize an explained aspect of this phenomenon. In one hand, hold up a bunch of magnetic marbles that are stuck together, and with the other, place additional marbles onto this bunch one at a time while you read the questions on the slide to problematize this aspect of the phenomenon that we haven't explained. Tell students to discuss their ideas with a partner for 2 minutes, and then have students share their ideas with the whole class. Example discussion prompts follow.

Suggested prompt	Sample student responses
Why don't those water droplets or ice crystals start falling to the ground the moment they first start forming?	*It has to get heavy enough to fall.* *Something is holding it up.* *I don't know.*

Suggested prompt	Sample student responses
What keeps this stuff that make up clouds floating in the air above us?	*Maybe they are less dense than the air below them?* *Maybe the air rising from below keeps them aloft?* *Wind?*

Connect cloud suspension to air movement. Say something like, *We have a few ideas about the role that air could play to prevent water droplets or ice crystals from falling out of a cloud. Some of us are saying that maybe the air in or below the cloud is moving it around or keeping it aloft. Let's work with these ideas further. Let's take a moment to recall any experiences you've had when air has moved something around or where you've seen air keeping something floating or suspended in the air.*

Discuss related phenomena. Show **slide B**. Read the first question on the slide. Pick a volunteer to give an example of air moving an object around. After the student shares, tell that student to call on the next student whose hand is raised, and so on to hear a few examples. Students may say things like leaves, trees, clouds, trash cans, boxes, or paper.

After a minute, pause and read the second question on the slide. Again, ask a few students to identify instances when air kept causing something to float or remain suspended above the ground. Students may say things like leaves, bubbles, smoke, dust, hawks, hang gliders, parachuters, balloons, kites, air hockey pucks, or hovercraft.

Introduce the lesson question and investigations. Say something like, *So we have shared a few examples of moving air helping to keep stuff suspended or floating above a surface or in the air. Let's experiment a little bit with using air to suspend stuff in the air so we can figure out how to explain why water droplets and ice crystals sometimes stay up in a cloud but at other times fall out of the clouds to the ground. Before our first exploration, let's make a note of the question we are trying to answer throughout our investigations today.*

Introduce and write the lesson question on the board, "Why don't water droplets or ice crystals fall from the clouds all the time?" Students don't have to write this in their notebooks yet.

2. Explore tissue paper and air interactions.

7 MIN

Materials: Straw and Tissue Paper Exploration, science notebook, Ping-Pong ball

Introduce the *Straw and Tissue Paper Exploration*. Show **slide C** and read the directions aloud. Tell students they have 2 minutes to explore this phenomenon. Hand out a piece of tissue paper and a bendy straw to each student and have them begin the exploration.

After 2 minutes, instruct students to pause and place their straw and paper under their science notebook for the time being.

Discuss what caused the piece of paper to move. Example prompts follow.

Suggested prompts	Sample student responses
What did you notice about the motion of the piece of tissue when the air from the straw hit it versus when it didn't?	*It moved up and down and fluttered all over.*
What direction was the air from the straw traveling when it hit the piece of tissue?	*It was moving upward.*
Why would air traveling upward cause the tissue to move upward? What did the molecules in that air do to the tissue when they hit it?	*The air pushed it upward.* *The air molecules collided with the tissue and pushed it upward.*

Use hands to represent the force of the air on the tissue paper. Have students follow your lead in holding out one hand flat, and establish that this represents the piece of tissue paper. Prompt students to use the fingers of their other hand to show which way the air was pushing on the tissue paper. Check to see that everyone has the fingers of their second hand pointing upward against the underside of their first hand.

Introduce the role of gravity. Ask questions about why the tissue falls when there is no air being blown on it to establish the role of gravity in the system. Example prompts follow.

Suggested prompts	Sample student responses
What causes the tissue to fall back toward the ground when we aren't blowing on it?	*gravity*
How does that compare to what causes a rock or a ball to fall when we let go of it?	*Gravity also causes the rock or ball to fall.*
Which direction is gravity pulling all of these objects?	*downward*

Hold up a Ping-Pong ball and ask if gravity pulls this downward too. They will say yes. Point out that it isn't moving right now but that when you release it, it will start to move downward. Ask why it will do that. Students will say because it is pulled downward by gravity. Release the ball to test this if you wish.

Introduce the idea of two different forces. Say, *OK, so we have been talking about how gravity pulls objects downward. And when we were talking about why the tissue moved upward, we said the air we blew out of the straw was pushing it upward. Since we are talking about pushes and pulls in different directions, let's start referring to these pushes and pulls as* ***forces****. A force is a push or pull on an object. A force can be described in terms of the direction that it's pushing or pulling on an object, and it can be described in terms of how strong that push or pull is. Let's collect some more evidence about the direction and strength of different forces acting on things in the air.*

3. Investigate weight.

8 MIN

Materials: Investigation A: Comparing Weights, science notebook, chart paper, marker

Prepare science notebook for investigations. Project **slide D**. Have students record the lesson question and set up the table in their science notebook for the two investigations listed (A and B).

This next series of demonstrations and discussions is easier with everyone seated around a demonstration table to record their observations. Since they will be there for a while, have them bring a chair to make a circle around the table so everyone can see. On the way to the table, have students dispose of their straw and tissue paper.

Additional Guidance

Canceling out the weight of the container by using the tare button on the digital scale, as demonstrated, is something students will need to do themselves in the investigations they will plan and conduct in the next lesson. Students will have done this previously in the Cup Design Unit, but it is worth reviewing in this new context.

Demonstrate how to use a digital scale. Turn on the scale. Adjust the units setting to report ounces rather than grams. Ask students what will happen to the reading on the scale when you put the plastic cup on it. They will say it will go up.

Additional Guidance

You are setting the scale to ounces because that is a unit for measuring force. In the next part of this demonstration, you will introduce the idea that the scale can also provide a value in grams that is a calculation of the mass of the object being weighed. Students will measure the mass of water in the next lesson, rather than a force, which is why we start making that distinction here. Students will revisit that distinction in more depth in 8th grade units.

Put the plastic cup on the scale. Have a student read the value on the scale and the unit abbreviation (oz). Record this in marker on a piece of paper or on the board large enough for all to see. Explain that "oz" stands for ounces, ounces are a measurement of force on the scale, and 16 oz is the same as 1 lb, which is also a measurement of force. Tell students that in this case, the value the scale reports in ounces is the object's weight, which is the downward force that gravity applies on an object.

Weigh the ball and cup system. Ask students to predict what will happen to the weight when you add the Ping-Pong ball to the cup. Students will say it will go up because there is more mass in the system, which should result in more force pushing down on the scale due to the weight of the Ping-Pong ball and cup together.

Add the ball to the cup. Have one student read the new force value on the scale and have another student record this in marker on another piece of paper or on the board large enough for all to see. Remove the ball and cup from the scale.

Demonstrate the tare button. Say, *It would be tricky to get the weight of the Ping-Pong ball by itself because it might roll off the scale. We could simply subtract the weight of the cup from the weight of the cup plus the ball to figure out what the ball weighs by itself, or we can put the cup on the scale and have the scale subtract the cup's weight for us. Let me show you how to use the tare button to do that.*

*** Supporting Students in Engaging in Using Mathematical and Computational Thinking**

Directly proportional relationships are an idea introduced in 6th-grade Common Core Mathematics Standards. If students have already explored the idea of directly proportional relationships in their math classes, you may want to dwell on some computational thought experiments a bit more to emphasize the mathematical relationship between the mass of an object and the force from gravity on that object when we measure it in the same location. You could, ask, for example how would the weight showing up on the scale change if we tripled the amount of mass on it or if we only put a quarter as much mass on it.

Place the cup on the scale. Press the tare button. Point out that the scale now subtracts the weight of the cup and is reporting a weight of zero for the system. Put the ball in the cup to show that the reported value is only the weight of the Ping-Pong ball. Have students record this value in the "Observations" column of the first row in their data table. Remove the ball and cup from the scale.

Investigate the weight of a tissue. Ask students to make a claim for whether a tissue has weight. Students should say yes, but very little. Place the empty cup on the scale. Tare the scale. Add 2 single plies of tissue to the cup. Announce the weight shown on the scale and have students record this also in their data table.

Ask students to predict how much a single ply of tissue would weigh. Students will say about half as much. Emphasize that this prediction seems reasonable, since if there are two layers of tissue, removing one would be removing half of the matter in the system, which seems like it should result in half as much weight. Point out that this sort of mathematical reasoning uses an assumption that the weight of an object should be proportional to the amount of matter that makes up that object.

Remove one ply of tissue from the cup, leaving one in it. Announce the weight again. Repeat the prediction question above and subsequent measurement of weight for half a single ply of tissue, then a fourth, and so on until the scale no longer registers the weight of the remaining piece of tissue.

Describe the relationship of mass to weight. Emphasize that at this point we have reached the limits of the scale and its ability to detect any smaller amounts of force. Say, *The scale can only detect differences in forces to an accuracy of 0.01 ounces. This means that any force on it that is less than 0.01 ounces can't be detected. So when we put a small piece of tissue on the scale and it says 0.00 ounces, that doesn't mean that it has no weight. It just means that the scale can't detect that small of a value. All matter has mass. And all mass is pulled downward toward Earth by gravity. The measure of that pull is its weight. The more matter that is there, the more mass it has and the more it is pulled down by gravity, which shows up as a greater weight on the scale. Twice as much mass should be pulled down with twice as much force, which the scale should* *register as twice as much weight. The scale can also use this proportional relationship to tell us how much mass makes up an object placed on the scale. It will automatically do this calculation if we switch its setting to report grams instead of ounces. When we do this, the scale will report the mass of the object on the scale.*

Additional Guidance

We recommend reading this description of matter, mass, and weight relationships verbatim. The distinction between mass and weight is subtle, and often confused by students in future grades, when it becomes more important in explaining some physical science phenomena. While it is not productive to have students dwell too much on this distinction at this time, this initial description will at least help them start thinking about how the two are related, but different.

Record data. Have students record the measured weights in their notebook and summarize what this tells us. Example data and interpretation of that data so far should look something like this:

Investigation	Observations	What does this tell us?
A. Pieces of tissue paper and a Ping-Pong ball placed on a scale	• Weight of Ping-Pong ball = 0.10 oz • Weight of 1 tissue = 0.07 oz • Weight of 2 tissues = 0.14 oz	The scale reports the weight of an object. Weight is the force (pull) from gravity on the mass of that object.

4. Investigate air forces.

8 MIN

Materials: Investigation B: Comparing Air Forces, science notebook

Use the scale to measure the force of air blown from a straw. Say, *Earlier we claimed that when we blew through the straw, the air hit the piece of tissue paper and pushed upward on it. Our scale may be able to help us get evidence for the claim that the air coming out of the straw pushes on the paper. Since this scale is a force measurement device, it can measure the force of anything that pushes against its plate. Let's see if the air we blow through a straw applies a force to the scale that it can detect. Remind us, how strong would the force from air blowing on the scale need to be for the scale to detect it?* Students should say it must at least be 0.01 oz.

Have a volunteer take a new straw, hold its opening a few inches from the surface of the scale, and blow through it toward the scale. A typical reading for this is about 0.15 oz.

Have students record this force in the "Observations" column for the second row of their table. Remind them that the ounces shown on the scale are not a measurement of weight in this case, but rather a measurement of the force applied on the scale from air molecules colliding with its surface.

Predict and measure the force of air blown from a hair dryer. Ask students to predict if air coming out of the nozzle from a hair dryer turned to high will register as much force as the straw.

Make sure the hair dryer is on the coolest temperature and the highest speed and the air intake vent isn't blocked. Hold the hair dryer facing downward and 6 ft or more above the scale. You may need to place the scale on the floor, which will also allow more students to see what the scale reports. Turn on the hair dryer. The scale will register a force of close to 0.00 oz with the hair dryer at this position. Ask why this is. Students will likely say you have to get closer for it to detect something, because the force is too small at this distance.

Poll students to find out who thinks the force of the air will get stronger the closer the hair dryer gets to the scale and who thinks it will not. Then test these predictions. Have a volunteer report the reading on the scale as you turn on the hair dryer and slowly decrease the distance between the nozzle and the scale. Have the volunteer report out a few different readings until the nozzle is just a few inches above the scale. Turn off the hair dryer.

Alternate Activity

You could have another student record the ounces the scale reports with the hair dryer at several distances if you wish, but this is not necessary. A qualitative observation that the force on the scale goes up as the hair dryer gets closer is adequate for the learning goals of the lesson.

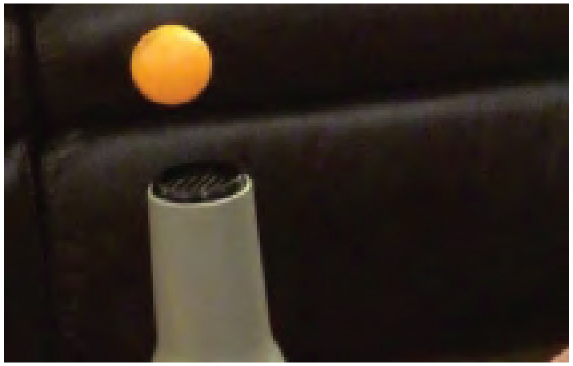
Have students write down what they observed with the straw and the hair dryer in the second row of their table, along with what this tells them about whether moving air can exert force on things it runs into. That table should now look something like this:

Investigation	Observations	What does this tell us?
A. Pieces of tissue paper and a Ping-Pong ball placed on a scale	• Weight of Ping-Pong ball = 0.10 oz • Weight of 1 tissue = 0.07 oz • Weight of 2 tissues = 0.14 oz	The scale reports the weight of an object. Weight is the force (pull) from gravity on the mass of that object.
B. Blowing air onto a scale	• Force of air blown from a straw a few inches away from the scale = 0.15 oz • The force of air blown from a hair dryer increased as it got closer to the scale.	Moving air can exert a force on objects in its path.

5. Investigate the behavior of a Ping-Pong ball in the air from a hair dryer. 8 MIN

Materials: Investigation C: Ping-Pong Ball Behavior, science notebook

Connect to previous investigations on rising air. Say, *Each of those tests involved measuring air moving downward onto the scale, but let's pause for a moment and think back to the hailstorm cloud phenomena. What sorts of things have* *we used to detect density changes in the air*? Give students a few moments to think of examples and then ask them to share out. Students will say we used the bottle and soap-bubble film, and the balloon on the heating pad, and saw a density change in the air in both.



Say, *We saw that density changes in a parcel of air can cause it to rise or fall. When scientists refer to the upward movement of air into and through a cloud, they sometimes call it an updraft. In this next investigation, we are going to simulate updrafts using the hair dryer and see how the Ping-Pong ball interacts with the air pushing up on it when it is released from various heights.*

Demonstrate what the Ping-Pong ball does when released above the hair dryer. Ask a volunteer to help out with this investigation, and give them a Ping-Pong ball to hold onto. Make sure the hair dryer is on the coolest temperature and the highest fan speed and the air intake vent isn't blocked. Point the hair dryer upward and turn it on. Ask the volunteer to hold the Ping-Pong ball in the air coming out of the hair dryer, about 6" from the end of the nozzle, and release it.

Have a couple of students share out their observations. They will say the ball is hovering or floating or bobbing in place. Ask how this is possible, using the following prompts, to help students articulate that there are two forces at work in the system and that they must be counterbalancing each other.

Suggested prompts	Sample student responses
Why isn't the Ping-Pong ball falling to the ground?	*The hair dryer is holding it up.*
But if gravity is still pulling down on it, what is pushing up on it?	*The air (or wind) from the hair dryer.* *The air molecules that are being blown from the dryer upward.*
So if air molecules are being blown upward from the hair dryer and hitting the ball and gravity is pulling it down, why does it tend to just stay at one height (or close to a single height)?	*They must be counterbalanced somehow.*

Demonstrate the phenomenon at two more heights above the hair dryer. Tell students that for the next two tests with the Ping-Pong ball and hair dryer, they are going to predict what the ball will do and show you their prediction by using hand signals. Demonstrate the three hand signals:

- *Make a horizontal hand if you think the ball will float in place at that height above the nozzle when released.*
- *Point your hand downward toward the ground if you think it will move downward toward the nozzle when released.*
- *Point your hand upward if you think it will move upward away from the nozzle when released.*

Have a new volunteer take the ball, hold it only 1" above the nozzle of the hair dryer turned on, and get ready to let it go. Take a class poll of the students' predictions via hand signals. They are likely to all predict it will move upward. Test this by having the volunteer release the ball, and point out that it starts moving upward when it is released from this location.

Have a new volunteer take the ball, hold it 12" above the nozzle of the hair dryer turned on, and get ready to let it go. Again, ask all students to predict what it will do, and poll the class via hand signals. Students are likely to all predict it will fall. Test this by having the volunteer release the ball, and point out that it starts moving downward from this location.

Summarize the results. Say, *We know gravity is pulling down on the Ping-Ball ball anytime we release the ball, but in each location we released it, it behaved differently. In one case it hovered, in another it moved upward, and in another it moved downward. Let's see if you can apply what we just figured out to help explain what is happening in a cloud to keep the water droplets or ice crystals in it from falling out.*

6. Develop predictions and explanations. — 7 MIN

Materials: science notebook, *Predicting and Explaining the Effects of Opposing Forces*

Make predictions about objects' movement in clouds. Project **slide E**. Hand out a copy of *Predicting and Explaining the Effects of Opposing Forces* to each student. Have students take 3 minutes to complete their predictions for Cases A and B with a partner.

Use evidence to answer the lesson question. Show **slide F.** Give students the remaining time to complete their response to the remaining question on their handout individually. Collect this handout as a formative assessment before they leave.

End of day 1

7. Update Progress Tracker. — 18 MIN

Materials: science notebook, *Predicting and Explaining the Effects of Opposing Forces*, 3 pieces of chart paper, markers

Develop initial explanations. Pass back students' completed copies of *Predicting and Explaining the Effects of Opposing Forces*. Say, *You developed some really insightful explanations last time. Let's prepare to merge our thinking and develop a consensus model to represent what we now understand about the role of opposing forces in the air in response to our lesson question. To do that, create a three-column entry in your Progress Tracker.*

Show **slide G**. Have students prepare a page in their Progress Tracker as shown and then bring their chair, notebook, and handout to form a Scientists Circle.

Facilitate a Consensus Discussion. Ask what our lesson question is and what sources of evidence we investigated to try to answer it. Write these on chart paper as students share them out, and instruct students to do the same in their Progress Tracker:

- Question: Why don't water droplets or ice crystals fall from the clouds all the time?
- Sources of Evidence: Investigations with a straw, tissue, Ping-Pong ball, hair dryer, and scale

Say, *OK. Before we draw a diagram to represent what we think is going on when opposing forces act on water droplets or ice crystals, let's review the predictions you made on your handout.*

Suggested prompts	Sample student responses
Which objects did you predict would move downward if released when there was 0.01 ounces of updraft force on them?	*Both hailstones.*
Which objects did you predict would start moving upward when released?	*The snowflake and small water droplet.*
Which object did you predict would float in place when released?	*The large water droplet.*

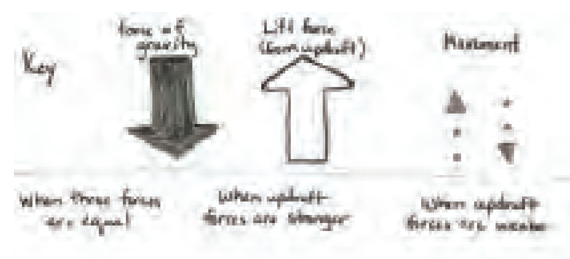
Ask the following three questions to help students generalize the relationship between the force of gravity downward on a droplet or crystal and the updraft force on it. For each question, have a couple of volunteers restate the ideas they heard their peers share, and whether they agree with them and why, before moving on to a new question.

Suggested prompts	Sample student responses
What can we say would happen to any object released in the air when the force due to gravity pulling it downward is equal in strength to an updraft force on it from rising air?	*The object would float (or hover) in place.*
What could happen to a droplet or crystal floating in a cloud if the weight of that droplet or crystal becomes less than the updraft force?	*The droplet or crystal could start to rise.*
What could happen to that droplet or crystal floating in a cloud if the weight of that droplet or crystal becomes greater than the updraft force?	*The droplet or crystal could start to fall.*

Develop a visual representation of these three cases. Say, *So to visualize this, we need a way to show the direction that an object might start moving and the direction of the two forces acting on it. Arrows would be useful for showing both of these, but telling them apart could get confusing, so let's make a key to show how we will represent forces versus motion for these three cases:*

- *when the forces are equal (case 1)*
- *when updraft forces are stronger (case 2)*
- *when updraft forces are weaker (case 3)*

Create the key and three cases on the top half of a piece of chart paper, so they look something like this:



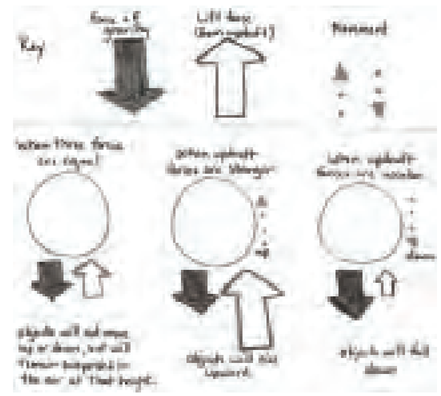
Draw a circle to represent an object in each case. Then ask students the following questions to establish how to represent differences in the forces on the object for the first two cases.

Suggested prompts	Sample student responses
OK. Before we draw arrows to represent forces in our first two cases, how could we make sure they show the forces are equal in strength in the first case but not equal in strength in the second case?	*Draw it the same length (or size) as the other arrow, but in the opposite direction for the first case.* *Draw an upward arrow on (or from or toward) the object that is bigger (or longer) for the second case.*
If it's the same object in both cases, then should its weight change?	*No.*
How would we represent that the weight doesn't change in case 1 versus case 2?	*Make the arrow for the force from gravity the same length (or size).*

Draw in these arrows for forces for cases 1 and 2. Then ask about motion:

Suggested prompt	Sample student response
How about motion? If we released an object under these two different conditions, would it start moving upward, downward, or neither direction?	*It should start to move upward in the second case, but neither direction in the first case.*

Update Progress Tracker. Instruct students to work with a partner to complete the third case together and add it to their Progress Tracker. This should take less than 3 minutes. If time permits have them add the other two force diagrams to their Progress Tracker as well. Walk around to check on students as they work. The model you should see them developing should look something like the one at right.



8. Brainstorm causes for forces of different strengths.

10 MIN

Materials: science notebook, 20 magnetic marbles, chart paper, markers

Hold out a handful of 10 magnetic marbles. Say, *We've used magnetic marbles to model individual water molecules before. I have a clump of 10 of these in one hand to represent a very small water droplet. Let's imagine there is just enough updraft force so that it is equal in strength to the droplet's weight. In that case, we know the droplet would end up hovering at the height it was released.*

Demonstrate with the marbles as you take a quick poll of students regarding how condensation, deposition, droplet collision, and evaporation would affect the mass and weight of droplets and crystals in a cloud. For each question, have students respond to the poll with the same three hand signals they used before:

- *Make a horizontal hand if you think it would continue to float in place at the height it was before.*
- *Point your hand downward if you think it would start to move downward toward Earth's surface.*
- *Point your hand upward if you think it would start to move higher into the air.*

*** Attending to Equity**
Ask students to remember their number as you count them off to divide the class in half (e.g., for a group of 30 students, count off 1-15 and then repeat; for a group of odd-numbered students, add an extra "1" to make a group of three students with that number).

If you notice that students tend to sit near students they know when they form a Scientists Circle,

Suggested prompts	Sample student responses
If more water molecules start condensing on this water droplet in a cloud, what would it do? (Demonstrate this by dropping another magnetic marble onto the clump.)	*Students should point their hand downward.*
What if a droplet that is floating runs into another droplet and they stick together? (Demonstrate this if necessary by bringing another clump of magnetic marbles near it.)	*Students should point their hand downward.*
What if a snowflake that is floating runs into another snowflake in a cloud and they stick together?	*Students should point their hand downward.*
What if a droplet that is floating is surrounded by relatively dry, warm air, and some of the water molecules on it start to evaporate off?	*Students should point their hand upward.*
What if a droplet or crystal is floating and the uplift force becomes stronger?	*Students should point their hand upward.*

Brainstorm what could change updraft strength and how to investigate this. Say, *We are claiming that if the strength of an updraft compared to the weight of the object changes, it could change the motion of an object suspended in the air in a cloud. Since this seems key to explaining why water would fall out of a cloud or not, it leaves us with a new question we need to answer: What causes updrafts in the first place, and what sorts of things might affect the strength of an updraft in the air outside?*

Show **slide H** and read the question on the slide aloud. Give students 2 minutes to stand up and walk over to talk with a partner that you assign them from a different location in the Scientists Circle.*

As students talk with the partner you assigned them, write the question from **slide H** on the top of a piece of chart paper:

- What would cause the strength of updrafts in the air to change on one day versus another or under one cloud versus another?

Hang this question near the demonstration table and then reconvene students at the table. For this next part, you will probably want to keep them standing around the table in an open semicircle so they can all see each other and the equipment on the table. Have students share out their ideas while you add them to the chart paper. There are likely to only be a few, such as these:

- more surface heating
- more energy transfer from the ground to the air above the ground
- a bigger density difference between the air that is rising in the cloud and the surrounding air

reuse this strategy in the future so they have an opportunity to work with hearing new voices. It is also a useful technique for providing a movement break after sitting in a Scientists Circle for an extended period.

Say, *These are great ideas and we should try to investigate them further by designing some experiments in our lab next time. But in addition to testing ideas in the lab, it would be nice if we could also take direct measurements of rising air outside and other things going on with the weather that it might be related to. Let's look at a kind of device that scientists have found useful for detecting changes in air that is rising or falling outside, and let's use it to collect some additional data.*

9. Introduce devices to measure rising or falling air.

10 MIN

Materials: Investigation D: Detecting Changes in Air Pressure, science notebook, chart paper, markers

Explore how a digital scale could detect updrafts. Say, *We've already used a digital scale to measure the strength of the air pushing against it when that air is moving downward. Let's start by revisiting how that worked.*

Turn on the digital scale, set it to ounces, place it where everyone can see it, and tare it. Take out a box fan and turn it to low. Hold it about a foot over the scale, blowing downward toward it, and ask a student to read the scale to report how much force it detects.

Make and test predictions. Ask, *What do you think the scale will show if we flip the fan around in the other direction to force the air to start rising away from it?* Ask a few students to volunteer their predictions. Students may not agree on whether the digital scale can detect rising air.

Turn the fan on low and hold it about a foot over the scale, blowing air upward. Ask students what the scale shows. They will report a negative value (e.g., -0.8 oz).

Turn off the fan and ask why the scale reported a negative instead of a positive value when the air was blowing upward from it. Students may say it is registering a force in the opposite direction from when the fan was pushing air down onto it, or they may say it shows less weight than was there when the air above the scale was still.

Recall the scale's sensitivity limitations. Say something like, *OK, so we just saw a digital scale could be useful to detect if the air above a location was moving upward or downward. But as we saw in the data earlier, some things in the clouds like snowflakes or small water droplets might be held aloft with updrafts that are applying as little as 0.001 ounces of force on them. And we've already determined that this scale is not sensitive enough to detect any amount of force less than 0.1 ounces. That means it wouldn't detect very small changes in the amount of force from the air that is rising or sinking outside.*

Introduce the barometer. Say, *But scientists have created a different device that can detect very small changes in the air. That device is called a barometer. I built a homemade one for us to analyze. Has anyone heard of a barometer before and knows how it works?* Accept all responses.

Tell students there are different designs for building a barometer, but the one you made has some important similarities to another air system we used in a previous lab that you want them to think about next. Show students the homemade barometer without the ruler next to it first.

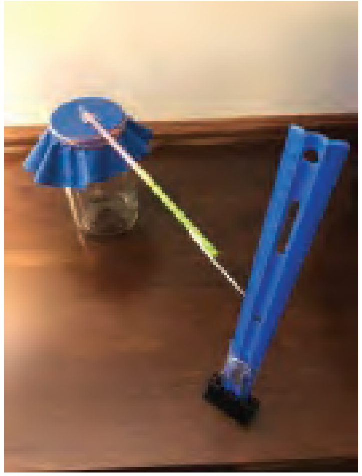
Project **slide I**. Prompt students think about the questions on the slide individually for a minute before discussing them as a class.

Suggested prompts	Sample student responses
What do you notice about the structure of this device?	*It has a container with a balloon stretched over its opening.* *It has a straw with a point on the end of it taped to the top of the balloon.*
How does it compare to the bottle and soap-bubble film you used to detect density changes in air in a previous investigation?	*The container appears to be a closed system filled with air.*

Remind students that the bottle and soap-bubble system was very useful for detecting density changes in the air **inside the bottle** due to heating and cooling, but this device is particularly useful for detecting density changes in the air **outside the bottle**.

Review what happens to parcels of air when they become less dense versus more dense than the surrounding air. Example prompts follow.

Suggested prompts	Sample student responses
When we made a parcel of air (in a balloon) less dense than the surrounding air, what did it do?	*It rose.*
What happens to parcels of air when they become more dense than surrounding air?	*They sink.*



Move a ruler with a binder clip base so it is lined up behind the end of the pointer from the barometer.

Show **slide J.** Read through the text on the top of the slide only. Demonstrate what it describes by pushing down lightly on the top of the balloon with your finger. Ask students what they notice the end of the pointer doing. They will say it is moving upward.

Have students discuss the slide's Turn and Talk question with a partner. After a minute, ask students to report their predictions. They will say the pointer should move in the opposite direction (downward).

10. Predict and record data on a weather log.

7 MIN

Materials: Investigation D: Detecting Changes in Air Pressure, science notebook, *Weather Log*, chart paper, markers, Air Pressure poster and a piece of blank chart paper covering it, tape

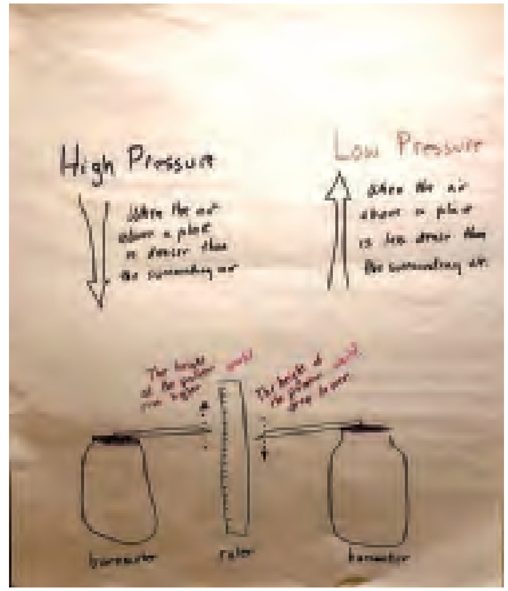
Make predictions. Project **slide K.** Say, *Now we have a device to help us detect changes in the density of the outside air.*

Uncover the Air Pressure poster and direct students' attention to it. Say, *Let's use this poster to represent how we expect the barometer to work. And let's use it to collect some data on how lift, clouds, and precipitation might be related. But first let's make some predictions. What changes do you predict you would see in the cloud cover on days when this device detects the air pressure outside increasing? How about when this device detects the air pressure outside decreasing? Record these*

*** Attending to Equity**
The local observations that students make in their weather log provide additional opportunities for students to connect their learning to events in their lives as they record observations and

predictions on this new handout and add it to your notebook. Hand out a copy of *Weather Log* to each student and have them tape it into their notebook.

After a couple of minutes, ask a volunteer to read the measurement on the ruler that the barometer point is at today. Tell students to add this to the first row of the table on their handout and also record a few notes for the current level of cloudiness (clear, partly cloudy, cloudy) and precipitation (none, light rain, heavy snow, and so forth), not what happened earlier in the day.*



Additional Guidance

We recommend having a new volunteer report the value of the barometer at the start of the period for each remaining day of instruction for this unit (or at least through Lesson 17). It should take only 2 minutes for the volunteer to report that out and for students to record it in their weather log along with the rest of the information in that row of their table. Encourage students to record new wonderings at the bottom of their weather log too as they think of them across subsequent lessons.

Recall the two current lines of investigation. Say, *OK, so now we have two investigations we want to pursue. We have this one, which we can take a measurement at the start of every class and keep a weather log for. But we also had a list of ideas for what might cause an updraft to be stronger in one cloud versus another.* Refer to the chart paper you made earlier in the period.

Emphasize that we will need to make more detailed plans on how to pursue an investigation or experiment into these ideas the next time we meet.

Cover the Air Pressure poster with a blank piece of chart paper before you teach this lesson to the next class.

generate questions based upon their daily experiences.

All About Clouds

1 Cloud Types
2 Cloud Seeding
3 Cloudy Understanding
4 Clouds and Cities

Literacy Objectives

- ✓ Summarize key points related to clouds.
- ✓ Distinguish cause(s) and effect(s) related to clouds, precipitation, and climate conditions.
- ✓ Organize related details about clouds.
- ✓ Translate text to visual/graphic representation of ideas.

Literacy Exercises

- Read varied text selections related to the topics explored in Lessons 9–11.
- Evaluate the reading selections according to provided prompts and criteria.
- Compare and contrast information gained from reading text with information gained from class investigation.
- Prepare a cloud concept map in response to the reading.

Instructional Resources

Student Reader

Collection 4

Science Literacy Student Reader, Collection 4
"All About Clouds"

Exercise Page

EP 4

Science Literacy Exercise Page
EP 4

Literacy Activities

Assign the Science Literacy reading and writing exercise *after* class completion of this lesson group:

- Lesson 9: Why don't we see clouds everywhere in the air, and what is a cloud made of?
- Lesson 10: Why do clouds or storms form at some times but not others?
- Lesson 11: Why don't water droplets or ice crystals fall from the clouds all the time?

Standards and Dimensions

NGSS

Disciplinary Core Idea ESS2.D: Weather and Climate: Weather and climate are influenced by interactions involving sunlight, the ocean, the atmosphere, ice, landforms, and living things. These interactions vary with latitude, altitude, and local and regional geography, all of which can affect oceanic and atmospheric flow patterns. (MS-ESS2-6).

Science and Engineering Practice: Obtaining, Evaluating, and Communicating Information

Crosscutting Concepts: Patterns; Cause and Effect

CCSS

English Language Arts

RST.6-8.1: Cite specific textual evidence to support analysis of science and technical texts.

RST.6-8.4: Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to grades 6-8 texts and topics.

RST.6-8.5: Analyze the structure an author uses to organize a text, including how the major sections contribute to the whole and to an understanding of the topic.

RST.6-8.6: Analyze the author's purpose in providing an explanation, describing a procedure, or discussing an experiment in a text.

RST.6-8.10: By the end of grade 8, read and comprehend science/technical texts in the grades 6-8 text complexity band independently and proficiently.

Core Vocabulary

Core Vocabulary: Core Vocabulary terms are those that students should learn to use accurately in discussion and in written responses. During facilitation of learning, expose students repeatedly to these terms. However, these terms are not intended for isolated drill or memorization. No Core Vocabulary terms are highlighted in Collection 4.

Language of Instruction: The Language of Instruction consists of additional terms, not considered a part of Core Vocabulary, that you should use when talking about any concepts in this exercise. Students will benefit from your modeling the use of these words without the expectation that students will use or explain the words themselves.

cloud seeding **condensation**

heat island **nucleus** **stratosphere**

troposphere

A Glossary at the end of the Science Literacy Student Reader lists definitions for Core Vocabulary and selected Language of Instruction.

1. Plan ahead.

Determine your pacing to introduce the reading selections, check in with students on their progress, and discuss the reading content and writing exercise. If you are performing Science Literacy as a structured, weekly routine, you might implement a schedule like this:

- Monday: Designate a ten-minute period at the beginning of the week to introduce students to the assignment.
- Wednesday: Plan to touch base briefly with students in the middle of the week to answer questions about the reading, to clarify expectations about the writing exercise, and to help students stay on track.
- Friday: Set aside time at the end of the week to facilitate a discussion about the reading and the writing exercise.

2. Preview the assignment and set expectations. (Monday)

- Let students know they will read independently and then complete a short writing assignment. The reading selection relates to topics they are presently exploring in their Weather, Climate, and Water Cycling unit science investigations.
- The reading and writing will be completed outside of class (unless you have available class time to allocate).
- Preview the reading. Share a short summary of what students can expect.
    - *First, you will explore an infographic that is a picture guide to cloud type identification. You'll also learn what kind of weather is associated with each type of cloud.*
    - *Next, you'll read the social media post of a young woman who is visiting China and takes a "cloud seeding" tour.*
    - *Then you'll read an article about some misconceptions related to clouds and why they are not entirely true.*

- *Finally, you'll read an article explaining why some cities are cloudier than others and cloudier than the surrounding environment.*

- Distribute Exercise Page 4. Preview the writing exercise. Share a brief summary of what students will be expected to deliver. Emphasize that Science Literacy exercises are brief. The focus is on thoughtful quality of a small product, not on the assignment being big and complex.
  - *For this assignment you will be expected to generate a cloud concept map that summarizes the main ideas in this collection.*

Exercise Page

EP 4

- Remind students of helpful strategies they can employ during independent reading. Offer the following advice:
  - *The reading should take approximately 30 minutes to complete.* (Encourage students to break reading into smaller sections over multiple short sittings if their attention wanders.)
  - *A good reading strategy is to scan through the collection first to see the titles, section headers, graphics, and images to see what the selections are going to be about before fully reading.*
  - *Next, "cold read" the selections without yet thinking about the writing assignment that will follow.*
  - *Then, carefully read the Exercise Page to understand the expectations for the writing part of the assignment.*
  - *Revisit the reading selections to complete the writing exercise.*
  - *Jot down any questions for the midweek progress check in class.* (Be sure students know, though, that they are not limited to that time to ask you for clarification or answers to questions.)

3. Touch base to provide clarification and address questions.

(Wednesday)

Touch base midweek with students to make sure they are on track while working independently. You may choose to administer a midweek minute-quiz to give students a concrete reason not to postpone completing the reading until the last minute. Ask questions such as these, and have students jot answers on a half sheet of paper:

Suggested prompts	Sample student responses
What is the name for a cloud that is close to or touches the ground?	*fog*
What is Emily Teng's concern about cloud seeding?	*that it might disrupt nature in a harmful way*
Does sunlight have to boil water on Earth's surface before it evaporates and becomes water vapor in the atmosphere? Explain.	*No. Water can evaporate without boiling first.*
Where in the United States are cities with the least cloudy days? Why?	*in the West* *because the West is where deserts are located and has land with little water on it or in the soil*

Ask a few brief discussion questions related to the reading that will help students tie the text content to students' classroom investigations.

Suggested prompts	Sample student responses
How does the reading "Clouds and Cities" help you answer this part of the Lesson 9 question, "Why don't we see clouds everywhere in the air?"	*The selection explains that places with an arid climate and little water in the soil will have less evaporation and, therefore, fewer clouds and that most places that are close to large bodies of water will have more evaporation and, therefore, more clouds.*
How did your work in Lesson 10 help you understand that thinking clouds are mostly made of dust is a misconception?	*In Lesson 10, we talked about how clouds form when there is high humidity. And we learned that humidity means how much water, not dust, is in the air.*
How did our discussion in Lesson 11 about what causes rain or snow to start falling from a cloud support what you read in "Cloud Seeding"?	*We discussed how water droplets or ice crystals have to get heavy enough to fall. So, it's not just their size but their weight that is important.*

Exercise Page

EP 4

- Refer students to the Exercise Page 4. Provide more specific guidance about expectations for students' deliverables due at the end of the week.
    - *The writing expectation for this assignment is to draw a concept map to summarize the main ideas of each of the four readings in this collection.*
    - *In keeping with the collection theme of clouds, write each concept inside a drawing of a cloud, and connect the clouds with lines.*
    - *While there is no highlighted vocabulary in the readings, you can still use science terms that seem important, drawing upon what you learned in our class activities.*
    - *The important criteria for your work are that your summary statements well represent the readings and are stated accurately.*
- Explain that students' concept maps should use cause-and-effect language to show relationships between clouds and the conditions that are important in their formation.
- Answer any questions students may have relative to the reading content or the exercise expectations.

4. Facilitate discussion.

(FRIDAY)

Facilitate class discussion about the reading collection and writing exercise. Students begin the reading activity by learning how clouds are classified based on altitude, shape, and the weather conditions associated with them. The photos are striking in their variety.

Student Reader

Collection 4

Pages 34–39 **Suggested prompts**	**Sample student responses**
What is the general purpose of the first selection, "Cloud Types"?	*It uses pictures and captions to describes how clouds are classified by their shapes, their altitude, and the weather they bring.*
If you ever looked up at the sky and thought that a cloud looked like a bunny or another kind of animal, what type of cloud were you likely looking at?	*probably cumulus clouds that sometimes look like cotton balls but can also take other shapes*
The author talks about the boundary between the stratosphere and troposphere. Nearly all weather occurs in the troposphere layer. How are the two layers positioned in relation to Earth's surface?	*The troposphere sits right above Earth's surface, and the stratosphere sits above the troposphere.*
The author says that lenticular clouds look like a pillow or stack of pancakes. What else do they resemble?	*They also look like a stack of plates or flying saucers (UFOs).*
What is the general purpose of the second selection, "Cloud Seeding"?	*It is a series of social media posts by a tourist in China that is accompanied by science explanations of what she is seeing.*
How did the author use the two types of text to communicate?	*The "Science in Here" text is a straightforward communication of facts, possibly how the tour guide would communicate. The social media posts are meant to create enthusiasm for the topic and to speculate about whether cloud seeding is a good idea or not.*

SUPPORT—If you are using the recommended word envelope convention, check the envelope to see if it contains any words, phrases, or sentences that students need help understanding. Read key sentences aloud, and provide concise explanation.

SUPPORT—All students, but especially English learners, may be mystified by the scientific names for cloud types. Explain that scientists have used these names, which are from the ancient Latin language, since 1803. Point out that *cirro* means "curl" because of the shape of the cloud, *alto* means "high" due to altitude, and *cumulo* means "heap" in Latin.

SUPPORT—Show students a handful of dried lentils (beans) and have them describe their shape. Explain that the word *lenticular* comes from the Latin language and means "lentil shaped." Point out that the word *lens* (as in a hand lens or the lens of the eye) comes from the same Latin word.

Pages 38–43 Suggested prompts	Sample student responses
How did the Collection 3 selection called "Sticky Water" support your understanding of precipitation?	*Because I read "Sticky Water," I understand that molecules of water cluster together due to a property called cohesion and that if there is a starting particle of dust or salt, the property of adhesion is at work.*
What substances act as condensation nuclei around which water droplets form?	*In nature, it may be a particle of dust or salt. When people seed clouds, it may be silver iodide.*
What is the general purpose of the third article, "Cloudy Understanding"?	*It compares misconceptions that some people may have about clouds with the correct science.*
Oftentimes, there is a kernel of truth in a misconception. Which of the misconceptions in this article are partly true, even if the entire statement is not true?	*Boiling water does produce steam.* *Smokestacks release a lot of water vapor, and the water vapor can condense to become a cloud.* *Clouds do block sunlight.*
Another common student misconception is that a cloud is made of substances that are all in the gaseous state. What is the reality?	*A cloud is a combination of gases such as water vapor and nitrogen, liquids such as water droplets, and solids such as ice crystals and dust particles.*
What is the general purpose of the fourth article, "Clouds and Cities"?	*It explains what conditions make some cities cloudy places and other cities sunny places.*
How does the data table support the text?	*The text summarizes the table by explaining that most of the sunny cities are found in the western United States. The table has the numerical data that can be analyzed to confirm the text is correct.*
Which U.S. state has the greatest number of sunny cities?	*Arizona*
How does this selection build on what you learned about heat islands in the Collection 2 reading called "Earth's Diverse Surfaces"?	*The Collection 2 selection explained that materials city structures are made from, such as concrete and asphalt, absorb a lot of sunlight and conduct the energy back into the air around the city as heat. The Collection 4 selection explains that this heat also causes a lot of water to evaporate from city surfaces, increasing the size of clouds over the city.*

CHALLENGE—Have students review and comment on other misconceptions about meteorology collected by science teachers and posted online. Reinforce the idea that there is often a core of truth in a misconception. Have students write a "Reality" explanation for several misconceptions they read online. (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)

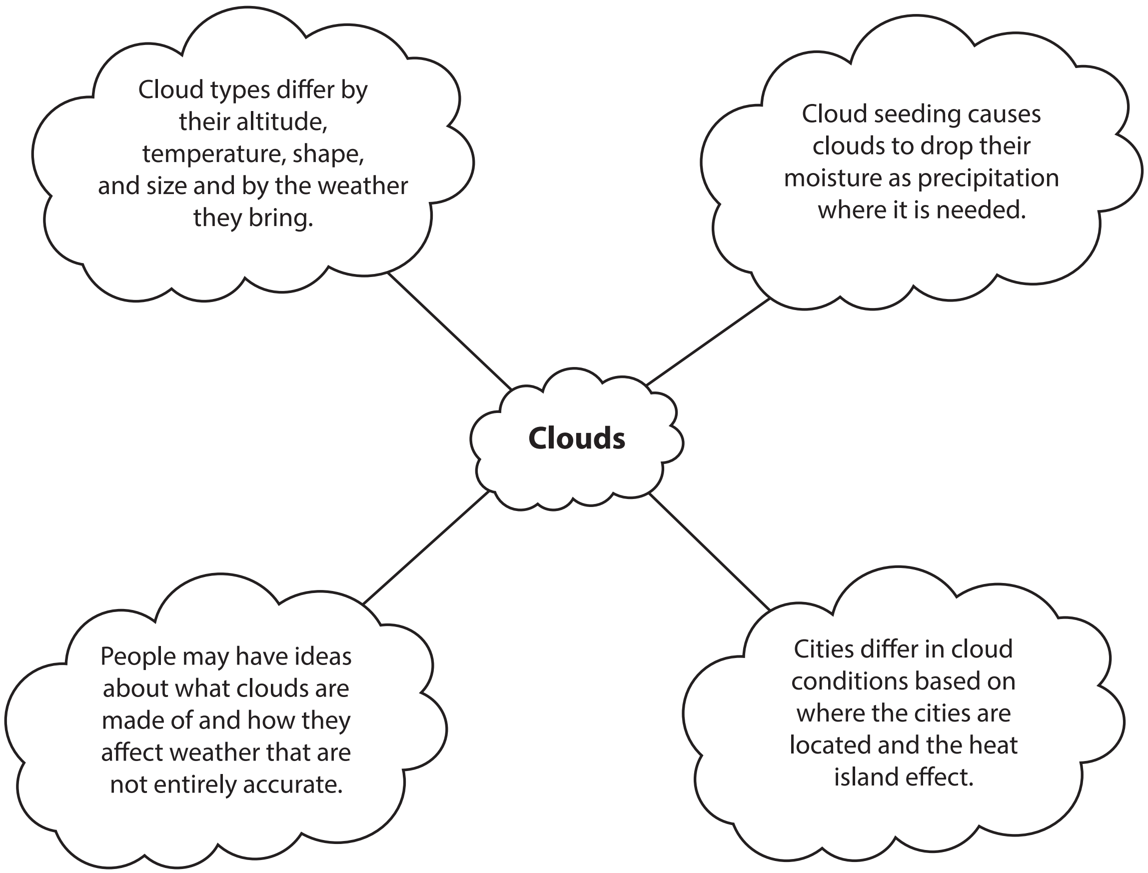
Online Resources

4. Check for understanding.

Evaluate and Provide Feedback

For Exercise 4, students should draw a concept map describing a main idea about clouds from each of the four reading selections. Look for evidence that students can distill each reading into a succinct and accurate summary sentence that shows understanding of cause-and-effect relationships.

A sample completed concept map is shown below, but students' main idea/summaries may be worded differently.



Use the rubric provided on the Exercise Page to supply feedback to each student.

EXTEND—Since the topic of this collection is "clouds," students may enjoy making word clouds from the text of one or all of the four readings. A word cloud is a graphic representation of text in which words that appear more frequently are displayed larger and more centrally than other words. To make a word cloud, students will copy and paste a selection of text into an online word cloud generator that analyzes the text and produces the graphic. The graphics can be printed or saved so that students can compare them in a gallery walk. (See the **Online Resources Guide** for a link to a useful resource for this. **www.coreknowledge.org/cksci-online-resources**)

Online Resources

What causes more lift in one cloud versus another?

Previous Lesson

We tried to lift or suspend different objects with air blown upward. We developed a model to show how an object might be lifted, fall, or remain suspended in the air depending on the relative strength of two different forces acting on it. We recorded the air pressure, using a homemade barometer, and the cloud cover and precipitation outside.

This Lesson

Investigation

2 DAYS

We plan and carry out an investigation to determine what variables affect the amount of lift produced by transferring thermal energy into a fluid. We explain how the results of our investigation help us understand how differences between air and ground temperatures can cause different amounts of lift and movement of air.

Next Lesson

We will add to our Gotta-Have-It Checklist and do a close reading to support and add to our ideas for how really big hail forms. We will develop a model to explain why some storms produce hail and others don't. We will take stock of our Driving Question Board to determine what questions we can now answer and apply our understanding to a new weather phenomenon, a hurricane, on a summative assessment.

Building Toward NGSS

MS-PS1-4, MS-ESS2-4, MS-ESS2-5, MS-ESS2-6

What Students Will Do

Collaboratively plan an investigation to collect data, identifying independent and dependent variables and controls and how the data are recorded, to serve as the basis for evidence that greater temperature differences between the ground and the air higher in the atmosphere cause greater lift (effect) of air.

Develop a model to represent how varying inputs of thermal energy affect the resulting movement of air (output) to show the relationships among variables that can predict greater lift and movement of air.

Construct an explanation that includes qualitative relationships between variables that predict the movement of a fluid (air), based on the transfer of energy that drives the motion.

What Students Will Figure Out

- When one spot in a fluid heats up, it becomes less dense, which causes it to rise. When it cools down, it becomes more dense and sinks. This leads to circular motion in fluids, called convection.
- The greater the thermal energy input into the fluid, the stronger the lift or convection currents. The more of Earth's surface that is in contact with the air above it, the more thermal energy it can transfer to that air.
- Some winds are the result of this convection. Air at the surface moves toward an area where warmed air rose, filling in the space left behind.

Lesson 12 • Learning Plan Snapshot

Part	Duration	Summary	Slide	Materials
1	3 min	**NAVIGATION** Review brainstormed ideas about what might cause stronger updrafts on one day versus another and how we might investigate them.	A	
2	5 min	**INTRODUCE FLUID BEHAVIOR** Introduce the idea of using another fluid (water) in place of air to explore what variables affect the speed or amount of lift. Map the elements of the experimental system to the air outside.	B-C	*Convection in Fluids*, Convection in Fluids: Teacher Demonstration
3	12 min	**MAKE INITIAL OBSERVATIONS AND PREDICTIONS** Observe what happens to the dye before and after thermal energy is added, and predict how changing what is in the cup below the tub could affect the movement of the dye.	D-E	Convection in Fluids: Teacher Demonstration
4	10 min	**DESIGN THE INVESTIGATION** Collaboratively plan an investigation to test which variables affect the amount and direction of lift in a fluid by identifying the independent, dependent, and controlled variables.	F, G	*Convection Investigation Plan*
5	15 min	**CONDUCT THE INVESTIGATION** Conduct the student-designed investigation in small groups and record observations.	G	Convection in Fluids: Student Investigation
				End of day 1
6	5 min	**NAVIGATION** Connect data collection from day 1 back to the lesson question.	H	*Convection Investigation Plan*

Part	Duration	Summary	Slide	Materials
7	15 min	**REPORT RESULTS AND MAKE SENSE OF DATA** Represent the investigation results on an image of the ground and a cloud and display them in a gallery walk. Respond to claims about which variables cause the most lift in a cloud.	I-J	*Explaining Convection in the Air Outside*, *Air Movement in Different Conditions*, tape
8	25 min	**CONDUCT A BUILDING UNDERSTANDINGS DISCUSSION AND UPDATE THE PROGRESS TRACKER** Gather in a Scientists Circle to share claims and make sense of our results.	K	*Explaining Convection in the Air Outside*, chart paper, markers

End of day 2

Lesson 12 • Materials List

	per student	per group	per class
Convection in Fluids: Teacher Demonstration materials	• *Convection in Fluids*		• 2 clear tubs filled with room-temperature water • 9 empty coffee cups • 1 coffee cup filled with warm water • electric coil or kettle • red food dye • blue food dye • 4 pipettes • paper towels • meat thermometer
Convection in Fluids: Student Investigation materials	• *Convection Investigation Plan*	• 1 clear tub • 5-6 coffee cups • 1 cup with 5 mL of red dye • 1 cup with 5 mL of blue dye • 2 pipettes • tap water • thermometer(s) • ruler • paper towels	• electric coil or kettle to heat water • ice or ice water • 2 oven mitts

	per student	per group	per class
Lesson materials **Student Procedure Guide** **Student Work Pages**	• science notebook • *Convection in Fluids* • *Convection Investigation Plan* • *Explaining Convection in the Air Outside*	• *Air Movement in Different Conditions*	• tape • chart paper • markers

Online Resources

Materials preparation (60 minutes)

Review teacher guide, slides, and teacher references or keys (if applicable).

Make copies of handouts and ensure sufficient copies of student references, readings, and procedures are available.

You need one single-sided copy of *Air Movement in Different Conditions* for each lab group.

Convection in Fluids: Demonstration and Student Investigation

- **Group Size**: Split the class into 6-8 groups, depending on your class size.
- **Setup**:
  - Watch the teacher demonstration video to see how to deploy the dye into the water with minimal disturbance and how to do the first demonstration. (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)
  - Put one tub and five coffee cups at each lab station. Put one tub on top of four upside-down coffee cups, one at each corner. Reserve one coffee cup for students to fill with hot, cold, or warm water. Each lab station should have one or two meat thermometers. Have a few extra coffee cups for groups that might need two (e.g., the group that tests having a lot of thermal energy input over a larger area will need two cups of hot water).
  - Put 5 mL of red and blue food coloring into separate cups for each lab station. Place two pipettes and a paper towel at each station. Rinse pipettes and refill food coloring before each class. Pipettes should be reused with other classes.
- **Notes for During the Lab**:
  - Use an electric coil in a ceramic coffee cup (or use an electric kettle) to heat water for students to fill their cups. The water should not be warmer than 160°F when poured, to avoid the risk of burns. If you boil the water, measure its temperature as it cools to make sure it is not too hot when students use it. Also have warm tap water available.
  - If your sink doesn't produce cold water, provide a tub or ice chest with ice water so students can add small amounts to their tub to lower the water temperature.
  - There are several options for having students control the temperature gradient in the tub system. You could have these test conditions:
    - with hot water in the cup

    - with lukewarm water in the cup
    - with cold water in the cup
    - with two cups of hot water
    - with one cup of hot water and one of cold water
    - with hot water in cups below and ice on top of the tub
- **Safety:** For the groups using very hot water, have the students use oven mitts to handle the cups.
- **Disposal and Storage:** The tubs of water can be emptied into a sink, and the pipettes either disposed or rinsed for reuse. The tubs are designed to be stacked for storage, with all pipettes stored inside. The coffee cups are intended to be reused as well and can be dried and stored too.

Lesson 12 • Where We Are Going and NOT Going

Where We Are Going

This lesson develops a fuller model of convection than previously introduced. In Lesson 6, students used a particle-level explanation of changes in the speed, spacing, and density of molecules due to temperature change to predict and explain why parcels of air rise or fall in the surrounding air when heated or cooled. In this lesson, students extend that model of convection to explain the circulation of any fluid (gas or liquid), including how movement changes with the input of thermal energy.

This lesson targets key ideas about convection outlined on p. 124 of *A Framework for K–12 Science Education* (NRC, 2011): “Energy moves out of higher temperature objects and into lower temperature ones . . . by the flow of liquid or gas (convection).” It also states, “The processes underlying convection and conduction can be understood in terms of models of the possible motions of particles in matter.”

The lesson also introduces the idea that the currents produced in liquid are the same as those produced by the mechanism that creates some of the winds at Earth’s surface. This lays the groundwork for explaining larger-scale phenomena of ocean current and atmospheric circulation and air mass interactions in the second half of the unit.

Students may not have thought before about what causes wind. Some may think that clouds block wind and slow it down or that cold temperatures produce fast winds. This lesson will help students understand not only the mechanisms behind varying updrafts of air in a storm system, but also the surface winds that result when air moves in to fill the space of the air that has been lifted.

Where We Are NOT Going

This lesson focuses on localized convection cells and the surface winds that result. It does not address large air mass movements or global convection, such as Hadley cells.

LEARNING PLAN FOR LESSON 12

1. Navigation

3 MIN

Materials: science notebook

Lead a class discussion. Show **slide A**. Remind students that in the last lesson we figured out that updrafts (rising air) can hold or lift things up in the air that would otherwise fall. Remind them that we saw the ball and tissue were suspended or pushed upward depending on the strength of the force of the updraft pushing on them. Ask students to share their ideas regarding things that might cause stronger updrafts on one day versus another and how we might investigate them. Example prompts follow.

Suggested prompts	Sample student responses
In earlier lessons, we developed models to explain why air parcels might rise or sink in the surrounding air. Let's use those models to consider what might cause stronger updrafts to be produced on one day versus another.	*Maybe if it is hotter at the ground, because we saw the balloon rise fast when it was heated on the heating pad (or hair dryer).*
How could we investigate whether adding more heat (or other factors) contributes to stronger updrafts?	*Heat up some of the same things (e.g., balloons or bags of air), but heat up one more than another and see if one rises faster.*

2. Introduce fluid behavior.

5 MIN

Materials: Convection in Fluids: Teacher Demonstration, *Convection in Fluids*

Introduce fluids. Show **slide B**. Read the text on the slide aloud, explaining how liquids can be used to visualize currents (or movements) and that many aspects of convection in gases and liquids are similar. Explain that we refer to gases and liquids as *fluids* because they can flow, move easily, and take different shapes (e.g., the shape of the container they are in).

Draw students' attention to the images of the tub and the cloud. Say, *We can use a setup like this to investigate what variables affect the amount of lift in a fluid and how fast it moves. But since we are using water rather than air, we first need to think about how the parts of our experimental setup relate to the phenomenon of updraft or lift in the air outside.*

Map the setup to the phenomenon. Show **slide C**. Distribute *Convection in Fluids* to each student. Point out the components of one lab setup with a tub of water supported by cups, a cup filled with water of a higher temperature than the water in the tub, and a pipette of dye as a visual to help students map the experimental elements to the phenomenon.

Supporting Students in Engaging in Developing and Using Models

Mapping the elements of the lab setup to the elements in the phenomenon that we are trying to explain is an important part of the practice of Developing and Using Models. Return to this mapping as needed when students interpret their results and describe the air movement below and within a cloud.

As a class, identify what each part of the lab setup represents in the real world, then have students complete the table on their handout. Use the sample table below to call out the important ways both systems are similar.

This part of the experimental setup . . .	is like . . .	this part of the phenomenon.	How are they the same?
A. Liquid water in a tub	--->	Air outside	Both are fluids and can show convection.
B. Cup with water in it at a temperature higher than A	--->	Earth surface (or the ground)	Both are the source of thermal energy that will heat the fluid above it through conduction.
C. Movement of dye	--->	Movement of the fluid (air or water)	Both can show us the direction of flow or current.

3. Make initial observations and predictions.

12 MIN

Materials: Convection in Fluids: Teacher Demonstration

Demonstrate the setup with no added thermal energy. Have students gather around your demonstration table so everyone can see. Set up two tubs similarly to what students will do for their own investigation. One should have a cup with nothing in it and the second should have a cup filled halfway with warm water (~110°F). Measure the temperature of the water in the cup and record it on the board.

Before you place the empty cup under the first tub and the cup of warm water under the second, ask students what this cup represents in our system (the thermal energy absorbed from sunlight by Earth's surface).

Additional Guidance

In their own investigation, students will vary the temperature or mass of the water they place under the system. For this demonstration, use only warm water at about 100–110°F. You can get this from the faucet or by using an electric coil for a short amount of time. If using an electric kettle, you might need to add a bit of cooler water to the water from the kettle. Measure the temperature of that water to ensure it's in this range. Fill the cup about halfway rather than all the way so students start considering whether they want to compare warmer or cooler and more or less water in the cups for the class's experiments.

Demonstrate how to slide the cup and dispense the dye. Slide the empty cup and the cup of warm water under their respective tubs. Use a pipette to withdraw a few drops of red dye. Repeat to make a second pipette of red dye and then two of blue dye. Ideally the amount of dye should be the same in each, with no air bubbles. Wipe each pipette with a paper towel so there is no dye on the outside or tip.

Start the demonstration on the tub with the empty cup. Insert a pipette with red dye into the water slowly so the tip is just above the bottom at the center of the tub. Explain to students that you are trying not to disturb the water as you slowly dispense the dye at that location. After adding the dye, carefully slide the pipette out of the water while minimizing disturbance.

Now use a blue dye pipette at a different location in the tub. Deploy half of the blue dye near the bottom of the tub at either the left or right edge. Slowly raise the pipette out of the water and deploy the second half of the blue dye just below the water's surface, above where you placed the first half.

Repeat this demonstration on the tub with the cup of warm water using the second set of pipettes with red and blue dye. Give students a couple of minutes to watch what happens in both tubs, then have them return to their seat.

Make observations. Display **slide D**. Give students a couple of minutes to record their observations regarding the dye's movement and direction in both tubs under question 1 on *Convection in Fluids*. Have a few students share their observations with the class. Students should notice these things:

- The dye above the cup with warm water moves up. The dye over the empty cup just remains in a puddle.
- When the dye rising over the warm water cup reaches the surface, it spreads out toward the left and right side of the tub.
- Dye that is not directly above the warm water moves along the bottom toward the region where lift (the current of upward-moving dye) is occurring.

Help students connect what happened in the water to events that might happen in the air outside by having them first talk with a partner about the question on **slide D** and then discuss as a class how the movement of the dye over the warm cup relates to what happens with the air in the atmosphere over warm ground. Example prompts follow.

Suggested prompts	Sample student responses
How is the movement of the red dye upward over the warm cup related to what happens with the air in the atmosphere over warm ground?	*The air rises outside over warm ground.*
Where did we see dye sinking? Where would we expect air do the same thing?	*Farther away from where it was warmed up.*
What happened to the blue dye along the bottom of the tub with the cup of warm water under it? What does that tell us would be happening to air along the ground outside?	*It would be moving toward the area where there was a warmer spot.*

Additional Guidance

Emphasize the horizontal movement of the dye along the top and bottom of the water in the tub during the demonstration. This will lead to naming that same movement of air as wind during the Building Understandings Discussion on day 2.

Say, *So, it seems like it will be important to keep track of the movement of the dye right above the thermal energy source, at the top, and any sideways motion along the bottom of the tub when you collect observations in your own investigation.*

Make predictions. Project **slide E**. Ask students to complete questions 2 and 3 on *Convection in Fluids*. Ask students to share their ideas with the class or a small group. Example prompts follow.

Suggested prompts	Sample student responses
What are some things we could modify about the setup that could lead to changes in the motion we observe in the fluid?	*We could use hotter water.* *Maybe we could add more water.*
What effect do you think those changes would have on the motion of the fluid above the cup? Why?	*If we make it hotter, it might move faster.* *Maybe if it is hotter, more of the dye will move.* *If you use more hot water, maybe the movement will last longer or keep going.*
What effect do you think those changes would have on the motion of the fluid along the bottom of the tub?	*Maybe that would move faster too.*

Alternate Activity

If students suggest making the water in the tub colder, ask why they think that might make a difference. They may argue it would better map to the really cold air high in the atmosphere. If they would like to test this, they can cool down the tub water with ice or add really cold tap water. Make sure to keep the volume of water in both tubs the same if they do either of these tests.

4. Design the investigation.

10 MIN

Materials: *Convection Investigation Plan*

Plan an investigation by identifying variables and test conditions.* Project **slide F**. Say, *To figure out what variables affect the amount and direction of lift, each group will get a lab setup for a different condition to test and then share observations with the class. Let's use our demonstration setup to think through how to design our investigation.*

Identify variables. Distribute *Convection Investigation Plan* to each student and project **slide G**. Refer to the teacher demonstration from earlier to think through the variables in the investigation setup. This demonstration can be used as "Condition 1" on the handout.

Suggested prompt	Sample student response
Let's think about what we did in the demonstration as one of our conditions. What was the initial temperature of our thermal energy source?	*110°F. (Or whatever temperature was recorded on the board.)*

*** Supporting Students in Engaging in Planning and Carrying Out Investigations**
In this investigation, the two dependent variables are the same for all test conditions: the amount and direction of movement in the fluid. Students must consider what needs to be controlled across the test conditions and what to change in their test condition. For example, all groups may control for the water temperature in the

Suggested prompts	Sample student responses
How could we figure out how much water is in each cup?	*We could measure its height.* *We could measure its volume using a graduated cylinder.* *We could weigh it, like we weighed the Ping-Pong ball in the last lesson. We would have to tare the scale with an empty cup on it first.*
If students suggest weighing it, say, "Right, we can weigh it. In cases like this when we just want to know the amount of matter on the scale and not the force of gravity on it, we need to set the scale to grams rather than ounces. Grams is a calculated value that reports the amount of matter on the scale."	
OK, we need to choose which variable we want to test. Why do we need each group to choose just one variable to test at a time?	*Because otherwise we won't know what makes a difference.*
So if I want to test the temperature of the thermal energy source, which variable do I change and which do I keep the same?	*You change the temperature of the water but keep the amount the same.*
OK, so I mark that I will test temperature and that the amount (volume or mass) will be controlled. What other variables should we keep the same in each condition?	*Time.* *Placement of the cup.* *Placement of the dye.* *Amount of dye used.* *Amount of water in the tub.*
Why is it important to keep those things constant?	*To keep it fair so we know if the thing we are testing really makes a difference.*
Our dependent variables are the things we want to measure to see if they are affected. What are the two things we are going to measure for our dependent variables?	*We could watch for the amount of dye that moves and the direction that the dye moves.*
What can we record to capture what we observe about the amount of dye that moves and the direction of its movement in each tub we test?	*We could describe how fast it is moving and draw a picture of the direction it moves.*

tub and test to make sure they are approximately equal. But one group might use this variable as their test condition and use colder or warmer water. It will be important for students to first identify all the variables before deciding which ones to change at each station, while controlling for the other variables.

Alternate Activity

An option is provided to have students identify either mass or volume as the way to control for the amount of matter in the thermal energy source. The former requires them to determine the mass (in grams) of water in their cup, similarly to what you demonstrated in Lesson 11. If you have more than one digital scale available for students to use, mass may be a feasible choice. For controlling for volume, students can use graduated cylinders (though this tends to cause thermal energy loss from the water) or simply make sure the level of the water in their cup is the same if it is the controlled variable or different if it is an independent variable. In that case, they can estimate the fraction of the cup that is filled with hot water. This qualitative comparison of volume is the recommended approach.

Plan the investigation. Give the groups time to plan which variables they will test and what their conditions will be for controlling the other variables. Have students record their decisions and check with you before gathering their materials for testing. Ensure a range of conditions is being tested across lab groups. Possible test conditions include these:

- hot water in the cup (half-full or full cups) and cold water in the tub
- lukewarm water in the cup (half-full or full cups) and cold water in the tub
- cold water in the cup and cold water in the tub
- two cups of hot water and cold water in the tub
- one cup of hot water and one cup of cold water, also using cold water in the tub
- ice floating on the surface of the tub and a cup of hot water below

5. Conduct the investigation. 15 MIN

Materials: Convection in Fluids: Student Investigation

Safety Precautions

Students in a couple of groups will work with hot water. The water should not be above 160°F. Oven mitts are recommended for working with hot water, so have at least two oven mitts available.

Conduct the investigation. Continue to display **slide G**. Each group needs one tub setup similar to the teacher demonstration. Students should first fill the tub with water (to their test volume) before setting up the rest of the investigation so the water can sit for at least 5 minutes undisturbed. They have 15 minutes total to set up the materials, deploy the investigation, gather their data, and clean up so the area and materials are ready for the next class to use.*

Additional Guidance

The investigation works better with cooler water in the tub because that creates a greater temperature difference between the tub and the warm water in the cup. Once the tubs are filled, it is not recommended to leave them at

* Supporting Students in Developing and Using Systems and System Models

As students work, keep the real-world “system” at the forefront of what they are investigating. Ask these questions:

- *What part of the system does this represent?*
- *What would that mean for the real world?*
- *How is this like _____ outside? How is it different?*
- *What would that mean for how tall a cloud could grow?*

room temperature too long or the investigation will not work as well. However, one test condition could be room-temperature water in the tub.

Emphasize that as students conduct their investigation they should record detailed notes in order to share with the class.*

Alternate Activity

Technology option: Consider having students video record their test condition and share the results with the class.

Demonstration option: Deploying the dye is tricky for students, and errors can skew the results. If you prefer, this lab can be run as a teacher demonstration. After students plan the seven or eight test conditions, you can assemble the setups and all students can watch as you deploy the dye for each condition. With this option, it is recommended that students create a data table in their science notebook to record their observations, as *Convection Investigation Plan* is formatted for only one test condition.

Summarize with an exit ticket. Include this step if time allows. As an exit ticket or for home learning, ask students to consider these questions: *Did your test condition produce more or less movement in the fluid than Condition 1? How do you think your results relate back to what happens in and around a cloud?*

End of day 1

*** Supporting Students in Engaging in Planning and Carrying Out Investigations**
An important part of Planning and Carrying Out Investigations is collecting data through either observation or instruments. In labs, data are often numerical. But in this investigation, students collect data in the form of observations as they manipulate the parts of a system to determine what inputs yield different outputs in terms of dye movement in water. Students should record their observations on the investigation handout and provide detailed notes about the direction and speed of the dye movement for comparison with other groups' results.

6. Navigation

5 MIN

Materials: science notebook, *Convection Investigation Plan*

Revisit the lesson question and investigation observations. Show **slide H**. Remind students of the question we are working on, "What causes more lift in one cloud versus another?" Importantly, ask how the data we collected at the end of day 1 help to develop an answer to that question. Have students share their ideas as a class.

7. Report results and make sense of data.

15 MIN

Materials: science notebook, *Explaining Convection in the Air Outside*, *Air Movement in Different Conditions*, tape

Map results in groups for sharing. Project **slide I**. Hand out one copy of *Air Movement in Different Conditions* to each group and ask students to work in their groups to map the results from the condition they tested. Remind them to show

*** Supporting Students in Engaging in Constructing Explanations and Designing Solutions**
Students must use their noticings across the investigations to evaluate claims posed on the handout and explain their thinking.

what would be different about the amount of lift in the air and the winds along the ground in each condition and what caused these differences. Give groups 5–7 minutes to complete their map.

Walk around and pose questions to help groups think about how to represent vertical movement of air (air rising or sinking) and horizontal movement of air (winds).

Students will bring this thinking to the Scientists Circle to share and refine as they update the Progress Tracker.

Conduct a gallery walk. Have students leave their *Air Movement in Different Conditions* out on a desk for other groups to look at, or tape the handouts to a wall or whiteboard. Give students 3 minutes for a silent walkaround to visit the findings from at least three groups who tested different temperatures and masses. Encourage students to use their science notebook to jot down their noticings and wonderings from the other groups' results.

Respond to claims. Project **slide J**. Distribute *Explaining Convection in the Air Outside* to each student and have them respond to the claims on the handout using evidence from the gallery walk.* They will bring their thinking to the class discussion in the next step.

Alternate Activity

You may want to collect *Explaining Convection in the Air Outside* to provide feedback. Or if students need more time to complete this handout, ask them to complete it or revise it as a home learning assignment. Make sure they have some time to complete at least some of the questions in class. If time is short, you can have one half of the class each respond to a different set of questions on the handout.

8. Conduct a Building Understandings Discussion and update the Progress Tracker.

25 MIN

Materials: science notebook, *Explaining Convection in the Air Outside*, chart paper, markers

Gather in a Scientists Circle for a Building Understandings Discussion. Ask students to bring their science notebook, *Explaining Convection in the Air Outside*, and a chair to form a Scientists Circle. Lead a discussion from what students completed on the handout, having them share their claims and the supporting evidence from our investigation, in preparation for updating their Progress Tracker. Example prompts follow.

Suggested prompts	Sample student responses
What were we trying to figure out with our investigation?	*What could cause more or less lift in a cloud.* *We were trying to figure out how really big updrafts could happen.*
What claims can we make about what causes different strengths or sizes of updrafts?	*The hotter it is, the more lift there is.* *The greater the temperature difference, the bigger and faster the updraft.*
Where does the thermal energy come from?	*From the ground (or bodies of water) that are warmed up.*

Suggested prompts	Sample student responses
What originally caused that to get warmed up?	*Light from the Sun.*
What happens in an updraft?	*The particles in the air above that warm surface area speed up and spread out.* *Parcels of air become less dense, so they rise.*
What did we call that kind of movement?	*Convection.*
Why would higher temperature differences between the surface and the air above cause stronger convection?	*More thermal energy is transferred to the air so it rises faster.*
Can we make any other claims about what else might also cause more updraft or lift?	*If more stuff on Earth's surface is warm, there is more lift.*
Why would more warm stuff lead to more convection?	*The more of Earth's surface that is warmer than the air above it, the longer it transfers thermal energy to that air.*
What about other movement? What did we notice happening in the water and dye investigation at the surface and at the bottom of the tub?	*The dye spread out in both directions when it got to the surface.* *The dye from the side moved toward the middle.*
Why did the dye move sideways along the bottom of the tub?	*When fluid leaves a spot, it leaves space for other fluid to come in.*
So if you were standing on the bottom of the tub in the investigation, what would you feel happening?	*You could feel the fluid moving toward you.*
If you were standing outside on Earth's surface, what might you feel in the air that is like that movement?	*Wind!*

Additional Guidance

During this discussion, emphasize that the movement we see in water is sometimes referred to as **currents** but that when this kind of movement happens in the air, it is referred to as **updrafts** if it is moving up, **downdrafts** if it is moving down, and **wind** if it is moving sideways. It is important for students to understand that air can move both vertically and horizontally—this idea will help them in the next lesson set as they study larger air mass interactions. If you use a word wall in your classroom, add these words.

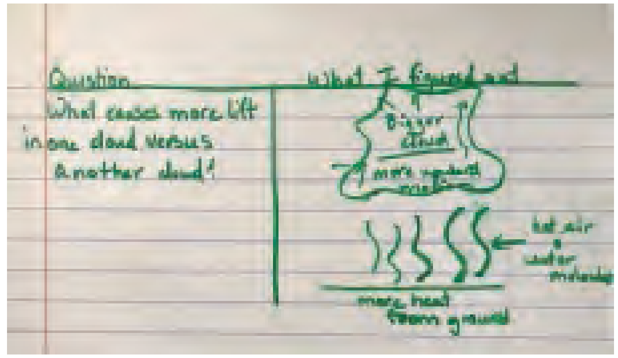
Update the Progress Tracker. Show **slide K**. Ask several students to share ideas about what we have figured out in this lesson to answer the question, "What causes more lift in one cloud versus another?" Record these on chart paper for the class to view. Press students to provide evidence for their idea.

What we figured out: What causes more lift in one cloud versus another?

When some fluid heats up, it becomes less dense, which causes it to rise. When it cools down, it becomes more dense, causing it to sink. This leads to circular motion called **convection**.

The greater the thermal energy input into the fluid, the stronger the lift or convection currents. The more of Earth's surface that is in contact with air above it, the more thermal energy it can transfer to that air.

Some **winds** are the result of this convection. Air at the surface moves toward the area where warmed air rose, filling in the space left behind.



With the class chart as a reference, have students update the Progress Tracker in their science notebook to record and illustrate their own response to the lesson question. They can use ideas from the class chart but can add their own representations and ways of thinking about these ideas.

To summarize at the end of class, say, *We've figured out quite a bit about the movement of air and water vapor. Next time, let's see if we can use all of our ideas to explain why hailstorms form.*

ADDITIONAL LESSON 12 TEACHER GUIDANCE

Supporting Students in Making Connections in Math

In 6th grade, students work on using rates and proportional thinking. This investigation supports students on:

- CCSS.MATH.CONTENT.6.RP.A.3 Use ratio and rate reasoning to solve real-world and mathematical problems . . .

Students consider which independent variable causes faster rates of lift (updraft) and consider the relationship that as more thermal energy is added to the system, the lift is faster.

This lesson also supports students in identifying variables in an investigation, with an emphasis on the independent variable. If students have not used this terminology before, it is equally fine to call this variable the "test variable" or "test condition."

Supporting Students in Making Connections in ELA

At the end of the lesson, students construct explanations using the handout *Explaining Convection in the Air Outside*. This supports students in the following writing standards:

CCSS.ELA-LITERACY.W.6.1 Write arguments to support claims with clear reasons and relevant evidence.

CCSS.ELA-LITERACY.W.6.1.A Introduce claim(s) and organize the reasons and evidence clearly.

CCSS.ELA-LITERACY.W.6.1.B Support claim(s) with clear reasons and relevant evidence, using credible sources and demonstrating an understanding of the topic or text.

CCSS.ELA-LITERACY.W.6.1.C Use words, phrases, and clauses to clarify the relationships among claim(s) and reasons.

LESSON 13

Why do some storms produce (really big) hail and others don't?

Previous Lesson

We planned and carried out an investigation to determine what variables affect the amount of lift produced by transferring thermal energy into a fluid. We explained how the results of our investigation helped us understand how differences between air and ground temperatures can cause different amounts of lift and movement of air.

This Lesson

Putting Pieces Together

3 DAYS

We add to our Gotta-Have-It Checklist from Lesson 10 and do a close reading to add to and support our ideas for how really big hail forms and add that to our checklist. We create a final model to explain why some storms produce hail and others don't and answer other storm-related questions. We take stock of our Driving Question Board to determine what questions we can now answer. We apply our understanding to a new weather phenomenon, a hurricane, on a summative assessment.

Next Lesson

We will explore a weather report and forecast. We will develop a model to explain how what was happening in one part of the country at one point in time could be connected to what is predicted to happen in another part of the country over a day later. We will develop questions for our Driving Question Board (DQB) and brainstorm ways to investigate these questions.

Building Toward NGSS

MS-PS1-4, MS-ESS2-4, MS-ESS2-5, MS-ESS2-6

What Students Will Do

Develop and use a model to describe and explain unobservable mechanisms that drive the cycling of matter and the flow of energy into and through the air to cause some storms to produce large hail while others do not.

Construct an explanation, using a model and previously developed science ideas, to explain what causes hurricanes to form, grow, and produce (effect) strong winds and large amounts of rain (cycling of matter and flow of energy).

What Students Will Figure Out

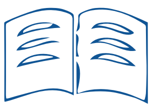
- Our model can explain why some storms produce hail and others don't.
- We are now able to answer many of our initial questions on our Driving Question Board.

Lesson 13 • Learning Plan Snapshot

Part	Duration	Summary	Slide	Materials
1	5 min	**NAVIGATION** Watch a video from our initial anchor in Lesson 1 to frame our modeling work in this lesson.	A-C	hailstorm video (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)
2	12 min	**COMPLETE THE FIRST PART OF THE FINAL MODEL: CLOUD FORMATION** Work in small groups to model the mechanisms behind hail cloud formation using a scaffolded template.	D-E	Gotta-Have-It Checklist from Lesson 10, *Final Hail Model Scaffold*, piece of chart paper, markers, Cloud Growth Time-lapse video (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)
3	10 min	**ADD TO THE GOTTA-HAVE-IT CHECKLIST** Work in pairs to review Progress Trackers from Lessons 11 and 12 to add ideas to the Gotta-Have-It Checklist.	F-G	*Lesson 13: Gotta-Have-It Checklist*, Gotta-Have-It Checklist from Lesson 10
4	18 min	**READ ABOUT THE PATH OF HAILSTONES** We realize that we might need more information to explain what is happening inside the cloud to form really big hail. We do a close reading to add to and support our ideas for how we can get really big hail and add this new information to our checklists.	H-J	*Reading: Tracing Paths of Hailstones*
				End of day 1
5	25 min	**COMPLETE THE MODEL TO EXPLAIN HAILSTORMS** Work in small groups to develop a final model to answer the question: "Why do some storms produce hail and others don't?"	K	*Lesson 13: Gotta-Have-It Checklist*, piece of chart paper, markers
6	20 min	**APPLY THE MODEL** Use the final models to answer questions related to other storm-related weather events.	L	*Revisiting Our Driving Question Board* with the questions from the DQB typed up
				End of day 2
7	30 min	**INDIVIDUAL SUMMATIVE ASSESSMENT** Students individually demonstrate understanding on an assessment to explain air and water movement in a hurricane.		*Hurricane Assessment Tasks*

Part	Duration	Summary	Slide	Materials
8	15 min	**REVISIT THE DQB** Revisit the DQB with the whole class and take stock of all the questions we've now answered.		*Revisiting Our Driving Question Board* with the questions from the DQB typed up
				End of day 3

Lesson 13 • Materials List

	per student	per group	per class
Lesson materials **Student Procedure Guide**  **Student Work Pages** 	• Gotta-Have-It Checklist from Lesson 10 • *Lesson 13: Gotta-Have-It Checklist* • science notebook • *Reading: Tracing Paths of Hailstones* • *Revisiting Our Driving Question Board* with the questions from the DQB typed up • *Hurricane Assessment Tasks*	• *Final Hail Model Scaffold* • piece of chart paper • markers	• hailstorm video (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**) • Cloud Growth Time-lapse video (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)

Materials preparation (30 minutes)

Review teacher guide, slides, and teacher references or keys (if applicable).

Make copies of handouts and ensure sufficient copies of student references, readings, and procedures are available.

Type up or take a high-resolution photograph of all the questions on the DQB.

Display all previous classroom consensus models around the room.

Make sure the DQB is displayed and space is available for the class to gather in a Scientists Circle.

Online Resources

Lesson 13 • Where We Are Going and NOT Going

Where We Are Going

This lesson provides an opportunity for students to synthesize their understanding to develop a final model for why some storms produce hail and others don't. At this point, students should have the pieces they need to explain why some storms produce hail and others don't. In this lesson, they will further explore ideas for why hail can be different sizes and look layered.

Hail is precipitation that is formed when updrafts in thunderstorms carry water droplets or raindrops upward into extremely cold areas of the atmosphere. The hail nucleus, buoyed by the updraft, is carried aloft and begins to grow in size as it collides with supercooled raindrops and other small pieces of hail. There are alternative models for the path that hailstones follow as they grow inside a cloud. One model holds that sometimes a hailstone is blown out of the main updraft and begins to fall to Earth. If the updraft is strong enough, it will move the hailstone back into the cloud where it once again collides with water and other hailstones and grows. This process may be repeated several times. Another model holds that all hailstones form as they continually rise and fall within a cloud, growing the whole time.

In all cases, when a hailstone can no longer be supported by the updraft it falls to Earth. The stronger the updraft, the larger the hailstones that can be produced by the thunderstorm.

Students are asked to apply their final models about hailstorms to explain other storms and why hailstorms don't happen all the time. This application includes using their model to revisit questions from the DQB as well as completing an individual assessment around relevant aspects of hurricanes.

Where We Are NOT Going

Water droplets that freeze and collect on hailstones are often supercooled (at a temperature below 32°F) before they change phases from a liquid to a solid. This can happen when there are no CCNs present to start the crystallization process. Why liquids can be supercooled in such conditions still puzzles scientists today and is not a focus of this lesson.

LEARNING PLAN FOR LESSON 13

1. Navigation

5 MIN

Materials: hailstorm video (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)

Frame the lesson by returning to the anchoring phenomenon from Lesson 1. Show **slide A**, which displays images of hail and presents the question, "What can we explain now?" Play the Fort Scott, KS, hail clip from Lesson 1 to link back to what happens when it hails. (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)

Solicit ideas about what we can now explain. Say, *We have figured out a lot over the past weeks. What are some things that are happening in this phenomenon that we can now explain?* Listen for ideas such as:

- what conditions are needed for hail to form
- how rain and hail can form
- how hail and rain stay up in the sky before falling out
- how clouds form

Introduce the modeling task. Show **slide B.** Say, *At the beginning of the unit we created a time-lapse model for what happens before, during, and after a hailstorm. We have now gathered lots of evidence to help us explain this phenomenon.*

We will create a model to explain the hailstorm and then see if our model can help explain other weather-related phenomena.

Show slide C. Say, *To help us with this task it seems like there are some key questions we can answer in our model. We will use these questions to guide our modeling as we go.*

In this lesson, students will use three questions to scaffold the development of a final model to explain a hailstorm.

- Q1: Why do hail clouds form?
- Q2: How does hail form in a cloud and how can it get bigger?
- Q3: Why does the hail eventually fall out?

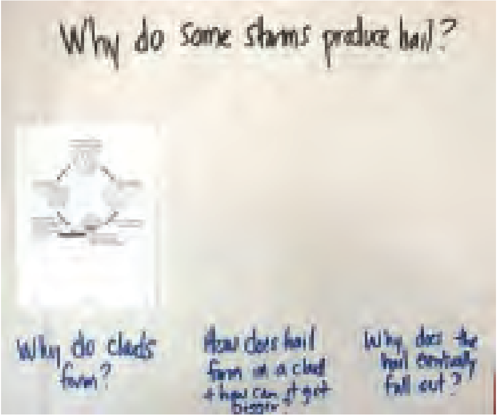
Say, *Let's start by recapping our existing explanation for how a hail cloud and other clouds form.*

2. Complete the first part of the final model: cloud formation. 12 MIN

Materials: Gotta-Have-It Checklist from Lesson 10, *Final Hail Model Scaffold*, piece of chart paper, markers

Re-watch the video of hail clouds forming. Display **slide D**. Say, *In Lesson 10 we worked on explaining how storms and clouds form. Let's look back at the video showing the formation and growth of a few different clouds over the course of the day. Toward the end of the video, one of them develops into a cumulonimbus cloud.*

Show the cumulonimbus cloud growth time-lapse video from Lesson 6. Ask students to share what they notice about the cumulonimbus cloud and its formation. Ask if we saw this movement anywhere else. (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**) Students may mention that they saw this movement in the simulation of a really big cloud forming and in their convection bins from the previous lesson.



Pass out *Final Hail Model Scaffold* and a large piece of chart paper. *Final Hail Model Scaffold* helps scaffold the first part of the model. Students revised their models and explanations for cloud and storm formation in Lessons 6-10. Accordingly, this portion of the final model is scaffolded so that students can develop a model in a relatively short amount of time before moving on to Q2 and Q3, which will ask them to apply new ideas that they have learned since Lesson 10.

Explain the modeling task. Show **slide E**. Tell students that they can use *Final Hail Model Scaffold* as a starting point. Explain that they should attach the scaffold for the first part of the model to the left side of their big chart paper. Tell students to add pictures, symbols, and words to explain why hail clouds form. Encourage them to use their Gotta-Have-It Checklist from Lesson 10.

Students model in small groups. Give students 8–10 minutes to complete this first part of the model.

3. Add to the Gotta-Have-It Checklist. 10 MIN

Materials: *Lesson 13: Gotta-Have-It Checklist*, science notebook, Gotta-Have-It Checklist from Lesson 10

Show slide F. Say, *But this doesn't explain hail formation and how it stays up there before falling out. Before we continue with our model, let's revisit our Gotta-Have-It Checklist from Lesson 10 and see what ideas we can add to help us answer Q2 and Q3 on our model.*

Review the use of the Gotta-Have-It Checklist. Pass *Lesson 13: Gotta-Have-It Checklist* to each student. This will be taped or glued into students' science notebooks. Use **slide G** to remind them how to build a checklist. Students will complete only the left column right now. They should leave the right columns blank for now.

Pairs work together to add to their checklists. Direct students to find their Progress Tracker in their notebooks and their Gotta-Have-It Checklists from Lesson 10. Tell students that our checklists from Lesson 10 have a lot of the pieces to be able to explain our hailstorm, but now we have even more information from our investigations in Lessons 11 and 12 that can help us answer why some storms produce hail and others don't.

Have students gather in pairs to add any additional ideas that aren't on their Progress Trackers from Lesson 10 to *Lesson 13: Gotta-Have-It Checklist*. They do not need to record all the model ideas from the Progress Tracker, only the ones they want to include in their new models. Students should spend up to 10 minutes working with their partner.

Listen in on groups as they are working. Ask students why the ideas they are discussing are important to the explanation. Listen for some of the following ideas as you talk with groups:

- There is air pushing up (lift) on water droplets and ice crystals that can keep them up in the air. Gravity is also exerting a force on those water droplets and ice crystals.
- When the lift force is greater than the force from gravity, particles that are suspended will start to move upward, but when the force from gravity is greater than the lift force (or there is no lift force), the particles will start to fall downward.
- The bigger the temperature differences between the ground and air, the bigger this movement of air (convection).
- When you have big movement upward, a lot of water, dust, and other particles can be pushed up really high where it is cold, so the water droplets freeze and you get hail.

*** Supporting Students in Engaging in Developing and Using Models**

An alternative to having students work on the Gotta-Have-It Checklist alone, in pairs, and in groups is to construct the checklist together as a class with a public representation of the ideas the class agrees should be part of the consensus model. If you make a modification to the current activity, keep in mind the following important components to make this activity a productive one:

- The process should be collaborative and involve students arguing from evidence for their ideas.
- There should be a public record, or artifact, of the ideas students agree to include in their models.

4. Read about the path of hailstones. 18 MIN

Materials: *Reading: Tracing Paths of Hailstones*

Problematize the formation of really big hail. Say, *While it seems like we can explain how hail forms, we haven't yet explained what is happening inside the cloud to cause hail of different sizes and looks to form.*

Show **slide H** and give students a moment to examine the photos of hail again. Ask students to describe the differences. Students should notice that some hailstones are bigger, some are clear, some are cloudy, and some have rings. Ask students to turn and talk about what might cause such large hailstones to form and what might cause differences in their appearance. Ask students to share a few ideas.

Students do a close reading. Tell students you have a reading that might provide us with some further information and allow us to compare the ideas we have so far with the ideas in the reading. Pass out *Reading: Tracing Paths of Hailstones*. Students should be familiar with the close reading strategies. Students should read to answer the bigger lesson question, "Why do some storms produce hail?" and more specifically, "How can hailstones get so big?" Show **slide I** as a reminder and give students 10-15 minutes to complete the close read.

Facilitate a whole-class discussion about new ideas from the reading. Project **slide J**. Bring the group together to discuss any new ideas students have gained from the reading that they think should be included in our models to help explain how hailstones can get so big and form rings. Add ideas to the Gotta-Have-It Checklist as the class agrees.

Suggested prompts	Sample student responses
Was there anything in the reading that supported the ideas we already had?	*Strong updrafts can make hail way up high in the cloud.* *Big differences between the ground and air make bigger storms.*
What were some new ideas you think we need to include in our models?	*The faster the updraft speed the bigger the hail.* *Bigger updrafts mean the hail stays in the cloud longer so hail can get bigger as water droplets stick to it.* *There are two ideas for how hail gets big:* ◦ *It goes up and down on the convection of air and gets bigger and bigger.* ◦ *It just keeps getting bigger as it goes up until it eventually falls out.* *Hailstones form by colliding with water droplets that freeze on it over time so the frozen water forms clear layers.* *Hailstones collide with supercooled water droplets that freeze immediately so the additional layers are cloudy.* *When hail forms both ways you get the layered look.*
How (if at all) would we need to revise our model to support either of the two ideas under consideration by the larger scientific community for how the hail gets as big as it does?	*It seems like our convection model could be used to explain either.* *We would just have to show the paths of hail in both cases and how convection in the storm cloud could explain either.*

Suggested prompt	Sample student responses
Can we explain now how hail is different from rain or snow?	*Hail needs warm temperatures near the ground to cause big updrafts. The updrafts keep the ice crystals in the atmosphere and they turn into hailstones.* *But with rain, the updrafts are not as strong, so the ice crystals fall back to Earth quicker and melt into raindrops.* *There are not very strong updrafts with snow, but because the air temperatures near the ground are cold, when the ice crystals fall, they don't melt before they land so they are snowflakes instead of raindrops.*

Tell students that in the next class they can start adding these ideas to their final models.

End of day 1

5. Complete the model to explain hailstorms.

25 MIN

Materials: *Lesson 13: Gotta-Have-It Checklist*, science notebook, piece of chart paper, markers

Small groups develop final models. Use **slide K** to orient students to the task. Ask students to label the Q2 (How does hail form in a cloud and how can it get bigger?) and Q3 (Why does the hail eventually fall out?) on their large chart paper next to the first part of the model they created on day 1 of this lesson.

Students should then use their Gotta-Have-It Checklists to create a model using words and pictures to answer the question, "Why do some storms produce (really big) hail and others don't?" As they use an idea from their checklists, students should check the appropriate column on their lists.

Additional Guidance

If time allows, this would be a great opportunity for students to provide and receive feedback on their models. Consider a gallery walk where students are asked to visit at least two other models and provide specific feedback on sticky notes.

6. Apply the model. 20 MIN

Materials: *Revisiting Our Driving Question Board* with the questions from the DQB typed up

Explain the activity. Show **slide L.** Say, *Models are most powerful when we can use them to explain other phenomena or answer questions we have. Let's see if our models can answer some of our questions.*

Pose a question or have students select a question they would like to answer. Students can use large sticky notes or pieces of paper on which their question is recorded and attach the sticky notes or paper to their models as they use their models to explain the answer to the question. Some possible questions include:

- Why don't hailstorms always happen?
- Why do hailstorms form sometimes and not others?
- Why would rain or snow form instead of hail?

Alternatively, pick a question off the DQB that students can use their models to explain (students can use *Revisiting Our Driving Question Board* or the class DQB).

Additional Guidance

Students can also use whiteboards, colored paper, or an electronic document to capture their thinking in response to the questions posed or that they choose. If they select a question off the Driving Question Board, they can attach the sticky note to a piece of paper, record the answer, and return it to the DQB.

Direct students' attention to the list of related phenomena from Lesson 1. Say, *Up until now we've been developing a model that explains lots of the short-term precipitation phenomena we brainstormed in Lesson 1. But if we look at this poster we can see that we also wanted to explain longer term precipitation phenomena at the start of the unit. Let's see if any parts of the model we developed for explaining hailstorms could also be used to explain a precipitation event that occurs over a longer time scale and is much bigger.* Let students know that they will have a chance to apply their understanding to another phenomenon, hurricanes, on an individual assessment the next day.

End of day 2

7. Individual Summative Assessment 30 MIN

Materials: *Hurricane Assessment Tasks*

Ask students to recall some of the larger scale precipitation phenomena we said we wanted to explain beyond hailstorms. Refer to the Related Phenomena poster as needed. Generate excitement around the idea of trying to apply our understanding to a hurricane, one of these phenomena.

Administer *Hurricane Assessment Tasks* to students to work on individually. This will take students a little over half of a class period to complete.

Attending to Equity
This assessment encourages students to demonstrate their understanding of key skills and concepts from the unit so far through multiple different

Assessment Opportunity

If your students are struggling or you think they will need support in creating the model, consider letting them use their Gotta-Have-It Checklists for this assessment task. See *Gotta-Have-It Checklist* for an example, but it is best to use the list that your students generated in previous lessons.

8. Revisit the DQB. 15 MIN

Materials: *Revisiting Our Driving Question Board* with the questions from the DQB typed up

Have students work in pairs to evaluate what questions the class has answered from the DQB. Project **slide N**. Refer students to *Revisiting Our Driving Question Board*, which contains all of the student questions from the DQB. If they did not do so on day 2, they can now tape it into their science notebooks. Have students work with a partner to mark questions they think the class has answered:

- We did not answer this question or any parts of it yet: **O**
- Our class answered some parts of this question, or I think I could answer some parts of this question: ✓
- Our class answered this question, or using the ideas we have developed, I could now answer this question: ✓+

Review and share the questions that students think we have answered. Present **slide O** and have students work with a partner to mark the questions on the class DQB that they think we have made progress on with sticky dots.

Then have students move into their Scientists Circle.

Look for patterns using the sticky dots. In the Scientists Circle, focus on the questions that have the most sticky dots.

Discuss as a class the questions the class can now answer. Present **slide P** if needed. Have the class discuss the answers to these questions as a group. If you have space, you might make a Takeaways board that has a record of the answers the class comes up with.

Assessment Opportunity

While students are answering questions from the Driving Question Board, this is an excellent formative assessment opportunity used to address partial understandings and see if any pieces need to be revisited.

Alternate Activity

Another option is to have students work on answering their own questions that they posed either individually or in pairs. This could be done by attaching a question to a sheet of paper and answering it in words and/or pictures. The focus should be on those questions that we have not answered but feel we could now (or partially could) with the ideas we have developed in order to help students feel like they made progress on their own questions.

modalities, including writing to explain and drawing models. Some students may benefit from using multiple modalities to show their thinking for any or all of the questions on this assessment. You may consider allowing some students to present their answers verbally with you or have another student acting as a scribe to record their thinking on paper. Other students may benefit from using gestures rather than images to describe parts of their models. Some students might also benefit from using manipulatives to represent parts of the model and to support a written or verbal explanation of what's happening in each part of the model. In each case, encouraging students to use multiple modalities to show their thinking creates a clear, accessible, and equitable pathway for all students to demonstrate proficiency.

Additionally, some teachers start a Wonder board, on which questions that have not yet been answered, but students are still interested in pursuing, are housed. These questions are available for students to pursue independently or as time allows.

ADDITIONAL LESSON 13 TEACHER GUIDANCE

Supporting Students in Making Connections in ELA

CCSS.ELA-LITERACY.RST.6-8.2: Determine the central ideas or conclusions of a text; provide an accurate summary of the text distinct from prior knowledge or opinions.

Tracing Paths of Hailstones and the close reading protocol provide an opportunity for students to summarize the central ideas of the text around the questions, “Why do some storms produce hail?” and more specifically, “How can hailstones get so big?”

LESSON 14

What causes a large-scale precipitation event like this to occur?

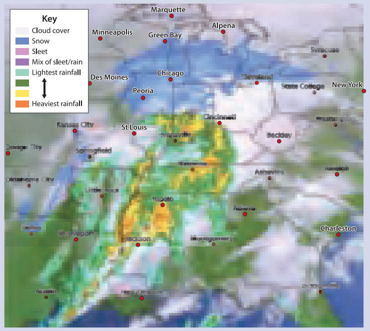
Previous Lesson

We added to our Gotta-Have-It Checklist from Lesson 10 and did a close reading to add to and support our ideas for how really big hail forms and add that to our checklist. We created a final model to explain why some storms produce hail and others don't. We took stock of our Driving Question Board to determine what questions we could now answer. We applied our understanding to a new weather phenomenon, a hurricane, on a summative assessment.

This Lesson

Anchoring Phenomenon

2 DAYS



We explore video and maps from three parts of a weather report and forecast from Jan. 19, 2019. We develop a model to explain how what was happening in one part of the country at one point in time can be connected to what is predicted to happen in another part of the country over a day later. We develop questions for our Driving Question Board (DQB) and brainstorm ways we could investigate these questions.

Next Lesson

We will use temperature, humidity, and radar data of the storm across eight-hour increments to track the movement of air and precipitation. We will consider how air moves horizontally in large parcels, called air masses, and notice that precipitation and storms develop where air masses of different characteristics meet. As a class, we will develop different ways of representing what is happening with warm air and cold air across the land.

Building Toward NGSS

MS-PS1-4, MS-ESS2-4, MS-ESS2-5, MS-ESS2-6

What Students Will Do

Analyze data using maps of national weather conditions and forecasts to identify temporal and spatial relationships (patterns) between precipitation, cloud cover, temperature, and air pressure.

Develop an initial model to explain how precipitation that is happening in one part of the country at one point in time could be connected (cause/effect) to what is predicted to happen in another part of the country at a later time. Use a previous model to identify mechanisms at the observable and the particle levels to explain the causes of this large-scale weather phenomenon.

Ask questions about possible patterns in and causes for a storm affecting large parts of the country over multiple days or causes shared between this precipitation event and a smaller-scale, shorter-duration precipitation event (a hailstorm).

What Students Will Figure Out

- Some storms are very large (hundreds of miles across) and can last for many days.
- These large-scale storms can produce different types and amounts of precipitation over different areas.
- Many of the mechanisms we used to explain smaller-scale precipitation events could be relevant for explaining large-scale storms.
- Large-scale storms also may have something to do with large areas of cold air and warm air moving over great distances.

Lesson 14 • Learning Plan Snapshot

Part	Duration	Summary	Slide	Materials
1	3 min	**NAVIGATION** Review the precipitation-related phenomena that we've explained and which we have not.	A	
2	17 min	**NOTICE AND WONDER**	B-D	*Snowfall and Ice Accumulation Forecast Maps*, *Cloud Cover and Precipitation Map*, Weather Report and Forecast video (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)
3	10 min	**DEVELOP AN INITIAL MODEL AND EXPLANATION** Individually develop an initial model and explanation to answer two questions related to this weather forecast.	E-F	*Initial Model*, colored pencils, *Cloud Cover and Precipitation Map*
4	11 min	**COMPARE MODELS AND EXPLORE MORE OF THE FORECAST** Make predictions on how previous model ideas might connect to this new phenomenon. Explore a third part of the video using a related transcript and maps.	G-H	*Evaluating Connections to Our Previous Model*, *Images from the Jan. 19, 2019 Weather Forecast*, Weather Report and Forecast video (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)
5	4 min	**UPDATE MODEL ALIGNMENT** Revise predictions on how previous model ideas might connect to this new phenomenon.	I	*Evaluating Connections to Our Previous Model*
				End of day 1

Part	Duration	Summary	Slide	Materials
6	17 min	**COMPARE MECHANISMS AND DEVELOP A CONSENSUS RECORD** Compare mechanisms with others. Convene a Scientists Circle to develop an initial consensus record of mechanisms we are in agreement on and additional ones we think may apply to explaining this new phenomenon.	J-K	Previously Used Mechanisms poster, chart paper, markers, sticky notes
7	20 min	**DEVELOP QUESTIONS AND ADD TO THE DRIVING QUESTION BOARD** Record initial questions for the DQB. Develop the DQB with contributions from all students in the class.	L-M	Previously Used Mechanisms poster, Additional Mechanisms poster, chart paper, markers, sticky notes
8	8 min	**IDENTIFY ADDITIONAL SOURCES OF DATA NEEDED** Develop ideas for future sources of data needed to investigate our questions.	N	Future Investigations and Data We Need poster, chart paper, markers *End of day 2*
		SCIENCE LITERACY ROUTINE Upon completion of Lesson 14, students are ready to read Student Reader Collection 5 and then respond to the writing exercise.		Student Reader Collection 5: *Convection, Hail, and Other Events*

Lesson 14 • Materials List

	per student	per group	per class
Lesson materials **Student Procedure Guide** **Student Work Pages**	• science notebook • *Snowfall and Ice Accumulation Forecast Maps* • *Initial Model* • colored pencils • *Evaluating Connections to Our Previous Model*	• *Cloud Cover and Precipitation Map* • *Images from the Jan. 19, 2019 Weather Forecast*	• Weather Report and Forecast video (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**) • computer and projector • Previously Used Mechanisms poster • chart paper • markers • sticky notes • Additional Mechanisms poster • Future Investigations and Data We Need poster

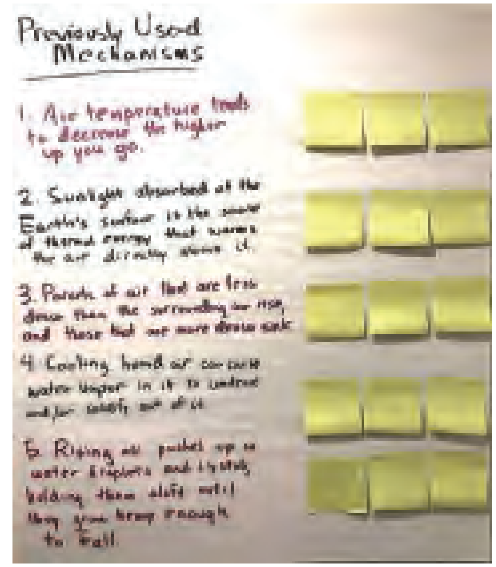
Materials preparation (20 minutes)

Online Resources

Review teacher guide, slides, and teacher references or keys (if applicable).

Make copies of all handouts and ensure sufficient copies of student references, readings, and procedures are available.

Make a Previously Used Mechanisms poster on chart paper. For each mechanism, place 3 blank sticky notes in a row. You will reuse this poster for each class by covering these sticky notes with additional blank ones.



Test the video link. (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)

Prepare a set of color copies of the following for each student in your largest class of students.

- Insert a color copy of *Snowfall and Ice Accumulation Forecast Maps* into a clear document protector.

Prepare a set of color copies of the following for every two students in your largest class of students.

- Insert a color copy of *Cloud Cover and Precipitation Map* into a clear document protector.
- Insert a color copy of *Images from the Jan. 19, 2019 Weather Forecast* into a clear document protect or.

You will collect these three color references at the end of each class to redistribute to students in the next class. These will be used on both day 1 and day 2 of this lesson, and again in lesson 17 and lesson 18.

LEARNING PLAN FOR LESSON 14

1. Navigation

3 MIN

Materials: science notebook

Take stock of the phenomena we've explained and which remain to be explained. Present **slide A.** Read the questions on the slide, give students a half minute to think on their own, remind them that we have a chart of related-precipitation phenomena that the class made from Lesson 1 to refer to, and then discuss the related questions as a class.

Suggested prompts	Sample student responses
What types of precipitation events have we explained so far?	*Hailstorms, small-scale rainstorms.* *Hurricanes (partially).*
What were some other types of precipitation events that occur on a larger scale that we also wanted to explain?	*Blizzards.* *Rainstorms that last for a really long time.*

Say something like, *We were able to apply some of the ideas we developed for explaining a small-scale precipitation event like a hailstorm to a large-scale precipitation event like a hurricane. Let's see whether any of those ideas can also help us explain anything about another large-scale precipitation event we thought of from Lesson 1.*

Additional Guidance

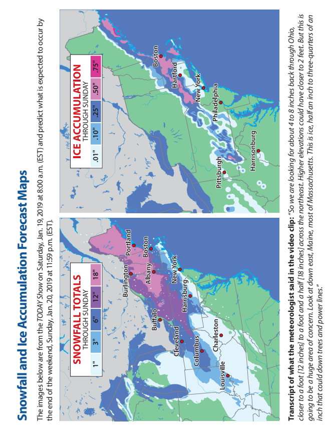
The Related Phenomena poster from Lesson 1 is very likely to have listed on it blizzards or snowstorms as well as hurricanes. This is what multiple pilots of this unit have uncovered is a recurring pattern in student thinking. If snowstorms or blizzards aren't listed on it from Lesson 1, take an extra couple of minutes before this point to brainstorm examples of additional large-scale precipitation events other than hurricanes that students have heard about or experienced. This is likely to generate examples such as blizzards, multi-day rainstorms, monsoons, and hurricanes, depending on your students' prior experiences.

2. Notice and Wonder

17 MIN

Materials: science notebook, *Snowfall and Ice Accumulation Forecast Maps*, *Cloud Cover and Precipitation Map*, weather report and forecast video, computer and projector

Prepare a Notice and Wonder chart in notebooks. Show **slide B**. Say, *We were interested in hearing about how big snowstorms can occur. I have an example of such a phenomenon for us to explore together. It is in the form of a short video clip of a weather report and forecast from January 19, 2019. Watching this forecast got me wondering about some things. Let's get ready to watch the video together and explore some of the related images from it.*



Distribute copies of *Snowfall and Ice Accumulation Forecast Maps* to students as they set up their Notice and Wonder chart. Show **slide C**. Play only the last part of the video (from 1:02 to the end). (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)

Say, What do you notice and wonder about these snow and ice accumulation predictions? Give students 3 minutes to record what they notice and wonder in the row for part 1.

Then for about another 3 minutes discuss what students recorded. Expected student responses include the following ideas:

- *This is a big event. It is going to affect a lot of the country. Is it all connected?*
- *The ice looks like it will fall and form in a line running to the northeast.*
- *The snow also looks like it forms a wide line running to the northeast. Why is that?*
- *The snow is predicted to fall over a bigger area than the ice forms, but they overlap. Why is there both ice and snow in some areas but just snow in others?*
- *The heavy snow and ice is in the center of where batches of snow and ice fall.*

*** Supporting Students in Developing and Using Patterns**
Students have had only one experience so far analyzing data on a map in the 6th grade scope and sequence: the hail maps from Lesson 2. If students have questions about where particular states are located, it may be useful to reference the location of your school on the map, if relevant, or point out the location of a few large states near the edges of the map such as Texas, Florida, and Maine. Students may wonder about what the cardinal directions on the map are. It may be helpful to draw a compass indicating the N, S, W, E directions on the board for reference. Students will be looking for spatial and temporal patterns in data on maps at this scale throughout the remaining

- *The ice and snow fall ends at the border with Canada. Does it just stop there or is it just cut off because the forecast is for the United States?*
- *There is no ice or snowfall accumulation on the Great Lakes (or on the Atlantic Ocean). What happens to it when it falls onto the surface of a lake or ocean?*
- *They said higher elevation will have more snow. Are these in the mountains or something?*
- *They said ice (½ to ¾ inch) could down trees and power lines. Is that frozen ice that is falling, like hail or sleet, or is it rain that fell and then froze when it hit the ground, trees, power lines?*

Explore more of the video and related data. Show **slide D**. Say, *We saw one part of a video showing predicted weather over the weekend. Let's look at another part of the video now that shows the actual cloud cover and precipitation over the middle and eastern parts of the United States just before the forecast was made. Just like before, you will get a related handout showing images from the video to explore after we watch the video. Discuss your noticings and wonderings from this section with an elbow partner and then record them in row 2 of your table.*

Distribute *Cloud Cover and Precipitation Map*, one to each pair of students. Play only the first part of the video (from 0:00 to 0:20). (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)

Give students four minutes to work with a partner to discuss and record what they notice and wonder about part 2.*

Then discuss these as a whole class for about 3 minutes. Expected student responses include these ideas:

- *There are different kinds of precipitation happening over the middle of the United States, including snow, sleet, and rain.*
- *The rain is falling in clusters, but the clusters kind of clump together to form a shape that also has a slant to the northeast, kind of like the shape of where the snowfall is predicted.*
- *A big area of snow is to the north of the rain, but there is also a thin line of snow and some sleet to the west of the rain.*
- *There is no precipitation in the northeast right now.*
- *She said that there were tornado watches further south until 1:00 p.m.*
- *She said that there are two parts to this storm: a cold part and a warm part.*
- *She said that the snow will move eastward.*
- *She said that there was a rainy side of the storm that will continue to move eastward.*

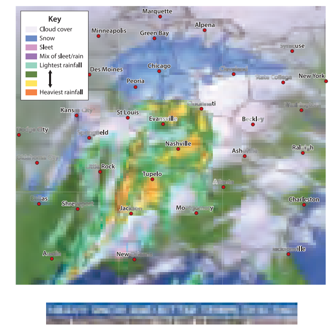
Additional Guidance

The last four expected responses come from an analysis of the transcript from the video, which is on *Cloud Cover and Precipitation Map*. The first of these is not a critical one to draw out, as it is an aspect of the storm system students will not develop an explanation for. The last three, however, are key ones to make sure students raise: that there is a cold part and a warm part to the storm and an eastward movement to the snow and rainfall. If students don't suggest these in the first pass of asking them what they notice, ask them what else they noticed from the transcript of the video.

lessons of the unit and in the next unit (the Everest Unit), so this also is a good opportunity to gauge their initial literacy with analyzing such data sources.

Cloud Cover and Precipitation Map

Cloud cover and precipitation falling at 8:00 a.m. (EST) on Saturday, Jan. 19, 2019



The image above illustrates separate images captured from the video.

Transcript of what the meteorologist said in the video clip:

"And it looks like the worst is yet to come. There is a lot going on here. There are two parts to this storm. We have the cold part and the warm part, and where it is snowing right now, this snow will continue to move eastward, and right in between the snow and the rain, that is where we have the icing potential. If you take this farther south, we have tornado watches in effect until 1:00 this afternoon. So the rainy side of this storm has the potential to be severe as well. So this will continue to move eastward."

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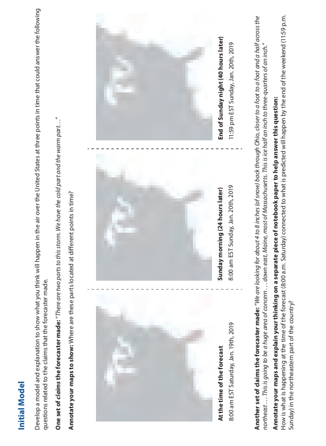
3. Develop an initial model and explanation. 10 MIN

Materials: science notebook, *Initial Model*, colored pencils, *Cloud Cover and Precipitation Map*


Initial Model

Frame the goal of the modeling work. Show **slide E**. Hand out *Initial Model*. Say, *In the past we found it useful to develop explanations for weather phenomena by showing what is happening over time. Let's do that again, but this time, develop a model to show what you think will happen in the air over the United States at three points in time that could address the claims the forecaster made in the video.*

Read the claim the forecaster made, *There are two parts to this storm. We have the cold part and the warm part*. Remind students to show and explain on their handout where these parts are located at different points in time. Tell students that they can look back at *Cloud Cover and Precipitation Map* to inform their predictions.

Explain that this is an important opportunity for you to understand their thinking before investigating this phenomenon in greater depth. Ask students if they have any questions about this part of the modeling task. Then tell students that you will pause their work after a few minutes to introduce a second part of the task.*

Show **slide F**. Read the additional claims that the forecaster made: *We are looking for about 4 to 8 inches (of snow) back through Ohio, closer to a foot to a foot and a half across the northeast . . . This is going to be a huge area of concern . . . down east, Maine, (and) most of Massachusetts. This is ice, half an inch to three-quarters of an inch.*

Read the new question students are considering, *How is what is happening at the time of the forecast (8:00 a.m. Saturday) connected to what is predicted to happen by the end of the weekend (11:59 p.m. Sunday) in the northeastern part of the country?* Instruct students to include additional annotations on their maps to answer this new question, add the map to their notebook, and respond to this question in writing on the adjoining page of their notebook.

* Supporting Students in Engaging in Developing and Using Models

Since this is students' first experience in the 6th grade unit scope and sequence in developing an explanatory model to account for phenomena at this large of a scale, be prepared to help support students further. They may need additional support around what they are trying to develop a system model of. Consider saying something like, *You may not be used to trying to visualize any differences in the air above Earth's surface when looking down on it from high above. Start by trying to show where the cold air and warm air are located. Colored pencils may be helpful for this. Then consider how to show any interactions or changes occuring in that air using other symbols, arrows, and labels.*

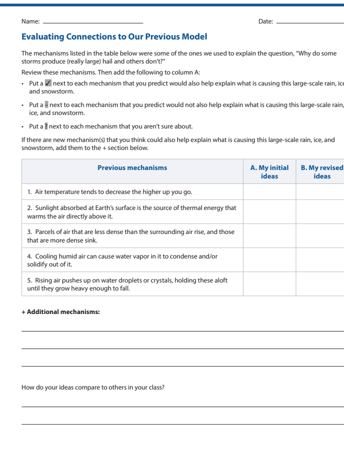
4. Compare models and explore more of the forecast. 11 MIN

Materials: science notebook, *Evaluating Connections to Our Previous Model*, *Images from the Jan. 19, 2019 Weather Forecast,* computer and projector, Weather Report and Forecast (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)

Connect to previous model ideas. Show **slide G**. Say something like, *I want you to now take a moment to compare your explanations so far for this phenomenon to the explanations we developed for hailstorms.*

Hand out a copy of *Evaluating Connections to Our Previous Model* to each student. Give students three minutes to complete the directions on **slide G.**

Explore the entire forecast. Show **slide H**. Explain to students that you will show them the whole forecast video now, which will include a third part they haven't seen yet. Tell students that after watching this, they will talk with a new partner about what they noticed and wondered and discuss which of the five mechanisms on their handout they think would apply to explaining why this phenomenon occurs. They will also record any additional mechanisms they think might be at work.


Name: ______ Date: ______

Evaluating Connections to Our Previous Model

The mechanisms listed in the table below were some of the ones we used to explain the question, "Why do some storms produce (really large) hail and others don't?"

Review these mechanisms. Then add the following to column A:

- Put a ✓ next to each mechanism that you predict would also help explain what is causing this large-scale rain, ice, and snowstorm.
- Put a – next to each mechanism that you predict would not also help explain what is causing this large-scale rain, ice, and snowstorm.
- Put a ? next to each mechanism that you aren't sure about.

If there are new mechanism(s) that you think could also help explain what is causing this large-scale rain, ice, and snowstorm, add them to the + section below.

Previous mechanisms	A. My initial ideas	B. My revised ideas
1. Air temperature tends to decrease the higher up you go.		
2. Sunlight absorbed at Earth's surface is the source of thermal energy that warms the air directly above it.		
3. Parcels of air that are less dense than the surrounding air rise, and those that are more dense sink.		
4. Cooling humid air can cause water vapor in it to condense and/or solidify out of it.		
5. Rising air pushes up on water droplets or crystals, holding these aloft until they grow heavy enough to fall.		

+ Additional mechanisms:

How do your ideas compare to others in your class?

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Distribute a copy of *Images from the Jan. 19, 2019 Weather Forecast* to each pair of students. Play the full video from start to finish. (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**) Give students the remaining time to work with their partner.

5. Update model alignment. **4 MIN**

Materials: science notebook, *Evaluating Connections to Our Previous Model*

Connect to previous model ideas. Show **slide I.** Say something like, *Look back at your predictions you made in column A of Evaluating Connections to Our Previous Model. What would you say now after having discussed the remainder of the weather video and related images and transcript with a partner? Have your predictions changed? Have you thought of additional mechanisms that you think might be at work? Add your revised ideas to column B. You can also add more ideas to the additional mechanisms now if you want, but don't fill out your response to the last question yet. We will save that for our next class.*

Give students the remaining time to complete their revised predictions and attach the handout to their notebooks. Their notebooks should now contain these two handouts: *Initial Model* and *Evaluating Connections to Our Previous Model*.

Collect all three of these from students to redistribute for your next class: *Snowfall and Ice Accumulation Forecast Maps*, *Cloud Cover and Precipitation Map*, *Images from the Jan. 19, 2019 Weather Forecast*.

End of day 1

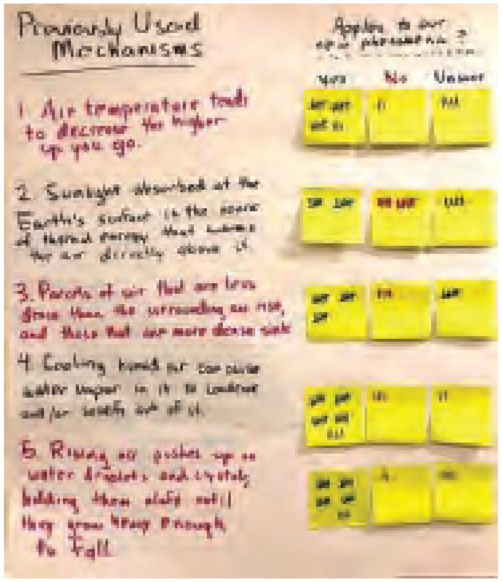
6. Compare mechanisms and develop a consensus record. **17 MIN**

Materials: science notebook, Previously Used Mechanisms poster, chart paper, markers, sticky notes

Hand back science notebooks to students that you collected last time. Pair students up with new partners. Show **slide J.** Have students compare and record areas of agreement and disagreement.

Gather in a Scientists Circle. Present **slide K**. Tell students to bring their science notebooks and their handouts with them, along with chairs, to form a Scientists Circle. Hang the Previously Used Mechanisms poster near the Driving Questions Board where students can see it.

Tell students, *Remember that the goal of this discussion is to figure out areas of agreement and disagreement between our initial models and explanations for this new kind of large-scale precipitation event. Knowing where we agree and disagree will help us figure out more about what might be happening in large-scale weather phenomena like this one.*



*** Strategies for This Consensus Discussion**
There are two goals of this discussion: (1) to help students continue to build the habit of sharing their initial ideas publicly and (2) to generate a variety of additional ideas about what might be causing these precipitation events. As such, it is important to accept all student responses and encourage students to share their ideas. Further, it is important to highlight any areas of disagreement and help students clearly explicate their thinking. Be

Classroom consensus model mapping. Poll students on mechanisms that we are in agreement about for applying to this phenomenon. Keep a record of results as a tally on the sticky notes on the chart.

Hang a new piece of chart paper and title it "Additional Possible Mechanisms". Have students share out additional mechanisms they came up with. For each idea shared, write it on the chart paper. Then poll students to determine how many had something similar. Keep a tally of these results next to each idea as well.

You will reuse the Previously Used Mechanisms poster by covering the sticky notes showing the tallies with additional blank sticky notes for each new class. You may want to sum up all the classes' totals after this lesson and post the total on top of each sticky-note stack to represent the results across all of your classes. The Additional Possible Mechanisms chart paper will be new in each class.*

careful not to favorably respond to any one idea over another so as not to "give away" what might be going on.

7. Develop questions and add to the Driving Question Board.

20 MIN

Materials: science notebook, Previously Used Mechanisms poster, Additional Mechanisms poster, chart paper, markers, sticky notes

Record additional individual questions. Remain in a Scientists Circle. Make sure extra markers and sticky notes are provided. Say, *Let's try to capture questions we now have about what is happening in this sort of large-scale precipitation event and add to our Driving Question Board.*

Present **slide L**. Give students 4 minutes to generate their questions on sticky notes.

Present **slide M**. Remind students that our goal is to capture all our questions and expand our DQB. Suggest that we post our questions around the edges of the Previously Used Mechanisms and Additional Mechanisms posters.

Review these steps as needed for forming the DQB:

- The first student comes up to the DQB with a sticky note, faces the class, and remains standing.
- The student reads their question off the note and then posts it on the DQB near the section of the consensus model or related phenomena it is most related to.
- Other students raise their hand if they have a question that connects to any previous question they heard
- The student selects the next student whose hand is raised.
- The next student reads their question and posts it on the DQB. This student also says what other posted questions it relates to and explains why or how it relates.*
- The student then selects the next student whose hand is raised.*
- This process continues until everyone has had a chance to post a question.
- Remind students to keep track of whether their question was already asked, put a check mark on that sticky note if it was, and then select a different question to share.

Once students have completed their sharing, propose that our unit question—**"Why does a lot of hail, rain, or snow fall at some times and not others?"**—could still serve as the driving question for investigating our new questions. If students suggest a modification to the driving question that better aligns to the scope of the questions they now have, make the modification.

*** Supporting Students in Engaging in Asking Questions and Defining Problems**

If students forget to explain how or why their questions are linked to someone else's question, press them to try to talk through their own thinking. This is a key way to emphasize the importance of listening to and building off each other's ideas and to help scaffold student thinking. If students cannot find a question to connect theirs to, encourage them to ask the class for help. After an idea is shared, ask the original presenter if there is agreement and why, and then post the question. If a question is similar to (or the same as) another one, have the student place it on top of that question so other students can visualize how many questions are identical or related. Emphasize that this provides us with evidence of where many people are thinking about similar things.

8. Identify additional sources of data needed.

8 MIN

Materials: science notebook, Future Investigations and Data We Need poster, chart paper, markers

Brainstorm ideas for future investigations and useful data sets. Present **slide N**. Give students 3 minutes to talk with a shoulder partner to generate ideas. You may want to encourage students to stand or stretch while they talk.

As students are doing this, put up a blank piece of chart paper and add the title "Ideas for Additional Sources of Data" to it.

In the remaining time, have students reconvene and stand in a semicircle around the Ideas for Future Investigations and Data We Need poster so all can see it.

Build the poster with students' ideas. Tell students you want to try to represent at least one idea from each pair of partners. Say something like, *To make sure we have your and your partner's ideas up here, I will pass a marker to the first person in this semicircle. That student should share one idea. I will write it up and number it. Once I've almost finished writing it, that student should pass the marker to the partners next to them. If their idea is on the poster already, the student should say which idea it is and how it is similar. I will put a tally mark next to it. The marker is then passed, and we continue until we have heard once from every set of partners in the class. If you have additional ideas that don't end up on the poster, feel free to raise your hand after the marker makes it all the way around the semicircle. If we run out of time, we'll pick up here in the next class. And if you think of new ideas as we go, feel free to jot them down. We should always be thinking of ways we can add to this list.*

In large classes, you may run out of time before all partners share out an idea. If needed, resuming this activity right where you left off is a natural point to launch the next lesson.

Collect students' unposted sticky note questions before they leave.

*** Attending to Equity**
Having the student who volunteered and posted a question pick the next student to share (from those whose hands are raised) is a great way to turn over the pacing and cadence of this group work to the students. Reuse this technique in future Scientists Circles to encourage increased student agency in the classroom learning community. When you do this, take a seat with the students in the circle to position yourself as an equal member of the learning community who is listening, making sense of questions, and trying to figure this out. If you have questions you want to share with the group, raise your hand and wait for someone to call on you.

ADDITIONAL LESSON 14 TEACHER GUIDANCE

Supporting Students in Making Connections in ELA

CCSS.ELA-Literacy.SL.6.1.c: Pose and respond to specific questions with elaboration and detail by making comments that contribute to the topic, text, or issue under discussion.

While the class is building the Driving Question Board, if a student forgets to explain why or how their question is linked to someone else's, press that student to talk through their own thinking. This is a key way to emphasize the importance of listening to and building off one another's ideas and to help scaffold student thinking. If students can't figure out which question to connect theirs to, encourage them to ask the class for help. After an idea is shared, ask the original presenter if there is agreement and why, and then post the question.

Convection, Hail, and Other Events

1 **Hailstorms**
2 **Severe Weather Hot Spots**
3 **Perspectives on Climate Change**
4 **Jet Streams and Weather**
5 **Convection and Storms**

Literacy Objectives

- ✓ Summarize key points related to storm development.
- ✓ Distinguish cause(s) and effect(s) related to severe weather and climate.
- ✓ Organize related details in an outline.
- ✓ Differentiate fact, reasoned judgment, speculation, and opinion.

Literacy Activities

- Read varied text selections related to the topics explored in Lessons 12–14.
- Evaluate the reading selections according to provided prompts and criteria.
- Compare and contrast information gained from reading text with information gained from class investigation.
- Prepare an outline in response to the reading.

Instructional Resources

Student Reader

Collection 5

Science Literacy Student Reader, Collection 5
"Convection, Hail, and Other Events"

Exercise Page

EP 5

Science Literacy Exercise Page
EP 5

Prerequisite Investigations

Assign the Science Literacy reading and writing exercise *after* class completion of this lesson group:

- Lesson 12: What causes more lift in one cloud versus another?
- Lesson 13: Why do some storms produce (really big) hail and others don't?
- Lesson 14: What causes a large-scale precipitation event like this to occur?

Standards and Dimensions

NGSS

Disciplinary Core Idea ESS2.D: Weather and Climate: Weather and climate are influenced by interactions involving sunlight, the ocean, the atmosphere, ice, landforms, and living things. These interactions vary with latitude, altitude, and local and regional geography, all of which can affect oceanic and atmospheric flow patterns. (MS-ESS2-6) Human activities, such as the release of greenhouse gases from burning fossil fuels, are major factors in the current rise in Earth's mean surface temperature (global warming). Reducing the level of climate change and reducing human vulnerability to whatever climate changes do occur depend on the understanding of climate science, engineering capabilities, and other kinds of knowledge, such as understanding of human behavior and on applying that knowledge wisely in decisions and activities. (MS-ESS3-5)

Science and Engineering Practices: Analyzing and Interpreting Data; Obtaining, Evaluating, and Communicating Information

Crosscutting Concepts: Cause and Effect; Stability and Change

CCSS

English Language Arts

RST.6-8.2: Determine the central ideas or conclusions of a text; provide an accurate summary of the text distinct from prior knowledge or opinions.

RST.6-8.6: Analyze the author's purpose in providing an explanation, describing a procedure, or discussing an experiment in a text.

RST.6-8.8: Distinguish among facts, reasoned judgment based on research findings, and speculation in a text.

RST.6-8.10: By the end of grade 8, read and comprehend science/technical texts in the grades 6-8 text complexity band independently and proficiently.

Core Vocabulary

Core Vocabulary: Core Vocabulary terms are those that students should learn to use accurately in discussion and in written responses. During facilitation of learning, expose students repeatedly to these terms. However, these terms are not intended for isolated drill or memorization.

convection

Language of Instruction: The Language of Instruction consists of additional terms, not considered a part of Core Vocabulary, that you should use when talking about any concepts in this exercise. Students will benefit from your modeling the use of these words without the expectation that students will use or explain the words themselves.

actuary	**downdraft**	**jet stream**
severe weather	**snowpack**	**tornado**
updraft		

A Glossary at the end of the Science Literacy Student Reader lists definitions for Core Vocabulary and selected Language of Instruction.

1. Plan ahead.

Determine your pacing to introduce the reading selections, check in with students on their progress, and discuss the reading content and writing exercise. If you are performing Science Literacy as a structured, weekly routine, you might implement a schedule like this:

- Monday: Designate a ten-minute period at the beginning of the week to introduce students to the assignment.
- Wednesday: Plan to touch base briefly with students in the middle of the week to answer questions about the reading, to clarify expectations about the writing exercise, and to help students stay on track.
- Friday: Set aside time at the end of the week to facilitate a discussion about the reading and the writing exercise.

You'll proceed with the in-class lesson investigations during this week.

2. Preview the assignment and set expectations. (Monday)

- Let students know they will read independently and then complete a short writing assignment. The reading selection relates to topics they are presently exploring in their Weather, Climate, and Water Cycling unit science investigations.
- The reading and writing will be completed outside of class (unless you have available class time to allocate).
- Preview the reading. Share a short summary of what students can expect.
  - *First, you will read an article about hail, how it forms, and how big hailstones can get.*
  - *Then, you'll interpret data on maps showing the probability of severe weather in the United States in different months of the year.*
  - *Next, you'll read a mock blog from an insurance company employee about changes in severe weather due to climate change and a social media discussion about how climate change may affect certain businesses.*
  - *You'll also read an article about jet streams and how changes to jet streams can cause severe weather.*
  - *Finally, you'll interpret an infographic showing how thunderstorms develop.*

Distribute Exercise Page 5. Preview the writing exercise. Share a summary of what students will be expected to deliver. Emphasize that Science Literacy exercises are brief. The focus is on thoughtful quality of a small product, not on the assignment being big and complex.

- *For this assignment you will be expected to complete an outline to summarize the main ideas and some details developed in Collection 5.*

Exercise Page

EP 5

Remind students of helpful strategies they can employ during independent reading. Offer the following advice:

- *The reading should take approximately 30 minutes to complete.* (Encourage students to break reading into smaller sections over multiple short sittings if their attention wanders.)
- *A good reading strategy is to scan through the collection first to see the titles, section headers, graphics, and images to see what the selections are going to be about before fully reading.*
- *Next, "cold read" the selections without yet thinking about the writing assignment that will follow.*
- *Then, carefully read the Exercise Page to understand the expectations for the writing part of the assignment.*
- *Revisit the reading selections to complete the writing exercise.*
- *Jot down any questions for the mid-week progress check in class.* (Be sure students know, though, that they are not limited to that time to ask you for clarification or answers to questions.)

3. Touch base to provide clarification and address questions.

(Wednesday)

Touch base midweek with students to make sure they are on track while working independently. You may choose to administer a mid-week minute-quiz to give students a concrete reason not to postpone completing the reading until the last minute. Ask questions such as these, and have students jot answers on a half sheet of paper:

Suggested prompts	Sample student responses
What role do updrafts play in the formation of hail?	*Updrafts lift falling raindrops upward where the air is colder, resulting in the water freezing to become hail.*
What kinds of storms are not considered "severe weather" by U.S. meteorologists?	*hurricanes and blizzards*
What is "snowpack," and why are climate scientists worried about it?	*Snowpack is the average depth of snow sitting on mountaintops. When snowpack is lost due to melting because the climate is warming, there will be less water flowing into streams and rivers for people to use.*
What type of severe weather can produce tornadoes?	*thunderstorms*

Ask a few brief discussion questions related to the reading that will help students tie the text content to students' classroom investigations.

Suggested prompts	Sample student responses
What does gravity have to do with downdrafts and updrafts?	*In a downdraft, cooled air falls toward the ground due to the force of gravity pulling it downward. In an updraft, warmed air moves upward against the force of gravity.*
In Lesson 12, you set a convection current in motion in a container of water. Why is it important to remember that gases, as well as liquids, are fluids?	*because the atmosphere (air) is a fluid, so the air can contain convection currents too, explaining why a thunderstorm is also known as a "convection storm"*
What causes a hailstone to finally fall to the ground?	*when the force of updrafts is not strong enough to support the weight of the hailstone*
In Lesson 15, you explored large-scale weather events. What evidence do you have from the readings to support the idea that jet streams might be involved in these large-scale events?	*The diagram in one reading showed that jet streams circle the entire Earth. Air currents this large are likely to effect weather of large regions.*

- Refer students to the Exercise Page 5. Provide more specific guidance about expectations for students' deliverables due at the end of the week.
  - *The writing expectation for this assignment is to complete an outline that summarizes important main ideas from all the readings in Collection 5.*
  - *When you work on the outline is up to you. You could begin it as you preview the selections, as you read for understanding, or afterward to review them.*
  - *When you copy the outline, leave a couple of lines of space for each main idea you will fill in.*
  - *Follow the style of the outline, and write complete sentences for each main idea.*
  - *Spend a couple of minutes perfecting your title for the outline, thinking about how to best summarize all the ideas using wording to show cause and effect.*
  - *The important criteria for your work are that your title and main ideas summarize using cause-and-effect language and that your sentences are scientifically accurate.*
- Answer any questions students may have relative to the reading content or the exercise expectations.

Exercise Page

EP 5

4. Facilitate discussion. (Friday)

Facilitate class discussion about the reading collection and writing exercise. Students begin the reading activity by learning how hailstones grow in size before they eventually fall to earth, where they can cause considerable damage.

Pages 44–45 **Suggested prompts**	**Sample student responses**
What is the general purpose of the first selection, "Hailstorms"?	*The purpose is to describe the variations in sizes of hailstones, how hail forms, and what kinds of damage are caused by hail.*
As the diameter of a hailstone increases, what happens to its mass?	*It also increases. And therefore the gravitational attraction with Earth is greater.*
You can probably understand why it's easier to estimate the diameter of a hailstone by comparing it to familiar objects. But what if you want to be more precise and measure a large hailstone? How would you do it?	*First, I'd handle it with gloves so it doesn't start to melt from the heat of my hands and place it on a piece of paper.* *Next, I would use a ruler to find the greatest distance across the hailstone, because most are not perfect spheres.* *Then, I would use a pencil to make a mark on the paper right below the starting and ending point of the greatest distance.* *Finally, I would use the ruler to measure the distance between the two points on the paper.*

Student Reader

Collection 5

SUPPORT—If you are using the recommended word envelope convention, check the envelope to see if it contains any words, phrases, or sentences that students need help understanding. Read key sentences aloud, and provide concise explanation.

Online Resources

SUPPORT—Some students benefit from learning through an auditory mode. Show these and other interested students a video in which an expert explains what hail is and how it forms.

Pages 46–51 **Suggested prompts**	**Sample student responses**
What is the general purpose of the second selection, "Severe Weather Hot Spots"?	*It shows through maps that the chance of severe weather varies by the time of year and location where you live.*
Which U.S. states are likely to have severe weather on all four days of the year shown—March 5, May 20, July 8, and October 7?	*Kansas, Oklahoma, and Texas*
How does the second selection help you build knowledge on top of what you learned in the first selection?	*The first article reveals how hail forms. The second article details where hailstorms are most likely to occur at different times of the year.*
Look at the Dig into Data box. Where in the United States and in what months do you predict blizzards are more likely to occur?	*in the most northern states, such as Minnesota (and Alaska); in states with high mountains, such as Colorado; and in the winter months from December to March*
What is the general purpose of the third article, "Perspectives on Climate Change"?	*There are three authors in this reading. The first is an actuary who, in a blog, shares his thoughts on some news about changes in weather due to climate change. The second is a social media post from a construction business owner who read the same report and wants to persuade others in his profession to meet and discuss it. The third author is replying to the second and wants to figure out how climate change will impact his windshield replacement business.*
What would a line graph showing the depth over time of the snowpack in western states look like?	*The line would start high at 1980 and slowly slope downward to a little more than halfway to the bottom by 2050.*
It is very important to be careful about choosing which sources of information to rely on. In this selection, you are relying on someone you don't know to provide information about an important scientific report. How can you evaluate if their comments contain facts or speculation?	*I could find the latest report by the Intergovernmental Panel on Climate Change online, read it myself, and decide if the authors were reporting it accurately.*
What is the general purpose of the fourth article, "Jet Streams and Weather"?	*This article explains what jet streams are, where they are located, and how changes in jet streams can change weather patterns.*

CHALLENGE—The Dig into Data box in the second selection refers to the historical probability of hurricanes. While maps similar to those in the reading are not available, students can interpret an online NOAA data table to draw conclusions about the historical probability of hurricanes by state.

EXTEND—The IPCC, a United Nations body, is the most authoritative and up-to-date source of climate change science. Have students find the panel's website and, from the home page, link to the latest report. Then they can choose among several options, including a Summary for Policy Makers and Frequently Asked Questions to scan. Then have them write their own social media posts commenting on the latest findings.

Pages 50–53 **Suggested prompts**	**Sample student responses**
So, how would you describe a jet stream?	*A jet stream is moving air, like a steady wind that is higher in altitude than normal winds, but it behaves more like an ocean current, in that the air always moves in one direction.*
How did you decide what the second main idea should be for the part of your outline about this selection?	*I thought the other most important idea was that climate change may affect jet streams.*
What is the general purpose of the fifth article, "Convection and Storms"?	*The purpose is to explain a diagram that shows the stages in the life cycle of a thunderstorm.*
At what stage in the life cycle do you predict hail could form? Why?	*in the second part of the "developing" stage or in the "mature" stage, when there are both updrafts and downdrafts*
There are four stages in the diagram yet only two blank lines in the outline. How did you decide what your two main ideas would be?	*First, I looked at the main idea listed for "C." I noticed that it summarized information about the term* tornado. *Then I found another important science term,* convection, *and explained its effects inside the thunderstorm clouds.*

5. Check for understanding.

Evaluate and Provide Feedback

For Exercise 5, students should complete a provided partial outline to summarize the important main ideas from each of the five readings in Collection 5. Students' summaries should incorporate statements that refer to cause-and-effect relationships, probability, and both short-term change (weather) and long-term change (climate).

An example of a completed outline with title is shown on the next page, but students may choose to focus on different main ideas and use their own wording.

Use the rubric provided on the Exercise Page to supply feedback to each student.

The Causes of Severe Weather and Other Weather Events

I. Hailstorms
   A. Hailstones vary from pea-sized to grapefruit-sized.
   B. Hail forms in thunderstorms when updrafts lift rain to where the air is colder and the water freezes.
   C. Hail can cause damage to cars and clog sewers.

II. Severe Weather Hot Spots
   A. The probability of severe weather depends on the month of the year.
   B. The probability of severe weather depends on the state where you live.
   C. Severe weather includes tornadoes, thunderstorms, and hail but not hurricanes and blizzards.

III. Perspectives on Climate Change
   A. Scientists think a warming climate may affect the frequency of hailstorms.
   B. Scientists think a warming climate will likely cause more floods.
   C. Scientists think a warming climate will likely cause more wildfires.

IV. Jet Streams and Weather
   A. When the polar jet stream moves north and south, it causes colder or warmer weather.
   B. A warming climate may weaken the jet streams.

V. Convection and Storms
   A. Convection begins with an updraft in which warm, moist air rises from Earth’s surface due to its low density.
   B. Rain or snow forms and drags cooled air down toward the ground.
   C. A large, steady updraft can produce a tornado.

LESSON 15

What happens with temperature and humidity of air in large storms?

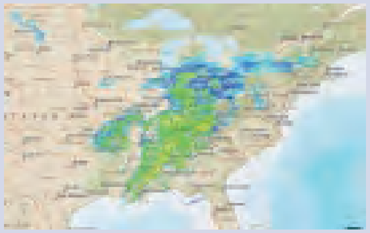
Previous Lesson

We explored a weather report and forecast. We developed a model to explain how what was happening in one part of the country at one point in time can be connected to what is predicted to happen in another part of the country over a day later. We developed questions for our Driving Question Board (DQB) and brainstormed ways to investigate these questions.

This Lesson

Investigation

2 DAYS



Data Source: NOAA

We use temperature, humidity, and radar data of the storm across eight-hour increments to track the movement of air and precipitation. We consider how air moves horizontally in large parcels, called air masses, and we also notice that precipitation and storms develop where air masses of different characteristics meet. As a class, we develop different ways of representing what is happening with warm air and cold air across the land.

Next Lesson

We will use models to observe and describe interactions that occur between warm and cold air masses. We will also use patterns in data to explain changes in precipitation that can occur when air masses collide.

Building Toward NGSS

MS-PS1-4, MS-ESS2-4, MS-ESS2-5, MS-ESS2-6

What Students Will Do

Use graphical displays of temperature, humidity, and radar data to identify temporal and spatial patterns as air masses interact in a large storm system.

Use an argument supported by empirical evidence and scientific reasoning based on patterns from data and maps to support an explanation that precipitation forms along the boundary of two air masses with different temperature and humidity characteristics.

What Students Will Figure Out

- Air masses are large parcels of air (hundreds of miles wide) with similar characteristics (e.g., temperature, humidity).
- Air masses move horizontally, such as from west to east across the United States.

- Storms and precipitation can develop where two air masses with different characteristics meet; this boundary is called a *front.*

Lesson 15 • Learning Plan Snapshot

Part	Duration	Summary	Slide	Materials
1	2 min	**NAVIGATION** Students recall the data sources they are interested in investigating related to the storm formation.	A	Ideas for Additional Sources of Data chart
2	18 min	**REPRESENTING TEMPERATURE AND HUMIDITY DATA** As a whole class, students first color temperature data and then humidity data in gradients to represent the weather at the first time point related to the storm.	B-E	1 red colored pencil, 1 orange colored pencil, 1 yellow colored pencil, 1 green colored pencil, 1 blue colored pencil, 1 purple colored pencil, *Time Point 1: Air Temperature, January 17, 2019, 4:00 p.m., Relative Humidity, January 17, 2019, 4:00 p.m., Time Point 1*
3	10 min	**MAKE SENSE OF DATA TO DEFINE AIR MASSES** Using two maps with air temperature and humidity data from a time close to the storm, students make sense of how these data help them identify air masses that have similar characteristics.	F	
4	15 min	**CREATE A TIME SERIES GALLERY WALK OF TEMPERATURE AND HUMIDITY** In small groups, students color ten more maps in eight-hour increments across the timeline of the storm. They complete a Notice and Wonder chart as they view all the data in a gallery walk.	G-H	1 orange colored pencil, 1 yellow colored pencil, 1 green colored pencil, 1 time point from *Air Temperature at Time Points 2-11* and *Relative Humidity at Time Points 2-11* *End of day 1*
5	15 min	**AIR MASS BOUNDARIES** Students predict where different air masses exist before, during, and after the storm event.	H-I	12-in length of yarn, tape, scissors, gallery walk maps
6	8 min	**CONSIDER ADDITIONAL RADAR DATA** Introduce a new set of radar data from the storm event and have students consider how temperature and humidity relate to the storm.	J	*Radar Map Series*
7	20 min	**CONSENSUS DISCUSSION** Gather students in a Scientists Circle around the gallery walk maps to build consensus of how air masses and where they meet are related to the storm.	K	initial model from Lesson 14, gallery walk maps, chart paper, markers

Part	Duration	Summary	Slide	Materials
8	5 min	**NAVIGATION** Students consider how different characteristics of air might impact how they interact.	L	Why would precipitation happen where two air masses meet?

End of day 2

Lesson 15 • Materials List

	per student	per group	per class
Lesson materials **Student Procedure Guide** **Student Work Pages**	• 1 red colored pencil • 1 orange colored pencil • 1 yellow colored pencil • 1 green colored pencil • 1 blue colored pencil • 1 purple colored pencil • *Time Point 1: Air Temperature, January 17, 2019, 4:00 p.m.* • *Time Point 1: Relative Humidity, January 17, 2019, 4:00 p.m.* • science notebook	• 1 time point from *Air Temperature at Time Points 2-11* and *Relative Humidity at Time Points 2-11* • 12-in length of yarn • tape • scissors	• Ideas for Additional Sources of Data chart • gallery walk maps • *Radar Map Series* • initial model from Lesson 14 • chart paper • markers • Why would precipitation happen where two air masses meet?

Materials preparation (15 minutes)

Online Resources

Review teacher guide, slides, and teacher references or keys (if applicable).

Make copies of handouts and ensure sufficient copies of student references, readings, and procedures are available.

Print the temperature and humidity maps for Thursday, January 17, 2019 at 4:00 p.m. for all students using *Time Point 1: Air Temperature, January 17, 2019, 4:00 p.m.* and *Relative Humidity, January 17, 2019, 4:00 p.m.*

Print 1 copy of the remaining time points from *Air Temperature at Time Points 2-11* and *Relative Humidity at Time Points 2-11* so that groups of students can work on one additional time point for the gallery walk. Each group of 2-3 students will get one temperature and humidity time point to color and display for the class on a chronological gallery walk.

Print 1 copy of *Radar Map Series* in color, single-sided. These will be added to the gallery walk on Day 2.

The class will build a gallery walk of 11 points in time during the Lesson 14 storm. The temperature, humidity, and radar maps can be posted together for each time point, with 11 stations total for the whole gallery walk. Students will walk the gallery walk on both day 1 and day 2 and should walk through the map series in chronological order.

Lesson 15 • Where We Are Going and NOT Going

Where We Are Going

This lesson presents temperature and humidity data to students from 11 time points before, during, and after the storm. Students classify the data into temperature and humidity gradients and consider how some places have similar temperature and humidity conditions and those places are different than others. It will be challenging for students to classify the data and then figure out where the large parcels of air with similar characteristics are located on the map. It's not that important for students to get the "right" air masses identified. The purpose is for students to understand that large sections of air have different characteristics and the air moves around in large swaths. Those are called *air masses*. And importantly, when the air masses with different characteristics meet, precipitation forms on that boundary. Sometimes air mass boundaries are very distinct, but at other times they are more spread out and it is hard to locate the exact boundary. What students need to get out of this lesson is that characteristics of air are different and air moves in large sections. Storms form when different air masses collide. They should leave the lesson wondering why that would happen.

Where We Are NOT Going

Students shouldn't spend too much time getting distracted by a few data points that do not cleanly match the pattern with other nearby cities. Local daily temperature and humidity fluctuate for many reasons, such as cloud cover, proximity to water sources, or topography. There is also a daily shift between day and night temperatures and humidity levels that would be expected as well. Acknowledge these influences on temperature and humidity, but try to focus students on the west to east movement of the colder temperatures and dropping humidity levels across a large part of the country.

LEARNING PLAN FOR LESSON 15

1. Navigation — 2 MIN

Materials: Ideas for Additional Sources of Data chart

Recall the need to consider additional data. Display **slide A**. Return to the Ideas for Additional Sources of Data chart. Ask students to quickly remind the class about what kinds of data they wanted to look at related to this storm.

It is likely that students listed temperature and humidity data as sources in Lesson 14, but if they didn't, ask students to think back to the Lesson 10 simulation and the two ingredients for stronger storms (higher temperatures and high humidity levels).

2. Representing Temperature and Humidity Data — 18 MIN

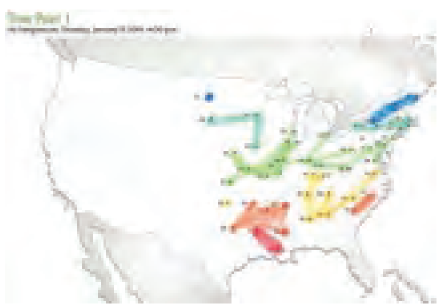
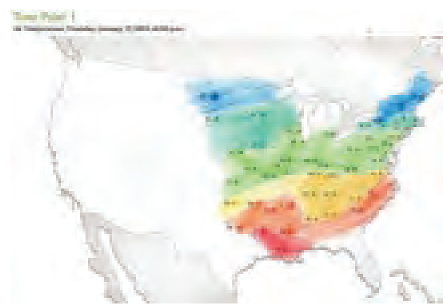
Materials: 1 red colored pencil, 1 orange colored pencil, 1 yellow colored pencil, 1 green colored pencil, 1 blue colored pencil, 1 purple colored pencil, *Time Point 1: Air Temperature, January 17, 2019, 4:00 p.m. and Relative Humidity, January 17, 2019, 4:00 p.m.*

Introduce the temperature data and look for initial patterns. Hand out a copy of *Time Point 1: Air Temperature, January 17, 2019, 4:00 p.m.* to each student. Ask students what they notice about the map.

Suggested prompts	Sample student responses
What is the title of the map?	*Air Temperature, Thursday, January 17, 2019, 4:00 p.m.*
What data are displayed on the map?	*Temperature in Fahrenheit for places in the United States.*
Are the data for cities across the whole United States?	*No, it looks like just the eastern United States.*
What kinds of patterns do you notice in the temperature data? For example, where is it colder and where is it warmer?	*It looks like it is colder in the north and warmer in the southern part of the United States.*
How do you think temperatures would change if it were a different time of day?	*It is usually warmer in the daytime, so I think the temperatures are higher at that time and it gets colder at night.*

Visualize the temperature data with colors. Display **slide B**. Tell students that in order to see patterns in temperature data across the United States, scientists often use color gradients to help them visualize their data. Point to the example map on the slide. Ask students what they notice about the map and legend. Ask, *Does it match some of the things we noticed about our map? How does this convention help us visualize additional patterns in the data?*

Display **slide C**. To study the storm better, the class is going to replicate a color gradient key onto the map of a time point at the beginning of the storm. Model for students how to color zones of temperatures according to the key on the slide. Before coloring whole sections, first have students use the correct color to fill in a circle over the temperature number for each city. Then students can go back and color the sections between the cities, matching similar temperatures into larger bands of color.

Make sense of the new visualization. Now that the map is colored with temperature gradients, give students a moment to make sense of patterns they notice on the map.

Suggested prompts	Sample student responses
Now what patterns do you notice on the map?	*It is still colder in the north and warmer in the south.* *It isn't straight lines though. Sometimes it is a little colder further south and a little warmer in places north of that.*
How does this help us understand what the air is like in between the cities?	*When we colored the area in between the temperature numbers we have, that tells us that the temperature in between is probably about the same as what is in the points.*

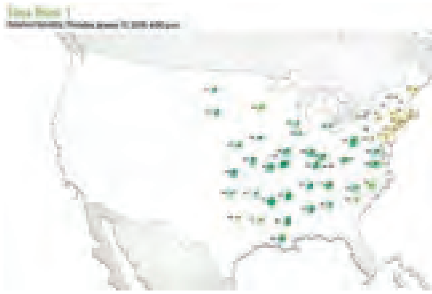
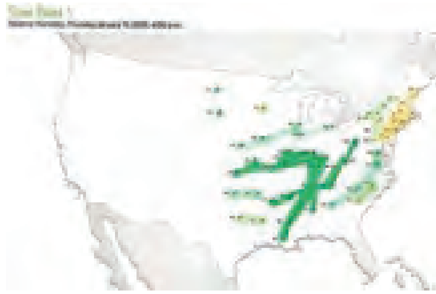
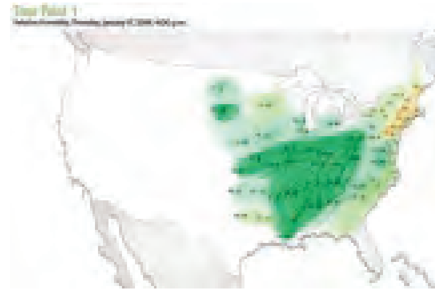
Transition to humidity data. Remind students that two important pieces of data in storms are air temperature and humidity. Pass out *Time Point 1: Relative Humidity, January 17, 2019, 4:00 p.m.* Similar to the *Air Temperature* map, take a moment to ask students what they notice about this new map.

Suggested prompts	Sample student responses
What is the title of the map?	*Relative Humidity, Thursday, January 17, 2019, 4:00 p.m.*
What data are displayed on the map?	*Relative humidity*
And what does relative humidity measure again?	*How much water is in the air.*
Are the data for cities across the whole United States?	*No, just the eastern part.*
What kinds of patterns do you notice in the humidity data? For example, what is the highest humidity? What is the lowest?	*It is 100 percent in some places and only 20 percent in others.*

Introduce conventions to study patterns in humidity data. Display **slide D**. Say, *Similar to temperature data, scientists study patterns in relative humidity, or how much water is in the air, to study areas that are really humid, have average humidity, or have really dry air.*

Suggested prompt	Sample student responses
What patterns do you notice in the map on the slide?	*It is darker green (more humid) in the eastern part of the United States and northern corners.* *It is not very humid in the southwest United States.*

Display **slide E**. To study the storm better, the class is going to replicate a color gradient in the key on the slide to represent relative humidity at the time near the start of the storm. Model for students how to color zones of humidity according to the key on the slide. Similar to temperature, first color the humidity numbers on the map and then begin making connections between data points with similar numbers to create larger bands of similar relative humidity.

Make sense of the new visualization. Now that the map is colored with humidity gradients, give students a moment to make sense of patterns they notice on the map.

Suggested prompts	Sample student responses
Now what patterns do you notice on the map?	*______areas have higher humidity. And ____ areas have lower humidity.*
How does this help us understand what the humidity is like in between the cities?	*When we colored the area in between the humidity data points, that tells us that the humidity in between is probably about the same as what is in the points.*

3. Make sense of data to define air masses.

10 MIN

Materials: None

Introduce the term *air mass*. Display **slide F**. Provide students an opportunity to consider how air masses are defined and then locate potential air masses on the temperature and humidity maps by finding large sections of air with similar temperature and humidity characteristics.* Have students share their thinking with a partner before sharing with the whole class.*

Key Ideas

Purpose of this discussion: To build understanding about how air masses are defined and identified.

What to listen for:

- ideas for how to locate bodies of air with similar temperature characteristics.
- ideas for how to locate more- or less-humid bodies of air.

*** Supporting Students in Developing and Using Scale, Proportion, and Quantity**

Up to this point, students have worked with smaller parcels of air in a localized storm system. In this lesson they transition to thinking about how temperature and humidity data can be similar across larger bodies of air. The scale at which they are dealing with air is now regional instead of localized.

Suggested prompts	Sample student responses
Can someone share their thinking about where they think an air mass is located based on temperature data?	*I think that this area in the northeast United States is a cold air mass because all the temperatures are cold.*
Can anyone locate a humid or dry air mass?	*This area in the middle of the country has really high humidity, so I think the air is more humid.*
Is the air uniform everywhere?	*Some places are warmer air masses and some places are colder.* *Some places are really humid and some are not.*
Do you think that air masses stay the same in these places?	*I think some places are warmer all the time compared to other places.* *But sometimes it gets colder, though, all over.* *It warms up in the summer but gets colder in the winter.*

Add "air mass" to Word Wall. Write the definition of *air mass* (a large section of air with similar humidity and temperature) on a notecard and have students suggest words and pictures to describe its meaning. Add it to a Word Wall so that it is visible for students. Students may also add it to a personal glossary, particularly if they would benefit from defining the term in their own words and pictures.*

4. Create a time series gallery walk of temperature and humidity. 15 MIN

Materials: science notebook, 1 orange colored pencil, 1 yellow colored pencil, 1 green colored pencil, 1 time point from *Air Temperature at Time Points 2-11* and *Relative Humidity at Time Points 2-11*

Develop a series of maps to represent temperature and humidity before, during, and after the storm. Divide the class into 10 groups. From *Air Temperature at Time Points 2-11* and *Relative Humidity at Time Points 2-11*, give each group a pair of temperature and humidity maps for the same time point (each group gets a different time point). These maps range from Friday, January 18, 12:00 a.m. to Monday, January 21, 12:00 a.m. and provide data in eight-hour time increments. Give students about 8 minutes to color the maps as previously done as a whole class.

Conduct a gallery walk. Display **slide G**. Have students hang the maps in chronological order on the wall once they are complete. Using their science notebook and a Notice and Wonder chart, students should conduct a gallery walk of the data from Time point 1 to Time point 11, tracking their noticings and wonderings.

As students do the gallery walk, listen for these ideas:

- Cold and warm air sections on the map shift over time. The cold and warm sections are really big.
- It is colder first in the places north and west, and that cold air shifts to the east later in the storm.
- Humidity seems to get lower when the air gets colder.

*** Attending to Equity**

Supporting emergent multilinguals: Before students engage in whole-class discussions, it can be helpful to first provide them with the opportunity to work with others—either in pairs, triads, or small groups—on ideas related to their reasoning. These smaller group structures can be especially helpful for emerging multilingual students because they offer students a chance to engage in sensemaking with their peers and also the space to use their linguistic and nonlinguistic resources to express their ideas (and learn from other students' uses of these resources too).

*** Attending to Equity**

Supporting emergent multilinguals: Teachers can support all students, particularly emerging multilingual students, in forming a deeper understanding of newly "earned" vocabulary by representing the new term in multiple ways. For example, students can (1) write the term, (2) draw a representation of the term, (3) use their own words to write an explanation for what the term means, and (4) use the new term in a sentence.

Exit ticket. Display **slide H**. As students finish the gallery walk, pose the question, *How do we know where one air mass ends and another begins?* Give students a minute to consider this question and jot down their thinking.

End of day 1

5. Air Mass Boundaries

15 MIN

Materials: science notebook, 12-in length of yarn, tape, scissors, gallery walk maps

Share out thinking from the exit ticket. Display **slide H** again. Ask students to turn and talk with a partner about their thinking to the exit ticket question. Then ask students to share their thinking as a whole class. Listen for ideas such as these:

- where warm air is versus cold air
- where humid air is versus dry air
- Air masses can be a combination of temperature and humidity, such as warm, humid air.

Transition to consider the edges of the air masses. Ask students to consider whether they are seeing one uniform section of air with similar temperatures and humidity or if they are seeing different sections of air with different temperature and/or humidity profiles. By now, students should notice that there is colder and less humid air on the maps in some places and warm, more humid air on the maps in other places. Ask students, *If you had to mark a boundary from where one type of air mass meets another type of air mass, could you do it? What would you look for?* Let a few students share their ideas of what they might look for to mark a boundary.

Mark boundaries of air masses on time-series maps. Display **slide I**. Give each group of students a strip of yarn, tape, and scissors. Ask students to consider the maps they worked on in their group on day 1 and determine where they might place one or more boundaries between air masses. Also ask students to annotate the map to describe the characteristics of the air mass(es) in their map, for example, by writing "warm, humid air" on the map in a place where temperatures are warmer and there is higher humidity. Give groups about 5 minutes to work on this task of marking boundaries (either with yarn and tape or a pencil) and annotating maps and then ask one or two groups to share out. If time allows, let each group briefly share their annotations.

Alternate Activity

Students can use a pencil in lieu of yarn, scissors, and tape. They can sketch lines on the map to denote boundaries between air masses.

Connect back to the anchor. Say, *So we are definitely seeing that the air masses are shifting and moving across the region during the storm. How does the precipitation in the storm relate to the air masses we identified?* Allow students to share their thinking related to this question.

6. Consider additional radar data.

8 MIN

Materials: science notebook, *Radar Map Series*

Provide a new source of data. Display **slide J**. Introduce the radar data from the storm event, which are matched to the same time points as in the maps of temperature and humidity data. Radar images show the intensity and type of precipitation (water) falling over an area.

Place the radar maps onto the gallery walk of the time points. One small group at a time, have students walk through the gallery walk in chronological sequence one more time to compare temperature and humidity data to the new radar images.

7. Consensus Discussion

20 MIN

Materials: science notebook, initial model from Lesson 14, gallery walk maps, chart paper, markers

Share noticings from the maps. Ask students, *How is precipitation from the storm related to temperature and humidity data before, during, and after the storm?* Listen for these ideas:

- The precipitation moves in the same pattern as the temperature shifts.
- The precipitation is located in areas with high humidity.
- The precipitation follows some of the places we marked as boundaries of the air masses.
- Sometimes there is a clear line of precipitation that runs along the front or where we think the air mass boundary is located.
- The type of precipitation is sometimes different depending on what side of the front you are on.

Update Progress Tracker. Give students a few minutes to draw and update a three-box Progress Tracker in their science notebook. Have students write this question (How is precipitation from the storm related to temperature and humidity data before, during, and after the storm?) in their notebook along with sources of evidence to account for their thinking. Then, in words and pictures, have students create a representation of what they figured out related to air masses and where they interact. Use **slide K** to prompt student thinking.

Question	Source of evidence
How is precipitation from the storm related to temperature and humidity data before, during, and after the storm?	Temperature and humidity data before, during, and after the storm, Radar images before, during, and after the storm

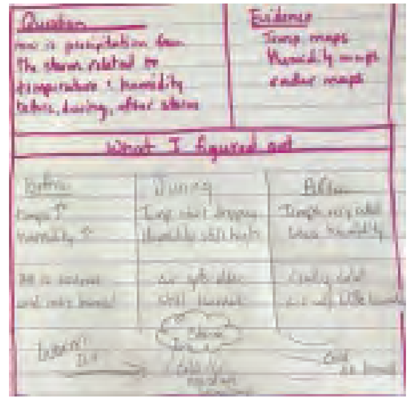
*** Strategies for This Consensus Discussion**

A Consensus Discussion is different from other kinds of discussions in that its purpose is to converge on one idea or a couple of ideas that the whole class agrees upon. In this discussion, your classroom community is pressing toward a common (class-level) explanation, model, or model representation. During this work, the class resolves disagreements where possible. Your role is to help students see where they agree and where they still disagree. Prompts that are helpful in these kinds of discussions include the following:

- What ideas are we in agreement about?
- Would anyone have put this point a different way?
- Who feels like their idea is not quite represented here?
- Are there still places where we disagree? Can we clarify these?

What I figured out in words and pictures

Air masses can be warm or cold, and humid or not humid. Before the storm the temperatures were warmer than after the storm. The humidity was higher before the storm than after the storm. Overvall, it looks like a cold air mass moved from west to east and the humidity dropped after the storm went through.



Build consensus on how air masses could interact and generate the revised model.* Post the initial model or ideas from Lesson 14 where all students can see it. Ask students to share ideas that we should include in a consensus model that could explain how air masses with different temperature and humidity interact and are related to storms. Prompt students to provide evidence from the gallery walk map data as they share ideas and how to represent those ideas in a consensus model. Remind students to refer to their Progress Trackers as well.*

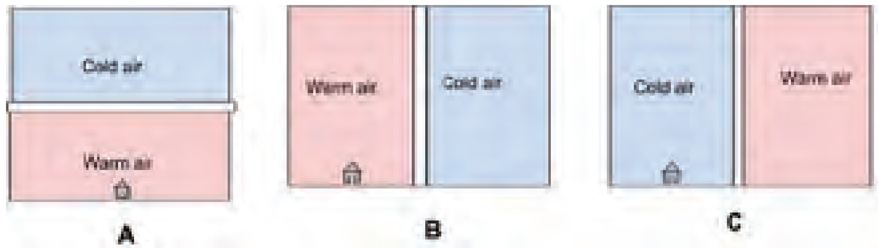
Suggested prompts	Sample student responses
Where is the warm air in the model? Where is the cold air?	*I think the warmer air is in the southern part of the model. And the colder air is in the north.* *I think the warmer air is near the ground.*
How could we represent the boundary between the warm air and the cold air? What is that called again?	*Let's use a line like they do in the forecasts.* *It's called a front.*
Where is the storm in our model? Is it with the warm air or cold air or both?	*I think it's where the line is, where the two meet.*
Could we try this from a different orientation? For example, if this is the school and we are standing here, and the boundary is where we are standing, then how could we draw it?	*The cold air would be on this side and moving this direction. And the warm air would be over here.*
What if the reverse happens? What would that look like?	*The warm air would be on that side instead where the cold air was.*

*** Supporting Students in Engaging in Argument from Evidence**

During this Consensus Discussion students should argue from evidence using temperature, humidity, and radar data from the map series to support the idea that large sections of air have different characteristics and that these large sections of air move great distances. Finally, students should use evidence to support that the development of the storm occurs on a boundary between two different air masses.

Additional Guidance

It is important to encourage students to represent their ideas in a cross-sectional view of air masses interacting. Up to this point, they have only viewed the data from "above," but a cross-sectional view will be needed in Lesson 16. Here are some examples of how this might look:



Students might bring the idea shown in A from Lesson Set 1 when they realize the air is cold high in the atmosphere and warmer near the ground. But now, after viewing larger air masses that move horizontally across the United States, it is important for them to consider how this can be represented using a cross section. If a student doesn't offer up an idea like those shown in B or C, it will be important to suggest drawing it this way. Use the house graphic and say, *So if I were at my house and this air was moving across the land, I might draw it like this* or *If you were standing on the ground when these air masses are moving around you, how might you draw where the cold air is? Or where the warm air is?*

To close the Consensus Discussion, summarize the key ideas for students. These ideas might look like the examples below:

- An air mass has similar temperature and humidity that makes it unique from other air masses.
- At any given time, there are different types of air masses moving around. Some are warm and humid (or dry) and others are cold and humid (or dry).
- Air masses move horizontally across the land and run into other air masses.
- The boundaries where air masses meet are called fronts.
- Storms and precipitation occur where these different air masses meet.

8. Navigation

5 MIN

Materials: Why would precipitation happen where two air masses meet?

Consider why precipitation happens where air masses meet. Display **slide L.** Ask students to talk with an elbow partner about this question: Why would precipitation happen where two air masses meet? Give students a moment to discuss their ideas related to this question and then have a few students share their thinking with the whole class.

ADDITIONAL LESSON 15 TEACHER GUIDANCE

Supporting Students in Making Connections in Math

CCSS.MATH.CONTENT.4.OA.C.5 Generate a number or shape pattern that follows a given rule. Identify apparent features of the pattern that were not explicit in the rule itself.

Students will use raw temperature and humidity data to create color gradients representing temperature and humidity ranges. They will track the shape pattern as it progresses across the country over a period of three days. While this is a 4th grade standard, this 6th grade unit intentionally reinforces mathematics standards from upper elementary as students work with data and mathematics.

LESSON 16

How do warm air masses and cold air masses interact along the boundaries between them?

Previous Lesson

We used temperature, humidity, and radar data of the storm across eight-hour increments to track the movement of air and precipitation. We considered how air moves horizontally in large parcels, called air masses, and we also noticed that precipitation and storms develop where air masses of different characteristics meet. As a class, we developed different ways of representing what is happening with warm air and cold air across the land.

This Lesson

Investigation

2 DAYS

We carry out an investigation to explore what happens along a frontal boundary where warm air and cold air meet. We develop models to describe interactions between warm and cold air masses and use patterns in data to explain changes in precipitation that can occur when air masses collide.

Next Lesson

We will analyze national pressure maps from around the time of the original forecast. We will construct an explanation of the patterns we notice among (1) the area of lowest air pressure, (2) the locations of the fronts, and (3) where precipitation would fall. We will apply scientific ideas to explain what is causing these three things to be connected to one another.

Building Toward NGSS

MS-PS1-4, MS-ESS2-4, MS-ESS2-5, MS-ESS2-6

What Students Will Do

Develop and use models to observe and describe the complex patterns of change that occur when warm and cold air masses interact in the atmosphere.

Use computational thinking to describe how patterns in data support explanations of the changes in weather that occur where warm and cold air masses interact.

What Students Will Figure Out

- When a warm air mass moves toward a cold air mass, the warm air slides over the cold air. When a cold air mass moves toward a warm air mass, the cold air pushes into and below the warm air, lifting the warm air up and over. Both interactions cause predictable changes in weather.

- The maximum amount of water vapor that air at a given temperature can hold is referred to as 100% relative humidity.
- The maximum amount of water vapor that can be in the air changes based on the temperature of the air; warmer air can hold more water vapor than colder air.
- Cooling air at 100% relative humidity will cause water vapor to condense out of the air; the greater the decrease in air temperature, the greater the amount of water vapor that will condense out of it.

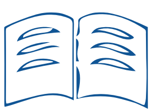
Lesson 16 • Learning Plan Snapshot

Part	Duration	Summary	Slide	Materials
1	8 min	**NAVIGATION** Students revisit previous lessons to surface what they know about warm and cold air interactions and to determine next steps.	A-D	
2	7 min	**MAP THE COMPONENTS OF THE EXPERIMENTAL SYSTEMS TO THE CORRESPONDING COMPONENTS IN THE ATMOSPHERE** Introduce the setup students will observe and map the components of the experimental system to the corresponding components in the atmosphere.	E	*Warm and Cold Water Interactions*, Warm and Cold Water Interactions: Teacher Demonstration
3	15 min	**OBSERVE AND DOCUMENT INTERACTIONS BETWEEN WARM AND COLD WATER** Observe and document interactions between warm and cold water along a vertical boundary.	F-G	*Warm and Cold Water Interactions*, Warm and Cold Water Interactions: Teacher Demonstration
4	15 min	**BUILDING UNDERSTANDINGS DISCUSSION ABOUT INTERACTIONS BETWEEN WARM AND COLD FLUIDS** Bring students together in a whole-group discussion to look for similarities in their observations. Use chart paper to document what we figure out about the ways in which warm and cold fluids interact along a boundary.	H	*Warm and Cold Water Interactions*, tape, chart paper, markers
				End of day 1
5	3 min	**NAVIGATION** Quickly review observations from the *Warm and Cold Water Interactions: Teacher Demonstration*.	I	
6	15 min	**MODEL WARM AND COLD AIR INTERACTIONS IN THE ATMOSPHERE** Connect our findings back to the lesson question, How do warm air masses and cold air masses interact along the boundaries between them?	J-L	

Part	Duration	Summary	Slide	Materials
7	20 min	**ANALYZE RELATIVE HUMIDITY DATA** Analyze relative humidity levels at various temperatures to figure out why weather changes occur along warm and cold fronts.	M-O	*Relative Humidity Data*, chart paper, markers
8	5 min	**REVISIT THE WEATHER MODELS** Use what we have figured out to explain why changes in the weather occur along fronts.	P	chart paper, markers
9	2 min	**NAVIGATION** Motivate the need to further investigate how scientists are able to determine when a front is approaching.		*Relative Humidity Data*, tape

End of day 2

Lesson 16 • Materials List

	per student	per group	per class
Warm and Cold Water Interactions: Teacher Demonstration materials			• 1 10-gallon aquarium • 1 foam barrier • 2 buckets of 1.5-gal warm water • 2 buckets of 1.5-gal cold water • blue food dye • 1 plastic spoon • paper towels • smart phone/tablet/or video camera
Lesson materials **Student Procedure Guide**  **Student Work Pages** 		• science notebook • *Warm and Cold Water Interactions* • tape • *Relative Humidity Data*	• chart paper • markers

Materials preparation (30 minutes)

Online Resources

Review teacher guide, slides, and teacher references or keys (if applicable).

Make copies of handouts and ensure sufficient copies of student references, readings, and procedures are available.

Day 1: *Observing Interactions Between Warm and Cold Fluids Demonstration*

- **Advance preparation**
    - Use the template *Template for the Foam Barrier* to build the foam barrier needed for the aquarium.
    - Be prepared to use a smartphone, tablet, or video camera to video the demonstration. The video can be used to give students a second look at the interactions between warm and cold water in the experimental setup.
- **Setup**
    - Collect materials needed for demonstration.
    - Place all materials on a table at the front of the classroom.
    - Have warm and cold water available. Warm water should be about 60°C, and cold water should be about 10°C. If your school has a hot water tap, this should be sufficient. If not, use an electric kettle from the Cup Design Unit to heat the water. You may also need to add ice to the cold water to ensure that there is a significant temperature difference between the warm and cold water.
- **Safety:** This activity is a demonstration, so students do not directly handle the warm water. However, exercise caution when pouring warm water into the aquarium so that students do not get splashed.

Lesson 16 • Where We Are Going and NOT Going

Where We Are Going

In the previous lesson, students analyzed patterns in data to figure out that large masses of air move and interact in the atmosphere. These large air masses can be warm or cold, and they interact along boundaries called fronts. The type of front and the direction it moves is related to the type of air mass along its leading edge. Whenever warm and cold air masses interact, predictable changes in weather, such as the formation of wind, clouds, and precipitation, can occur.

Students have prior understanding of the differences in density between warm and cold fluids (water and air). They know that when warm air is below cold air, the more-dense cold air sinks and pushes the less-dense warm air upwards. However, students do not know how warm and cold air masses interact when they come into contact along a vertical boundary (front).

In this lesson, students observe demonstrations that help them see how warm and cold fluids (water) interact when they meet along a vertical boundary:

- Warm water on the left and cold water on the right
- Warm water on the right and cold water on the left

First, students review prior understandings of the interactions between warm and cold fluids. They know that when a warm fluid is below a cold fluid, the cold fluid sinks and pushes the warm fluid upwards. Students then document the interactions they observe in a teacher demonstration and notice the following:

- **Warm water on the left and cold water on the right:** Warm water moves over the cold water and to the right. Cold water pushes under the warm water and moves to the left.
- **Warm water on the right and cold water on the left:** Warm water moves over the cold water and to the left. Cold water pushes under the warm water and moves to the right.

Students then look at data that show the relationship between air temperature and the amount of water vapor that air can hold at both 100% and 50% relative humidity. Students use these data and their observations of the interactions between warm and cold water to to explain the types of interactions that occur between warm and cold air masses.

This will lead students to wonder, "How can we predict when warm and cold air masses will meet and cause changes in the weather?"

Where We Are NOT Going

Students will figure out the relationship between air pressure and the interactions that occur when warm and cold air masses interact in Lesson 17. This includes these ideas:

- how areas of low and high pressure are formed;
- what interactions create these differences in air pressure; and
- what types of changes in weather can be expected due to changes in air pressure.

LEARNING PLAN FOR LESSON 16

1. Navigation

8 MIN

Materials: science notebook

Revisit Lesson 15. Show **slide A** and say, *In the last lesson, we analyzed air temperature and relative humidity data. As we looked for patterns in the data, what were we able to figure out? Take a few moments to look back at Lesson 15 in your science notebook, then turn and talk with a partner. Be prepared to share your thinking with the class.*

Give students a few minutes to review and discuss the data and conclusions from the previous lesson, then ask a few to share their responses to the question with the class. Listen for the following ideas:

Suggested prompt	Sample student responses
As we looked for patterns in air temperature and relative humidity data, what were we able to figure out?	*We figured out that large masses of air move and interact in the atmosphere.* *These large air masses can be warm or cold, and they interact along boundaries called fronts.*

Suggested prompt	Sample student responses
	The type of front and the direction it moves is related to the type of air mass along its leading edge. Warm fronts occur along the leading edge of warm air masses, while cold fronts occur along the leading edge of cold air masses. *Whenever warm and cold air masses interact, predictable changes in weather, such as the formation of wind, clouds, and precipitation, can occur.*

Show **slide B** and say, *So now that we know that warm and cold air masses interact in the atmosphere, what interesting things did we see happening along the boundary between a warm air mass and a cold air mass that we wanted to explore further?*

Solicit a few responses from students.

Suggested prompt	Sample student response
What interesting things did we see happening along the boundary between a warm air mass and a cold air mass that we wanted to explore further?	*Whenever warm and cold air masses interact, predictable changes in weather, such as the formation of wind, clouds, and precipitation, can occur.*

Surface previous understandings and determine next steps. Show **slide C** and say, *We want to explore how warm air masses and cold air masses interact along the boundaries between them and understand why the weather changes when this happens. When warm and cold air masses meet along a front, they interact along a vertical boundary. Therefore, we need a setup that lets us explore the interactions between warm and cold air that occur along a vertical boundary, and the setup would be most helpful if it allows us to see a cross-sectional view of the interactions. This means we need to observe what happens when*

- *warm air is to the left of cold air and*
- *warm air is to the right of cold air.*

And we need to see these interactions from a side view in order to observe what happens from the ground up. We will also need to use prior understandings developed in earlier lessons to help us as we investigate these interactions.

Show **slide D**. Use the questions on the slide to guide a discussion, which should surface students' prior knowledge of fluids in preparation for investigating the interactions that occur between warm and cold air masses in the atmosphere. As students share their thinking, listen for the following ideas:

Suggested prompts	Sample student responses
What do we already know about what happens to the air near the surface when it is warmed up? How does that happen?	*When the Sun heats the surface of Earth and thermal energy transfers from the surface to the air directly above it, this creates a warm air mass below colder air. We know that warm air is less dense than cold air, so the warm air near the surface rises and the colder air above it sinks. When the rising warm air cools off, it sinks, creating a convection current.* *We know that convection currents at relatively small scales can create clouds that might be a few miles wide.* *This made us wonder about the interactions that occur along a vertical boundary between air masses that are hundreds of miles wide. We know that when a warm air mass and a cold air mass come into contact along a vertical boundary (or front), changes in the weather occur.* *We don't know why the weather changes, so we need to learn more about these interactions.*
How can we observe interactions between cold and warm air masses if we can't actually see air?	*Well, we know that water and air are both fluids, and they have similar characteristics—they flow, move easily, and take different shapes.* *In previous lessons, we observed convection currents in warm and cold water. So, we should be able to use warm and cold water to help us better understand what happens when warm and cold air masses come into contact along a boundary.*

Tell students, *Let's use these ideas to get ready to make some additional observations.*

2. Map the components of the experimental systems to the corresponding components in the atmosphere.

7 MIN

Materials: Warm and Cold Water Interactions: Teacher Demonstration, *Warm and Cold Water Interactions*

Introduce the investigation setup materials. Tell students, *In Lesson 12, we learned that scientists and engineers use liquids to observe and understand interactions between gases since both liquids and gases are fluids and behave in similar ways. So we will once again use water at different temperatures to simulate interactions that occur between air masses at different temperatures in the atmosphere.*

Draw students' attention to the materials on the table in front of you and say, *We will use an aquarium, 1.5-gal warm and 1.5-gal cold water, and a foam barrier to model air masses meeting along a vertical boundary. When we are ready to observe the interaction between warm and cold water, we will slide the foam barrier upward and observe what happens. Before we begin, let's quickly map out the components of our experimental setup as they relate to the components of the atmosphere.*

Map the components of the experimental setup to the corresponding components of the atmosphere. Ask students to gather around the table with the lab materials. Pass out *Convection in Fluids*. Show **slide E** and say, *Look at Part A on your handout. There are four important components in the setup. They are listed in the first table on your handout. We need to* identify *what each component of the experimental setup represents in the real world and describe how each compares to its real-world counterpart.*

As a class, identify what each component of the setup represents in the real world, then give students a few minutes to complete the table on the handout. Use the sample ideas below to help students compare both systems.

This component of the experimental setup . . .	. . . is like . . .	. . . this part of the atmosphere.	How are they the same?	How are they different?
Warm water	➪	warm air mass	Both are fluids; both have similar temperatures; each is less dense than the corresponding cold fluid.	The experimental setup uses water, while air is a gas.
Cold water	➪	cold air mass	Both are fluids; both have similar temperatures; each is more dense than the corresponding warm fluid.	The experimental setup uses water, while air is a gas.
Aquarium	➪	the atmosphere	Both represent a system that includes warm and cold fluids; both allow the fluids to interact along a vertical boundary.	The aquarium has an exterior boundary with liquids inside; the atmosphere is an open system that includes warm and cold masses of air.
Foam barrier	➪	the boundary between warm and cold air masses	Both are boundaries between warm and cold fluids.	The boundary (front) between warm and cold air masses in the atmosphere is not a solid boundary, while the foam barrier is.

3. Observe and document interactions between warm and cold water. **15 MIN**

Materials: Warm and Cold Water Interactions: Teacher Demonstration, *Warm and Cold Water Interactions*

Give directions for recording observations. Say, *Since we have some experience observing interactions between warm and cold fluids, you will watch two demonstrations that focus on the interactions between warm and cold water along a vertical boundary. These demonstrations will help us better understand what happens when warm and cold air masses meet along a front.*

For each demonstration, you will need to make a prediction about what will happen when the boundary between the warm and cold water is removed. I will add a few drops of blue food dye to the cold water to help us better observe what happens when the warm and cold water interact. After I remove the boundary, use pictures and words to record your observations.

Additional Guidance

Students have prior experiences observing fluid interactions, so allow them to first make predictions. Then conduct the demonstrations quickly and have them document what they observe using both pictures and words.

You may also want to use a smartphone or a tablet to record the demonstrations. Recording the demonstrations in this way allows you to immediately replay a video of what students observed. This might prove to be helpful during discussion, especially if students disagree or aren't quite certain of what they saw.

Make sure to only dye the cold water. Dying the warm water a different color will make it much harder to see a pattern in how they interact, so avoid adding any dye to the warm water.

Conduct first demonstration using warm water to the left of the cold water. Show **slide F** and say, *Turn to page 2 of your handout. You will see another chart where you can record predictions and observations as you watch how warm and cold water interact along a vertical boundary.* As you set up this demonstration, remember to explain each step as you work.

Directions:

1. Place the foam barrier in the center of the aquarium.
2. Add 6-8 drops of blue food dye to a bucket of cold water.
3. Use a plastic spoon to mix the food dye in the cold water.
4. Pour the bucket of dyed 1.5-gal cold water into the right side of the aquarium.
5. Pour the bucket of 1.5-gal warm water into the left side of the aquarium.
6. Do not remove the foam barrier yet.

Ask students, *With the warm water to the left of the cold water, what do you think will happen when I remove the foam barrier between them? Why?*

As students record their predictions on their handouts, prepare to video the demonstrations using either a smart phone, tablet, or video camera. When students are ready, ask a few to share their predictions with the whole group. Encourage them to justify their predictions.

Then, as students watch, quickly slide the foam barrier upwards, allowing the warm and cold water to interact. (Make sure you remember to video the demonstration.) Give students a few minutes to document what they observe using pictures and words.

Conduct the last demonstration using warm water to the right of cold water. Say, *Let's now see what happens when we move the warm water to the right of the cold water in the aquarium.*

Dump out the water from the aquarium, then set up the second demonstration. As you set up this demonstration, remember to explain each step as you work. Directions:

1. Place the foam barrier in the center of the aquarium.
2. Add 6-8 drops of blue food dye to a bucket of cold water.
3. Use a plastic spoon to mix the food dye in the water.
4. Pour the bucket of dyed cold water into the left side of the aquarium.
5. Pour the bucket of warm water into the right side of the aquarium.
6. Do not remove the foam barrier yet.

Ask students, *With the warm water to the right of the cold water, what do you think will happen when I remove the foam barrier between them? Why?*

Give students a minute to record their predictions on their handouts, then ask a few to share with the whole group. Encourage them to justify their predictions.

Then, as students watch, quickly slide the foam barrier upwards, allowing the warm and cold water to interact. (Remember to use a smartphone, tablet, or video camera to video this demonstration, also.) Give students a few minutes to document what they observe using pictures and words.

When students finish, show **slide G** and say, *On page 3 of your handout, you will find these two questions. Discuss your thoughts with a partner, then answer the questions on your handout.*

4. Building Understandings Discussion About Interactions Between Warm and Cold Fluids

15 MIN

Materials: science notebook, *Warm and Cold Water Interactions*, tape, chart paper, markers

Conduct a Building Understandings Discussion using students' observational data. Say, *You have had a few minutes to share your observations with a partner. Think about the things that you and your partner both observed when watching warm and cold water interact. Let's surface the things we saw in common, then make a list of what we know about how warm and cold fluids interact.**

Show **slide H** and use the questions on the slide to guide the discussion. Focus on one question at a time and document on chart paper students' responses to the second question.

*** Strategies for this Building Understandings Discussion**
The purpose of this Building Understandings Discussion is to find patterns in our observational data and generalize our descriptions of how warm and cold fluids interact. These generalized descriptions will help us begin to

Suggested prompts	Sample student responses
What patterns do we notice among our observations?	*When the warm water was to the left of the cold water and the foam barrier was lifted, the cold water pushed under the warm water and moved to the left. The warm water moved over the cold water and to the right. Then the warm water stayed above the cold water across the entire aquarium, with some mixing between the two layers.* *When the warm water was to the right of the cold water, we observed the same interactions. The cold water pushed under the warm water and moved to the right, while the warm water moved over the cold water and to the left. Then the warm water stayed above the cold water across the entire aquarium, with some mixing between the two layers.*
What do we now know about how warm and cold fluids interact?	*We know that a warm fluid is less dense than a cold fluid, so a warm fluid rises when it comes into contact with a cold fluid.* *When a warm fluid and a cold fluid interact along a vertical boundary, the warm fluid rapidly moves toward and over a cold fluid and the cold fluid rapidly moves toward and under a warm fluid. The fluids move along a diagonal slant as they interact.* *Due to the differences in density, a warm fluid tends to stay on top of a cold fluid until it cools down and becomes more dense.*

understand some of the weather changes that occur along warm and cold fronts.

Additional Guidance

If you were able to use a smartphone, tablet, or video camera to video the demonstrations, you may want to put those files on your computer and project the videos, if needed and if time permits. Viewing the videos may help students make more detailed observations, find commonalities, and better describe how warm and cold fluids interact.

Please note: If you were not able to video the demonstrations, there are videos of the demonstrations available in the unit resources.

Wrap up the activity. Summarize what has been accomplished during day 1 of this lesson by saying, *Today we observed two demonstrations using warm and cold water. We made predictions and documented our observations of the interactions along a vertical boundary*

- *when warm water was on the left of cold water and*
- *when warm water was on the right of cold water.*

Next time, we will think about some of the implications regarding weather changes that occur when warm and cold air masses interact in the atmosphere.

Have students tape *Warm and Cold Water Interactions* into their science notebooks before the end of class.

End of day 1

5. Navigation

3 MIN

Materials: None

Revisit the investigation. Show **slide I** and say, *Last class, we conducted an investigation to help us answer our lesson question. Take a quick two minutes to turn and talk with your partner. What did we observe when warm and cold water interacted after we removed the vertical boundary between them?*

Suggested prompt	Sample student responses
What did we observe when warm and cold water interacted after we removed the vertical boundary between them?	*The warm fluid rapidly moved toward and over the cold fluid.* *At the same time, the cold fluid rapidly moved toward and under the warm fluid.* *The fluids moved along a diagonal slant as they interacted.*

6. Model warm and cold air interactions in the atmosphere.

15 MIN

Materials: science notebook

Draw initial models that show warm and cold air interactions in the atmosphere. Show **slide J** and say, *So let's work on connecting what we observed back to our lesson question: How do warm air masses and cold air masses interact along the boundaries between them? Turn to the next page in your notebook, and follow the directions on the slide to set it up.*

Give students a minute or two to set up their notebooks, then say, *Look back at your observations of the interactions between warm and cold water along a vertical boundary.*

*** Supporting Students in Developing and Using Systems and System Models**

At this point in the lesson, students' models will have both similarities and differences when compared to weather models. It is important that students feel comfortable sharing both. There

When students are ready, say, *Use your drawings and written observations from the water investigation to create initial models of what you think happens*

1. *when warm air moves toward cold air and*
2. *when cold air moves toward warm air.*

For the first model, focus on your observations of warm water moving toward cold water. For the second, focus on your observations of cold water moving toward warm water. Be prepared to share your models with a partner.

Compare models with a partner. Give students 3–4 minutes to develop their models. Then have them share their models with a partner and look for similarities among their models. Have a few students share similarities they noticed among their models. Look for the following ideas:

1. Warm air moves toward cold air
   - The warm air mass moves over the cold air mass.
   - As the warm air moves diagonally over the cold air mass, it slides over the top of the denser cold air.
2. Cold air moves toward warm air
   - The cold air mass pushes under the warm air mass.
   - As the cold air pushes under the warm air mass, it pushes the warm air mass upward.

Additional Guidance

If students' models do not show any difference between how the warm air slides over the cold air and how the cold air pushes below the warm air, it might be useful to revisit the videos of the demonstrations. Students can watch for differences in how the warm water moves over the cold and how the cold water moves under the warm.

Compare models to standard models of warm and cold fronts. Show **slide K**. Then say, *On the slide you see a model that represents the interactions that scientists think are happening along a warm front—a warm air mass moving toward a cold air mass. How does your model compare with this model of a warm front? Look for both similarities and differences and be prepared to share what you notice.**

Suggested prompt	Sample student responses
How does your model compare with this model of a warm front?	*The model on the slide is similar to our models and to what we observed because it shows the warm air mass moving over the cold air mass.* *Like our models, the model on the slide shows the warm air mass sliding diagonally over the top of the cold air mass.* *I forgot to include clouds in my model. But I know that weather changes, like the formation of clouds and precipitation, occur along fronts.*

are strategies that you can use to help students feel comfortable sharing both similarities and differences between their initial models and the weather models shared on **slide K** and **slide L**.

- Revisit classroom norms prior to the discussion.
- Remind students that when we develop models, our models represent our thinking and understanding of a phenomenon at that point in time. Our ideas change and develop as we learn more. Therefore, we should each expect our initial models to be incomplete or incorrect in some ways since we have more to learn.
- Allow students to share their models with a partner before the whole-group discussion. This provides all students a chance to share their ideas in a safe, more comfortable way.
- If students are used to thinking about phenomena in terms of systems, then they have experience in modeling system components and interactions. Use this to students' advantage as follows:
  - When opening up the whole-group discussion, focus first on comparing the system components in students' models to those in the

Show **slide L**. Say, *On this slide you see a model that represents the interactions that scientists think happen along a cold front—a cold air mass moving toward a warm air mass. How does your model compare with this model of a cold front?*

Suggested prompt	Sample student responses
How does your model compare with this model of a cold front?	*The model on the slide is similar to our models and to what we observed because it shows the cold air mass moving under the warm air mass.* *Like our models, the model on the slide shows the cold air mass pushing under the warm air mass.* *I put clouds at the front because I remembered that there are changes in the weather that happen when warm and cold air interact along a front.*

Make connections to weather changes that occur along weather fronts. Once again, ask students to look at the models on **slides K** and **L** and say, *Notice that along both fronts we see clouds forming due to the lifting of warm, moist air. Earlier in the unit, we figured out that when moist, warm air rises and cold air sinks, the water vapor in the moist, warm air begins to condense as it cools off higher in the atmosphere. This results in the formation of clouds and, at times, precipitation. However, we need enough humidity in the air for condensation to happen. Condensation will only start to happen when air reaches 100% relative humidity. One hundred percent relative humidity means the air cannot hold any more water vapor. So, how do scientists know if and when precipitation will happen along a front? Let's look at some data charts that will help us begin to figure this out.*

weather models. Students will most likely experience success in documenting the same system components in their own models as those in the weather models on **slide K** and **slide L**.

- Next, focus on the interactions that students documented on their models and how these compare to the interactions documented on the weather models. This will help students recognize the interactions they might have overlooked when developing their own initial models.

7. Analyze relative humidity data.

20 MIN

Materials: *Relative Humidity Data*, chart paper, markers

Analyze temperature and water vapor data for air at 100% relative humidity. Pass out *Relative Humidity Data*. Show **slide M** and say, *Take a look at the graph in Part A of your handout. Work with your partner to make sense of the information in the graph, then answer questions 1 and 2. Also, notice that question 1 has some additional parts (a, b, and c) that are not displayed on the slide. Make sure you answer these questions, too. Be prepared to share your responses with the class.*

As students work, walk around and listen to their conversations.

After a few minutes, ask them to share their responses to the questions in Part A. Look for the following ideas to surface:

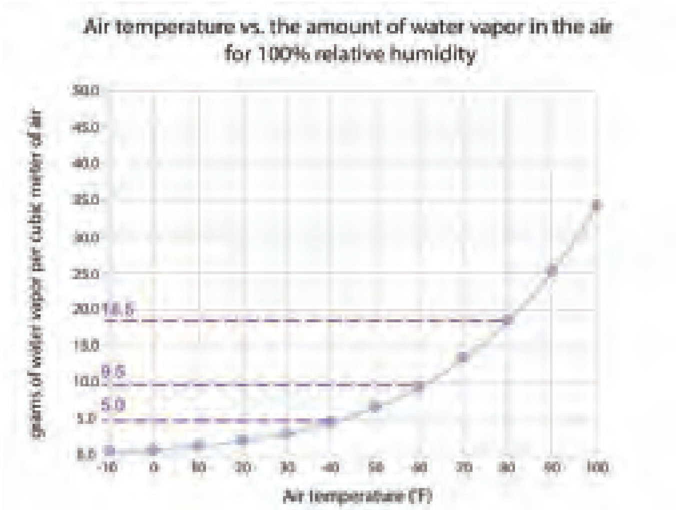
Suggested prompt	Sample student response
What do the points along the graphed line represent?	*The points along the graphed line tell us how much water vapor is in the air at different temperatures when the air is at 100% relative humidity.*

*** Supporting Students in Engaging in Using Mathematical and Computational Thinking**

Students may not have experience with comparing data and using mathematical thinking to figure out relationships among the data, so you may need to guide their thinking. You can use prompts to break down analysis of data into small steps. For example, if students are struggling to figure out the relationship between air temperature and the amount of

Suggested prompts	Sample student responses
How much water vapor is in air that is 80°F and at 100% relative humidity?	*A little more than 18 grams per cubic meter of air, but a little less than 19 grams per cubic meter of air.* *About 18.5 grams per cubic meter of air.*
How much water vapor is in air that is 60°F and at 100% relative humidity?	*A little more than 9 grams per cubic meter of air but a little less than 10 grams per cubic meter of air.* *About 9.5 grams per cubic meter of air.*
How much water vapor is in air that is 40°F and at 100% relative humidity?	*About 5 grams per cubic meter of air.*

If you are projecting on a whiteboard as students share their responses to 1a, 1b, and 1c, use a dry-erase marker on the projected graph to mark each of the *y*-values that students report along the *y*-axis of the graph along with a dotted line to show how they connect to the point on the graph.



Suggested prompt	Sample student response
Based on the information in the graph, what is the relationship between air temperature and the amount of water vapor that the air can hold?	*As the temperature of the air increases, so does the amount of water vapor it can hold at 100% humidity.*

Determine how much water would condense out of the air for two different temperature changes. Tell students, *Remember, if air at 100% relative humidity is cooled, the water vapor in the air begins to condense. That's when we see clouds form and experience precipitation. This is due to the relationship between air temperature and the amount of water vapor in the air—cooler air cannot hold as much water vapor as warmer air. So, let's use this graph to figure out how much water would condense out of the air when it cools.*

water vapor it can hold, you might guide them with prompts such as these:

- What does it mean for air to be at 100% relative humidity?
- As we move from left to right along the *x*-axis on the graph, what do we see?
- As we move up along the *y*-axis, what do we see?
- How much water vapor does air at 30°F and 100% relative humidity hold?
- How much water vapor does air at 40°F and 100% relative humidity hold?
- What changes in the amount of water vapor do we notice as we increase the temperature of the air at 100% relative humidity?

You can use similar guidance if students are struggling to answer questions in Parts B and C; however, do not guide the entire class in this way. It is OK to let students think through the questions with their partners and to struggle just a bit as they work together to figure out answers to the questions. When the struggle is no longer productive and students appear frustrated, then you should step in with guidance.

Tell students, *We will work together to calculate how much water would condense out of the air if the temperature dropped from 80°F to 60°F. We can do this by finding the difference between the first two y-values we marked on the graph. What would that difference be?*

Suggested prompt	Sample student response
What is the difference between the first two y-values we marked on the graph?	*18.5 – 9.5 = 9 grams per cubic meter of air.*

Say, *Now, work with a partner and determine how much water would condense out of the air if the temperature dropped from 60°F to 40°F.*

Give students a minute to work, then bring students back together to report out. Students should say 4.5 grams per cubic meter of air.

Next, ask students, *Which temperature drop would cause more water to condense out of the air at 100% humidity—a 20°F decrease in air that started out at 80°F or a 20°F decrease in air that started out cooler at 60°F?*

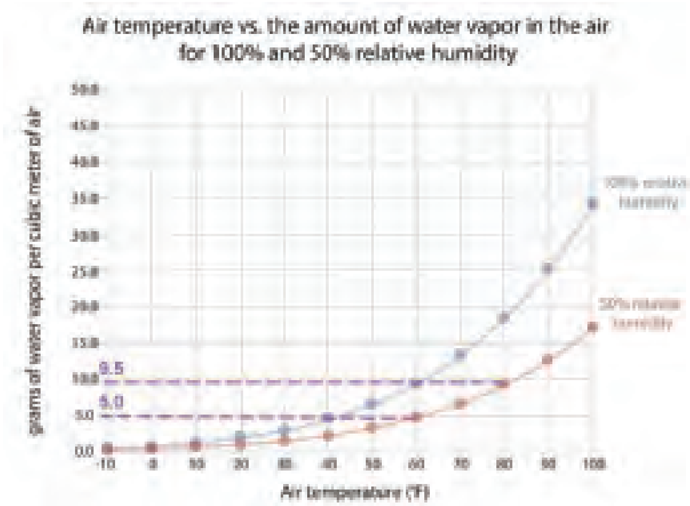
Based on their calculations, students should say a 20°F decrease in the air that started out warmer should lead to more water condensing out.

Analyze temperature and water vapor data for air at 50% relative humidity. Erase the previous *y*-values that still may be on your whiteboard. Show **slide N** and say, *Now let's look at Part B on your handout. Notice that an additional set of data has been added to the graph. Work with your partner to make sense of this additional information in the graph, then answer questions 3 and 4. As before, be prepared to share your responses with the class.*

Give students a few minutes to work then ask them to share their responses to questions 3 and 4. Look for the following ideas to surface and use dry-erase markers to mark the corresponding new *y*-value locations students report on the graph:

Suggested prompts	Sample student responses
What do the points along the bottom graphed line represent?	*The points along the bottom line tell us how much water vapor is in the air at different temperatures when the air is at 50% relative humidity.*
How much water vapor is in air that is 80°F and at 50% relative humidity?	*A little more than 9 grams per cubic meter of air but a little less than 10 grams per cubic meter of air.* *About 9.5 grams per cubic meter of air.*
How much water vapor is in air that is 60°F and at 50% relative humidity?	*About 5 grams per cubic meter of air.*

Suggested prompt	Sample student responses
Do we still see the same relationship between air temperature and the amount of water vapor that air can hold? How do you know?	*The relationship between air temperature and the amount of water vapor that the air can hold is the same at 50% relative humidity as it is at 100% humidity.* *As the air temperature increases, so does the amount of water vapor it can hold at 50% relative humidity.* *Both graphs move upward (increase in the amount of water vapor in the air) as we move to the right (increase in air temperature).*



Use mathematical thinking to further analyze data. Tell students, *Remember, if air at 100% relative humidity is cooled, the water vapor in the air begins to condense. Notice that when the air is at 50% relative humidity and 80°F, it looks like it has just as much water vapor in it as air at 60°F and 100% relative humidity. This tells us that if you cool air that is at 80°F and 50% relative humidity all the way down to 60°F, it would have 100% relative humidity. How much of a temperature drop is that from 80°F to 60°F?* Students should say 20°F.

Say, *So this air has to cool 20°F before any precipitation will condense out of it. It has to reach 100% relative humidity—the point at which it can't hold any more water vapor in it. Cooling helps it reach that point, but until it reaches that point, no water will condense out. Let's use that same sort of thinking to figure out how much the air would have to cool if it is at 50% relative humidity and 60°F.*

Point to the corresponding spot on the graph. Ask students to work with a partner to figure out how much the temperature would need to change to get that air to 100% relative humidity. Give students a minute to discuss, then bring them back together to report out. Students should say that you have to cool this air 20° too. Emphasize that in both of these cases we have to cool the air quite a bit before it reaches the point at which any water vapor would condense out at 100% relative humidity.

Show **slide O** and say, *Once again, work with your partner to answer the questions in Part C of your handout Relative Humidity Data.*

Document what we have figured out. As students finish, ask a few to share out their responses to the questions in Part C of the handout. Then say, *Let's take a few minutes to document what we know and have figured out about the relationship between air temperature and the amount of water vapor air can hold.*

Use chart paper to document what students have figured out. Look for the following ideas to surface:

- The maximum amount of water vapor that air at a given temperature can hold is referred to as 100% relative humidity.
- The maximum amount of water vapor that can be in the air changes based on the temperature of the air.
- Warmer air can hold more water vapor than colder air.

- When air is at 100% relative humidity, additional cooling will cause water vapor to condense out of the air.
- The greater the decrease in air temperature, the greater the amount of water vapor that will condense out of the air.
- If air is at less than 100% relative humidity and it cools down enough, it will reach 100% relative humidity.

8. Revisit the weather models. 5 MIN

Materials: science notebook, chart paper, markers

Revisit the weather models. Show **slide P** and say, *Let's take what we have figured out and explain why the weather changes along a front.* Give students the opportunity to share their thinking and chart their ideas that help them explain why weather changes along a front.

Suggested prompt	Sample student responses
Why does the weather change along a front?	*A warm air mass and a cold air mass interact along a front.* *When warm air and cold air meet, the warm air lifts up and over the cold air. This lift pushes the warm air up into the atmosphere, where the surrounding air is much, much colder.* *As the warm air rises and cools, the water vapor in the warm air condenses, which causes clouds and precipitation to form.* *When cold air runs into warm air (cold front), the cold air pushes into the warm air, causing an extreme lift of the warm air and a quick change in temperature. This causes clouds to form and strong storms with a lot of precipitation along the cold front. When warm air runs into cold air (warm front), the lift is along a diagonal and not as steep or as quick, so clouds and precipitation do not form as fast and the storms along a warm front are not as extreme.*

9. Navigation 2 MIN

Materials: science notebook, *Relative Humidity Data*, tape

Navigate to the next lesson. Before closing the lesson, direct students to tape *Relative Humidity Data* into their notebooks. When students are ready, close the lesson by saying, *We have figured out* ***what*** *happens when a warm air mass and a cold air mass interact and we have figured out* ***why*** *it happens. But I wonder . . . How do scientists know* ***when*** *a* *front is moving into an area? We can't see warm and cold air masses, so how do they know **when** a front is moving into an area and the weather is going to change? I think we need to figure out how scientists do this.*

ADDITIONAL LESSON 16 TEACHER GUIDANCE

Supporting Students in Making Connections in Math

CCSS.MATH.CONTENT.6.NS.C.8: Solve real-world and mathematical problems by graphing points in all four quadrants of the coordinate plane. Include use of coordinates and absolute value to **find distances between points with the same first coordinate or the same second coordinate.**

Students will also interpret the *y*-axis label as a unit rate (grams of water vapor per cubic meter of air). This is a connection to this related math standard.

LESSON 17

Is there a relationship between where the air is rising and where precipitation falls?

Previous Lesson

We used models to observe and describe interactions that occur between warm and cold air masses and used patterns in data to explain changes in precipitation that can occur when air masses collide.

This Lesson

Investigation

1 DAY

Data Source: NOAA

We analyze national pressure maps from around the time of the original forecast. We construct an explanation of the patterns we notice among (1) the area of lowest air pressure, (2) the locations of the fronts, and (3) where precipitation would fall. We apply scientific ideas to explain what is causing these three things to be connected to one another.

Next Lesson

We will explore a weather report and forecast. We will develop a model to explain how what was happening in one part of the country at one point in time could be connected to what is predicted to happen in another part of the country over a day later. We will develop new questions for our Driving Question Board (DQB) and brainstorm ways to investigate these questions.

Building Toward NGSS

MS-PS1-4, MS-ESS2-4, MS-ESS2-5, MS-ESS2-6

What Students Will Do

Analyze data using maps of air pressure recorded over the country at different points in time and forecasts (temporal and spatial relationships) to identify patterns (the movement of low-pressure systems) and the relationship between this (patterns) and the location of fronts and precipitation.

Construct an explanation that includes the qualitative relationships presented in a weather forecast among (1) the area of lowest air pressure and where it will move to, (2) the locations of the fronts, and (3) where precipitation will fall, using scientific ideas and principles to explain what would be causing these three things to be connected to one another.

What Students Will Figure Out

- When the air pressure outside decreases, it tends to correspond with the appearance of cloudier skies and in some cases precipitation.

- Large-scale, low-pressure air masses can move, and their movement can be predicted.
- The movement and location of warm and cold fronts appear to be connected to this low-pressure center.
- In one storm, precipitation tends to fall along the line of the cold front and warm front and behind the low-pressure center.

Lesson 17 • Learning Plan Snapshot

Part	Duration	Summary	Slide	Materials
1	5 min	**NAVIGATION**	A	Air Pressure poster
2	10 min	**ANALYZING OUR WEATHER LOGS**	B	2 large sticky notes, markers, Air Pressure poster
3	12 min	**MAKING PREDICTIONS AND ANALYZING DATA**	C-F	*Air Pressure Prediction and Map Analysis*, tape, *Air Pressure Maps*, 11 orange colored pencils
4	15 min	**EXPLAINING PATTERNS IN THE ORIGINAL FORECAST**	G	*Explaining Patterns and Predictions in the Forecast*, resource from Lesson 14: *Images from the Jan. 19, 2019 Weather Forecast*, Previously Used Mechanisms poster, computer, projector, Weather Report and Forecast video (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)
5	3 min	**NAVIGATION**		*Air Pressure Prediction and Map Analysis*, *Explaining Patterns and Predictions in the Forecast*
				End of day 1

Lesson 17 • Materials List

	per student	per group	per class
Lesson materials **Student Procedure Guide** **Student Work Pages**	• science notebook • *Air Pressure Prediction and Map Analysis* • tape • *Explaining Patterns and Predictions in the Forecast* • resource from Lesson 14: *Images from the Jan. 19, 2019 Weather Forecast*	• *Air Pressure Maps* • 11 orange colored pencils • tape	• Air Pressure poster • 2 large sticky notes • markers • Previously Used Mechanisms poster • Weather Report and Forecast video (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**) • computer • projector

Materials preparation (20 minutes)

Online Resources

Review teacher guide, slides, and teacher references or keys (if applicable).

Make copies of handouts and ensure sufficient copies of student references, readings, and procedures are available.

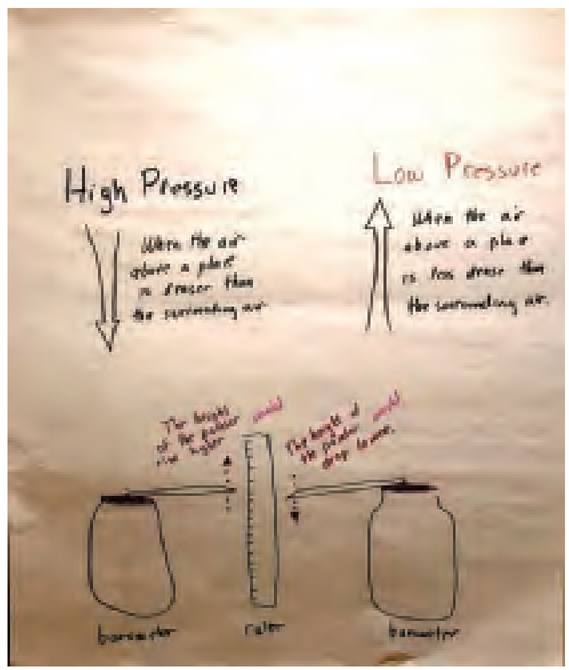
Print 1 copy of *Air Pressure Prediction and Map Analysis* and 1 copy of *Explaining Patterns and Predictions in the Forecast* for each student.

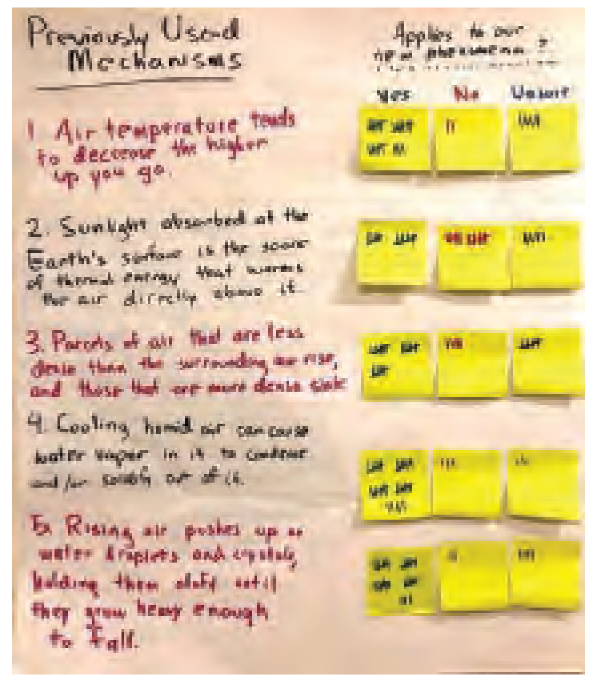
Print 1 single-sided copy of *Air Pressure Maps* for every 11 students you have across each class, including an extra copy for any students in each class not evenly divisible by 11. So for example, if you have 22 students, you would print 2 copies, and if you have 23 students, you would print 3 copies.

Pool together your previously prepared set of color copies of *Images from the Jan. 19, 2019 Weather Forecast* from Lesson 14 so that every student in your largest class can have one.

Test the video link. (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)

Relocate the Air Pressure poster from Lesson 11 to a central location in the room at the start of this lesson.





Relocate the Previously Used Mechanisms poster with the total of the tallies from all classes from Lesson 14 to a central location in the room to refer to at the end of this lesson.

Gather 1 orange colored pencil and 1 blue colored pencil for every student in your largest class.

Lesson 17 • Where We Are Going and NOT Going

Where We Are Going

This lesson follows up on the role of air pressure that was introduced in Lesson 11. In that lesson the class built a homemade barometer to detect changes in the amount of force the air outside exerts on it. Students established that rising or falling air pressure should cause the barometer needle to shift upward or downward respectively. They made predictions about whether such differences may relate to the level of sunniness or cloudiness (and precipitation) outside.

In this lesson students start out by following up on the ideas predicted by the model they developed in lesson 16, including the idea that along front lines warm air would move upward over cold air and this would lead to cloud formation and potential precipitation.

Students will review the data they collected from the barometer and the level of cloudiness outside every day since Lesson 11 to look for evidence of this predicted relationship. They then will analyze pressure maps from across the country from before, during, and after the storm and compare these to the pressure changes predicted in the weather forecast from Lesson 14 to determine that an area of low pressure air that moves from the southwest to the northeastern part of the country corresponds to the northern portion of the warm air mass that was running into the cold air mass over the duration of the storm.

Where We Are NOT Going

Stick with the idea of air pressure as a way of describing relative changes in the density of air above the barometer. Other ways of thinking about pressure, such as the force applied to a surface from the particles that hit it or the force per unit area, will be counterproductive to introduce in this unit and are likely to add barriers to student understanding of the phenomena they are trying to explain in this unit.

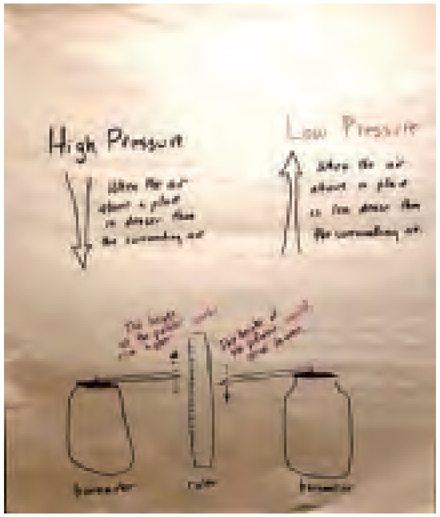
1. Navigation

5 MIN

Materials: Air Pressure poster

Connect to the previously developed model. Present **slide A**. Read the text on the top of the slide. Give students a couple of minutes to discuss the questions below it with an elbow partner. Then discuss these questions as a class.

Suggested prompts	Sample student responses
Where does this model show air rising upward?	*At the edge of a cold front, where the warm air was pushed upward over the cold air moving inwards.* *At the edge of a warm front, where the warm air slides over the back edge of the cold air as it moves away from it.*
How could a barometer help detect this?	*The pointer on a barometer would move when air around it is sinking or rising, when it becomes more or less dense.*
Why would clouds tend to develop over where this is happening?	*In both cases, the warm air moves upward. As it moves upward, it cools. As it cools, it can hold less water vapor. That water vapor starts to condense or solidify, which forms clouds.*
How is this connected to where precipitation would occur?	*The more water that condenses, the larger the water droplets and crystals will grow, until they eventually are too heavy to be held aloft. This is when they will fall as precipitation.*



Connect this to the barometer you made from Lesson 11. Say something like, *The arguments you are making based on this model are grounded in the idea that air that rises and has water vapor in it will tend to produce clouds as it cools as it gets higher up. After barometers were invented, this was a pattern that scientists looked for in the weather data they collected.*

Point to the Air Pressure poster from Lesson 11 as you describe some of the patterns that scientists have noticed. Say, *And they started to see a pattern like we are predicting. When the air outside the barometer becomes less dense than air in neighboring air masses, it tended to correspond to it becoming overcast or cloudy. Let's look for such a pattern in the weather observations we collected along with our measurements from our homemade barometers.*

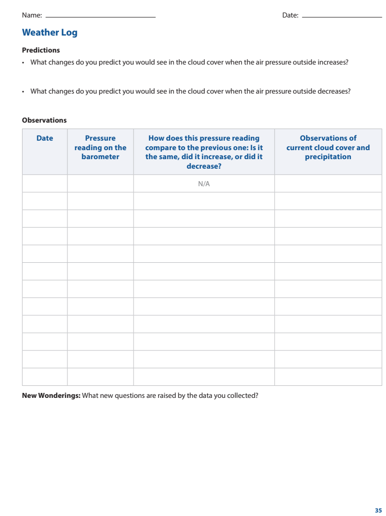
Additional Guidance

If the class didn't collect data over multiple days with the homemade barometer from Lesson 11, skip the reference to homemade barometers above and skip reference to slide B in the next activity but still summarize the two relationships between high and low pressure and sunny and cloudy skies and add the related sticky notes to the Air Pressure poster. If students in your class are using the Student Procedures, then they will also skip step 2 in those.

2. Analyzing Our Weather Logs

10 MIN

Materials: science notebook, 2 large sticky notes, markers, Air Pressure poster


Name: ____________ Date: ____________

Weather Log

Predictions

- What changes do you predict you would see in the cloud cover when the air pressure outside increases?
- What changes do you predict you would see in the cloud cover when the air pressure outside decreases?

Observations

Date	Pressure reading on the barometer	How does this pressure reading compare to the previous one: Is it the same, did it increase, or did it decrease?	Observations of current cloud cover and precipitation
		N/A	

New Wonderings: What new questions are raised by the data you collected?

35

Revisit the homemade barometer. Present **slide B**. Read the text on the slide. Help students see the pink arrows on the images show that the pointer would tilt in the opposite direction as the movement of air above it. Add the following ideas to the word wall:

- **Higher pressure air** outside causes the barometer pointer to tilt upward. This happens when the air outside becomes denser than the air inside the barometer.
- **Lower pressure air** outside causes the barometer pointer to tilt downward. This happens when the air outside is less dense than the air inside the barometer.

Analyze weather logs. Have students open their notebooks to the page with *Weather Log* on it from Lesson 11 and discuss the questions on the slide with an elbow partner for about three minutes.

Discuss the patterns in weather log data. Students may notice the following (depending on the changes in air masses that have moved over your region since Lesson 11 and the amount of data you have recorded on back-to-back days):

- When the air pressure decreased, it tended to become cloudier.
- When the air pressure increased, it tended to become clearer or sunnier.

Summarize general patterns in air pressure vs. cloudiness. Say, *Weather scientists have discovered similar patterns in the data from barometers in different parts of the world and at different times of year. Whenever the density of the air over a region decreases, it typically corresponds to the air in that part of an air mass rising. And when there is sufficient humidity in that air, rising air tends to produce clouds as the water vapor in it condenses as it is pushed higher up where it cools.*

Add two large sticky notes to the top of Air Pressure poster indicating this trend. The one on the left should say “clear or clearing skies” with a sun drawn on it. The one you add on the right should say “cloudy skies” with a cloud drawn on it.

3. Making Predictions and Analyzing Data

12 MIN

Materials: science notebook, *Air Pressure Prediction and Map Analysis*, tape, *Air Pressure Maps*, 11 orange colored pencils

Make predictions. Say, *In order to figure out what was happening with the winter storm we’ve been investigating, we’ve developed some ways to visualize where the cold air and warm air were located before, during, and after precipitation was dumped on different parts of the country. Since we know that rising air corresponds to a drop in air pressure and that rising air leads to cloud formation, let’s make some predictions about where we think barometers would have detected lower-pressure air over the United States from the afternoon of January 17, 2019 to end of January 20, 2019.*

Show **slide C**. Hand out a copy of *Air Pressure Prediction and Map Analysis* to each student. Give students three minutes to record their predictions and tape these into their science notebooks.

Assign initial maps to analyze. Form groups of 11 students. Distribute 11 orange colored pencils to each group. Give the 11 pages of *Air Pressure Maps* to the group to split up amongst their group members.

Introduce the visualization convention. Present **slide D**. Ask if there are any questions about how to locate or mark the data on the maps.

Analyze maps. Give students a couple of minutes to work individually to analyze their maps and create the related color visualization of the data.

Organize the maps. Present **slide E.** Designate a location in the room for each group of students to tape their 11 maps on a wall in order (Map 1, Map 2, Map 3, and so forth) in preparation for a gallery walk. This will take about 2 minutes.

Conduct the gallery walk. Show **slide F.** Cue students to start their gallery walk and to summarize the patterns they notice when they are done. This will take about four minutes.

4. Explaining Patterns in the Original Forecast

15 MIN

Materials: science notebook, *Explaining Patterns and Predictions in the Forecast*, resource from Lesson 14: *Images from the Jan. 19, 2019 Weather Forecast*, Previously Used Mechanisms poster, computer, projector, Weather Report and Forecast video (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)

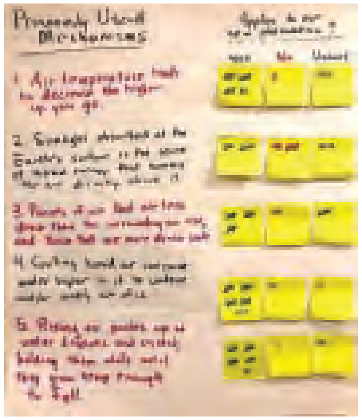
Connect to previous model ideas. Show **slide G.** Say, Let's use this new information about actual changes in air pressure occurring over time to see if it helps us make sense of what was predicted to happen in the original weather forecast. In addition to precipitation predictions, the video we are about to rewatch will show us where the weather scientists predicted the location of lowest air pressure would be found over the weekend. That will be indicated by a white "L" on a red circle.

Review the entire forecast. Tell students that after watching this video, you will ask them to develop an explanation of this phenomenon as a formative assessment. Play the full video, from start to finish. (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**) After showing the video once, emphasize that the part of the video they saw with the fronts and lowest pressure marked on the maps was a forecast that showed weather that hadn't happened yet at the time of the forecast. But the data on the maps they have analyzed are what actually ended up occurring after the forecast was made.

Prepare students for writing the explanation.

- Distribute a copy of *Explaining Patterns and Predictions in the Forecast* and ask students to keep it separate from their notebooks as you want to collect it as a formative assessment.
- Distribute a copy of *Images from the Jan. 19, 2019 Weather Forecast* to each student to use as a reference.

Say, *Questions 1 and 2 on Explaining Patterns and Predictions in the Forecast will help you summarize what the patterns were in the forecast and how these compared to the actual pressure data you analyzed in the gallery walk.*



Reference the Previously Used Mechanisms poster. Say, *Question 3 will ask you to develop an explanation of the patterns you saw in the forecast. When we first explored this forecast we considered whether this set of ideas (reference the Previously Used Mechanisms poster) could explain the related phenomenon associated with it. We also brainstormed additional mechanisms that we thought might be needed to explain it. The investigations we have done since then helped us determine what those are. Use this poster and all the new mechanisms you figured out over the past few lessons when you develop your explanation. Let's watch the portion of the video you will be explaining one more time before you start your explanation.*

Show the video a second time. But this time only show from 0:20 to 1:02. (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)

Develop explanations. Give students the remaining time to complete *Explaining Patterns and Predictions in the Forecast*.

5. Navigation

3 MIN

Materials: science notebook, *Air Pressure Prediction and Map Analysis*, *Explaining Patterns and Predictions in the Forecast*

Ask students to frame the work of the next lesson. Say something like, *I will review your explanations tonight to get a sense of how the ideas you all are using to explain how and why this phenomenon occurs compare. If we want to come to agreement on what those ideas are, what is our next step as a class?*

Students will say things like this:

- *We need to compare these explanations.*
- *We need to argue for different explanations.*
- *We need to work together to decide what the ideas are that are really needed to explain the phenomena.*
- *We need to develop a consensus model.*
- *We will need to work in groups or in a Scientists Circle.*

Foreground these as what we need to do next. Say something like, *Next time we meet, let's prepare to do some of this, where you share your explanations with others and where we work to fold all our thinking together to develop consensus around the ideas we think are needed to explain what caused this phenomenon.*

Collect *Air Pressure Prediction and Map Analysis* and *Explaining Patterns and Predictions in the Forecast* at the end of the period. Remove the two sticky notes from the Air Pressure poster and reuse them in the next class.

ADDITIONAL LESSON 17 TEACHER GUIDANCE

Supporting Students in Making Connections in ELA

Students engage in the following while completing *Explaining Patterns and Predictions in the Forecast*:

- CCSS.ELA-LITERACY.W.6.2 Write informative/explanatory texts to examine a topic and convey ideas, concepts, and information through the selection, organization, and analysis of relevant content.
- CCSS.ELA-LITERACY.W.6.2.B Develop the topic with relevant facts, definitions, concrete details, quotations, or other information and examples.
- CCSS.ELA-LITERACY.W.6.2.D Use precise language and domain-specific vocabulary to inform about or explain the topic.

LESSON 18

How can we explain what is happening across this storm (and other large-scale storms)?

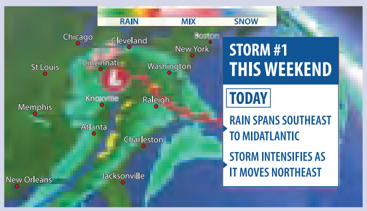
Previous Lesson

We analyzed national pressure maps from around the time of the original forecast. We constructed an explanation of the patterns we noticed among (1) the area of lowest air pressure, (2) the locations of the fronts, and (3) where precipitation would fall. We applied scientific ideas to explain what was causing these three things to be connected to one another.

This Lesson

Putting Pieces Together, Problematizing

2 DAYS



We explore video and maps from three parts of a weather report and forecast from Nov. 22, 2019. We develop a model to explain how what was happening in one part of the country at one point in time can be connected to what is predicted to happen in another part of the country over a day later. We develop new questions for our Driving Question Board (DQB) and brainstorm ways we could investigate these questions.

Next Lesson

We will view a visualization showing precipitation movement across the United States and annotate a class map. We will figure out that air mostly moves in the same pattern across most of the United States, but some places near the coasts show a slightly different pattern. We will zoom out to a global view and notice that patterns in the northern hemisphere mirror patterns in the southern hemisphere and see that precipitation is heavier in locations near the ocean. We will wonder how the ocean changes a place's weather.

Building Toward NGSS

MS-PS1-4, MS-ESS2-4, MS-ESS2-5, MS-ESS2-6

What Students Will Do

Compare and critique two arguments on the same topic and analyze whether they emphasize similar or different mechanisms (cause) in their explanations of the patterns in how the weather changed (effect) during the Jan. 19, 2019 storm.

Apply scientific ideas and related evidence to evaluate whether the new mechanisms (air mass movement, interaction of fronts, and low pressure areas [cause]) that were used in an explanation of one large-scale storm are also needed to explain the patterns in the how the weather will change [effect] in the predictions made for three other storms occurring at a different time of year.

Ask questions about typical patterns and causes related to these in how air masses move across the country and how where a place is located (near the coast or inland, high elevation or low, in the northeast vs. southwest) affects the amount and type of precipitation that the place receives over more than a few years.

What Students Will Figure Out

- Many storms are due to the path that air masses follow as they move, other air masses they interact with along their boundaries (fronts), and how much lift occurs in the air mass or along those fronts.
- We have new questions about whether certain weather patterns are typical for different places in our country and what causes any differences in those from one place to another over longer periods of time.

Lesson 18 • Learning Plan Snapshot

Part	Duration	Summary	Slide	Materials
1	4 min	**NAVIGATION** Review previous mechanisms and explanations.	A	*Comparing Ideas Used Between Explanations*, previously completed *Explaining Patterns and Predictions in the Forecast*, Previously Used Mechanisms poster
2	15 min	**COMPARE EXPLANATIONS** Share and compare explanations in small groups.	B-C	*Comparing Ideas Used Between Explanations*, timer
3	13 min	**DEVELOP A CONSENSUS MODEL AND MAKE PREDICTIONS** Establish consensus around the mechanisms that are needed to explain the cause of this larger-scale precipitation event.	D-E	*Progress Tracker: Ideas Needed in Our Consensus Explanation*, 1 blank piece of chart paper, the top ¼ of a second piece of chart paper, markers, sticky notes (in a different color than those already used on the Previously Used Mechanisms poster), Previously Used Mechanisms poster, New Mechanisms poster
4	4 min	**PREPARE TO INVESTIGATE OUR PREDICTIONS** Introduce what will be in the next weather report and forecast and when it was broadcast.	F-G	computer, projector, Lesson 18 Weather Report and Forecast (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)

Part	Duration	Summary	Slide	Materials
5	6 min	**RECORD OBSERVATIONS FOR STORM 1 AND 2** Analyze the first storm and second storm predictions made in a weather forecast.	H-I	*Nov. 22, 2019 Weather Forecast Maps*, computer, projector, Lesson 18 Weather Report and Forecast (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**) *End of day 1*
6	5 min	**RECORD OBSERVATIONS FOR STORMS 2 AND 3** Analyze the third storm predictions made in a weather forecast.	J	*Nov. 22, 2019 Weather Forecast Maps*, computer, projector, Lesson 18 Weather Report and Forecast (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)
7	8 min	**SHARE OBSERVATIONS AND ESTABLISH LINES OF EVIDENCE FOR THE MODEL IDEAS** Share observations from noticings and argue for how these are evidence for our new mechanisms.	K	*Nov. 22, 2019 Weather Forecast Maps*, New Mechanisms poster, markers
8	15 min	**SHARE WONDERINGS AND INITIAL EXPLANATIONS** Discuss wonderings with a partner.	L-O	*Nov. 22, 2019 Weather Forecast Maps*
9	14 min	**RECORD ADDITIONAL QUESTIONS AND EXPAND OUR DRIVING QUESTION BOARD**	P-Q	sticky notes, marker, pencil, chart paper, timer
10	3 min	**IDENTIFY ADDITIONAL SOURCES OF DATA NEEDED** Develop ideas for future sources of data needed to investigate our questions.	R	sticky notes, markers *End of day 2*
		SCIENCE LITERACY ROUTINE Upon completion of Lesson 18, students are ready to read Student Reader Collection 6 and then respond to the writing exercise.		Student Reader Collection 6: *A Closer Look at Weather*

Lesson 18 • Materials List

	per student	per group	per class
Lesson materials **Student Procedure Guide** **Student Work Pages**	• science notebook • *Comparing Ideas Used Between Explanations* • previously completed *Explaining Patterns and Predictions in the Forecast* • *Progress Tracker: Ideas Needed in Our Consensus Explanation* • *Nov. 22, 2019 Weather Forecast Maps* • sticky notes • marker • pencil		• Previously Used Mechanisms poster • timer • 1 blank piece of chart paper • the top ¼ of a second piece of chart paper • markers • sticky notes (in a different color than those already used on the Previously Used Mechanisms poster) • New Mechanisms poster • Lesson 18 Weather Report and Forecast (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**) • computer • projector • chart paper • sticky notes

Materials preparation (20 minutes)

Online Resources

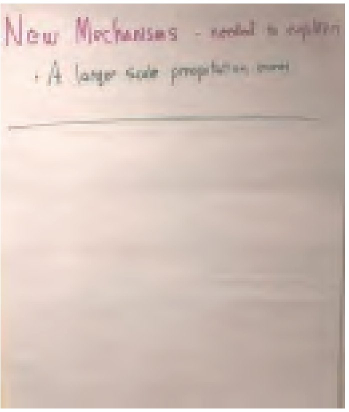
Review teacher guide, slides, and teacher references or keys (if applicable).

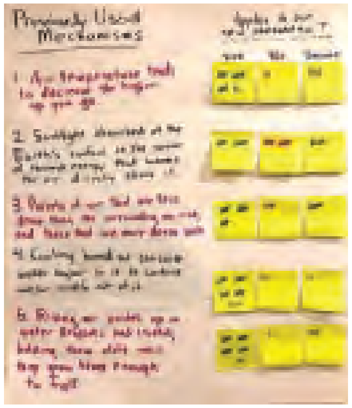
Make copies of handouts and ensure sufficient copies of student references, readings, and procedures are available.

Prepare a set of color copies of *Nov. 22, 2019 Weather Forecast Maps* for each student in your largest class of students. You will collect them at the end of each class to redistribute to students in the next class. These will be used on both day 1 and day 2 of this lesson.

Relocate the Previously Used Mechanisms poster with the total of the tallies from all classes from Lesson 14 to a central location in the room to refer to at the end of day 1 and the start of day 2 of this lesson. Make a separate New Mechanisms poster as shown for each class.

Test the video link. This video was selected because it provides a time-effective way to show students more storms affecting many other parts of the country. (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)





You may want to add a weather forecast video from your own region, particularly from a storm that students recently experienced. This could replace any one of the three storms in the provided video, or you could use it as a case for students to analyze. This may be particularly productive when it comes to helping students form new questions that are based upon their real-life experiences, which is the focus of the last half of day 2 of this lesson. If you do this, look for a weather forecast that shows evidence of the following:

- A clearly indicated low pressure center in the storm system that moves over time
- One or more fronts moving along with that system
- Precipitation falling near the fronts and over and around places near the center of low pressure

If you do this, provide a color handout of at least two screenshots from the forecast for students to analyze closely so they can see some of the changes over time occurring in the system. Plan to set aside at least one additional hour to search for and prepare these resources for your students.

Lesson 18 • Where We Are Going and NOT Going

Where We Are Going

This lesson problematizes three aspects of the precipitation patterns related to three storms that are reported on in a new weather forecast introduced in the lesson to get students to start wondering about climate-level questions. The remaining lessons of this unit will attempt to answer those questions related to how air masses typically move over different places and why some places receive more precipitation on average than others. Lesson 19 will formally reintroduce the distinction between climate and weather from 3rd grade (*ESS2.D Climate describes a range of an area's typical weather conditions and the extent to which those conditions vary over years [3-ESS2-2]*). The next lesson will extend students' understanding of this difference.

Where We Are NOT Going

While this lesson is designed to get students thinking about climate-level questions, it is important that you not use the word *climate* yet nor make any distinction between weather and climate in this lesson. This distinction will be introduced in the next lesson.

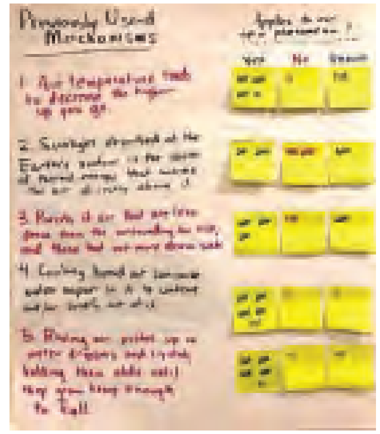
1. Navigation

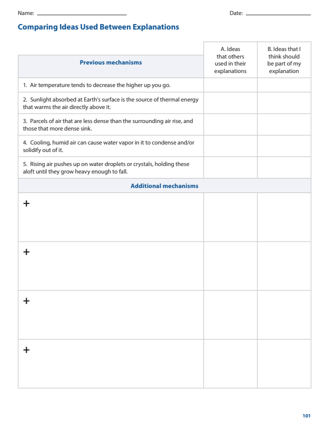
4 MIN

Materials: science notebook, *Comparing Ideas Used Between Explanations*, previously completed *Explaining Patterns and Predictions in the Forecast*, Previously Used Mechanisms poster

Refer to the explanations you collected from students at the end of the last lesson. Say something like, *It was really helpful for me to see how you were explaining your thinking in the handout you completed and turned in last time. Question 3, in particular, helped me see what mechanisms you thought were needed to explain this phenomenon.*

Reference the Previously Used Mechanisms poster. Say something like, *I will give you back your explanations so you can share them with others. This will help us narrow in on the sets of ideas we think we need to explain this phenomenon. That might include some or all of the ideas listed on this poster and/or it may include new ideas that we think we need to add to this list. I will give you a copy of these ideas on a new handout so you can keep track of which ideas other people are using in their explanations compared to your own.*





Name: ______________ Date: ______________

Comparing Ideas Used Between Explanations

Previous mechanisms	A. Ideas that others used in their explanations	B. Ideas that I think should be part of my explanation
1. Air temperature tends to decrease the higher up you go.		
2. Sunlight absorbed at Earth's surface is the source of thermal energy that warms the air directly above it.		
3. Parcels of air that are less dense than the surrounding air rise, and those that more dense sink.		
4. Cooling, humid air can cause water vapor in it to condense and/or solidify out of it.		
5. Rising air pushes up on water droplets or crystals, holding these aloft until they grow heavy enough to fall.		
Additional mechanisms		
+		
+		
+		
+		

Return to each student their previously completed *Explaining Patterns and Predictions in the Forecast* you collected last time and pass out a copy of *Comparing Ideas Used Between Explanations* to each student.

Show **slide A**. Give students two minutes to review their explanations and add them to their science notebooks.

2. Compare explanations.

15 MIN

Materials: science notebook, *Comparing Ideas Used Between Explanations*, timer

Introduce the small-group talking stick protocol. Present **slide B**. Read through the directions. Ask if there are any questions. Assign students to groups of 3.*

Set the timer for 1 min. Cue the start of the small-group discussions. Start the timer. Reset it each time it goes off to cue the next step (set it for 2 min for the third step).

Assessment Opportunity

Listen in on small-group discussions, particularly where can you listen to particular students. Focus on groups that have students who struggled to articulate connections to any new or old science ideas in explanations you collected and reviewed before this lesson. Pose questions such as this: *Did you hear anything from Student X's explanation that you didn't have but think you might want to include?*

Pause the small-group discussions. Present **slide C**. Review the directions on it. Give students two minutes to fill in column B on the related handout.

*** Attending to Equity**
If you have a class size that is not divisible by three, form either one or two groups of 2 students rather than a group of 4. The discussion requires careful listening to others' ideas and therefore benefits from a bit of a slower-paced discussion rather than faster.

3. Develop a consensus model and make predictions.

13 MIN

Materials: science notebook, *Progress Tracker: Ideas Needed in Our Consensus Explanation*, 1 blank piece of chart paper, the top ¼ of a second piece of chart paper, markers, sticky notes (in a different color than those already used on the Previously Used Mechanisms poster), Previously Used Mechanisms poster, New Mechanisms poster

Frame the goal of the consensus model. Present **slide D**. Explain that we are now going to finalize the set of ideas we think are part of the key mechanisms that are needed to explain the cause of this larger-scale precipitation event.*

Hand out *Progress Tracker: Ideas Needed in Our Consensus Explanation* and have students tape it to the next blank page of their Progress Tracker.

Reference the Previously Used Mechanisms poster again. Remove the old sticky notes from the poster. Go through each mechanism on it, one at a time, asking whether each is important for explaining observed patterns from the Jan. 19, 2019 storm. Then ask others to weigh in on why they think we do (or do not) need this idea to explain the observed patterns.

Key Ideas

Purpose of this discussion:

- Establish consensus on which previously-established mechanisms for explaining other precipitation events are also needed to explain this question: How could the movement of different air masses and the interaction between them cause patterns in (a) the area of lowest air pressure, (b) the locations of the fronts, and (c) where precipitation fell over time?
- Make a public record of which ideas are needed.
- Anticipate consensus on needing mechanisms 1, 3, 4, and 5. While it is most likely there will also be consensus on needing mechanism 2, some classes may argue that we should remain unsure on needing that mechanism in this context (for now).

Listed for these *anticipated student responses a*bout each of the five mechanisms:

- **Mechanism #1:** Yes, it is needed. We need it to explain cloud formation high above the ground and precipitation due to rising air, and we know there is rising air in the system.
- **Mechanism #2:** Yes, it is needed (or unsure). If they say "yes", they will argue that the Sun warms the surface regardless of the time of year. If they say "unsure", they are likely to argue that because we didn't examine direct evidence for light levels across the country (or differences in light levels at the surface) during the time of this storm, it's hard to know what role it plays during that window of time. They might also argue that maybe it plays a role in the original formation of the warm air mass, but we need more data to be certain. This uncertainty will be resolved in Lesson 20.
- **Mechanism #3:** Yes, it is needed. We need it to explain why air in certain air masses (warmer air masses) has lower pressure and why it tends to get pushed up (when it is warmer) or slide below (when it is colder) along front boundaries.

*** Supporting Students in Engaging in Developing and Using Models**

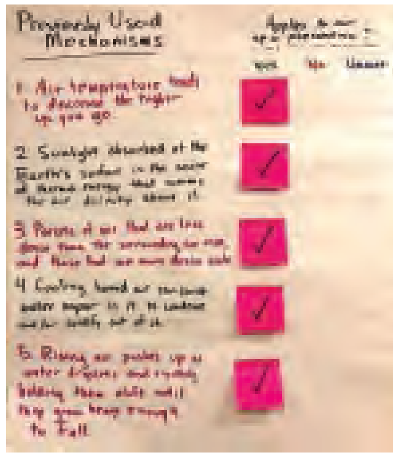
This is the first time in the Scope and Sequence where students have heard reference to a list of science ideas without a diagram as a model. Students will benefit from explaining this in terms of what the purpose is of developing explanatory models. Emphasize that words alone can be a way to develop a model since one key aspect of engaging in scientific modeling is to make our thinking visible to others to try to figure out how and why phenomena happen in the world. In that way, words alone can sometimes be sufficient. Explain that another key aspect of refining a model in science is to understand its limits. This means that we need to apply it to a wider range of phenomena to see how far the ideas in it can be applied. Remind students that the list of ideas we have here are ones that include things we already represented in other ways, particularly for those happening at a scale that was too small to see directly (like the motion of particles) or too large to see directly, like an air mass or the boundaries between air masses. Propose that since we've already established a detailed chain of causes for how these can be used

- **Mechanism #4:** Yes. Same as reason as for #1.
- **Mechanism #5:** Yes, it is needed. It can help (partially) explain why some areas closer to the fronts and the lowest pressure center tended to get heavier precipitation than others during this storm.

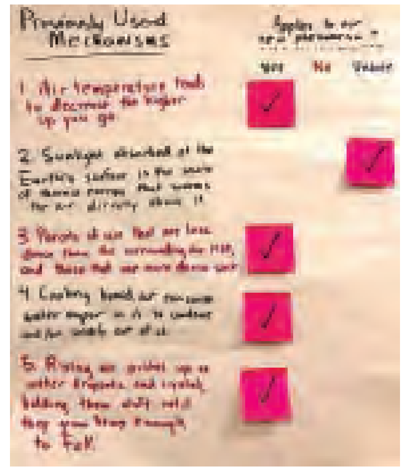
Prompt students to nominate new ideas they heard brought up in the explanations so far. As students suggest a new idea, ask others to restate the idea and then weigh in on (a) whether this is a new idea we developed over the past few lessons and (b) whether we need it to explain the patterns we see happening in this storm. After establishing an idea is needed, add it to the chart.*

Update the Previously Used Mechanisms poster. Add new sticky notes (in a different color and each with a large check mark on it) to the corresponding column for each row of the poster to indicate the thinking of the entire class at this point. Here are images showing the two anticipated possible states of that poster after doing this.

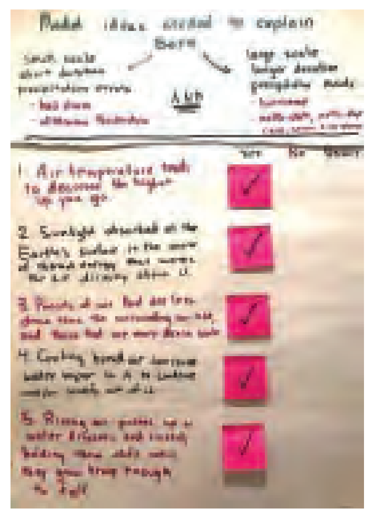
The more likely agreement that most classes will come to:



Another possible agreement some classes may come to:



Once the check marks have been added to the poster, stick the top ¼ piece of chart paper over the top of the poster. Write a new heading for it, as shown in the image here, that indicates that this set of model ideas is needed to explain the two categories of precipitation phenomena we listed on our original Related Phenomena poster at the start of the unit.



Have students add a record of these check marks on their copy of *Progress Tracker: Ideas Needed in Our Consensus Explanation*. They can use a question mark to designate any idea the class is still uncertain about (e.g., idea #2).

Shift to discussing new mechanisms. Point out that in their previous discussion students were raising ideas about air masses and fronts, and yet we don't have anything up here about those ideas that explains what they are, how they interact, or what sort of other things they cause. Reference the New Mechanisms poster as a space for us to record those ideas now.

Continue facilitating a Consensus Discussion to come to agreement on what those ideas are and add those to the poster.

to explain smaller-scale weather phenomena like a hailstorm or thunderstorm as well as a larger-scale phenomenon like a hurricane, let's now see if we think they are also needed to explain what is happening in a large-scale rain, snow, and ice storm, hundreds of miles wide, moving over much of the country that lasts over a day.

* Strategies for This Consensus Discussion

This is still considered a Consensus Discussion because, though we developed these ideas in Lessons 1-13, the introduction of the Jan. 19 storm raised questions about whether these ideas would be needed to explain that phenomenon. You are using the Previously Used Mechanisms poster to show that it used to be a record of our divergent ideas and shared uncertainty from Lesson 14, and we are updating the poster now to reflect that it now shows areas of convergent thinking and related certainty.

* Supporting Students in Engaging in Developing and Using Models

Here you are explicitly drawing students' attention to the idea that models can be used to make predictions and that the only way to find their limits is to keep testing them to see if they explain

Key Ideas

Purpose of this discussion:

- Establish consensus on new mechanisms that the class agrees are needed to explain this question: How could the movement of different air masses and the interaction between them cause the patterns in (a) the area of lowest air pressure, (b) the locations of the fronts, and (c) where precipitation fell over time?
- Add these to the New Mechanisms poster.

Listen for these ideas:

- Air masses are hundreds of miles wide; they have similar temperature and humidity across them; these air masses move horizontally across Earth's surface and run into other air masses.
- Warmer air tends to be lifted up over the colder air mass along the boundaries where different air masses meet (fronts).
- Clouds and precipitation tend to form in places where there is rising air (where the air pressure decreases); if that air is humid enough and cooled enough it will produce condensation (or more condensation).

Prompt students to nominate new ideas they heard brought up in the explanations so far. As students suggest a new idea, ask others to restate the idea and then weigh in about (a) whether this was a new idea we developed over the past few lessons and (b) whether we need this idea to explain the patterns we see happening in this storm. Add identified ideas to the New Mechanism poster, giving each idea a new number in order starting with #6.

Have students record the set of agreed-upon ideas that were added to the New Mechanisms poster in the "Additional mechanisms" section on their copy of *Progress Tracker: Ideas Needed in Our Consensus Explanation*, which should be in the Progress Tracker section of their science notebook. The public record of these should now look similar to what is shown in the image here.

Motivate the need to test these ideas against more cases. Say something like, *While we agree that we need these ideas to explain one large-scale precipitation event, is that the limit of what these ideas can explain? Or do we think these ideas will be needed to explain other large-scale precipitation events? To know for sure we would have to test these ideas. And for that we need more data than a single storm. So, let's take a moment to make some predictions about this.**

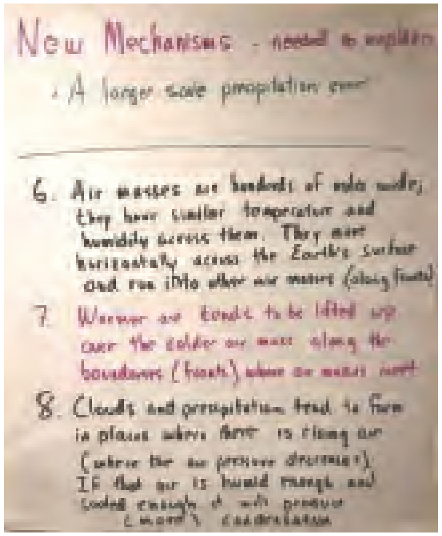
Make predictions. Show **slide E**. Read through the text on the slide. Accept all ideas. Give four minutes for this discussion.

Wrap up this discussion by saying, *Checking some additional weather forecasts could help us resolve any remaining uncertainty we have about the generalizability of our newly proposed ideas.*

Additional Guidance

If students are in agreement on the generalizability of these ideas, then you can still motivate the next activity by asking whether they need at least a small number of cases to confirm their prediction. If they are uncertain, then you can ask how collecting more evidence would help potentially resolve any lingering uncertainty. You can emphasize that in such cases scientists collect more data in determining the limits of what they can explain with a given set of ideas.

a broader and broader range of phenomena. This is an example of how science makes progress by going back and forth among developing ideas from evidence, making predictions about whether these ideas will work in new cases, and then testing the ideas against the new cases. This is also an opportunity to explicitly say that scientific explanations are "based on valid and reliable evidence obtained from sources (including the students' own experiments) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future" (*Appendix F*, National Research Council, 2013, p. 11). This is an element of SEP2, as indicated in *APPENDIX F: Science and Engineering Practices in the Next Generation Science Standards.*



4. Prepare to investigate our predictions. 4 MIN

Materials: science notebook, computer, projector, Lesson 18 Weather Report and Forecast (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)

Introduce the context of the next phenomenon. Show **slide F**. Explain that you will show the class a new video from a weather report in which the forecaster refers to three different storms in three different parts of the report. Tell students that this is a video from the *TODAY Show*, which was broadcast on Nov. 22, 2019 at 8:00 a.m (EST), which was the Friday before Thanksgiving that year.

Show **slide G**. Give students at least 2 minutes to set up their notebooks as shown on the slide.

Then say, *Before you record any observations, I want you to watch all three parts of the video from start to finish. After that I will replay each part one at a time, giving you time after each replay to record what you notice and wonder about that part. I will also give you a copy of some of the images from the video to refer to when we do that. With the time remaining today you will get to rewatch one of the parts of the video in detail. Next time, you will rewatch, in detail, the other two parts*.

Show the Lesson 18 Weather Report and Forecast. (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)

5. Record observations for storms 1 and 2. 6 MIN

Materials: science notebook, *Nov. 22, 2019 Weather Forecast Maps*, computer, projector

Distribute a copy of *Nov. 22, 2019 Weather Forecast Maps* to each student. Say, *This handout shows images from the forecasts for all three storms shown in the video.*

Present **slide H**. Indicate that students should record their noticings only in places where it has a 1, but they can record wonderings anywhere in the right column ("Wonder").

Show the video from 0:00 to 0:40. After showing this, remind students that the first two images on *Nov. 22, 2019 Weather Forecast Maps* are for storm 1 from this part of the forecast. Give students three minutes to record their noticings and wonderings for storm 1. (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)

Present **slide I.** Show the video from 0:40 to 0:57. After showing this, remind students that the two images in the second row on *Nov. 22, 2019 Weather Forecast Maps* are for storm 2 from this second part of the forecast. Give students three minutes to record their noticings and wonderings.

Assessment Opportunity

Walk around to see what noticings students are recording before asking the whole class to report out. Here is a time you can recruit participation from students who don't normally share. Quietly check in with students who you identify and ask them if they would be willing to share a specific noticing and why they think it counts as evidence for the related science idea. Point to the specific noticing on their paper you want them to share and have the student put a star near it to remind them which one they will share the next day. Continue this as you resume this activity on day 2.

After this you will need to pause and collect *Nov. 22, 2019 Weather Forecast Maps* to redistribute in the next class and on the next day.

End of day 1

6. Record observations for storms 2 and 3. 5 MIN

Materials: science notebook, *Nov. 22, 2019 Weather Forecast Maps*, computer, projector, Lesson 18 Weather Report and Forecast (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)

Analyze the third storm. Remind students that last time we saw the predictions for only two of the three storms in the forecast. Tell students that you will replay what they saw last time and keep it going until the end when the forecaster talks about the third storm.

Present **slide J**. Distribute copies of *Nov. 22, 2019 Weather Forecast Maps* to each studetns. Show the video from 0:00 to 1:40. After showing this, remind students that the last two images on *Nov. 22, 2019 Weather Forecast Maps* are for storm 3 from the last part of the forecast. Give students three minutes to record their noticings and wonderings.

7. Share observations and establish lines of evidence for the model ideas. 8 MIN

Materials: science notebook, *Nov. 22, 2019 Weather Forecast Maps*, New Mechanisms poster, markers

Project **slide K**. Facilitate a Consensus Discussion on how what they noticed provides evidence for the three related ideas in their chart.*

Start by asking students to share some of their related noticings. Work through each of these three categories in order:

- air masses moving
- lower pressure within part of an air mass or along fronts
- precipitation along fronts or around a center of lowest pressure air

Key Ideas

Purpose of this discussion:

- Establish consensus on new mechanisms that the class found evidence for in the storms they analyzed from the new forecast.
- Don't write any new words on chart paper. This is a very short Consensus Discussion. Instead, focus on establishing how this noticing provides evidence for the related science idea. So, once a noticing is proposed, poll students to weigh in on whether they noticed something similar and poll again to determine whether they too think this

*** Strategies for This Consensus Discussion**
This is still considered part of the Consensus Discussion because the ideas being evaluated now were established and agreed upon as being relevant for explaining the Jan. 19, 2019 storm. Students are simply arguing from evidence for why those mechanisms are clearly still at work in the three storms from the Nov. 22, 2019 forecast.

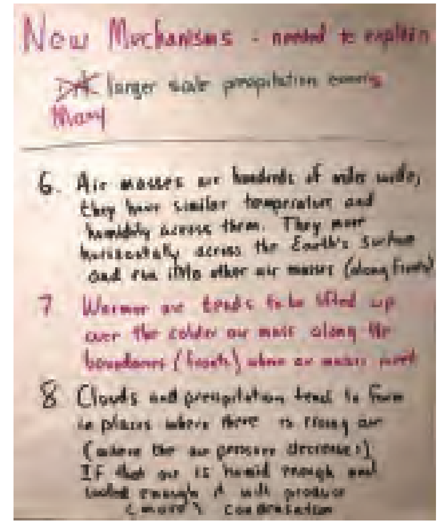
provides evidence for the related idea. Follow up with a new student volunteer to explain why. This will move things along quickly while also getting the class to articulate why they all think there is evidence for that idea.

Listen for these ideas: Anticipated student responses are in italics for each category.

- air masses moving
  - *You could see the "L" and front lines moving, and they tended to move together.*
  - *All three storms tended to move to the east, even though some veered southward or northward along part of their path.*
- lower pressure within part of an air mass
  - *They all have an "L" connected to them, which we learned is the area of lowest pressure in the forecast.*
- precipitation along fronts or around a center of lowest pressure air
  - *The rain tended to fall close to where the front line(s) was located.*
  - *There were two front lines in the first storm that rain tended to fall around and one front line in the second and third storm.*
  - *There was precipitation both in front of and behind where the area of lowest pressure ended up moving through.*

Once all three sections are complete, emphasize that after looking for evidence of these model ideas in three other storms, we can now establish that we are in consensus that these new ideas are useful in helping explain a lot of really large-scale storms.

Modify the title of the New Mechanisms poster as shown here.



8. Share wonderings and initial explanations.

15 MIN

Materials: science notebook, *Nov. 22, 2019 Weather Forecast Maps*

Start problematizing. Say, *We haven't shared our wonderings yet. And I bet that by looking at these additional weather events, you may have noticed some things that raised some new questions for you. Let's take a moment and share those with a partner.*

Show **slide L**. Give students three minutes to share their most compelling question(s) with an elbow partner. Emphasize that it is OK if students share only a subset of their questions as long as each person shares at least one, which is why it's important to take turns sharing one question at a time.*

Shift to sharing explanations. Say, *Already I heard you sharing some new questions that I haven't heard raised in our class before. That is exciting. Just when it seemed like we had answered all of our old questions, new ones start bubbling up. That is how science works. Often when we start trying to explain more and more phenomena that we haven't tried explaining before, we start to notice new patterns in those new phenomena. And those new patterns lead us to new areas of inquiry. Let's work with three different partners to briefly explain three aspects of the forecast to help us think about what it is we think we can explain, whether there is anything we are less certain about, and what other new questions we may have that we still need to figure out.*

*** Strategies for This Initial Ideas Discussion**

At this point the focus of the lesson shifts. Up until now, you have engaged students in a putting-pieces-together instruction routine. From here until the end of the lesson, you are engaging in a problematizing routine. For more information on the difference between these two routines, consult the teacher handbook. Each remaining activity the class does will be aimed at trying to help students identify new areas

Assign groups. Divide the class into groups of four students. Have the group members count off a number to assign each member: 1, 2, 3, 4.

Carry out three rounds of discussion using the next three slides (**slide M**, **slide N**, and **slide O**), which will take a little over nine minutes total time. Start each round of discussion by reading the text at the top of the slide, then cue specific partners (as indicated on the slide) to discuss the question at the bottom of the slide. Pause each round of discussion after three minutes.

9. Record additional questions and expand our Driving Question Board. 14 MIN

Materials: science notebook, sticky notes, marker, pencil, chart paper, timer

Record individual questions. Present **slide P**. Hand out sticky notes and markers. Give students three minutes to generate questions.

Present **slide Q**. Have students bring something to write with, their chair, and their sticky note questions stuck on the front of their notebook to a Scientists Circle. Form this circle around the Driving Question Board.

Introduce a different sharing protocol for the Driving Question Board (DQB). Post a piece of blank chart paper next to the DQB to add their questions onto. Emphasize that it is important that everyone has at least one of their questions represented up here, so to ensure that happens in the time remaining, you will ask them to build this extension to the Driving Question Board in a different way than before. Explain the following steps:

- *After a new question is shared, that person should ask for a show of hands of other people who had a very similar question. That person then should add tally marks to their sticky note to show how many other people had a similar question and only then should they post it on our expanded Driving Question Board.*
- *Everyone who raised their hand should put a check mark on their sticky note with the similar question on it so they know which of their questions has been represented on the board.*
- *After that question has been posted with tally marks on it, the person who posted it will ask who else has a new question. At that point everyone should look through their questions and raise their hand only if they have one or more questions that don't have a check mark on it. The person who shared last will pick the next person to share from those that have hands up. This will ensure that we get to everyone who doesn't have one of their questions represented up there.*
- *After a few minutes, I will pause us and ask how many of you have a check mark on at least one of your questions. Once we find that everyone has a hand raised, I will switch to asking you to raise your hand if you have at least one sticky note left without a check mark on it.*

Start sharing questions. Set a timer to check in as indicated above about four minutes in.

Once you have about two minutes left, ask whether all of these questions still fall under our previous driving question, **"Why does a lot of hail, rain, or snow fall at some times and not others?"** and if we can keep it as is or need to modify it. Students may say that it still works or they may suggest that it needs to be expanded to include the phrase *"and in some places"*. For example, **"Why does a lot of hail, rain, or snow fall at some times *and in some places* and not others?"**

of curiosity, uncertainty, or gaps in understanding in order to help them generate new questions. The initial explanations they are developing and sharing in the next 3 slides will help prime students to frame new questions to add to the Driving Question Board. These new questions will likely be related to why (and if) there are differences in long-term patterns of precipitation from one region to another. These will likely be the first time you hear students forming climate-oriented questions. Up until now most if not all student questions have been about weather-related events (that happen over minutes, days, or weeks) rather than climate-level patterns (average weather patterns over many years). Answering some of these new types of questions is the focus of the remaining lessons in this unit.

10. Identify additional sources of data needed.

3 MIN

Materials: science notebook, sticky notes, markers

Brainstorm ideas for other types of datasets we need. Present **slide R**. Read the slide aloud. Give students the remaining time to stop and jot their ideas in their notebooks to share at the start of the next lesson. You may want to assign additional brainstorming as a home-learning assignment opportunity or give a couple more minutes for this at the start of the next lesson if you run short of time.

Collect students' unposted sticky-note questions and *Nov. 22, 2019 Weather Forecast Maps* before the end of the period.

Assessment Opportunity

If you don't see a lot of questions about typical patterns over longer periods of time coming out during or after students add them to the DQB, you could revisit the DQB again at the start of the next lesson and ask students to brainstorm places in our country that they think might get more or less water than where we live and then give a short explanation for why. Have them share these with a partner and then have them write new questions based on what this led them to wonder.

At the end of the day, reorganize all the sticky-note questions on this new portion of the DQB to put them into related clusters. Put a label on a sticky note next to each cluster to identify the types of questions in that cluster. Anticipate that the questions will tend to fall into these three clusters: 1) typical paths that air masses move through different places, 2) typical amounts or types of precipitation that fall in different places, 3) typical temperatures in different places.

ADDITIONAL LESSON 18 TEACHER GUIDANCE

Supporting Students in Making Connections in ELA

Students engage in the following while carrying out their small-group discussion protocols on the start of day 1 of this lesson:

CCSS.ELA-LITERACY.SL.6.1 Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grade 6 topics, texts, and issues, building on others' ideas and expressing their own clearly.

- CCSS.ELA-LITERACY.SL.6.1.D Review the key ideas expressed and demonstrate understanding of multiple perspectives through reflection and paraphrasing.
- CCSS.ELA-LITERACY.SL.6.3 Delineate a speaker's argument and specific claims, distinguishing claims that are supported by reasons and evidence from claims that are not.
- CCSS.ELA-LITERACY.SL.6.4 Present claims and findings, sequencing ideas logically and using pertinent descriptions, facts, and details to accentuate main ideas or themes; use appropriate eye contact, adequate volume, and clear pronunciation.

A Closer Look at Weather

1 Destination: Florida
2 Barometers: Then and Now
3 How Air Masses Behave
4 Hailstone Factory

Literacy Objectives

- ✓ Summarize key points related to Florida climate, barometers, and weather fronts.
- ✓ Describe bias exhibited by a source.

Prerequisite Investigations

Assign the Science Literacy reading and writing exercise *after* class completion of this lesson group:

- Lesson 15: What happens with temperature and humidity of air in large storms?
- Lesson 16: How do warm air masses and cold air masses interact along the boundaries between them?
- Lesson 17: Is there a relationship between where the air is rising and where precipitation falls?
- Lesson 18: How can we explain what is happening across this storm (and other large-scale storms)?

Instructional Resources

Student Reader

Collection 6

Science Literacy Student Reader, Collection 6
"A Closer Look at Weather"

Exercise Page

EP 6

Science Literacy Exercise Page
EP 6

Literacy Activities

- Read varied text selections related to the topics explored in Lessons 15–18.
- Evaluate the reading selections according to provided prompts and criteria.
- Compare and contrast information gained from reading text with information gained from class investigation.
- Prepare a rap song verse that refers to weather in response to the reading.

Standards and Dimensions

NGSS

Disciplinary Core Idea ESS2.D: Weather and Climate: Weather and climate are influenced by interactions involving sunlight, the ocean, the atmosphere, ice, landforms, and living things. These interactions vary with latitude, altitude, and local and regional geography, all of which can affect oceanic and atmospheric flow patterns.

Science and Engineering Practice: Obtaining, Evaluating, and Communicating Information

Crosscutting Concepts: Cause and Effect; System and System Models

CCSS

English Language Arts

RST.6-8.1: Cite specific textual evidence to support analysis of science and technical texts.

RST.6-8.6: Analyze the author's purpose in providing an explanation, describing a procedure, or discussing an experiment in a text.

RST.6-8.10: By the end of grade 8, read and comprehend science/technical texts in the grades 6-8 text complexity band independently and proficiently.

WHST.6-8.4: Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience.

Core Vocabulary

Core Vocabulary: Core Vocabulary terms are those that students should learn to use accurately in discussion and in written responses. During facilitation of learning, expose students repeatedly to these terms. However, these terms are not intended for isolated drill or memorization.

front

Language of Instruction: The Language of Instruction consists of additional terms, not considered a part of Core Vocabulary, that you should use when talking about any concepts in this exercise. Students will benefit from your modeling the use of these words without the expectation that students will use or explain the words themselves.

barometer **cyclone** **metaphor**

millibars (mb) **occluded front**

stationary front

A Glossary at the end of the Science Literacy Student Reader lists definitions for Core Vocabulary and selected Language of Instruction.

1. Plan ahead.

Determine your pacing to introduce the reading selections, check in with students on their progress, and discuss the reading content and writing exercise. If you are performing Science Literacy as a structured, weekly routine, you might implement a schedule like this:

- Monday: Designate a ten-minute period at the beginning of the week to introduce students to the assignment.
- Wednesday: Plan to touch base briefly with students in the middle of the week to answer questions about the reading, to clarify expectations about the writing exercise, and to help students stay on track.
- Friday: Set aside time at the end of the week to facilitate a discussion about the reading and the writing exercise.

You'll proceed with the in-class lesson investigations during this week.

2. Preview the assignment and set expectations. (Monday)

- Let students know they will read independently and then complete a short writing assignment. The reading selection relates to topics they are presently exploring in their Weather, Climate, and Water Cycling unit science investigations.
- The reading and writing will be completed outside of class (unless you have available class time to allocate).
- Preview the reading. Share a short summary of what students can expect.

- *First, you will read a mock travel ad promoting the beautiful weather and beaches of Florida.*
- *Then, you'll read an article that details how the design of barometers has changed over the last few hundred years.*
- *Next, you'll read an infographic showing four kinds of fronts between air masses and the weather associated with each.*
- *Finally, you'll explore a diagram of how hail forms in a storm system.*

- Distribute Exercise Page 6. Preview the writing exercise. Share a summary of what students will be expected to deliver. Emphasize that Science Literacy exercises are brief. The focus is on thoughtful quality of a small product, not on the assignment being big and complex.
    - *For this assignment you will be expected to generate four lines of lyrics for a rap song about weather.*

Exercise Page

EP 6

- Remind students of helpful strategies they can employ during independent reading. Offer the following advice:
    - *The reading should take approximately 30 minutes to complete.* (Encourage students to break reading into smaller sections over multiple short sittings if their attention wanders.)
    - *A good reading strategy is to scan through the collection first to see the titles, section headers, graphics, and images to see what the selections are going to be about before fully reading.*
    - *Next, "cold read" the selections without yet thinking about the writing assignment that will follow.*
    - *Then, carefully read the Exercise Page to understand the expectations for the writing part of the assignment.*
    - *Revisit the reading selections to complete the writing exercise.*
    - *Jot down any questions for the midweek progress check in class.* (Be sure students know, though, that they are not limited to that time to ask you for clarification or answers to questions.)

3. Touch base to provide clarification and address questions.

(Wednesday)

Touch base midweek with students to make sure they are on track while working independently. You may choose to administer a midweek minute-quiz to give students a concrete reason not to postpone completing the reading until the last minute. Ask questions such as these, and have students jot answers on a half sheet of paper:

Suggested prompts	Sample student responses
What weather pattens in Florida make beach activities so enjoyable?	*that the air temperature is over 70 degrees F from April to October and that the ocean water is warm*
How are fronts depicted on a weather map?	*with a line having either triangles, semicircles, or both; in red, blue, or purple*
How is a barometer used to get a weather forecast?	*A change in atmospheric pressure on the barometer indicates that there will be a change in the weather.*

Ask a few brief discussion questions related to the reading that will help students tie the text content to students' classroom investigations.

Suggested prompts	Sample student responses
Which of the barometers shown in Selection 2 is most like the model barometer made from a jar, balloon, rubber bands, and straws you used in Lesson 11?	*None of them look much like it, but maybe the mercury barometer because it has a horizontal surface that moves when the air presses down on it with more or less force.*
What information can you get from a model that views a front from the side that you cannot see on a weather map that views fronts from above?	*The side view lets you visualize the thickness of the air mass and how one air mass moves under or over another at a front.*

Exercise Page

EP 6

- Refer students to the Exercise Page 6. Provide more specific guidance about expectations for students' deliverables due at the end of the week.
    - *A rap is a poem with a strong beat that is set to music.*
    - *Don't worry: I will not ask you to perform your song. Just focus on developing some lyrics that use weather as a metaphor for something else you are feeling.*
    - *Do try to include some rhyming words in your lyrics. The first two lines can end with words that rhyme, and the third and fourth lines can end with words that rhyme. If the words don't rhyme, make sure they lend themselves to a strong beat.*
    - *Try slant rhymes, which are words that almost rhyme, but not quite, such as* block *and* broke.
    - *Keep the language and ideas in your lyrics appropriate for a general audience—something your little sibling could listen to.*
    - *Try reading your lyrics aloud, and then make any changes that are needed.*
    - *The important criteria for your work are that you use a concept from the readings as a metaphor for your message and that your lyrics show understanding of the science.*
- Answer any questions students may have relative to the reading content or the exercise expectations.

4. Facilitate discussion. (Friday)

Facilitate class discussion about the reading collection and writing exercise. The first selection consists of a travel agency ad for Florida vacations accompanied by a Consider the Source feature that shows students how to analyze the motivations and intent behind the ad.

Student Reader

Collection 6

Pages 54–63 Suggested prompts	Sample student responses
What is the general purpose of the first selection, "Destination: Florida"?	*It tries to persuade readers to book vacations in Florida with Fan-Florida Travel.*
For what reasons would you say this author is exhibiting bias?	*Advertisements are by nature biased, in that they want to sell you either goods or services.*
	The author only gives one piece of climate information and leaves out others, such as how often Florida gets thunderstorms, lightning strikes, and hurricanes.
Take a look at the Consider the Source box on page 55. Did the ad do a good job or not at appealing to your emotions? Explain.	*Yes, it did a good job, especially by showing the empty beach with clean sand and the blue sky. It made me feel calm just to imagine being there.*
	No, I think this ad might be better for people who like the beach more than I do. If the ad were about Florida theme parks and space centers, I would be more excited.
What is the general purpose of the second selection, "Barometers: Then and Now"?	*It compares the designs of barometers from a long time ago with those that are more recently designed.*
How could you find out if a smartphone includes a digital barometer?	*I could do an online search for the model of the phone and the key words "barometer chip."*
Take a look at the Dig into Data box on page 58. If the average pressure at sea level is 1013 mb, what might be the measurement for a low-pressure air mass? A high-pressure air mass?	*A low-pressure air mass should be below 1013 mb, and a high-pressure air mass should be above 1013 mb.*
If you had a map with only air pressure measurements on it, how could you predict where the cloudy and rainy weather might be?	*I would look for large regions where the numbers were below 1013 to find low-pressure air masses that tend to have cloudy weather. Then, I would look for measurements that are below and above 1013 in a line, showing a front where there is likely to be clouds and rain.*
What is the general purpose of the third article, "How Air Masses Behave"?	*It explains how air masses move when they meet one another, including moving under or over one another.*
What is the difference between the two diagrams of occluded fronts?	*In the cold type, a cold air mass is behind a cool air mass as the two move in the same direction.*
	In the warm type, a cool air mass is behind the cold air mass as the two move in the same direction.

SUPPORT—If you are using the recommended word envelope convention, check the envelope to see if it contains any words, phrases, or sentences that students need help understanding. Read key sentences aloud, and provide concise explanation.

SUPPORT—Explain to students that a cyclone is an area of low pressure around which, in the Northern Hemisphere, winds blow counterclockwise. The circular shape of a cyclone can better be seen in a diagram that looks down from above, as shown at this recommended site. (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)

Online Resources

Pages 60–65 Suggested prompts	Sample student responses
When you were thinking about writing rap lyrics, what ideas or imagery in this reading struck you as helpful?	*I thought about weather fronts as two people who have to get along with one another.* *I thought about feeling low and high emotions, like low-pressure and high-pressure air masses.* *I thought about two people stuck in a disagreement, as a stationary front.*
What is the general purpose of the fourth article, "Hailstone Factory"?	*It diagrams how hailstones form inside the clouds in a storm.*

5. Check for understanding.

Evaluate and Provide Feedback

For Exercise 6, students should draft four lines for a new rap song that uses weather elements or weather concepts from Collection 6 as a metaphor. Look for evidence that the science is accurate, that there was an effort to be original, that there is either a strong beat or the use of rhyming, and that the mechanics of writing are suited to written lyrics (e.g., beginning each line with a capital letter). Weather elements and concepts may include the following:

- Average air temperatures in a certain climate
- Atmospheric pressure
- Barometers
- Millibars
- Air masses
- Cold, warm, stationary, and occluded fronts

Use the rubric provided on the Exercise Page to supply feedback to each student.

Online Resources

SUPPORT—While rhyming is not required, students may want to incorporate it. If they are struggling, suggest they access an online rhyming tool where they can submit words and get an output of rhyming words.

LESSON 19

Are there patterns to how air masses move that can help predict where large storms will form?

Previous Lesson

We explored a weather report and forecast. We developed a model to explain how what was happening in one part of the country at one point in time can be connected to what is predicted to happen in another part of the country over a day later. We developed new questions for our Driving Question Board (DQB) and brainstormed ways to investigate these questions.

This Lesson

Investigation

1 DAY

NASA Scientific Visualization Studio

We make observations about simulated satellite and ground observation data to answer our questions about patterns in air and storm movement. We view a visualization showing precipitation movement across the United States and we annotate a class map. We figure out that air mostly moves in the same pattern across most of the United States, from west to east, bringing colder air from the north and warmer air from the south. There are some places near the coasts where air and precipitation show a slightly different pattern. We zoom out to a global view and notice the U.S. pattern is the same as other places in the northern hemisphere and a mirror image of patterns in the southern hemisphere. We notice precipitation is more common over or near the ocean and wonder how the ocean changes a place's weather.

Next Lesson

We will develop a representation for the temperature and movement of air masses but are still curious about whether air masses' proximity to the ocean matters. We will gather additional information about the ocean by observing a visualization of ocean temperatures, through a reading about ocean currents, and through interpretation of precipitation data for coastal cities. We will figure out that the ocean affects the humidity and temperature of air masses. We will wonder why the moisture from the Atlantic Ocean and Gulf of Mexico travels so far inland compared to the moisture from the Pacific Ocean.

Building Toward NGSS

MS-PS1-4, MS-ESS2-4, MS-ESS2-5, MS-ESS2-6

What Students Will Do

Use visualized precipitation data from a large data set to identify spatial patterns in the direction of air masses' movement that influences long-term weather patterns in predictable ways.

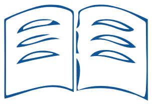
What Students Will Figure Out

- There are patterns in the direction that air and precipitation move over a region.
- Patterns in air movement are caused by prevailing winds, and the prevailing winds in the northern hemisphere mirror the southern hemisphere.
- These patterns help us predict where air and precipitation come from (colder from the north and warmer from the south).
- Climate is the long-term average of weather in an area, typically averaged over 30 years.

Lesson 19 • Learning Plan Snapshot

Part	Duration	Summary	Slide	Materials
1	5 min	**NAVIGATION** Review categories of questions added to the DQB.	A	Driving Question Board, chart paper, markers
2	20 min	**OBSERVE AIR AND PRECIPITATION PATTERNS IN THE U.S.** Gather students in a Scientists Circle around a NASA visualization that shows air and precipitation movement across the United States. Record noticings and wonderings and annotate a class map.	B-D	computer and projector, NASA IMERG precipitation rates: U.S. August 2014 visualization, NASA IMERG precipitations rates: U.S. west coast January 2017 visualization, whiteboard or chart paper, dry erase or chart markers
3	15 min	**GLOBAL VIEW WITH A BUILDING UNDERSTANDINGS DISCUSSION** Watch a second visualization depicting 8 months of air and precipitation movement globally. Use this visualization to facilitate a Building Understandings Discussion about patterns in prevailing winds across the U.S and around the world.	E-F	computer and projector, NASA IMERG precipitation rates worldwide: April to September 2014, whiteboard or chart paper, dry erase or chart markers
4	5 min	**NAVIGATION** Motivate wanting to consider how closeness to the ocean could also impact large amounts of precipitation. Have students complete an exit ticket.	G	scrap of paper
				End of day 1

Lesson 19 • Materials List

	per student	per group	per class
Lesson materials Student Procedure Guide  Student Work Pages 	• science notebook • scrap of paper		• Driving Question Board • chart paper • markers • computer and projector • NASA IMERG precipitation rates: U.S. August 2014 visualization • NASA IMERG precipitations rates: U.S. west coast January 2017 visualization • whiteboard or chart paper • dry erase or chart markers • NASA IMERG precipitation rates worldwide: April to September 2014

Materials preparation (20 minutes)

Online Resources

Review teacher guide, slides, and teacher references or keys (if applicable).

Make copies of handouts and ensure sufficient copies of student references, readings, and procedures are available.

Prior to the lesson, test the NASA visualizations on your device.

- NASA IMERG precipitation rates: U.S. August 2014 visualization.
- NASA IMERG precipitations rates: U.S. west coast January 2017 visualization.
- NASA IMERG precipitation rates worldwide: April to September 2014 visualization.

If internet connectivity is a concern, the NASA visualizations can be downloaded to your desktop from the original source:

- NASA IMERG precipitation rates: U.S. August 2014 visualization.
- NASA IMERG precipitations rates: U.S. west coast January 2017 visualization.
- NASA IMERG precipitation rates worldwide: April to September 2014 visualization.

NASA's resources are continuously updated as new data are collected and shared. Over time, NASA will release new visualizations with more current data. You may want to explore their resources prior to the lesson to see if more current visualizations are available. Visit NASA's Scientific Visualization Studio gallery. NASA's Precipitation Measurement Missions page is also a good starting point for the most current data visualizations showing precipitation rates.

(See the **Online Resources Guide** for links to these items. **www.coreknowledge.org/cksci-online-resources**)

Prior to the lesson, decide how to project the visualizations, assuming your students are arranged in a Scientists Circle around the projections for most of the lesson. Options include projecting

- over your classroom whiteboard,
- onto your smartboard, or
- over a piece(s) of chart paper attached to a classroom wall.

Project the first visualization, *NASA IMERG precipitation rates: U.S. August 2014*, onto the space you have selected. Use a dark-colored marker to outline the United States on the whiteboard, smartboard, or chart paper. The outline can be a rough estimate of borders as shown in the image on the previous page. Outline your state and draw a "star" where your community is located on the map to give your students more context about where they live on the map.

Note: You will need a similar map for the navigation at the start of Lesson 20. If using chart paper, make a 2nd map now to save time in your preparation for Lesson 20.

Lesson 19 • Where We Are Going and NOT Going

Where We Are Going

In Lesson 18, students figured out that large storms with precipitation occur because air masses of different temperatures and moisture levels interact and collide as they move across the country. Students were left wondering whether this is a typical pattern of air mass interaction and movement. This lesson gives students evidence that the movement of the air masses is part of a predictable pattern over the continental United States, in which cooler air from the north/northwest flows eastward before it interacts with warmer air from the south/southeast.

This lesson builds on previous lessons to specifically target these important DCIs:

- The complex patterns of movement of water in the atmosphere are determined by winds (prevailing winds).
- These interactions vary with latitude, which can affect atmospheric flow patterns.
- Because these patterns are so complex, weather can only be predicted probabilistically.

These science ideas are part of ESS2.C: The Roles of Water in Earth's Surface Processes and ESS2.D: Weather and Climate. This lesson focuses on figuring out latitudinal patterns of winds (prevailing winds) that impact the direction of air masses with varying temperatures and, therefore, where interactions (and storms) will occur. Students will focus on identifying how cold and warm air interact in predictable ways based on the prevailing winds across the U.S., and will connect the role of the ocean and ocean currents on air mass humidity in the next lesson.

This lesson revisits climate versus weather from 3rd grade (*ESS2.D Climate describes a range of an area's typical weather conditions and the extent to which those conditions vary over years (3-ESS2-2))*. This lesson extends students' understanding by having them recognize a predictable pattern in air movement across a location and how that pattern impacts the air that moves into and out of locations and where air masses of differing temperature will interact. Students reflect on how this predictable pattern relates to a location's long-term weather patterns, which we call climate. This extends students' understanding because students are recognizing the different dynamic factors at play that determine climate.

Where We Are NOT Going

This lesson intentionally avoids naming the prevailing winds (i.e., trade winds, westerlies, polar easterlies). Identifying the prevailing winds by name does not enhance student understanding of the main underlying science idea that there is a regular pattern of air movement in a predictable direction at different latitudes.

Likewise, this lesson avoids providing a mechanistic explanation for the different directions of the prevailing winds and the circular, rotational movement of fluids on Earth. The mechanisms, which involve global convection cells and the Coriolis Effect, require above grade level content and should be considered something students should build toward in their high school Earth science courses. An optional reading is provided in the Student Edition should the circular motion of air or ocean currents be the focus of students' curiosity. Use this reading to satisfy their questions, but avoid requiring students to understand the related content completely to demonstrate mastery of the lesson's learning objective.

The distinction between weather and climate used in this unit. An understanding of weather versus climate is the focus of 3-ESS2-1 and you should not repeat that level of instruction in this lesson.

LEARNING PLAN FOR LESSON 19

1. Navigation

5 MIN

Materials: Driving Question Board, chart paper, markers

Review the new DQB questions. Display **slide A**. Direct students' attention to the DQB to review the questions added in the previous lesson. Ask students to point out a few of the questions that the class added last time and whether the categories you clustered them into across all your different classes and the labels you added for those clusters are a reasonable way to refer to the topic that the question is about. The new questions may include:

- *Is this sort of pattern of air movement from west to east something that happens all the time?*
- *Does the air move only west to east, or does it also move north to south?*
- *Does a place need to be near the ocean to get a lot of precipitation?*
- *Does it always snow in the mountains?*
- *Why is the weather nicer near the places along the coast in the winter?*
- *Why does our state (or that other state) get so much rain?*
- *Why does our region (or that other part of the country) get so little rain?*
- *Why is our part of the country so much warmer than other parts?*

Alternate Activity

If students have not yet shared ideas about the types of data we need to investigate these questions during the previous lesson, do that now. Record their ideas on chart paper as students share. That will require a few extra minutes.

Don't skip this step if you did not get to it at the end of the last lesson, as this is a key piece to supporting coherence for students. You will be able to refer to the ideas they come up with to motivate this lesson and the remaining lessons in the unit. Be prepared to move the navigation section at the end of the lesson to the start of the next lesson to accommodate the extra time you might need for this. Anticipated student ideas for additional data needed include

- data on air movements / winds over the country over a year or many years,
- precipitation data for different parts of the country over many years,
- elevation data vs. precipitation data, and
- data overlays of all of this information projected on maps.

2. Observe air and precipitation patterns in the U.S.

20 MIN

Materials: science notebook, computer and projector, NASA IMERG precipitation rates: U.S. August 2014 visualization, NASA IMERG precipitations rates: U.S. west coast January 2017 visualization, whiteboard or chart paper, dry erase or chart markers

Introduce students to the use of satellite data. Gather students in a Scientists Circle around the area you plan to project the *NASA IMERG precipitation rates: U.S. August 2014* visualization. (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**) Tell students that one way to identify regular patterns in air and precipitation movement is to look at weather from above. Say, *Scientists do this with satellites and they check their satellite data with data from weather stations located at the surface.* *How much time do you think we'd need to look at a location to decide if the weather happening there was part of a typical pattern?* Listen for students to suggest:

- several days
- several weeks
- years
- a really long time

Prepare for observations. Display **slide B.** Give students background about the NASA visualization they are about to observe. For example, the visualization:

- Is a computer simulation based on real-time data.
- Is from a satellite perspective, but it used both satellite data and ground observations from weather stations.
- Includes data for only 1 week in the United States from August 4-11, 2014.

Remind the class of the questions they wanted to answer and ask them how the visualization could help them answer them. Explain that the visualization is going to show movement of precipitation. Ask students to share their ideas about things they want to pay attention to in the visualization to answer their questions.

Suggested prompt	Sample student response
How will this data visualization help us answer our questions?	*We were wondering if it was a pattern so we can look to see if the air moves the same each time.*

*** Supporting Students in Engaging in Analyzing and Interpreting Data**

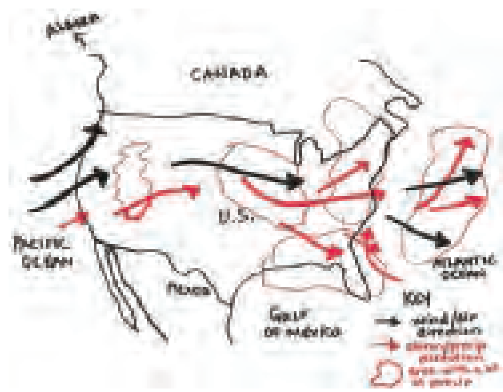
In this lesson, students make observations from simulated data. The simulated data is derived from a computer model that was originally sourced from real-time satellite data and ground observations. The original data sets are massive, accounting for hourly and daily observations around the world spanning 15-20 years. Students will view the visualized data for only part of this data set. For example, analyzing a few months' worth of data should be sufficient for students to notice patterns. Use this opportunity to share with students how scientists collect and use large data sets to visualize information that helps them communicate what they have observed to others. Also, this is an opportunity to emphasize to students that this kind of data collection requires coordinating

Suggested prompts	Sample student responses
Do you have any concerns about whether this data will answer the questions?	*One week may not be long enough to see a pattern.*
	We will need multi-year data if we are going to make claims about the climate.
What should we pay attention to as we make observations of the data?	*Whether the air is moving in the same or different directions.*
	Whether the air movement is a pattern or if the air movement changes over time.

many scientists and science organizations around the world. A particularly valuable partner to NASA's precipitation missions is the Japan Aerospace Exploration Agency (JAXA), with whom we share satellite data.

Have students find a new page in their science notebooks to set up a Notice and Wonder chart. If needed, use **slide C**.

Observe storm movement patterns across the United States over a few months. Project the *NASA IMERG precipitation rates: U.S. August 2014* visualization over a class whiteboard, smart board, or chart paper. Make certain that all students are able to view the visualization. Use a black marker to outline the U.S. border if not done previously. The outline does not need to be perfect, but should allow you to refer to air and storm movement over parts of the U.S. after the visualization is no longer showing. Note that the visualization zooms in on the U.S. slightly so the border will not stay exactly aligned.



Watch the visualization for the first time. As students view the visualization, remind them to record noticings in their science notebooks. Once the visualization is complete, give students one minute to share their noticings with a partner.

Decide on what to pay close attention to and how to annotate the class chart. Tell students they will watch the visualization again, but this time they will record, as a class, a few things on their outlined map. Based on students' initial observations, decide together what to pay close attention to and record and how to record it. This could include

- recording the direction of air movement with a black arrow,
- recording the direction of a major storms or precipitation with a [another color] arrow, or
- recording areas where there is a lot of precipitation by circling the area.

Replay the visualization. Be prepared to stop and restart the visualization as needed to allow time for you or a student to record air and storm movement and notable areas of precipitation on the map. This will become your class's annotated class map. Encourage students to add to their noticings in their notebooks. Rewatch the animation as much as needed to document observations.

* Supporting Students in Developing and Using Patterns

During this discussion, ask students how visualizations, such as the ones they've been making observations about, are useful for identifying patterns over time (temporal relationships) or over space (spatial relationships). Have the students reflect on how decisions about data and how to represent data are part of the work of science. For example, a still image of a single snapshot in time would not have been an appropriate representation to use for trying to identify predictable patterns.

Additional Guidance

In this one-week visualization, the path of air and precipitation along the west coast is less clear. You may also want to show the *NASA IMERG precipitation rates: U.S. west coast January 2017* visualization along with the first visualization so that students get a more comprehensive look at the United States. Note that the time period is different. The first visualization is for August 4-11, 2014 and the second visualization is for January 1-11, 2017. (See the **Online Resources Guide** for links to these items. **www.coreknowledge.org/cksci-online-resources**)

Facilitate a discussion from students' observations. Ask students to share what they noticed and invite students to use the class's annotated map to help them articulate their observations. Use students' questions from the navigation to guide this discussion. Partway through the discussion, transition students to think about how predictable air movement influences the kinds of air masses that move across the U.S.*

Suggested prompts	Sample student responses
Do you think this sort of pattern of air movement from west to east is something that happens all the time?	*Air seems to mostly move west to east across the U.S. (left to right), but sometimes goes downward (southeast) or upward (northeast).* *The west coast seems to get air from the Pacific Ocean.* *Air in the middle of the country seems to come from the west or north.*
Which parts of the U.S. clearly have this air movement pattern?	*The middle part of the country.*
Does the air only move west to east, or does it also move north to south?	*The east coast and gulf coast areas seem to get air coming from the south moving to the north, but then it moves off to the east (right).* *Some air comes down from Canada/the north.*
What do we think the air is like that comes up from the south, like the Gulf of Mexico? What is the air like that comes from the north?	*Warmer air comes from the south because it's warmer near the equator.* *Air from the north is probably colder air.*
How do you think this could influence the precipitation in these places?	*Anywhere there are a lot of storms, there are probably warm and cold air masses colliding.*
Does a place need to be near the ocean to get a lot of precipitation?	*It looks like places near the ocean get a lot of precipitation.* *A lot of precipitation moves across the middle of the U.S.* *Washington/Oregon get a lot more precipitation than California.* *There is precipitation that seems to come from the Gulf of Mexico.*

Motivate needing to look at a longer time period to be more confident with conclusions. Remind students that these visualizations only showed 1-2 weeks of time. Display **slide D**. Use the prompts on the slide to elicit student ideas:

- Do you think if we looked at a longer time period this pattern would change?
- How much data do we need to feel confident in our conclusions?

Take a picture of your whiteboard and erase it for the next data visualization or move your annotated class map on chart paper to the side. If using chart paper, you will want to place another piece of chart paper under the global view visualization to annotate.

Additional Guidance

We selected this specific visualization over other similar visualizations that show air movement via cloud cover or water vapor to reduce the likelihood that students will fixate on the swirling and rotating of fluids that occur due to the Coriolis Effect. The Coriolis Effect is key to making sense of why fluids rotate on Earth, but the mechanisms that result in the Coriolis Effect are above grade band. If your students become preoccupied with the swirling motion of precipitation or ocean currents in this lesson or the next, there is an optional reading located in the Student Edition (*Why do air and water spin in different directions on Earth?*) that you can use with your students at any time you deem appropriate. This reading provides a close-to-grade level explanation of the Coriolis Effect and should be sufficient to answer your students' questions.

3. Global View with a Building Understandings Discussion

15 MIN

Materials: science notebook, computer and projector, NASA IMERG precipitation rates worldwide: April to September 2014, whiteboard or chart paper, dry erase or chart markers

Make observations over a longer time period. Remain in a Scientists Circle. Display **slide E.** Give students background about the *NASA IMERG precipitation rates worldwide: April to September 2014* visualization they are about to observe. For example, the visualization:

- Is a computer simulation based on real-time data.
- Is from a satellite perspective, but uses both satellite and ground observation data from weather stations.
- Shows the entire world, but NASA is still working on producing this data for polar regions.
- Data are only for the 8 months from April 14, 2014 through September 30, 2014.

Ask students to share how we should approach the analysis of this new visualization.

Suggested prompt	Sample student response
How will this new data visualization help us feel more confident in the patterns we were seeing in the one-week visualization?	*It's a lot more time. It probably uses a lot more data.*

Suggested prompts	Sample student responses
How should we approach our analysis now that we are looking at the whole world and not just the United States?	*We can look at the United States only.* *We can look at the United States first and then look at other parts of the world.* *We could divide up where we look.*
What should we pay attention to again?	*The direction that the air is moving.* *The direction storms or precipitation are moving.* *Look for patterns.*

Have students add to their Notice and Wonder charts in their science notebooks by first drawing a line under their previous observations and starting a new section for the new visualization. Prepare a space (whiteboard, smartboard, or new chart paper) on which to project the visualization to annotate new observations. There is no need to outline continents unless you believe this would benefit your students.

Watch the visualization focused on the United States. The visualization is 5 minutes long so you can continue to play it as the class shares their observations or you can pause as needed. Prompt students to observe the first 30 seconds before they record noticings in their science notebooks. After a minute, pause the visualization and ask students to individually think about their new observations compared to their original observations for the 1-week visualization and to be prepared to share similarities or differences. Then facilitate a brief whole-group discussion.

Suggested prompts	Sample student responses
What did you notice was similar?	*The air still moved mostly west to east.* *There is still a lot of air and precipitation around the southeast and east coast and sometimes on the northwest coast.*
What did you notice was different or new now that we are observing more time?	*Sometimes there is a lot of precipitation and other times there isn't much.* *You can see where the air is coming from for the west coast easier.* *You can see the bigger picture where air is coming from and going.*

Review what students know about the difference between climate and weather. Say, *Some of you mentioned that sometimes there is a lot of precipitation in an area and then other times there is less or even none at all. From this, it seems like we are seeing variability, or changes, from day to day and week to week, but we are also seeing a few things that are more constant or predictable. Let's record our thinking here.*

On a piece of chart paper or a white board, draw a basic T-chart with "Day-to-day change" in one column and "Predictable/more stable" in the other column. Record the students' observations that would fit in each column. Examples may include:

- Day-to-day change: rainy one day and sunny the next, a major blizzard one year
- Predictable/stable: storms come mostly from the west, get snow every winter in our state

Say, *When things from the day-to-day column start to average out in a pattern over many years, like 30 years, scientists can calculate the average weather conditions in a place or region. This is what we call climate. Remember that weather is usually the way we describe the conditions over an hour, day, or week, or maybe even a significant storm, but climate is how we describe a place's long-term weather conditions. What are ways you would describe our climate and how it compares to the climate in other parts of the country?*

Give students a moment to share their prior knowledge about climate.

Additional Guidance

An understanding of weather versus climate is the focus of 3-ESS2-1 and you should not repeat that level of instruction at this moment. However, a middle school level understanding of climate versus weather would focus on the short-term and long-term trends in weather conditions. One year of data is insufficient for examining a place's climate. Scientists tend to report climate data using observations collected over decades of time. If you need to go further with students on the distinction between climate and weather, have your class reflect on what amount of data a scientist would need to draw a conclusion about weather versus a conclusion about climate.

Additional Guidance

After this lesson is complete, you may want to post a reference on the Word Wall to help students refer to the distinction between weather and climate. But don't stop right now to do this. Such a poster might say something like: The difference between **weather** and **climate** <u>is a measure of time.</u>

- **Weather** = conditions of the atmosphere in a place over a **short period of time** (minute-to-minute and week-to-week)
- **Climate** = the typical conditions of the atmosphere in a place. It is usually determined by averaging the weather there over 30 years

Transition the class back to the visualization. Refocus the class on the visualization. Say, *We made close observations of the United States, but let's take a moment to look at how air mass movement in the U.S. compares to other parts of the world to see if this is just a pattern we experience.* Assign students to pay close attention to different areas on the map, such as:

(1) the equator area across northern South America and the middle of Africa,

(2) the equator area across Indonesia,

(3) Eurasia, and

(4) Australia and the southern ocean.

Play the visualization again focusing on patterns in air movement and precipitation in these regions. Students need to make observations of their focal region, but do not need to record notes. After 30 seconds to 1 minute, pause the visualization. Ask 1 student from each assigned region to annotate the map in their area to account for the direction of air and precipitation in the region.

Facilitate a Building Understandings Discussion based on students' observations. Display **slide F.** Start the discussion by moving towards an agreement about the direction of air movement in each region. During the discussion, introduce students to the term "prevailing winds". The term itself is not critical to students' science learning, but understanding that there is a predictable direction for winds at different latitudes can help them understand where air masses with different temperatures interact.

Throughout the discussion, use the annotated class map as a reference to support students' ideas. At the start of the next lesson (lesson 20), the class will review important ideas from this discussion to create a consensus map about movement and temperature of air masses.

Key Ideas

Purpose of the discussion: To identify that there are predictable patterns of wind movement in different regions of the world and that these predictable patterns of wind relate to where air masses of different temperatures interact.

Listen for students ideas, such as:

- The direction of the winds affects the movement of air across that region, where the air comes from and goes.
- Air moves from west to east (left to right) in the northern hemisphere over the U.S. and Europe and Asia and this is the same for part of the southern hemisphere.
- In the middle, near the equator, air moves in the opposite direction from east to west (right to left).
- If the air moves over the ocean it seems to relate to a place getting a lot more precipitation.
- Air coming into the U.S off the Gulf of Mexico, Pacific Ocean, or Atlantic Ocean seems to have more moisture or bring more precipitation compared to air moving in from over land.
- There is steadier precipitation near the equator where there are warmer temperatures.

Suggested prompts	Sample student responses
What did we notice when we looked at the whole world?	*Around the equator the air moves from east to west, but above and below the equator it moves the opposite direction.*
After 8 months of data, did you notice a pattern? How do you know?	*The direction was the same and it didn't change, so it seems like a pattern.*

Suggested prompts	Sample student responses
[Point to a couple example locations] How could the winds flowing in this direction [here] affect the air masses in the area?	*If the air seems to come from a pole, it could be colder air. If the air is at the equator, it could be warmer air.* *Anywhere this is a lot of precipitation, this could be a place where warm and cold air meet.*
How can these predictable winds, which scientists call "prevailing winds", help us predict whether a place will get precipitation?	*Some places seem to have more mixing of warm and cold air than other places.*

Assessment Opportunity

As students share their thinking, listen for students to identify (1) the pattern of air movement at different latitudes but specifically from west to east across the U.S., (2) cold air from the north or northwest moving to the east and colliding with warm air from the south/southeast (i.e., Gulf of Mexico), (3) places with a lot of precipitation as likely locations where warm and cold air masses interact or collide, and (4) predictable winds bringing cold or warm air as one way for us to predict a location's long-term precipitation pattern. If students struggle with identifying the ideas above, revisit the first visualization of one week of precipitation rates in the United States. Pause the visualization at a moment with a large storm. Label the flow of a cold air mass from the north and a warm air mass from the south that resulted in the storm. Unpause the simulation and pause again at a second storm. Have your students describe how they would label the cold air mass (from the north or northwest) and the warm air mass (from the south or southwest) that resulted in the storm.

4. Navigation

5 MIN

Materials: scrap of paper

Have students make predictions about how the ocean affects air masses on an exit ticket. Display **slide G**. Say, *Sounds like we realize how a cold air mass moves across the country. When it gets toward the middle or east side of the country, it collides with a warm air mass from the south. This seems like what is happening in the large storm we've been looking at. And we have some idea that the ocean is part of this explanation, but not quite certain how the ocean influences the air masses before they move into and over the country.*

Prompt students to think for a moment about what they know already about the ocean, and how it could be a piece of the explanation. Then ask students to respond to the two questions on the slide as an exit ticket.

- How do oceans impact an air mass?
- Does "closeness" to the ocean affect precipitation in a location?

Collect students' exit tickets before they leave and review before the beginning of the next lesson.

LESSON 20

How do oceans affect whether a place gets a lot or a little precipitation?

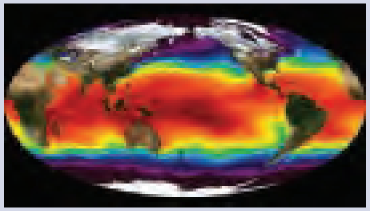
Previous Lesson

We viewed a visualization showing precipitation movement across the United States and annotated a class map. We figured out that air mostly moves in the same pattern across most of the United States, but some places near the coasts show a slightly different pattern. We zoomed out to a global view and noticed patterns in the northern hemisphere mirror patterns in the southern hemisphere and saw that precipitation is heavier in locations near the ocean. We wondered how the ocean changes a place's weather.

This Lesson

Investigation

2 DAYS



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We come to agreement about the temperature of air masses and the direction of their movement. We are still curious about precipitation and storm patterns and how the ocean is involved in these patterns. We gather additional information by observing a visualization of ocean temperatures, through a reading about ocean currents, and through interpretation of precipitation data for coastal cities. We figure out that the ocean affects the humidity of air masses and update our model to show the predictable formation and movement of different kinds of air masses. We are curious as to why the moisture from the Atlantic Ocean and Gulf of Mexico can travel so far inland compared to the moisture from the Pacific Ocean.

Next Lesson

We will analyze precipitation, temperature, and elevation data at five locations along two different prevailing wind pathways to explore why there is less precipitation inland in the Pacific Northwest than inland from the Gulf Coast. We will model what happens as an air mass moves over mountains and flat areas.

Building Toward NGSS

MS-PS1-4, MS-ESS2-4, MS-ESS2-5, MS-ESS2-6

What Students Will Do

Integrate text and media to gather additional information to clarify how ocean currents that circulate cooler and warmer waters to different latitudes affect air mass temperature and humidity.

Use sea surface temperature maps and tabular precipitation data to articulate a spatial pattern connecting offshore ocean temperatures to precipitation on land.

What Students Will Figure Out

- The ocean is warmer near the equator and cooler near the poles.
- Ocean currents can bring warmer water toward the poles and cooler water toward the equator.
- More evaporation occurs over warmer ocean waters.
- The temperature of the ocean affects the humidity of the air moving over it.

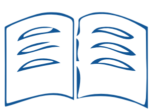
Lesson 20 • Learning Plan Snapshot

Part	Duration	Summary	Slide	Materials
1	3 min	**NAVIGATION** Have students review what they know about the direction of air masses across the United States and where air masses of different temperatures tend to collide.	A	Annotated United States map from Lesson 19
2	10 min	**CREATE A CONSENSUS MAP FOR AIR MASS TEMPERATURE AND DIRECTION** Work together to diagram a class representation of the location and direction of air mass with cold and warm temperatures.	B	Annotated United States map from Lesson 19, blank outline map of the United States (drawn before the lesson), markers
3	12 min	**OBSERVATION OF OCEAN TEMPERATURES** Review students' questions about the role of the ocean and make observations of an ocean temperature animation.	C	computer and projector, NASA Sea Surface Temperature visualization, Consensus Air Mass Map (made in this lesson)
4	17 min	**OBTAIN INFORMATION ABOUT OCEAN CURRENTS** Have students use close reading strategies to gather additional information about how ocean temperatures and currents affect air masses.	D-G	*Reading: How the ocean changes our weather*
5	3 min	**NAVIGATION AND EXIT TICKET** Have students share their current thinking to the lesson question as a formative assessment to inform the Consensus Discussion on day 2.	H	scrap of paper
				End of day 1
6	8 min	**SUMMARIZE KEY IDEAS FROM THE READING** Have students finish their close reading strategies by summarizing key ideas from the text.	I	*Reading: How the ocean changes our weather*
7	8 min	**ANALYZE THE PRECIPITATION DATA FOR COASTAL CITIES** Arrange students into small groups to examine the precipitation data for coastal cities and compare the data to the information from the reading.	J	*Precipitation in Coastal Cities of the United States* handout

Part	Duration	Summary	Slide	Materials
8	17 min	**CONSENSUS DISCUSSION TO REVISE THE AIR MASS MAP** Facilitate a Consensus Discussion to merge students' summary ideas from the reading and their analysis of precipitation to update the class's Air Mass Map.	K-L	*Reading: How the ocean changes our weather, Precipitation in Coastal Cities of the United States* handout, Consensus Air Mass Map (made in this lesson), markers, chart paper or whiteboard
9	5 min	**UPDATE PROGRESS TRACKER** Update the Progress Tracker individually to reflect the ideas students discovered about the formation of different kinds of air masses and how these formation processes relate to the precipitation they have been investigating.	M	
10	7 min	**NAVIGATION** Project the *NASA Rainfall Accumulation Across the United States* visualization that shows accumulated precipitation in the United States. Elicit from students initial ideas about why the precipitation in the southeast is so widespread compared to precipitation in the northwest.	N	computer and projector, NASA Rainfall Accumulation Across the United States visualization

End of day 2

Lesson 20 • Materials List

	per student	per group	per class
Lesson materials **Student Procedure Guide**  **Student Work Pages** 	• science notebook • *Reading: How the ocean changes our weather* • scrap of paper • *Precipitation in Coastal Cities of the United States* handout		• Annotated United States map from Lesson 19 • blank outline map of the United States (drawn before the lesson) • markers • computer and projector • NASA Sea Surface Temperature visualization • Consensus Air Mass Map (made in this lesson) • chart paper or whiteboard • NASA Rainfall Accumulation Across the United States visualization

Online Resources

Materials preparation (30 minutes)

Review teacher guide, slides, and teacher references or keys (if applicable).

Make copies of handouts and ensure sufficient copies of student references, readings, and procedures are available.

Prepare an outline map of the United States on chart paper that the class will annotate in the beginning of day 1 of this lesson. You can use a map similar to the one the class annotated in Lesson 19. This map may look similar to the map depicted to the right.

Prior to the lesson, test the NASA visualizations on your device.

- NASA Sea Surface Temperature visualization.
- NASA Rainfall Accumulation Across the United States visualization.

(See the **Online Resources Guide** for links to these items. **www.coreknowledge.org/cksci-online-resources**)

If internet connectivity is a concern, the NASA visualizations can be downloaded to your desktop from the original source:

- NASA Sea Surface Temperature visualization.
- NASA Rainfall Accumulation Across the United States visualization.

NASA's resources are continuously updated as new data are collected and shared. Over time, NASA will release new visualizations with more current data. You may want to explore their resources prior to the lesson to see if more current visualizations are available. Visit NASA's Scientific Visualization Studio gallery. In particular, NASA's Precipitation Measurement Missions is also a good starting point for the most current data visualizations showing precipitation rates.

(See the **Online Resources Guide** for links to these items. **www.coreknowledge.org/cksci-online-resources**)

Lesson 20 • Where We Are Going and NOT Going

Where We Are Going

In Lesson 19, students figured out that large storms occur in predictable patterns of prevailing winds that tend to make cooler air masses from the north/northwest collide with warmer air mass from the south/southeast, and that these winds move these air masses from west to east across the United States. Students were left wondering how the ocean impacts these storms. This lesson gives students evidence that the warmer air masses in these storms get their moisture from warm ocean water to the south and east, and that relatively warm ocean waters also affect moisture entering the northwest. Students also get evidence that sometimes ocean currents reduce evaporation and can make coastal cities dry.

This lesson builds from previous lessons to specifically target these important DCIs:

- Weather and climate are influenced by interactions involving sunlight, the ocean, and atmosphere.
- These interactions vary with latitude, which can affect oceanic and atmospheric flow patterns.
- Because these patterns are so complex, weather can only be predicted probabilistically.

- The ocean exerts a major influence on weather and climate by absorbing energy from the sun, releasing it over time, and globally redistributing it through ocean currents.

These science ideas are part of ESS2.C: The Roles of Water in Earth's Surface Processes and ESS2.D: Weather and Climate. This lesson focuses on figuring out the connection between ocean currents, evaporation, and the formation of moist air masses.

This lesson builds on 5th grade DCIs (*ESS2.A The ocean supports a variety of ecosystems and organisms, shapes landforms, and influences climate (5-ESS2-1))*. This lesson extends students' understanding by having them look at ocean currents that move warmer waters to higher latitudes and cooler waters to lower latitudes, thereby influencing the moisture that becomes available in air masses.

Where We Are NOT Going

This lesson intentionally avoids naming air masses, such as "maritime polar" or "maritime tropical", and instead focuses on identifying two important characteristics of these air masses—temperature and humidity—as they relate to where an air mass forms.

This lesson also intentionally avoids introducing students to the upwelling current system associated with the California Current as students will focus their time on making connections between a current's temperature as it relates to latitude and precipitation, and will not have time to dig into vertical current movements.

LEARNING PLAN FOR LESSON 20

1. Navigation — 3 MIN

Materials: Annotated United States map from Lesson 19

Review important ideas from the previous class. Display **slide A** and have the annotated class map from Lesson 19 visible for students.

Arrange students in partners and direct their attention to the prompts on the slide:

- What are the important ideas we figured out in the last class period?
- How do prevailing winds affect where air masses go?

Provide 2-3 minutes for pairs of students to review important ideas they figured out and to summarize what they learned about prevailing winds from Lesson 19.

2. Create a consensus map for air mass temperature and direction. — 10 MIN

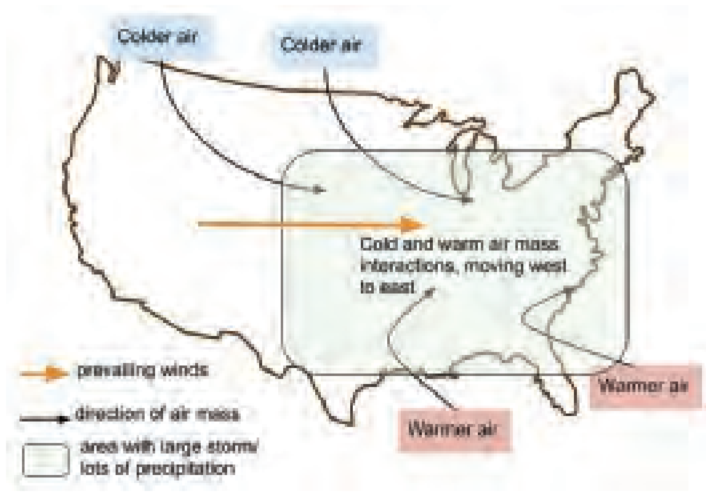
Materials: Annotated United States map from Lesson 19, blank outline map of the United States (drawn before the lesson), markers

Facilitate a class discussion to annotate a class map. Bring students together for a whole-group discussion and display **slide B.** Discuss, as a class, the three prompts below:

- Where do air masses of different temperatures come from?
- How do they move across the United States?
- Where do they often collide to form large storms?

As the class agrees upon the different questions, represent the students' ideas on a class map. An example is shown to the right. Each of the blue and pink boxes in the example represent air masses that generally come from these directions. The class will add to this map on day 2 of this lesson once they figure out more about the role of the ocean and how oceans impact the humidity of these air masses.

Title this map, "Consensus Air Mass Map".



3. Observation of Ocean Temperatures

12 MIN

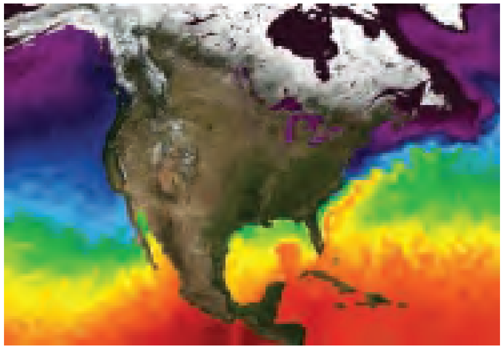
Materials: science notebook, computer and projector, NASA Sea Surface Temperature visualization, Consensus Air Mass Map (made in this lesson)

Brainstorm ideas for how the ocean could impact air masses. Keep the Consensus Air Mass Map displayed and prompt students to share their thinking about how the ocean could impact the air masses on the map.

Suggested prompts	Sample student responses
How does the ocean affect an air mass?	*Air masses near the ocean or over the ocean could have more water.* *Air masses over land may have some water from the ocean, but maybe less water than an air mass over the ocean.*
What would we need to know about the ocean to see if it's adding water to the air above it?	*How much water is evaporating. We know rain mostly comes from the ocean because of the water cycle.*
I have an animation of the temperature of the ocean. How could we use this to test our ideas?	*If it's hot, then there may be more evaporation.* *If it's cold water, less water could be evaporating.* *We could see if the air masses over warm water have more evaporation.*

Setup notebooks for observations. Have students find a new page in their science notebooks to set up a Notice and Wonder chart. If needed, use **slide C**.

Orient students to the NASA Sea Surface Temperature visualization. Explain the color shading to students, with red colors near the middle (equator) representing warmer ocean water and the purple color near the poles representing cooler ocean water. (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)



NASA/Goddard Space Flight Center

Play the visualization. Let students watch the visualization first without writing notes. Pause about 30 seconds into the visualization and cue students to document their first set of noticings. Then continue to play the visualization. At 1:00, pause the visualization again and cue students to make additional noticings, this time focusing their noticings on the ocean temperatures around the coasts of the United States.

Replay the visualization as needed until students have time to make their noticings. Give students another minute or two to add wonderings to their chart as well.

Facilitate the sharing of noticings and wonderings. Ask students to share what they noticed from the visualization. As they share, prompt students to predict how the observation could relate to what they are figuring out about air masses and large precipitation events, or large storms, on land.

Suggested prompts	Sample student responses
What did you notice from the visualization?	*It was really red near the equator, meaning the water is a lot warmer there compared to the poles.*
How could this affect the air above the ocean at the equator?	*It may make the air warmer.* *There may be more evaporation because it's warming up and when water warms up it evaporates.*
What else did you notice?	*The colors changed at different times of the year.*
Why do you think the temperature of the ocean would change at different times of the year?	*In the summer, the ocean is probably a lot warmer because it's hotter and the sun is out longer. In the winter, the water probably gets colder.*
What did you notice around the United States?	*It was really warm on the east coast (right) but cold on the west coast (left).* *It was really warm in the Gulf of Mexico.*
How do you think this could affect the air above the ocean in these places?	*There could be more evaporation happening when the water gets warmer.*

Give students time to share their wonderings and use these wonderings to motivate the need for more information about how the ocean affects the air above it.

4. Obtain information about ocean currents.

17 MIN

Materials: science notebook, *Reading: How the ocean changes our weather*

Introduce students to the article about differences on the west and east coast. Distribute *Reading: How the ocean changes our weather* to each student. Note that there is a color copy of this reading in the back of the Student Edition and the handout version can be used for students to annotate and attach to their science notebooks.

Additional Guidance

You will likely not complete the full close reading strategy within this class period and will need to reserve the beginning of the next class for students to finish their summaries. Alternatively, you can assign the summary as Home Learning, which will give you more time for data analysis and the Consensus Discussion on day 2. Before the class period ends, reserve the final 3 minutes for students to complete an exit ticket. The exit ticket will provide you valuable formative assessment information to help you tailor the Consensus Discussion on day 2.

Display **slide D.** Tell students that they are going to use their close reading strategies to help them gather additional information about the ocean. Review the close reading strategies that should be familiar to your students from previous lessons.

Identify the question(s) to answer. Show **slide E**. Ask, *What is the main question or questions that we are trying to answer using this reading?* The class has yet to articulate the main lesson question, so use this opportunity to articulate one together.

Suggested prompt	Sample student responses
What is the main question that we are trying to answer using this reading?	*How does the ocean affect air or air masses?* *How does the ocean affect weather?* *Does the ocean cause these large storms?*

While the lesson started by having students think about factors affecting air masses, ultimately our purpose in this lesson is to connect the ocean to the large-scale precipitation events in the U.S. Help the class articulate a question similar to the lesson question, *How do oceans affect whether a place gets a lot or a little precipitation?* and write this on the front whiteboard.

Say, *Writing the main question at the top of the reading is a key strategy, because it reminds us of our purpose. Take a few moments to write the question at the top of the reading.*

Show **slide F.** Give students about 8-10 minutes to read the text on their own.

Show **slide G**. Have students reread the text again, this time using any previously agreed upon annotations, such as circling key words, underlining main ideas, and writing notes in the margins.

As students read, circulate around the room to check for understanding, particularly among students who may need your extra support.*

*** Attending to Equity**
Check in regularly with students who need additional reading support. Ask them to practice summarizing the main idea from a single paragraph and jotting this idea down in the margins of their reading. Partner emergent multilingual learners (EMLLs) with a reading buddy and cue the reading buddies to pause after each paragraph, discuss each paragraph's main points, and write notes in the margins of their readings. Allow EMLLs to discuss and write notes in the language they prefer to process the text.

5. Navigation and Exit Ticket

3 MIN

Materials: scrap of paper

Complete an exit ticket. Display **slide H**. Ask students to share their ideas about the lesson question so far and what they have been learning about air masses:

- How do oceans affect whether a place gets a lot or a little precipitation?
- How do oceans relate to the air masses we've been investigating?

Prompt students to support their ideas with evidence from the reading, images, data, maps, or visualizations that they have seen. Collect students' exit tickets before they leave the classroom.

Assessment Opportunity

Examine students' exit tickets to see if they are (1) making causal connections between ocean temperatures and air mass humidity, (2) using information from multiple sources, and (3) identifying important ideas about ocean circulation and temperature that would affect the chance of precipitation in a location. Use this information to adjust your approach to the Consensus Discussion on day 2.

End of day 1

6. Summarize key ideas from the reading.

8 MIN

Materials: science notebook, *Reading: How the ocean changes our weather*

Summarize important ideas from the reading. Project **slide I**. Remind students of the lesson question that was articulated on day 1 (something similar to *How do oceans affect whether a place gets a lot or a little precipitation?*).

Tell students they are going to finish their close reading of the text, *Reading: How the ocean changes our weather*, by (1) reviewing their notes from the previous class period and then (2) completing steps 4 and 5 of the close reading protocol by adding a summary of key ideas and new questions they have in relation to the question they are working on in their notebooks. Sample of ideas students may record:

- *Ocean currents move warmer waters toward the poles and colder waters toward the equator.*
- *There is a warm current on the east coast and a cold current on the west coast.*
- *Warm ocean water evaporates more, which causes more humid air to form.*
- *Cold ocean water has less evaporation, which causes less humid air to form.*
- *If ocean water is warmer, there is more evaporation and more humidity, which is important for storms.*

Encourage students to reference specific evidence from the reading to support their concluding ideas and to be prepared to share their summary ideas later in the class period.

7. Analyze the precipitation data for coastal cities. 8 MIN

Materials: science notebook, *Precipitation in Coastal Cities of the United States* handout

Test our thinking by checking precipitation data. Share one more piece of evidence with students. Use the analysis of precipitation data as one way for students to test some of the ideas they developed from the reading to see if their conclusions make sense compared to precipitation data for cities along the coasts.

Display **slide J**. Arrange students in groups of 3 and pass out 1 copy of *Precipitation in Coastal Cities of the United States* to each student. Ask each group of students to:

- Examine the average annual precipitation data for 8 coastal cities.
- Apply ideas about ocean temperatures and currents from day 1 and the reading to make sense of the data.

Encourage students to mark up the data, as needed, as they discuss the analysis questions at the bottom of the handout:

- What patterns do you notice in the data?
- How could the ocean be part of explaining these patterns?
- What could explain the precipitation that happens all along the east coast?
- Why is there such a difference between Portland, Oregon and Los Angeles, California on the west coast?

Students should attach the handout to their science notebooks near their readings.

8. Consensus Discussion to Revise the Air Mass Map 17 MIN

Materials: science notebook, *Reading: How the ocean changes our weather, Precipitation in Coastal Cities of the United States* handout, Consensus Air Mass Map (made in this lesson), markers, chart paper or whiteboard

Facilitate a Consensus Discussion around the Air Mass Map. Arrange students in a Scientists Circle for the discussion and remainder of the class period. Ask students to bring their science notebooks with them to the circle. Have the Consensus Air Mass Map from day 1 clearly displayed. You will need an additional piece of chart paper or whiteboard nearby to document a cause-effect diagram as the discussion unfolds. This discussion will focus on producing three main knowledge artifacts:

- a summary of ideas that are supported by evidence from the reading, visualizations, and other resources
- a cause-effect diagram that traces how oceans are connected to large precipitation events in the United States
- an updated model to explain how large precipitation events are part of a pattern or air mass formation and movement

Key Ideas

Purpose of this discussion: Take stock of where we are, based on what we figured out using the reading and additional data, and publicly modify or add to the class's earlier ideas on the Consensus Air Mass Map.

Listen for these ideas:

Areas of agreement

- The ocean is warmer near the equator and cooler near the poles.
- Ocean currents can bring warmer waters toward the poles and cooler waters toward the equator.
- The ocean is warmer on the east coast and cooler on the west coast.
- The temperature of the ocean affects the humidity of the air moving over it.
- More evaporation occurs over warmer ocean waters.

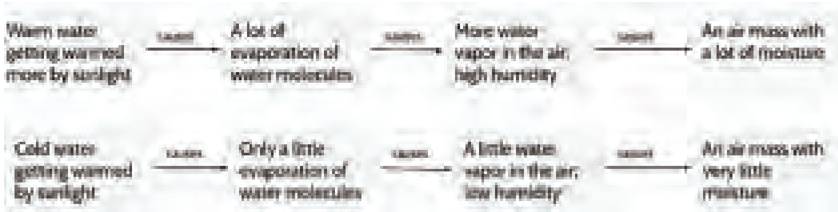
Possible areas of disagreement / uncertainty

- **How the northwest (Washington/Oregon) gets so much rain.** Students may agree that these locations have more precipitation because they are near the ocean, but may struggle with understanding how the relatively warmer Northern Pacific Current is responsible for cold, but moist, air masses to continually affect this area. It is fine for students to only recognize that the ocean must be the source of a humid air mass even if they do not fully understand how a cold, moist air mass could develop.

Have students summarize central ideas and support them with evidence. Display **slide K**, which includes the lesson question (modify the question to fit the one articulated by your class on day 1). Facilitate a sharing of new ideas learned in response to this question and prompt students for evidence as they share.

Suggested prompts	Sample student responses
What new things have we learned?	*We learned that ocean currents can move warm water north on the east coast.* *We learned that there is cold water on the west coast.*
How do these currents seem to affect precipitation?	*On the west coast, Los Angeles and San Francisco get a lot less rain, maybe because there is a cold current.* *On the east coast, there is a lot more rain in all locations because of the warm water.*
It sounds like you're saying water temperature could affect precipitation. How does that happen?	*Warmer water evaporates more than cold water.*
Can you connect that to the precipitation data we examined?	*There is a warm water current all along the east coast and all of those towns had a lot of precipitation, and there was a warm water current coming into where Seattle and Portland are and those places had a lot of precipitation. But the location in California only had a cold water current and that is why they had less precipitation.*

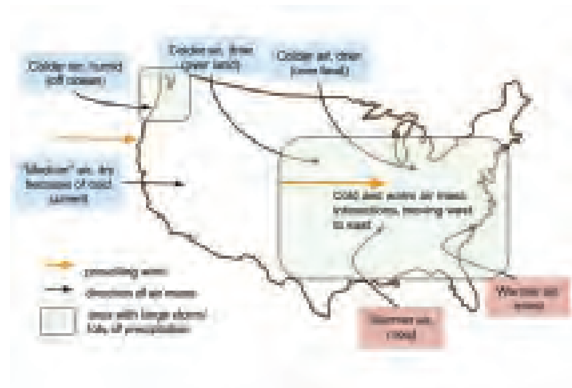
Represent students' ideas on a cause-effect diagram. As students start to describe the connection between water temperature and evaporation, transition the class to documenting a cause-effect diagram to record their thinking. Create a diagram for both warm ocean water and cold ocean water, like the examples below. Prompt students to support each box with evidence from prior lessons.



Have students summarize the connection between the ocean and air mass formation.

Suggested prompts	Sample student responses
What can we conclude about where a moist air mass could form?	*It needs to be in a place with a lot of moisture, so probably over the ocean or big lakes, or even a place where there is a lot of water in the soil.*
What else would it need to form?	*The water needs to evaporate into the air, so there has to be sunlight and heating.*
Where do we think a "dry" air mass would form?	*A place with very little water to evaporate or not enough energy to evaporate.*

Represent students' ideas on the Consensus Air Mass Map. Display **slide L.** Say, *Let's use these ideas to update our Consensus Air Mass Map*. Use students' ideas from the cause-effect diagram to revise the Consensus Air Mass Map, similar to the example shown to the right. The final representation should include a way of showing (1) where cold and warm air masses with either high or low humidity form and (2) the directions in which the air masses move.



- Ask students to decide where high humidity or moist air masses form, and then document them on the map.
- Ask students where low humidity or dry air masses would form. Document these on the map, focusing particularly on air masses that form over land or cold water currents. Students will not have data to support the "dry air mass" so they will need to use logical reasoning to decide that likely air over land will have less water to evaporate so air masses forming over land may have less humidity.

Once the map is constructed, conclude with a discussion about the probabilistic nature of these air masses and how they interact to form precipitation events.

Suggested prompts	Sample student responses
It looks like from our map that California would never get precipitation, but our data suggest otherwise. How could we explain this?	*Maybe sometimes the moist air from up north comes down further?* *Maybe there are days when enough evaporation happens.* *Maybe there are storms that can come up from the south that we are seeing.*
What can we conclude about these air masses and where they interact that we think is part of a pattern?	*We probably get colder air masses from the north and warmer air masses from the south and they meet somewhere in the middle.* *We are probably getting a lot of moisture from the warm waters in the south and east and some from the Pacific Ocean.*
Can we always say with certainty this is how it works?	*There are probably examples that don't match this.* *Seems like there are a lot of different things happening so if any one of those things changes, then things would happen in a different way.*

Assessment Opportunity

During the discussion, listen for students to (1) reference central ideas from the text to support their conclusions, (2) use evidence from the text and data about precipitation amounts at different coastal cities to support their conclusions, and (3) reference at least 2 or more sources of data—from text, maps, or visualizations—to support their conclusions. Focus students on integrating or corroborating their evidence sources to support their ideas as they share them. Listen specifically for students to draw conclusions that show progress toward these disciplinary core ideas components:

- Weather and climate are influenced by interactions involving sunlight, the ocean, and atmosphere, which vary by latitude.
- The ocean is a major influence on weather and climate through its absorption and global redistribution of energy from the sun through ocean currents.
- Because these patterns are so complex, weather can only be predicted probabilistically.

9. Update Progress Tracker.

5 MIN

Materials: science notebook

Update Progress Tracker. Display **slide M**. Have students remain in the Scientists Circle to add an entry to their Progress Trackers.

10. Navigation

7 MIN

Materials: computer and projector, NASA Rainfall Accumulation Across the United States visualization

Use a visualization to problematize the next lesson. Display **slide N**. Introduce students to the *NASA Rainfall Accumulation Across the United States* visualization that will show accumulated precipitation over time. Play the visualization once for students. (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)

Ask students to first share what this map reminds them of from previous lessons. Students may share:

- the hail map from Lesson 2: *Hail Frequency Map*
- all of the storms they saw from Lesson 19
- other maps from previous lessons

Say, *Seems like we've figured out why there is so much rain in this part [southeast] of the country. Can someone summarize this for us?* Listen for students to describe

- cold, dry air from the north coming down,
- warm, moist air from the south moving upward,
- the two meeting in the middle,
- cold air pushing warm, moist air upward causing precipitation, and
- prevailing winds moving the air masses mostly from west to east as they cause this precipitation.

Say, *It's interesting to me how the moisture from the Gulf of Mexico and Atlantic makes it all the way into Illinois over here, but I'm not seeing the same pattern on the west coast where we know there is a lot of moisture coming in too.*

Watch the visualization again with this focus in mind. Ask students to try to explain how the moisture from the Gulf can travel so far inland in the southeast, but the moisture off the Pacific Ocean seems to stop in the small area. Listen for students to suggest:

- Maybe there is just more moisture.
- Maybe there is something stopping it from moving more inland.
- Maybe it hits the cold air right away and drops its water vapor.

If time permits, take a moment to add any new questions that emerge from this visualization to the DQB.

ADDITIONAL LESSON 20 TEACHER GUIDANCE

Supporting Students in Making Connections in ELA

CCSS.ELA-LITERACY.RST.6-8.2: Determine the central ideas or conclusions of a text; provide an accurate summary of the text distinct from prior knowledge or opinions.

Reading: How the ocean changes our weather and the close reading protocol provide an opportunity for students to summarize the central ideas of the text around the question, “How does the ocean affect precipitation?” They connect the central ideas from the text to other data and visualizations they have seen.

LESSON 21

Why is there less precipitation further inland in the Pacific Northwest than further inland from the Gulf Coast?

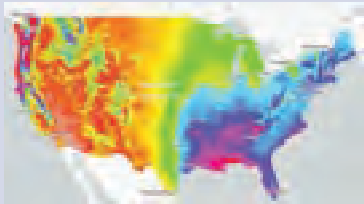
Previous Lesson

We developed a representation for the temperature and movement of air masses but were still curious about whether their proximity to the ocean matters. We gathered additional information about the ocean by observing a visualization of ocean temperatures, through a reading about ocean currents, and through interpretation of precipitation data for coastal cities. We figured out that the ocean affects the humidity and temperature of air masses. We wondered why the moisture from the Atlantic Ocean and Gulf of Mexico travels so far inland compared to the moisture from the Pacific Ocean.

This Lesson

Investigation

2 DAYS



Data Source: Prism Climate Group. Oregon State University.

We analyze precipitation, temperature, and elevation data at five locations along two different prevailing wind pathways to explore why there is less precipitation further inland in the Pacific Northwest than there is further inland from the Gulf Coast. We model what happens as an air mass moves from above the ocean to locations over tall mountains and relatively flat landforms. We develop a list of key ideas and data we would need to explain climate patterns in places outside of the United States.

Next Lesson

We will use our key ideas list from Lesson 21 to explain why the rainforests are located where they are and why they have different climates. We will revisit the Driving Question Board and discuss all of our questions that we have now answered.

Building Toward NGSS

MS-PS1-4, MS-ESS2-4, MS-ESS2-5, MS-ESS2-6

What Students Will Do

Analyze and interpret data to identify patterns in the data to provide evidence of the relationship between elevation (cause), air temperature, and precipitation (effect).

What Students Will Figure Out

- Changes in elevation affect the flow of air over the land.
- As elevation increases, the air flowing over the land is forced upward; as elevation decreases the air flowing over the land can fall back downward.

- Air that is forced upward cools as it rises and tends to lose much of the water vapor in it through condensation and precipitation.

Lesson 21 • Learning Plan Snapshot

Part	Duration	Summary	Slide	Materials
1	5 min	**NAVIGATION** Revisit the lesson phenomenon (there is less precipitation further inland in the Pacific Northwest than further inland from the Gulf Coast, despite heavy precipitation along both coasts) and review students' initial ideas to explain this phenomenon.	A	
2	25 min	**ANALYZE PACIFIC NORTHWEST AND GULF COAST DATA** Use the I^2 sensemaking strategy to analyze data at five locations along prevailing wind pathways in the Pacific Northwest and the Gulf Coast.	B-D	*Maps and Data for the Pacific Northwest and Gulf Coast*, tape
3	10 min	**MODEL WHAT IS HAPPENING TO THE AIR AS IT MOVES ALONG THE PATHWAY** Develop a model to explain what is happening to air masses in the Pacific Northwest and in the Gulf Coast as they move inland over different landforms.	E	*Profile Views: Pacific Northwest and Gulf Coast*, tape
4	2 min	**NAVIGATION** Tell students they will share their models and work on a class consensus model during the next class session.	F	
				End of day 1
5	5 min	**NAVIGATION** Revisit the lesson question and review the models students developed in small groups during the previous session.	G	*Profile Views: Pacific Northwest and Gulf Coast*
6	13 min	**BUILDING UNDERSTANDINGS DISCUSSION** Develop a shared understanding about what happens to air masses as they move inland from the coast based on the data analysis and modeling.	H-J	*Maps and Data for the Pacific Northwest and Gulf Coast, Profile Views: Pacific Northwest and Gulf Coast*
7	7 min	**UPDATE OUR PROGRESS TRACKERS** Update our Progress Trackers to explain why there is less inland precipitation in the Pacific Northwest than inland in the Gulf Coast.	K	

Part	Duration	Summary	Slide	Materials
8	17 min	**DEVELOP A KEY IDEAS LIST** Develop a list of key ideas and data needed to prepare students to be able to explain climate patterns outside of the United States.	L	chart paper, marker
				End of day 2

Lesson 21 • Materials List

	per student	per group	per class
Lesson materials **Student Procedure Guide** **Student Work Pages**	• science notebook • *Maps and Data for the Pacific Northwest and Gulf Coast* • tape • *Profile Views: Pacific Northwest and Gulf Coast*		• chart paper • marker

Materials preparation (30 minutes)

Online Resources

Review teacher guide, slides, and teacher references or keys (if applicable).

Make copies of handouts and ensure sufficient copies of student references, readings, and procedures are available.

Lesson 21 • Where We Are Going and NOT Going

Where We Are Going

In Lessons 18–20, students figured out that warm air masses from the equator and cooler air masses from the poles tend to collide in the middle of the United States and move from west to east due to prevailing winds. They figured out that ocean circulation and ocean temperatures play an important role in explaining whether an air mass is moist and explaining coastal precipitation patterns. In this lesson, students build on these ideas to consider how landforms, and specifically mountain ranges, can affect precipitation patterns.

Through investigation of the Pacific Northwest, students will develop ideas to explain why there is often substantial precipitation on the windward side of mountain ranges, but very little precipitation on the leeward side.

Through investigation of the Gulf Coast, students will develop the idea that when there are no large landforms, warm, wet air masses can move very far inland, causing precipitation throughout a region.

Where We Are NOT Going

The focus of this lesson is on explaining precipitation patterns along only coastal areas of the United States. In Lesson 22, students will apply the ideas from Lessons 18-21 to explain climate patterns in different parts of the world.

1. Navigation

5 MIN

Materials: None

Review coastal precipitation patterns. Present **slide A**. Remind students that in the previous lesson, we observed heavy precipitation along coastal areas, including Seattle and New Orleans. However, further inland, Washington state has very little precipitation, whereas Mississippi and Alabama still have a lot of precipitation. With the whole group, have students review the initial ideas they developed during the previous class to explain this phenomenon.

Suggested prompt	Sample student responses
What were our initial ideas about why there was less precipitation further inland in the Pacific Northwest than further inland from the Gulf Coast?	*Maybe there are different things happening over the land.* *Maybe the swamps in the Gulf Coast or the mountains in Washington play a role?*

Introduce the lesson question. Share that we will investigate this phenomenon today.

Record the related lesson question on the board: Why is there less precipitation further inland in the Pacific Northwest than further inland from the Gulf Coast?

Focus on the direction of the prevailing winds. Consider where the air masses move from the coast to inland areas to help us think about how to answer our question.

Suggested prompts	Sample student responses
If it's raining in Seattle and New Orleans, where would those air masses move next?	*The air mass over Seattle will move East.* *The air mass over New Orleans will move Northeast.*
How could investigating data about how the land compares along both of the pathways that these air masses move across help make progress answering our question?	*The air mass moves in the direction of the prevailing winds. That's the direction that weather travels.* *Knowing about the land that one air mass travels over compared to the land another travels over might help us understand why there's less precipitation further inland in Washington than further inland from the Gulf Coast.*

2. Analyze Pacific Northwest and Gulf Coast data.

25 MIN

Materials: science notebook, *Maps and Data for the Pacific Northwest and Gulf Coast*, tape

Introduce datasets along two pathways of air mass movement. Present **slide B**. Introduce students to two datasets that may help us understand what is happening as we move from the coast inland. Point out the locations of the two different pathways, one in the Pacific Northwest from Seattle to Spokane, WA and other in the Gulf Coast region from New Orleans, LA to Chattanooga, TN. Explain that each pathway has five different locations along it with data we can analyze. These pathways follow the direction of the prevailing winds, which is the direction that one air mass would travel.

Additional Guidance

Emphasize that we have data along these two specific pathways because these locations follow the direction of the prevailing winds in each area. This will help us consider what happens as the same air mass moves over a larger area. If students have forgotten the directions of the regional prevailing winds, revisit what we figured out in Lesson 19.

Introduce and prepare to analyze data using the I^2 sensemaking strategy. Present **slide C.**

Remind students how to use the I^2 strategy to analyze data. Divide students into groups of 4–5. Within each group, have students divide again into pairs or groups of three. Have each group decide whether they want to analyze data for Pathway 1 (Pacific Northwest) or Pathway 2 (Gulf Coast).

Hand out a copy of *Maps and Data for the Pacific Northwest and Gulf Coast* to each student. Students can tape this in their science notebooks. *Maps and Data for the Pacific Northwest and Gulf Coast* has the same information in color, located in the student edition.

Make and interpret observations of the data. Prompt students to write "What I see" (WIS) statements in their small groups. Remind students to write directly on the graphs, drawing arrows to their observations. Have students write "What it means" (WIM) statements next to each of their "What I see" statements.

Supporting Students in Engaging in Analyzing and Interpreting Data

Students will use the Identify and Interpret (I^2) sensemaking strategy to analyze the data table. Consider modeling one observation (WIS) and one interpretation (WIM) with your students before they begin small-group work. This strategy helps students break down information-rich graphs into smaller pieces to interpret, which will allow them to identify patterns that provide evidence for a phenomenon.

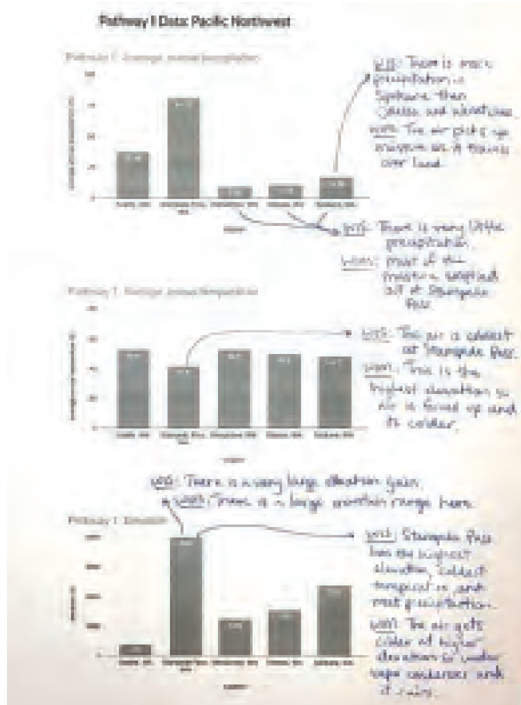
Supporting Students in Developing and Using Patterns

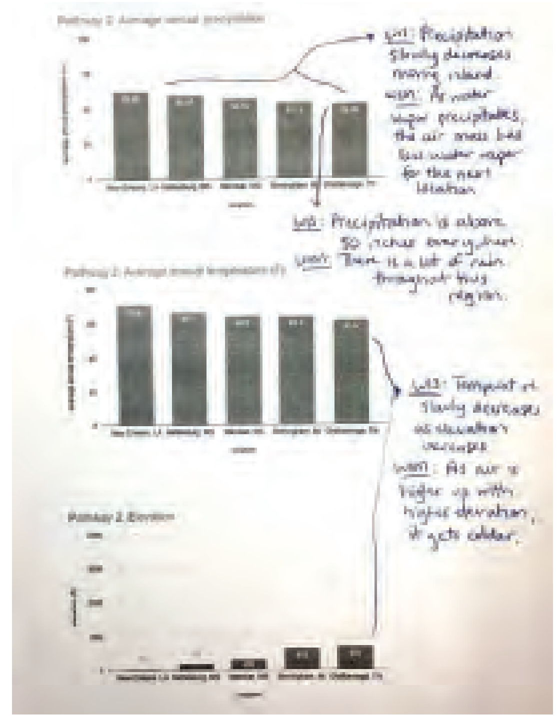
WIS statements from the Pacific Northwest pathway will help students identify patterns in the data about the relationship between elevation, precipitation, and air temperature. WIM statements are students' initial explanations about what they think is happening to cause the observations and patterns.

Additional Guidance

As students annotate *Maps and Data for the Pacific Northwest and Gulf Coast*, circulate and use the following prompts to ensure that they notice key aspects of the graphs.

- What do you notice about how precipitation changes as the air mass moves further inland?
- Where do you see the largest changes in precipitation? What else is changing in those locations?
- What do you think that means?
- Why would mountains cause precipitation to form in the air that flows towards them?
- Why would mountains change precipitation patterns?





Share and compare observations and interpretations of Pathways 1 and 2. Present **slide D**. Give groups 6-7 minutes to share their observations and interpretations with each other. Have students compare patterns and interpretations between the Pacific Northwest and Gulf Coast pathways. Then have a few groups share out their observations and interpretations with the class. Listen for:

- *Pathway 1 Patterns*
  - *Stampede Pass has the highest elevation, coldest temperature, and most precipitation. There is much less precipitation east of the mountains.*
- *Pathway 2 Patterns*
  - *Precipitation slowly decreases, temperature decreases, and elevation slowly increases.*
- *Interpretations:*
  - *The mountains play an important role. As the air moves higher up and gets cold, water condenses and it rains.*
  - *There are no mountains in Pathway 2, so the wet air mass can go a long distance and rain everywhere.*
  - *The rain emptied out from the clouds over the mountains so there was not much left after the mountains.*
  - *The air can pick up some moisture as it moves over the land (e.g., It's rainier in Spokane than Wenatchee).*
  - *A slow and small change in elevation doesn't seem to make a huge difference (e.g., New Orleans to Chattanooga).*

Additional Guidance

The elevation increase and precipitation decrease in Pathway 2 may be counterintuitive to the patterns students observed in Pathway 1. Focus students on careful analysis and comparison between the differences in the two pathways. The profile map on *Maps and Data for the Pacific Northwest and Gulf Coast* may be particularly useful to help students compare and visualize these differences:

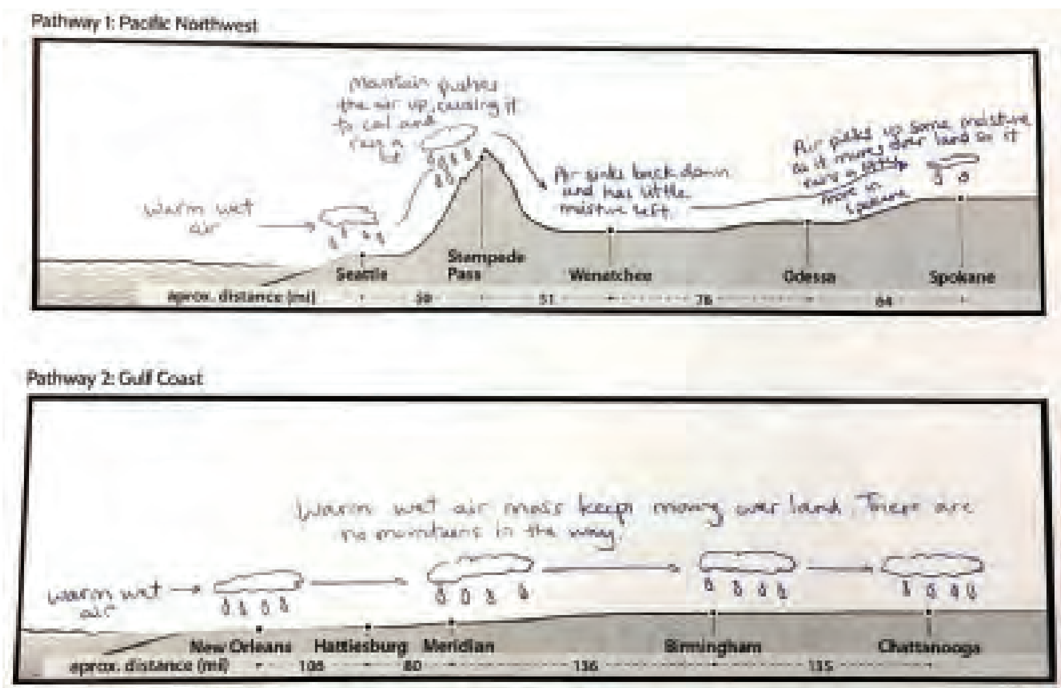
- How large is the elevation gain? Emphasize that it's relatively small in Pathway 2 compared to Pathway 1.
- How long is the distance between points? Emphasize that it's a much larger distance in Pathway 2 than Pathway 1.
- Why would a sudden large increase in elevation cause a large increase in precipitation, but a slow and small increase in elevation wouldn't?

3. Model what is happening to the air as it moves along the pathway. 10 MIN

Materials: science notebook, *Profile Views: Pacific Northwest and Gulf Coast*, tape

Summarize what we've figured out so far about the role of elevation. Say, *It seems like the mountains in Washington might help us explain why there is less precipitation further inland in Washington than in Mississippi or Alabama. Let's use what we already know about air, temperature, and precipitation to model what we think is happening in the locations along both pathways.*

Model air mass movement across the prevailing wind pathways. Present **slide E**. Pass out *Profile Views: Pacific Northwest and Gulf Coast* to each student, which contains the profile views of both pathways, and have students tape these into their science notebooks. Have students work in small groups to model what is happening with air and water at each point along the pathways, including over the ocean. An example model follows.



4. Navigation

2 MIN

Materials: None

Look forward to the next class session. Present **slide F**. Say, *Next time, we'll share our models about what we think is happening and develop a consensus model.*

Have students leave their science notebooks so you can review their data analyses and models to assess their current thinking and anticipate how to best facilitate the Building Understandings Discussion during the next class session.

Assessment Opportunity

Review students' models as well as their WIS and WIM statements from data analysis. Assess that students have identified key patterns in the data through reviewing their WIS statements and models. Then assess where student thinking is as they try to explain these patterns by reviewing the WIM statements and models. This will provide you an opportunity to assess places of student thinking that you need to address on day 2.

End of day 1

5. Navigation

5 MIN

Materials: *Profile Views: Pacific Northwest and Gulf Coast*

Revisit the lesson question. Present **slide G**. Remind students that we've been trying to explain why there is less precipitation further inland in the Pacific Northwest than further inland from the Gulf Coast. Have students briefly review their models with their small groups to explain precipitation patterns in the Pacific Northwest and the Gulf Coast.

6. Building Understandings Discussion

13 MIN

Materials: science notebook, *Maps and Data for the Pacific Northwest and Gulf Coast*, *Profile Views: Pacific Northwest and Gulf Coast*

Gather in a Scientists Circle to explain patterns of inland precipitation. Facilitate a Building Understandings Discussion in which students share their interpretations and make claims about what is happening inland from the coast in Washington state and how it differs from what is happening inland from the Gulf Coast. Have students bring their science notebooks to the discussion. *Maps and Data for the Pacific Northwest and Gulf Coast* and *Profile Views: Pacific Northwest and Gulf Coast* should be taped into their notebooks for reference.

Key Ideas

Purpose of this discussion: to help students make claims about how elevation affects precipitation patterns in the Pacific Northwest and Gulf Coast.

Listen for these ideas:

Pacific Northwest

- Pattern:
  - There is a large and fast increase in precipitation that coincides with an elevation increase and drop in temperature.
  - After the mountains, there is less precipitation.
- Explanation:
  - A warm, moist air mass forms over the ocean. Prevailing winds push that air mass east over the land.
  - When that air mass moves over land, the increase in elevation forces the moving air mass upward. The decrease in elevation allows the air mass to fall downward.
  - Air that is forced upward cools as it rises. Because there is moisture in the air, it condenses as it cools, causing precipitation to fall.
  - This is similar to what happens on a frontal boundary.
  - As the air mass moves over the mountains, it has much less water vapor, leading to very little precipitation east of the mountains.

Gulf Coast

- Pattern:
  - There is steady precipitation along the prevailing wind pathway that slowly decreases further inland. The temperature drops slightly and elevation increases slightly.
- Explanation
  - A warm, moist air mass forms over the Gulf. Prevailing winds push that air mass northeast over the land.
  - The air mass moves over land unobstructed by large mountains. It can stay warm and wet for a long distance. There is slightly less precipitation inland because some of the moisture condenses and precipitates, but there are not major changes.

Use **slide H** to focus first on the Pacific Northwest. Have students share their ideas about what is happening to the air mass as it moves from the over the ocean to Spokane.

Suggested prompt	Sample student response	Follow-up question
What happens with the air mass as it moves from over the ocean to the land?	*The ocean water hitting Seattle is warm—so warm, moist air evaporates.*	*Where does the air go next and why?*

Suggested prompts	Sample student responses	Follow-up questions
What is happening with the air mass as it moves over land to Stampede Pass?	*The air mass is pushed up because of the mountains.*	*What happens when air rises higher up in the atmosphere?* *Why does the air mass moving up in the atmosphere cause precipitation?* *What happens after the air passes over the mountains?*
Why is there so little precipitation in Wenatchee?	*All of the moisture fell out at the mountains. There's very little water vapor left in the air mass.*	
Why is there more precipitation in Spokane than Wenatchee?	*Spokane is at a higher elevation and cooler, so maybe more water condenses.*	
Where does the new moisture come from?	*As the air mass passes over more land, more water evaporates into the air mass.*	

Present **slide I**. Have students compare the model explaining the Pacific Northwest precipitation patterns to the frontal storm model they developed in Lessons 16–18.

Suggested prompts	Sample student responses
How is our model to explain precipitation patterns in the Pacific Northwest similar to our frontal storm model?	*In both models, a cool air mass gets pushed up in the atmosphere. That causes air to get cooler, condense, and cause heavy rain.*
How is it different?	*The mountains push the air up in our Pacific Northwest model.* *The warm air mass pushes the air up in the frontal storm model.*

Use **slide J** to focus next on the Gulf Coast. Have students share their ideas about what is happening to the air mass as it moves from the over the Gulf of Mexico to Chattanooga.

Suggested prompts	Sample student responses
What happens with the air mass over the Gulf?	*Warm, moist air evaporates over the warm Gulf water.*
What is happening with the air mass in New Orleans and Hattiesburg?	*The air mass loses some moisture as precipitation, but it just keeps moving.*

Why is there still so much precipitation in Birmingham and Chattanooga?	*The air mass doesn't hit any landforms with major elevation so it can just keep going and dumping out moisture.*
Why is there less precipitation in Birmingham and Chattanooga compared to New Orleans?	*As there is rain, there's slightly less moisture in the air by the time the air mass gets to Birmingham and New Orleans.*
What would happen to precipitation patterns if there was a large mountain range in between Meridian and Birmingham?	*There would be a spike in precipitation in Meridian and then less precipitation in Birmingham and Chattanooga.*

7. Update our Progress Trackers.

7 MIN

Materials: science notebook

Update individual Progress Trackers. Present **slide K**. Have students create another entry in their 2-column chart and record the lesson question and what the class figured out using words and/or pictures.

Assessment Opportunity

This is a good formative assessment opportunity. Compare students' responses here to student models from Day 1. This will provide you an opportunity to assess student growth in understanding over Day 2.

8. Develop a key ideas list.

17 MIN

Materials: chart paper, marker

Consider precipitation patterns outside of the United States. Say, *We've now explained the precipitations along the coastal areas of the country. Earlier in the unit, we explained precipitation patterns in the central United States. Now that we've developed ideas to explain what we see happening in our country, let's try to extend them to predict and explain what we expect to see in climate patterns in other parts of the world besides the United States. This would be a good way to test the ability of our ideas to explain the widest possible set of phenomena we know of, which is what scientists are always trying to do with the models they develop. And it would also be a good summative assessment of the understanding each of you have individually here at the end of the unit.*

Make a list of key ideas and data needed that explain regional climate differences. Present **slide L**.

Ask students to brainstorm the data they would need to predict or explain such differences in precipitation. Have students work in small groups to generate these two lists.

Share key ideas and data needed as a whole class. As students share suggestions for key ideas, ask if other groups had similar ideas. Generate a class list on chart paper. For each key idea, have students share the kind of data they would need to determine whether or not the key idea in question might help explain regional climate differences.

Key ideas	Data needed
Prevailing wind patterns describe the direction that air moves over a region.	Air circulation map
The source of moisture is where water comes from before it evaporates into an air mass.	Map showing oceans, lakes, rivers, and land areas
Ocean temperature influences the temperature and humidity of air moving over it.	Ocean temperature map Air temperature data
Sunlight warms water causing evaporation and increasing humidity. This causes the average surface temperature of the land and the air above it to change.	Solar radiation data Land temperature data Air temperature data
Increases in **elevation** force air moving over land to rise and cool, causing condensation and precipitation.	Elevation data or profile of the land in the direction of prevailing winds

Navigate to the next session. Tell students that in the next lesson, we'll use these key ideas and data needed lists to explain climate patterns elsewhere in the world.

LESSON 22

How can we explain differences in climate in different parts of the world?

Previous Lesson *We analyzed precipitation, temperature, and elevation data at five locations along two prevailing wind pathways in the Pacific Northwest and the Gulf Coast. We modeled what happens as an air mass moves over mountains and flat areas. We developed a list of key ideas and data to explain climate patterns in places outside the United States.*

This Lesson

Putting Pieces Together

1 DAY

We use our key ideas list from Lesson 21 to explain why the rainforests are located where they are and why they have different climates. We revisit the Driving Question Board and discuss all of our questions that we have now answered.

Next Lesson *There is no next lesson.*

Building Toward NGSS

MS-PS1-4, MS-ESS2-4, MS-ESS2-5, MS-ESS2-6

What Students Will Do

Use graphical displays of global climate datasets (e.g., sunlight, ocean temperature, water and wind movement) to identify relationships between the transfer of energy and the cycling of matter that explain the location and climate of rainforests around the globe.

What Students Will Figure Out

- The interaction of air masses, prevailing winds, proximity to the ocean, ocean currents, and surface elevation profiles work together to influence how much precipitation different regions receive.

Lesson 22 • Learning Plan Snapshot

Part	Duration	Summary	Slide	Materials
1	5 min	**PREPARE FOR FINAL ASSESSMENT: SOUTH AMERICAN RAINFORESTS**	A-F	
2	28 min	**INDIVIDUAL SUMMATIVE ASSESSMENT** Students individually demonstrate their understanding through an assessment in which they explain the locations and types of climates found in the rainforests of South America.	G	*Rainforest Climate Assessment Tasks*, optional *Revisiting Our Driving Question Board*
3	12 min	**EVALUATE OUR DQB QUESTIONS** Gather around the Driving Question Board and place sticky dots on the questions we think we have made progress on.	H	optional *Revisiting Our Driving Question Board*, 5 sticky dots
				End of day 1
		SCIENCE LITERACY ROUTINE Upon completion of Lesson 22, students are ready to read Student Reader Collection 7 and then respond to the writing exercise.		Student Reader Collection 7: *Weather and Climate*

Lesson 22 • Materials List

	per student	per group	per class
Lesson materials **Student Procedure Guide** **Student Work Pages**	• science notebook • *Rainforest Climate Assessment Tasks* • optional *Revisiting Our Driving Question Board* • 5 sticky dots		

Materials preparation (30 minutes)

Online Resources

Review teacher guide, slides, and teacher references or keys (if applicable).

Make copies of handouts and ensure sufficient copies of student references, readings, and procedures are available.

Display all previous classroom consensus models around the room.

Make sure there is space to gather in a Scientists Circle around the DQB.

Optional: Take a high-resolution photograph of all the questions on the DQB *or* type them and add to *Revisiting Our Driving Question Board*.

Lesson 22 • Where We Are Going and NOT Going

This lesson provides a final opportunity for students to apply the understanding they have gained throughout the unit to explain how weather and climate are influenced by interactions involving sunlight, the ocean, atmosphere, and landforms and how those interactions vary with latitude, altitude, and local and regional geography (ESS2D).

LEARNING PLAN FOR LESSON 22

1. Prepare for final assessment: South American rainforests.

5 MIN

Materials: science notebook

Connect back to the key ideas list from Lesson 21. Display the list of key ideas and data needed that the class generated at the end of Lesson 21. Say, *Yesterday, we created a list of key ideas and data to explain climate patterns in places outside the United States. Let's see if we can use this list to help explain a new phenomenon.*

Introduce students to the rainforests of South America. Display **slide A** and then **slide B** and explain that South America is home to much of the world's rainforests. There are two kinds of rainforests—tropical rainforests and temperate rainforests. They are home to different ecosystems and different plants and animals.

Show **slide C**. Explain that many of the species in the world live in rainforests. Two reasons for this are the abundance of water (needed for plant growth) and stable temperatures (animals may more easily survive year-round). Rainforests are essential to the survival of many unique species in the world. So, *How can South America be home to so many of the world's rainforests?*

Orient to South America. Show **slide D**. Help students orient to the location of South America. Show students where the rainforests are on the map of South America. Then, show students where South America is on the world map in the upper righthand corner of the slide. Point out the United States on the world map. Highlight the fact that South America includes countries like Venezuela, Peru, Brazil, Chile, and Argentina and, like North America, is surrounded by the Pacific Ocean on the west and the Atlantic Ocean on the east. Ask students if they notice any differences between North and South America (e.g., South America is further south, the equator goes through it).

Highlight high precipitation and differing temperatures. Show **slide E.** Explain that there are two types of rainforests and that both types receive much more rain over a year than other parts of the world. They each receive an average of 80 inches of rain or more a year. **But** tropical rainforests are warmer than temperate rainforests. The average temperature range of tropical rainforests is 70 to 85°F, while the average temperature range of temperate rainforests is 45 to 55°F.

Apply the key ideas list to this new phenomena. Say, *Throughout this unit we have developed a list of mechanisms for small-scale storms, added ideas about large scale-storms, and then added some more ideas about longer-term patterns of precipitation and temperatures in a region.* Show **slide F**. Ask students to refer to the key ideas list that they generated in Lesson 21 and Turn and Talk with a partner about what key ideas and data might help us explain why the rainforests are located where they are and why they have different climates. After students have discussed in pairs, ask a few students to share their ideas.

Additional Guidance

It will be helpful to have the list of mechanisms developed in Lesson 18 visible for students to reference as they discuss the ideas needed to explain the location and climate of South American rainforests.

2. Individual Summative Assessment

28 MIN

Materials: *Rainforest Climate Assessment Tasks*, optional *Revisiting Our Driving Question Board*

Preview and administer the assessment. Pass out *Rainforest Climate Assessment Tasks*. Preview the questions with students. As you go through the questions, ask students to think about our key ideas list and whether those ideas will help explain each section of the assessment. Give students time to work on the assessment individually. Keep the chart of key ideas available for students to reference.

Additional Guidance

As students finish the *Rainforest Climate Assessment Tasks*, they can work on the optional *Revisiting Our Driving Question Board* to evaluate our progress on any remaining questions on our DQB. You may wish to extend or move the examination of the DQB to the next day.

3. Evaluate our DQB questions.

12 MIN

Materials: science notebook, optional *Revisiting Our Driving Question Board*, 5 sticky dots

Gather at the DQB and mark questions that students think we have answered. Present **slide H** and have students place sticky dots on the class DQB next to the questions that they think we have made progress on.*

*** Attending to Equity**

It is important to revisit the DQB to ensure students feel as though their questions are valued and recognized. While not all questions will have been addressed (it's more likely that most will be at least partially answered), this helps students see that they have done hard work to help answer many of their own questions.

Alternate Activity

If you have more time, you can have students work in pairs to evaluate what questions from the DQB the class has answered using the optional *Revisiting Our Driving Question Board* before coming to the Scientists Circle.

Look for patterns using the sticky dots. In the Scientists Circle, focus on the questions that have the most sticky dots.

Discuss as a class the questions the class can now answer. Present **slide I** if needed. Have the class discuss the answers to these questions as a group. If you have space, you might make a Takeaways board to record the answers the class comes up with.*

Alternate Activity

Another option is to have students work either individually or in pairs to answer the questions they posed. This can be done by asking them to write their questions on a sheet of paper and answer the questions in words and/or pictures. To help students feel like they made progress answering their own questions, create a focus on the questions that we have not answered, but now feel we could (or partially could) using the ideas we have developed.

As another option, some teachers may start a Wonder board, on which questions that have not yet been answered, but students are still interested in pursuing, are housed. These questions are available for students to pursue independently or as time allows.

*** Supporting Students in Engaging in Asking Questions and Defining Problems**

Revisiting the DQB at the end of the unit helps students see the progress they have made toward answering the questions that were important to them at the onset of the unit. At that time, students asked questions “that require sufficient and appropriate evidence to answer”. Through investigations and individual and whole-group sensemaking, they can now answer many of their initial questions. This final visit to the DQB also allows students to see how their work toward a shared learning goal can help them figure out the phenomenon and also explain other phenomena in the world.

SCIENCE LITERACY: READING COLLECTION 7

Weather and Climate

Literacy Objectives

- ✓ Summarize key points related to climate phenomena.
- ✓ Distinguish cause(s) and effect(s) related to weather and climate.
- ✓ Organize related details to support a claim about weather or climate.

Prerequisite Investigations

Assign the Science Literacy reading and writing exercise *after* class completion of this lesson group:

- Lesson 19: Are there patterns to how air masses move that can help predict where large storms will form?
- Lesson 20: How do oceans affect whether a place gets a lot or a little precipitation?
- Lesson 21: Why is there less precipitation further inland in the Pacific Northwest than further inland from the Gulf Coast?
- Lesson 22: How can we explain differences in climate in different parts of the world?

Instructional Resources

Student Reader

Collection 7

Science Literacy Student Reader, Collection 7
"Climate and Weather"

Exercise Page

EP 7

Science Literacy Exercise Page
EP 7

Literacy Activities

- Read varied text selections related to the topics explored in Lessons 19–22.
- Evaluate the reading selections according to provided prompts and criteria.
- Compare and contrast information gained from reading text with information gained from class investigation.
- Prepare a well-reasoned paragraph in response to the reading.

Standards and Dimensions

NGSS

Disciplinary Core Ideas: ESS2.D: Weather and Climate: Weather and climate are influenced by interactions involving sunlight, the ocean, the atmosphere, ice, landforms, and living things. These interactions vary with latitude, altitude, and local and regional geography, all of which can affect oceanic and atmospheric flow patterns. (MS-ESS2-6) Because these patterns are so complex, weather can only be predicted probabilistically. (MS-ESS2-5)

ESS3.D: Global Climate Change: Human activities, such as the release of greenhouse gases from burning fossil fuels, are major factors in the current rise in Earth's mean surface temperature (global warming). Reducing the level of climate change and reducing human vulnerability to whatever climate changes do occur depend on the understanding of climate science, engineering capabilities, and other kinds of knowledge, such as understanding of human behavior and on applying that knowledge wisely in decisions and activities. (MS-ESS3-5)

Science and Engineering Practices: Using Mathematical and Computational Thinking; Obtaining, Evaluating, and Communicating Information

Crosscutting Concepts: Stability and Change; Cause and Effect

CCSS
English Language Arts

RST.6-8.1: Cite specific textual evidence to support analysis of science and technical texts.

RST.6-8.6: Analyze the author's purpose in providing an explanation, describing a procedure, or discussing an experiment in a text.

RST.6-8.10: By the end of grade 8, read and comprehend science/technical texts in the grades 6-8 text complexity band independently and proficiently.

LITERACY.W.6.1: Write arguments to support claims with clear reasons and relevant evidence.

Math

CONTENT.7.SPB.3: Understand that the probability of a chance event is a number between 0 and 1 that expresses the likelihood of the event occurring. Larger numbers indicate greater likelihood. A probability near 0 indicates an unlikely event, a probability around ½ indicates an event that is neither unlikely nor likely, and a probability near 1 indicates a likely event.

CONTENT.6.SPB.5: Summarize numerical data sets in relation to their context.

Core Vocabulary

Core Vocabulary terms are those that students should learn to use accurately in discussion and in written responses. During facilitation of learning, expose students repeatedly to these terms. However, these terms are not intended for isolated drill or memorization.

climate **rain shadow**

Language of Instruction: The Language of Instruction consists of additional terms, not considered a part of Core Vocabulary, that you should use when talking about any concepts in this exercise. Students will benefit from your modeling the use of these words without the expectation that students will use or explain the words themselves.

hygrometer **jet stream** **probability**
radiosonde **variable** **water cycle**

A Glossary at the end of the Science Literacy Student Reader lists definitions for Core Vocabulary and selected Language of Instruction.

1. Plan ahead.

Determine your pacing to introduce the reading selections, check in with students on their progress, and discuss the reading content and writing exercise. If you are performing Science Literacy as a structured, weekly routine, you might implement a schedule like this:

- Monday: Designate a ten-minute period at the beginning of the week to introduce students to the assignment.
- Wednesday: Plan to touch base briefly with students in the middle of the week to answer questions about the reading, to clarify expectations about the writing exercise, and to help students stay on track.
- Friday: Set aside time at the end of the week to facilitate a discussion about the reading and the writing exercise.

You'll proceed with the in-class lesson investigations during this week.

2. Preview the assignment and set expectations. (Monday)

- Let students know they will read independently and then complete a short writing assignment. The reading selection relates to topics they are presently exploring in their Weather, Climate, and Water Cycling unit science investigations.
- The reading and writing will be completed outside of class (unless you have available class time to allocate).
- Preview the reading. Share a short summary of what students can expect.
    - *First, you will explore a timeline showing some inventions that make weather observations and forecasts more accurate and precise.*
    - *Next, you'll read an article, and interpret its graphics, about two climate patterns that affect land masses bordering the Pacific Ocean.*
    - *Then, you'll read an amusing mock podcast, in which a science correspondent interviews a talking snowflake.*
    - *Next up is a simulated travel magazine article about camping in Death Valley, a desert with a very extreme climate.*
    - *Finally, you'll read a cartoon that explains how the math concept of probability is essential to understanding weather forecasts.*
- Distribute Exercise Page 7. Preview the writing exercise. Share a summary of what students will be expected to deliver. Emphasize that Science Literacy exercises are brief. The focus is on thoughtful quality of a small product, not on the assignment being big and complex.
    - *For this assignment you will be expected to generate a well-reasoned paragraph supporting a claim of your choice about weather or climate.*
- Remind students of helpful strategies they can employ during independent reading. Offer the following advice:
    - *The reading should take approximately 30 minutes to complete.* (Encourage students to break reading into smaller sections over multiple short sittings if their attention wanders.)
    - *A good reading strategy is to scan through the collection first to see the titles, section headers, graphics, and images to see what the selections are going to be about before fully reading.*

Exercise Page

EP 7

- *Next, "cold read" the selections without yet thinking about the writing assignment that will follow.*
- *Then, carefully read the Exercise Page to understand the expectations for the writing part of the assignment.*
- *Revisit the reading selections to complete the writing exercise.*
- *Jot down any questions for the midweek progress check in class.* (Be sure students know, though, that they are not limited to that time to ask you for clarification or answers to questions.)

3. Touch base to provide clarification and address questions. (Wednesday)

Touch base midweek with students to make sure they are on track while working independently. You may choose to administer a midweek minute-quiz to give students a concrete reason not to postpone completing the reading until the last minute. Ask questions such as these, and have students jot answers on a half sheet of paper:

Suggested prompts	Sample student responses
Radiosondes were invented in the 1920s and are still used to collect atmospheric data today. What is another name for a radiosonde?	*a weather balloon*
What do El Niño and La Niña have to do with jet streams?	*One effect of these climate patterns is that jet streams are pushed north or south of where they usually are located. This causes changes in the usual weather north or south of the jet stream.*
If there are many more instances of recent snowfalls near the equator where it never has fallen in thousands of years, what hypothesis does that support?	*a hypothesis that the climate is changing*
How does a rain shadow work to affect Death Valley?	*When moist air from the Pacific Ocean meets the mountain ranges in California, the air is pushed higher and drops most of its moisture. By the time the air moves down the other side of the mountains and into Death Valley, the air is so dry that it rarely rains.*
What does probability have to do with weather forecasting?	*Because weather involves so many variables, forecasts can only predict how likely it is that there will be rain, clouds, storms, or other weather events.*

Ask a few brief discussion questions related to the reading that will help students tie the text content to students' classroom investigations.

Suggested prompts	Sample student responses
Which invention described in the first reading did you use to investigate prevailing winds in Lesson 19?	*We use satellite data and looked for patterns in precipitation to detect air movements.*
Based on what you discovered in Lesson 20 about air masses, what would be the characteristics of an air mass that forms over the Death Valley region?	*warm and dry*
Based on your learning in Lesson 21, why are there no deserts, or desert climates, in the eastern United States?	*because there are no tall landforms near the Atlantic Ocean coastline to block moist air from traveling inland and dropping precipitation*

- Refer students to the Exercise Page 7. Provide more specific guidance about expectations for students' deliverables due at the end of the week.
    - *The expectation for this assignment is that you will develop a paragraph in support of a chosen claim, using clear reasons and relevant evidence.*
    - *"Reasons and relevant evidence" means that you should draw upon the scientific and mathematical ideas presented in the readings and in our classroom activities to use in your argument.*
    - *Your concluding sentence is an opportunity to explain why understanding the paragraph is important. Think about your audience as being other students in your grade.*
    - *The important criteria for your work are that you support the claim with accurate science and math ideas and explain why people should care.*
- Answer any questions students may have relative to the reading content or the exercise expectations.

Exercise Page

EP 7

4. Facilitate discussion.

(FRIDAY)

Facilitate class discussion about the reading collection and writing exercise. Students begin the reading activity with a timeline of important inventions in the history of meteorology.

Pages 66–67 Suggested prompts	Sample student responses
What is the general purpose of the first selection, "Inventions in Weather"?	*It illustrates some weather instruments that have been invented over the past 2,000-plus years.*
The telegraph is not actually a weather instrument, but using it to send weather data did help people. How?	*If there was a dangerous storm, the information could be sent ahead of the storm to warn people to prepare.* *Weather scientists could map the size of weather systems such as air masses and fronts while they were forming and use the information to make predictions.*

Student Reader

Collection 7

SUPPORT—If you are using the recommended word envelope convention, check the envelope to see if it contains any words, phrases, or sentences that students need help understanding. Read key sentences aloud, and provide concise explanation.

Pages 66–75 Suggested prompts	Sample student responses
What are some weather tools mentioned on the timeline that might be carried aloft by a weather balloon?	*thermometers, barometers, and hygrometers*
What is the general purpose of the second selection, "El Niño and La Niña"?	*It explains the causes and effects of these two climate patterns.*
Which sentence identifies the cause of El Niño?	*"During an El Niño year, the trade winds that usually blow from east to west across the tropical Pacific are slowed or even reversed."*
According to the map, what are some effects on weather in North America during El Niño?	*Northern states and Canada have a warmer winter.* *The Midwest states are drier.* *The southern states across the entire United States are wetter.* *The southeastern states are colder.*
Look at the Connection box on page 70. What might be some effects of El Niño on tourism in North America?	*There might not be enough snow in Canada and in the northern Rocky Mountains for people to go skiing.* *If it is rainier and colder in the South, people may not want to vacation on the beaches there in winter.*
What is the general purpose of the third article, "Science Interviews Podcast"?	*It uses a fictitious snowflake to argue that there is evidence of climate change by looking at changes in snowfall near the equator.*
In certain western U.S. states, there is more precipitation in the form of snow than rain. How does the water cycle work there?	*It snows in winter, and the snow piles up on mountain slopes. In spring, the snowpack begins to melt, and liquid water flows into streams that carry the water downhill. Plants use the water and release some of it by evaporation from leaves (transpiration). The water vapor rises with warmed air and may condense to form water droplets and clouds.*
Look at the Spot the BS box. How is making a claim based on a single data point bad science?	*Evidence in support of hypotheses, such as climate change, are based on finding patterns in data. The more data points there are, the more certain you can be about the pattern. There are always data points that do not fit the overall pattern, so using one of these would be misleading.*

Online Resources

SUPPORT—Explain to students that the probability, or likelihood, of an event taking place can be expressed as a ratio, a fraction, a decimal, or a percent. The ratio 70:100 (or 7:10) is equivalent to the fraction 7/10. The fraction 7/10 can be converted to the decimal 0.70. The decimal 0.70 is equal to 70%. So, the probability of it raining on the morning of the proposed basketball game was 7 chances out of 10, 7/10, 0.70, or 70%. Consequently, there were 3 chances out of 10 that it would not rain.

Pages 76–79 **Suggested prompts**	**Sample student responses**
What is the general purpose of the fourth article, "Fall Camping in Death Valley"?	*It informs readers about what it is like to visit Death Valley in October and why the climate is so dry there.*
Most travel writing tries to persuade people to visit the place described. What did this author say that might keep people away?	*The writer said that, even though they chose the best month to visit for air temperatures, the air was so dry that it was uncomfortable.*
If there was "a 40-month stretch with just 0.64 inches of rain," how much rain, on average, was there each month?	*0.016 inches, or a little more than one hundredth of an inch per month*
What is the general purpose of the fifth article, "Dear Weather Detective"?	*It explains why knowing something about probability and variables is essential to interpreting weather forecasts.*
At what percent probability does the app shown switch from displaying a cloud icon to displaying a rain icon? Explain your reasoning.	*probably at 50%, because I see that at 49% there is a cloud icon and at 54% there is a rain icon*
Recall the story about the basketball game in the preface of this unit. Would you have shown up to play that day? Why or why not?	*Yes, I would have gone because the icons showed it would be only partly cloudy and the chance of any rain at all was less than 50 percent.*

5. Check for understanding.

Evaluate and Provide Feedback

For Exercise 7, students should, from a provided topic sentence that they select, write a well-reasoned paragraph to argue in support of a claim about weather or climate. Students' paragraphs should include evidence from the readings and class activities and discussions. Reasoning in support of any of the claims requires understanding

- probability,
- variables, and
- the complexity of weather and climate.

Use the rubric provided on the Exercise Page to supply feedback to each student.

EXTEND—Invite students to watch a video that explains probability in depth, including how to use a number line to show that an event is impossible, certain, or somewhere in between. The video also explains what randomness is and why the number of trials affects how close the results will be to an expected probability.

Teacher Resources

Table of Contents

ASSESSMENT SYSTEM OVERVIEW

Each unit includes an assessment system that offers many opportunities for different types of assessments throughout the lessons, including pre-assessment, formative assessment, summative assessment, and student self assessment. Formative assessments are embedded and called out directly in the lesson plans. Please look for the “Assessment Icon” in the teacher support boxes to identify places for assessments. In addition, the table below outlines where each type of assessment can be found in the unit.

Overall Unit Assessment

When	Assessment and Scoring Guidance	Purpose of Assessment
Lesson 1	*Pre-Assessment Reference for Students’ Initial Models*	**Pre-Assessment** The student work in Lesson 1 should be considered a pre-assessment. It is an opportunity to learn what level of understanding and ideas students have. The more ideas in your classroom the better. Revealing these ideas early can help you be more strategic in how to build from and leverage student ideas across the unit. Specifically, look for students’ initial understandings of modeling, asking questions, cause and effect, scale, systems and systems models, and matter and energy. The initial models developed in the lesson are an opportunity to pre-assess student understandings in the context of a small-scale weather event. The most important time to do this is at the end of day 1, when you collect the initial models on *Initial Model* and *Representing Particle-Level Changes in the System*. As a pre-assessment, don’t expect the models to have all the elements identified below. This unit will help students to (1) develop a causal model that links all the elements together and (2) develop additional mechanisms (phase changes driven by thermal energy transfer, density changes in air, lift and convection due to temperature differences). Refer to *Pre-Assessment Reference for Students’ Initial Models* for additional guidance on specific ideas to look for in these models. Make a copy of the students’ initial models for future reference so you can assess individual student growth between now and future key summative assessment points in the unit. Use your review of students’ ideas, as represented in their models, to get a sense of commonalities and differences across models and help you plan for the consensus model discussion on day 2. The Driving Question Board (DQB) is another opportunity for pre-assessment. Use the DQB to allow students to generate open-ended questions (such as how and why questions), post to the board, and celebrate any questions that students share even if they are close-ended questions. Collect questions that students have recorded on sticky notes but did not post at the end of day 3. You will also have a record of the questions they did post on the Driving Question Board. Assess how many closed (yes/no) vs. open (how/why) questions are generated. If students are asking mostly closed questions, you can provide them with copies of the questions on the DQB and ask them to work on refining three or more of these questions so they become “how” and “why” questions that can also address parts of the original “yes” or “no” question. This could be either an in-class or home learning assignment. Also assess whether students generated questions that were only hail-specific or if they also considered other precipitation-related phenomena of different durations (long and short). If students only asked questions about the hail events

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		and not other longer-duration precipitation events, plan to revisit question generation and take additional time to have students add new questions to the DQB about other types of precipitation events they've experienced. These other precipitation event related questions help motivate the third and fourth lesson sets of the unit.
Lesson 6	*Explaining the Movement of Air in a Hailstorm Cloud* L6 assessment scoring guidance: *Explaining the Movement of Air in a Hailstorm Cloud - Key*	**Formative** This lesson is a "putting the pieces together" lesson. It includes a midpoint assessment along with a scoring guide. However, because it is still relatively early in the unit, this is considered a formative assessment. This midpoint assessment is important formatively to make sure the class has made progress and is ready to move forward in the unit. At this point, students should be comfortable with making the following claims: • The Sun heats up the ground, which causes the air next to the ground to heat up. • Heating up the air next to the ground causes it to become less dense. • Air that is less dense rises up through the denser air around it. • The temperature of the air above the ground depends on the temperature of the ground below it. • The Sun's radiation transfers energy to the ground, which in turn transfers energy to the air above it. For the air to be warm enough to become less dense and move upward, it needs sufficient energy from the Sun to cause it to start moving. • Eventually, the warm air transfers its energy to the surrounding air, causing it to become just as cold and dense as the air above and around it and to stop rising.
Lesson 13	Student Transfer Task: *Hurricane Assessment Tasks* L13 Assessment Scoring Guidance: *Key for Hurricane Assessment Tasks*	**Summative** This lesson is a "putting the pieces together" lesson. It includes a summative assessment for the first two lesson sets of the unit along with a scoring guide. See *Key for Hurricane Assessment Tasks*. It should be considered a good summative assessment for the first two lesson sets of the unit. If students are struggling to apply their understanding about hailstorms to hurricanes, encourage them to use their Gotta-Have-It Checklist. Students could pause and examine the models that they have created and then return to the assessment to apply their ideas. Some students may benefit from using multiple modalities to show their thinking for any or all of the questions on this assessment. You may consider allowing some students to present their answers verbally with you or another student acting as a scribe to record their thinking on paper. Other students may benefit from using gestures rather than images to describe parts of their models.

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<tr><th>When</th><th>Assessment and Scoring Guidance</th><th>Purpose of Assessment</th></tr>
<tr><td>Lesson 14</td><td>Initial Model and related written explanation on notebook paper

Evaluating Connections to Our Previous Model</td><td>Pre-Assessment

The student work in Lesson 14 should be considered a pre-assessment. By this point, students have had only one experience analyzing data on a map in the 6th grade scope and sequence (when they analyzed the hail maps from Lesson 2). In this lesson, students will look for spatial and temporal patterns in data on maps at this scale throughout the remaining lessons of the unit and in the next unit (Unit 6.4 - the Everest Unit), so this also is a good opportunity to gauge their initial literacy with analyzing such data sources. Students record noticings and wonderings in their science notebooks for 3 different portions of the weather report. Collect these at the end of day 1. Look for the following noticings in parts 1, 2, and 3:

<u>Noticings in part 1</u>
The scale of the predicted snowfall is large and covers multiple states.
There is a structure to the predicted snowfall and ice (e.g., falls or forms in a line running to the northeast).
There is a pattern where ice vs. snow falls (e.g., snow is predicted to fall over a bigger area than the ice forms, but they overlap).
<u>Noticings in part 2</u>
There are different types of precipitation happening over multiple states in the middle of the United States.
Frozen water (snow, sleet, and ice) is falling to the north and to the west of where the rain is falling.
There is no precipitation in the northeast at the time of the forecast.
There is a cold part and a warm part of the storm.
<u>Noticings in part 3:</u>
The precipitation moves to the east over time.
The forecast includes two colored lines drawn through two bands of precipitation. These lines move east over time too.
The forecast includes a large L connected to both colored lines. This also moves east over time.
This is also a good opportunity to assess students’ application of Disciplinary Core Ideas and Crosscutting Concepts from the prior portion of the unit to a larger-scale class of weather phenomenon. Make a copy of or photograph the students’ initial models for future reference so you can assess individual student growth as they explain weather resulting from large-scale frontal interactions in this lesson set. Look for these ideas in their initial models and the explanations they develop on day 1 of this lesson:
Students identify large areas of colder air and warmer air over the United States at different points in time.</td></tr>
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		• Students show areas of colder and warmer air moving or changing in size over time. • Students explain that something is causing those areas of air to move over time. Students may connect this to the movement of water vapor or clouds over time. You may (or may not) see some students using the ideas and representations listed below as well. These are ideas that will be developed in subsequent lessons: • Air masses are large parcels of air (hundreds of miles wide) with similar characteristics (e.g., temperature, humidity). • There is an imaginary system boundary between where two air masses meet (a front). • Low pressure systems and fronts are where air is rising; they tend to produce clouds and precipitation over and around them when there is enough water vapor in the air.

Lesson 17		**Formative/Summative**
		Lesson 17 provides a key opportunity to make sure all students have made adequate progress on the new ideas about air mass interactions they have been developing since Lesson 14. Lesson 18 provides an additional opportunity to help students look for evidence of those ideas in another forecast, so use the artifacts from this lesson to strategically plan which students will need a bit more coaching in Lesson 18.
		In Lesson 17, students record the patterns they notice on *Air Pressure Prediction and Map Analysis* at the start of the lesson and in their responses to the first two questions on *Explaining Patterns and Predictions in the Forecast*. Monitor students' analysis of the data in the first map they are assigned. Monitor their work on the first two questions on *Explaining Patterns and Predictions in the Forecast*, as this is the most effective time to step in to help break down what these questions are asking, if needed. Listen and look for ideas such as:
		• The low-pressure center moves from west to east over time.
		• The movement and location of warm and cold fronts appear to be connected to this low-pressure center.
		• Precipitation tends to fall along the line of the cold front and warm front and behind the low-pressure center.
		If students are struggling with determining which data to assign a particular color on their pressure maps, pair students up to work on producing the first map that they work on together.
		Students develop an explanation in their response to question 3 on *Explaining Patterns and Predictions in the Forecast*. Collect these at the end of the period. Listen and look for ideas related to:
		• The use of old mechanisms in the explanation, such as:
		  ◦ Air temperature tends to decrease the higher up you go.
		  ◦ Sunlight absorbed at Earth's surface is the source of thermal energy that warms the air directly above it.

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		◦ Parcels of air that are less dense than the surrounding air rise, and those that are more dense sink. ◦ Cooling, humid air can cause water vapor in it to condense and/or solidify out of it. ◦ Rising air pushes up on water droplets or crystals, holding these aloft until they grow heavy enough to fall. • The use of new mechanisms in the explanation, such as: ◦ The area of lowest air pressure corresponds to where air is rising. ◦ The area of rising air could partially be explained by the locations where cold and warm air masses are moving into each other (the front lines) and/or the area of rising air could be partially explained by thermal energy transferring from the surface to the air right above it. ◦ The areas where air is rising (the low-pressure center and along the front lines) would produce precipitation if the warmer air that is lifted is humid and cool enough. If some students struggle to articulate connections to more than a couple of these mechanisms, in the next lesson, strategically assign those students to small groups with at least one member who references multiple mechanisms in their response. Listen in on these groups. Pose questions such as: *Did you hear anything from Student X's explanation that you didn't have but think you might want to include?* For all students who are missing at least one old or new mechanism, leave written feedback on question 3 of *Explaining Patterns and Predictions in the Forecast*. Provide this feedback in the form of one question that is targeted at having them consider whether one additional old mechanism or new mechanism helps explain this phenomenon and why. Vary your feedback by asking each student about a different mechanism to consider further.
Lesson 18		**Summative** This lesson is a "putting the pieces together" lesson. Listen in on small-group discussions involving students that struggled to articulate connections to any new or old science ideas in explanations you collected and reviewed before this lesson. Pose questions such as: *Did you hear anything from Student X's explanation that you didn't have but think you might want to include?* Listen and look for these ideas: • Students identify related mechanisms that others mention and note these by adding check marks on their *Comparing Ideas Used Between Explanations*. • Students discuss their own explanations of these mechanisms. • Students identify and discuss new mechanisms, including ◦ air masses movement, ◦ air masses interacting with other air masses along boundaries where they meet (fronts), and ◦ lift (due to differences in density or pressure) occurring in some air masses and/or along fronts between air masses, which causes (increased) precipitation.

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		After watching the video, students record their noticings in their Notice and Wonder chart to align these noticings with particular science ideas for which they provide evidence. Look for *noticings* that align with each of the three rows of their charts. These noticings should include the following ideas: • Regarding air mass movement: ◦ The precipitation, low pressure center, and front lines all move together. ◦ The path air masses move in tends to be toward the east. • Regarding the interaction of fronts: ◦ The line symbols indicate a front that is at least one front associated with each storm (there may be more than one). ◦ There are two such fronts in storm 1. • Regarding low pressure areas producing clouds and precipitation: ◦ There is a circle with an "L" in it associated with each storm. ◦ Precipitation is falling around the "L". ◦ Precipitation is falling in front of and behind the front lines.
Lesson 22	Student transfer task: : *Rainforest Climate Assessment Tasks* L22 assessment scoring guidance: *Key for Rainforest Climate Assessment Tasks*	**Summative** This is a summative assessment at the end of the unit. Students apply their understanding to explain phenomena in a new context (climate differences across South America). If students struggle to apply their understanding, have them pause, reexamine the models they created in previous lessons, and then resume the assessment. They should apply the ideas they noticed in the models when they continue. If students struggle to interpret the maps, work with them to orient what the maps are showing. For example, on question 2, you can ask students to draw the locations of the rainforests on the maps of average ocean temperature and prevailing winds.
After each lesson	Lesson Performance Expectations Assessment Guidance	**Formative Assessment** Use this document to see which parts of lessons or student activity sheets can be used as embedded formative assessments.
Occurs in most lessons	Progress Tracker	**Formative and Student Self Assessment** The Progress Tracker is a thinking tool that was designed to help students (1) keep track of important discoveries that the class makes while investigating phenomena and (2) figure out how to prioritize and use those discoveries to develop a model to explain phenomena. It is important that what the students write in the Progress Tracker reflects their own thinking at that particular moment in time. In this way, the Progress

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		Tracker can be used to formatively assess individual student progress to allow students to assess their own understanding throughout the unit. Because the Progress Tracker is meant to be a thinking tool for kids, we strongly suggest it is not collected for a summative "grade", other than to ensure completion.
Anytime after a discussion	Student Self Assessment Discussion Rubric	**Student Self Assessment** The student self assessment discussion rubric can be used anytime after a discussion to help students reflect on their participation in the class that day. Choose to use this at least once a week or once every other week. Initially, you might give students ideas they can try in the next class to improve discussion, such as sentence starters. As students gain practice and proficiency with discussions, ask for their ideas about how the classroom and small-group discussions can be more productive.
After students complete substantial, meaningful work	Peer Feedback Facilitation: A Guide	**Peer Feedback** There will be times in your classroom when facilitating a discussion in which students give each other feedback will be very valuable for their three-dimensional learning and for understanding how to give and receive feedback from others. We suggest that peer review should happen at least two times per unit. This document is designed to give you options for how to support peer feedback in your classroom. It also includes student-facing materials to support giving and receiving feedback along with self-assessment rubrics students can use to reflect on their experience with the peer feedback process. Peer feedback is most useful when there are complex and diverse ideas visible in student work and not all work is the same. When students work on models or explanations, these are good times to use a peer feedback protocol. These protocols do not need to be final pieces of student work. Peer feedback will be more valuable to students if they have time to revise their ideas after receiving peer feedback. The protocol should be a formative, not summative, type of assessment. It is also necessary for students to have experience with past investigations, observations, and activities in which they can use these experiences as evidence for their feedback.

For more information about the approach to assessment and general program rubrics, visit the Teacher Handbook.

Lesson-by-Lesson Assessment Opportunities

Every lesson includes one or more lesson-level performance expectations (LLPEs). The structure of every LLPE is designed to be a three-dimensional learning, combining elements of science and engineering practices, disciplinary core ideas and cross cutting concepts. The font used in the LLPE indicates the source/alignment of each piece of the text used in the statement as it relates to the NGSS dimensions: alignment to Science and Engineering Practice(s), alignment to Cross-Cutting Concept(s), and alignment to the Disciplinary Core Ideas.

The table below summarizes opportunities in each lesson for assessing every lesson-level performance expectation (LLPE). Examples of these opportunities include student handouts, home learning assignments, progress trackers, or student discussions. Most LLPEs are recommended as potential formative assessments. Assessing every LLPE listed can be logistically difficult. Strategically picking which LLPEs to assess and how to provide timely and informative feedback to students on their progress toward meeting these is left to the teacher's discretion.

Lesson	Lesson-Level Performance Expectation(s)	Assessment Guidance
Lesson 1	Develop an initial model to describe changes and mechanisms at both the observable and the particle level that cause hail to fall during a brief time period. Ask questions that arise from careful observation of phenomena and gaps in our current models to clarify and seek additional information about how changes to the flow of matter and energy in the air above and around a location on Earth's surface could cause short-duration precipitation events and longer-duration precipitation events (scale).	**Developing and Using Models; Cause and Effect, Scale, Systems and System Models** **When to check for understanding:** Collect the initial models on *Initial Model* and *Representing Particle-Level Changes in the System* at the end of day 1 to pre-assess students' fluency in three-dimensional learning. **What to look for/listen for:** As a pre-assessment, don't expect the models to have all the elements identified below. This unit will help students to (1) develop a causal model that links all the elements together and (2) develop additional mechanisms (phase changes driven by thermal energy transfer, density changes in air, lift and convection due to temperature differences). Refer to *Pre-Assessment Reference for Students' Initial Models* for additional guidance on specific ideas to look for in these models. **What to do:** Make a copy of the students' initial models for future reference so you can assess individual student growth between now and future key summative assessment points in the unit. Use your review of students' ideas, as represented in their models, to get a sense of commonalities and differences across models and help you plan for the consensus model discussion on day 2. **Asking Questions; Cause and Effect, Energy and Matter** **When to check for understanding:** Collect questions that students have recorded on sticky notes but did not post at the end of day 3. You will also have a record of the questions they did post on the Driving Question Board (DQB). **What to look for/listen for:** Assess how many closed (yes/no) vs. open (how and why) questions are generated. If students are asking mostly closed questions, you can provide a copy of the questions on the DQB, and ask them to work on refining three or more of these questions so they become how and why questions that can also address parts of the original yes/no question. This could be either an in-class or home learning assignment. You will also be assessing if students generated questions that were only hail-specific or also considered precipitation-related phenomena of different durations (long and short). If students only asked questions about the hail events and not other longer-duration precipitation events, plan to revisit question generation and take additional time to have students add new questions to the DQB about other types of precipitation events they've experienced. These other precipitation event related questions help motivate the third and fourth lesson sets of the unit. One element of asking questions in the middle school grade band is to help students develop some questions that can be investigated within the scope of the classroom. Therefore, you may want to include opportunities for students to practice asking questions and thinking about how they might investigate them, perhaps as a recurring home learning assignment or exit or entrance ticket. For example, the following two questions could be posed at the end or start of any class period in any future lesson: • What questions were raised for us (now or at the end of the last lesson)? • How might we investigate (one or more of) those questions using equipment in our classroom or using data that other people have collected in other ways and places?

Lesson	Lesson-Level Performance Expectation(s)	Assessment Guidance
Lesson 2	Analyze and interpret data using graphical displays (e.g., maps, charts, graphs, tables) of large data sets to identify temporal and spatial patterns in the range of weather conditions that lead to the formation of precipitation (hail).	**Analyzing and Interpreting Data; Patterns** **Patterns in the location of hailstorms:** **When to check for understanding:** During the *Analyze Hailstorm Map Data* activity, including when students individually record patterns in their notebooks, when they share with the class, and with the exit ticket at the end of day 1. **What to look for/listen for:** • There are more days of hail in the middle of the country. • There aren't very many days of hail on the west coast, particularly near the ocean. • Some places have a *lot* of hail (more than 13 days). **What to do:** If students struggle with interpreting the color and number notations on the map, project and annotate the map by asking them to give examples of what the map is showing; for example, *Where is a location that has more than 10 days of large hail? How do you know?* If students struggle with identifying patterns, pose questions such as, *Are there places that have more days of hail than others?* or provide sentence starters such as, *There are more days of large hail in ___________. Places that don't have much hail include ___________.* **Patterns in the conditions associated with hailstorms:** **When to check for understanding:** With the exit ticket on day 1, during the Building Understandings Discussion on day 2, and in students' individual progress trackers. **What to look for/listen for:** • Hail isn't seen in the winter months. • Hail happens later in the day. • The temperature is relatively warm (above 50°F) on days when it hails. • Hailstorms are relatively short. • Hailstorms appear in "lines". • Humidity is relatively high when it hails. • There are changes in wind when it hails. **What to do:** If students struggle to identify patterns, prompt them with questions such as, *What time of day do hailstorms seem to happen? What time of year? How would you characterize the duration (length of time) of hailstorms? How would you characterize the temperature during a hailstorm? How did that compare across sites?* If students struggle with the variability in the data (e.g., the temperatures differ from site to site), help them look for the broader pattern using a visual representation of the class data.

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Lesson 3	Analyze and interpret sets of data to identify patterns (similarities across data sets) that provide evidence that air temperature changes based on altitude above Earth's surface independently of geographical location or time of year. Develop a model to show the relationship between the motion of the molecules that make up air and the energy of those molecules to explain the patterns of change in air temperature at various altitudes.	**Analyzing and Interpreting Data; Patterns** **When to check for understanding:** As a class, students analyze one set of air temperature data from Albany, NY, on June 11, 2018. With a partner, students analyze four sets of weather balloon data (January, April, June, and October) from one site. Working in groups of four (two pairs), students compare their data and observations, looking for similarities among their observations and across sets of data. After working in small groups, students write a claim using evidence from the data and their observations (slide G). This is another opportunity to formatively assess students' understanding of the data and patterns, and also to see how well they can write evidence-based claims. **What to look/listen for:** As students work with partners and in small groups, and share as a class, listen for the following ideas in their conversations and look for the same ideas in their written observations and claims: • Regardless of the time of year, the temperature of the air always decreases as you move away from Earth's surface and higher into the atmosphere. • The air temperature at very high altitudes is coldest in winter. • The air temperature at 16,000 ft and higher is cold enough for hailstones to form. (In a few cases, the air temperature in winter and spring at altitudes lower than 16,000 ft is cold enough for hailstones to form.) **What to do:** • Throughout the lesson, students are asked to look for patterns in the data and to document their observations in their science notebooks. As students work, listen to their conversations and look at their written observations to do a quick formative assessment of their understanding of the data and the patterns they find. • When students write claims, look for the use of data as evidence to support their claims. • When students come together in the Scientists Circle, listen to the ideas students share and how they connect their thinking with evidence from the weather balloon data. **Developing and Using Models; Patterns; Energy and Matter** **When to check for understanding:** At the end of this lesson, students use a two-column Progress Tracker to document what they have figured out related to the lesson question: "How does the air higher up compare to the air near the ground?" **What to look/listen for:** When analyzing students' thinking and the evidence they use to support it in the Progress Tracker, look for the following ideas: • The air higher in the atmosphere is much colder than the air near the ground.

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		• When the temperature of the air increases, the speed of the molecules that make up air increases, and when the temperature of the air decreases, the speed of the molecules that make up air decreases. • The molecules that make up air at higher altitudes move slower and are closer together than air at lower altitudes closer to the ground. **What to do:** Use students' Progress Tracker to formatively assess (1) their understanding of the relationship between temperature and kinetic energy of particles of matter and (2) their ability to apply this understanding to develop a model that represents the differences in temperature (thermal energy) of the air at different altitudes.
Lesson 4	Plan an investigation collaboratively by identifying variables of interest, tools to gather data, methods for obtaining measurements, and how many sites are necessary to determine if a pattern exists between the temperature of the ground and the temperature of the air right above it. Collect, analyze, and interpret data using graphical displays (tables of data we obtain from our own investigations) to identify ground and surface air temperature patterns as they relate to incoming and reflected solar radiation. Develop and use a model to describe phenomena and unobservable mechanisms that track the transfer of energy from the Sun to the ground and then to the air at the surface.	**Plan an Investigation; Patterns** **When to check for understanding:** On day 1 when students use *Sunlight and Temperature Investigation* to determine what data they will collect, how it will be collected and with which tools, and which sites are optimal. **What to look for/listen for:** Agreement about which data to collect, tools to use, and how to collect the data. Identification of sites that allow for accurate data collection, including sites with exposure to the Sun and one shady site to compare. Potentially the inclusion of ideas about light, absorption, and energy transfer from previous units in the prediction of what the data might show. **What to do:** If students do not identify the correct data or tools to collect it, reference previous units: Unit 6.1: *Why do we sometimes see different things when looking at the same object?* (One-way Mirror Unit) and Unit 6.2: *How can containers keep stuff from warming up or cooling down?* (Cup Design Unit). Ask students how the investigations in those units helped uncover relationships between light and temperatures. Students may struggle to make predictions about what they might see when they collect data outside. Prompt them with: *What do we know about the air? Is it a solid or a gas? What about the ground? Which has more matter?* These questions are intended to help connect previous units and this current investigation. **Carrying Out an Investigation; Analyze and Interpret Data; Patterns** **When to check for understanding:** On day 2 during the outside data collection and the small-group and whole-class sensemaking of the data. **What to look for/listen for:** Students should notice consistent patterns across data collection sites of the ground being warmer than the air above; students should also notice that incoming light is greater than reflected light, making the connection that some energy from the Sun (light) is absorbed by the ground. Finally, students need to connect that absorption to the warmer ground temperatures. **What to do:** Students are transitioning between macroscopic data collection and using the patterns that emerge from their analysis to connect back to their understanding of thermal energy and energy transfer. If students struggle, diagram the data by tracing incoming energy from the Sun, light reflection off the ground, and the temperature of the ground. This should help them connect the data to the patterns they notice.

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		Develop and Use a Model; Matter and Energy **When to check for understanding:** On day 3 during the Scientists Circle. **What to look for/listen for:** Some of these ideas should emerge on day 2, but definitely by day 3 in the Scientists Circle, students should say these things and add them to the Progress Tracker: (1) The light that doesn't end up bouncing off the ground is absorbed. (2) The ground surfaces that absorb more light tend to be warmer (higher temperature). (3) Light transmits through air and reaches the ground, where some of it is absorbed and some is reflected. (4) When energy is absorbed, it causes the particles in the ground to vibrate more, increasing their kinetic energy and the temperature of the ground. (5) Particles in the ground with more kinetic energy transfer energy to particles in the air through conduction when they collide. **What to do:** If students struggle to make the connection between the temperature and sunlight data to explain why the ground heats up more and how it transfers energy back to the air, diagram the system and trace the energy. Include bubbles to "zoom in" on different locations to show what the particles are doing as energy from the Sun travels through the air, is absorbed by the ground, and then transfers back to the air.

Lesson 5	Conduct investigations to collect and use observations and data as evidence to determine the effects of thermal energy transfer to the air in contact with Earth's surface.
	Develop and use a model to track and describe how transferring thermal energy to and from a fixed amount of air (matter) in a closed system affects its volume and density due to unobservable mechanisms (causes), including changes in the speed and spacing of the molecules that make up that air.
		Carry Out an Investigation and Developing and Using Models; Energy and Matter; Stability and Change; Cause and Effect; Systems and System Models
		There are two separate opportunities to assess student understanding of the results from their two investigations. It is recommend you use both opportunities to provide students feedback on the development of their particle level model.
		Opportunity #1
		When to check for understanding: Slide O is the first good opportunity to assess their understanding of the relationship between what they observed in their density and particle packing/spacing.
		What to look for/listen for: After the scenario is presented, students are directed to talk with a partner and make a claim supported with evidence. Listen for the following ideas to surface:
		• Which sample is less dense?
		  ◦ Sample A has a greater number of molecules in the same amount of space as Sample B.
		  ◦ Sample B is less dense than Sample A because it has fewer molecules that are less densely packed in the same size space.
		• What caused this difference?
		  ◦ The ground in direct sunlight receives more sunlight than the ground in the shade.
		  ◦ The blacktop absorbs more sunlight and gets warmer than the grass in the shade.
		  ◦ The air is heated through direct contact with the ground (conduction).

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		◦ The air over the blacktop gets warmer than the air over the grass, because the blacktop has more thermal energy than the grassy area. ◦ The molecules that make up the air over the blacktop have more energy, move faster, and spread farther apart, so the air in Sample A is less dense than the air in Sample B, which is above the grassy area in the shade. **What to do:** If students struggle with the term *density*, use the phrase “amount of matter in a given space” or “how closely packed together the particles are” to help them think about density in conceptual terms. If they need additional scaffolding, use questions to help guide their thinking. For example, ask, *What is the same about both samples? What is different? Which of these differences is causing the air to look different in each sample?* If students need help formulating a claim with supporting evidence and reasoning, use sentence starters, such as *Sample* ______ *is less dense because* ______________. *When a sample of the same type of matter is less dense than another sample of that matter, the particles that make it up* ____________________. **Opportunity #2** **When to check for understanding:** The second opportunity to assess student understanding is when students fill out their two-column Progress Tracker on **Slide X.** **What to look for/listen for:** Progress Trackers should include the many of these ideas, represented in words and/or pictures: • The ground warms the air near it through conduction. • As the air near the ground warms, the molecules that make up the air speed up and spread farther apart. • The warm air becomes less dense than the cooler air above it. • The warm, less dense air rises. • As the warm, less dense air rises high up in the atmosphere, it transfers thermal energy to the cooler air around it. • The warm, less dense air cools down, becomes more dense, and sinks back down toward the ground. **What to do:** If students struggle to model what happens to the air near the ground when it is warmed up, have them think about the important components—air, the ground, and energy—and the interactions between them. Encourage them to use words and pictures to represent how energy affects the ground and the air near it. You can also prompt them to think about the changes energy caused in the air in the *Soap Bubble and Bottle Investigation* and in the helium in the *Heated Balloon Investigation*. You can also revisit the lesson question at the beginning of the next class by analyzing one or two examples of completed Progress Trackers with students.

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Lesson 6	Analyze and interpret data including graphical displays of large data sets to identify cause-and-effect relationships to construct an explanation of how the movement of parcels of air via conduction and convection causes the upward and downward movement of air in clouds. Develop and use a model to describe how thermal energy from the Sun causes movement of parcels of air via conduction to cause the formation of clouds. Obtain information by reading scientific texts adapted for classroom use and summarize key ideas to determine that the air is a mixture of different types of gases (matter), including water vapor, and that relative humidity is a measure of a small proportion of molecules of water vapor in the air.	**Analyze and Interpret Data, Develop and Use a Model; Energy and Matter, Cause and Effect** **When to check for understanding:** This lesson is a "putting the pieces together" lesson. It includes a midpoint assessment along with a scoring guide. This midpoint assessment is important formatively to make sure the class has made progress and is ready to move forward in the unit. **What to look for:** See key for guidance on what to look for in student responses. **What to do:** Provide written feedback to students on their responses. Feedback can be particularly powerful when phrased in the form of questions. You can invite students to respond to these questions on their own as a way to demonstrate their understanding to thinking they did not make visible in their first set of responses. **Obtain and Communicate Information; Energy and Matter** **When to check for understanding:** This portion of the lesson is not a minor formative assessment opportunity. At **slide N**, students will use their close reading strategies on their own to record a summary of key ideas and new questions in their notebook based on their work with *What Is Air?* **What to look for:** A look for one or more of these ideas: • Air is a mixture of different types of molecules (substances) in the gas state, which we can't see. • There are also some larger particles in the air, which we can sometimes see (pollen, ash, dust). • Water vapor in the air, measured as humidity, makes up a relatively small fraction (or percent) of the molecules in the air. **What to do:** If students struggle, direct them to work on a single and summarize one key idea from it, in a single sentence, that answers the question "What is in the air?"
Lesson 7	Plan and conduct an investigation using a model to gather data to serve as evidence to support a claim about where water in the air originates (inputs).	**Plan and Conduct an Investigation; Systems and Systems Models** **When to check for understanding:** On day 1 during the *Plan Our Investigation* discussion and the exit ticket. **What to look for/listen for:** • The humidity probes measure how much water vapor is in the air, so if the humidity reading increases over a particular surface, then it is a place that could contribute water to the air.

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	Develop and use a model to predict and describe changes in particle motion and the movement of water molecules from a liquid into the air (via evaporation) when the thermal energy of the water increases (cause).	• The bottle system is similar to the real world because real-world environments have earth materials that are surrounded by air and get heated up by the Sun. • The bottle system is different from the real world because the bottle is a closed system, while Earth is not. **What to do:** If students don't connect the elements of the bottle system to the real world, use the handout images and slides to help make the connection. If they struggle to understand how the humidity probes are a source of evidence, connect back to the reading and the initial investigations of humidity in the room from earlier in the lesson. **Develop and Use Models; Cause and Effect** **When to check for understanding:** When students individually model how some of the water in or on the ground gets into the air and then revise their model based on feedback using *Model for How Water Gets into the Air* and during the whole-class discussion as they update their Progress Tracker. **What to look for/listen for:** Energy from the Sun causes the water molecules in and on Earth's surface to heat up and move faster. When they move fast enough, they leave the liquid and become a gas. Also look for representations showing that the air and ground are made of different kinds of particles, including water molecules. **What to do:** If students struggle to represent their ideas, encourage them to look back at their Progress Trackers from Lessons 4 and 5 to see how they represented particles and their motion. If they do not connect the motion of the particles to the increase in thermal energy, ask them to show what caused the particles to start moving faster.
Lesson 8	Carry out an investigation to collect data about the patterns in the appearance and growth of water droplets in humid air that is cooled down and how water droplets interact to serve as evidence to explain the causes of condensation (effect). Develop and use a model to describe unobservable mechanisms that explain why the mutual attraction between water molecules and a decrease in their	**Carry Out an Investigation; Patterns** **When to check for understanding:** Compare the observations students record in their science notebook on day 1 for *Investigation A* and *Investigation B* and what they share in class discussion. **What to look for/listen for:** • water droplet formation and/or cloudiness or fogginess more in the cooler parts of the bottle (e.g., only at the top of the bottle or more at the top of the bottle near the ice bag) • growth of water droplets in the bottle over time • description of what water droplets do when they get really close to each other or just barely touch (e.g., two become one, they merge, they move toward each other, they speed up toward each other) **What to do:** If students don't recognize that the top of the bottle is cooler than the bottom part, provide them with thermometers to take measurements during the making-sense discussion after *Investigation A*. If they don't recall seeing attraction between water molecules when they get near each other, suggest looking at one of these events together at a different time scale. Tell them you have a slow-motion video of this phenomenon and then play the video. After the video, have them describe the behavior of the droplets again.

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	speed causes them to condense (effect) when water reaches a low enough temperature (condensation/boiling point).	**Develop and Use a Model; Cause and Effect, Stability and Change** **When to check for understanding:** Compare what students record in their Progress Tracker and at the end of day 2 to what they wrote in their exit ticket on day 1. **What to look for/listen for:** Responses in the Progress Tracker should show evidence of growth in understanding as compared to first responses at the end of day 1 (in the exit ticket). Look for old ideas developed in Unit 6.2: *How can containers keep stuff from warming up or cooling down?* (Cup Design Unit) and new ideas developed in this lesson: • Temperature is related to the average speed of the particles or molecules. (old idea) • When molecules are in a gas state, they are spread far apart and moving relatively fast and bounce off other molecules they collide with. (old idea) • Liquids are made of molecules that are moving, but in a different pattern than in gas form—they move closer together and slide past each other; they also bump into neighboring molecules. (old idea) • Water molecules have some sort of attractive property or force between them that pulls them toward each other. (new idea) • When water is below a certain temperature (its condensation/boiling point), the molecules are moving slow enough that they remain stuck to each other, which keeps them in liquid form. When water is above that temperature, the molecules are moving fast enough that they don't remain stuck together—they bounce off each other, which keeps them in gas form. (new idea) **What to do:** Students are unlikely to use all the ideas listed above. Remember not to grade the Progress Tracker for "correctness", as it is designed to be an individual thinking space. If you want to provide written feedback, offer things for students to consider at the start of day 2, such as the following: *This is a great start on an initial explanation for the phenomenon. Today, I encourage you to be thinking about these things: a) What is happening to the water molecules at the particle level? b) How is this related to whether water molecules remain in gas form or liquid form? c) What causes them to change from one form to another (liquid to gas, or gas to liquid)?* You can look for the use of these mechanisms again at the end of Lesson 9, when students will construct individual explanations for the appearance of frost on the cold pack.
Lesson 9	Obtain and communicate information by reading scientific texts adapted for classroom use to determine key ideas and cause-and-effect relationships related to what clouds are made of, why we can see them, the	**Obtaining, Evaluating, and Communicating Information; Cause and Effect** **When to check for understanding:** Students work with a partner to identify key ideas from the reading *Reading: What Are Clouds?*, and they document those ideas in their science notebooks. **What to look for/listen for:** Look for these ideas in students' science notebooks and listen for them in their conversation with partners: • Clouds are made of gases and water droplets or ice crystals suspended in those gases. • The water droplets and ice crystals reflect light, which allows us to see clouds.

Lesson	Lesson-Level Performance Expectation(s)	Assessment Guidance
	role of cloud condensation nuclei, and methods of cloud seeding. Apply scientific ideas and principles to **construct an explanation** and represent interactions between energy and matter that lead to the condensation and crystallization of water in the atmosphere and the formation of clouds.	• For clouds to form, the air has to be at 100% relative humidity and cooled down enough for water vapor to change state from a gas to a liquid (water) or solid (ice). • Water vapor needs a solid surface to stick to in order to form droplets or ice crystals. In the air, small particles, such as dust, ash, pollen, and pollutants, provide this solid surface for droplet or crystal formation. Scientists call these particles cloud condensation nuclei (CCN). • Cloud seeding is a process in which CCN are added to the air to increase cloud formation and precipitation. **What to do:** As students work with their partners, listen in on their conversations and check their science notebooks. Remind students to check the important ideas they highlighted in *Reading: What Are Clouds?* to make sure their list of key ideas is complete. Use questions to guide students to think about ideas that are missing in their lists of key ideas, then direct them back to *Reading: What Are Clouds?* to search for answers to your questions. Examples include these: *What are clouds made of? What conditions are needed for clouds to form? How do clouds form? Why are we able to see clouds?* **Constructing Explanations and Designing Solutions; Systems and System Models** **When to check for understanding:** Collect *Explaining a Related Phenomenon* at the end of the class period. **What to look for/listen for:** Students' written explanations will be relatively brief, so don't look for them to cite sources of evidence from previous experiments. Look for them to connect to previously constructed scientific principles and models as well as new ideas introduced in *Reading: What Are Clouds?* These include: 1. Some of the molecules in the liquid water at the bottom of the cup have enough kinetic energy to break away from their attraction to neighboring molecules, which allows them to become water vapor (a gas). 2. As the water vapor moves upward in the bottle, it begins to cool down, causing the molecules to slow down. Some of the molecules of water vapor slow down enough that they stick to the surface of the gel pack and stick to each other when they collide with either. 3. Any solid particle in a cloud (e.g., dust and pollen) serves the same function as the gel pack. The gel pack and those cloud condensation nuclei (CCN) provide a solid surface for water molecules to stick to and form ice crystals (or water droplets). **What to do:** Since this is an opportunity to formatively assess students' ability to apply what they have learned to explain a related phenomenon, it is important to provide feedback to students in a timely manner. In addition, if students struggle with specific portions of the assessment, use these strategies: • Revisit, reteach, or reinforce ideas from the lesson to help students fill in gaps in their learning. • Use examples of actual student work to prompt discussion about what we have and haven't figured out up to this point in the unit. • Ask additional questions at the beginning of the next lesson to help them make connections and build understandings.

Lesson	Lesson-Level Performance Expectation(s)	Assessment Guidance
Lesson 10	Modify a model—based on evidence—to build a storm system by changing the input variables, such as temperature and humidity, and measuring changes in the output, the size of storm formation. Evaluate the limitations of the thunderstorm simulation, identifying which aspects of the system are represented in the model and which additional aspects could be added to account for thunderstorm development. Construct an explanation that includes correlational relationships between temperature and humidity that can be used to predict storm development.	**Develop and Use a Model; System and System Models** **When to check for understanding:** On day 1 when students are manipulating the simulation for the first time. **What to look for/listen for:** Observe data students are recording on their data table in *Data Table for Making a Thunderstorm* and listen for ideas about a greater temperature difference between the air at the ground and higher in the atmosphere, along with high levels of humidity, being related to stronger storms. **What to do:** If students are not seeing the relationship to the temperature gradient, ask them to think back to earlier in the unit and describe what the temperatures were like before it hailed (temperatures were warm to hot). Remind them that hail is frozen, so challenge them to think about what the temperatures must be like where hail forms (cold). Also challenge them to think about what hail is made of (water) and how we measure water in the air (humidity). **Develop and Use a Model; System and System Models** **When to check for understanding:** On day 2 during the simulation revision and gallery walk. **What to look for/listen for:** Students should clearly identify what is represented in the model related to storm development, and also ideas for things that could be added, such as sunlight data, ground absorption, presence of CCN, and so forth. **What to do:** If students struggle to represent other ideas in the simulation, challenge them with questions such as, *Where is the energy coming from that heats the ground? The air? How does water in the air form a cloud? What does it need?* Prompt them to look back in their science notebook at previous lessons to pull in other ideas they recorded earlier in the unit. **Construct an Explanation; Cause and Effect** **When to check for understanding:** On day 2 at the end of the lesson when students write their explanation. **What to look for/listen for:** Students should specifically point out a relationship between storm development and the magnitude of the temperature difference between the air at the ground and higher in the atmosphere. High levels of humidity are also related to storm development. When combined, these two variables are related to stronger storms. However, additional factors need to be considered in storm development. **What to do:** If students struggle with their explanation, encourage them to think about one relationship at a time by asking questions such as, *What were ground temperatures like with strong storms? Weak storms?* As students work through one variable at a time, they can piece together how each one is related to a stronger or weaker storm. Prompt them to look back at *Data Table for Making a Thunderstorm* for help tracking these relationships.

Lesson	Lesson-Level Performance Expectation(s)	Assessment Guidance
Lesson 11	Use mathematical thinking and construct an explanation to predict patterns in the relationship between the relative strength of two opposing forces on different objects and the resulting change in motion of those objects. Develop a model to represent balanced and unbalanced forces on an object suspended by an upward current of air, and use the model to predict and explain whether the object would remain suspended (stability) or start moving downward or upward (change) due to the relative strength of the opposing forces.	**Using Mathematical Thinking, Constructing Explanations; Cause and Effect, Stability and Change** **When to check for understanding:** Collect student responses on *Predicting and Explaining the Effects of Opposing Forces* at the end of day 1. **What to look for/listen for:** Look for these predictions in their data table: • These objects would remain floating at the height they were released: the large water droplet in Case A and the small hailstone in Case B. • These objects would start to rise: the small snowflake and large snowflake in Cases A and B and the large water droplet in Case B. • These objects would start to sink: the large hailstone in Cases A and B and the small hailstone in Case A. Look for these ideas in their explanations: • Water droplets and ice crystals have mass and therefore have weight (a downward force on them from gravity). • They should start to fall from this unless there is an updraft force in the opposite direction that is as strong as (or stronger than) the downward force on them from gravity. **What to do:** If students' predictions are not correct, return their handout and ask them to compare their predictions with those reported out in the Scientists Circle on day 2 and have them make corrections in line with the claims of the class. Then have them write a short summary of why these changes make sense and add a new Case C (a new column) to the table on their handout to record their new predictions for an updraft force of 0.001 oz. If students' explanations are incomplete, ask them to make revisions after completing the consensus modeling in the Scientists Circle. Encourage them to try putting into words what is shown in each of the three cases on the chart paper. Collect these handouts again either at the end of day 2 or the start of the next lesson. **Developing and Using Models; Cause and Effect, Stability and Change** **When to check for understanding:** Quickly look over students' shoulders as they complete their Progress Tracker with a partner in the Scientists Circle. **What to look for/listen for:** The following elements should be visible in student models for Case C: • a force of gravity arrow pointing downward • a lift force arrow pointing upward • a smaller lift force arrow than the gravity arrow • a movement arrow pointing downward and/or a description that the object will begin to fall (or sink) **What to do:** If some students' models are missing any of those key elements, bring the class back together and work through the four elements together, asking what the reason is for including each one.

Lesson	Lesson-Level Performance Expectation(s)	Assessment Guidance
Lesson 12	Collaboratively plan an investigation to collect data, identifying independent and dependent variables and controls and how the data are recorded, to serve as the basis for evidence that greater temperature differences between the ground and the air higher in the atmosphere cause greater lift (effect) of air. Develop a model to represent how varying inputs of thermal energy affect the resulting movement of air (output) to show the relationships among variables that can predict greater lift and movement of air. Construct an explanation that includes qualitative relationships between variables that predict the movement of a fluid (air), based on the transfer of energy that drives the motion.	**Planning and Carrying Out Investigations; Cause and Effect** **When to check for understanding:** On day 1 as small groups plan their investigation to test one condition using *Convection Investigation Plan*. **What to look for/listen for:** Students should correctly identify which variables will be held constant across groups (control variables) and which will be the independent variable. They should express understanding that the independent variable is the variable they are testing to determine the effect on the dependent variable (movement of dye in a tub of water). **What to do:** If students struggle with variables, rephrase this language to call the independent variable the "test variable" or the "condition that is being changed by the group." **Developing and Using Models; Systems and System Models** **When to check for understanding:** On day 2 as small groups diagram their test condition and synthesize data from other groups using *Air Movement in Different Conditions*. **What to look for/listen for:** Students should notice that when fluid is heated, it rises and spreads out. As it cools, it sinks again. This forms a circular movement of fluid known as convection. The greater the thermal energy input into this circular movement, the faster the fluid will rise (or lift). When little thermal energy is added to the system, there is very little lift. These results map back to the movement of air in and around a cloud by showing that when there is great thermal energy input, air can rise very fast with a lot of force. **What to do:** Students need to synthesize findings across 7-8 test conditions. If this is challenging, discuss the results of each condition as a class and highlight the findings as related to the amount of thermal energy input and the movement of the dye. Frequently remind students that the dye represents the movement of air in and around a cloud. **Construct an Explanation; Matter and Energy** **When to check for understanding:** On day 2 when students individually complete *Explaining Convection in the Air Outside* and bring their explanations to the class to update the Progress Tracker. **What to look for/listen for:** Students should trace the input of thermal energy into the system as the mechanism that causes air to rise (or gives it lift). When the thermal energy is greater, air rises faster with more force. Another key ingredient is the difference between temperatures near the ground where they are warmest and higher in the atmosphere where they are colder (students should recall this from Lesson 10). Stronger storms result from a greater difference, and the lift of air is strongest when the thermal energy input is greatest. **What to do:** Ask students to remember from Lesson 10 what conditions caused stronger storms to form (warmest temperatures near the ground, coldest higher in the atmosphere, high humidity). Encourage students to use this idea and integrate the new idea that more thermal energy causes air to rise faster and with more force. These two ideas together can help them explain why big storms form and why clouds can rise very high in the atmosphere.

Lesson	Lesson-Level Performance Expectation(s)	Assessment Guidance
Lesson 13	Develop and use a model to describe and explain unobservable mechanisms that drive the cycling of matter and the flow of energy into and through the air to cause some storms to produce large hail while others do not. Construct an explanation, using a model and previously developed science ideas, to explain what causes hurricanes to form, grow, and produce (effect) strong winds and large amounts of rain (cycling of matter and flow of energy).	**Developing and Using Models; Matter and Energy** **When to check for understanding:** When students are developing their models on day 1 and day 2. **What to look/listen for:** See *Gotta-Have-It Checklist* for key ideas students should include in their models. **What to do:** Cue students to use their Gotta-Have-It Checklist as they work through the model. Pose questions to help students connect to how the cycling of matter and flow of energy are leading to the phenomenon with prompts such as: • *Where in this system are energy changes occurring*? • *What is driving the movement of the water and hail*? If groups indicate that they are done but there are still ideas or parts of the explanation missing, pause the groups and have them do a quick gallery walk and then cue them to continue to add to their group model. **Constructing Explanations; Cause and Effect, Matter and Energy** **When to check for understanding:** On *Hurricane Assessment Tasks*. **What to look/listen for:** See *Key for Hurricane Assessment Tasks* **What to do:** If students are struggling to apply their understanding about hailstorms to hurricanes, encourage them to use their Gotta-Have-It Checklists. Students can pause and examine the models that they have created and then return to the assessment to apply their ideas. Some students may benefit from using multiple modalities to show their thinking for any or all of the questions on this assessment. You may consider allowing some students to present their answers verbally with you or having another student act as a scribe to record their thinking on paper. Other students may benefit from using gestures rather than images to describe parts of their models.

Lesson	Lesson-Level Performance Expectation(s)	Assessment Guidance
Lesson 14	Analyze data using maps of national weather conditions and forecasts to identify temporal and spatial relationships (patterns) between precipitation, cloud cover, temperature, and air pressure. Develop an initial model to explain how precipitation that is happening in one part of the country at one point in time could be connected (cause/effect) to what is predicted to happen in another part of the country at a later time. Use a previous model to identify mechanisms at the observable and the particle levels to explain the causes of this large-scale weather phenomenon. Ask questions about possible patterns in and causes for a storm affecting large parts of the country over multiple days or causes shared between this precipitation event and a smaller-scale, shorter-duration precipitation event (a hailstorm).	**Analyze data; Patterns** **When to check for understanding:** Students record noticings and wonderings in their science notebooks for 3 different portions of the weather report. Collect these at the end of day 1. **What to look for/listen for:** Students will be looking for spatial and temporal patterns in data on maps at this scale throughout the remaining lessons of the unit and in the next unit (Unit 6.4—the Everest Unit), so this also is a good opportunity to gauge their initial literacy with analyzing such data sources. Noticings in part 1 • The scale of the predicted snowfall is large and covers multiple states. • There is a structure to the predicted snowfall and ice (e.g., fall or forms in a line running to the northeast). • There is a pattern where ice vs. snow falls (e.g., snow is predicted to fall over a bigger area than the ice forms, but they overlap. Noticings in part 2 • There are different types of precipitation happening over multiple states in the middle of the United States. • Frozen water (snow, sleet, and ice) is falling to the north and to the west of where the rain is falling. • There is no precipitation in the northeast at the time of the forecast. • There is a cold part and a warm part of the storm. Noticings in part 3: • The precipitation moves to the east over time. • The forecast includes two colored lines drawn through two bands of precipitation. These lines move east over time too. • The forecast includes a large L connected to both colored lines. This also moves east over time too. Students have had only one experience analyzing data on a map in the 6th grade scope and sequence so far: the hail maps from Lesson 2. If students have questions about where particular states are located, it may be useful to reference the location of your school on the map, or point out the location of a few larger states. It may be helpful to draw a compass indicating the N, S, W, E directions on the board for reference. **Develop a Model; Cause and Effect** **When to check for understanding:** Students develop an initial model and explanation on day 1 and add it to their science notebook. Collect these at the end of day 1.

Lesson	Lesson-Level Performance Expectation(s)	Assessment Guidance
		What to look for/listen for: • Identifying large areas of colder air and warmer air over the United States at different points in time. • Showing areas of colder and warmer air moving or changing in size over time. • Explaining that something is causing those areas of air to move over time. Students may connect this to the movement of water vapor or clouds over time. You may (or may not) see some students using these ideas and representations as well. These are ideas that will be developed in subsequent lessons: • Air masses are large parcels of air (hundreds of miles wide) with similar characteristics (e.g., temperature, humidity). • There is an imaginary system boundary between where two air masses meet (a front). • Low pressure systems and fronts are where air is rising; they tend to produce clouds and precipitation over and around them when there is enough water vapor in the air. **What to do:** Make a copy of or photograph the students' initial models for future reference so you can assess individual student growth in this lesson set in explaining weather resulting from large-scale frontal interactions. **Asking Questions; Patterns, Cause and Effect** **When to check for understanding:** At the end of day 3 collect questions that students have recorded on sticky notes but did not post. You will also have a record of the questions they did post on the Driving Question Board (DQB). All these sticky notes will have students' initials on the back. **What to look for/listen for:** Assess how many closed (yes or no) vs. open (how and why) questions are generated. **What to do:** If students are asking mostly closed questions, you can provide a copy of the questions on the DQB and ask them to work on revising three or more of these questions to become how and why questions. This could be either an in-class or home learning assignment.
Lesson 15	Use graphical displays of temperature, humidity, and radar data to identify temporal and spatial patterns as air masses interact in a large storm system.	**Analyzing and Interpreting Data; Patterns** **When to check for understanding:** On day 1 during and after the gallery walk. **What to look for/listen for:** • Ideas about temperature and humidity shifting over time during the storm. • Ideas about places that have similar or different temperature and humidity to another place.

Lesson	Lesson-Level Performance Expectation(s)	Assessment Guidance
	Use an argument supported by empirical evidence and scientific reasoning based on patterns from data and maps to support an explanation that precipitation forms along the boundary of two air masses with different temperature and humidity characteristics.	**What to do:** It might be challenging for students to figure out air masses using the raw temperature and humidity data on the maps, but classifying data by color will help them notice shifting patterns as large air masses move across the country during the storm. Prompt students to notice one distinct type of air mass by asking, *How would you describe the air in _______(a place on the map)? Is that similar or different than _______(another place)?* **Argue from Evidence; Patterns** **When to check for understanding:** On day 2 after students update their Progress Tracker and build consensus with the class. **What to look for/listen for:** Ideas that the storm or precipitation happens in places where the colder air is meeting the warmer air (or where two different types of air meet). **What to do:** The storm is very large and spans many states. In some places, there isn't a distinct boundary between two air masses. But in general there is much colder air on the western and northern sides of the storm, and that same air has lower humidity than air in the region of the storm or east of the storm. Ask students to consider, *On this side of the precipitation (or storm), what is the air like? What about the other side? And where is the precipitation happening then?*

Lesson 16	Develop and use models to observe and describe the complex patterns of change that occur when warm and cold air masses interact in the atmosphere.
	Use computational thinking to describe how patterns in data support explanations of the changes in weather that occur where warm and cold air masses interact.
		Developing and Using Models; Systems and System Models
		When to check for understanding: Students' responses on *Warm and Cold Water Interactions*, in their conversations with partners, and during whole-group conversations
		What to look/listen for:
		• How a warm air mass and a cold air mass interact along a front, particularly related to the resulting lift of the warm air over the cold air at this boundary.
		• How warm air that is pushed upward would end up cooling, which if there is water vapor in warm air, would cause it to condense, which then would cause clouds and precipitation to form.
		What to do: As students are working with their partners, you can walk around and listen in on their conversations and check their work on *Warm and Cold Water Interactions*. If students are struggling to find certain key ideas, you can try the following responses:
		• Revisit the demonstration by watching video taken during the demonstration. (See Advance preparation.) This will give students additional opportunities to look for things that they might not have noticed during the actual demonstration.
		• Use questions to guide them to think about ideas that they are struggling to figure out. Here are some examples:
		  ◦ What happens to air when it is warmed up?
		  ◦ What happens to air when it is cooled down?

Lesson	Lesson-Level Performance Expectation(s)	Assessment Guidance
		◦ What have we learned about the interactions between warm and cold air from previous lessons? ◦ What happens to warm, humid air when it is cooled? **Using Mathematics and Computational Thinking; Patterns** **When to check for understanding:** As students are working with their partners, listen in on their conversations and check their work in their notebooks and on *Relative Humidity Data*. **What to look/listen for:** Guidance for expected responses is embedded in the learning plan. **What to do:** If students are struggling to find certain key ideas, you can use questions to guide them to think about ideas that they are struggling to figure out. These are some examples: • What does it mean when air is at 50% relative humidity? • What about 100% relative humidity? How much water vapor can air hold when it is __°F? • Can air hold more water vapor when it is warmer or colder? • What happens to the water vapor in warm air when the air is cooled?
Lesson 17	Analyze data using maps of air pressure recorded over the country at different points in time and forecasts (temporal and spatial relationships) to identify patterns (the movement of low-pressure systems) and the relationship between this (patterns) and the location of fronts and precipitation. Construct an explanation that includes the qualitative relationships presented in a weather forecast among (1) the area of lowest air pressure and where it will move to, (2) the locations of the fronts, and (3) where precipitation will fall, using scientific ideas and principles to explain	**Analyzing and Interpreting Data; Patterns** **When to check for understanding:** Students record the patterns they notice on *Air Pressure Prediction and Map Analysis* at the start of the lesson and in their responses to the first two questions on *Explaining Patterns and Predictions in the Forecast*. Monitor students' analysis of the data in the first map they are assigned. Monitor their work on the first two questions on *Explaining Patterns and Predictions in the Forecast*, as this is the most effective time to step in to help break down what these questions are asking, if needed. **What to look for/listen for:** These patterns should include these ideas: • The low-pressure center moves from west to east over time. • The movement and location of warm and cold fronts appear to be connected to this low-pressure center. • Precipitation tends to fall along the line of the cold front and warm front and behind the low-pressure center. **What to do:** If students are struggling with determining which data to assign a particular color on their pressure maps, pair students up to work on producing the first map that they work on together. **Constructing Explanations; Patterns, Cause and Effect** **When to check for understanding:** Students develop an explanation in their response to question 3 on *Explaining Patterns and Predictions in the Forecast*. Collect these at the end of the period.

Lesson	Lesson-Level Performance Expectation(s)	Assessment Guidance
	what would be causing these three things to be connected to one another.	**What to look for/listen for:** • The use of old mechanisms in the explanation, such as: ◦ Air temperature tends to decrease the higher up you go. ◦ Sunlight absorbed at Earth's surface is the source of thermal energy that warms the air directly above it. ◦ Parcels of air that are less dense than the surrounding air rise, and those that more dense sink. ◦ Cooling, humid air can cause water vapor in it to condense and/or solidify out of it. ◦ Rising air pushes up on water droplets or crystals, holding these aloft until they grow heavy enough to fall. • The use of new mechanisms in the explanation, such as: ◦ The area of lowest air pressure corresponds to where air is rising. ◦ The area of rising air could partially be explained by the locations where cold and warm air masses are moving into each other (the front lines) and/or the area of rising air could be partially explained by thermal energy transferring from the surface to the air right above it. ◦ The areas where air is rising (the low-pressure center and along the front lines) would produce precipitation if the warmer air that is lifted is humid and cool enough. **What to do:** If some students are struggling to articulate connections to more than a couple of these mechanisms, strategically assign those students to small groups in the next lesson that will have at least one member who references multiple mechanisms in their response. Listen in on those groups. Pose questions such as this: *Did you hear anything from Student X's explanation that you didn't have but think you might want to include?* For any students who are missing at least one old or new mechanism, leave written feedback on question 3 of *Explaining Patterns and Predictions in the Forecast* in the form of only one question which is targeted at asking them to consider whether one additional old mechanism or new mechanism helps explain this phenomenon and why. Vary which mechanism you ask different students to consider further.
Lesson 18	Compare and critique two arguments on the same topic and analyze whether they emphasize similar or different mechanisms (cause) in their explanations of the patterns in how the weather changed (effect) during the Jan. 19, 2019 storm.	**Argue from Evidence; Patterns, Cause and Effect** **When to check for understanding:** Listen in on small-group discussions, particularly with students you identified as struggling with their own written explanations. **Look for these ideas:** • Identifying related mechanisms others mention with check marks on their *Comparing Ideas Used Between Explanations* • Referring to these mechanisms in their own explanations • Identification and discussion of new mechanisms, including: ◦ air masses movement

Lesson	Lesson-Level Performance Expectation(s)	Assessment Guidance
	Apply scientific ideas and related evidence to evaluate whether the new mechanisms (air mass movement, interaction of fronts, and low pressure areas [causse]) that were used in an explanation of one large-scale storm are also needed to explain the patterns in the how the weather will change [effect] in the predictions made for three other storms occurring at a different time of year. Ask questions about typical patterns and causes related to these in how air masses move across the country and how where a place is located (near the coast or inland, high elevation or low, in the northeast vs. southwest) affects the amount and type of precipitation that the place receives over more than a few years.	◦ air masses interacting with other air masses along boundaries where they meet (fronts) ◦ lift (due to differences in density or pressure) occurring in some air masses and/or along fronts between air masses, which causes (increased) precipitation. **What to do:** Listen in on small-group discussions involving students that struggled to articulate connections to any new or old science ideas in explanations you collected and reviewed before this lesson. Pose questions such as: *Did you hear anything from Student X's explanation that you didn't have but think you might want to include?* **Constructing Explanations; Patterns, Cause and Effect** **When to check for understanding:** Students record their noticings in their Notice and Wonder chart to align with particular science ideas they provide evidence for after watching the video. **What to look for:** Recording *noticings* that align to each of the three rows of their chart: • air mass movement: ◦ The precipitation, low pressure center, and front lines all move together. ◦ The path they move tends to be toward the east. • interaction of fronts: ◦ Symbols indicate a front that is a line associated with each storm. ◦ There are two such lines in storm 1. • low pressure areas producing clouds and precipitation: ◦ There is a circle with an "L" in it associated with each storm. ◦ Precipitation is falling around the "L". ◦ Precipitation is falling in front of and behind the front lines. **What to do:** Walk around to see what noticings students are recording before asking the whole class to report out. Here is a time to identify and recruit participation from students who don't normally share or who are now making connections but have were struggling earlier. **Asking Questions; Patterns, Cause and Effect** **When to check for understanding:** Collect questions at the end of this lesson that students have recorded on sticky notes but did not post. You will also have a record of the questions they did post on the Driving Question Board (DQB). All of these sticky notes will have students' initials on the back. **What to look for/listen for:** Look for questions that get at if, how, or why certain weather trends and patterns hold over a long period (e.g., Are they typical across the year or from one year to the next?). These include questions about the following ideas: a) typical paths of storms or air masses, b) typical amounts of precipitation in different places, c) typical types of precipitation in different places.

Lesson	Lesson-Level Performance Expectation(s)	Assessment Guidance
		What to do: If you don't see a lot of these sorts of questions after students add to the DQB, you could revisit the DQB again at the start of the next lesson and ask students to brainstorm places in our country that they think might get more or less water than where we live and develop a short explanation why. Then have them share their ideas with a partner and write new questions based on what this led them to wonder.
Lesson 19	Use visualized precipitation data from a large data set to identify spatial patterns in the direction of air masses' movement that influences long-term weather patterns in predictable ways.	**Analyze and Interpret Data; Patterns** **When to check for understanding:** During the visualization discussions, particularly at the end of the lesson. **What to look/listen for:** Students to identify (1) the pattern of air movement at different latitudes, but specifically from west to east across the U.S., (2) cold air from the north or northwest moving to the east and colliding with warm air from the south/southeast (i.e., Gulf of Mexico), (3) places with a lot of precipitation as likely locations where warm and cold air masses interact or collide, and (4) predictable wind patterns, bringing cold or warm air, as one way for us to predict a location's long-term precipitation pattern. **What to do:** If students struggle with identifying the ideas above, revisit the first visualization of one-week precipitation rates in the United States. Pause the visualization at a moment with a large storm. Label the flow of a cold air mass from the north and a warm air mass from the south that resulted in the storm. Unpause the simulation and pause again at a second storm. Have your students describe how they would label the cold air mass (from the north or northwest) and the warm air mass (from the south or southwest) that resulted in the storm. If students are getting confused due to the curving of the air, consider using *Why do air and water spin in different directions on Earth?* as a resource for additional information to support a discussion about air flow.
Lesson 20	Integrate text and media to gather additional information to clarify how ocean currents that circulate cooler and warmer waters to different latitudes affect air mass temperature and humidity. Use sea surface temperature maps and tabular precipitation data to articulate a spatial pattern connecting offshore ocean temperatures to precipitation on land.	**Obtaining, Evaluating, and Communicating Information; Cause and Effect** **When to check for understanding:** Exit ticket at the end of day 1 and Consensus Discussion on day 2. **What to look/listen for:** Students to (1) reference central ideas from the text to support their conclusions, (2) use data from the text, such as precipitation amounts at different coastal cities to support their conclusions, (3) reference at least 2 or more sources of data—text, maps, or visualizations—to support their conclusions, (4) construct a plausible causal chain to explain why locations near that coast get more or less precipitation that includes the concepts of (a) ocean currents circulating warmer and cooler water to different locations, (b) more evaporation happening over warmer waters, and (c) therefore warmer and more humid air above warmer waters leading to more likely precipitation, (5) the use of words such as "likely", "may", "probably", and "could" to indicate this warming water and more humid air does not always lead to precipitation.

Lesson	Lesson-Level Performance Expectation(s)	Assessment Guidance
Lesson 21	Analyze and interpret data to identify patterns in the data to provide evidence of the relationship between elevation (cause), air temperature, and precipitation (effect).	**What to do:** Review students' exit tickets from day 1 to prepare for the Consensus Discussion on day 2. During the Consensus Discussion on day 2, focus students on integrating or corroborating their evidence sources to support their ideas. Near the Air Mass Map, draw a causal chain diagram to help students articulate how warming of the ocean, ocean currents, evaporation, and air mass movement cause precipitation events. **Data Analysis and Interpretation; Patterns** **When to check for understanding:** During the Consensus Discussion on day 2. **What to look/listen for:** Students to (1) connect the ocean temperature visualization on day 1 with the precipitation for coastal cities on day 2, (2) conclude that warmer ocean water offshore is related to more precipitation on land, (3) identify a general spatial pattern that coastal cities get more precipitation due to their proximity to the ocean and—unless the ocean water is unusually cold given its latitude—due to the evaporation of the coastal water. **What to do:** Project the ocean temperature visualization again, pausing when North America is clearly visible (at 00:18). Have students locate the cities with higher and lower precipitation from the reading and make connections between the temperature of ocean water and rain. Then review the reading about the Northern Pacific Current and how it impacts the northwest, bringing precipitation despite the cooler waters. **Analyze and Interpret Data; Patterns** **When to check for understanding:** At the end of Day 1, review students' "What I see" (WIS) and "What it means" (WIM) statements from *Predicting and Explaining the Effects of Opposing Forces* as well as the group models on *Weather Log* at the end of Day 1. At the end of Day 2, review students' Progress Trackers. **What to look for/listen for:** Look for these observed patterns: • Pacific Northwest: Stampede Pass has the highest elevation, coldest temperature, and most precipitation. There is much less precipitation east of the mountains and further inland where it is warmer and lower in elevation. • Gulf Coast: Precipitation slowly decreases, temperature decreases, and elevation slowly increases moving inland from the Gulf of Mexico. Look for these ideas in students' WIM statements and group models: • As air passes over tall mountains (e.g., Stampede Pass), it gets pushed upward and cools down, causing water vapor to condense and form precipitation. Once the air passes over the mountains, there is little water vapor left in the air mass, causing less precipitation. The air can fall back downward along the mountains as elevation decreases.

Lesson	Lesson-Level Performance Expectation(s)	Assessment Guidance
		• As a warm, wet air mass passes over a relatively flat landform (e.g., New Orleans to Chattanooga), it can move a long distance, so there can be a lot of precipitation over the entire pathway. • Air can pick up some moisture as it moves over land (e.g., Wenatchee to Spokane). **What to do:** If students have difficulty identifying key patterns from the data, project the profile view as a class and use visual representations to illustrate patterns of precipitation and air temperature (e.g., draw lots of rain and an image of it being very cold over Stampede Pass). If students' ideas are not accurate at the end of Day 1, have students compare their models with other groups prior to the whole-group Scientists Circle discussion on Day 2. This will allow them to get new ideas from their peers. Pay attention to students' ideas during the Scientists Circle. If students' explanations are still incomplete, project an example of a group model that is complete. Encourage students to try to use this example model to explain what is happening. To check to see if students have made progress in their thinking, review students' Progress Trackers at the end of Day 2.
Lesson 22	Use graphical displays of global climate datasets (e.g., sunlight, ocean temperature, water and wind movement) to identify relationships between the transfer of energy and the cycling of matter that explain the location and climate of rainforests around the globe.	**Analyzing and Interpreting Data; Constructing Explanations; Matter and Energy; Patterns** **When to check for understanding:** On *Rainforest Climate Assessment Tasks*. **What to look/listen for:** See *Key for Rainforest Climate Assessment Tasks.* **What to do:** If students struggle to apply their understanding, have them pause, reexamine the models they created in previous lessons, and then resume the assessment. They should apply the ideas they noticed in the models when they continue. If students struggle with interpreting the maps, work with them to orient what the maps are showing. For example, on question 2, you can ask students to draw the locations of the rainforests on the maps of average ocean temperature and prevailing winds.

Name: ______________________ Date: ______________________

LESSON 1: TEACHER REFERENCE

Pre-Assessment Reference for Students' Initial Models

As a pre-assessment, don't expect the students' models to have all the elements identified below. This unit will help students to (1) develop a causal model that links all the elements together and (2) develop additional mechanisms (phase changes driven by thermal energy transfer, density changes in air, lift and convection due to temperature differences). Ideas that are less likely to appear in students' initial models are shown *in italics and also marked with this symbol**.

- **Multiple causal mechanisms and interactions**
  - Clouds are present overhead as the hail falls (to account for where the hail and rain precipitate from).
  - Temperature differences must occur in different places in the system (to account for why some of the water falling is in liquid form and some is in solid form).
  - Horizontal winds occur at the Earth's surface (to account for observed gusts accompanying the precipitation event).
  - Horizontal winds higher up (to account for the movement of clouds into and out of the places where the hail falls).
  - ** A colder region is located within a cloud than below the cloud (to account for why the cloud is located where it is).*
  - ** Upward movement of air is occurring under and/or through the cloud (to account for what is keeping water droplets and crystals in the cloud suspended in the air after they condense and before they precipitate out).*
- **Identification of distance and scale**
  - **The approximate height and/or width of clouds is indicated.*
  - ** The approximate distance the clouds moved over the course of an hour is indicated.*
- **Matter at the particle level**
  - Some water particles and non-water particles are in the air as a gas.
  - Gas particles are spread far apart compared to water particles in a liquid or a solid (a piece of ice or in a raindrop), which are packed close together.
  - ** Models may also include phase changes of water at the particle level—showing flow of matter (e.g., water molecules going into the air to represent evaporation), students are unlikely to show this as being caused by corresponding thermal energy going into or out that part of the system.*
- **Energy and/or energy flow in the system**
  - Parts of the system that are at different temperatures have different amounts of particle motion in the matter located there (e.g., particles are moving slower where there are lower temperatures and particles are moving faster where there are higher temperatures).
  - Sunlight is reaching Earth's surface before the precipitation falls.
  - ** That surface is absorbing some of the energy from the light that reaches it; the energy it absorbs is converted to increased thermal energy of the surface.*
  - ** Energy is transferring in the system through conduction (collisions between neighboring particles) at the Earth's surface.*
  - ** Energy is transferring in the system through conduction (collisions between neighboring particles) between air in the cloud (or air rising under the cloud) and the surrounding air.*

Name: ______________________ Date: ______________

Explaining the Movement of Air in a Hailstorm Cloud

QUESTION 1

This is an image of a cloud with data from Salem, Oregon (OR), during the summer at around 4 p.m.

A. The date and time of day

B. Data of the temperature at the ground and 4 feet above the ground for that day in Salem

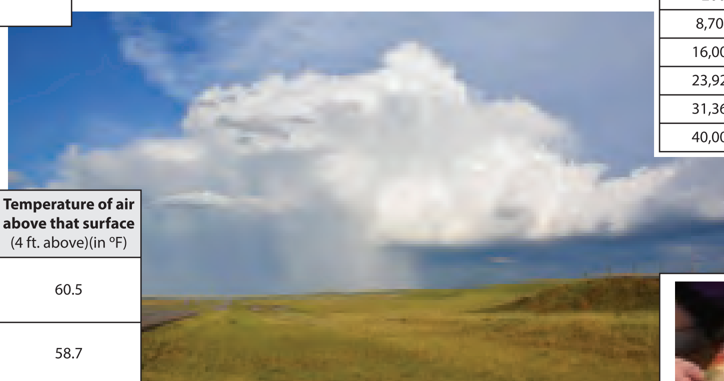
C. Data from a weather balloon

D. An image of a helium balloon—remember the observational data you collected.

Use the data below and what you know about air movement to answer the following questions.

A

Salem on July 11, 2018
Time of Day: 4 p.m.



0.48 Seconds

B

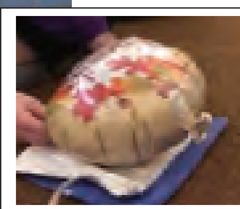
Data source: Describe the surface	Temperature of that surface (in °F)	Temperature of air above that surface (4 ft. above)(in °F)
Blacktop parking lot in the sun	64.0	60.5
Blacktop parking lot in the shade	61.5	58.7
Sidewalk in the sun	60.3	57.2
Sidewalk in the shade	59.2	57.0
Clearing in the forest (brown)	62.7	60.7

C

Salem, OR, July 11, 2018

Height (ft)	Air Temperature (°F)
200	47.8
8,704	39.4
16,000	30.8
23,928	14.7
31,365	–0.7
40,000	–20.8

D



When a Helium balloon was heated it expanded and rose up, floated in the air for a while, and then sunk back down.

Part 1. Make a claim that answers the question, "What caused this upward movement of air in the cloud?"

What evidence from the data sources above supports your claim?

How does this evidence support your claim about what caused the upward movement of air? Use ideas about energy transfer and particle density in your explanation.

Part 2. Make a claim that answers the question, "Why does this type of cloud motion tend to happen more on sunny days?"

What evidence from the data above supports your claim?

How does this evidence support your claim about what causes cloud motion on sunny days?

Part 3. Make a claim that answers the question, "Why did the rising air in the cloud eventually stop rising (or start falling)?"

What evidence from the data above supports your claim?

How does this evidence support your claim about what caused the rising air to stop rising? Use ideas about energy transfer and particle density in your explanation.

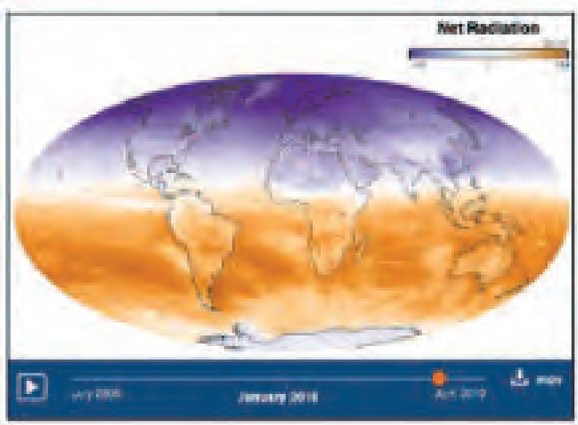
QUESTION 2

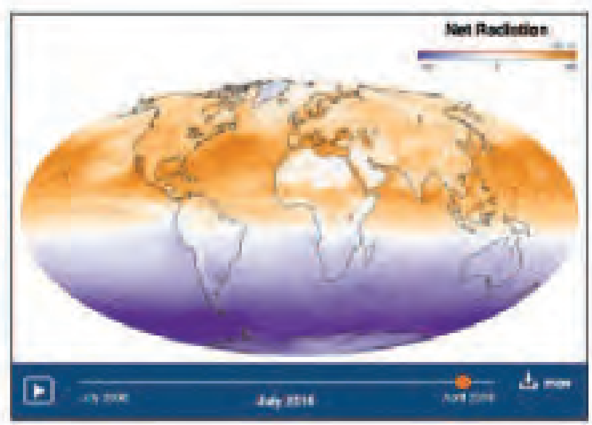
Big tall clouds that produce hail rarely occur in January in the Northern Hemisphere. Use the radiation and land surface temperature data from NASA to support the claim:

Hailstorms tend to occur more in the summer than in the winter in the Northern Hemisphere.

Net Radiation Data - January 2018 and July 2018

Net radiation = amount of energy from sunlight that is absorbed by the surface





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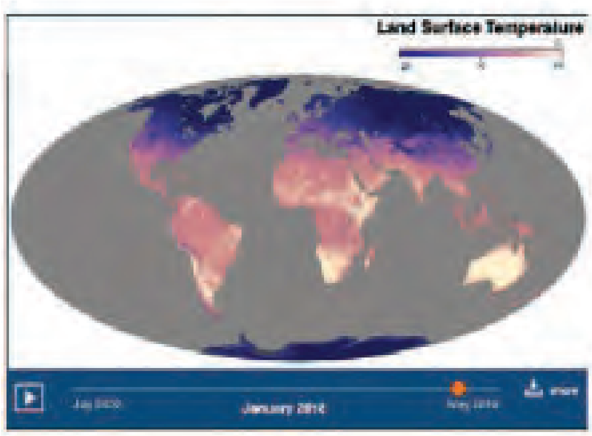
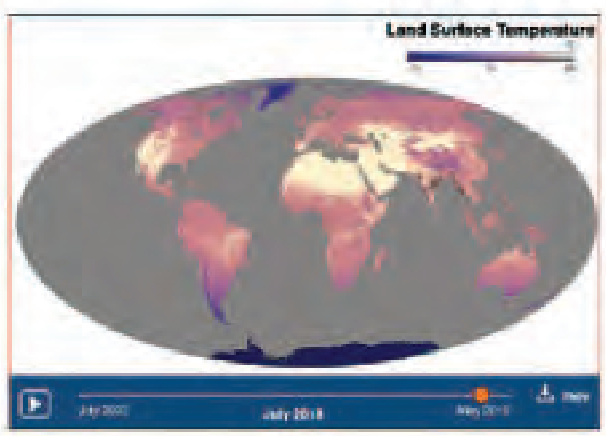
Land Surface Temperature Data - January 2018 and July 2018





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What evidence from the data above supports the claim?

How does this evidence support the claim?

Explaining the Movement of Air in a Hailstorm Cloud - Key

QUESTION 1

This is an image of a cloud with data from Salem, Oregon (OR), during the summer at around 4 p.m.

A. The date and time of day

B. Data of the temperature at the ground and 4 feet above the ground for that day in Salem

C. Data from a weather balloon

D. An image of a helium balloon—remember the observational data you collected.

Use the data below and what you know about air movement to answer the following questions.

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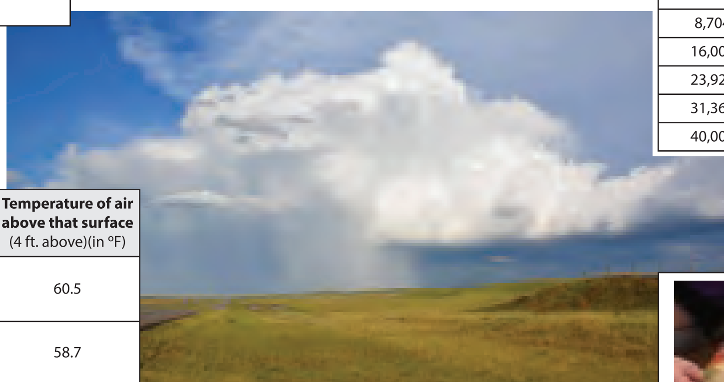
Salem on July 11, 2018
Time of Day: 4 p.m.



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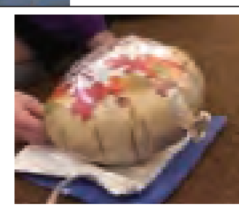

When a Helium balloon was heated it expanded and rose up, floated in the air for a while, and then sunk back down.

Part 1. Make a claim that answers the question, "What caused this upward movement of air in the cloud?"

- *The warm air from near the ground rises and causes the upward movement of air.*

What evidence from the data sources above supports your claim?

- *The image/video of the air moving upward.*
- *The hot air in the balloon rising.*
- *Air closer to the ground is warmer than air farther from the ground.*

How does this evidence support your claim about what caused the upward movement of air? Use ideas about energy transfer and particle density in your explanation.

- *The light from the sun transfers energy to the ground (heating it up).*
- *The ground transfers energy to the air right above it.*
- *Heating up the air causes the particles in it to become less dense (or less closely packed together or more spread out).*
- *Density differences cause the less dense air to rise up through the denser air around it.*

Part 2. Make a claim that answers the question, "Why does this type of cloud motion tend to happen more on sunny days?"

- This type of air movement happens more on sunny days because the air right above the ground gets warmed up more by the Sun on those days.

What evidence from the data above supports your claim?

- The parking lot or sidewalk in the sun is warmer than the parking lot or sidewalk in the shade at ground level and above the ground.
- The cloud movement in the video occurred on a summer day in the afternoon.

How does this evidence support your claim about what causes cloud motion on sunny days?

- The temperature of the air right above the ground depends on the temperature of the ground below it.
- The Sun's radiation transfers energy to the ground, which in turn transfers energy to the air right above it. For the air to be warm enough to become less dense and move upward, it needs sufficient energy from the Sun to cause it to start moving.

Part 3. Make a claim that answers the question, "Why did the rising air in the cloud eventually stop rising (or start falling)?"

- The air stopped rising because it was the same density as the surrounding air - or - The air stopped rising because it wasn't warmer than the surrounding air anymore.
- It started falling when it became cooler than the surrounding air.

What evidence from the data above supports your claim?

- The air higher and higher above the ground gets cooler and cooler.

How does this evidence support your claim about what causes the rising air to stop rising? Use ideas about energy transfer and particle density in your explanation.

- Eventually, the warm air that rose upward transfers its energy to the cooler surrounding air.
- Cooling that air that rose causes the particles in it to become more dense (or more closely packed together or less spread out).
- When that air that rose becomes as dense as the surrounding air, it stops rising.
- If that air becomes even cooler than the surrounding air, it sinks.

QUESTION 2

Big tall clouds that produce hail rarely occur in January in the Northern Hemisphere. Use the radiation and land surface temperature data from NASA to support the claim:

Hailstorms tend to occur more in the summer than in the winter in the Northern Hemisphere.

Net Radiation Data -January 2018 and July 2018

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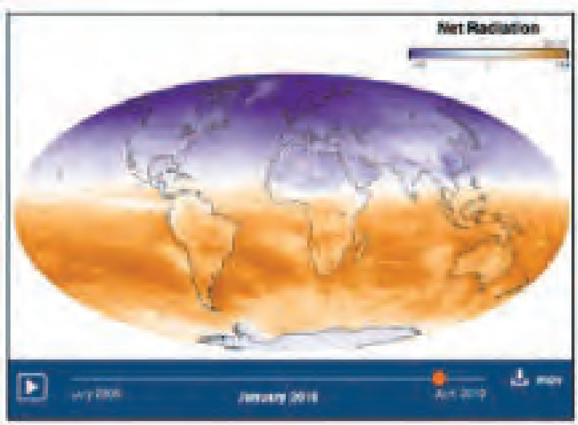

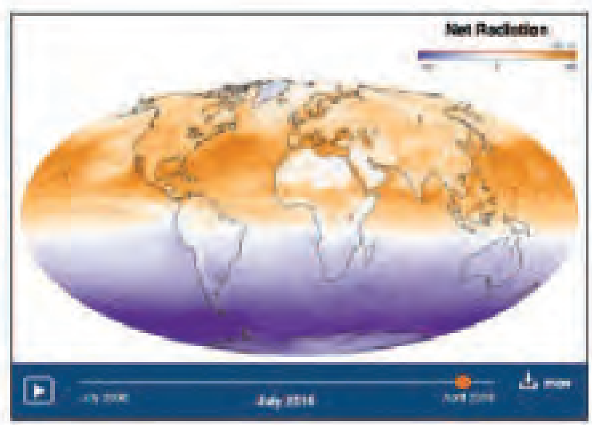

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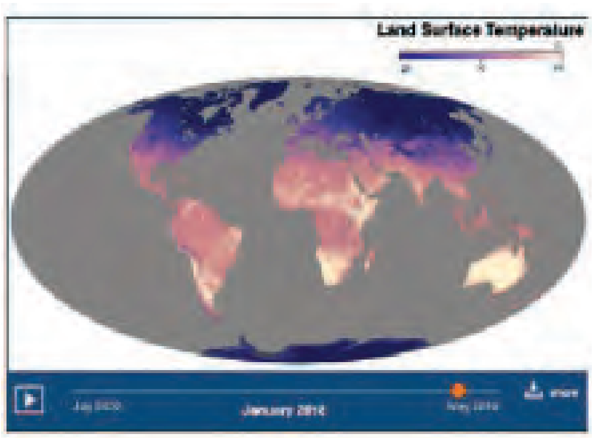
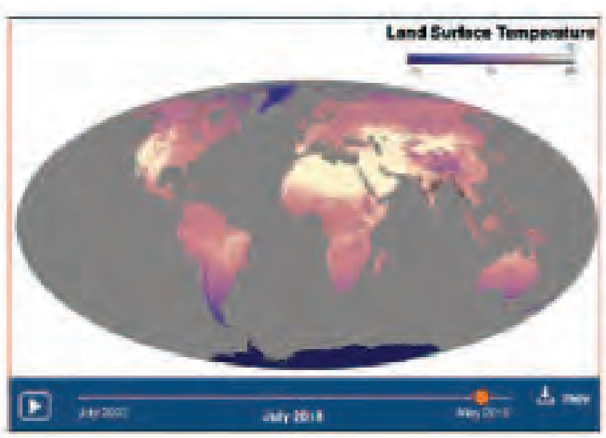
Land Surface Temperature Data -January 2018 and July 2018





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What evidence from the data above supports the claim?

- In January 2018 the net radiation in the Northern Hemisphere was around -100 W/m2, and in July 2018 the net radiation was around +100 W/m2.
- In January 2018 the land surface temperature in the Northern Hemisphere was between -25°C and 30°C, and in July 2018 the land surface temperature was between 25°C and 45°C.

How does this evidence support the claim?

- In the winter in the Northern Hemisphere, there is less sunlight absorbed (less net radiation) at the surface (lower land surface temperature) than in the summer.
- In the winter, the surface doesn't get as warm as it does in other times of year, and therefore it can't transfer as much thermal energy to the air right above it.
- Hail clouds need to grow really tall, so the air has to go really high. Without enough thermal energy, air does not get warm enough to rise and create taller clouds.

Reference: Peer Feedback Guidelines
Teacher Instructions

There will be times when helping students to give each other feedback will be very valuable for their three-dimensional learning and for learning to give and receive feedback. We suggest that peer review happen at least once, but preferably two times, per unit. This document provides options for how to support this in your classroom. It also includes student materials to support giving and receiving feedback, along with self-assessment rubrics with which students can reflect on their experience with the process.

When is a good time to facilitate peer review?

Peer feedback is most useful when complex and diverse ideas are visible in student work and not all work is the same. Student models or explanations are good opportunities to use a peer feedback protocol. They do not need to be final pieces of student work; rather, peer feedback will be more valuable to students if they have time to revise their work after receiving the feedback. It should be a formative, not summative, type of assessment. It is also necessary for students to have experience with past investigations, observations, and activities so they can use these experiences as evidence for their feedback.

What classroom structures can I use for peer review?

Below are three examples of ways to organize peer review in your classroom. You may choose to use all of them as your time or material constraints allow, or you may choose to always use the same structure so your students get familiar with it and better at it over time.

Sticky Note Peer Review: In this protocol—shared on *Tools for Ambitious Science Teaching*—students use sticky notes to leave questions and comments on posted student work. Time is built in for students to respond to the feedback. Use the self-assessment rubrics in this document at the end of the class period to have students reflect on their experience in this feedback session.

Peer Review with Unit Rubrics: Each unit—and the curriculum overall—has Science and Engineering Practice (SEP)-specific rubrics for teachers to assess student work. You can also use these as a way for students to assess each other's work and give feedback on how to improve. For example, in the first lesson set of Unit 8.2: *How can a sound make something move?* (Sound Waves Unit), students develop models of how objects vibrate to produce sound. We suggest having students use the rubric to give each other specific feedback. You can use this in a gallery walk context or have students exchange models.

Group Review: Ask students to form groups of four and bring their individual models or explanations (or other work) to their group. Review the peer feedback guidelines as a class, giving examples of productive and nonproductive feedback. Then, in pairs, have students provide feedback on the other two pieces of student work. They can use sticky notes or write directly on the work. Make sure to allow time after feedback is exchanged for students to individually revise their models and complete the self-assessment rubrics.

Giving Feedback to Peers

This tool was inspired by the Sticky Note Feedback resource originally developed by Ambitious Science Teaching. (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)

Feedback needs to be specific and actionable.

For feedback to be productive, it needs to be related to science ideas and provide suggestions for improvement.

Here are some examples of productive feedback:

- "Your model shows that the sound source changes position when it is hit. I think you should add detail about how the sound source moves back and forth after it is hit."
- "You said that the drum moves when it makes a sound, but the table doesn't move when it makes a sound. We disagree and suggest reviewing the observation data from the laser investigation."

Here are some examples of nonproductive feedback that does not help other students improve:

- "I like your drawing."
- "Your poster is really pretty."
- "I agree with everything you said."

How to Give Feedback

Your feedback should give ideas for specific changes or additions the person or group can make. Use the sentence starters below if you need help writing feedback.

- "The poster said ____________________. We disagree because ____________________. We think you should change ____________________."
- "I like how you ____________________. It would be more complete if you added ____________________."
- "We agree that ____________________. We think you should add more evidence from the ____________________ investigation."
- "We agree/disagree with your claim that ____________________. However, we do not think the ____________________ (evidence) you used matches your claim."

Receiving Feedback from Peers

The purpose of receiving feedback is to get ideas from your peers about things you might improve or change to make your work more clear, more accurate, or better supported by evidence. It can also help you to communicate your ideas more effectively to others.

When you receive feedback, you should take these steps:

- Read it (or listen to it) carefully. Ask someone else to help you understand it, if necessary.
- Decide if you agree or disagree with the feedback, and say why you agree or disagree.
- Revise your work to address the feedback as needed.

Self-Assessment: Giving Feedback

How well did you give feedback today?

Today, I . . .	YES	NO
Gave feedback that was **specific and about science ideas.**		
Shared a suggestion to help improve my peer's work.		
Used evidence from investigations, observations, activities, or readings to support the feedback or suggestions I gave.		

One thing I can do better the next time I give feedback is:

Self-Assessment: Receiving Feedback

How well did you receive feedback today?

Today, I . . .	YES	NO
Read the feedback I received carefully.		
Asked follow-up questions to better understand the feedback I received.		
Said or wrote why I agreed or disagreed with the feedback.		
Revised my work based on the feedback.		

What is one piece of feedback you received?

What did you add or change to address this feedback?

Name: ____________________ Date: ____________

LESSON 13: TEACHER REFERENCE 1

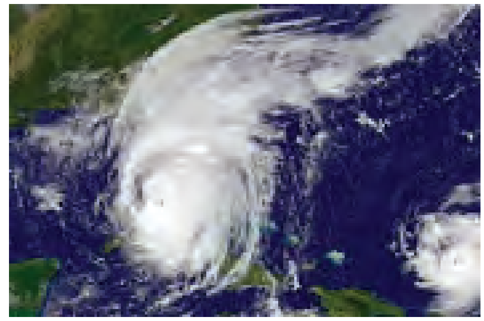
Gotta-Have-It Checklist

Instructions: Use your science notebook to make a checklist of the most important ideas you need to explain why clouds and storms form at some times but not others.

What our model needs to have to answer the question, "Why do some storms produce (really big) hail and others don't?" TREF KEY: Blue = ideas added at the beginning of L10 Purple = ideas added after working with the simulation in L10 Red = ideas added at the beginning of L13 *Green* = ideas added after the reading in L13	*Check off pieces of the model as you use them.*	
	used	*did not use*
1. Air near the ground is warmer than air higher up, which is cold.		
2. The ground is warmed by energy from the Sun.		
3. Air particles near the ground get warmed up when energy is transferred from the particles in the ground to the air through conduction.		
4. As heat is added, water molecules from a water source and moist soil also heat up. As more energy is added, some water molecules turn into a gas and become water vapor (evaporation).		
5. When the air particles (including water vapor) warm up, they move faster and spread out.		
6. Pockets of warm air rise because they are less dense, but as they rise, they begin to cool, slow down, and become more dense and sink.		
7. As water vapor rises in the atmosphere, it cools and will turn back into liquid. It condenses on dust particles or other things in the air and begins to form clouds.		
8. You can get bigger storms when there is a bigger difference between the ground temperature and the temperature up high.		
9. Higher humidity is correlated to bigger storms.		
10. There is air pushing up (lift) on water droplets and ice crystals that can keep them up in the air. Gravity is also exerting a force on those water droplets and ice crystals.		
11. When the lift force is greater than the force from gravity, the particles will be pushed upward, but when the force from gravity is greater than the lift force (or there is no lift force), the particles will fall downward.		
12. The bigger the temperature differences between the ground and air, the bigger this movement (convection).		
13. When you have big movement upward, a lot of water, dust, and other particles can be pushed up really high where it is cold, so the water droplets freeze and you get hail.		
14. The faster the updraft speed, the bigger the hail.		
15. Bigger updrafts mean the hail stays in the cloud longer so hail can get bigger as water droplets stick to it.		
16. There are two ideas for how hail gets big: • *It goes up and down on the convection of air and gets bigger and bigger.* • *It just keeps getting bigger as it goes up until it eventually falls out.*		

Name: ______________________ Date: ______________________

Hurricane Assessment Tasks

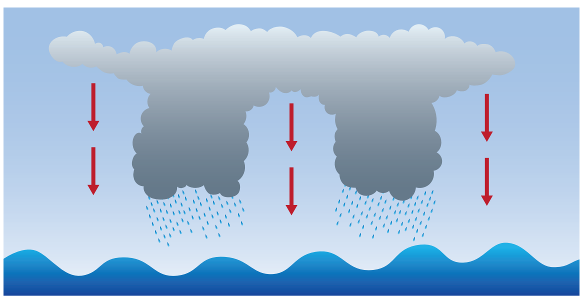

NASA/NOAA

Hurricane Irma in 2017 caused widespread destruction on some islands. Hurricane Irma formed over the Atlantic Ocean on August 30, 2017, moved toward and eventually over the United States over the next 2 weeks, and lasted until September 14, 2017.

All hurricanes form over water and usually occur between June 1 and November 30 each year. Hurricanes are powerful storms that bring heavy rain and winds.

Below is a model that shows initial hurricane formation. A hurricane forms around a series of cumulonimbus clouds that can grow up to 30,000 feet tall and hundreds of miles wide. The red arrows show general patterns in the movement of air in and around these clouds as the hurricane forms.

Initial formation of a hurricane:



1. Annotate the model above to show how the patterns of air movement lead to the formation of a hurricane. Include these in your annotation:
   - changes in the air temperature
   - differences in air density
   - the flow of energy

Hurricanes tend to develop in certain parts of the ocean. They also tend to happen only during a certain part of the year (June 1 to November 30), which is called hurricane season. The data below show how the water temperature and humidity in the air compare in these parts of the ocean during 2 times of the year.

Time of year	Water temperature	Humidity
March average (not hurricane season)	60°F	53%
July average (hurricane season)	82°F	95%

2. Hurricanes produce mass amounts of rain. Use your model and the data table above to explain how hurricanes can collect and hold so much water.

A. Hurricanes can **collect** so much water because . . .

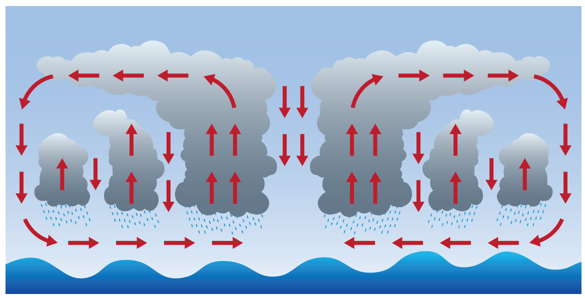
The data that support this are . . .

B. Hurricanes can **hold** so much water because . . .

The data that support this are . . .

3. CCN are missing from the model above. In oceans, there is a unique source of CCNs: sea salt. Sea salt can get kicked up into the air from ocean spray produced by surface winds and waves. Using this idea, explain how ocean spray could contribute to a hurricane's ability to hold water.

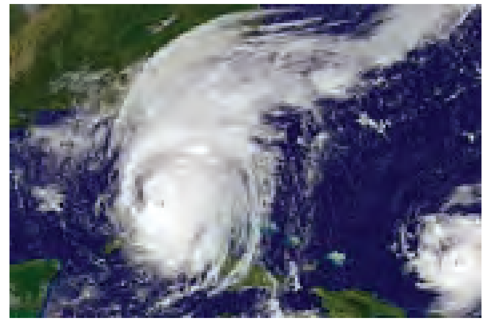
4. This model shows a hurricane that has been growing over the ocean for several days. The news typically reports on "hurricane-force winds." Hurricane-force winds are any winds that exceed 74 miles per hour. Use the model to explain why hurricanes produce such powerful surface winds.



LESSON 13: ANSWER KEY

Key for Hurricane Assessment Tasks

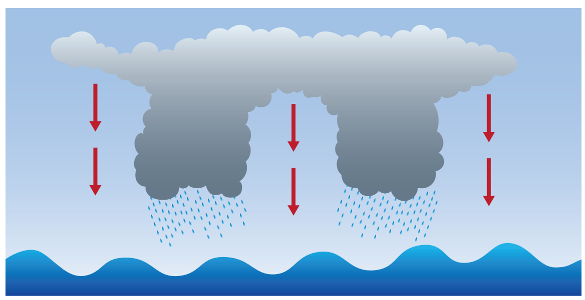
Hurricane Irma in 2017 caused widespread destruction on some islands. Hurricane Irma formed over the Atlantic Ocean on August 30, 2017, moved toward and eventually over the United States over the next 2 weeks, and lasted until September 14, 2017.


NASA/NOAA

All hurricanes form over water and usually occur between June 1 and November 30 each year. Hurricanes are powerful storms that bring heavy rain and winds.

Below is a model that shows initial hurricane formation. A hurricane forms around a series of cumulonimbus clouds that can grow up to 30,000 feet tall and hundreds of miles wide. The red arrows show general patterns in the movement of air in and around these clouds as the hurricane forms.

Initial formation of a hurricane:



1. Annotate the model above to show how the patterns of air movement lead to the formation of a hurricane. Include these in your annotation:

- changes in the air temperature
- differences in air density
- the flow of energy

+ Air temperature is warm at the surface and gets cooler farther up.

+ Warm air is less dense than the air around it and moves upward. Air that is more dense than the surrounding air sinks downward.

+ Energy is transferred from the water to the air above it; then as the air parcel rises, energy is transferred to the air around it; losing that energy causes some of the air to go back down toward the water as its density increases.

Hurricanes tend to develop in certain parts of the ocean. They also tend to happen only during a certain part of the year (June 1 to November 30), which is called hurricane season. The data below show how the water temperature and humidity in the air compare in these parts of the ocean during 2 times of the year.

Time of year	Water temperature	Humidity
March average (not hurricane season)	60°F	53%
July average (hurricane season)	82°F	95%

2. Hurricanes produce mass amounts of rain. Use your model and the data table above to explain how hurricanes can collect and hold so much water.

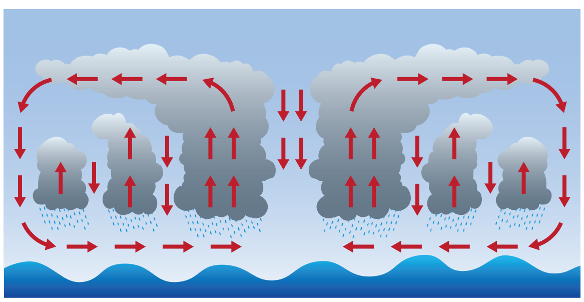
- Hurricanes can collect so much water because water changes from liquid to gas when the water is really warm (or there is a source of heat energy), so there is water vapor in the moving air.
- The data that support this are: when hurricanes form, the water is warm and the humidity is 95%, and when they don't form, the water is cool and the humidity is lower (53%).
- Hurricanes can hold so much water because the constantly moving air parcels push on the air above them, which contains water vapor and condensed water.
- The model shows this happening with arrows. It shows that the air keeps moving up and the cloud continues to form.
- Gravity is acting on the air particles and water vapor, but the push from moving air is stronger than gravity, so the water stays up there.

3. CCN are missing from the model above. In oceans, there is a unique source of CCN: sea salt. Sea salt can get kicked up into the air from ocean spray produced by surface winds and waves. Using this idea, explain how ocean spray could contribute to a hurricane's ability to hold water.

+ Water vapor condenses around CCN in the cloud.

+ The more CCN there are in the cloud, the more water vapor can condense.

4. This model shows a hurricane that has been growing over the ocean for several days. The news typically reports on "hurricane-force winds." Hurricane-force winds are any winds that exceed 74 miles per hour. Use the model to explain why hurricanes produce such powerful surface winds.



+ Hurricanes create winds because when the air parcels are moving up fast, they get replaced by cooler air where the energy is transferring from the water to the air.

+ This model shows there are multiple places in the growing storm where air parcels are moving up from the surface of the water and then being replaced by other air (which is what wind is).

Radar Map Series

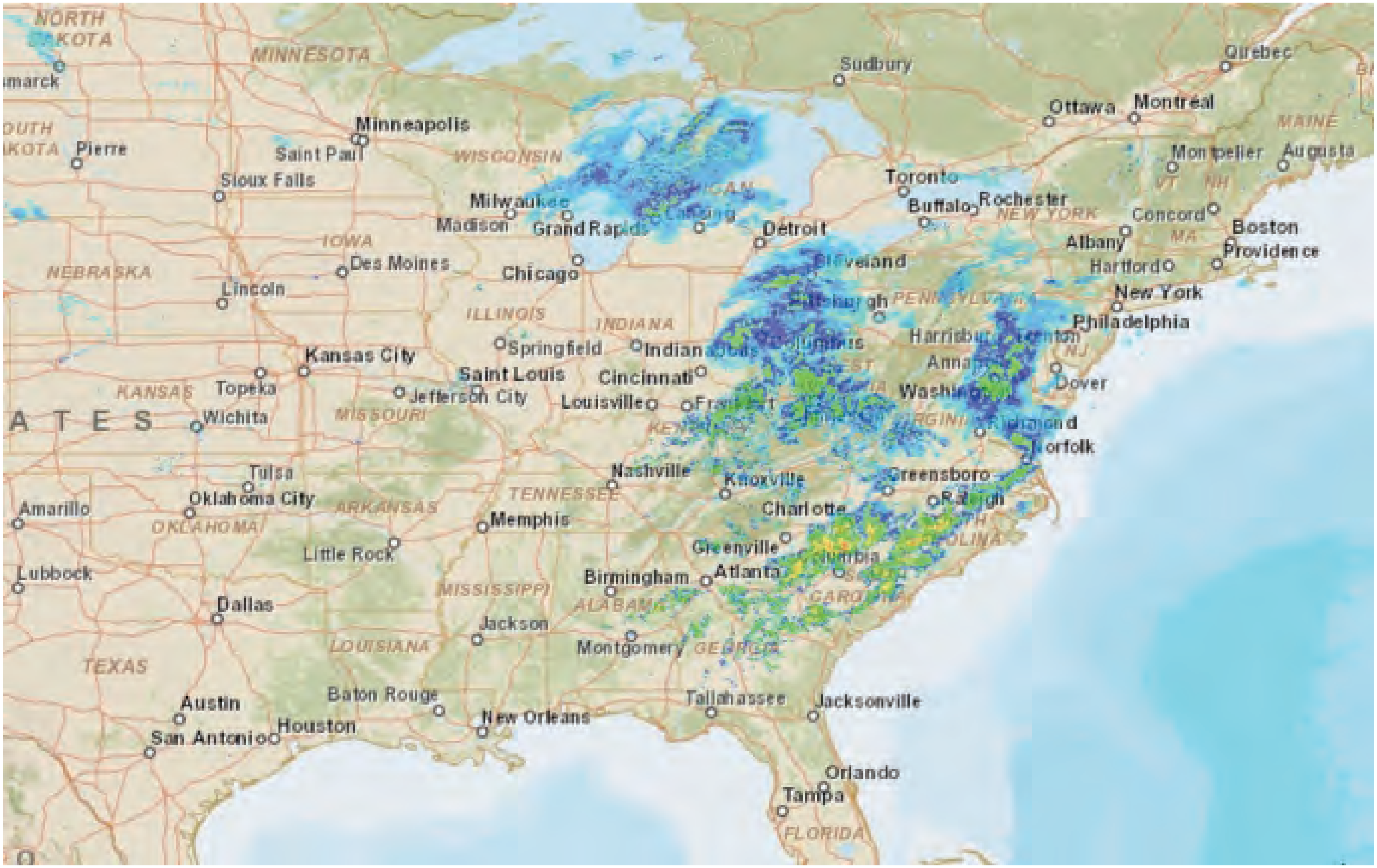
Time point 1

Radar, Thursday, January 17, 2019, 4:00 p.m.

Data Source: NOAA

Time point 2

Radar, Friday, January 18, 2019, 12:00 am



Data Source: NOAA

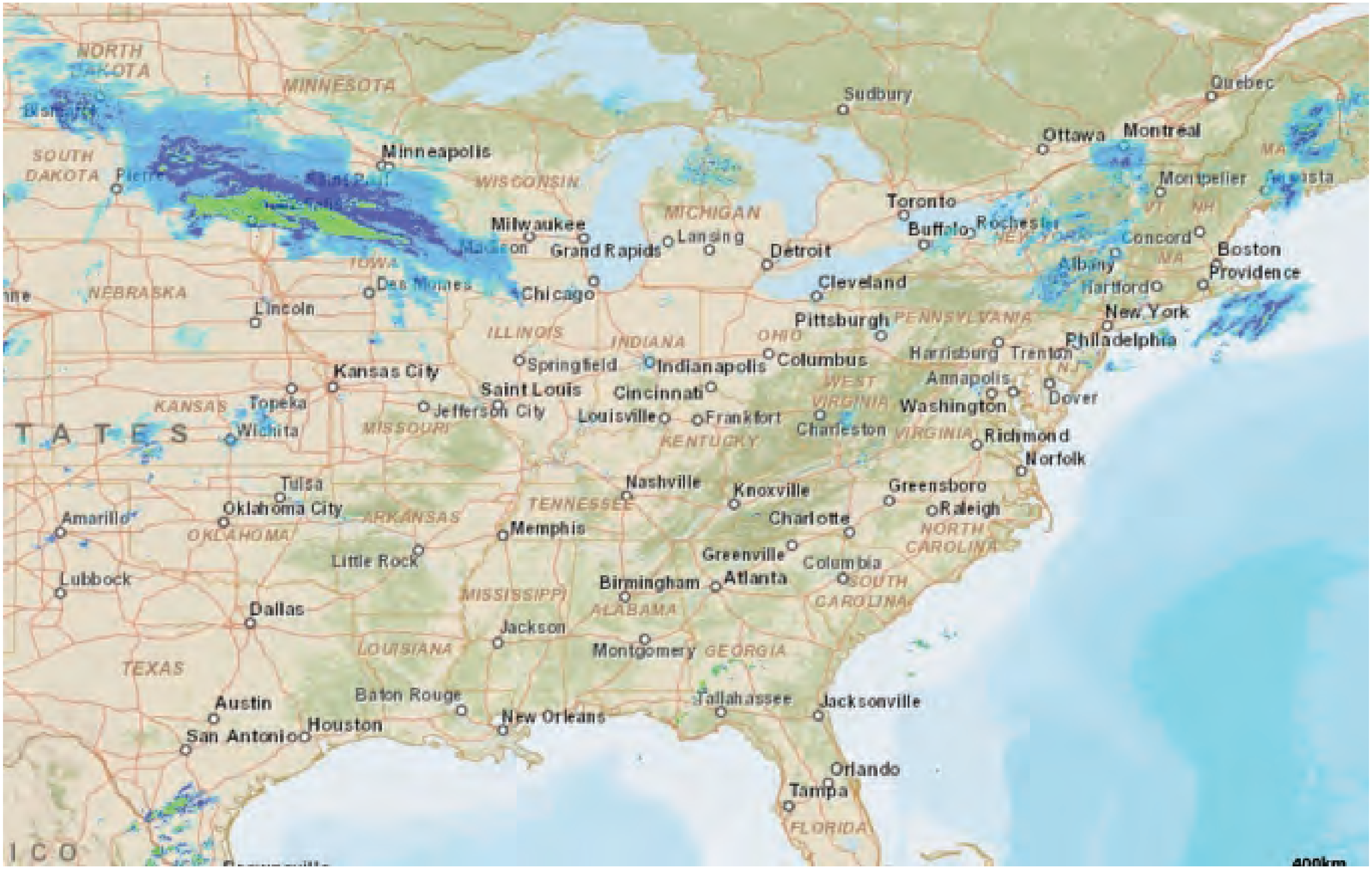
Time point 3

Radar, Friday, January 18, 2019, 8:00 am

Data Source: NOAA

Time point 4

Radar, Friday, January 18, 2019, 4:00 p.m.



Data Source: NOAA

Time point 5

Radar, Saturday, January 19, 2019, 12:00 a.m.

Data Source: NOAA

Time point 6

Radar, Saturday, January 19, 2019, 8:00 am

Data Source: NOAA

Time point 7

Radar, Saturday, January 19, 2019, 4:00 p.m.

Data Source: NOAA

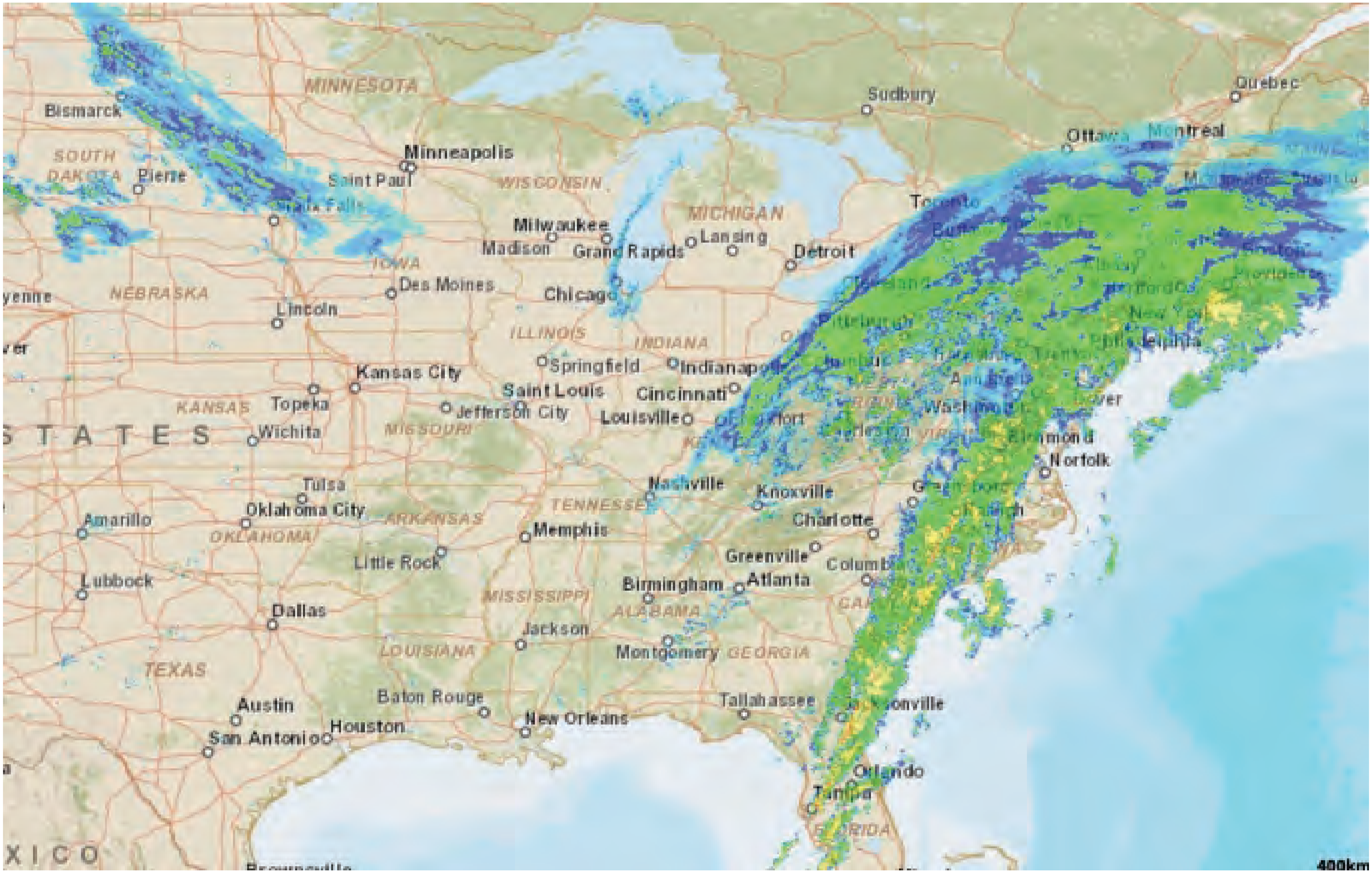
Time point 8

Radar, Sunday, January 20, 2019, 12:00 am

Data Source: NOAA

Time point 9

Radar, Sunday, January 20, 2019, 8:00 am



Data Source: NOAA

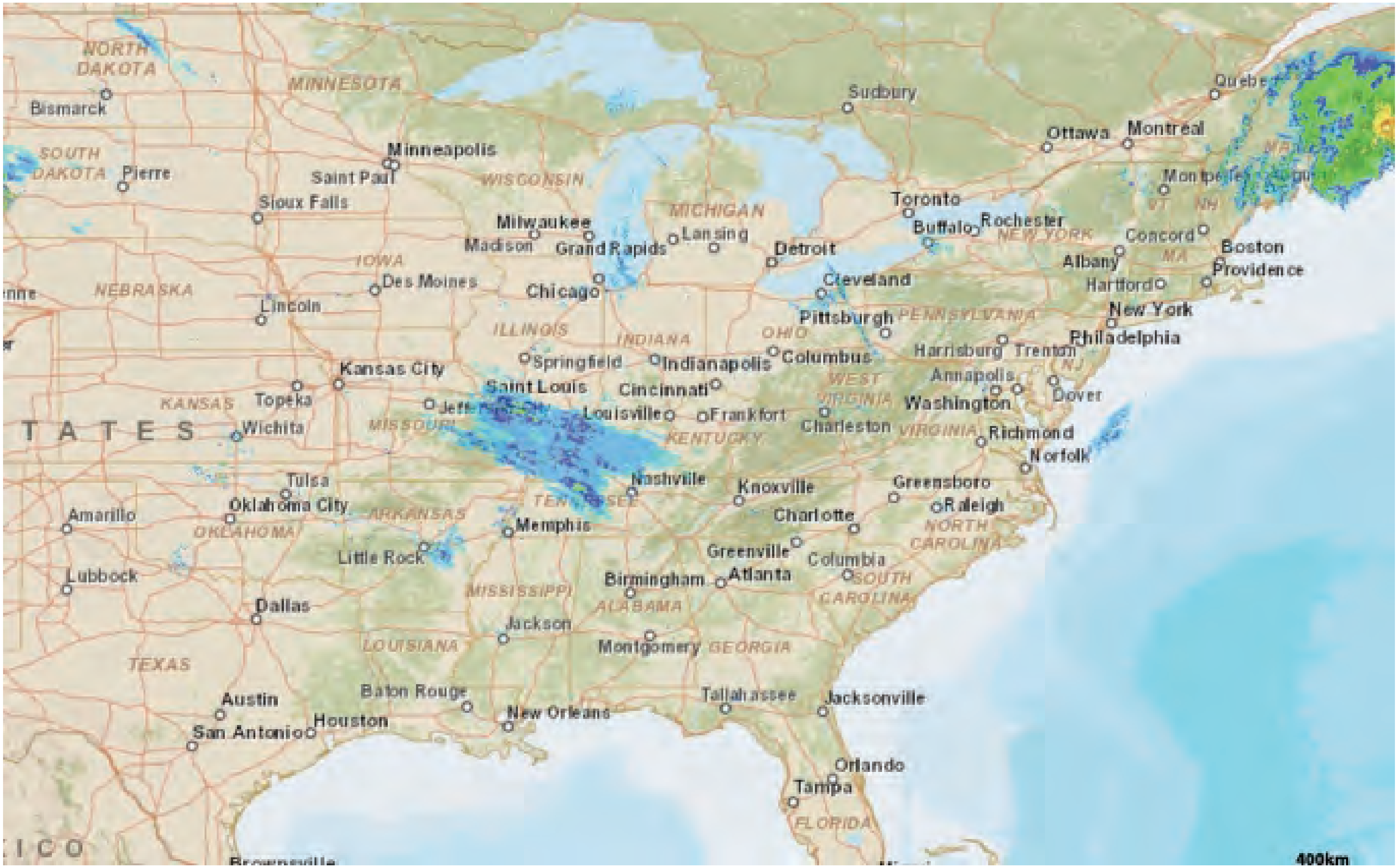
Time point 10

Radar, Sunday, January 20, 2019, 4:00 p.m.

Data Source: NOAA

Time point 11

Radar, Monday, January 21, 2019, 12:00 am



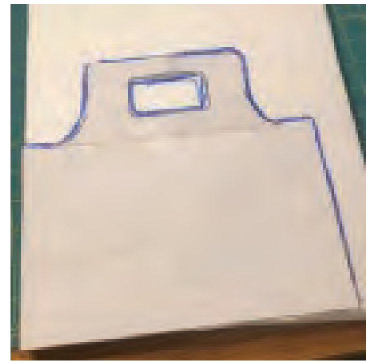
Data Source: NOAA

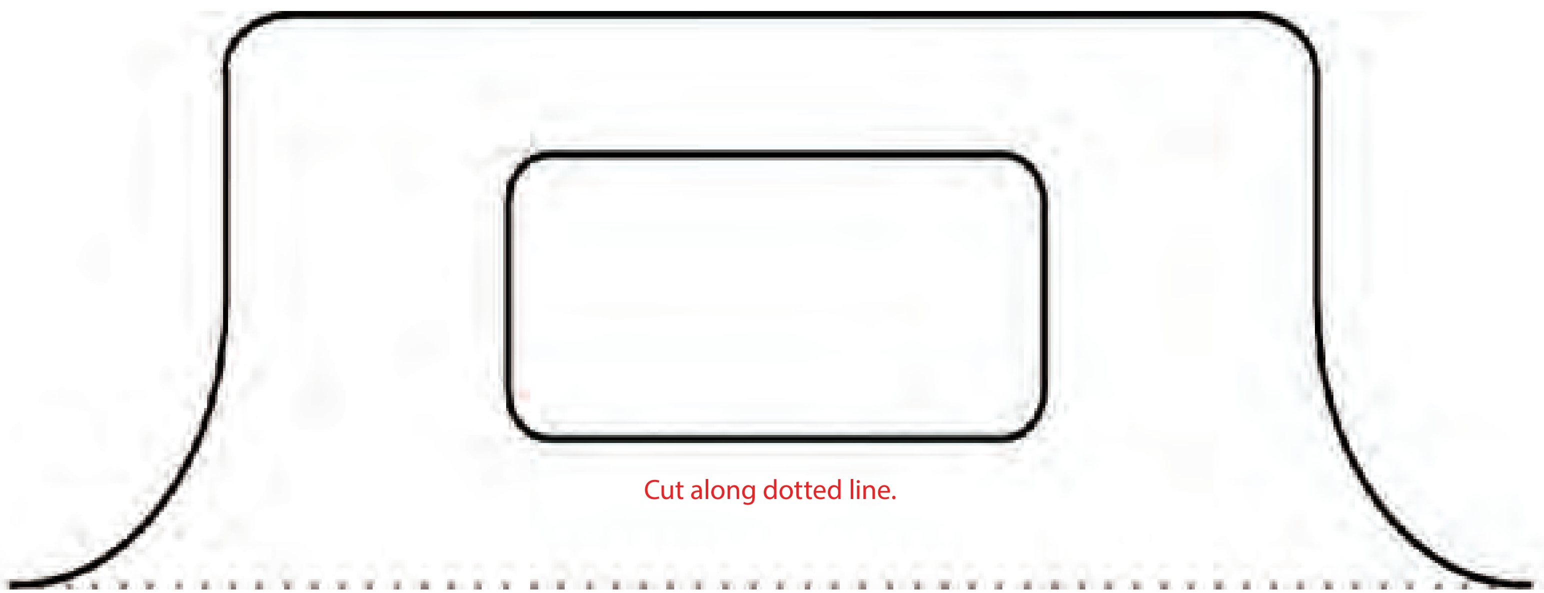
Template for the Foam Barrier

These directions will guide you in creating a foam barrier that is 16-20 mm thick. It will fit a 10-gallon aquarium that measures 10.5 inches wide externally and 11 inches wide internally. If your aquarium is wider than this, you will need to adjust the width of the foam barrier.

Directions

1. Cut along the dotted line on the top portion of the template.
2. Tape the top portion to the bottom portion of the template.
3. Cut along the solid lines, then place the template on a sheet of foam (8-10 mm thick).
4. Trace the template onto the foam.
5. Repeat the tracing process on a second sheet of foam.
6. Cut out the shape on both sheets of foam.
7. Place one foam cutout on top of the other and hot glue the two together.





Tape top portion of template here.

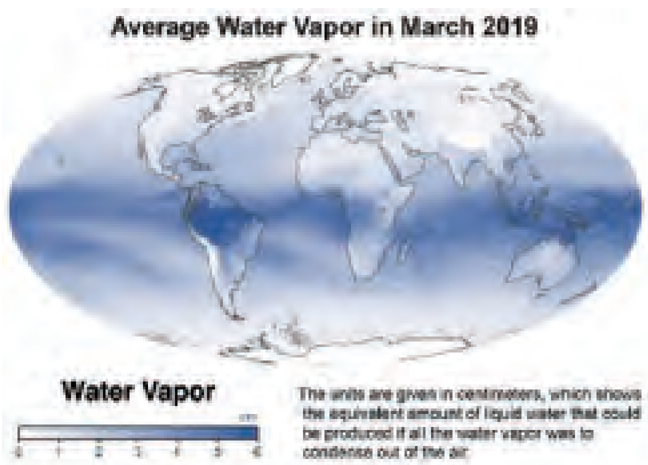
Name: ______________________ Date: ______________________

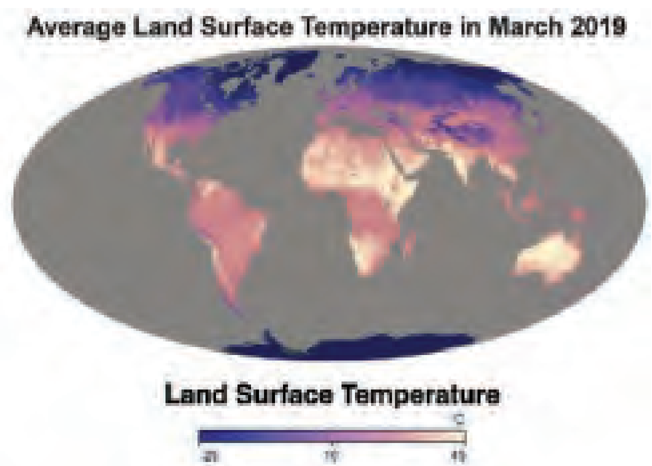
Rainforest Climate Assessment Tasks

Remember from your class discussion: Many species of the world live in rainforests due to the abundance of water year round and stable temperatures. South America is home to two kinds of rainforests—tropical rainforests with warmer average temperatures (70 to 85°F) and temperate rainforests with cooler average temperatures (45 to 55°F).

Answer the following questions on the following pages using the key ideas you and your class brainstormed regarding what might contribute to the location and climate of these rainforests.

Q1) Tropical and temperate rainforests are also found in other parts of the world. Where do you predict you would find other **tropical rainforests?** Use the first two maps to inform your prediction. Draw on the third map to show where you predict you would find other **tropical rainforests around the world, in addition to South America.**





Draw and label where you predict you would find other tropical rainforests around the world.

Explain why you predicted what you did:

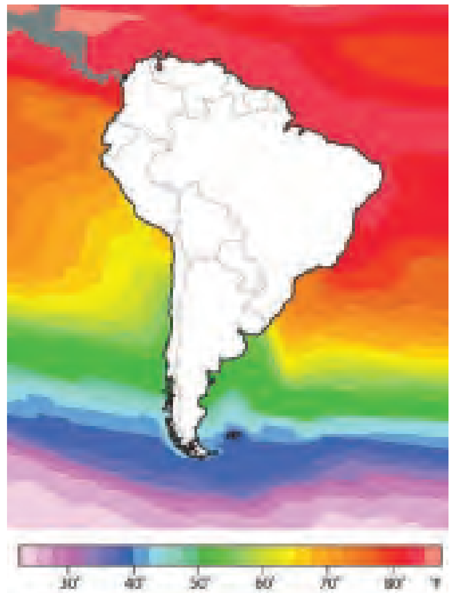
- What data did you use to inform your prediction?
- What science ideas about how rainfall is produced did you use to inform your prediction?

Q2) On the previous pages, you developed a prediction for where you would expect tropical rainforests to be located around the world. There are also temperate rainforests that have lower average temperatures. South America has both temperate and tropical forests in different parts of the continent, as shown in the first map below.

The second map shows the average temperature of the oceans around South America and the third map shows the prevailing winds over South America and the surrounding oceans. Use these maps and what you know about energy transfer to answer questions 2a-2c.

1. Location of tropical and temperate rainforests in South America

2. Average temperature of the oceans



3. Prevailing winds

2a. Which ocean(s) would have the most effect on the air temperature over the **tropical rainforest (the green area on map 1)**? Use ideas related to thermal energy and energy transfer in your explanation.

2b. Which ocean(s) would have the most effect on the air temperature over the **temperate rainforest (the purple area on map 1)**? Use ideas related to thermal energy and energy transfer in your explanation.

2c. Use the prevailing winds map to explain whether the prevailing winds entering both rainforests are relatively moist or dry. Why do you think this is the case?

Q3. The driest places in the world are also located in South America.

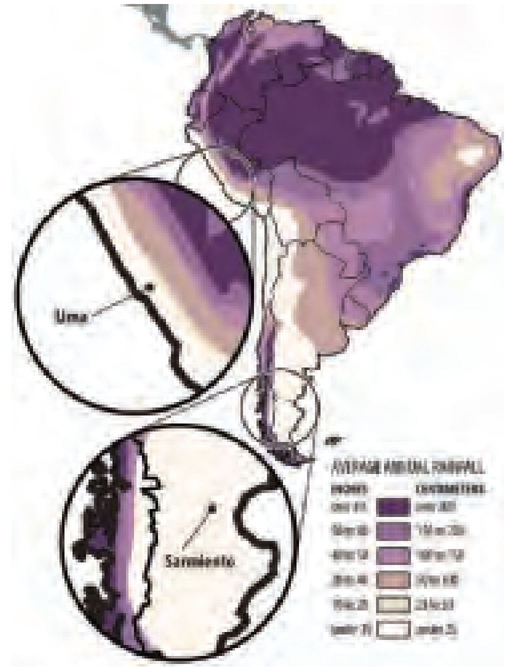
Two of these dry places are shown on the map to the right:

- Lima, Peru
- Sarmiento, Argentina

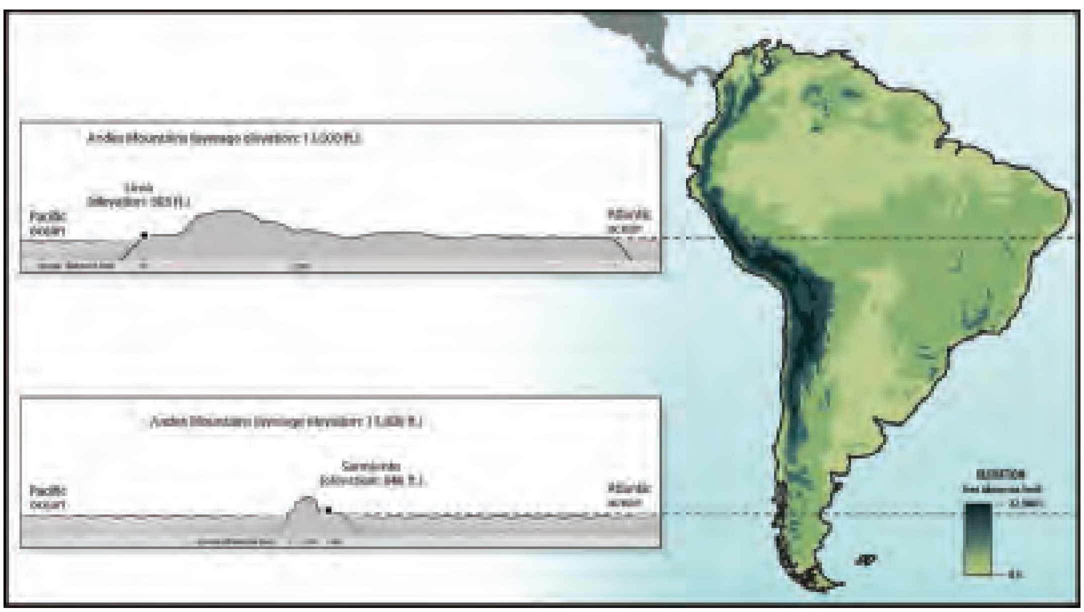
Some characteristics that both places share are that

- both are very close to the ocean,
- neither has rainforests, and
- both receive very little rainfall (under 10 inches a year).

The map to the right also shows the elevation in South America.



Below is an elevation map along with elevation diagrams (cross sections) of South America. Use the diagrams of elevation profiles and the elevation map to explain why Lima and Sarmiento receive so little rainfall.



3a. First, annotate both the Lima and Sarmiento diagrams above by

- adding arrows to each diagram to show the prevailing winds and
- adding trees to each diagram to show the location of the rainforests.

3b. Choose either Lima or Sarmiento and use the diagram for that city to write an explanation for why the city is so dry even though the rainforest nearby gets so much rain.

Name: ______________________ Date: ______________

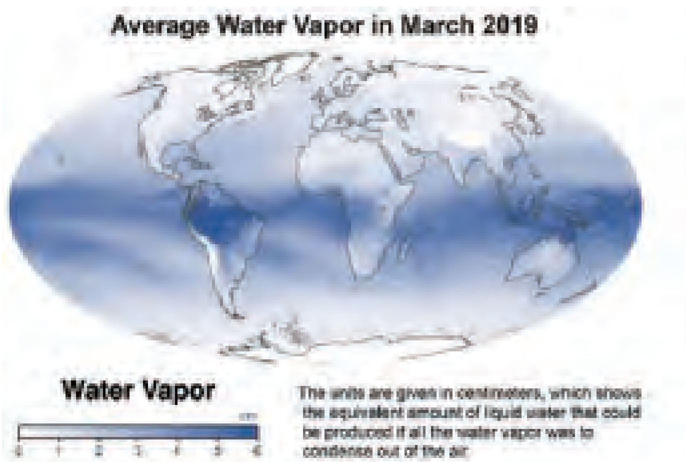
LESSON 22: ANSWER KEY

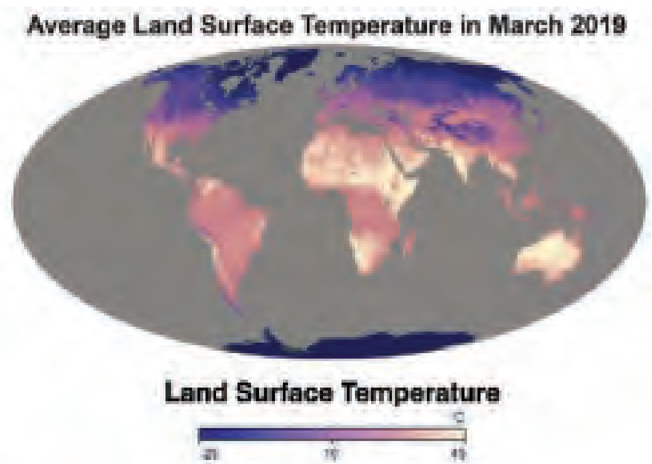
Key for Rainforest Climate Assessment Tasks

Remember from your class discussion: Many species of the world live in rainforests due to the abundance of water year round and stable temperatures. South America is home to two kinds of rainforests—tropical rainforests with warmer average temperatures (70 to 85°F) and temperate rainforests with cooler average temperatures (45 to 55°F).

Answer the following questions on the following pages using the key ideas you and your class brainstormed regarding what might contribute to the location and climate of these rainforests.

Q1) Tropical and temperate rainforests are also found in other parts of the world. Where do you predict you would find other **tropical rainforests?** Use the first two maps to inform your prediction. Draw on the third map to show where you predict you would find other **tropical rainforests around the world, in addition to South America.**

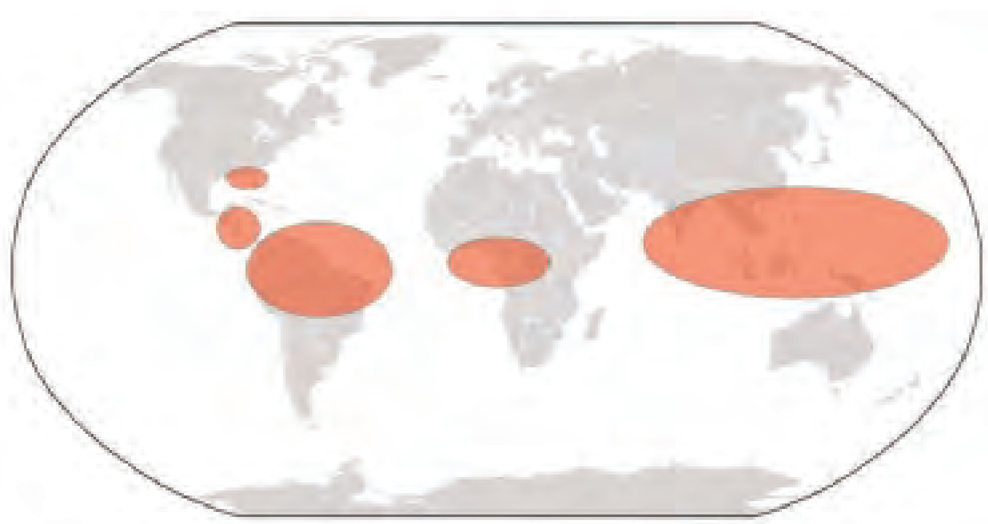




NASA Earth Observatory

Average Land Surface Temperature in March 2019

Draw and label where you predict you would find other tropical rainforests around the world.
On the map: Students should draw around the area of the equator. It is okay for students to have a general area predicted. It doesn't have to be exact. For example:



Explain why you predicted what you did:

- What data did you use to inform your prediction?
- What science ideas about how rainfall is produced did you use to inform your prediction?

Student responses should include any of the following. Students can inform their prediction using mechanisms or patterns, but they need to include the concepts of both (1) high amounts of water vapor and (2) high amounts of thermal energy.

High amounts of water vapor are needed:

- Because water vapor is a cause of precipitation (mechanism)
- Because higher water vapor patterns (dark blue) are found over the Amazon. If these patterns are found over other areas, it is likely these areas also have rainforests (pattern).

Higher amounts of thermal energy are needed:

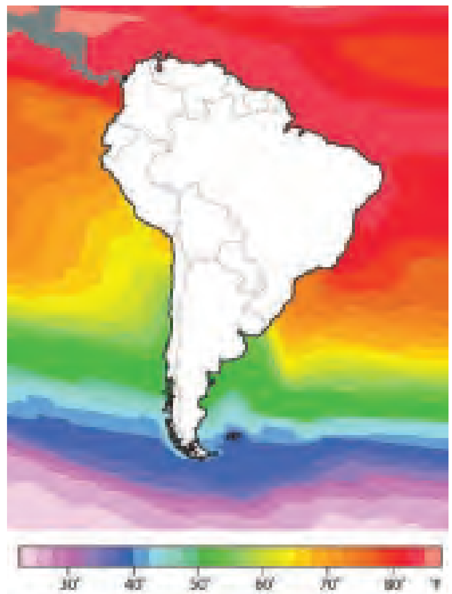
- Because more thermal energy is a cause of more convection and evaporation (mechanism).
- Because tropical rainforests have avg. temps. between 70-85°F, and are shown as red and dark red on the map. So, any areas would need to have these colors to be considered a tropical rainforest (pattern/quantity).
- Because higher temps (red) are found over the Amazon, and it is a tropical rainforest. If that pattern is found over other areas, those areas are also likely to have rainforests (pattern).

Q2) On the previous pages, you developed a prediction for where you would expect tropical rainforests to be located around the world. There are also temperate rainforests that have lower average temperatures. South America has both temperate and tropical forests in different parts of the continent, as shown in the first map below.

The second map shows the average temperature of the oceans around South America and the third map shows the prevailing winds over South America and the surrounding oceans. Use these maps and what you know about energy transfer to answer questions 2a-2c.

1. Location of tropical and temperate rainforests in South America

2. Average temperature of the oceans



3. Prevailing winds

2a. Which ocean(s) would have the most effect on the air temperature over the **tropical rainforest (the green area on map 1)?** Use ideas related to thermal energy and energy transfer in your explanation.

Student responses should include:

2a. Tropical Rainforest

- The Atlantic Ocean has the most effect on the tropical rainforest.
- The prevailing winds travel over the ocean near the equator and into the tropical rainforest.
- The air warms up or cools down as energy is transferred to or from the surface below it.
- The Atlantic Ocean is relatively warm (80°C) near the equator.
- These things would bring relatively warm air into the rainforest off the ocean.

2b. Which ocean(s) would have the most effect on the air **temperature over the temperate rainforest (the purple area on map 1)?** Use ideas related to thermal energy and energy transfer in your explanation.

Student responses should include:

2b. Temperate Rainforest

- The Pacific Ocean has the most effect on the tropical rainforest.
- The prevailing winds travel over the ocean further south and into the temperate rainforest.
- Air warms up or cools down as energy is transferred to or from the surface below it.
- The Pacific Ocean is relatively cool (10-15°C) further south.
- These things would bring relatively cool air into the rainforest off the ocean.

2c. Use the prevailing winds map to explain whether the prevailing winds entering both rainforests are relatively moist or dry. Why do you think this is the case?

Student responses should include:

2c. Humidity

- Both sets of prevailing winds would be relatively moist because:
    - All the prevailing winds we've seen coming off the ocean in the U.S. carried moist air with them, so that general pattern can be assumed to be true for other continents (pattern).
    - Evaporation can occur over any water source. The ocean is a large source of water. The wind carries the water vapor in it (principle).
- Optional - some students may say (but this is not required):
    - The prevailing winds into the tropical rainforest would have more water vapor in them than the winds going into temperate rainforest because warmer air can hold more absolute humidity in it than cooler air (principle).

Q3. The driest places in the world are also located in South America.

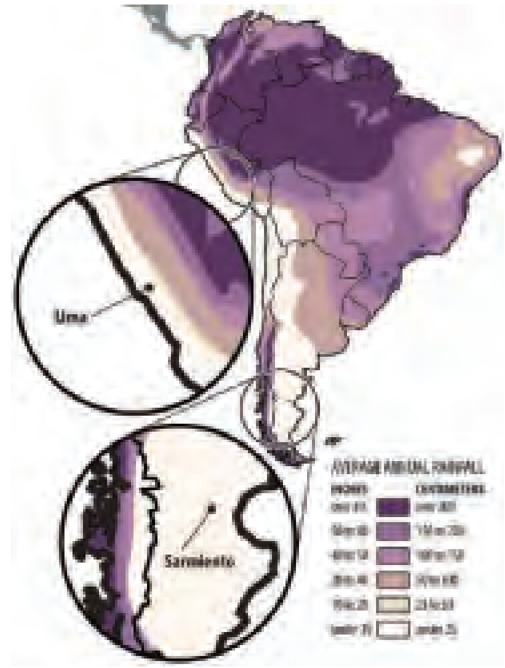
Two of these dry places are shown on the map to the right:

- Lima, Peru
- Sarmiento, Argentina

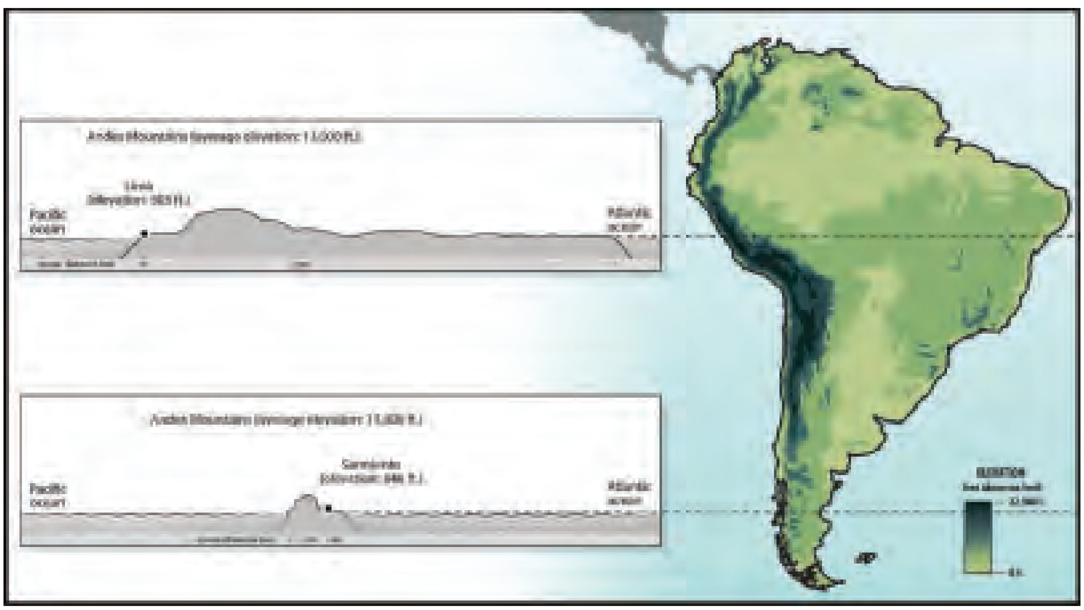
Some characteristics that both places share are that

- both are very close to the ocean,
- neither has rainforests, and
- both receive very little rainfall (under 10 inches a year).

The map to the right also shows the elevation in South America.



Below is an elevation map along with elevation diagrams (cross sections) of South America. Use the diagrams of elevation profiles and the elevation map to explain why Lima and Sarmiento receive so little rainfall.



3a. First, annotate both the Lima and Sarmiento diagrams above by

- adding arrows to each diagram to show the prevailing winds and
- To answer this, students should draw arrows next to Lima demonstrating that the prevailing winds go East to West from the Atlantic Ocean.
- To answer this, students should draw arrows next to Sarmiento demonstrating that the prevailing winds go West to East from the Pacific Ocean.
- adding trees to each diagram to show the location of the rainforests.
- To answer this, students should draw trees next to Lima demonstrating that the rainforest is located to the East of the Andes Mountains and covers much of that area.
- To answer this, students should draw trees next to Sarmiento demonstrating that the rainforest is located to the West of the Andes Mountains.

3b. Choose either Lima or Sarmiento and use the diagram for that city to write an explanation for why the city is so dry even though the rainforest nearby gets so much rain.

Either (Lima or Sarmiento) explanation needs:

- The city is further inland from where the initial prevailing winds hit the land.
- As winds move over the land, the elevation rises. This forces the air moving over it upward.
- When air goes upward, it cools as it goes higher up.
- When air with water vapor is cooled enough, water can condense out of it.
- This happens on the rainforest side/windward side of the mountains.
- When water condenses out of air, less water vapor is left behind in it.
- The air that makes it to the other side of the mountains has relatively little water vapor in it. It is dry.
- This is the air that comes into the dry town (Lima or Sarmiento).

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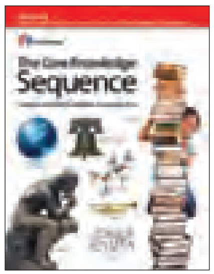

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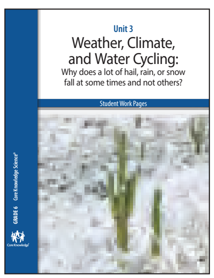

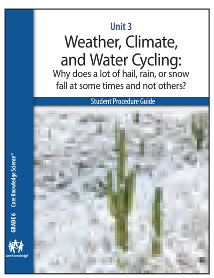

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