Unit 3

Weather, Climate, and Water Cycling:

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

Student Procedure Guide

GRADE 6 Core Knowledge Science®

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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?

Student Procedure Guide

Core Knowledge Science

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Weather, Climate, and Water Cycling

Table of Contents

Student Procedures

References

Readings

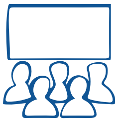
Lesson 1: What causes this kind of precipitation event to occur?

Explore some storm-related phenomena.

In your notebook

1. Prepare to explore some videos that show a perplexing phenomenon occurring outdoors. Start a new page in your science notebook, titled “Exploring an Outdoor Phenomenon”. Make a 2-column chart below it to record your noticings and wonderings for 3 different video clips.

With your class

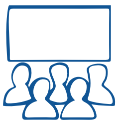


2. Watch the first video: https://youtu.be/9PeACgaLC4A, which was recorded on April 7, 2013, in Fort Scott, Kansas.
3. Record what you notice and wonder in your 2-column chart.
4. Share your observations with your class.

Turn and talk

5. Share with your partner any experiences you’ve had with hail and how your experience compared to what you saw in the video.

With your class



6. Watch the second video: https://youtu.be/Lx4TUg3TD-s, which was recorded on October 5, 2010, in Phoenix, Arizona.
7. Record what you notice and wonder in your 2-column chart.
8. Share your observations with your class.
9. Watch the third video: https://youtu.be/wwPnb-1qRtQ, which is a time-lapse video recorded on June 10, 2013, in Winnipeg, Manitoba, Canada. It is sped up 60 times faster, so each second in the video is equal to 1 minute of real time; this means that though the video is only 99 seconds long, it represents 99 minutes of real time.
10. Record what you notice and wonder in your 2-column chart.
11. Share your observations with your class.

Create an initial model.

On your own

12. Create an initial model to explain “What causes this kind of precipitation event to occur?” on your copy of the handout *Initial Model*.

Connect to previous unit ideas.

Turn and talk

13. In our previous Cup Design Unit, we developed some useful ways to represent what was happening to the matter and energy in a system. Let's recall what those were, so we can figure out if they could help us explain what caused some of the changes happening outside in the videos' precipitation events. Discuss these ideas with a partner:

- How did we represent the particles that make up different states of matter in a gas, a liquid, and a solid?
- How did we represent the different ways that energy can be transferred into and out of a system like a cup with liquid in it?

With your class

14. Review these ideas with the class.

Develop your initial model.

On your own

15. Use your copy of the handout *Representing Particle-Level Changes in the System* to extend your initial model to help explain "What causes this kind of precipitation event to occur?"

Target a norm to focus on.

With a partner

16. Look at our classroom norms. Which of the norms do you think might be particularly challenging to follow if we are out of practice? Which do you think we need to intentionally work at more to get better at?

- Choose 1 norm from the sheet that you personally will work on for the rest of class.
- Share the norm you chose with a partner, and tell them why it is important for you.

Compare models.

With your class

17. Place both pages of your model on your desk for others to see on a silent gallery walk.

18. Quietly walk around the room and look at others' models. Look for similarities and differences in:

- changes happening over time that we would see above and around the area where the precipitation fell
- what was causing changes in the air and water above that we couldn't see (particle-level representations)

Scientists Circle

19. Bring your science notebook, handouts, and a chair with you to form a Scientists Circle.

20. Work with your classmates to develop a whole-group record of what we agree on and where we have competing ideas or areas of uncertainty across our models.

- What do we all seem to agree on?
- What do we disagree on?
- What are some new ideas we may want to consider?

Develop initial questions.

On your own

21. Look back at these things:

- your noticings and wonderings from the videos
- your initial model
- your partner's ideas
- our initial consensus model

22. Then write 1 question per sticky note. Write in marker, big and bold. Put your initials on the back of each question in pencil.

23. Stick these questions into your science notebook to save for sharing next time.

Identify related phenomena.

In your notebook

24. Add a "Related phenomena" section to your science notebook and record the following:

- Describe some times when you've seen a lot of precipitation fall in one place in a relatively short time (minutes).
- Describe some times when you've seen a lot of precipitation fall continuously in one place over a much longer time.

Reflect on norms.

On your own

25. Put your name on a new sticky note and write the answers to the following questions:

- What norm did you select to work on today?
- How did you do with the norm you selected to work on during the last class?

26. Turn this sticky note in to your teacher along with your 2 handouts: *Initial Model* and *Representing Particle-Level Changes in the System*.

Share related phenomena.

With your class

27. Share your related phenomena with the class.
28. Keep track of whether any of your listed phenomena are added to the poster(s), and put a check mark next to them in your notebook if they are.

Connect mechanisms across related phenomena.

Turn and talk

29. Discuss the following with a partner:
    - Do you think any of the same mechanisms and interactions that cause hailstorms could cause these other precipitation events? Which ones? Why?

Record additional questions.

On your own

30. Look over our list of related phenomena. Consider the related mechanisms you discussed with your partner.
31. Then record any additional questions you have: 1 question per sticky note. Write in marker, big and bold. Put your initials on the back of each sticky note in pencil.

Build our Driving Question Board (DQB).

Scientists Circle

32. Bring your sticky notes with questions on them, your science notebook, and a chair to a Scientists Circle.
33. 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. That 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.
    - That student then selects the next student whose hand is raised.
    - This next student reads their question and posts it on the DQB. This student also says what other posted questions it relates to. They should also explain why or how it relates.

- This student then selects the next student whose hand is raised. This process continues until everyone has had a chance to post a question.
- Keep track of whether your question was already asked, put a check mark on that sticky note if it was, and then select a different question to share.

34. Build the DQB with your class.

Develop ideas for future investigations.

Turn and talk

35. Brainstorm the following with a shoulder partner:

- What kinds of investigations could we do and/or what additional sources of data might we need to help figure out the answers to our questions?

With your class

36. Share these ideas with the class as your teacher makes a public record of them.

37. Turn in your unposted sticky note questions to your teacher before you leave.

Turn and talk

38. Discuss the following with a shoulder partner:

- If you could take observations yourself outside at a place where hail was falling, what sort of observations would you want to take and why?

Lesson 2: What are the conditions like on days when it hails?

Navigation

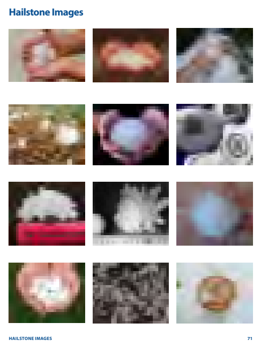
Turn and talk

1. Imagine you were at a spot where you knew a hailstorm was going to occur. Discuss these questions:
   - What do you think the conditions outside are like on a day when it hails?
   - What data would you want to collect before, during, and after the hail event to try to figure out what caused it?

Hailstone Observations

In your notebook

2. Make a 2-column chart in your science notebook and record what you notice and wonder about the hailstone images.



Hailstone Observations	
Notice	**Wonder**

Make sense.

With your class

3. Share with the class:
   - What are some patterns you noticed as you examined the hailstone images?
   - What new ideas and questions do you have about how hailstones are produced?

Analyze the frequency map data.

In your notebook

4. Tape the *Hail Frequency Map* into your notebook. Record patterns you notice and new questions these patterns raise in a 2-column chart on the opposite page.

5. Share your observations with the class.

Analyze the Fort Scott, KS, hailstorm case together.

With a partner

6. Review the source of the weather data with your class. Write the question, "What patterns do we notice in the location, scale, timing, and weather conditions during hailstorms?" in your notebooks.
7. Make observations about the hail map for Fort Scott, KS.
   - Draw an arrow to something you notice in the zoomed-in map.
   - Write "What I see" (or "WIS") on your handout, then write your observation in a complete sentence.
8. Make observations about the weather data for the Fort Scott hailstorm.
   - Draw an arrow to something you notice in the data table.
   - Write "What I see" (or "WIS") on your handout, then write your observation in a complete sentence.

Analyze a hailstorm case with a partner.

With a partner

9. Make observations about the map and weather data for your assigned site.
   - Draw arrows to things you notice in the zoomed-in map and data table.
   - Write "What I see" (or "WIS"), then write your observations in complete sentences.
   - Share your observations with a partner.

Compare cases with another pair.

With your group

10. Share your observations with another pair of students.
    - Give each pair 2 minutes to share, then switch.
    - Listen for similarities and differences between the 2 cases.

Exit Ticket

On your own

11. Record 1 pattern you noticed for each of the following:
    - the location of hailstorms
    - the timing or conditions of hailstorms

Navigation

Turn and talk

Last time, we analyzed a hail frequency map and started examining hailstorm case data that included zoomed-in maps, timing of the storm, and weather conditions.

12. What was 1 pattern you noticed from these data sources?

Building Understandings Discussion: Identifying Patterns

Scientists Circle

13. Bring your notebook and a chair to the Scientists Circle.

14. Compile our hailstorm case data. Share what you noticed in the data for your case regarding these things:

a. location and scale

b. timing

c. conditions

d. any other things you think are important in helping us identify patterns in hailstorms

15. Identify patterns. Using our compiled data, discuss this question:

- What patterns do we notice in the location, scale, timing, and conditions of hailstorms?

Progress Tracker: What have you figured out?

In your notebook

16. Turn to the pages in your notebook reserved for your Progress Tracker.

17. Write the heading "Progress Tracker" at the top of the page.

18. Draw another 2-column chart down the page. Write "Question" at the top of the left column and "What I've figured out" at the top of the right column.

Question	What I've figured out

19. Write the lesson question in the left column: "What are the conditions like on days when it hails?"

20. Write and/or draw what you figured out in the right column.

Navigation

On your own

21. Stop and jot your thoughts in your notebook on this question:

- How is it possible for hail to form and fall from the sky when the temperature near the ground is not cold enough to cause ice to form?

Lesson 3: How does the air higher up compare to the air near the ground?

Navigation

We looked at weather data for several sites where hailstorms occurred, and we noticed that the air on a day when it hailed was usually warm.

Stop and Jot

1. Think about this question: 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?
    - Jot down your thinking on a new page in your science notebook.

Identify data we need.

Turn and talk

2. Discuss these questions with a partner:
    - How could we find out if the air up high is colder than the air near the ground?
    - How high up in the atmosphere do you think we would need to go?
    - What are some ways that we could put tools that record such measurements up in the air?

Weather Balloons

In your notebook

3. Watch the weather balloon video.
4. In your notebook, write down what weather balloon instruments measure.

Make predictions.

In your notebook

5. If we examine weather balloon data, how does the air higher up compare to the air near the ground?
    - Record the question and your predictions in your notebook. Include a brief explanation to support your thinking.

Weather Balloon Data

In your notebook

We have some weather balloon data for different locations at different times of year. Let's look at the data collected from 1 of these sites in the summer of 2018.

6. Preview the handout *Weather Balloon Data*.

7. Analyze the data for Albany, NY, on July 11, 2018.
    - What patterns do you notice in this set of weather balloon data?
    - Record your observations in your notebook.

Analyze the data for your assigned site.

With your partner

8. Work with a partner.
    - Analyze the 4 sets of data for the site that is assigned to you.
    - In your notebook, document any patterns you notice in the data for . . .
        - January
        - April
        - July
        - October

Compare data and observations.

With your partner

9. Work with another pair of students.
    - Compare your observations with another pair of students who analyzed the data from a different site.
    - In your notebook, document any patterns (similarities) you notice across the data sets for the 2 sites.

Make a claim and support with evidence.

In your notebook

10. After comparing your data and observations with another pair, what claim can you now make about the relationship between the temperature of the air and the distance from the ground (altitude)?
    - Write your claim and support it with evidence from your analysis of the data.
    - Draw a box around your claim.
    - Be prepared to share your claim and supporting evidence with the class.

Engage in a Building Understandings Discussion.

Scientists Circle

11. Think about the following questions and share your responses in a Scientists Circle.
    - What did you notice about the air temperature in the data sets you analyzed?
    - Was this pattern true for all four sites?
    - What did you notice when you compared the data over the four time periods?

Quick Write

Let's revisit what we already know and understand about energy and matter. This will help us understand what might be happening with the molecules that make up air at different altitudes and explain the observed temperature patterns.

In your notebook

12. Think about this question: What do we know about temperature and the kinetic energy of particles of matter?

- In your notebook, take a few minutes to jot down what you know and understand about temperature and the kinetic energy of the particles that make up matter.

Represent temperature differences in air.

Turn and talk

13. 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 the air high up in the atmosphere and those closer to the ground?

- Document your thinking using pictures and/or words in your notebook.

Document a consensus model.

With your class

14. Work as a class to 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.

Progress Tracker: What have we figured out?

In your notebook

15. Draw a 2-column Progress Tracker in your notebook.

Question	What I've figured out

16. Record the lesson question in the left column: "How does the air higher up compare to the air near the ground?"

17. Use words and/or pictures to document what you have figured out in the right column.

Navigation

In your notebook

18. Add the title "Predictions" to the next page in your notebook.

19. Based on what we have figured out from the weather balloon data, record your predictions in response to the following questions:

- If we gathered data by moving closer to the ground, what do you think we would see in that data?
- 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?

Lesson 4: Why is the air near the ground warmer than the air higher up?

Share some predictions.

Go to the “Predictions” page of your science notebook.

With your class

1. Based on what we have figured out from the weather balloon data, discuss these questions:
    - If we gathered data by moving closer to the ground, what do you think we would see in that data?
    - 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 for either scenario? Why or why not?

How could we study air close to the ground?

To plan the investigation, work through each row of the table in your handout with your group.

With your group

2. What data should we collect and why?
3. Which tools should we use and why? How will we collect the data?
4. How will we select sites? Can we identify some potential sites now?

Best Practices for Data Collection

With your class

5. Data collection tips
    - When taking a measurement, make sure to hold the equipment the right way.
    - Record the information in the data table on your handout.
    - Take 2-3 readings and have a partner check your readings for accuracy.
    - Switch jobs at each new surface so everyone can work with all the equipment.
6. Things to avoid
    - Do not take temperature readings without blocking the wind.
    - Do not hold the light meter or thermometers at different angles for each site.
    - Do not hold the light meter or thermometers at different distances for each site.

What might we see?

Turn and talk

7. Look closely at this photo and think about our data collection procedures.

- What might we see if we collect temperature and sunlight data in different parts of this photo?

Report results.

With your class

8. As a class, populate a shared data table:

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)

Making Sense of Sunlight Data

With your class

9. What do you notice about the sunlight data?

- Was there a difference between incoming and reflected light?
- Where did the other light go?
- How did the surfaces differ in the incoming and reflected light?

Making Sense of Temperature Data

With your class

10. What do you notice about the temperature data?

- Which surfaces were warmer? Which were cooler?
- How does the sunlight data relate to the temperature data?
- Were the ground temperature and the air temperature the same?
- What do you think happens at the ground that makes temperatures there hotter than the air above the ground?

How are sunlight and temperature related?

Turn and talk

11. Energy from the Sun enters Earth's atmosphere. It travels to the surface of Earth where it reaches the ground. Think about how the representations we developed in the cup design unit help explain the following questions.

- What happens when the light reaches the ground?
- What happens to the temperature of the ground?
- What happens to the air in contact with the ground?

Be ready to share your thinking in a Scientists Circle.

Scientists Circle

12. Share the ideas you and your partner discussed with the class.

Connect to the Anchoring Phenomenon.

We now know why Earth's surface gets warm and why different surfaces get warmer than others and how this warms the air above it.

On your own

13. Stop and Jot in your notebook:

- 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?

Lesson 5: What happens to the air near the ground when it is warmed up?

Connecting to the Anchoring Phenomenon

Turn and talk

1. At the end of the last lesson, we were still wondering, "What happens to the air close to the ground once it warms up?"
   - 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?

Identify necessary data.

With your class

2. We want to figure out what happens to air when it is warmed up.
   - How could we trap some air in contact with a warm surface to observe what happens to it after it is warmed up?

Set up your science notebook.

In your notebook

3. Set up your science notebook for the *Soap Bubble and Bottle Investigation*.
   - Write the title of the investigation on a new page in your science notebook.
   - Include a heading and some space for recording your predictions.

Initial Ideas

In your notebook

4. Think about these questions and make 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?

Investigate our ideas.

With your group

5. Prepare your materials:
   - Send a group member to gather your materials:
     - 1 empty bottle
     - 2 6-quart tubs
     - 1 small container of soap bubble solution

- Pour cold water into the first 6-quart tub until the water is about 3 inches deep.
- Wait for your teacher to pour hot water into the second 6-quart tub.

6. Test your air parcel:

- Seal your parcel of air (the bottle) with with a layer of soap bubble solution.
- Place it in the cold water and observe what happens.
- Then place your parcel of air in the hot water and observe what happens.
- Repeat the process a second time, and record what you observe when you place the bottle in each tub. Feel free to use pictures and/or words.
- **IMPORTANT:** If the soap bubble sealing the bottle pops, seal the bottle again and repeat the process.

Develop a model.

With your partner

7. Work with a partner to complete the handout *Soap Bubble and Bottle Investigation*.

8. Be prepared to share your thinking with the class.

Building Understandings

With your class

9. In a Scientists Circle, discuss the following questions:

- When representing the molecules that made up the air in the closed bottle system after cooling down and after warming up, how many dots should you draw? Why?
- In what ways did changing the temperature of the air in the closed bottle system affect the molecules that made up the air?
- What evidence supports the changes you represented in the molecules that made up the air in the bottle?

Connect to the Anchoring Phenomenon.

Turn and talk

10. Think about what we now know happens to air when it is warmed up.

- In what ways are the closed bottle system and the air near the ground similar?
- How does investigating the closed bottle system help us investigate our ideas about how a hailstorm forms?

Develop a Model: Tracking the Flow of Energy

With your class

11. When we consider the closed bottle system represented in each model, think about these questions:

- What do we know about the temperature of the following?
    - the air outside the closed bottle system
    - the water in the tub
    - the air inside the closed bottle system
- Where can we locate energy in and around the bottle system?
- What energy transfers are causing the changes we observed in each model?
- How might we document these transfers of energy?

What is density?

Turn and talk

12. The relationship between the amount of matter (mass) in a sample and the amount of space it takes up (volume) is the **density** of that sample.

- When we placed the bottle in the cold water, what happened to the air inside the bottle?
- When we placed the bottle in the hot water, what happened to the air inside the bottle?

Connect to the Anchoring Phenomenon.

With your partner

13. These are models of the air near the ground in a schoolyard:

- **Sample A** is a sample of the air near the ground in a grassy, shady area.
- **Sample B** is a sample of the air near the ground in an area of blacktop in direct sunlight.

14. Think about these questions:

- Which sample is less dense?
- What causes this difference?

15. Make a claim and support your claims with evidence.

Set up your science notebook.

In your notebook

16. Set up your science notebook for the *Heated Balloon Investigation*:

- Write the title of the investigation on the next available page in your notebook.
- Include a heading and some space for recording your predictions.

Initial Ideas

In your notebook

17. Think about these questions and make predictions:

- 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?
- What do you think happens to air near the ground on a day when it hails?

Investigate our ideas.

In your notebook

18. Continue to set up your science notebook:

- Add a section for observations of the balloon.
- Record what you notice happening to the balloon at various points in the investigation.

Create a model.

On your own

19. Complete the handout *Heated Balloon Investigation*.

20. Be prepared to share your thinking with the class.

Develop a consensus model.

With your class

21. In a Scientists Circle, think about the following questions as we build a classroom consensus model:

- What happened to the balloon when it was held against the heating pad? Why?
- What happened to the density of the helium in the balloon as it was heated?
- What happened to the density of the helium in the balloon as it floated back down to the floor? Why?

Document the flow of energy.

With your class

22. Think about the balloon at each position in the time series model:

- Where was energy located?
- Where and when did energy transfer?
- How do we show the flow of energy?

Draw conclusions.

Turn and talk

23. Discuss these questions with a partner:

- How did the density of the helium inside the balloon change when thermal energy transferred into the balloon from the heating pad?
- How did the density of the helium change when thermal energy flowed out of the balloon into the surrounding air?
- How did these changes in density affect the behavior of the balloon?

Make connections.

Turn and talk

24. Discuss the following with a partner:

- Do you think the air close to the ground will behave in the same way as the helium in the balloon when warmed up? Why or why not?
- Support your thinking with evidence from the investigations:
  - *Soap Bubble and Bottle Investigation*
  - *Heated Balloon Investigation*

Progress Tracker: What have you figured out?

In your notebook

25. Draw a 2-column Progress Tracker in your science notebook:

- Record the lesson question in the left column, "What happens to the air near the ground when it is warmed up?"
- Use words and/or pictures to document what you have figured out in the right column.

Question	What I've figured out
What happens to the air near the ground when it is warmed up?	

Navigation

Turn and talk

26. 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?

Connect to the Anchoring Phenomenon.

With your partner

27. These are models of the air near the ground in a schoolyard:

- **Sample A** is a sample of the air near the ground in a grassy, shady area.
- **Sample B** is a sample of the air near the ground in an area of blacktop in direct sunlight.

28. Think about these questions:

- Which sample is less dense?
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29. Make a claim and support your claims with evidence.

Set up your science notebook.

In your notebook

30. Set up your science notebook for the *Heated Balloon Investigation*:

- Write the title of the investigation on the next available page in your notebook.
- Include a heading and some space for recording your predictions.

Initial Ideas

In your notebook

31. Think about these questions and make predictions:

- 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?
- What do you think happens to air near the ground on a day when it hails?

Investigate our ideas.

In your notebook

32. Continue to set up your science notebook:

- Add a section for observations of the balloon.
- Record what you notice happening to the balloon at various points in the investigation.

Create a model.

On your own

33. Complete the handout *Heated Balloon Investigation*.

34. Be prepared to share your thinking with the class.

Develop a consensus model.

With your class

35. In a Scientists Circle, think about the following questions as we build a classroom consensus model:

- What happened to the balloon when it was held against the heating pad? Why?
- What happened to the density of the helium in the balloon as it was heated?
- What happened to the density of the helium in the balloon as it floated back down to the floor? Why?

Document the flow of energy.

With your class

36. Think about the balloon at each position in the time series model:

- Where was energy located?
- Where and when did energy transfer?
- How do we show the flow of energy?

Draw conclusions.

Turn and talk

37. Discuss these questions with a partner:

- How did the density of the helium inside the balloon change when thermal energy transferred into the balloon from the heating pad?
- How did the density of the helium change when thermal energy flowed out of the balloon into the surrounding air?
- How did these changes in density affect the behavior of the balloon?

Make connections.

Turn and talk

38. Discuss the following with a partner:

- Do you think the air close to the ground will behave in the same way as the helium in the balloon when warmed up? Why or why not?
- Support your thinking with evidence from the investigations:
    - *Soap Bubble and Bottle Investigation*
    - *Heated Balloon Investigation*

Progress Tracker: What have you figured out?

In your notebook

39. Draw a 2-column Progress Tracker in your science notebook:

- Record the lesson question in the left column, “What happens to the air near the ground when it is warmed up?”
- Use words and/or pictures to document what you have figured out in the right column.

Question	What I’ve figured out
What happens to the air near the ground when it is warmed up?	

Navigation

Turn and talk

40. 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?

Lesson 6: How can we explain the movement of air in a hail cloud?

Navigation

Turn and talk

1. Turn and talk 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?

Clouds that Tend to Produce Hail

Examine the cloud images on *Comparing Hail Clouds to Other Clouds*.

With your class

2. Discuss these questions with your class:
   - What do you notice about these clouds?
   - How do hail clouds compare to the other clouds?
   - What do we know about the temperature of the air at different heights of the cloud?
   - How might the air temperature at different heights be related to the formation of hail?

Formation of a Hail Cloud (Cumulonimbus)

On your own

3. Watch the video and record the movement of the hail cloud on *Tracking Air Movement in Cloud Formation* when your teacher pauses the video at 6 time points:
   - Use upward-pointing arrows to label spots in the hail cloud where you saw air moving upward.
   - Use an "x" to label any spots in the hail cloud where you saw air that had been rising stop moving upward.
   - Use downward-pointing arrows to label any spots in the hail cloud where you saw air moving downward.

Construct a scientific explanation.

On your own

4. Individually complete *Explaining the Movement of Air in a Hailstorm Cloud*. You may want to use your Progress Tracker entries from previous lessons to help with this task.

Revise our class model.

Scientists Circle

5. As a class, use the ideas from our individual explanations to revise our initial consensus model.

Revisit our DQB.

With your class

6. Revisit our DQB and note which questions we have made progress on:

- 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: ✓+

Navigation

Turn and talk

7. Examine the image.

If you could compare what is in the air at a location below the cloud, in the middle of the cloud, and up high in the cloud, discuss these questions:

- What might be the same?
- What might be different?

Close Reading Strategy for "What Is Air?"

In your notebook

8. Use the following close reading strategy to make sense of *What Is Air?*:

- Identify the question(s) you are trying to answer in the reading.
- Read once for understanding to see what the reading is about.
- Read a second time to highlight a few key ideas that help answer the questions you had.
- Summarize the key idea(s) in your own words, in diagrams, or both.
- Jot down new questions that this raises for you.

Lesson 7: Where did all that water in the air come from, and how did it get into the air?

Navigation

Last time, we explained how the air is moving below and within a hail cloud, but we wondered what that air was made of.

Turn and talk

1. What did we learn about what air is made of?
2. What is humidity, and how can it be measured?

Measuring Humidity

With your class

3. If we use a probe to measure the relative humidity of the air in the room, what do you predict it will be?
4. What could we do to make the air near the probe more humid?
5. How do you think this will compare to the air outside?
6. Measure humidity inside the classroom, right above boiling water, a couple of distances away, and outside of the classroom window.

Make predictions and plan our investigation.

Turn and talk

7. Where is the water in the atmosphere coming from?
    - Write this investigation question in your science notebook.

In your notebook

8. Add your *Sources of Water in the Air* handout to your science notebook.
    - Record a prediction: Which of these places could water in the air be coming from?

Turn and talk

9. What data should we collect? Why?
10. How could we use a humidity probe, a lamp, and a container to see whether water is going into the air from each of these places?

Connecting Our Bottle System to the Real World

With your class

11. What does each part of the bottle system represent in the real world?

- bowl with earth material
- air in the bottle
- lamp

12. How is it like the real world?

13. How is it different?

Conduct the investigation.

With your group

14. Decide which environment you would like to test and how you will simulate that environment with the available materials. Follow the planned investigation procedures.

15. Record your data on *Sources of Water in the Air.*

16. Add your group's data to the class data table.

Exit Ticket

On your own

17. How is our bottle system similar to or different from the real world?

18. How does the data we collected help us answer our question: "Where did all that water in the air come from?"

Navigation

With your class

What are we trying to figure out?

19. Which of these places could water in the air be coming from, and how did it get into the air?

20. What data did we collect, and how will that data help us answer this question?

Making Sense

With a partner

21. Which containers provided evidence that water went into the air?

22. What claim can you make in response to the question, "Which of these places could water in the air be coming from?"

Be prepared to share with the class.

Develop a model to explain our results.

On your own

23. Draw and label model on your *Model for How Water Gets into the Air* handout to show how some of the water in or on the earth material gets into the air.

Compare models.

With a partner

24. 1 minute: Use your model to explain how the water got into the air.

25. 1 minute: Receive feedback from your partner. Take notes about what they say.

26. Switch.

27. Consider these prompts as you give feedback:

- 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 ________?

Responding to Feedback

On your own

28. We use peer feedback to improve our work, making it more clear, more accurate, and better supported by evidence.

- 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 as needed.

What have we figured out?

Where did all that water in the air come from, and how did it get into the air?

Scientists Circle

29. Draw a 3-column Progress Tracker:

- Write the lesson question in the left column.
- In the right column, "How does what we just figured out help us explain what is happening in the clouds?"
- We'll work together on "What we figured out".

Navigation

Turn and talk

30. Turn and talk: How does what we just figured out help us explain what is happening in the clouds?

Lesson 8: What happens to water vapor in the air if we cool the air down, and why?

Navigation

With your class

1. Discuss what you figured out in the last lesson:
    - What did we figure out is happening at the particle level when water evaporates from an environment?
2. Review what we know happens to the temperature of the air the higher up it is.

Prediction

With a partner

3. Discuss the following:
    - What do you think you would see happen if we took some of the warm air with water vapor in it that we captured yesterday and cooled it down?
    - What do you picture going on with the water vapor molecules in the air as that happens?

Prepare to investigate our question.

In your notebook

4. Record our lesson question on the top of a new page in your notebook: "What happens to water vapor in the air if we cool the air down?"
5. Add a table to that page to record your observations from the 2 investigations we will do to explore this question further.

Investigation	Observations
A	
B	

Carry out Investigation A.

With your group

6. Follow the procedure for *Investigation A* as outlined on slide D.

Make sense of the results.

With your class

7. Discuss the following questions:

- Where in the bottle did you see the strongest evidence of water molecules turning from water vapor back into liquid water?
- Why do you think this happened more in this part of the bottle than in other parts?
- What caused the droplets that appeared at those spots to get larger over time?

Expand our lesson question.

In your notebook

8. Add the following bold text to our lesson question in your science notebook: "What happens to water vapor in the air if we cool the air down, **and why?"**

Carry out Investigation B.

With your group

9. Follow the procedure for *Investigation B* outlined in *Procedures for Investigations A and B*.

Make sense of the results.

With your class

10. Discuss the following:

- What did you see 2 water droplets do right after they got really close to each other or just barely touched?
- What other things have you seen that behave this way?

Construct initial explanations.

On your own

11. Complete an exit ticket on a separate piece of notebook paper by answering the following questions:

- What might have been happening between the water droplets that would make them move towards each other and merge into a single droplet when they get close to each other?
- Imagine the same thing happening between 2 water molecules when they get close to each other. How could you use these ideas to help explain why droplets appeared on the inside of the bottle and grew larger as you lowered the temperature of the air?

12. Turn in your completed exit ticket to your teacher.

Navigation

With your class

13. Discuss your responses to the following questions as a class:

- What might have been happening between the water droplets that would make them move towards each other and merge into a single droplet when they get close to each other?
- Imagine the same thing happening between 2 water molecules when they get close to each other. How could you use these ideas to help explain why droplets appeared on the inside of the bottle and grew larger as you lowered the temperature of the air?

Map the elements of our model.

With your class

14. Add *Elements Map and Results for Investigation C* to your notebook.

15. Complete the elements map on *Elements Map and Results for Investigation C* together.

Carry out Investigation C.

With your group

16. Overview the series of steps you will follow (C1-C4) in this investigation *(Investigation C)*.

17. Follow the procedure for *Investigation C1* outlined in slide M. Listen for signals from your teacher to pause this part of the activity.

18. Watch your teacher's demonstration of the technique to use for *Investigation C2*.

19. Follow the procedure for *Investigation C2* outlined in slide N. Listen for signals from your teacher to pause this part of the activity.

20. Watch your teacher's demonstration of the technique to use for *Investigation C3*.

21. Follow the procedure for *Investigation C3* outlined in slide O. Listen for signals from your teacher to pause this part of the activity.

22. Follow the procedure for *Investigation C4* outlined in slide P. Listen for signals from your teacher to pause this part of the activity.

Update your Progress Tracker.

On your own

23. Turn to your Progress Tracker.

24. Add an entry to it. Write the question we are working on in the left column:

Question	What I've figured out
What happens to water vapor in the air if we cool the air down, and why?	

25. Write what you figured out in the column on the right. Use words and/or pictures. Take as much space as you need to record your thoughts.

Follow your small-group discussion protocol.

With your group

26. Review the following small-group discussion protocol.

27. Follow the protocol with the group you have been assigned.

- **Small-Group Talking Stick Round 1:**
  - Pass around a pencil as a talking stick. Use it to take turns sharing what each of you wrote (or part of what you wrote) in your Progress Tracker. Each person must end their turn after 1 minute.
  - As each person shares, be thinking about how the different responses are connected—whether that is something similar you heard or an important difference or addition. But don't comment on how these are connected yet.
- **Small-Group Talking Stick Round 2:**
  - Pass the talking stick around again. This time each person shares 1 or more connections they heard between what different people shared. Take no more than 1 minute per person.

Update your Progress Tracker.

On your own

28. Take 2 minutes to add to your Progress Tracker to include some of these connections from the discussion in a different colored pen or pencil.

Navigation

With a partner

29. Discuss the following questions:

- Why don't we see clouds everywhere in the air all the time? For example, why is there a cloud at B and C but not at A?

Mathieu Descombes Photographie

- What is a cloud made of, anyway?
- How could what we figured out today be used to help us start developing an answer to these questions?

Lesson 9: Why don't we see clouds everywhere in the air, and what is a cloud made of?

Navigation

With your class

1. 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.
    - 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?
    - What are clouds made of?
    - How could what we figured out in the last lesson be used to figure out answers to these questions?

Read strategically—use close reading strategies.

In previous lessons, we have used close reading strategies to help us read and understand scientific text in a strategic way.

On your own

2. Follow the close reading process:
    - Identify the question(s) you are trying to answer in the reading.
    - Read once for understanding to see what the reading is about.
    - Read a second time to highlight a few key ideas that help answer the questions you had.
    - Summarize the key idea(s) in your own words, in diagrams, or both.
    - Jot down new questions that this raises for you.

Observe a related phenomenon.

We need to pause in the reading to set up a demonstration. The demonstration will produce a phenomenon that you will need to explain using ideas from the reading. It will take a few minutes to produce this interesting outcome, so we need to set it up now, return to the reading to summarize the key ideas, then check the setup in a few minutes.

Turn and talk

3. Set up the demonstration:
    - Fill a small container or cup with hot (100°F–120°F) water.
    - Place a 2-L bottle (with the bottom and top cut off) over the container or cup of hot water.
    - Take a cold gel pack out of the freezer and wipe down the gel pack's surface with a paper towel.
    - Place the gel pack over the top of the 2-L bottle.

4. Turn and talk with your partner and make a prediction:
    - Do you think we will see anything on the surface of the gel pack that is facing the water? If so, what?

Set up your notebook.

In your notebook

5. Set up your science notebook for the reading:
    - Write the title of the reading: **"What Are Clouds?"**
    - Add the heading: **"Main question"**
    - Add the main question: **"Why don't we see clouds everywhere in the air, and what is a cloud made of?"**
    - Add the heading: **"Key ideas from the reading"**

Read strategically—summarize key ideas.

With your partner

6. Record these in your science notebook:
    - Summarize the key idea(s) in your own words, in diagrams, or both.
    - Jot down new questions that this raises for you.

Construct an explanation.

On your own

7. A white solid appeared on the surface of the gel pack that wasn't there at the start of the demonstration. Answer the questions on the handout *Explaining a Related Phenomenon*.

Home Learning Opportunity

You now have an opportunity to use the close reading strategies on your own, outside of class. Turn to a partner and review the close reading strategies we used today. When you get home, use those same strategies to complete the reading, *Reading: Can Other Gases in the Air Turn into Liquids or Solids?*.

Home Learning

8. Use close reading strategies to answer the question, "Can Other Gases in the Air Turn into Liquids or Solids?"
    - On the handout, circle the question you are trying to answer in the reading.
    - Read once for understanding to see what the reading is about.
    - Read a second time to highlight a few key ideas that help answer the question.
    - Summarize the key idea(s) in your own words, in diagrams, or both on the back of the handout.
    - Jot down new questions this raises for you.

Lesson 10: Why do clouds or storms form at some times but not others?

What have we been up to?

Turn and talk

1. What are we trying to figure out about storms, and about hailstorms in particular? Be ready to share your thinking with the class.

What can we explain now?

In your notebook

2. Look back through your science notebook at your work to see if we can answer this question: "Why do clouds or storms form at some times but not others?"
   - Look at your first model for the storm from Lesson 1.
   - Think about the investigations we have done since then.
   - Highlight the parts of the model where you think we know more now because we have collected more evidence about how storms form.

Gotta-Have-It Checklist

With a partner

3. **Part 1:** Make your *Gotta-Have-It Checklist*. Only include important ideas you need to explain why storms form.

Make a thunderstorm.

With a partner

4. Work with a partner to use the Make a Thunderstorm simulation to test your ideas about what causes a storm to form. Go to https://scied.ucar.edu/make-thunderstorm.

University Corporation for Atmospheric Research (UCAR)

Navigation

With your class

5. Remember, our question is: “Why do clouds or storms form at some times but not others?”
6. Our task is: Use your *Gotta-Have-It Checklist* and manipulate input conditions, like temperature and humidity, to achieve different outputs of storm development.

Revisit the Gotta-Have-It Checklist

With a partner

7. **Part 2:** Now that you’ve tried out the simulation, let’s revisit the checklist and think about these questions:
    - 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?

Improve the simulation.

With a partner

8. **Part 3:** Develop revisions to the simulation. Use your *Gotta-Have-It Checklist* to help you think through what other features you would like the simulation to have or conditions you think it could include.

The question the simulation should help us answer is: “Why do clouds or storms form at some times but not others?”

Gallery Walk

With your partner

9. Compare your proposed modifications and discuss similarities and differences across the other teams.
    - Consider what you like about the ways that other teams have represented the ideas in their simulation. Take note of the similarities and differences.
    - Choose which representations help you best understand and answer the question: “Why do clouds or storms form at some times but not others?”

Class Discussion

Why do clouds or storms form at some times but not others?

With your class

10. Share your ideas with the class:

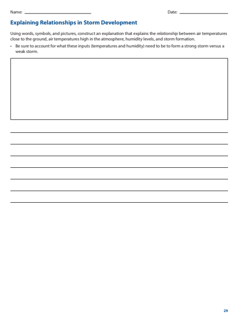
- What does the simulation do well to answer this question?
- How would we revise the simulation?
- Why would these revisions be important to do?

What can we explain?

On your own

11. 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.

Consult your science notebook if needed.


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.

Where next?

With your class

12. Did you notice how the storm clouds got really tall in the simulation when we made a big storm? How does that happen?

13. Can we explain how hail forms yet?

Lesson 11: Why don't water droplets or ice crystals fall from the clouds all the time?

Navigation

We now know that clouds are made of water droplets or ice crystals that first form when many millions of water molecules start sticking to cloud condensation nuclei (CCN).

Turn and talk

1. Discuss the following questions with a shoulder partner. Be prepared to share your ideas with the class:
   - Why don't those water droplets or ice crystals start falling to the ground the moment they start forming?
   - What keeps this stuff that makes up clouds floating in the air above us?

Share related phenomena.

With your class

2. Share examples of where you have seen these things happen:
   - air causing something else to move
   - air causing something to float or remain suspended above the ground

Explore interactions from moving air.

On your own

3. Title a new page in your science notebook with our lesson question: "Why don't water droplets or ice crystals fall from the clouds all the time?"
4. Add the table shown below to record your observations:

Investigation	Observations	What does this tell us?
A. Pieces of tissue paper and a Ping-Pong ball placed on a scale		
B. Blowing air onto a scale		

With your class

5. Carry out the investigations identified above with your class and complete the table as you do so.
6. Carry out an additional investigation (C) with a hair dryer and Ping-Pong ball.

Predict and explain force interactions in the air.

With a partner

7. Compare the amount of updraft force for Cases A and B in the table at the top of the handout *Predicting and Explaining the Effects of Opposing Forces*.

8. Record your predictions for each object in each case in that table.

On your own

9. Write an individual response to the lesson question on the bottom of your handout.

Update class Progress Tracker.

Scientists Circle

10. Add a 3-column chart to your Progress Tracker.

11. Bring your notebook and chair to our Scientists Circle. Work together to develop a consensus model to answer our lesson question.

Brainstorm possible causes for differences in updrafts.

With a partner

12. Work with a new partner, assigned by your teacher, to discuss the following question. Be prepared to share your ideas with the class:

- What would cause the strength of updrafts in the air to change on one day versus another or under one cloud versus another?

With your class

13. Share your ideas with the class.

Observe a device for measuring changes in the air.

With your class

14. Discuss, predict, and observe how the air the fan blows toward the digital scale and away from the digital scale affects the force detected on the plate of the scale.

On your own

15. Observe the homemade barometer your teacher built. This device can detect changes in the density of the air outside of it. Take a minute to think about these questions:

- What do you notice about the structure of this device?
- How does it compare to the bottle and soap-bubble film you used to detect density changes in air in a previous investigation?

With your class

16. Discuss the questions above with your class.

Make predictions and record data.

When the air outside the barometer becomes denser than the air trapped inside of it, it exerts more downward force on the balloon. This causes the pointer on it to tilt upward. Weather forecasters refer to this change as an “increase in the air pressure outside”.

With a partner

17. Discuss the following question with your partner. Be prepared to share your prediction with the class:

- The pressure of the air outside can also decrease. This can happen when the air outside the barometer becomes less dense than the air trapped inside of it. Which way would the pointer on the barometer tilt when this happens?

On your own

18. Record your prediction at the top of the handout *Weather Log*.

19. Record your observations for today in the first row of your weather log table.

20. Add this handout to your science notebook. Add new entries to it across future lessons.

Lesson 12: What causes more lift in one cloud versus another?

Navigation

We figured out that updrafts (rising air) can hold or lift things up in the air that would otherwise fall down. We've also developed models to explain why air might start to rise or sink.

With your class

1. What are some of the things we found that might cause stronger updrafts to be produced on one day versus another?
2. What ideas do we have for how we might investigate those things?

Introduction to Fluid Behavior

Scientists and engineers often use liquids to understand and visualize currents. They have found that many aspects of how currents move are similar in both gases and liquids. For example, both liquids and gases exhibit similar patterns related to **convection**.

Let's design some experiments where we use a liquid in place of air to explore what variables affect the speed and amount of lift in a **fluid**.

Map the elements in both systems.

With your class

3. Use the table below to map the elements in the investigation setup to what we are studying in the real world.

This part of the experimental setup ...	is like ...	this part of the phenomenon.	How are they the same?
A. Liquid water in a tub			
B. Cup with water at a temperature higher than A			
C. Movement of dye			

Make initial observations and predictions.

On your own

4. Describe the movement of the dye after it was added to the water.

Turn and talk

5. How does the movement of the dye over the warm cup relate to what happens with the air in the atmosphere over warm ground?

With your group

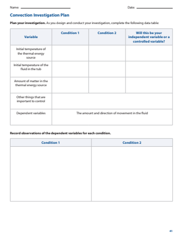
6. What are some things we could change about what is in the cup below the tub that might increase the amount or rate of thermal energy transferred from the cup to the fluid above it?

7. What effect do you think those changes would have on the motion of the fluid above the cup and along the bottom of the tub?

Design and conduct your investigation.

With your group

8. Complete the data table on the handout *Convection Investigation Plan* to plan your investigation. Use this same handout to record your observations.



Navigation

With your class

9. How does what happened in the tubs connect to what we think happens in the air in and around a cloud?

Share your results.

With your group

10. Use the diagram on *Air Movement in Different Conditions* to illustrate the results from the condition your group tested. Use words and pictures to represent your findings.

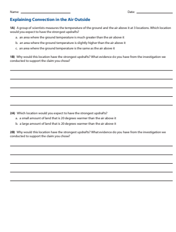
11. Post this diagram for other groups to view as a gallery walk.

12. Review other groups' results and record your noticings and wonderings in your science notebook.

Respond to claims.

On your own

13. Respond to the claims made on the handout *Explaining Convection in the Air Outside.*
    - Which ones do you agree with? Why?
    - What evidence do you have from the investigations we conducted to support the claims you chose?



Update your Progress Tracker.

On your own

14. Update the Progress Tracker in your science notebook to capture your thinking in response to the lesson question, "What causes more lift in one cloud versus another?"

Lesson 13: Why do some storms produce (really big) hail and others don't?

Navigation

1. Re-watch the Fort Scott, KS, hailstorm video clip and examine the hail images.
2. Discuss with your class: What are some things that are happening in this phenomenon that we can now explain?
3. We will create a final model to explain **"Why do some storms produce hail?"** Our explanation will be focused around these 3 questions:
   - Q1: Why do clouds form?
   - Q2: How does hail form in a cloud and how can it get bigger?
   - Q3: Why does the hail eventually fall out?

Complete the first part of the final model: cloud formation.

With your group

4. Re-watch the video of hail clouds forming.
5. Use *Final Hail Model Scaffold* as a starting point for modeling the first part of our final model for Q1: Why do clouds form?
   - Attach the scaffold for the first part of the model to the left side of your big chart paper.
   - Add pictures, symbols, and words to explain why hail clouds form.
   - Use your Gotta-Have-It Checklist from Lesson 10.

Add to the Gotta-Have-It Checklist.

With a partner

6. Work in pairs to review your Progress Trackers from Lessons 11 and 12 to add ideas to *Lesson 13: Gotta-Have-It Checklist*.

Read about the path of hailstones.

Turn and talk

7. Examine the photos of hail again.
8. Turn and talk about what might cause such big hailstones to form and what might cause their appearance. Be prepared to share ideas with the class.

On your own

9. Do a close reading to add to and support our ideas for how we can get really big hail. Use the following close reading strategy to make sense of *Reading: Tracing Paths of Hailstones*.
    - Identify the question(s) you are trying to answer in the reading.
    - Read once for understanding to see what the reading is about.
    - Read a second time to highlight a few key ideas that help answer the questions you had.
    - Summarize the key idea(s) in your own words, in diagrams, or both.
    - Jot down new questions that this raises for you.

With your class

10. Discuss new ideas from the reading that we think are important for explaining how hailstones can get so big and how they can form rings.
11. Add ideas to *Lesson 13: Gotta-Have-It Checklist* as your class agrees.

Complete the model to explain hailstorms.

With your group

12. Use your Gotta-Have-It Checklist to develop a model to answer Q2 and Q3 of our final model.
13. As you include ideas on your group's model, check them off on the checklist and label the concept on your model with its number from the checklist.

Applying Your Model

With your group

Models are the most powerful when we can use them to explain other phenomena or answer questions we have.

14. With your small group, use your model to answer questions from our Driving Question Board (DQB) and other questions that your teacher might pose.

Individual Summative Assessment

On your own

15. Use what you have figured out to demonstrate your learning on the assessment to explain air and water movement in a hurricane.

Evaluate our Driving Question Board questions.

With a partner

16. Turn and talk with a partner. Discuss which questions from our DQB that you think we have answered. Mark any questions you think the class has answered on *Revisiting Our Driving Question Board* 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: ✓+

What questions have we made progress on?

With a partner

17. Bring *Revisiting Our Driving Question Board* and 10 sticky dots over to the DQB.

18. Work with a partner to place your sticky dots on the sticky notes that match questions you think we have made progress on.

19. Once you have placed your 10 dots, move to the Scientists Circle.

20. As you are waiting for others to place their sticky dots:

- Be prepared to share out your evidence for what the answers to the questions might be.
- Notice and wonder about which questions have the most sticky dots.

Scientists Circle

21. As a class, discuss the answers to the questions that have the most sticky dots.

Lesson 14: What causes a large-scale precipitation event like this to occur?

Navigation

With your class

1. Discuss with your class:
    - What types of precipitation events have we explained so far?
    - What were some other types of precipitation events that occur on a larger scale that we also wanted to explain?

Exploring a Large-Scale Precipitation Event

On your own

2. Set up a Notice and Wonder chart in your notebook like the one on the slide.
3. Record in part 1 of your chart what you notice and wonder from the maps on *Snowfall and Ice Accumulation Forecast Maps* and from the forecast video.
4. Be ready to share your ideas with the class.

Continue exploring a large-scale precipitation event.

With a partner

5. With a partner, record in part 2 of your chart what you notice and wonder from the video and map on *Cloud Cover and Precipitation Map*.

Develop an initial model.

On your own

6. On your own, using *Initial Model*, develop a model to show what you think will happen in the air over the United States at three points in time related to the claims the forecaster made.

Compare models and explore more of the forecast.

On your own

7. Using *Evaluating Connections to Our Previous Model*, fill in column A with your predictions for the mechanisms causing the storm to produce large-scale rain, ice, and snowstorm.

With a partner

8. With a partner, record in part 3 of your chart what you notice and wonder from the video and maps on *Images from the Jan. 19, 2019 Weather Forecast*.

Update model alignment.

On your own

9. Revisit *Evaluating Connections to Our Previous Model* and look at your predictions in column A. Now that you have discussed the remainder of the video, images, and transcript, fill in column B with any revised predictions.

10. Add to the + section below the table any additional mechanisms you think might be at work. Don't fill out your response to the last question yet.

Compare mechanisms and develop a consensus record.

With a partner

11. With a new partner, compare and record at the bottom of *Evaluating Connections to Our Previous Model* any areas of agreement or disagreement.

Scientists Circle

12. Bring your notebook and handouts to the Scientists Circle.

13. As a class, develop a record of predicted model connections that is agreed on and where there are competing or alternative ideas.

Develop questions and add to the Driving Question Board (DQB).

On your own

14. Look back at your noticings and wonderings, your initial model and explanation, and the class consensus model mapping to find questions you want to add to our DQB.

15. Record one question per sticky note using a marker. Put your initials on the back in pencil.

16. Be ready to share your questions.

Identify additional sources of data needed.

Turn and talk

17. Turn and talk with a partner about the following question:

- What additional sources of data might we need to help figure out the answers to our questions?

Lesson 15: What happens with temperature and humidity of air in large storms?

Ideas for Future Investigations and Data We Need

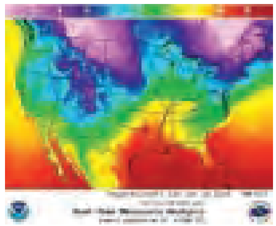
With your class

1. What additional sources of data did we need to help figure out how this storm formed in the first place?

Visualizing Temperature Data

With your class

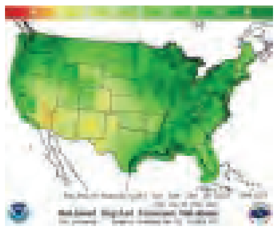
2. How does this convention help us visualize patterns in data?
3. Create a version of a temperature map colored by different bands using temperature data from January 17, 2019, 4:00 p.m.



Visualizing Humidity Data

With your class

4. How does this convention help us visualize patterns in data?
5. Create a version of this map using humidity data from January 17, 2019, 4:00 p.m.



Introduction to Air Masses

An *air mass* is defined as a large body of air with uniform temperature and humidity.

On your own

6. Given this definition, can you identify air masses on these two maps?
   - Where are warmer or colder air masses?
   - Where are humid or dry air masses?

With your group

7. Now, create another map of temperature and humidity data at a point during the storm.

Gallery Walk of Time-Series Maps

Place the time-series maps in order and view them closely from Time point 1 to Time point 11.

In your notebook

8. Track your noticings and wonderings in your notebook as you analyze the data from Time point 1 to Time point 11.

Exit Ticket

On your own

9. How do we know where one air mass ends and another begins?

Identifying Boundaries in Air Masses

The term *front* is used to identify where two different air masses meet. Weather reports identify fronts with lines.

With your group

10. Consider where the boundaries between air masses are on your map based on temperature and humidity.

Gallery Walk: Consider Where Precipitation Occurred

In your group

11. Review the time series again and consider this question:

- **How does the precipitation in the storm relate to the air masses we identified?**

12. Study the air mass boundaries and radar data closely.

Update your Progress Tracker.

With your class

13. Update the Progress Tracker in your science notebook to capture your thinking to the lesson question, "How is precipitation from the storm related to temperature and humidity data before, during, and after the storm?"

Question	Source of evidence
How is precipitation from the storm related to temperature and humidity data before, during, and after the storm?	
What I figured out in words and pictures	

What is happening at the boundaries of air masses?

With a partner

14. Why would precipitation happen where two air masses meet?

- Think about what you know about how storms form, including how air moves to generate clouds and precipitation.

Lesson 16: How do warm air masses and cold air masses interact along the boundaries between them?

Navigation

With a partner

1. Think about the data we analyzed in our last lesson. Talk with a partner about the following question:
   - As we looked for patterns in the air temperature and relative humidity data, what were we able to figure out?

With your class

2. 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?

Turn and talk

3. Talk with a partner about the following questions:
   - What do we already know about what happens to the air near the surface when it is warmed up? How does that happen?
   - How can we observe interactions between cold and warm air masses if we can't actually see air?
   - Be ready to share with the class.

Map the components of the experimental systems to the corresponding components in the atmosphere.

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 flow and interact 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.

With your class

4. Your teacher will pass out *Convection in Fluids*. Fill in the third column together with your class.

On your own

5. On your own, fill in the last two columns of *Convection in Fluids*.

Observe and record interactions between warm and cold water.

On your own

6. Make predictions on *Convection in Fluids* about what you think will happen when the boundary is removed.

7. Then, using pictures and words, record your observations for each setup.

Turn and talk

8. Discuss with a partner and record on page 3 of *Convection in Fluids*:

- How does warm water interact with cold water after we remove the vertical boundary?
- Why do you think this happened?

Discuss the observed interactions between warm and cold fluids.

With your class

9. Discuss with your class:

- What patterns do we notice among our observations?
- What do we now know about how warm and cold fluids interact?

Turn and talk

10. Turn and talk with a partner:

- What did we observe when warm and cold water interacted along a vertical boundary?

Model warm and cold air interactions in the atmosphere.

On your own

11. On the next blank page in your notebook, write this label at the top: "Warm and Cold Air Interactions".

12. Then use your observations from the water demonstration to draw an initial model of what you think happens

- when warm air moves towards cold air and
- when cold air moves towards warm air.

With a partner

13. Share your models with a partner. Look for similarities and differences between your models.

14. Be ready to share with the class.

With your class

15. Discuss with the class:

- How does your model compare to the model shown on the slide that scientists developed to represent what they think is happening along a warm front?
- How does your model compare to the model shown on the slide that scientists developed to represent what they think is happening along a cold front?

Analyze relative humidity data.

With a partner

16. Work with a partner to analyze the data in part A on *Relative Humidity Data*.

- What do the points along the graph line represent?
- 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?

With your class

17. What would cause more water to condense out of the air at 100% relative humidity?

With a partner

18. Work with a partner to analyze the data in part B on *Relative Humidity Data*.

- What do the points along the lower line represent?
- Do we still see the same relationship between air temperature and the amount of water vapor that air can hold? How do you know?

19. Work with your partner to answer the questions in part C of your handout. Use the graph on page 2 of *Relative Humidity Data* to help you.

20. Be ready to share your responses with the class.

Revisit weather models.

With your class

21. Why does the weather change along a front?

Navigation

On your own

22. Tape *Relative Humidity Data* in your notebook.

Lesson 17: Is there a relationship between where the air is rising and where precipitation falls?

Navigation

With a partner

Last time, we used a model to show how the air along a cold front and along a warm front interact.

1. With a partner, discuss your ideas about these questions:
   - Where does this model show air rising upward?
   - How could a barometer help detect this?
   - Why would clouds tend to develop over where this is happening?

Analyzing Our Weather Logs

Turn and talk

2. Open your notebooks to the page with *Weather Log*. With an elbow partner, discuss these questions:
   - Find days when the air pressure outside was higher than the day before. Did it tend to be cloudy or clear that day?
   - How about when the air pressure outside was lower than the day before? Did it tend to be cloudy or clear that day?

Making Predictions and Analyzing Data

On your own

3. Record your predictions in the response to the first two questions on the top of *Air Pressure Prediction and Map Analysis*.
4. Tape the handout into your notebook.
5. Find every city on your map that recorded an air pressure value that was below 29.80.
6. Circle each of those locations with an orange pencil and color it in.

With your group

7. Meet with your assigned group in the part of the room your teacher designates.
8. Layout your 11 maps on a wall in order (Map 1, Map 2, Map 3, and so forth) in preparation for a gallery walk.

Analyzing and Interpreting Data

On your own

9. Start a silent gallery walk to analyze the patterns in the 11 maps your group posted.
10. Answer the question at the bottom of *Air Pressure Prediction and Map Analysis* in your notebook when you are done.

Explaining the Original Forecast

With your class

11. Watch the weather forecast video from Jan. 19, 2019 again as a class.

On your own

12. Refer to the images from the video on *Images from the Jan. 19, 2019 Weather Forecast*.
13. Answer the questions on *Explaining Patterns and Predictions in the Forecast*.

Lesson 18: How can we explain what is happening across this storm (and other large-scale storms)?

Navigation

On your own

1. When you receive your *Explaining Patterns and Predictions in the Forecast* back, take 2 minutes to review your own explanation and add it to your science notebook.

Compare explanations.

With your group

2. Using *Explaining Patterns and Predictions in the Forecast* and *Comparing Ideas Used Between Explanations*, follow the Talking Stick Protocol to share and compare your explanations:
    - (1 minute) Pass a pencil to use as a talking stick to one person to share their explanation. Listen carefully for any reference they make to old model ideas or to a new model idea.
    - (1 minute) After they share, put a check mark in column A on *Comparing Ideas Used Between Explanations* next to each old model idea that was used.
    - (2 minutes) Now discuss any new ideas you heard used. Record each one of these in the **+ Additional Mechanisms** section of the table on *Comparing Ideas Used Between Explanations*. Add a check mark next to them in column A.
    - Repeat the steps above until every person has shared. For any idea that comes up again, add another check mark to it in column A.

On your own

3. Review all the ideas on *Comparing Ideas Used Between Explanations* that have a check mark in column A. If you think that this idea is also needed to explain what caused the patterns in the data from the Jan. 19-20 snow and ice storm, put a check mark next to it in column B.

Develop a consensus model.

With your class

4. Tape *Progress Tracker: Ideas Needed in Our Consensus Explanation* on the next blank page in your Progress Tracker section of your notebook.
5. With your class, discuss what model ideas are agreed upon and still disagreed upon for representing both large- and small-scale precipitation events.
6. As ideas are added to the class poster as agreed upon, put a check mark in the "Needed?" column on your *Progress Tracker: Ideas Needed in Our Consensus Explanation*.

With your class

7. Make predictions about whether you think weather forecasts for other parts of the country from different times of the year show evidence of any of these concepts:

- Large-scale air masses moving
- Frontal boundaries between those air masses producing lines of clouds and precipitation
- Areas of lower air pressure within or between different air masses

Prepare to investigate our predictions

We will explore predictions made for three different storms. These predictions were all made on the *TODAY Show* on Friday, Nov. 22, 2019 at 8:00 a.m. (EST).

On your own

8. Prepare two pages of your notebook with a table like the one represented below to record noticing and wonderings for 3 different parts of the forecast from Nov. 22, 2019:

Exploring a Second Weather Forecast from Nov. 22, 2019		
Evidence of	**Notice**	**Wonder**
Air masses moving	1. 2. 3.	
Lower pressure within part of an air mass	1. 2. 3.	
Precipitation along fronts or around a center of lowest pressure air	1. 2. 3.	

With your class

9. Watch the video of the forecast with your class all the way through one time. ***Do not*** record anything yet in your notebook.

Record your observations.

On your own

10. Your teacher will hand out *Nov. 22, 2019 Weather Forecast Maps*. This handout shows images from the video forecast of all three storms.

11. Watch the first part of the forecast again about storm 1. Record what you notice and wonder for the predictions about storm 1.

12. Watch the second part of the forecast again about storm 2. Record what you notice and wonder for the predictions about storm 2.

13. Watch the third part of the forecast again about storm 3. Record what you notice and wonder for the predictions about storm 3.

Consensus Discussion

With your class

14. Share with the class your noticings from the predictions about the three storms that support the three lines of evidence.

Turn and talk

15. Share some of your wonderings with a partner.

Share initial explanations.

In your group

16. Count off with your group so each of you is assigned one number: 1, 2, 3 or 4.

17. Pair up into partners: 1 & 2 and 3 & 4. Discuss with this partner your ideas about these questions:

- Do you think that all the other storm systems that affect these different parts of the country would follow similar paths? Why or why not?

18. Now switch partners: 1 & 3 and 2 & 4. Discuss with this partner your ideas about these questions:

- Are the places highlighted on the slide (New England, the Rockies, and the Southwest) the parts of the country that typically receive more precipitation than others? Why or why not?

19. Switch partners one more time: 1 & 4 and 2 & 3. Discuss with this partner your ideas about these questions:

- Do you think that higher-elevation places typically receive different types of precipitation than lower-elevation places? Why or why not? How do you think the amount of precipitation they typically receive compares?

Record additional questions.

On your own

20. Look over your wonderings from earlier in this lesson. Consider ideas you discussed with your partners. Write your most compelling question(s) on a sticky note, one question per sticky note. Use a marker to write your question and put your initials on back in pencil.

Scientists Circle

21. Bring your sticky notes and science notebook to the Scientists Circle.

22. Be ready to share your questions with the class.

Ideas for Future Investigations and Data We Need

Turn and talk

23. Talk with a partner about what additional sources of data we will need to help figure out the answers to our new questions.

24. Jot these ideas down in your notebook.

Lesson 19: Are there patterns to how air masses move that can help predict where large storms will form?

Navigation

With your class

1. Discuss with your class:
    - What are the important ideas we figured out in the last class period?
    - What questions did we add to our DQB and why did we add them?

Observations of Precipitation in the U.S. over 1 Week

Scientists Circle

2. The visualization includes:
    - real data
    - satellite data and data from weather stations on the ground
    - worldwide from August 4 to 11, 2014
3. Discuss with your class:
    - How will this data visualization help us answer our questions?
4. Set up your notebook for observations.
5. Record observations in your notebook.

Turn and talk

6. Share what you noticed with a partner.
7. Add additional noticings to your science notebook.

Scientists Circle

8. Decide on how to annotate the class chart.
9. Make observations of the visualization for a 2nd time.
10. Work with your class to annotate your class map.
11. Discuss with your class:
    - Is this sort of pattern of air movement from west to east something that happens all the time?
12. Then discuss:
    - Do you think if we looked at a longer time period this pattern would change?
    - How much time do we need to feel confident in our conclusions?

Observations of Precipitation in the World over 8 Months

Scientists Circle

13. The visualization includes:

- real data
- satellite data and data from weather stations on the ground
- worldwide from April 1 to September 30, 2014

14. Discuss with your class:

- How will this new data visualization help us feel more confident in what we were seeing in the one-week visualization?

15. Set up your notebook for observations.

16. Focus on the United States when your teacher plays the visualization.

17. Record observations in your notebook.

18. Discuss the following questions:

- What did you notice was similar?
- What did you notice was different or new now that we are observing more time?

19. Share what you know about weather compared to climate. Build a class chart with examples of day-to-day weather events and predictable and stable climate patterns.

20. Now, focus on your assigned location when your teacher plays the visualization.

21. Record observations in your notebook. Your teacher will prompt someone with your assigned location to annotate the class map.

Building Understandings Discussion

Scientists Circle

22. Discuss the following questions with your class:

- What did we notice when we looked at the whole world?
- After 8 months of data, did you notice a pattern. How do you know?
- How could the winds flowing in a certain direction affect air masses and where they may collide?
- How can these predictable winds, which scientists call “prevailing winds”, help us predict whether a place will get precipitation?

Navigation and Exit Ticket

On your own

23. Share your thinking about how the ocean influences air masses and precipitation:

- How do oceans impact an air mass?
- Does “closeness” to the ocean affect precipitation in a location?

Lesson 20: How do oceans affect whether a place gets a lot or a little precipitation?

Navigation

Turn and talk

1. Discuss with a partner:
   - What are the important ideas we figured out in the last class period?
   - How do prevailing winds affect where air masses go?

Air Mass Movement

With your class

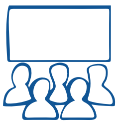
2. Discuss, as a class, the three prompts below:
   - Where do air masses of different temperatures come from?
   - How do they move across the United States?
   - Where do they often collide to form large storms?
3. Work with your class to represent your thinking on a class map.

Observations of Ocean Temperatures

In your notebook

4. Find a new page in your science notebook and draw a Notice and Wonder chart.
5. Title the page "Ocean Temperatures".

With your class



6. Prepare to make observations from a visualization showing sea surface temperatures. This visualization uses real data collected from satellites and bouys over several months.
7. Watch the visualization without recording noticings. When your teacher pauses the visualization, take a moment to write down noticings in your notebook.
8. Continue to watch the visualization and add noticings following your teacher's instruction.
9. Make sure to make observations about the ocean around the United States.
10. Add wonderings to your science notebook.
11. Share your noticings and wonderings with your class.

Close Reading Strategy of the "How the Ocean Changes Weather" Reading

On your own

12. Use the following close reading strategy to make sense of *How the ocean changes our weather*:

- Identify the question(s) you are trying to answer in the reading.
- Read once for understanding to see what the reading is about.
- Read a second time to highlight a few key ideas that help answer the questions you had.
- Summarize the key idea(s) in your own words, in diagrams, or both.
- Jot down new questions this raises for you.

Navigation and Exit Ticket

On your own

13. Complete the exit ticket before you leave class:

- How do oceans affect whether a place gets a lot or a little precipitation?
- How do oceans relate to the air masses we have been investigating?

Remember to support your thinking with evidence from the reading and other sources of data that we have seen.

Finish your close reading of the "How the ocean changes weather" reading.

On your own

14. Finish using the close reading strategy to summarize what you learned from *How the ocean changes our weather*:

- Summarize the key idea(s) in your own words, in diagrams, or both.
- Jot down new questions this raises for you.

15. Attach the reading to your science notebook.

Precipitation in Coastal Cities

With your group

16. Examine the average annual precipitation data for 8 coastal cities using *Precipitation in Coastal Cities of the United States*.

17. Apply ideas about ocean temperatures and currents to make sense of the data as your group discusses the analysis questions.

18. Add notes to the data sheet as your group discusses the analysis questions.

19. Attach the data to your science notebook.

Consensus Discussion

Scientists Circle

20. Our question: How do oceans affect whether a place gets a lot or a little precipitation?

- What new things have we learned?
- What can we conclude from the evidence we have gathered?

21. What new things about the ocean seem important to capture on our Air Mass Map?

- What do we agree on? How do we want to represent these new ideas?
- Do we have evidence to support our ideas?
- What are we still wondering about?

Update your Progress Tracker.

In your notebook

22. Locate your Progress Tracker in your notebook.

23. Draw a line under the last entry.

24. Write the lesson question in the left column.

25. In the right column, use words and/or pictures to document what you have figured out related to the lesson question.

Navigation

Scientists Circle

26. Watch the precipitation visualization with your class.

- What parts of the visualization can you already explain?
- What are new things you notice that you cannot yet explain?

27. Discuss with your class:

- What do the different precipitation patterns in the east compared to the west make you wonder about?

Lesson 21: Why is there less precipitation further inland in the Pacific Northwest than further inland from the Gulf Coast?

Navigation

With your class

1. Discuss with the class:
   - What were our initial ideas about why there is less precipitation further inland in the Pacific Northwest than further inland from the Gulf Coast?

Analyze data with the I^2 strategy.

We will look at two different pathways, one in the Pacific Northwest from Seattle to Spokane, WA and the other in the Gulf Coast region from New Orleans, LA to Chattanooga, TN. Each pathway has five different locations along it with data we can analyze. These pathways follow the directions of the prevailing winds, which are the directions that air masses would travel.

With a partner

2. Divide into partners within your group. Within each group, one partnership should analyze Pathway 1 and the other partnership should analyze Pathway 2 on *Maps and Data for the Pacific Northwest and Gulf Coast*.
3. Use the I^2 strategy when analyzing the data for your chosen Pathway.
4. When you are finished, tape *Maps and Data for the Pacific Northwest and Gulf Coast* into your notebook.

With your group

5. Share your analysis and interpretations with your group.
   a. What patterns did you notice?
   b. How do the patterns from your pathway compare to the other pathway?
   c. What interpretations do you have for the observed patterns?
   d. How do your interpretations about your pathway compare to the other pathway?

Model what is happening to air along the pathways.

With your group

6. Using *Profile Views: Pacific Northwest and Gulf Coast*, model what you think is happening to an air mass as it moves over each of the five locations on one of the pathways. Then model what you think is happening to an air mass that moves over each of the five locations on the other pathway.
7. Tape this handout into your notebook.

Building Understandings Discussion

Scientists Circle

8. Bring your notebook to the Scientist Circle. Both *Maps and Data for the Pacific Northwest and Gulf Coast* and *Profile Views: Pacific Northwest and Gulf Coast* should be taped into your notebook.

9. Share with the class your interpretations and 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.

Update Progress Tracker.

On your own

10. Locate your Progress Tracker in your notebook.

11. Draw a line under the last entry.

12. Write the question we are working on in the left column: "Why is there less precipitation further inland in the Pacific Northwest than further inland from the Gulf Coast?"

13. Write what you figured out in the column on the right, using words and/or pictures. Take as much space as you need to record your thoughts.

Explaining Climate Patterns Outside of the United States

With a partner

14. Discuss with a partner and record your ideas in your notebook:

    a. What are all the key ideas that could help you explain long term temperature and precipitation patterns?

    b. What data would you need to evaluate if each key idea was part of the explanation?

With your class

15. Share the ideas you and your partner discussed with the class.

Lesson 22: How can we explain differences in climate in different parts of the world?

Rainforests of South America

South America is home to many of the world's rainforests. Many of the species in the world live in these rainforests. Two reasons for this include

- the abundance of water (needed for plant growth) and
- stable temperatures (animals may more easily survive year-round).

There are two kinds of rainforests—tropical rainforests and temperate rainforests. South America has both types of rainforests. These rainforests are located in the sections of the map shown below:

Both types of rainforest receive much more rain over the course of a year than other parts of the world. But tropical rainforests are warmer than temperate rainforests.

What key ideas and data do we need?

Turn and talk

1. Turn and talk with your elbow partner about what key ideas and data might be needed to help us explain
   - why the rainforests are located where they are and
   - why they have different climates.

Individual Assessment

On your own

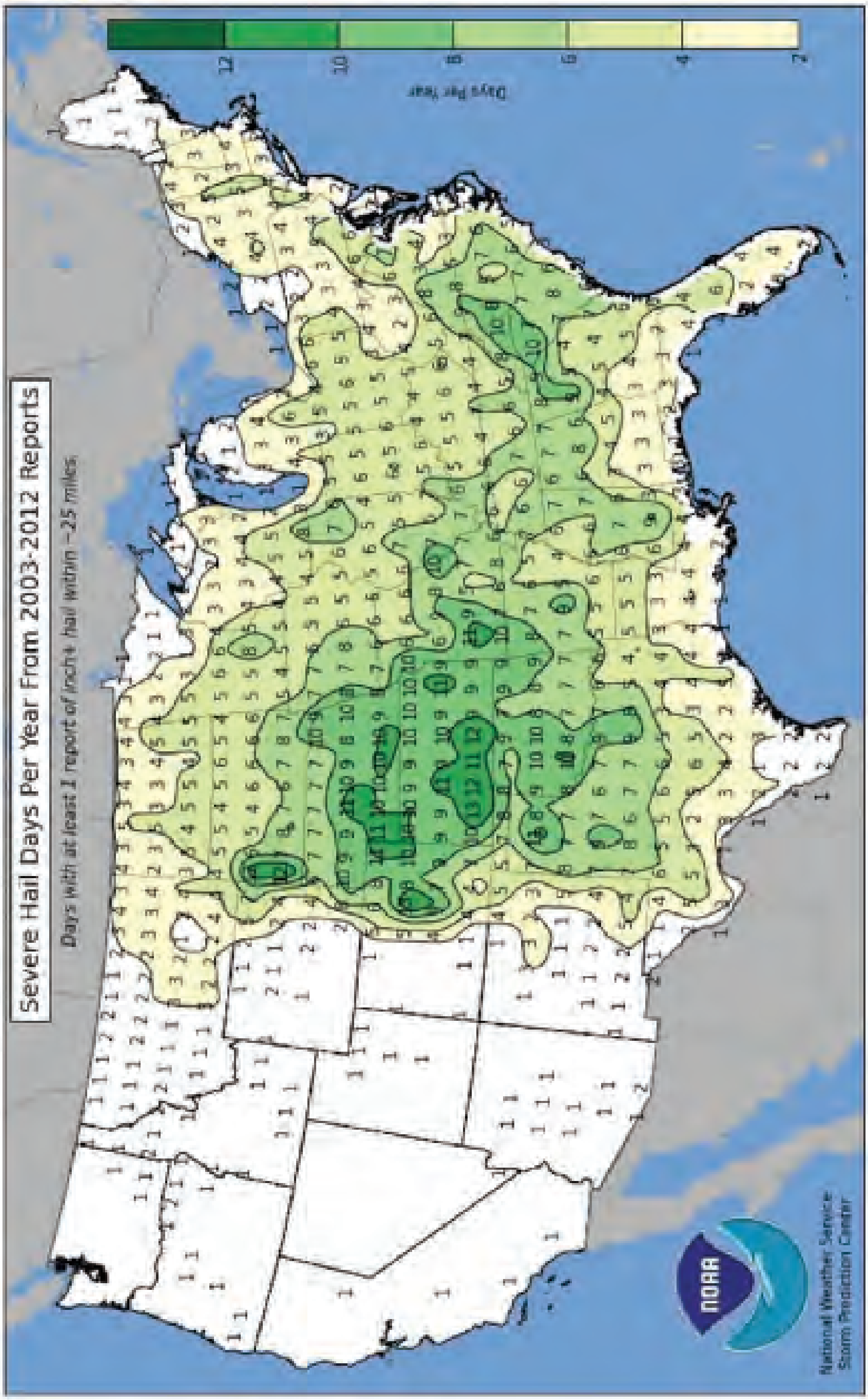
2. Complete the *Rainforest Climate Assessment Tasks*.

Revisit our DQB.

Scientists Circle

3. Place your sticky dots on the sticky notes that match the questions you think we have made progress on.
4. Once you have placed your 5 dots, step back to the Scientists Circle.
5. As you are waiting for others to place their sticky dots:
   - Be prepared to share out your ideas for the answers to the questions, along with your evidence for these answers.
   - Notice which questions have the most sticky dots and wonder about why these questions have the most dots.
6. Which questions have we made the most progress on?
7. What have we figured out?

Hail Frequency Map

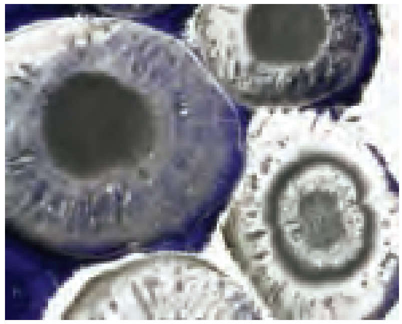


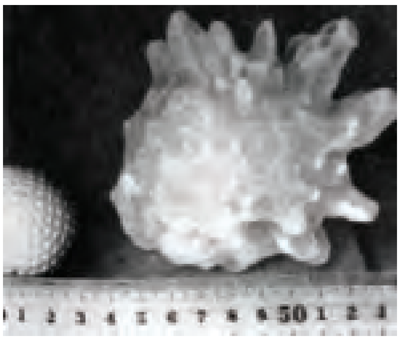
NOAA/National Weather Service

Hailstone Images





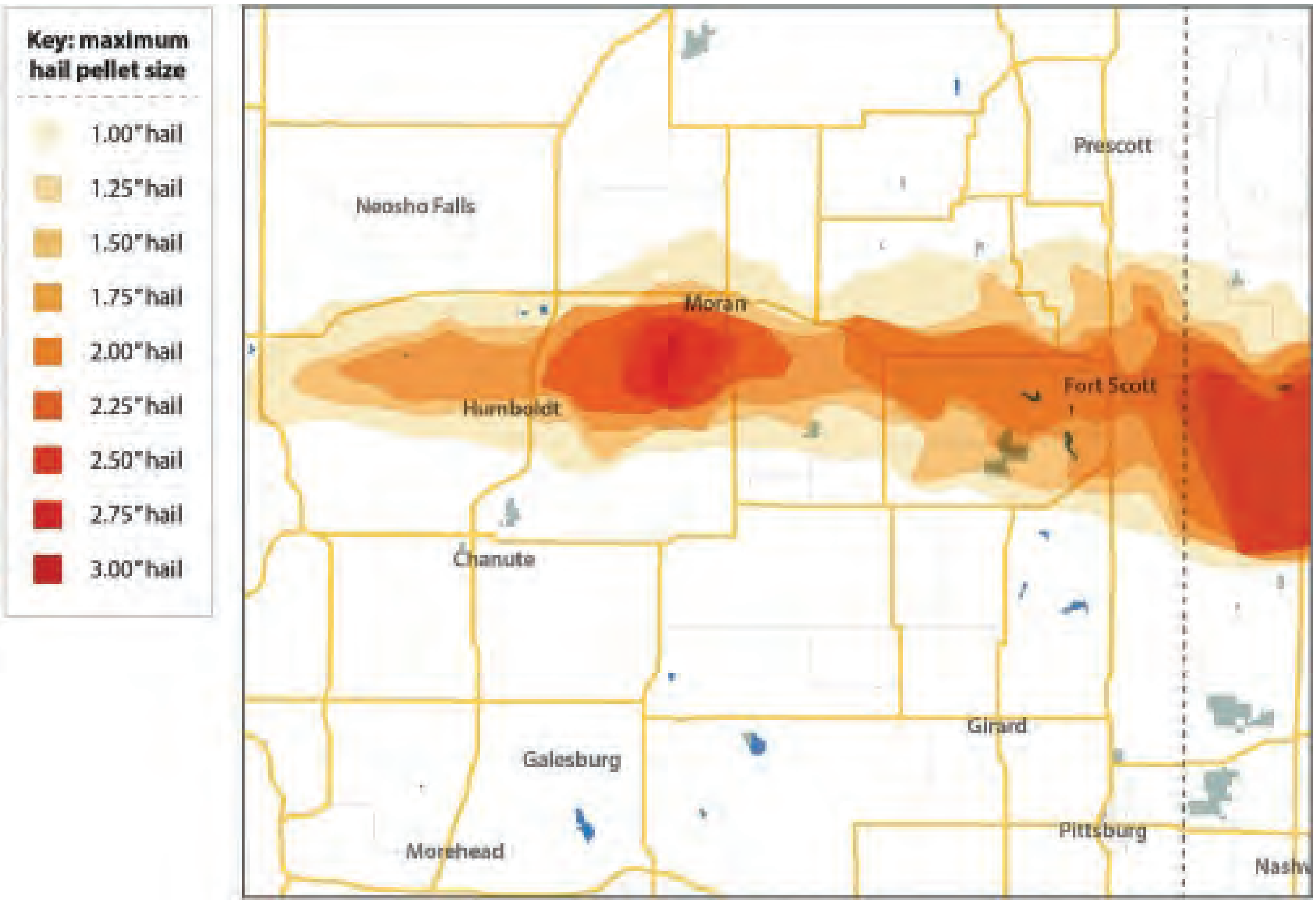





Weather Data for Fort Scott

Site	Location	Date	Approximate time of day
❇	Fort Scott, KS	April 7, 2013	4:25 PM
A	Phoenix, AZ	Oct. 5, 2010	12:30 and 4:30 PM
B	Oklahoma City, OK	April 26, 2013	8:30 PM
C	Dallas, TX	June 13, 2012	6:30 PM
D	Winnipeg, Manitoba, Canada	June 10, 2013	6:30 PM
E	New Orleans, LA	Feb. 24, 2013	9:15 PM
F	Indianapolis, IN	Aug. 25, 2018	5:30 PM
G	Pittsfield, MA	May 15, 2018	No record avail.

Hail map



Weather Data for Fort Scott, continued

Weather station: Chanute Martin Johnson Station, KS

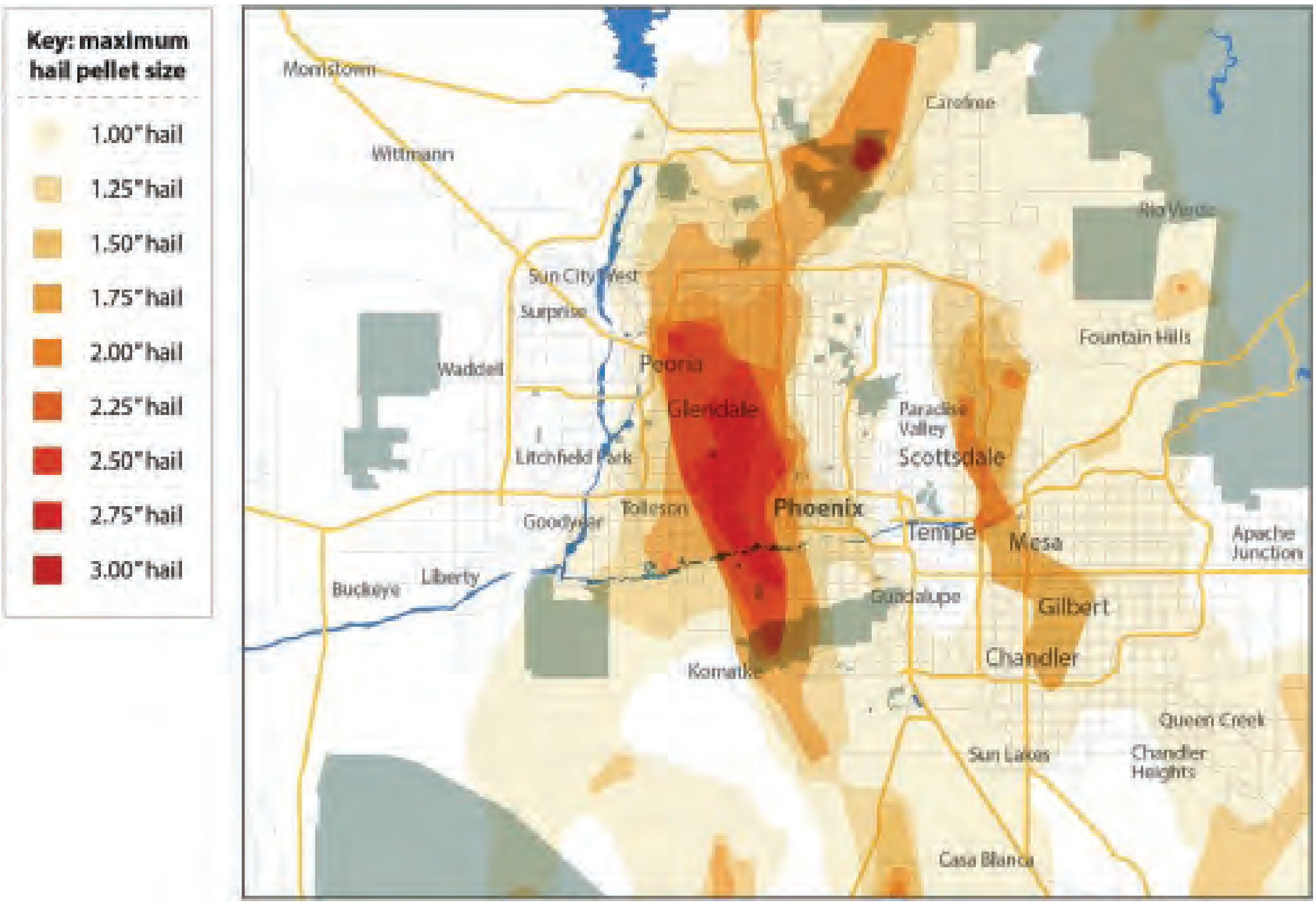
Time	Temperature (°F)	Relative humidity (%)	Wind speed (mph)	Wind gust (mph)
5:52 AM	44	93	3	0
6:52 AM	46	89	0	0
7:52 AM	50	89	0	0
8:52 AM	55	83	5	0
9:52 AM	62	72	9	0
10:52 AM	64	75	8	0
11:52 AM	67	70	8	0
12:52 PM	70	63	13	17
1:52 PM	73	57	17	24
2:52 PM	70	65	15	20
3:52 PM	68	68	12	17
4:52 PM	59	78	30	37
4:59 PM	59	77	17	37
5:30 PM	63	72	6	0
5:52 PM	65	68	3	0
6:52 PM	64	75	6	0
7:35 PM	66	73	17	25
7:52 PM	63	84	17	28

Weather Data from Seven Hailstorm Sites

Weather Data for Site A (Phoenix)

Site	Location	Date	Approximate time of day
*	Fort Scott, KS	April 7, 2013	4:25 PM
A	Phoenix, AZ	Oct. 5, 2010	12:30 and 4:30 PM
B	Oklahoma City, OK	April 26, 2013	8:30 PM
C	Dallas, TX	June 13, 2012	6:30 PM
D	Winnipeg, Manitoba, Canada	June 10, 2013	6:30 PM
E	New Orleans, LA	Feb. 24, 2013	9:15 PM
F	Indianapolis, IN	Aug. 25, 2018	5:30 PM
G	Pittsfield, MA	May 15, 2018	No record avail.

Hail map



Weather Data for Site A, continued

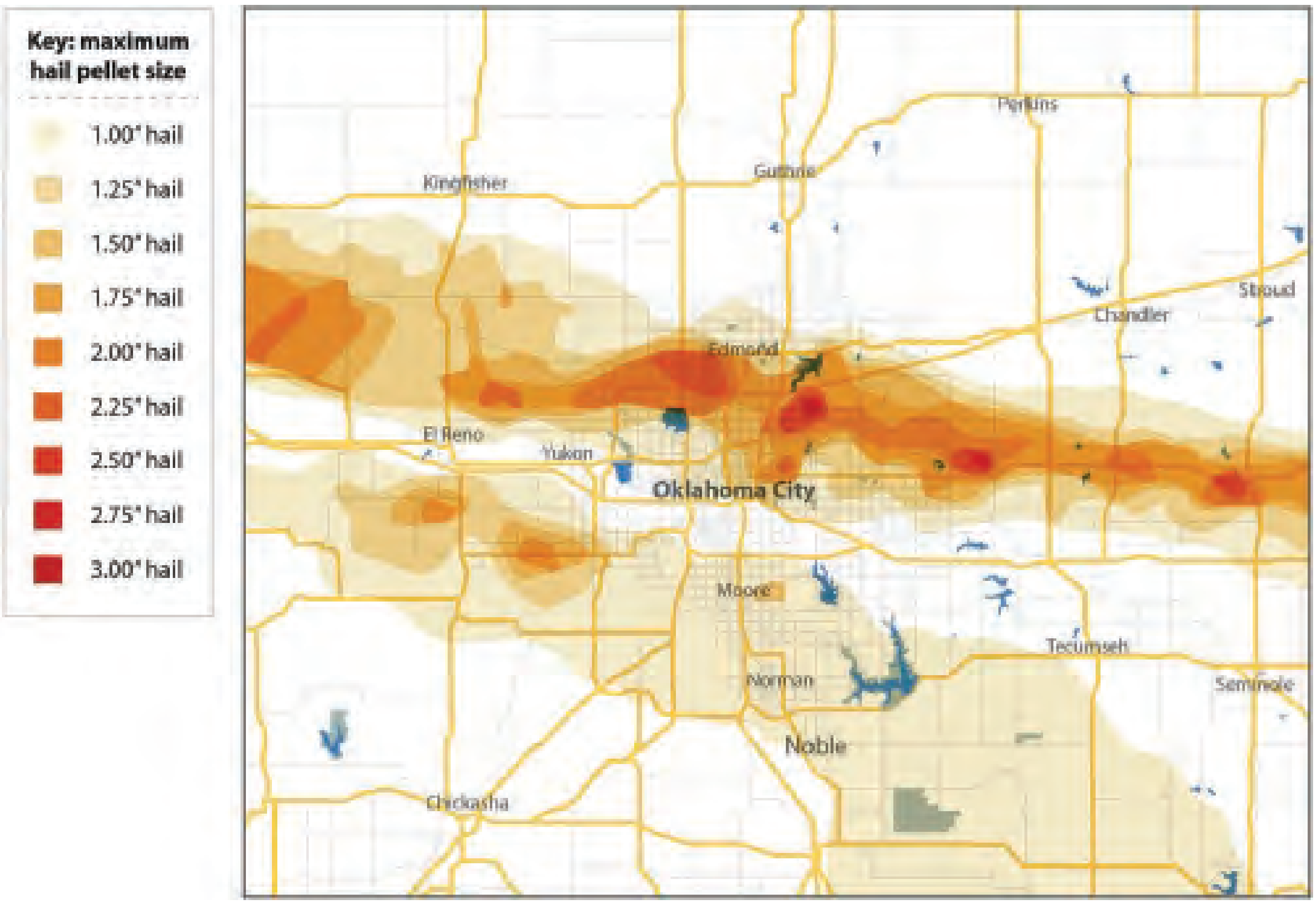
Weather station: Phoenix Sky Harbor International Station, AZ

Time	Temperature (°F)	Relative humidity (%)	Wind speed (mph)	Wind gust (mph)
6:51 AM	73	66	9	0
7:51 AM	73	64	10	0
8:51 AM	77	54	13	17
9:51 AM	78	52	15	0
10:51 AM	81	45	10	0
11:51 AM	86	38	13	21
12:06 PM	86	37	1	0
12:36 PM	81	45	17	37
12:38 PM	75	53	15	37
12:49 PM	73	57	6	0
12:51 PM	74	55	9	0
1:16 PM	72	60	8	0
1:40 PM	73	65	9	0
1:51 PM	75	57	12	0
2:11 PM	75	53	9	0
2:51 PM	79	48	6	0
3:24 PM	73	69	16	0
3:51 PM	71	78	7	0
4:13 PM	72	83	14	0
4:51 PM	68	94	3	25
5:04 PM	66	94	10	0
5:35 PM	66	94	7	0
5:51 PM	69	84	8	0
6:51 PM	70	84	8	0
7:51 PM	70	81	9	0

Weather Data for Site B (Oklahoma City)

Site	Location	Date	Approximate time of day
✻	Fort Scott, KS	April 7, 2013	4:25 PM
A	Phoenix, AZ	Oct. 5, 2010	12:30 and 4:30 PM
B	Oklahoma City, OK	April 26, 2013	8:30 PM
C	Dallas, TX	June 13, 2012	6:30 PM
D	Winnipeg, Manitoba, Canada	June 10, 2013	6:30 PM
E	New Orleans, LA	Feb. 24, 2013	9:15 PM
F	Indianapolis, IN	Aug. 25, 2018	5:30 PM
G	Pittsfield, MA	May 15, 2018	No record avail.

Hail map



Weather Data for Site B, continued

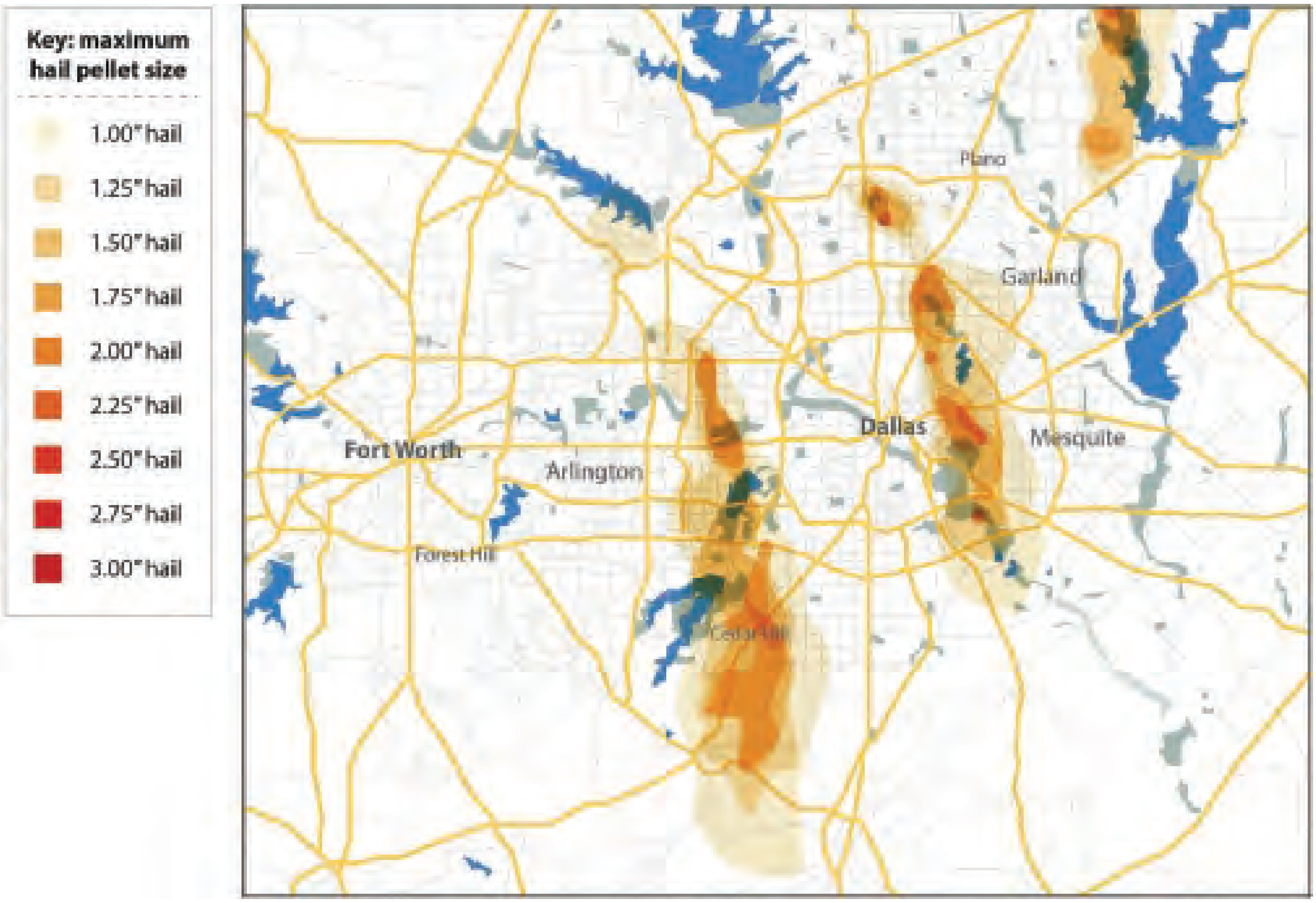
Weather station: Will Rogers World Station, OK

Time	Temperature (°F)	Relative humidity (%)	Wind speed (mph)	Wind gust (mph)
5:53 AM	73	76	12 mph	0 mph
6:53 AM	71	84	6 mph	0 mph
7:44 AM	73	78	7 mph	0 mph
7:53 AM	73	76	6 mph	0 mph
8:53 AM	73	76	3 mph	0 mph
9:53 AM	74	73	3 mph	0 mph
10:53 AM	75	69	13 mph	0 mph
11:53 AM	77	69	12 mph	0 mph
12:53 PM	82	65	10 mph	0 mph
1:53 PM	85	57	10 mph	20 mph
2:53 PM	87	53	13 mph	0 mph
3:53 PM	89	50	15 mph	0 mph
4:53 PM	90	48	16 mph	22 mph
5:53 PM	88	49	18 mph	0 mph
6:53 PM	81	60	24 mph	33 mph
7:53 PM	79	74	13 mph	0 mph
8:53 PM	77	79	6 mph	0 mph
9:53 PM	78	76	0 mph	0 mph

Weather Data for Site C, (Dallas)

Site	Location	Date	Approximate time of day
✻	Fort Scott, KS	April 7, 2013	4:25 PM
A	Phoenix, AZ	Oct. 5, 2010	12:30 and 4:30 PM
B	Oklahoma City, OK	April 26, 2013	8:30 PM
C	Dallas, TX	June 13, 2012	6:30 PM
D	Winnipeg, Manitoba, Canada	June 10, 2013	6:30 PM
E	New Orleans, LA	Feb. 24, 2013	9:15 PM
F	Indianapolis, IN	Aug. 25, 2018	5:30 PM
G	Pittsfield, MA	May 15, 2018	No record avail.

Hail map



Weather Data for Site C, continued

Weather station: University Park Station, TX

Time	Temperature (°F)	Relative humidity (%)	Wind speed (mph)	Wind gust (mph)
5:52 AM	59	53	17 mph	0 mph
6:52 AM	59	55	17 mph	22 mph
7:06 AM	59	55	21 mph	29 mph
7:52 AM	58	58	17 mph	25 mph
8:52 AM	58	62	10 mph	0 mph
9:52 AM	61	56	21 mph	26 mph
10:52 AM	61	64	20 mph	24 mph
11:52 AM	62	67	16 mph	0 mph
12:52 PM	59	78	16 mph	0 mph
1:04 PM	63	77	14 mph	0 mph
2:52 PM	66	73	17 mph	0 mph
3:52 PM	66	75	8 mph	0 mph
4:52 PM	68	70	13 mph	0 mph
5:52 PM	70	65	14 mph	0 mph
6:52 PM	69	68	15 mph	0 mph
7:52 PM	66	75	9 mph	0 mph
8:44 PM	63	82	18 mph	0 mph
8:52 PM	62	86	16 mph	25 mph
9:03 PM	61	82	31 mph	38 mph
9:12 PM	57	88	17 mph	40 mph
9:18 PM	57	88	15 mph	30 mph
9:46 PM	57	94	25 mph	32 mph
9:52 PM	56	93	15 mph	32 mph
10:03 PM	55	94	10 mph	22 mph
10:16 PM	55	94	12 mph	0 mph

Weather Data for Site D (Winnipeg)

Site	Location	Date	Approximate time of day
✻	Fort Scott, KS	April 7, 2013	4:25 PM
A	Phoenix, AZ	Oct. 5, 2010	12:30 and 4:30 PM
B	Oklahoma City, OK	April 26, 2013	8:30 PM
C	Dallas, TX	June 13, 2012	6:30 PM
D	Winnipeg, Manitoba, Canada	June 10, 2013	6:30 PM
E	New Orleans, LA	Feb. 24, 2013	9:15 PM
F	Indianapolis, IN	Aug. 25, 2018	5:30 PM
G	Pittsfield, MA	May 15, 2018	No record avail.

Hail map

No hail map available for this event

Weather Data for Site D, continued

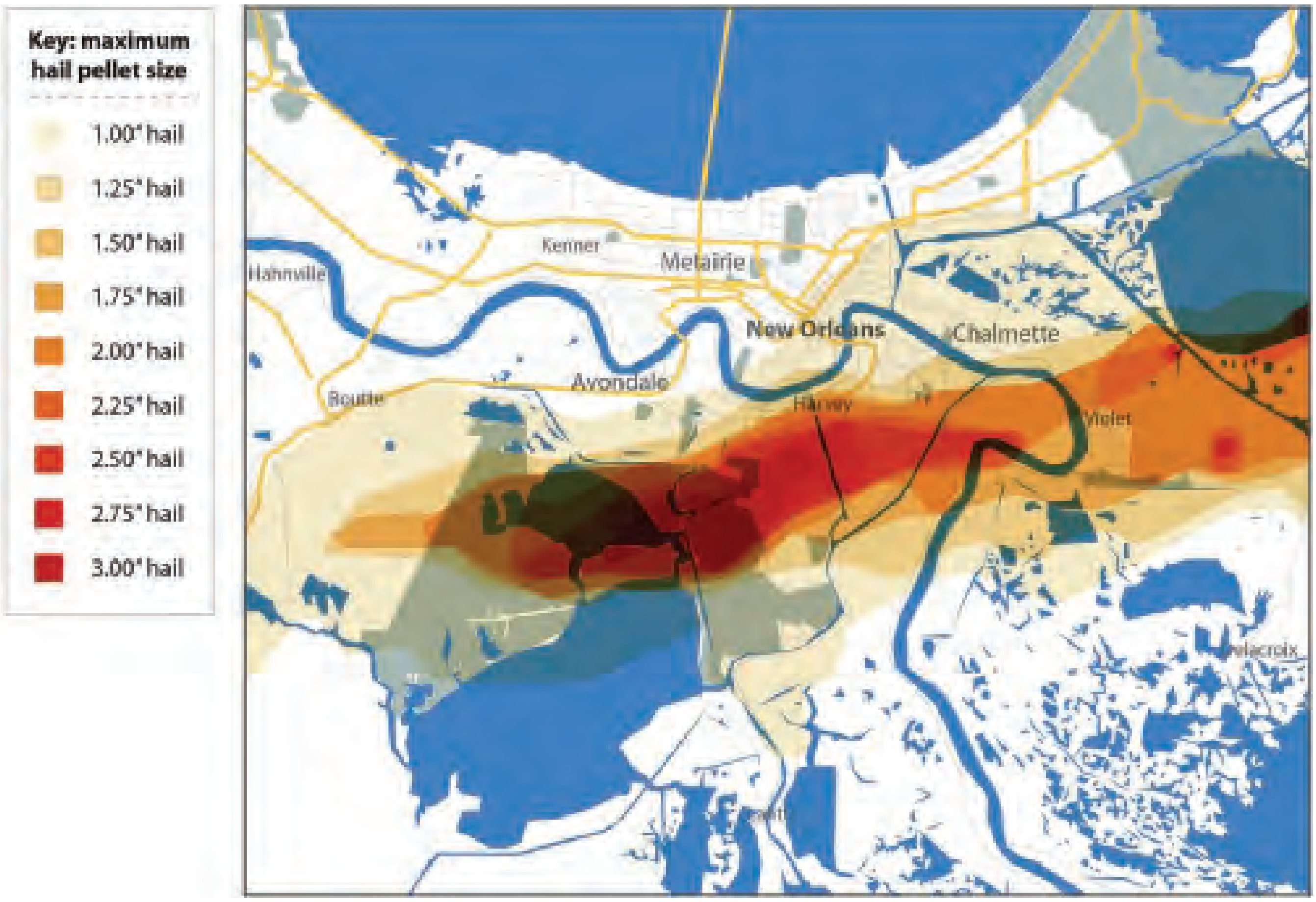
Weather station: University of Winnipeg Station, Manitoba, Canada

Time	Temperature (°F)	Relative humidity (%)	Wind speed (mph)	Wind gust (mph)
5:00 AM	55	94	8 mph	0 mph
6:00 AM	57	88	9 mph	0 mph
7:00 AM	57	88	9 mph	0 mph
8:00 AM	59	88	9 mph	0 mph
9:00 AM	63	77	10 mph	0 mph
10:00 AM	63	82	10 mph	17 mph
11:00 AM	64	73	13 mph	0 mph
12:00 PM	66	68	10 mph	0 mph
1:00 PM	66	73	12 mph	0 mph
2:00 PM	68	64	8 mph	0 mph
3:00 PM	72	60	6 mph	0 mph
4:00 PM	75	53	14 mph	21 mph
4:20 PM	72	57	13 mph	21 mph
4:32 PM	66	78	18 mph	39 mph
4:43 PM	68	83	25 mph	0 mph
5:00 PM	68	73	14 mph	21 mph
6:00 PM	70	64	8 mph	0 mph
7:00 PM	72	53	22 mph	29 mph
8:00 PM	64	59	14 mph	22 mph
9:00 PM	64	64	9 mph	0 mph
10:00 PM	57	82	8 mph	0 mph

Weather Data for Site E (New Orleans)

Site	Location	Date	Approximate time of day
✻	Fort Scott, KS	April 7, 2013	4:25 PM
A	Phoenix, AZ	Oct. 5, 2010	12:30 and 4:30 PM
B	Oklahoma City, OK	April 26, 2013	8:30 PM
C	Dallas, TX	June 13, 2012	6:30 PM
D	Winnipeg, Manitoba, Canada	June 10, 2013	6:30 PM
E	New Orleans, LA	Feb. 24, 2013	9:15 PM
F	Indianapolis, IN	Aug. 25, 2018	5:30 PM
G	Pittsfield, MA	May 15, 2018	No record avail.

Hail map



Weather Data for Site E, continued

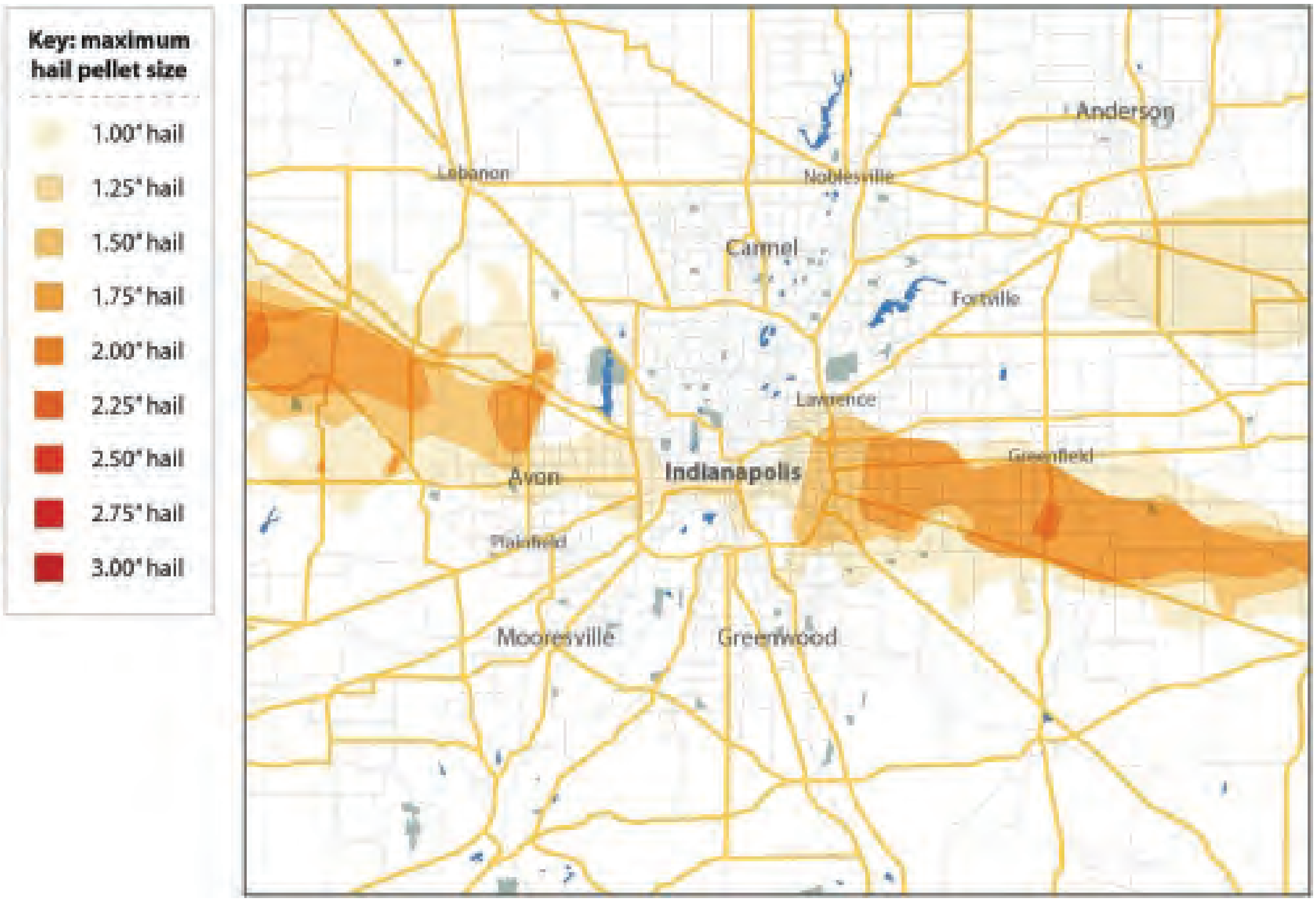
Weather station: New Orleans Naval Air Station, LA

Time	Temperature (°F)	Relative humidity (%)	Wind speed (mph)	Wind gust (mph)
5:55 AM	50	82	5 mph	0 mph
6:55 AM	54	72	10 mph	0 mph
7:55 AM	54	79	8 mph	0 mph
8:55 AM	60	76	6 mph	0 mph
9:55 AM	60	75	14 mph	0 mph
10:55 AM	63	71	8 mph	0 mph
11:55 AM	63	70	9 mph	0 mph
12:02 PM	63	72	10 mph	0 mph
12:55 PM	----	----	----	----
1:55 PM	62	75	12 mph	0 mph
2:55 PM	60	72	7 mph	0 mph
3:55 PM	60	75	9 mph	0 mph
4:55 PM	60	81	9 mph	0 mph
5:55 PM	59	81	9 mph	0 mph
6:55 PM	63	84	8 mph	0 mph
7:55 PM	62	86	12 mph	17 mph
8:55 PM	62	89	10 mph	0 mph
9:17 PM	61	94	23 mph	35 mph
9:36 PM	61	94	12 mph	0 mph
9:51 PM	61	94	8 mph	0 mph
9:55 PM	61	90	8 mph	0 mph
10:55 PM	61	90	7 mph	0 mph

Weather Data for Site F (Indianapolis)

Site	Location	Date	Approximate time of day
✻	Fort Scott, KS	April 7, 2013	4:25 PM
A	Phoenix, AZ	Oct. 5, 2010	12:30 and 4:30 PM
B	Oklahoma City, OK	April 26, 2013	8:30 PM
C	Dallas, TX	June 13, 2012	6:30 PM
D	Winnipeg, Manitoba, Canada	June 10, 2013	6:30 PM
E	New Orleans, LA	Feb. 24, 2013	9:15 PM
F	Indianapolis, IN	Aug. 25, 2018	5:30 PM
G	Pittsfield, MA	May 15, 2018	No record avail.

Hail map



Weather Data for Site F, continued

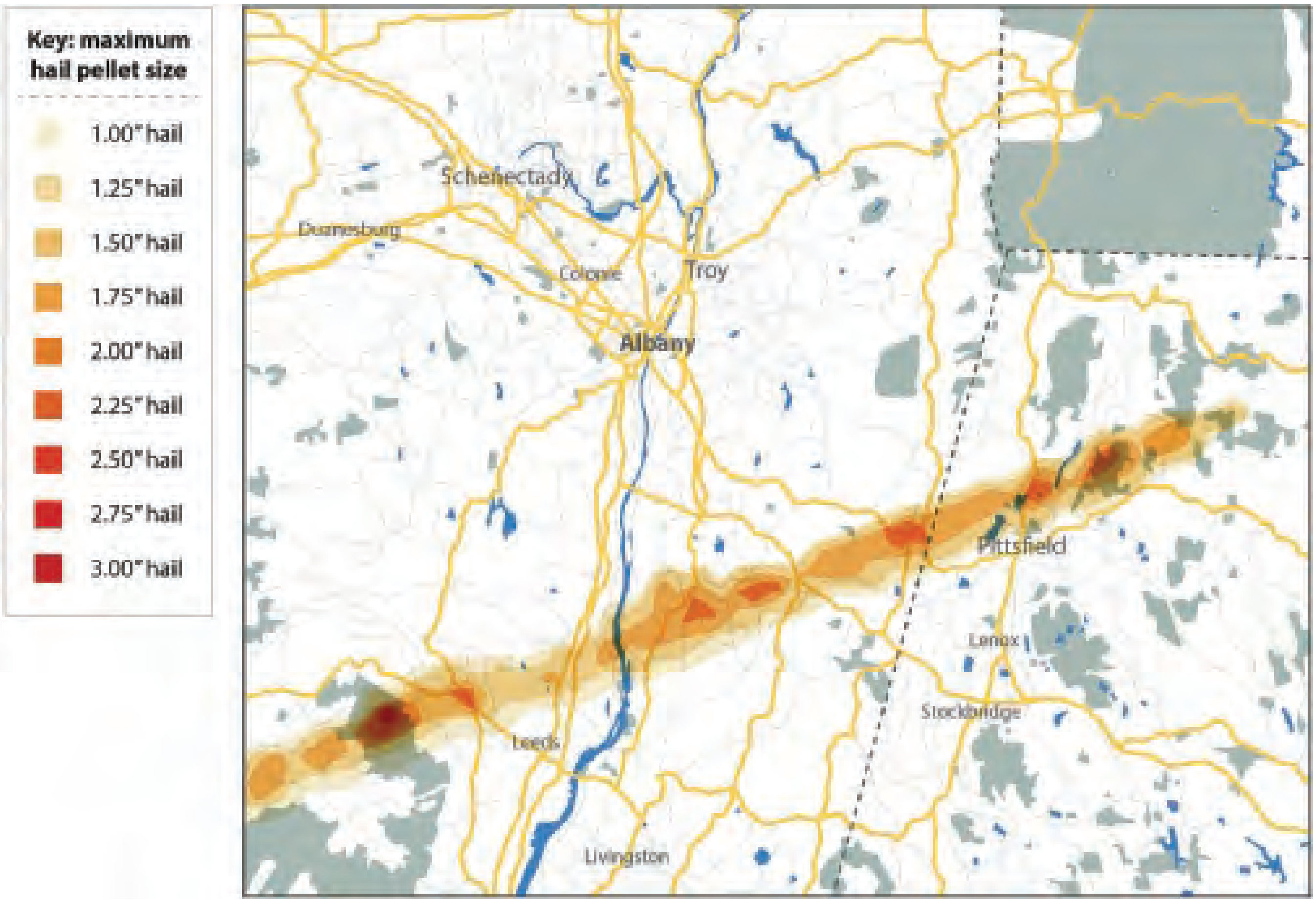
Weather station: Indianapolis International Station, IN

Time	Temperature (°F)	Relative humidity (%)	Wind speed (mph)	Wind gust (mph)
8:42 AM	70	84	9 mph	0 mph
8:54 AM	70	87	7 mph	0 mph
9:54 AM	69	90	26 mph	32 mph
10:20 AM	69	93	20 mph	33 mph
10:47 AM	69	93	24 mph	37 mph
10:54 AM	69	93	23 mph	33 mph
11:54 AM	69	96	9 mph	0 mph
12:54 PM	72	87	9 mph	0 mph
1:54 PM	76	85	16 mph	0 mph
2:54 PM	70	81	8 mph	0 mph
3:54 PM	81	74	17 mph	25 mph
4:54 PM	81	74	14 mph	0 mph
5:20 PM	81	74	13 mph	22 mph
5:50 PM	82	74	10 mph	0 mph
5:54 PM	82	74	10 mph	0 mph
6:09 PM	81	77	7 mph	0 mph
6:54 PM	80	85	6 mph	0 mph
7:54 PM	80	85	9 mph	0 mph
8:54 PM	79	88	9 mph	0 mph
9:54 PM	79	84	9 mph	0 mph

Weather Data for Site G (Pittsfield)

Site	Location	Date	Approximate time of day
✻	Fort Scott, KS	April 7, 2013	4:25 PM
A	Phoenix, AZ	Oct. 5, 2010	12:30 and 4:30 PM
B	Oklahoma City, OK	April 26, 2013	8:30 PM
C	Dallas, TX	June 13, 2012	6:30 PM
D	Winnipeg, Manitoba, Canada	June 10, 2013	6:30 PM
E	New Orleans, LA	Feb. 24, 2013	9:15 PM
F	Indianapolis, IN	Aug. 25, 2018	5:30 PM
G	Pittsfield, MA	May 15, 2018	No record avail.

Hail map



Weather Data for Site G, continued

Weather station: Pittsfield Municipal Station, MA

Time	Temperature (°F)	Relative humidity (%)	Wind speed (mph)	Wind gust (mph)
5:54 AM	53	93	0 mph	0 mph
6:54 AM	56	93	3 mph	0 mph
7:54 AM	61	83	0 mph	0 mph
8:54 AM	67	81	6 mph	0 mph
9:54 AM	68	78	12 mph	0 mph
10:54 AM	71	68	9 mph	0 mph
11:54 AM	71	73	5 mph	0 mph
12:54 PM	77	56	12 mph	16 mph
1:54 PM	---	---	---	---
2:54 PM	75	60	12 mph	0 mph
3:11 PM	70	76	15 mph	0 mph
3:16 PM	68	84	18 mph	26 mph
3:28 PM	68	84	9 mph	0 mph
3:54 PM	68	84	0 mph	0 mph
4:54 PM	67	87	17 mph	22 mph
5:04 PM	64	87	13 mph	20 mph
5:12 PM	63	81	10 mph	21 mph
5:27 PM	60	83	6 mph	20 mph
5:54 PM	59	81	8 mph	0 mph
6:54 PM	59	83	5 mph	0 mph
7:54 PM	58	87	3 mph	0 mph
8:54 PM	57	87	3 mph	0 mph
9:54 PM	55	89	7 mph	0 mph

Sunny Day: Sample Data for Colorado Springs

Weather conditions

Partly sunny, cold, and breezy. The air temperature was about 36 degrees Fahrenheit.

Data

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)
Black and brown mulch in the sun	~36,000	2,400	42.6	36.3
Black asphalt in the sun	~36,000	600	44.7	36.5
Tan-colored concrete sidewalk in the sun	~36,000	1,200	44.0	36.4
Tan-colored concrete sidewalk in the shade	~5,000	480	35.7	36.5

As you look at these data, think about the following 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 a few feet above the ground compared to the temperature right at the ground?

Cloudy Day: Sample Data for Colorado Springs

Weather conditions

Cloudy, cold, and breezy. The air temperature was about 36 degrees Fahrenheit.

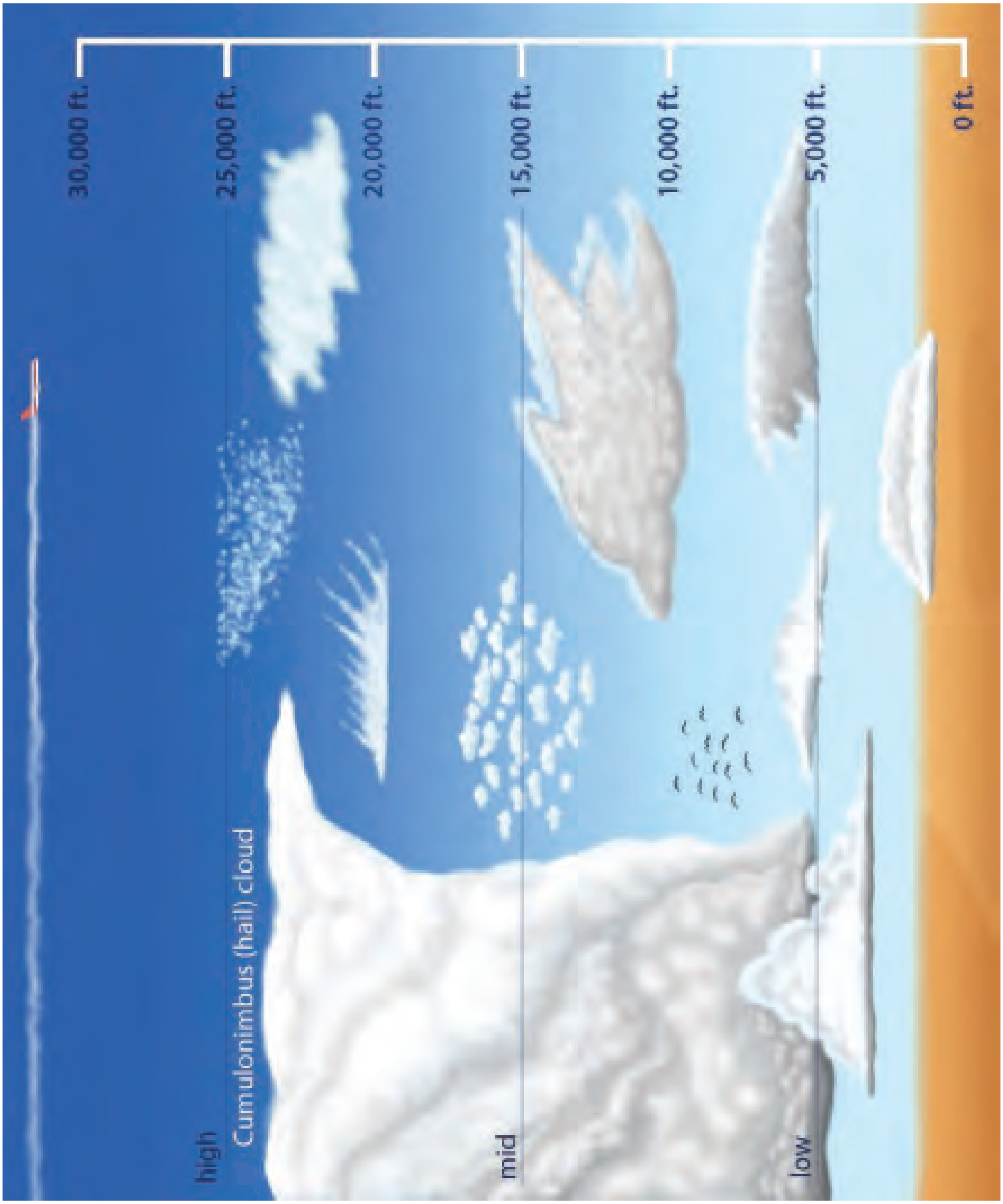
Data

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 (°F)
Black and brown mulch	~8,000	800	36.4	36.3
Black asphalt	~8,000	600	36.6	36.5
Tan-colored concrete sidewalk	~8,000	1,200	35.8	36.7

As you look at these data, think about the following 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 a few feet above the ground compared to the temperature right at the ground?

Comparing Hail Clouds to Other Clouds



Peer Feedback Guidelines

Giving Feedback to Peers

This tool was inspired by the Sticky Note Feedback resource originally developed by Ambitious Science Teaching at: https://ambitiousscienceteaching.org/sticky-note-student-feedback/

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."

Nonproductive feedback does not help other students improve. Here are some examples:

- "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.

Procedures for Investigations A and B

Procedure for Investigation A

1. Get some warmed water in a small container or cup.
2. Place the 2-L bottle cover over it.
3. Get a sealed bag with ice in it. Make sure it does not leak. Drape it over the top of the capped 2-L bottle cover.
4. Watch for any changes happening on the inside surface of the 2-L bottle cover.
5. Use a magnifying glass to observe up close what is happening at those places.
6. Record your observations in part A of the table in your notebook at two points in time:
    a. about 2 minutes after you started
    b. about 5 minutes after you started

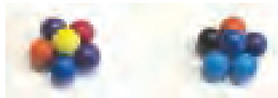
Procedure for Investigation B

1. Each group member places their own piece of wax paper on the table directly in front of them.
2. Use a pipette to scatter some drops of water across each piece of wax paper.
3. Each member uses their own straw to blow a water drop on their paper so it moves slowly across the paper. Blow it toward another drop of water until it just barely touches that other drop of water.
4. Record your observations in part B of the table in your notebook.
5. Repeat the blowing and recording a second time.
6. Dispose of your own piece of wax paper and straw.

Procedure for Investigation C

Procedure for Investigation C1

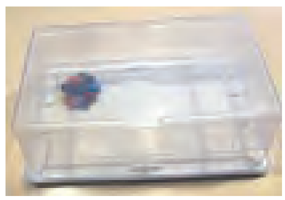
1. Read the "Real-World Interactions" for row C1 together.
2. Remove the lid. Place 7 marbles on the lid in a small clump and another 7 marbles about 6-8 inches away from it.
3. Slide 1 clump across the lid so it collides with the other clump. Observe how they interact when they collide.



4. Repeat the clump placement and sliding 2 more times, each time giving another member of the group a chance to try it.
5. On your teacher's signal, return all marbles to the bin, put the lid on it, and place it in the middle of the table. Read the "Investigation Question" for row C1 silently and record your answer in "Results".

Procedure for Investigation C2

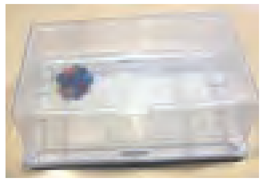
1. Keep the lid on the bin in the middle of the table as you read the "Real-World Interactions" for row C2 together.
2. Have 1 group member flip the container upside down while holding both ends of the lid tightly against the container so you can see what is happening to the marbles. Slowly shake the container as your teacher demonstrates.
3. Shake the container a bit faster to model how the motion of the particles in a solid or liquid would change as the temperature increases.



4. On your teacher's signal, flip the bin upright, keep the lid on it, and place it in the middle of the table. Read the "Investigation Question" for row C2 silently and record your answer in "Results".

Procedure for Investigation C3

1. Keep the lid on the bin in the middle of the table as you read the "Real-World Interactions" for row C3 together.
2. Give a different group member a turn to do the following:
   a. Keep the container flipped upside down while holding both ends of the lid tightly against the container so you can see what is happening to the marbles in the next step.
   b. Shake the container a bit faster and faster as your teacher demonstrates to model how the motion of the particles in a liquid would change as the temperature increases until it becomes a gas.



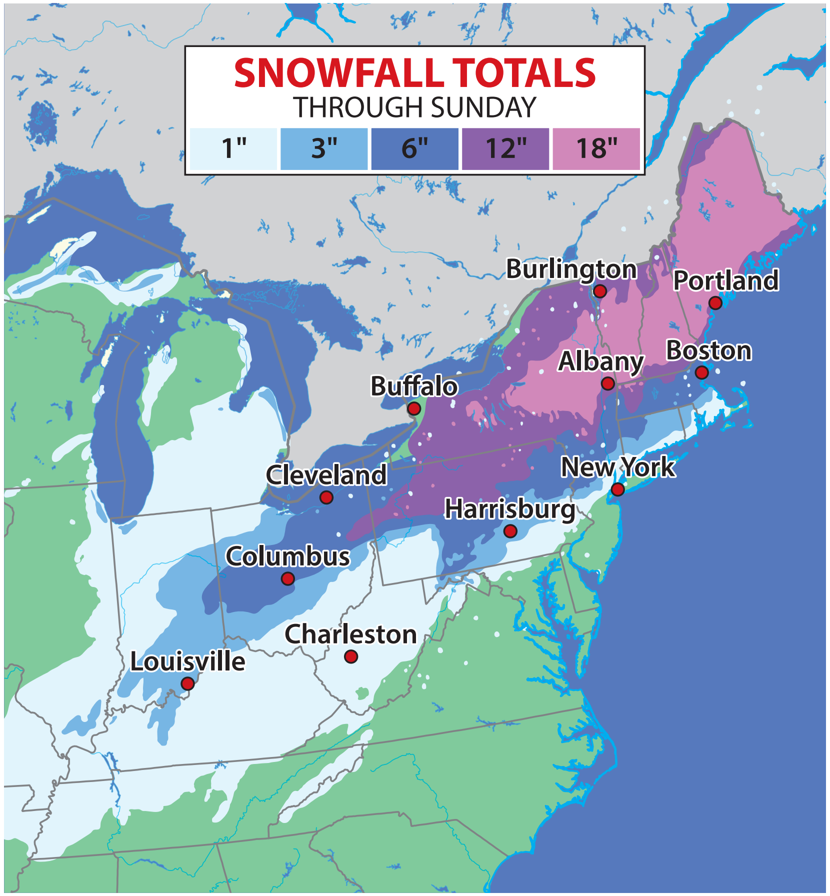
3. On your teacher's signal, flip the bin upright, keep the lid on it, and place it in the middle of the table. Read the "Investigation Question" for row C3 silently and record your answer in "Results".

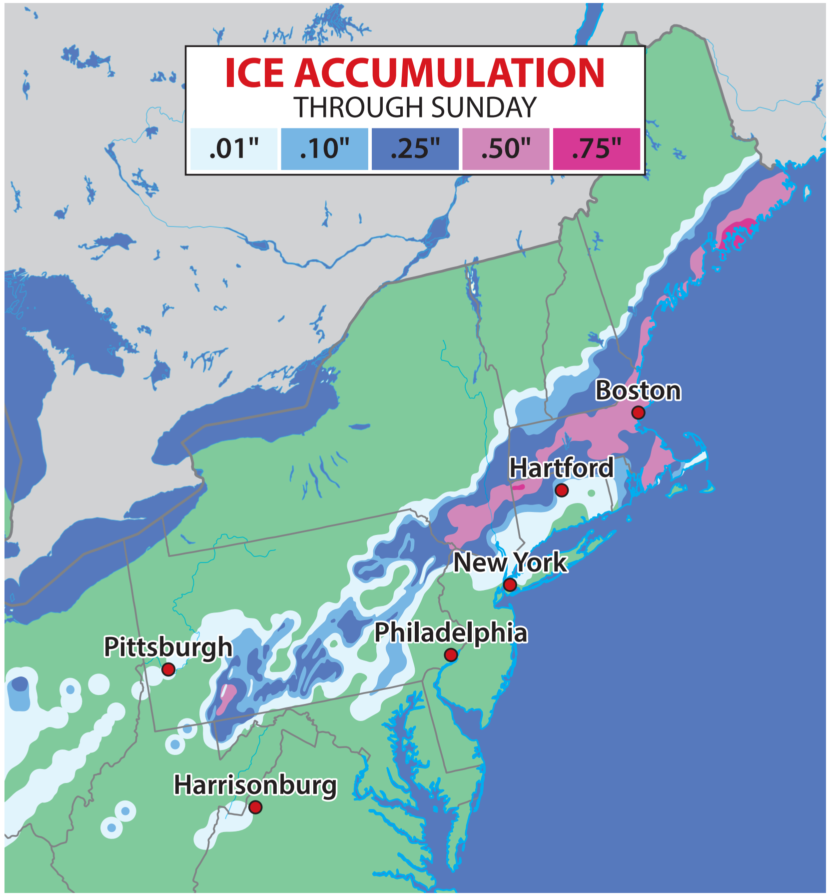
Procedure for Investigation C4

1. Keep the lid on the bin in the middle of the table as you read the "Real-World Interactions" for row C4 together.
2. Remove the lid. Each person in the group should do these steps:
   a. Take out 2 marbles and put them on the table in front of you.
   b. Roll your marbles toward each other fast enough that they bounce off each other. Do this along the edge of the lid, the bin, or a book.
   c. Repeat the rolling at slower and slower speeds until you see the marbles do something different than bounce off each other.
3. On your teacher's signal, return all marbles to the bin, put the lid on it, and place it in the middle of the table. Read the "Investigation Question" for row C4 silently and record your answer in "Results".

Snowfall and Ice Accumulation Forecast Maps

The images below are from the *TODAY Show* on Saturday, Jan. 19, 2019 at 8:00 a.m. (EST) and predict what is expected to occur by the end of the weekend, Sunday, Jan. 20, 2019 at 11:59 p.m. (EST).

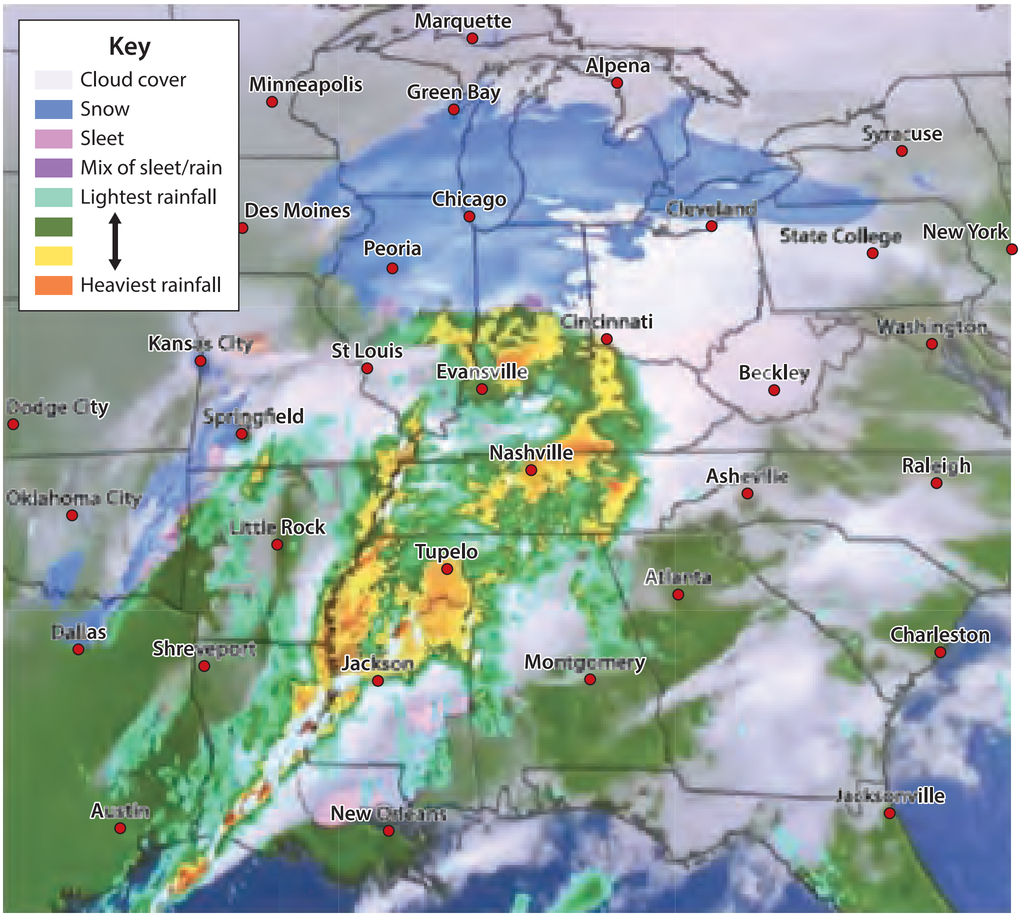




Transcript of what the meteorologist said in the video clip: *"So we are looking for about 4 to 8 inches back through Ohio, closer to a foot [12 inches] to a foot and a half [18 inches] across the northeast. Higher elevations could have closer to 2 feet. But this is going to be a huge area of concern. Look at down east, Maine, most of Massachusetts. This is ice, half an inch to three-quarters of an inch that could down trees and power lines."*

Cloud Cover and Precipitation Map

Cloud cover and precipitation falling at 8:00 a.m. (EST) on Saturday, Jan. 19, 2019

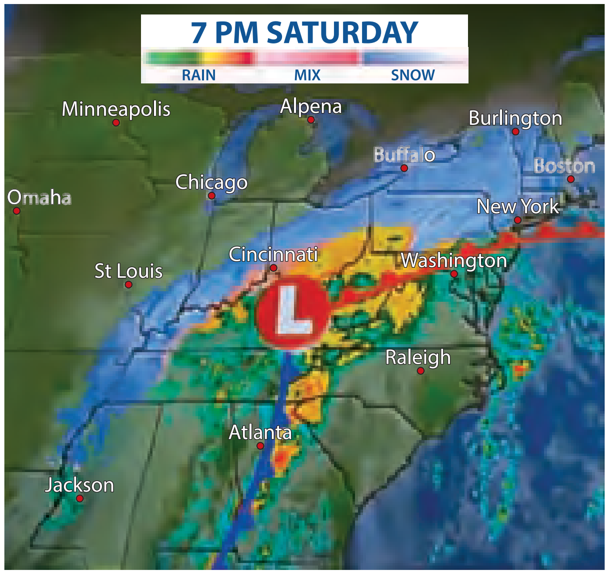


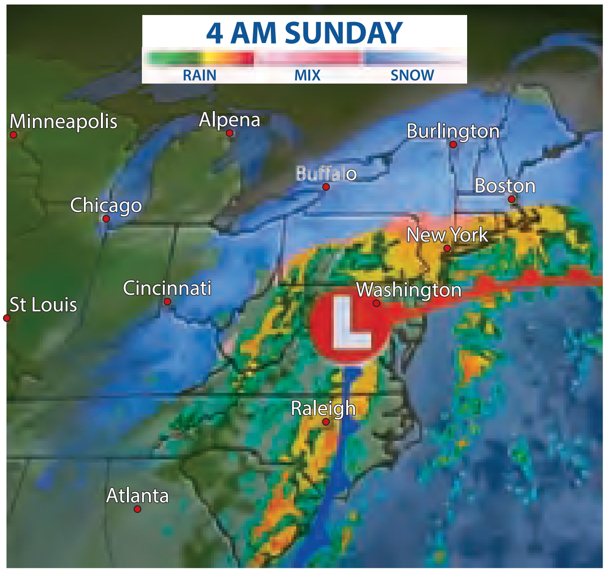
The image above illustrates separate images captured from the video.

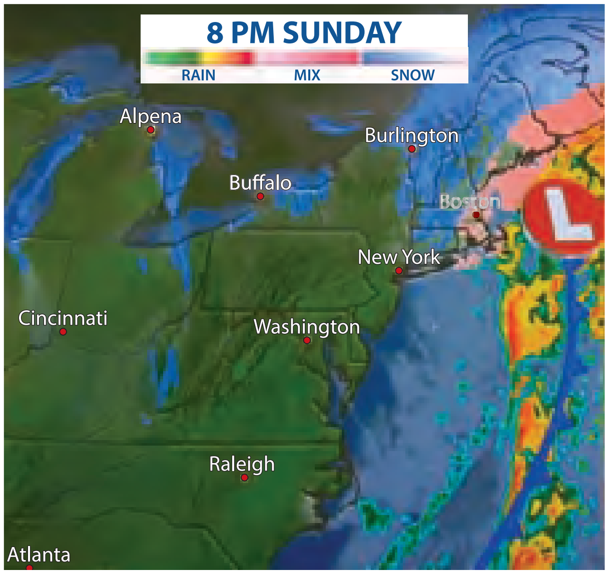
Transcript of what the meteorologist said in the video clip:

"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."

Images from the Jan. 19, 2019 Weather Forecast



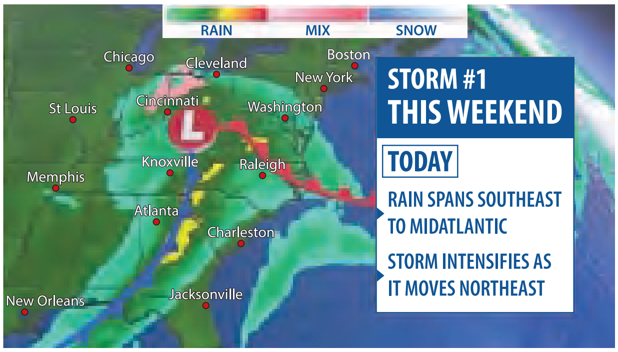




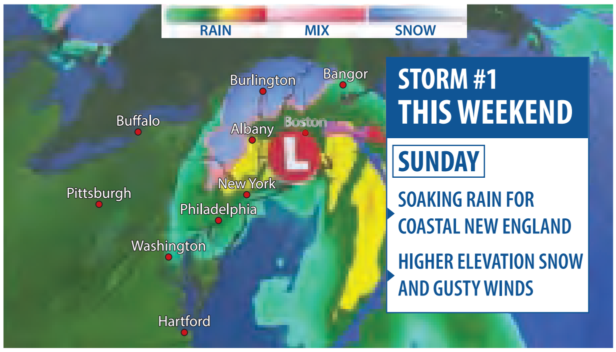
Another set of claims the forecaster made: *"So, let's take you through the timeline. We are going to see the snow fall across central and northern Ohio all day long. We could see totals up to 8 inches there. Later on, this afternoon and evening it starts to approach the northeast. The storm itself is tracking a little warmer for areas across New Jersey, up into New York, Long Island, and parts of southern Connecticut, and into the rest of southern New England. So that means we could see a changeover to rain. But you go just a little further to the north and west and we are looking at ice—ice that could bring down trees and power lines. And then, even farther to the north, we are looking for the potential for significant snowfall, especially in the higher elevations."*

Nov. 22, 2019 Weather Forecast Maps

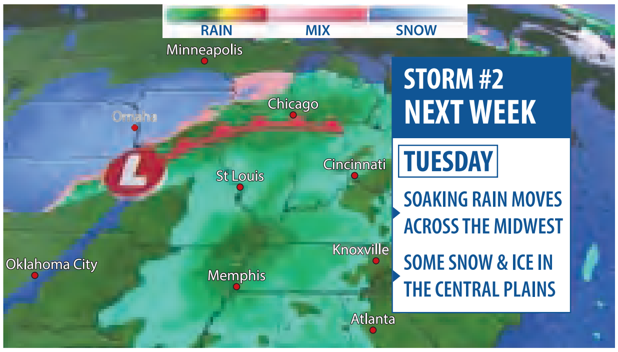
The images below are from the *TODAY Show* on Friday, Nov. 22, 2019 at 8:00 a.m. (EST).



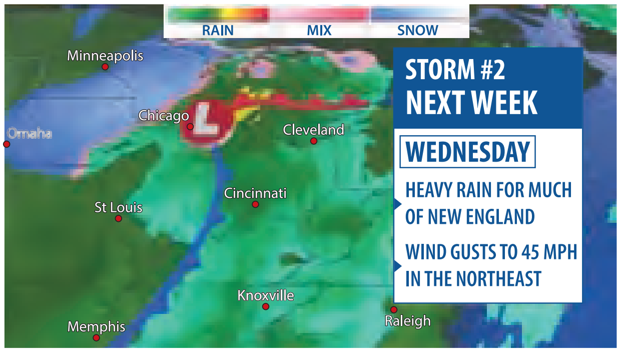
Prediction of what will happen on Fri., Nov. 22



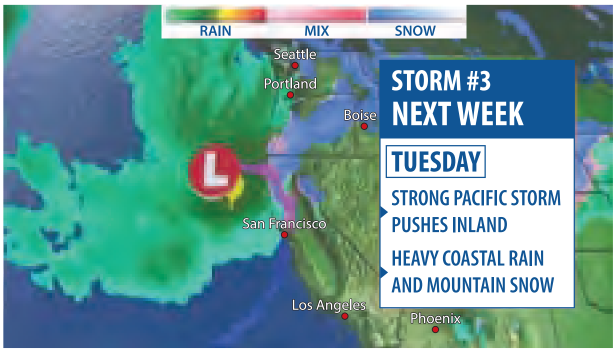
Prediction of what will happen on Sun., Nov. 24



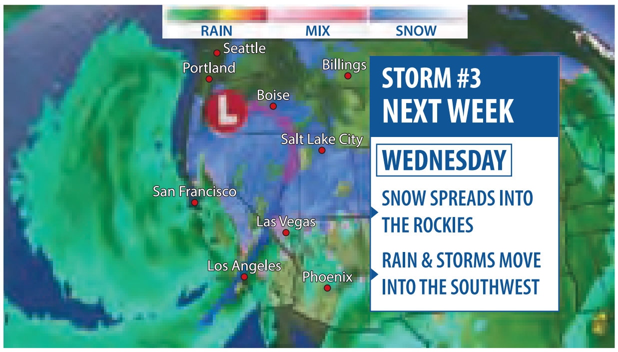
Prediction of what will happen on Tue., Nov. 26



Prediction of what will happen on Wed., Nov. 27



Prediction of what will happen on Tue., Nov. 26



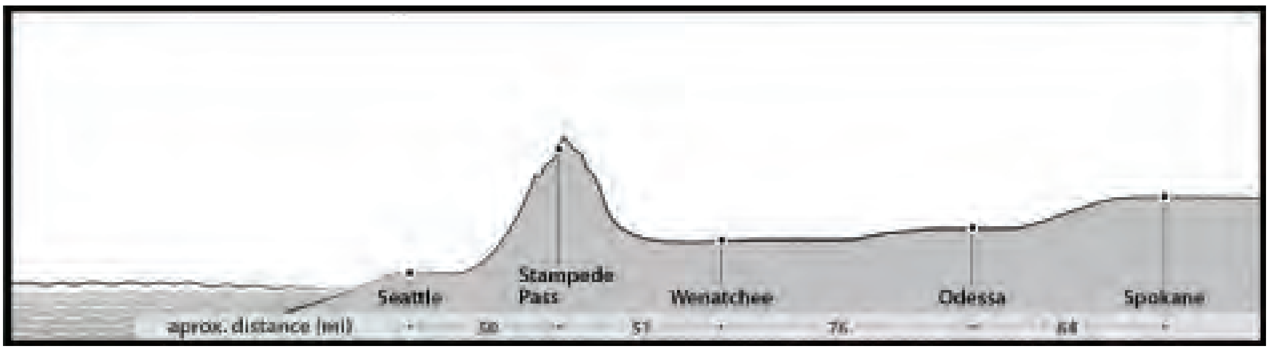
Prediction of what will happen on Wed., Nov. 27

Maps and Data for the Pacific Northwest and Gulf Coast

Pathway #1: Pacific Northwest

Figure 1. Pathway in the Pacific Northwest with five locations (birds-eye view)

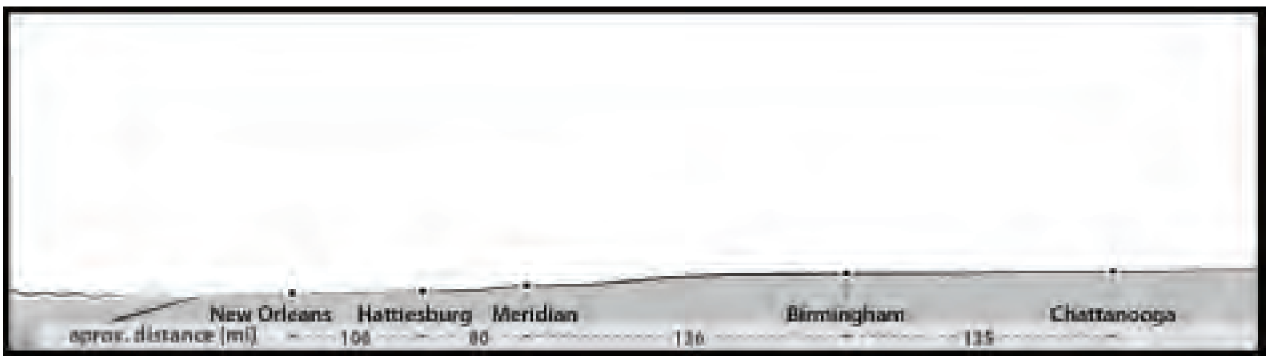
Figure 2. Pathway in the Pacific Northwest with five locations (profile view)



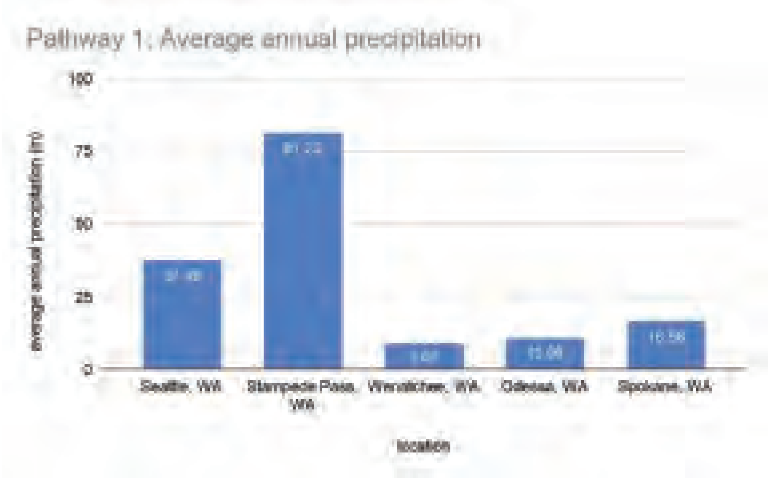
Pathway #2: Gulf Coast

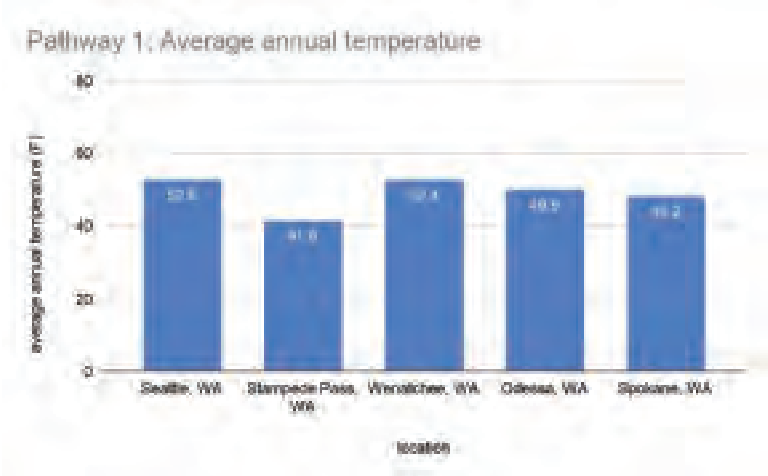
Figure 3. Pathway in the Gulf Coast with five locations (birds-eye view).

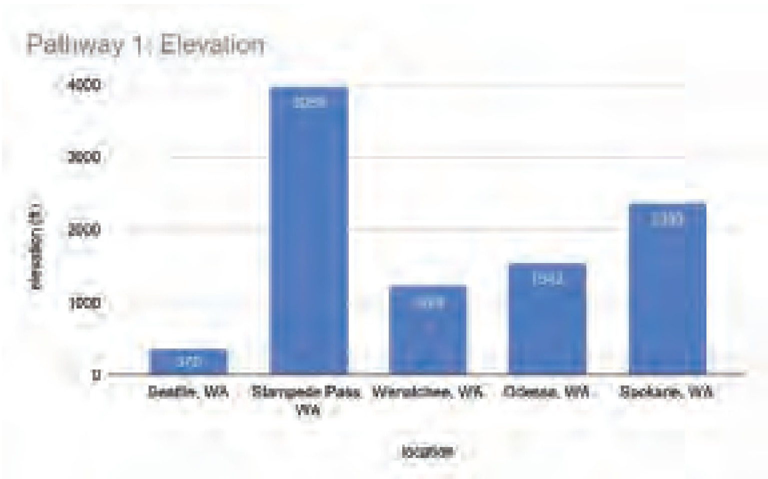
Figure 4. Pathway in the Gulf Coast with five locations (profile view).



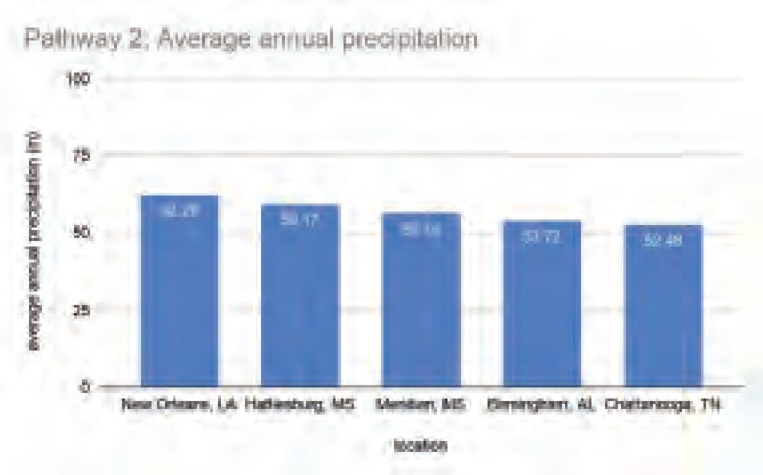
Pathway 1 Data: Pacific Northwest

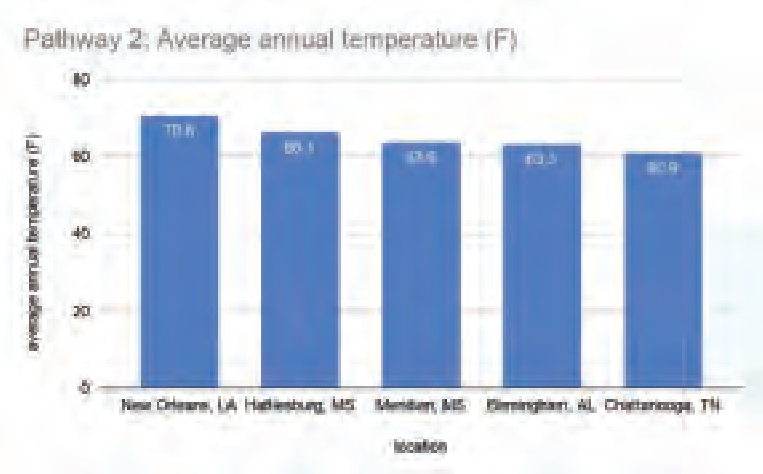


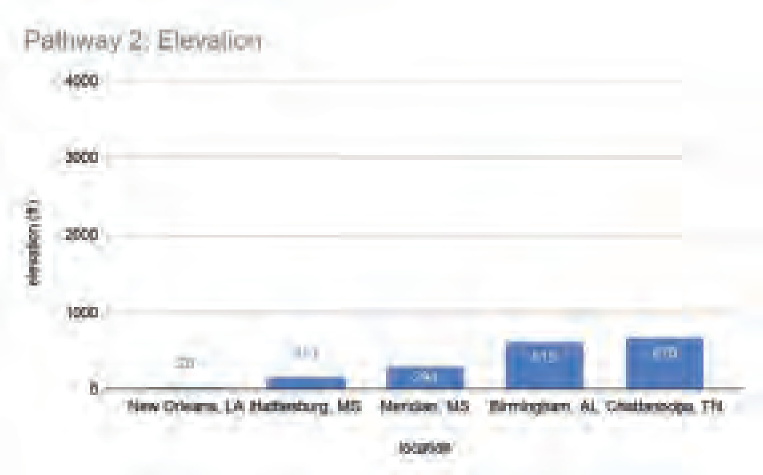




Pathway 2 Data: Gulf Coast







Data Source: NOAA

Name: ______________________ Date: ______________

Reading: What Is Air?

The air around us is a mixture of different types of gases. The molecules that make up those gases are too small for us to see. But there are other pieces of matter in the air that are bigger than a single molecule. These include things like dust, ash, spores, pollen, and pollution.

Most of the gas in the air is either oxygen or nitrogen. A smaller amount of it is carbon dioxide, water, and argon. Water in gas form is often called *water vapor.* The amount of water vapor in the air is referred to as *humidity.*

Humidity probes can help us measure changes in the amount of water vapor in the air. They often report the amount of water vapor in the air as something called *relative humidity.* Relative humidity is reported as a percentage from 0 to 100 percent. A relative humidity reading of 100 percent means the air has reached the maximum amount of water vapor it can hold. It doesn't mean that the air is only made of water vapor molecules.

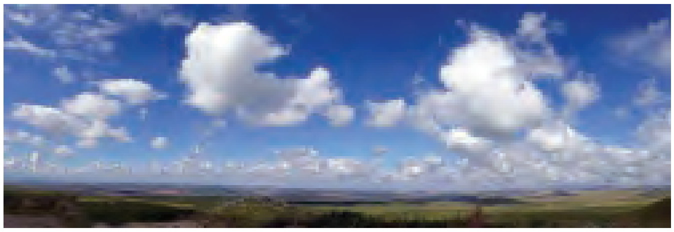
Substance	Gas by volume
Nitrogen	Around 78%
Oxygen	Around 21%
Argon	About 1%
Carbon dioxide	Less than 1%
Water	From 0% to around 6%
Other substances	Less than 1%

The humidity probe to the right is shown measuring a relative humidity of 39 percent in air that is 19.5°C. This shows that the water vapor in the air is about halfway between the minimum and maximum amounts that air can possibly hold at this temperature.

Reading: What Are Clouds?

Why can we see clouds?

When there is humidity in the air, we can't see the water vapor in the air. Why not? We can't see the water vapor because it is a gas. In a gas, the molecules are too small and too spread apart for us to see them.



So what are we seeing when we look at a cloud in the sky? Clouds are visible, which tells us they must be made of something large enough for us to see.

Clouds are made of two things. They are made of gases, and they are made of much larger water droplets or ice crystals suspended in those gases. We can see clouds because those droplets or crystals are big enough to reflect a noticeable amount of light. That is also what makes clouds appear white. But the more droplets or crystals in the cloud, or the bigger they are, the more sunlight they absorb. Depending on the direction the sunlight is coming from, this can result in less sunlight reaching parts of the cloud. This will make parts of the cloud appear darker.

What is needed for droplets or crystals to form?

Water has to turn from gas into liquid or solid form for a cloud to start forming. This can only happen when the air is at a relative humidity of 100 percent and the air is cooled down. When cooling a substance turns it from a gas into a liquid, it is referred to as *condensation*. When cooling a substance turns it from a gas into a solid, it is referred to as *deposition*.

But cooling really humid air alone is not enough to start either of these processes. Something else is needed. The missing ingredient is a solid surface for the water vapor to start sticking to.

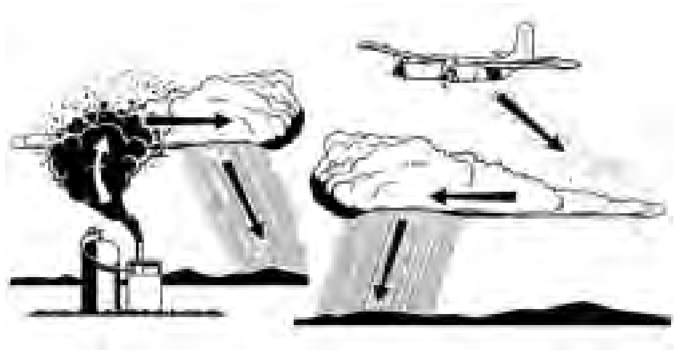
In the experiment you did in class, that solid surface was the inside of a bottle. When you are outside, that surface can be the ground. You might find water has condensed out of the air to form dew on the grass in the morning. If it gets even colder, you might find it has deposited out of the air as frost. But if water vapor needs a solid surface to do this, how does this help explain cloud formation?

The air outside also contains small pieces of solids, such as dust, ash, pollen, and pollutants. These are the solid surfaces that water droplets or ice crystals start forming on when clouds form. Any type of solid particle that water vapor sticks to as it cools down is referred to as *cloud condensation nuclei* (CCN) or *cloud seeds*. When there aren't enough CCN in the air, droplets or crystals won't form, so no cloud will form.

Can we change the weather by adding CCN to the air?

Scientists and engineers have tested ways to add CCN into the air to try to increase the amount of cloud formation and the amount of precipitation. These types of processes are called *cloud seeding.*

CCN used in cloud seeding can be dumped into the air from aircraft. They can also be launched into the air from the ground in generators or canisters fired from guns or rockets.



All these techniques have been tested, but there isn't consensus among experts on whether the tests produced a significant increase in precipitation at locations where they have been attempted.

Reading: Can Other Gases in the Air Turn into Liquids or Solids?

Why is water the only gas in the air outside that we see turn into a liquid or solid?

You've learned about how air is a mixture of different types of gases, and you've learned about what happens when water vapor turns into a liquid or solid. However, water isn't the only gas that turns into a liquid or solid. All the gases in our atmosphere can also do this. So why don't we see those other gases condense into liquids when the temperature outside drops?

Every substance has a temperature at which it can go from being a gas to a liquid as it is being cooled. This temperature is called its **condensation point**. The condensation point for water is 212°F or 100°C. This temperature is also called its **boiling point**, as this is the temperature at which it can change from a liquid to a gas if it is being heated.

Every substance also has a temperature at which it can go from being a liquid to a solid if cooled. This temperature is called its **freezing point**. The freezing point for water is 32°F or 0°C. This is the same temperature at which it can go from being a solid to a liquid if heated. It is also called its **melting point**.

The data table to the right summarizes these temperatures for some of the different gases found in the air. Notice how much lower these temperatures are for things like nitrogen, oxygen, and argon, compared to water.

Melting/freezing points and boiling/condensation points for different substances

Substance	Melting and freezing point	Boiling and condensation point
Water	32°F	212°F
Nitrogen	–346°F	–320.4°F
Oxygen	–361.8°F	–297.3°F
Argon	–308.8°F	–302.5°F

The temperature of the air outside never gets cold enough for these other gases to turn into liquids or solids naturally. The lowest temperature ever recorded in the air outside was -128.6°F in Antarctica on July 21, 1983, by ground measurements.

Reading: Tracing Paths of Hailstones

How does hail form?

Hail forms when water droplets in a cloud get very, very cold (supercooled) and collide with other supercooled water droplets. This happens in thunderstorms when the clouds grow so tall they lift the water droplets into very cold parts of the atmosphere. Hailstones grow by colliding with other water drops and become bigger as those droplets freeze on them. The more collisions with droplets that freeze to it, the bigger a hailstone gets.

Why does hail get really big?

All storms have some sort of updraft. The source of this updraft is the transfer of thermal energy to the air above. The strength of the storm's updrafts depends on the temperature differences between the air near the ground and the air higher in the atmosphere. Hail is formed in clouds with relatively strong updrafts (compared to clouds that have just rain or snowflakes suspended in them).

Hailstone size	Measurement		Updraft speed	
	in	cm	mph	kh/h
BB	<1/4	<0.64	<24	<39
pea	1/4	0.64	24	39
marble	1/2	1.3	35	56
dime	7/10	1.8	38	61
nickel	7/8	2.2	46	74
quarter	1	2.5	49	79
half dollar	11/4	3.2	54	87
walnut	11/2	3.8	60	97
golf ball	13/4	4.4	64	103
hen egg	2	5.1	69	111
tennis ball	21/2	6.4	77	124
baseball	23/4	7.0	81	130
tea cup	3	7.6	84	135
grapefruit	4	10.1	98	158
softball	41/2	11.4	103	166

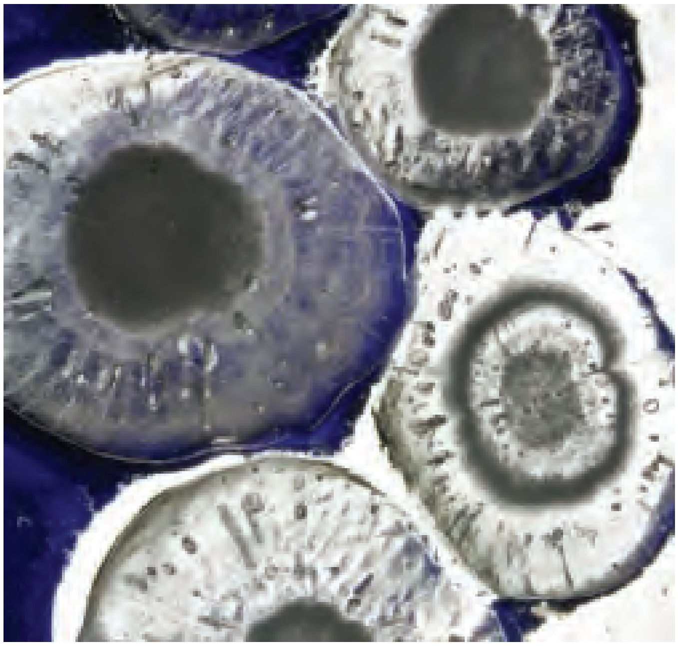
Some hailstones can get very big while others remain small. What is the difference? When updrafts are stronger, they produce stronger lift forces and therefore can keep hailstones in the cloud longer. The longer hailstones are in the cloud, the more time there is for water droplets to stick together, causing the hailstones to grow in size. As long as the updrafts are strong enough, the hailstones will get bigger and bigger. Look at the table to the left, which shows how different sizes of hailstones are related to the updraft speeds in the clouds that produce them. **What pattern do you notice in the data shown in the table?**

There is some debate about the path that hailstones follow as they grow inside a cloud. One explanation involves hailstones traveling up and down in the cloud many times as they get caught up in updrafts, start to fall out, but then get caught in another updraft on their way down.

A second, competing explanation, developed more recently, suggests that the first explanation may not necessarily be true and that many or maybe all hailstones form as they continually rise within a cloud, growing the whole time, until they are so big that they fall out of the cloud. New techniques for collecting evidence of where the ice is forming in clouds and new models to explain convection in fluids are always being developed.

Why do some hailstones have layers?

Hailstones can grow in 2 ways: (1) colliding with water droplets that are not supercooled and do not freeze together immediately and (2) colliding with supercooled water droplets that freeze together immediately. In the first type of growth, air molecules can escape from the slowly freezing water drops, giving the hailstones a clear color. But in the second type, the supercooled water droplets freeze instantly, trapping air molecules and giving the hailstones a whitish appearance. Sometimes hailstones go through both types of growth and develop a layered look.



How are hail, rain, and snow different?

Many storms that produce rain at the ground rather than hail actually do produce pieces of ice near their cloud tops. But if those pieces of ice are too small when they start to fall, they will begin melting as they pass through the warmer air below them. If all that ice has melted on the way down to the ground, then the only thing that hits the ground is raindrops.

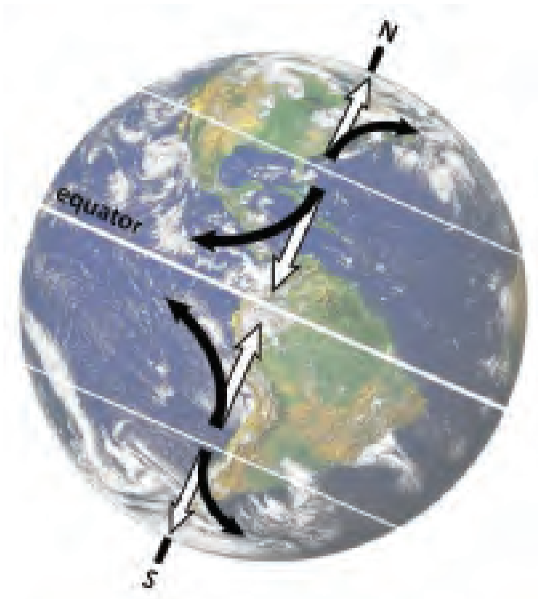
Rain forms when temperatures near the ground are above freezing and there is enough updraft to put moisture into the atmosphere. That water vapor condenses into ice crystals, which almost immediately fall back to Earth because the updrafts are relatively weak and cannot keep the droplets aloft. The ice crystals melt into raindrops before they reach the ground.

Snow, on the other hand, forms on days when temperatures near the ground are relatively low, close to 32°F (water's freezing/melting point) or lower. Moisture can still be lifted into the atmosphere (which is colder than the air near the ground), but the updrafts are much weaker and will not keep snow aloft in the cloud if snowflakes get very big, so they fall back to Earth. The snow does not melt before it reaches the ground because the air temperatures are cold enough to keep snowflakes frozen on their way down.

Reading: Why do air and water spin in different directions on Earth?

Even with disruptions like weather fronts and storms, there is a consistent pattern to how air moves around our planet's atmosphere. This pattern, called atmospheric circulation, is caused when light from the sun heats the Earth more at the equator than at the poles. It's also affected by the spin of the Earth.

In the tropics, near the equator, warm air rises. When it gets about 10–15 km (6–9 miles) above Earth's surface, it starts to flow away from the equator and toward the poles. As the air moves toward the poles, it cools and drops back to the surface around 20–30 degrees north or south of the equator. When the air reaches the surface, some of it flows back toward the equator and some of it flows toward the poles. Eventually this air will warm again and the cycle will repeat. This pattern, known as convection, happens on a global scale. Convection also happens on a small scale within individual storms, as you have already learned.



Earth is always on the move. Earth rotates, or spins, making one full turn every 24 hours. Because Earth is spinning, air and other fluids do not travel in a straight line above the surface (like the white arrows on the picture to the right). Instead, air moving due to convection follows a curved path (like the black arrows). Air north of the equator turns to the right as it moves. Air south of the equator turns to the left as it moves. This is called the Coriolis effect. It is caused by the spin of the Earth.

But why does the air curve in opposite directions?

If Earth did not spin, air would rise at the equator and sink at the poles. But because Earth spins, there are three areas of convection north of the equator and three south of the equator. Convection causes winds to move across Earth's surface toward the equator in the tropics, away from the equator in the midlatitudes, and toward the equator around each pole. These winds are called prevailing winds. Prevailing winds curve because of the Coriolis effect. Winds in the midlatitudes curve, moving west to east. Winds in the tropics generally move from east to west.

Reading: How the ocean changes our weather

The ocean water along the west coast of the United States is very different from the ocean water along the east coast. The difference in the water affects the weather and climate of the communities on the coast. We will look at one example of how differences in the ocean could affect a place's weather and climate.

In the month of June, the temperature of the ocean water near Long Beach, California is around 64°F. People who live in Long Beach have pleasantly warm days with low humidity. The days may have a high temperature near 79°F with a 0% chance of rain.

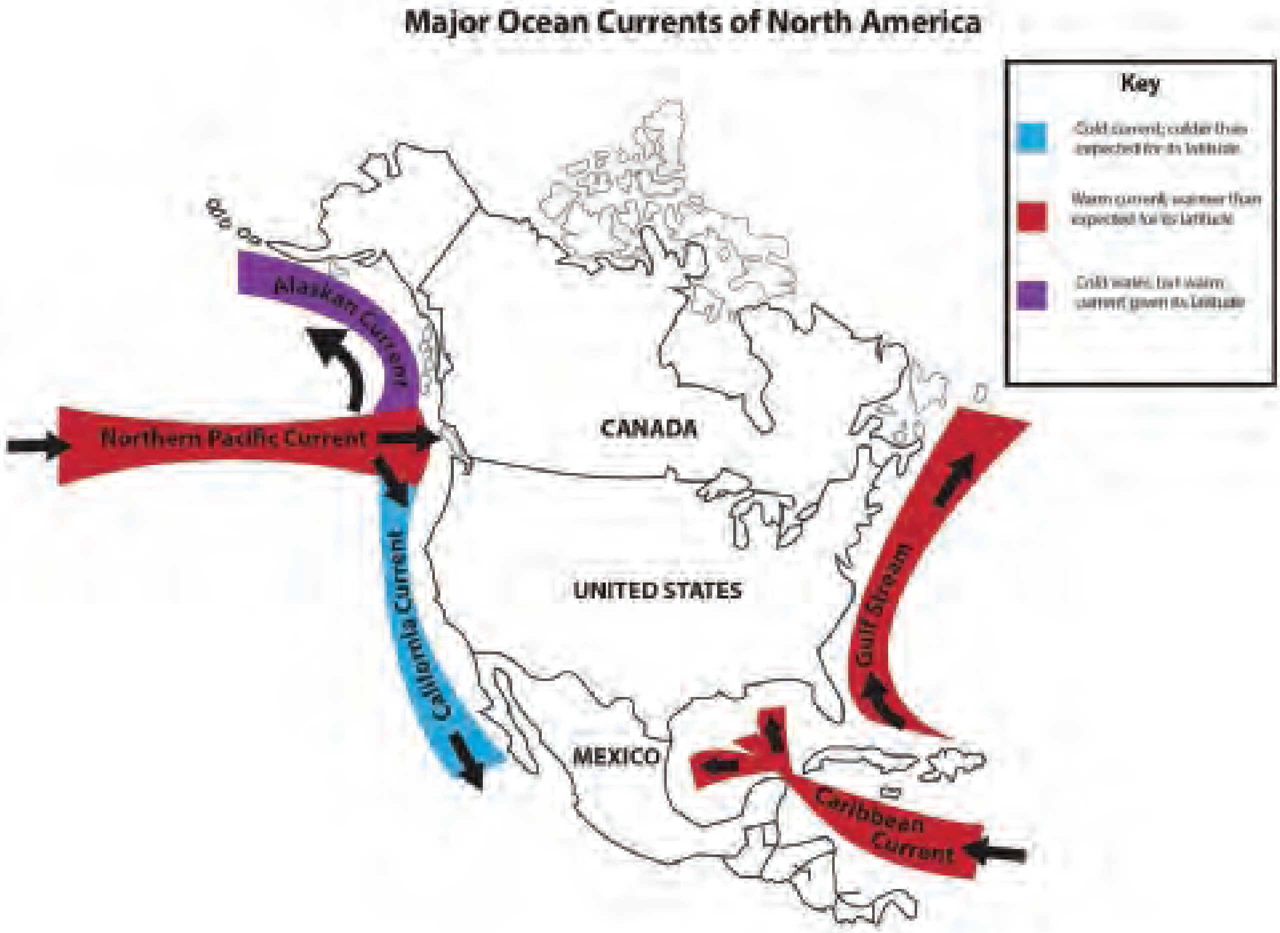
If you were to trace a line at the same latitude to the other side of the United States, you would arrive at Myrtle Beach, South Carolina. The ocean water near this location is much warmer at 77°F. People who live in Myrtle Beach experience warm, humid days. The high temperatures may reach 85°F and there is a 35-50% chance of rain.

The temperature difference between the ocean water near Long Beach and Myrtle Beach has a lot to do with the weather people experience in these two places. Imagine zooming in on the surface of the ocean water in each location. What do you think you would see happening to water molecules at the surface of the warmer ocean water near Myrtle Beach compared to the surface of the colder ocean water near Long Beach?

As sunlight warms the ocean water, energy from light transfers into the water. When enough energy transfers, the water molecules evaporate into the air. As more water molecules enter the air, the humidity of the air increases. As more evaporation occurs over warmer waters, the air above the warm ocean water becomes more humid. If the ocean water is cooler, then less evaporation occurs. Therefore, the air above the cooler water is less humid.

Since Long Beach and Myrtle Beach are about the same distance from the equator, should we expect their water temperatures to be similar? If the water in the ocean never moved, this would be true. But the ocean is always on the move, just like the air in the atmosphere. This movement of water in the ocean is called an **ocean current**. Some ocean currents move warm water away from the equator toward the poles. Other ocean currents bring colder water from the poles toward the equator. Can you guess which type of current is located next to Long Beach and which is located next to Myrtle Beach?

The California Current runs along the west coast of the United States. This current brings much cooler waters to Long Beach. This cool water current is the reason that Long Beach tends to have slightly cooler and sunnier summer days than Myrtle Beach. Off the coast of Myrtle Beach, there is another powerful current called the Gulf Stream. This current circulates warm water from the equator toward the poles. The warm water is ideal for more evaporation and brings Myrtle Beach warmer, more humid or rainy days.



The temperature of ocean currents does not always match what we would expect. In the northern Pacific Ocean, for example, we may think the water would be cold because it is really far from the equator. While you would not want to swim in the water because the water is chilly, it is not as cold as you would expect. The Northern Pacific Current is considered a warm ocean current. Even though it is far from the equator, this current constantly causes evaporation to occur, which brings lots of moisture toward Alaska, Canada, and the northwest United States.

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