Core Knowledge® SCIENCE

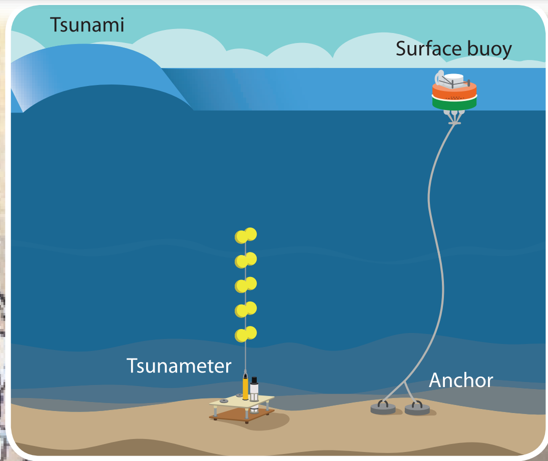
Science Literacy

Natural Hazards:

Where do natural hazards happen, and how do we prepare for them?

Science Literacy Student Reader

Storms, floods, tsunamis



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Natural Hazards

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ISBN: 978-1-68380-795-7

Natural Hazards

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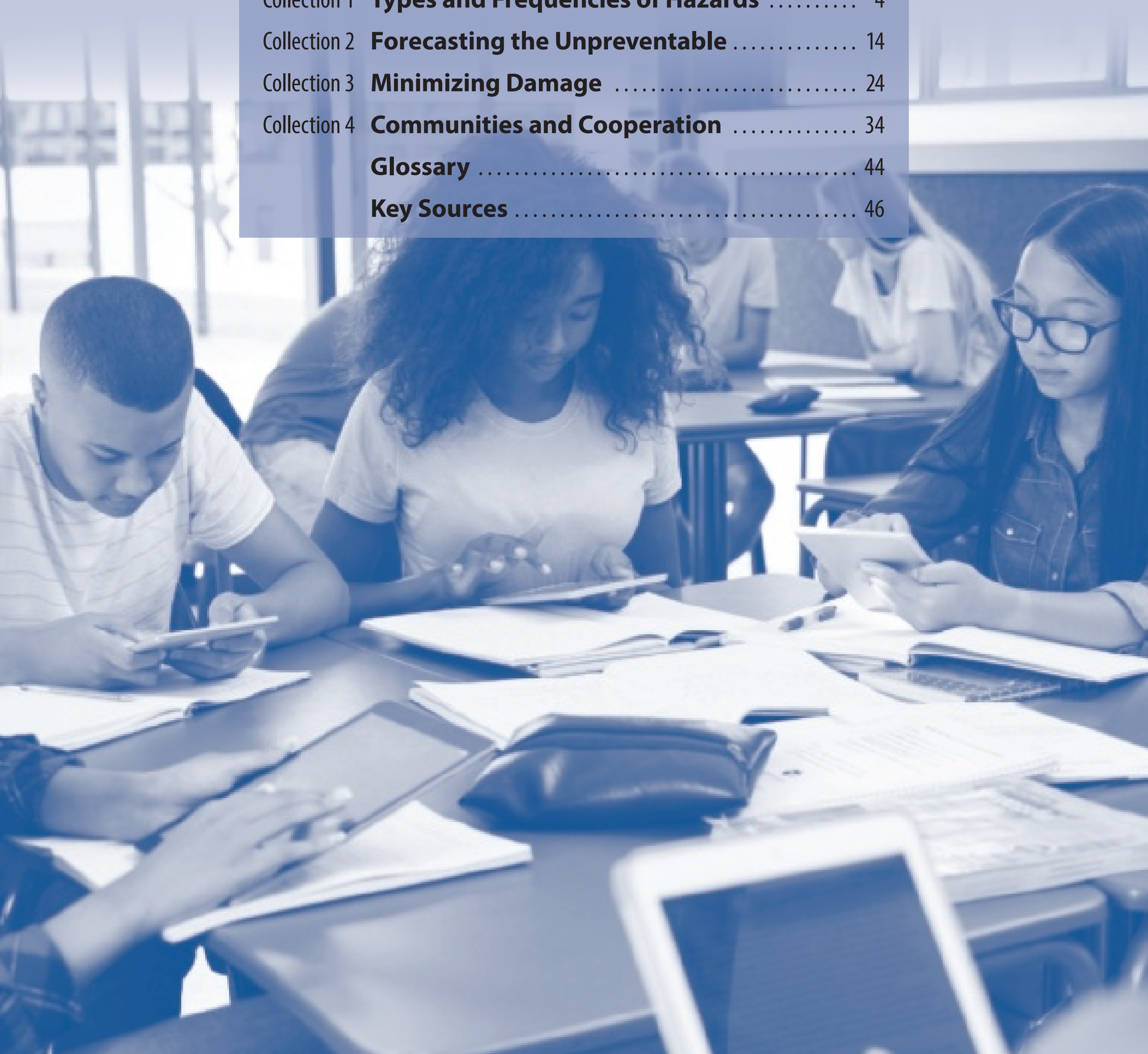


Put Yourself in This Scene

Imagine you are given a choice about where to live. You might stay put in your current town, or maybe you would move someplace else. Discussing where to live might look something like this.

Guys, it looks like my options for a new job are now down to these two locations: Portland, OR, and Charleston, SC. Two very different places, but both have a lot of appeal. We need to decide later this week. I know we'll all miss Chicago in a lot of ways, but either of these cities will be much more pleasant in the winter, so at least there's that. Great food in both, too. Anyhow, we'll chat more about this at dinner tonight, but share your initial thoughts.

Hmmm. Portland vs. Charleston. I feel like both of those cities were in the news lately for different natural disasters. Charleston got hit hard by a hurricane, and sea level rise is an issue that isn't going away in our lifetimes. IIRC, wildfires have been common in OR.

Great point, Dan. Both places face natural hazards, but they're different. We should probably weigh the risks and also consider what the quality of our life will be like in each place.

I just learned about some of this in Earth science class. There's a big threat of earthquakes and even tsunamis in the Pac NW. They don't get a lot of them, but when they hit they are BIG. Portland will see billions in damages to buildings. Thousands of lives lost. Tens of thousands without homes.

So, we're either drowning or getting buried in an earthquake? I can almost hear your excitement…

Honey, I think what Dan and Emma are saying is we need to look closely at both places' hazards. I also see the point about it costing a lot of money to rebuild structures, like homes, after they are hit from a natural hazard. I mean, what if we bought a house and then it got ruined from an earthquake?

Yeah, sorry, Dad, I didn't mean to rain on your parade—or dump a tsunami on it. I think we basically need to think about whether we're more comfortable with Charleston getting a pretty big hurricane and some tropical storms that cause flooding in the city, versus living in Portland where a really bad earthquake might be on the horizon.

I vote for Portland. It has a pro basketball team, and I'd rather face the risk of one really big disaster that might not even happen versus the regular, going-to-happen hazards of hurricanes and sea level rise.

Okay, this is a good start. Let's look for some real data online later. Let the debate continue at dinner!

The conversation on these pages is not uncommon in today's world, in which people might have several options about where to live along with access to tons of information—and not all of it is good, reliable information.

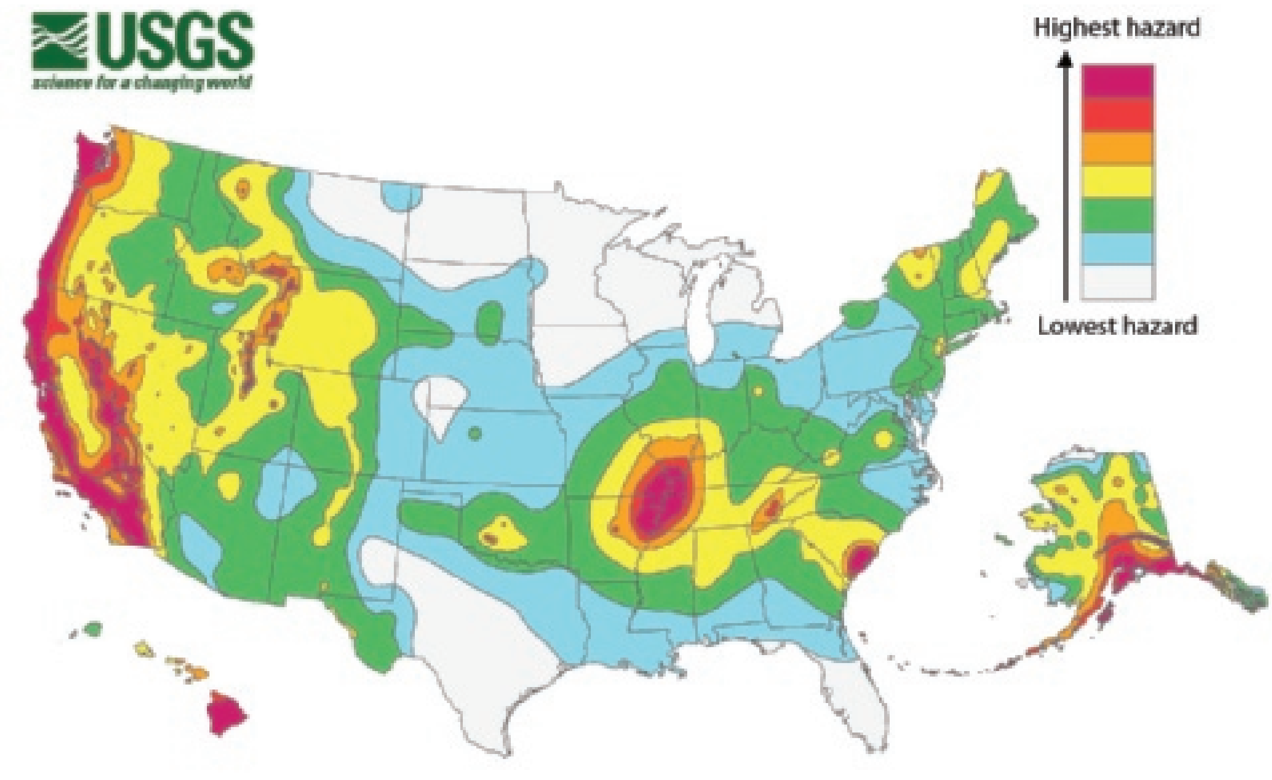
That's what this book is about—scientific literacy, which means knowing how to think about science topics that you read or hear about. Our world has 24–7 news, social media, and too many websites to count. The amount of information we have to sort through is overwhelming, and all the information is not reliable. In the internet age, sources of information are often obscure or not trustworthy. It is good to process information with a healthy degree of skepticism.

We will make our way back to the topic of making choices based on hazard and risk by the end of the book. Along the way, the series of reading selections and the writing exercises that go with them will help you flex your mental muscles and sharpen your science literacy skills. The ability to read about science, understand the information, and tell truth from fallacy or misrepresentation is important. Science literacy helps you as an individual and as a consumer, and it shapes the ways you affect the community in which you live.

Natural Hazards, Visualized

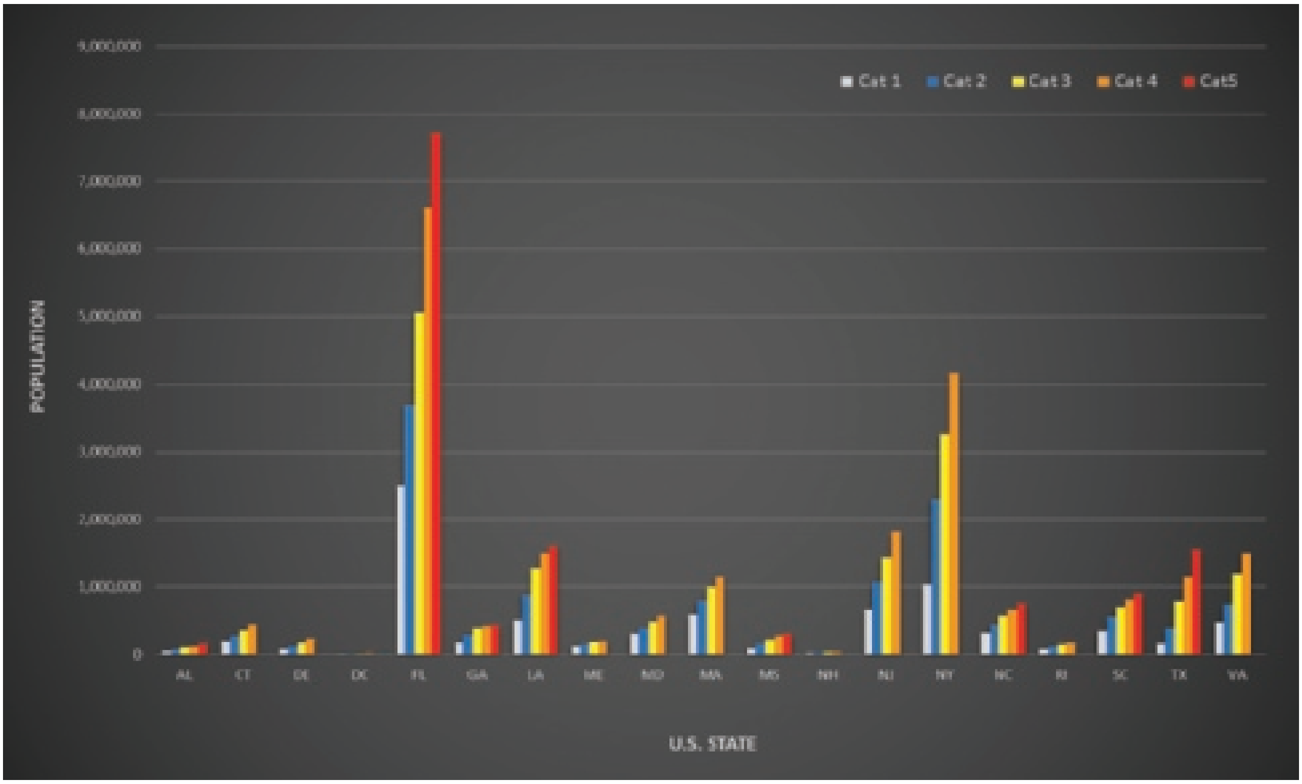
There are many types of hazards and different ways to display information about what a hazard does, where it occurs, how hazardous it is, and more. Graphical displays, like maps, make it easier to understand hazards and, in some cases, avoid them.

Earthquake Maps



What if you could see into the future to tell when the next earthquake would strike? Scientists around the world study earthquake activity to do their best to predict this type of data, based on recent events. This 2018 map from the United States Geological Survey is based on years of earthquake research. It shows how different parts of the United States can expect to experience earthquakes over the next 50 years. The colors make it easy to see which areas have the highest or lowest hazards.

Storm Surge and Hurricane Graphs

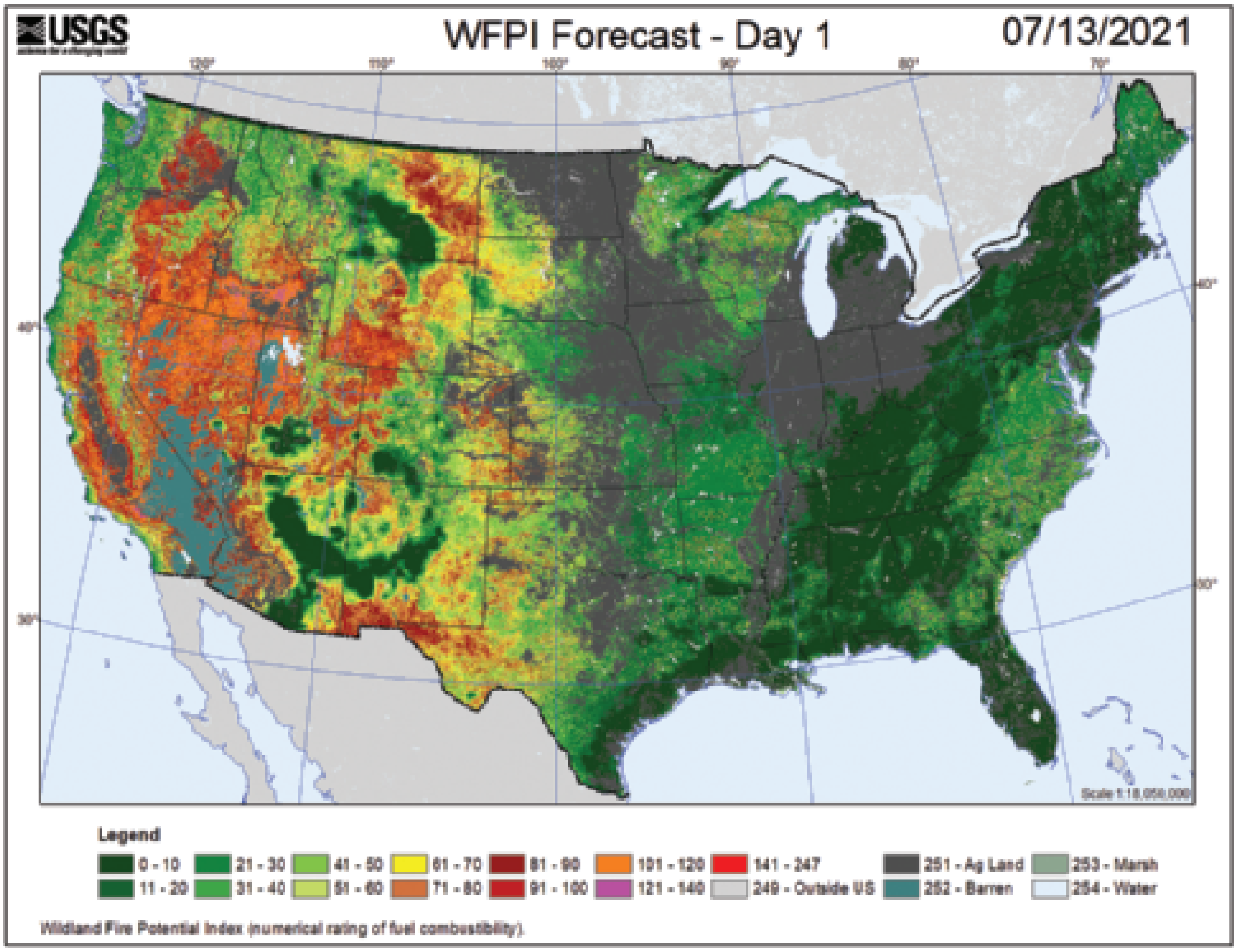


Hurricanes that reach the United States make landfall in Florida more than any other state. This bar graph identifies the number of people per state that would be threatened by the storm surge from five categories of hurricanes. The most powerful hurricane is a Category 5, which has winds of at least 157 miles per hour. Not only is Florida hit by the most hurricanes, but its population is most susceptible to danger from storm surges.

Vocabulary

natural hazards, n. events in Earth's physical environment that are harmful to people but are not directly caused and cannot be controlled by them

Wildfire Maps

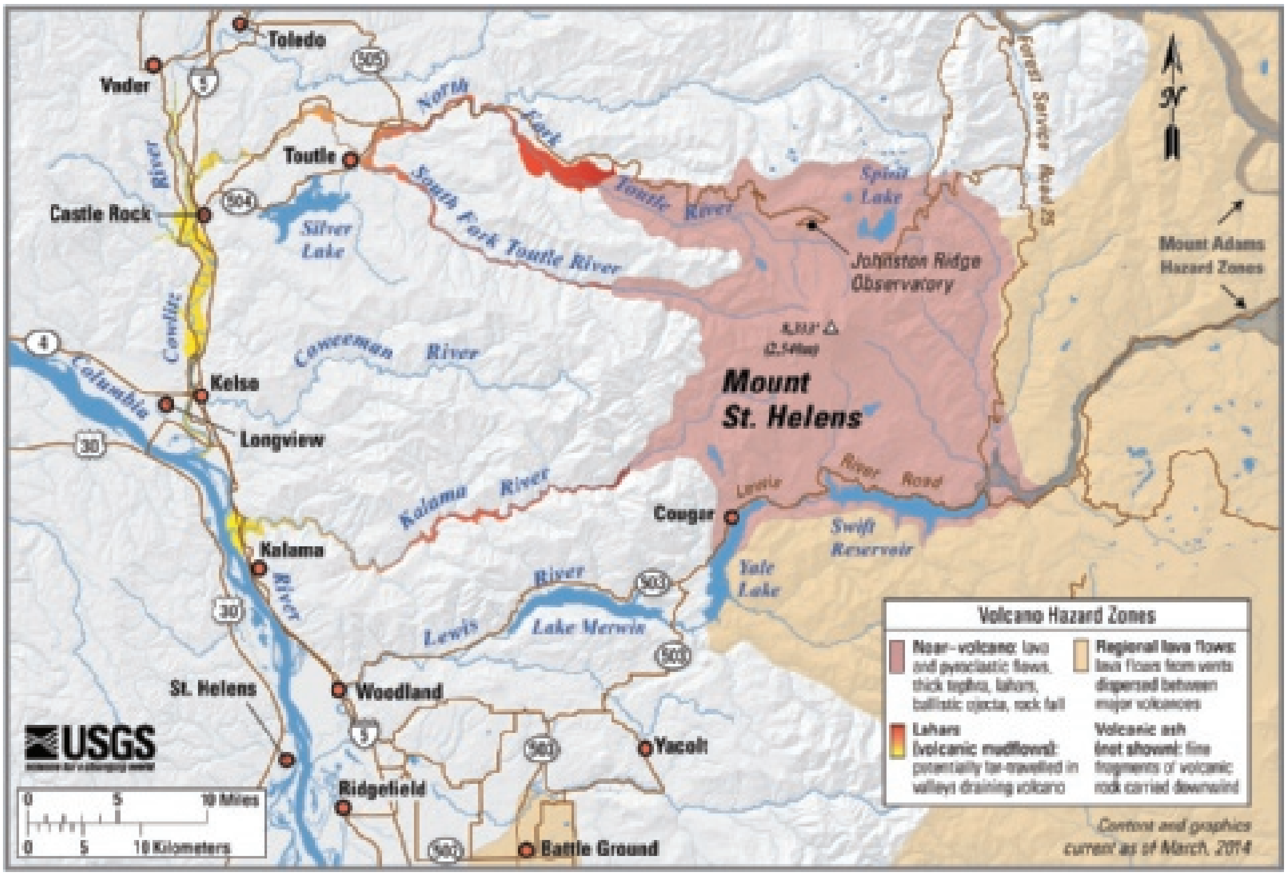


Wildfire can burn through thousands or millions of acres of forest or grassland. Oxygen and some kind of combustible material, such as dry wood, provide the conditions for fire to burn. Wind can enhance a fire by delivering more oxygen to it and blowing flames to new areas that have fuel. The map shows the wind-enhanced fire potential index on a summer day in the United States. Note that the index is higher in the west, where woody landscapes can be both dry and quite windy in summertime. Again, the color scheme for the map is based on a gradient. Warm or hot colors indicate areas that have more potential to burn. Cooler, darker colors indicate the land that lacks combustible fuel or land where a fire would not count as a wildfire.

Word to Know

An *index* is an indicator, sign, or measure of something. In science, an index often represents a combination of different data points.

Volcano Maps



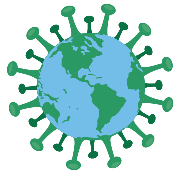
The United States still has active volcanoes, like Mount St. Helens in Washington, which most recently erupted in 2008. Volcanoes pose a variety of hazards. A large-scale, rapid eruption can produce a pyroclastic flow, which is a mix of gases, rock, ash, and lava that moves very quickly over a landscape. Flows of hot lava can demolish everything in their paths. Some volcanoes can also produce mudflows called lahars. This regional map shows the potential for all three volcanic eruption hazards near Mount St. Helens. A reader can determine how specific hazards might affect the different towns near the volcano. Like water, lava and mudflows tend to move downhill, so some rivers could be filled with volcanic mud if Mount St. Helens erupts again.

Drought Data Tables

- Number of Droughts: 10
- Longest Drought: 18 weeks
- Average Duration: 8 weeks
- Time in Drought: 19.47%

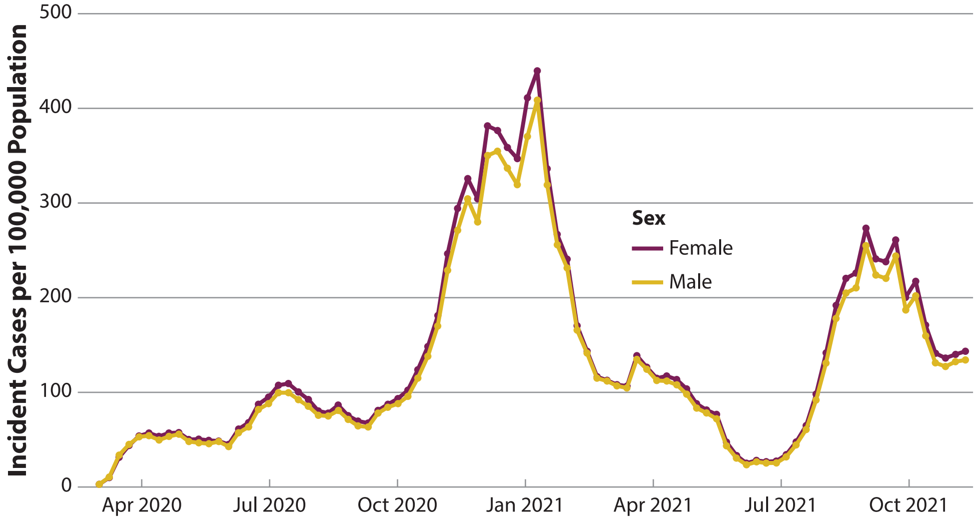
Drought Start	Drought End	Duration (weeks)
2/19/2010	3/26/2010	5
1/22/2011	3/5/2011	6
11/12/2011	1/22/2012	10
9/23/2012	11/25/2012	9
2/19/2013	4/2/2013	6
4/30/2013	5/14/2013	2
10/22/2013	2/26/2014	18
6/4/2014	7/2/2014	4
1/22/2015	5/14/2015	16
6/3/2016	7/8/2016	5

Droughts are natural disasters that are defined by prolonged periods of low rainfall, making water scarce for the humans, plants, and animals that rely on it. This drought data table comes from the hydrology station in Alturus, California. When the precipitation index—a measure of how much rain or snow fell in the town—was–1, this meant a drought was occurring. The new millennium has featured several droughts in states like California. By studying drought data, local and state governments can determine how different activities or industries might be affected and what actionable steps can be done in response. For example, during a drought, residents of the area may be asked to reduce their water usage to help conserve it. This might mean doing fewer loads of laundry, taking fewer showers, or not watering the grass in your yard until the drought ends.

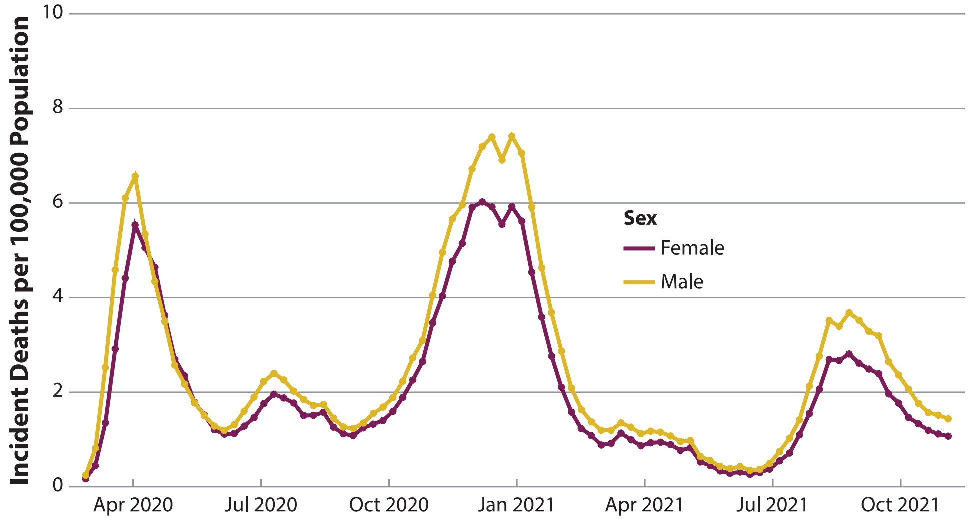


Pandemic Charts and Graphs

COVID-19 Weekly Cases per 100,000 Population by Sex, United States
March 01, 2020 – November 06, 2021



COVID-19 Weekly Deaths per 100,000 Population by Sex, United States
March 01, 2020 – November 06, 2021



The COVID-19 pandemic began in 2020 and resulted in millions of deaths and large-scale disruptions of people's lives. The data from the pandemic can be analyzed through a wide variety of graphical displays. The two graphs here show how many cases of the virus the United States had between March 2020 and November 2021 for men and women. The top graph suggests that women tested positive for COVID-19 more frequently than men. The bottom graph suggests that men were more likely to die from the disease. Throughout history, there have been many pandemics, so it is likely that another will occur in the future. Studying data trends can help physicians and scientists fight communicable diseases.

Hazards Depicted in Art and Literature

The following text is an excerpt of a translation of two letters that were sent to the Roman historian Tacitus from Pliny the Younger, whose uncle Pliny the Elder was another well-known scholar. The elder died during the eruption of Mount Vesuvius. His nephew attempted to capture the scenes of the eruption and its aftermath in these letters. It is one of the oldest written records of a volcanic eruption. The footnotes provide more detail.

On the 24th of August, about one in the afternoon, my mother desired my uncle to observe a cloud which appeared of a very unusual size and shape… He immediately arose and went out upon a rising ground from whence he might get a better sight of this very uncommon appearance. A cloud, from which mountain was uncertain, at this distance (but it was found afterwards to come from Mount Vesuvius), was ascending, the appearance of which I cannot give you a more exact description of than by likening it to that of a pine tree, for it shot up to a great height in the form of a very tall trunk, which spread itself out at the top into a sort of branches; occasioned, I imagine, either by a sudden gust of air that impelled it, the force of which decreased as it advanced upwards, or the cloud itself being pressed back again by its own weight, expanded in the manner I have mentioned… He ordered the vessels to be put to sea[1], and went himself on board with an intention of assisting not only Rectina, but the several other towns which lay thickly strewn along that beautiful coast. Hastening then to the place from whence others fled with the utmost terror, he steered his course direct to the point of danger… He was now so close to the mountain that the cinders, which grew thicker and hotter the nearer he approached, fell into the ships, together with pumice stones, and black pieces of burning rock: they were in danger too not only of being aground by the sudden retreat of the sea, but also from the vast fragments which rolled

down from the mountain, and obstructed all the shore. Here he stopped to consider whether he should turn back again; to which the pilot advising him, "Fortune," said he, "favors the brave." …They consulted together whether it would be most prudent to trust to the houses, which now rocked from side to side with frequent and violent concussions as though shaken from their very foundations; or fly to the open fields, where the calcined stones and cinders, though light indeed, yet fell in large showers, and threatened destruction. In this choice of dangers they resolved for the fields… They went out then, having pillows tied upon their heads with napkins; and this was their whole defense against the storm of stones that fell round them[2]. It was now day everywhere else, but there a deeper darkness prevailed than in the thickest night… They thought proper to go farther down upon the shore to see if they might safely put out to sea, but found the waves still running

[1] Pliny the Elder was a scholar of nature as well as a commander of the Roman navy. His nephew most likely learned a great deal from him about natural phenomena, such as what might cause clouds to form and behave as the younger describes here.

[2] The falling chunks of volcanic rock or lava are known as ballistic ejecta or bombs.

extremely high, and boisterous. There my uncle, laying himself down upon a sail cloth, which was spread for him, called twice for some cold water, which he drank, when immediately the flames, preceded by a strong whiff of sulfur, dispersed the rest of the party, and obliged him to rise. He raised himself up with the assistance of two of his servants, and instantly fell down dead; suffocated, as I conjecture, by some gross and noxious vapor[3], having always had a weak throat, which was often inflamed…

My uncle having left us, I spent such time as was left on my studies, till it was time for my bath. After which I went to supper, and then fell into a short and uneasy sleep. There had been noticed for many days before a trembling of the earth[4], which did not alarm us much, as this is quite an ordinary occurrence in Campania; but it was so particularly violent that night that it not only shook but actually overturned, as it would seem, everything about us… By morning, the light was still exceedingly faint and doubtful; the buildings all around us tottered, and though we stood upon open ground, yet as the place was narrow and confined, there was no remaining without imminent danger: we therefore resolved to quit the town. A panic-stricken crowd followed us, and (as to a mind distracted with terror every suggestion seems more prudent than its own) pressed on us in dense array to drive us forward as we came out. Being at a convenient distance from the houses, we stood still, in the midst of a most dangerous and dreadful scene… On the other side, a black and dreadful cloud, broken with rapid, zigzag flashes, revealed behind it variously shaped masses of flame: these last were like sheet-lightning, but much larger… Soon afterwards, the cloud began to descend, and cover the sea. It had already surrounded and concealed the island of Capri… The ashes now began to fall upon us, though in no great quantity. I looked back; a dense dark mist seemed to be following us, spreading itself over the country like a cloud. "Let us turn out of the high-road," I said, "while we can still see, for fear that, should we fall in the road, we should be pressed to death in the dark, by the crowds that are following us." …You might hear the shrieks of women, the screams of children, and the shouts of men; some calling for their children, others for their parents, others for their husbands, and seeking to recognize each other by the voices that replied; one lamenting his own fate, another that of his family; some wishing to die, from the very fear of dying… Among these there were some who augmented the real terrors by others imaginary or wilfully invented. I remember some who declared that one part of Misenum had fallen, that another was on fire; it was false, but they found people to believe them[5]… Again we were immersed in thick darkness, and a heavy shower of ashes rained upon us, which we were obliged every now and then to stand up to shake off, otherwise we should have been crushed and buried in the heap… At last this dreadful darkness was dissipated by degrees, like a cloud or smoke; the real day returned, and even the sun shone out, though with a lurid light, like when an eclipse is coming on… The earthquake still continued, while many frenzied persons ran up and down heightening their own and their friends' calamities by terrible predictions…

And now, you will read this narrative without any view of inserting it in your history, of which it is not in the least worthy; and indeed you must put it down to your own request if it should appear not worth even the trouble of a letter. Farewell.

[3]Gases released by volcanoes can be deadly. Sulfur dioxide is one gas that can damage lungs and cause death if it is at a high concentration. Some people exploring volcanoes have fallen into vents and craters after inhaling these gases and losing consciousness.

[4]Pliny the Younger is describing earthquakes, which often occur before or during a large-scale volcanic eruption.

[5]In the absence of good information, people come up with explanations and spread rumors. This can fuel panic in a natural disaster. It can also lead to myths and other types of stories that explain such phenomena.

Art has been used to represent hazardous natural phenomena for thousands of years. While a two-dimensional image cannot provide as much information or data as a long, first-person narrative such as Pliny the Younger's to Tacitus, it can evoke how nature makes us feel or take us to places or scenes we've never been.

Hokusai was an artist who produced many woodblock prints in the early 19th century in Japan. He did a whole series of prints focused on Mount Fuji, a volcanic mountain on Japan's main island, Honshu. His *Great Wave* print features the mountain, but only in the background. In the foreground, terrified fishermen deal with a turbulent sea. This image has been used to evoke tsunami waves, hurricanes, and other phenomena. The fact that the mountain appears to be dwarfed by the wave adds to the sense of the wave as a hazard.

Winslow Homer's *Gulf Stream*, painted in 1899, shows a lone man on a damaged sailboat in stormy waters, with sharks lurking in the foreground while a waterspout—a tornado on the sea surface—whirls ominously in the background.

Poetry and song have been used to describe natural hazards, particularly storms. Gordon Lightfoot's "The Wreck of the Edmund Fitzgerald," released in 1976, describes a storm on the Great Lakes that sank a cargo ship. While ocean storms get much-deserved attention, storms on large lakes and rivers can be extremely hazardous, too. After all, heavy wind on a large lake can whip up waves just as it does on the ocean.

The music of this song builds in intensity and volume, like the storm it depicts. The *Edmund Fitzgerald* was a real ship that sank in November 1975 with all 29 of its crew.

In a musty old hall in Detroit they prayed
In the maritime sailors' cathedral
The church bell chimed 'til it rang twenty-nine times
For each man on the *Edmund Fitzgerald*
The legend lives on from the Chippewa on
down
Of the big lake they called Gitche Gumee
Superior, they said, never gives up her dead
When the gales of November come early

Model of the *Edmund Fitzgerald*, Great Lakes Shipwreck Museum, Paradise, Michigan

Tsunami Models

With waves as tall as buildings and ocean water that washes over entire cities, Hollywood movies about tsunamis, like *Tidal Wave* and *San Andreas*, are action packed and exciting to watch. The storylines of some of these kinds of films often involve scientists who discover data that predict a tsunami will occur weeks into the future. These scientists try to warn people of the impending natural disaster, but their attempts are disregarded, even though they have scientific models and tools that confirm their predictions.

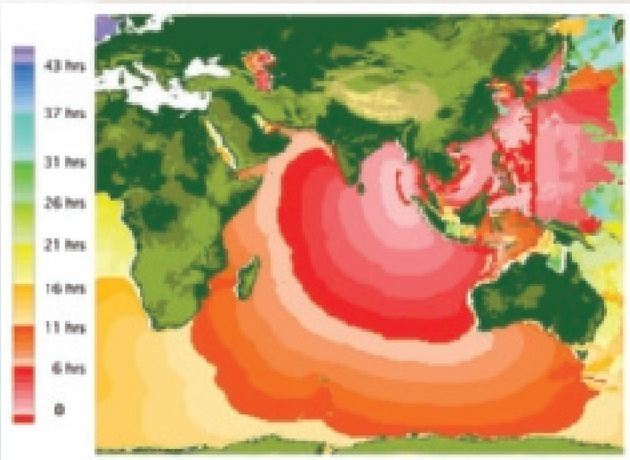
Although Hollywood gets a lot of science wrong, these movies do get some things right. Scientists *do* have the tools and technology that make it possible for them to study and predict tsunamis and other natural events.

Let's look at a real-life example where scientists studied a tsunami using different kinds of visual models. In 2004, an earthquake off Indonesia's main island caused the seafloor to move. This caused a tsunami that devastated coastal nations around the Indian Ocean.

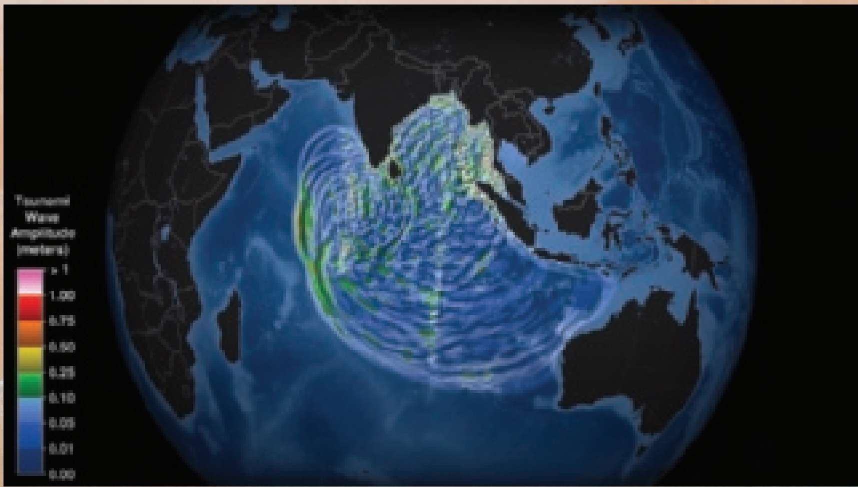
The undersea earthquake triggered alerts on different networks, and scientific models calculated how long it would take the tsunami waves to arrive at different points around the world. This information is important for giving people enough time to evacuate coastal areas. The models were based on a variety of factors, such as the speed of the tsunami waves, the different contours of ocean basins, and the presence of landmasses, which cause tsunami waves to bend and thus slow down.

How well did the original tsunami models predict the wave arrival times? The graph on the facing page compares those predictions with the observed, actual wave arrival times at different stations around the world. The nearer the station to the source of the tsunami waves, the more accurate the prediction. You will see that the regional model arrival times were very accurate. The global model arrival times were less accurate.

Unfortunately, what we can't predict in a timely manner are the earthquakes that cause tsunamis. There's a big difference between predicting where and how fast a tsunami will go once it's triggered and when it will occur. That depends on the triggering mechanism.



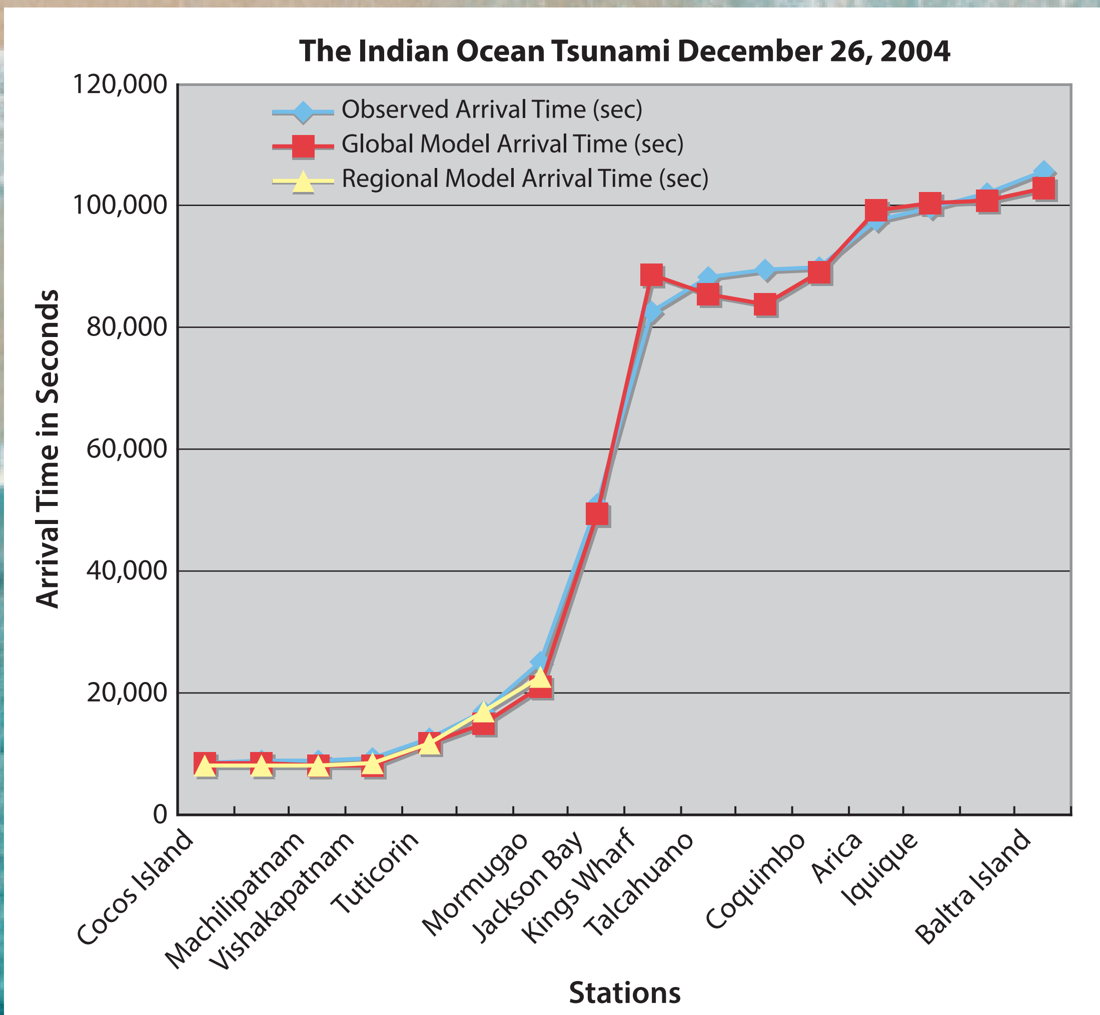
The map above shows estimated tsunami wave arrival times based on a model that was in use at the time.



This image is taken from an animation based on the tsunami's actual movements and the specific way in which the seafloor moved in the earthquake.

Words to Know

An *accurate* prediction is one that matches the actual, observed result or event. An arrow that strikes a bull's-eye means the shot was accurate. If multiple arrows strike a specific area of a target, that means the shots were *precise*. When multiple arrows hit the bull's-eye, the shots were both accurate and precise.



Dear Scientist Column

Tsunami Q & A

Dear Scientist,

Today I saw a picture of a tsunami wave in my science class. It did not look like a normal wave that you see in the ocean. It almost looked like it was standing up in the water, but I don't know how that would even be possible. The tsunami didn't even seem to bend like waves typically do when they reach the shore. Am I seeing this correctly? Also, how tall can tsunamis get? I've read differing things about this on the internet.

Sincerely,

Tsunami Curious

Dear Tsunami Curious,

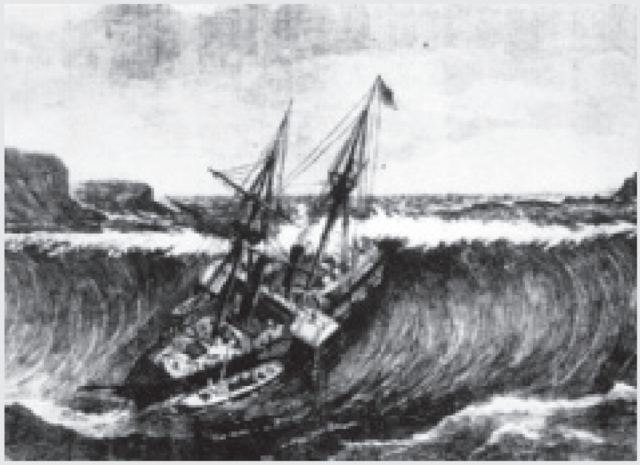
You are 100% seeing things correctly. A tsunami wave does not often resemble a neat, wind-driven ocean wave that rises and then curls as it breaks. Instead, it can look and behave like a wall of water, as though the sea has simply risen.

People believe myths about tsunamis. They think they are huge, always hundreds of feet tall. The fact is the height of a tsunami wave depends on where it hits the shore. The height of a tsunami wave increases as it reaches narrow areas of the coast, known as the run-up height. Out in the middle of the ocean, a tsunami wave is transferring energy and will transfer it to the shore. According to the NOAA Center for Tsunami Research, the average run-up height of a tsunami wave can be 30–70 feet!

In 2011, a huge earthquake caused tsunamis off the northeast shore of Japan. If you had been on a boat in the area, you might not have even noticed the sea level rise. But things changed near the shore.

Where there was a broad, gently sloped shoreline or an open harbor, the entire sea level rose maybe ten feet or more above normal. But think about it. A ten-foot rise happened not only at the shore but the water rose a mile or more inland. The flooding was massive. Huge parts of many coastal cities were devastated.

But what would happen if that same amount of water were channeled into a narrow harbor? In that case, the ocean water would behave very differently. The water would pile up, and a huge wave would result. Such a wave destroyed the ship *La Plata* in 1867. This is the kind of wave you hear about in myth—but it happens in real life, too.



Not all tsunamis that occur are massive. In fact, there are tsunami waves that happen quite frequently in the ocean but are only a few inches tall and are very weak, so they don't cause any destruction or draw attention to themselves. However, scientists still monitor them, and studying how they move is important.

Cranky Yankee Blog

Another week, another storm, another opportunity for someone to insist that the storm and all kinds of other weather here in Connecticut are caused by climate change. This time, it's a hurricane that's heading our way. Six months from now, it'll be a blizzard.

Do people not realize that this area has been hit by hurricanes for as long as anyone can remember? The worst one in our recorded history was way back in 1938, long before we heard all this talk about global warming. So, did climate change take a time machine back to that year, open the door, and make that hurricane happen as well? Or maybe, just maybe, that hurricane and the one that's poised to make landfall here tomorrow night are natural events that have been occurring forever and will keep occurring forever more?

Likewise, when we get heavy snowfall this winter from a standard nor'easter, don't tell me it's because the ocean is warmer and therefore there's more moisture in the air and that leads to more snowfall. The biggest snowstorm I ever saw was in Providence, Rhode Island, in 1978. I was eight years old, and the snow was piled up as high as my eyes. My dad tried to drive home from work and ended up having to abandon his car in the middle of the street and trudge to our house in whiteout conditions. This was before the concentration of carbon dioxide passed 340 parts per million and decades before it got near 400. What caused that storm? Same thing that causes other snowstorms: moist air colliding with cold air, causing water vapor to freeze into crystals of ice that then aggregate into snowflakes, which fall to Earth.

The climate has always been changing, and the weather is always changing, too. Like my uncle used to say, if you don't like the weather right now, just wait fifteen minutes. And while you're waiting, stop blaming climate change for everything!

~ The Cranky Yankee

Spot the BS

Heads up! There's some **b**ad **s**cience on this page. Can you list the ways this cranky blogger misrepresents facts? How does the blogger try to convince readers that climate change is not a real threat?

Dear Cranky Yankee,

I normally enjoy your blog, but your post about the connection between climate change and weather phenomena is an odd take.

It's true that blizzards and hurricanes and other storms have visited the shores of Connecticut for centuries, without being fueled by the rise of atmospheric carbon dioxide and its warming effect. But climate scientists deal in probabilities, not absolute certainties. As such a scientist, I cannot say with 100% certainty that last week's Category 3 hurricane was due to global warming. What I can say is that hurricanes and other types of severe storms are made more likely by climate change. And I can tell you why.

Greenhouse gases trap heat. Heat is the movement of thermal energy from a warmer to a colder place, and more thermal energy just means particles moving about at a higher rate. Something that is "hot" has particles that have a lot of kinetic energy. They're moving around a lot. Something that is "cold" has particles with less kinetic energy, less motion. A warmer atmosphere has more kinetic energy than a cold one. Some of this energy gets into the ocean, too, warming its surface. Warmer surface water evaporates at a higher rate than cooler water. In winter, a warm ocean feeds storms such as nor'easters. There's more moisture to make snow, and the warmed air is better able to hold that added moisture. Mix that warm, moist air with cold air blowing in from the Arctic and—wham!—it's blizzard time. As our offshore waters get warmer, we can expect nor'easters to be more frequent and/or more severe. I cannot say that this or any other storm would not have happened without our current atmospheric CO_2 level exceeding 400, but it absolutely is more likely because of it, and we can expect more stormy weather in the years to come—including hurricanes.

Regards,

Winston Cummings, PhD
Department of Chemistry
Harkness College
New London, CT

Vocabulary

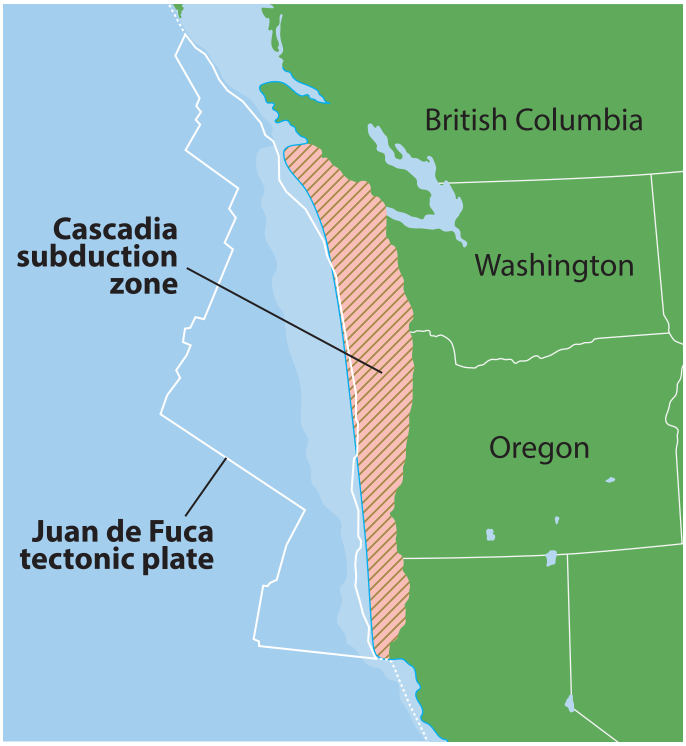
probability, n. the mathematical likelihood that something will occur

Consider the Source

What information does the commenter provide that makes him seem like a credible source?

The Cascadia Subduction Zone

In the Pacific Northwest, there is a fault zone called the Cascadia subduction zone. The oceanic Juan de Fuca tectonic plate is subducting, or diving under, the continental North American plate. At subduction zones, the edge of the overlying plate can get stuck. This causes its rock to get compressed over time. This is occurring right now at the Cascadia subduction zone.



The rock of part of the West Coast is getting compressed to the east and nudged upward millimeter by millimeter, year by year. This compression causes stress to build up. Eventually, the compressed plate edge can't take any more stress. It reacts through an earthquake—a release of a massive amount of energy through Earth's crust.

The evidence for the Cascadia subduction zone and its pattern of activity comes from several different sources of knowledge.

Physical Evidence The physical evidence of the Cascadia subduction zone includes the death of a red cedar forest along the Copalis River near Washington's coast. The "ghost forest" was known for its leafless, skeletal tree trunks, which suggested the trees had been dead for a very long time. Initially, scientists thought the trees died as the sea level rose and flooded their roots with saltwater. But analysis of the trees' growth rings showed they had all died at the same time, in late 1699 or early 1700. Instead of the sea level rising, scientists thought the land had dropped, which would explain a sudden rush of seawater into the river and up its banks.

Historical Evidence The historical evidence of the Cascadia subduction zone and its cycle of activity came from across the ocean, in Japan, where tsunami records have been kept for five centuries. On January 27, 1700, a large tsunami struck a 600-mile length of Japan's east coast. However, there were no signs of an earthquake locally. This tsunami had been generated somewhere else. This "orphan tsunami" and its timing lined up perfectly with the physical evidence of an earthquake and tsunami on Washington's coast from that same time. The historical data from Japan allowed scientists to calculate that the earthquake occurred at 9:00 at night, local time, on January 26, 1700, and the tsunami struck Washington 15 minutes later and Japan 10 hours later.

Anthropological Evidence After the physical and historical evidence led to the conclusion that the Cascadia subduction zone had last experienced a massive earthquake and tsunami in 1700, stories from Native Americans of the Pacific Northwest began to make more sense. In British Columbia, north of Washington, members of the Huu-ay-aht First Nation passed down stories of a violent earthquake that occurred at night, sinking an island, with seawater receding from the shore and then surging back in, wiping out whole villages. Careful analysis of these stories and the generations that had told them suggested that they were about an earthquake and tsunami that occurred around 1700. This was anthropological evidence that further supported the physical and historical evidence.

Connections

This is a great example of how science can work by seeking knowledge from other sources of data. But it is also bad news for the Pacific Northwest. On average, major earthquakes and tsunamis have occurred there every 243 years on average, which means the region may at some point have a destructive earthquake and a tsunami that could devastate low-lying coastal areas.

Dig into Data

What data in the article most strongly support the argument that the oceanic Juan de Fuca plate is, in fact, subducting? What data appear to be the weakest?

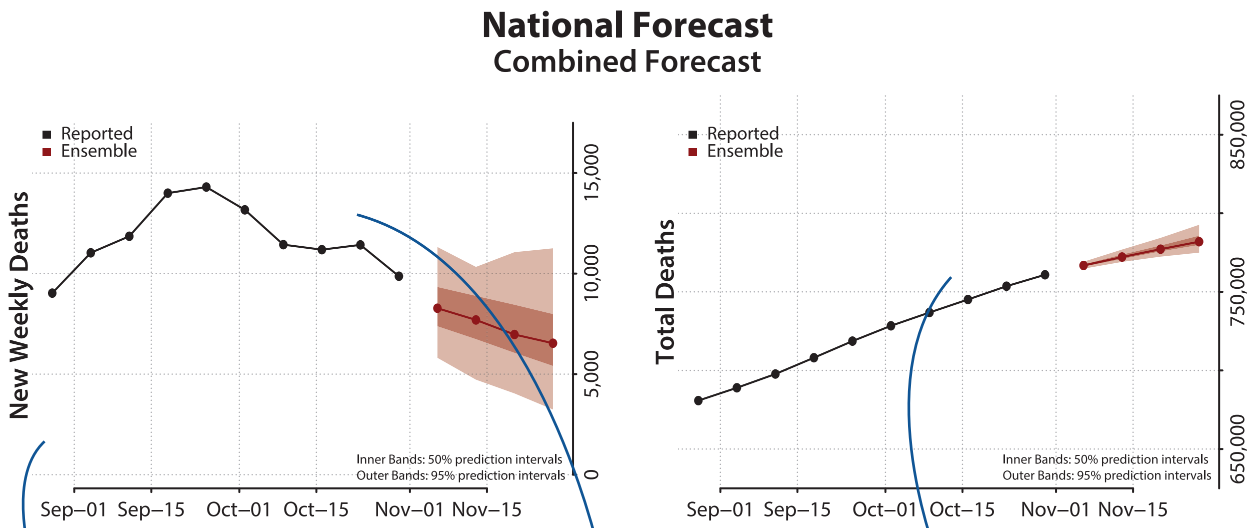
Word to Know

Anthropology is the study of humans and human groups over time. It relies on evidence ranging from bones to stories to tools to piece together the history of humanity.

COVID Forecasts

People usually think of natural disasters as floods or earthquakes. But a mass viral outbreak can be considered a type of natural disaster, too. The COVID-19 **pandemic** came on swiftly. The ways it affected different populations around the world varied quite a bit. In densely populated places where the virus struck before people knew to take precautions such as wearing face masks, the virus took a very heavy toll. Studying how the virus affected these early hot spots helped epidemiologists develop models to forecast how the virus would likely affect other populations as the virus spread. Governments used forecasts to make decisions about opening and closing restaurants, and other measures that might prevent the spread of COVID-19. It may take many years of piecing together data to reliably reveal cause-and-effect relationships in pandemic outcomes.

National Forecasts



In the United States, the Centers for Disease Control and Prevention (CDC) developed a national forecast for cases and deaths from COVID-19. This forecast was updated regularly.

The curve for new deaths per week was finally starting to decline. Many scientists believe this is because of vaccinations and precautions.

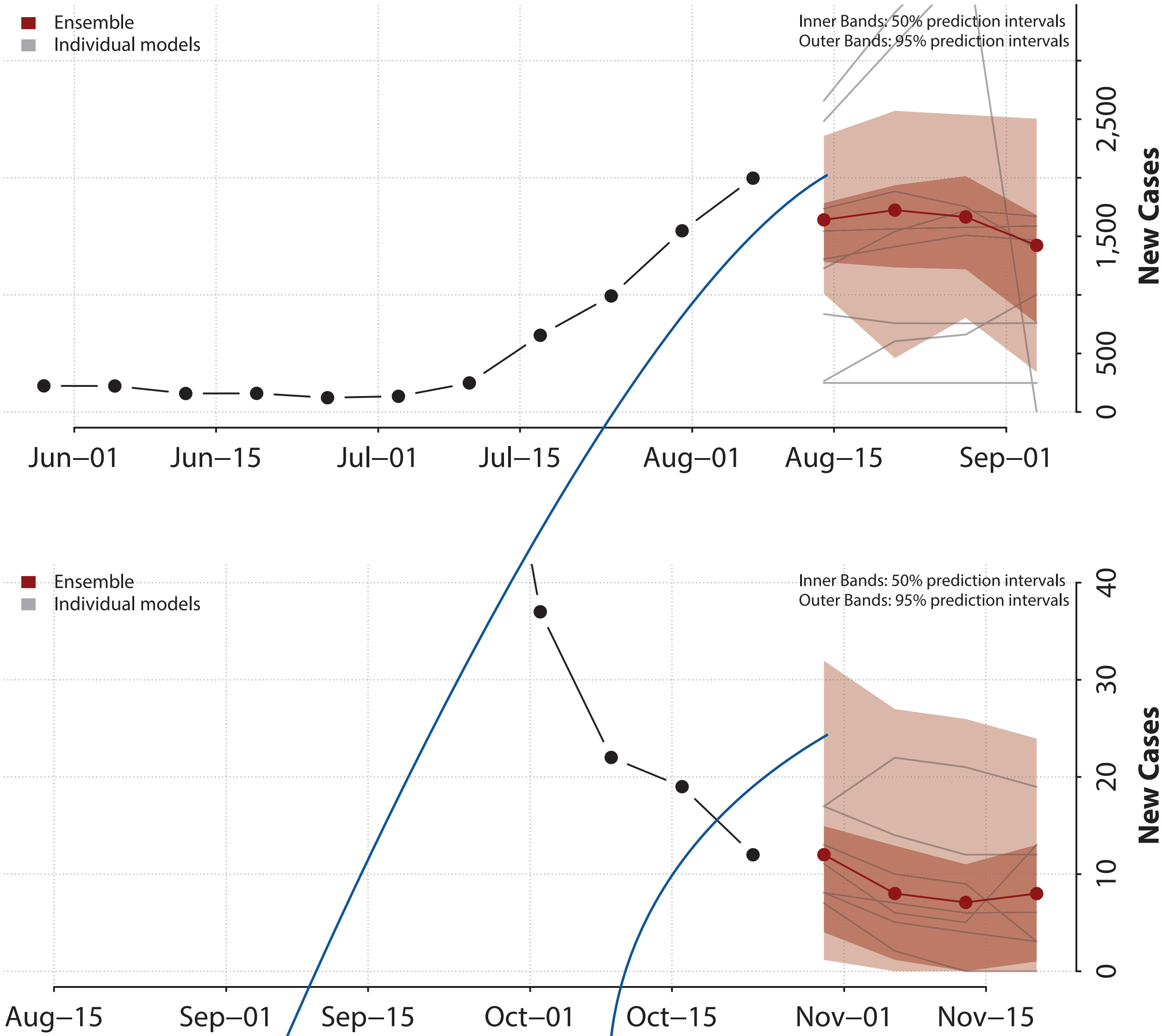
By late October 2021, over 700,000 Americans had died from the disease. But the total death forecast curve flattens out a little bit with the introduction of vaccines.

Dig into Data

The tan shaded areas around each forecast curve represent upper and lower limits on where the numbers might go if assumptions built into the models are incorrect. Sometimes a model or forecast can fail to account for something that's actually happening, such as a new variant of a virus that makes it more infectious or data that were held back by a specific state or city.

Local Forecasts

Here are two forecasts for new COVID cases in Manatee County, Florida, first from August 9 and then from October 27, 2021.



The summertime spike in cases in Manatee is clear in the August graph. The two gray lines are actually off the chart.

There is a decline in new cases in October. Look at the vertical axes of the two graphs. Instead of counting new cases by the hundreds or thousands, the number dropped into double digits and was projected to drop below ten by late November.

Vocabulary

pandemic, n. an outbreak of a disease that occurs over multiple continents and affects a large portion of the population

Word to Know

An *epidemiologist* is a scientist who studies infectious diseases and how they spread in populations.

Contrasting Natural Hazards

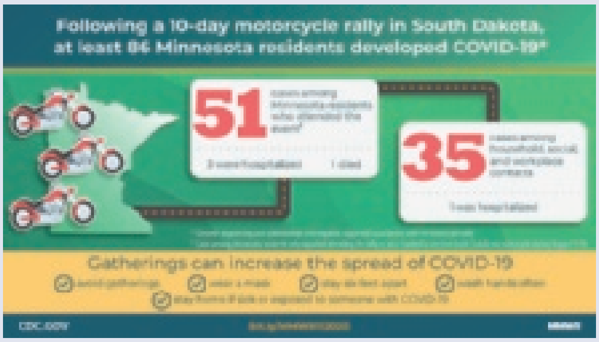
You may have heard and sung this nursery rhyme when you were a little kid:

Ring around the rosy
A pocketful of posies
"Ashes, Ashes"
We all fall down!

As innocent as this nursery rhyme appears, urban legend believes it is a reference to the Great Plague of London in 1665. The Great Plague was a bacterial infection that killed about 15% of London's population. London was (and still is) a very densely populated area, and the plague was a natural hazard that easily spread from one person to another.

Some natural hazards are density-dependent. This means the hazard is more of a threat if there are more people or other organisms in the area where the hazard is occurring. Infectious diseases, like the Great Plague, are density-dependent hazards, causing people to spread the disease to each other more easily because they are closer together. Other types of natural hazards, like earthquakes and tsunamis, are also density-dependent. They cause more destruction in areas that are highly populated than those with fewer people and structures.

Throughout history, there have been incidents of natural hazards in the form of contagious and infectious diseases that have particularly affected densely populated areas. COVID-19 is another example of such a disease. It spread worldwide and killed millions of people but was particularly hazardous in large cities, often called "hot spots," and spread easily at large group gatherings, known as super-spreader events.



The annual motorcycle rally in Sturgis, South Dakota, draws about half a million people. The rally happened in 2020 despite the COVID-19 pandemic. According to the Centers for Disease Control and Prevention, the high density of people helped the COVID-19 virus spread at the rally. When attendees rode home to states across the United States they served as carriers, sparking outbreaks in those communities. This rally was considered a super-spreader event.

Cholera is another natural hazard in the form of an infectious disease that affects densley populated areas. In the mid-1800s in London, people shared drinking water pumps in central locations, like parks. Many of these pumps drew water from the nearby river, the Thames. At that time, the Thames was being treated as a dumping ground for sewage and was a breeding ground for bacteria like *Vibrio cholerae*. Cholera outbreaks began to occur in London, but people did not know why.

A physician named John Snow studied the outbreak more closely. He researched who was getting the disease and how they got their drinking water. He made a connection between cholera patients and water supplies to confirm that cholera was caused by something in the water. Snow eventually discovered that a water pump was the source of the cholera outbreak in the surrounding neighborhood. The pump was shut down, and the outbreak stopped.

This map by John Snow (1813–1858) marks where cholera cases occurred. The cases cluster around Broad Street (highlighted yellow). A pump on Broad Street was fed by a well that had been dug next to a cesspool where sewage went. The contaminated well was the culprit.

Words to Know

Contagious diseases are passed from one animal to another through contact. For example, the common cold is a contagious disease. It is also an *infectious* disease, because it infects humans fairly easily once contact is made. Some infectious diseases are not contagious. For example, Lyme disease, which people can get from certain ticks, is not contagious between humans despite being infectious.

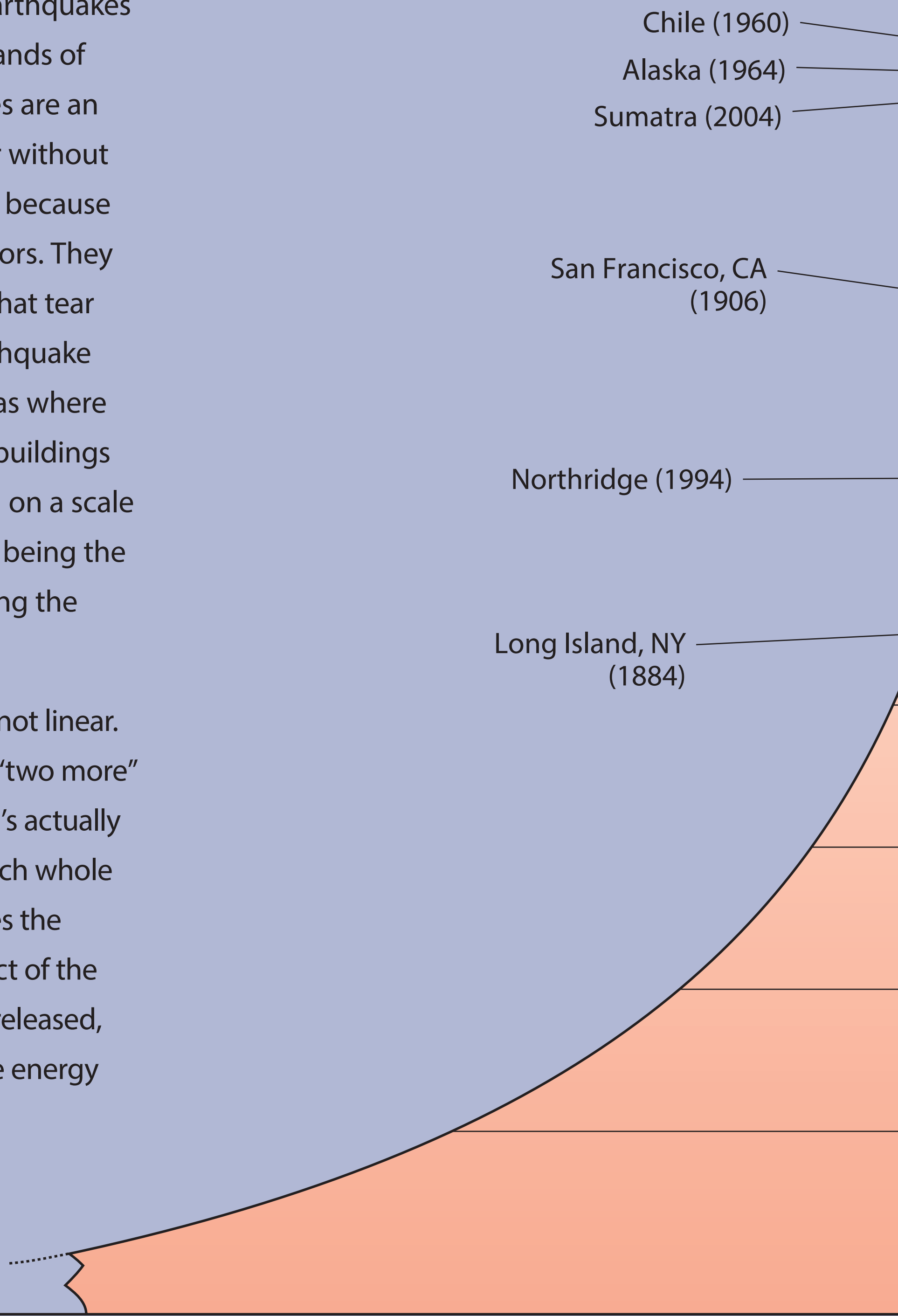
Vocabulary

magnitude, n. size or extent

Infectious hazards can unfold over months or years and affect millions of people across borders. Natural hazards such as earthquakes can occur quickly and affect thousands of people or no one at all. Earthquakes are an example of a hazard that can occur without anyone but seismologists noticing, because earthquakes can be very mild tremors. They can also be catastrophic disasters that tear down cities. The severity of an earthquake is based on its **magnitude** as well as where it occurs and whether people and buildings are nearby. Magnitude is measured on a scale from 1 to 10, with a 1.0 earthquake being the smallest and a 10.0 earthquake being the largest and most destructive.

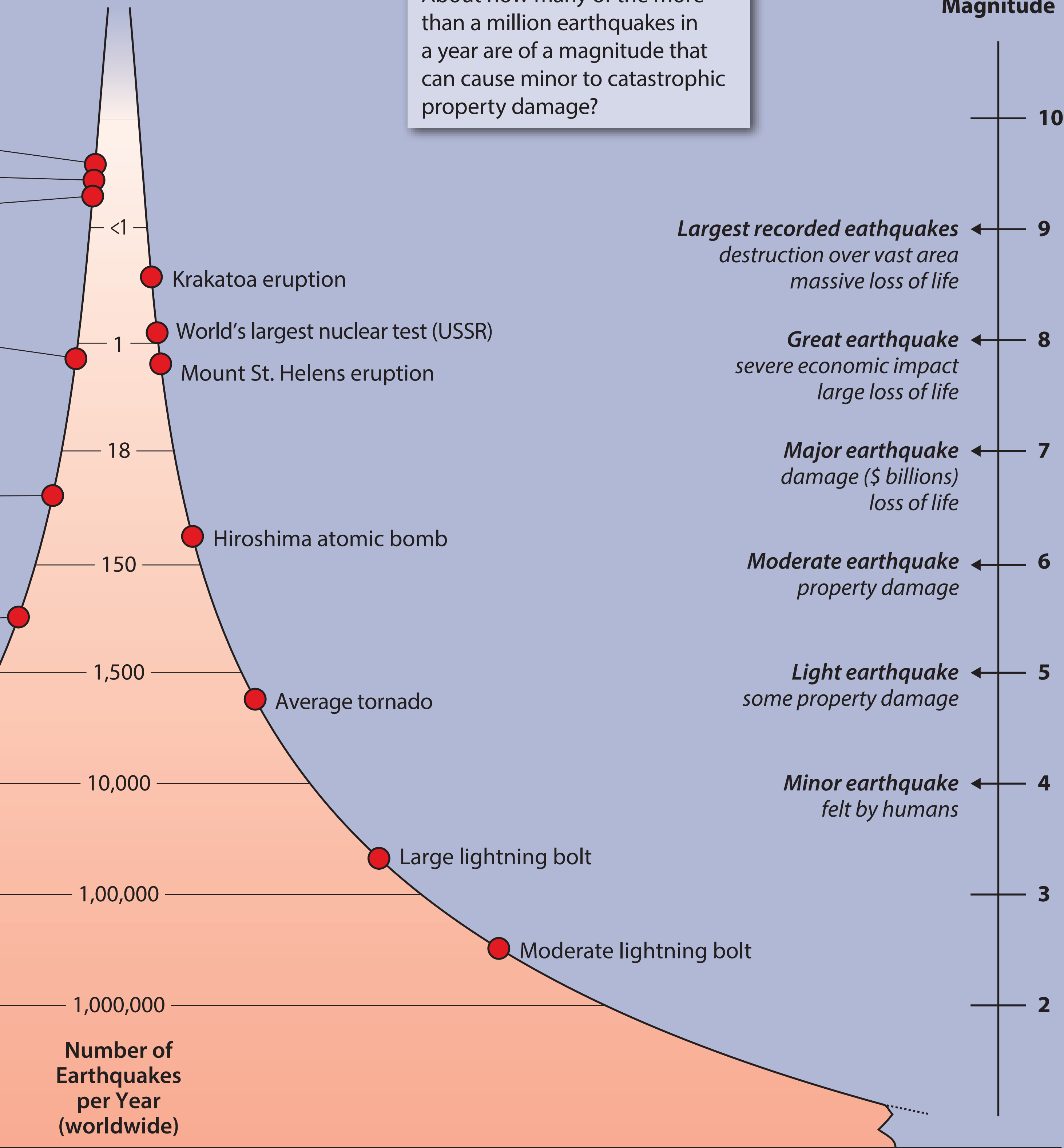
The earthquake magnitude scale is not linear. A 9.0-magnitude earthquake is not "two more" than a 7.0-magnitude earthquake. It's actually 100 times bigger! This is because each whole step on the scale represents 10 times the size. But size captures just one aspect of the earthquake. In terms of the energy released, 9.0 means one *thousand* times more energy released than the 7.0 quake.

The chart summarizes different earthquakes in history and compares their magnitudes.



Dig into Data

About how many of the more than a million earthquakes in a year are of a magnitude that can cause minor to catastrophic property damage?



Natural Hazard Survival 101

The world can be a dangerous place. There are natural hazards that can and will occur no matter what we do, and some of them will occur without any warning. Here are some basic precautions that people can take to minimize the amount of damage and suffering that hazards cause.

1 Move away from hazard zones.

Know the hazards in different areas, and let that help you decide where to live. In areas with tsunami risks, move to the middle of any continent or live on higher ground, where flooding would not be an issue. Move away from places with frequent earthquakes or tornadoes.

Japanese villagers who suffered catastrophic losses from tsunamis did their descendants a big favor by carving messages into stones set on hillsides at locations that tsunami waves had reached. One example: "Remember the calamity of the great tsunamis. Do not build any homes below this point." Homes built below that marker were damaged in the 2011 tsunami.

2 Stay connected.

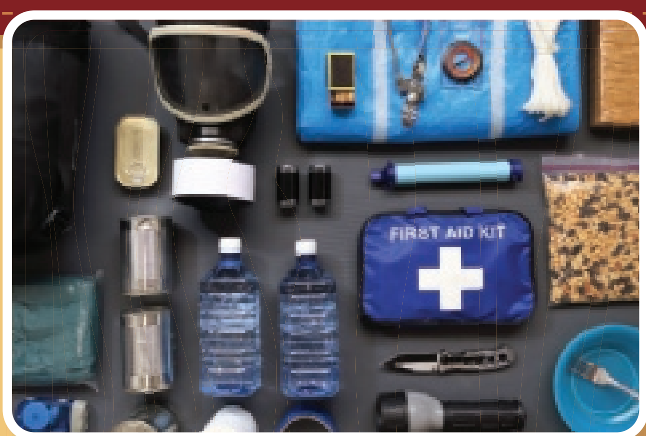
Use technology to stay safe. Smartphones today can alert you of tremors, earthquakes, and other natural hazards before or as they occur. Even a simple radio can help keep you informed. You'll need electricity to power it, so keep some batteries handy. Subscribe to different hazard alert services, such as USGS's Earthquake Notification Service or the National Tsunami Warning Center's alerts by text message. Social media can be useful as well, but pay attention to sources of information.

3 Make a plan.

Make a hazard safety plan with the people in your home, or share your plan with those who might be looking for you in the event of a natural disaster. Know where to go if you need to evacuate. Map out a safe route for escaping different types of hazards, like wildfires or floods. Have a list of emergency phone numbers written out, as well as a physical map with directions, in case you can't access your contacts or navigation apps on your cell phone.

4 Stock up on supplies.

Stock up on supplies in case you need to shelter in place for days or weeks. You'll need extra gallons of water for drinking, bathing, and even flushing your toilet. If you can, invest in a backup generator or some small solar cells that can be used to charge your mobile devices. Prepare some type of basic cooking setup that doesn't require electricity, such as an outdoor grill, a solar oven, or flameless food warmers. If you can bring water to a boil, the same setup can be used to make unfiltered water safer to drink. Iodine tablets are another way to treat water. Have backup batteries for your electronic devices, and don't forget a first aid kit. If you take medication, get an extra month's supply in advance.



Disaster Domino Effect

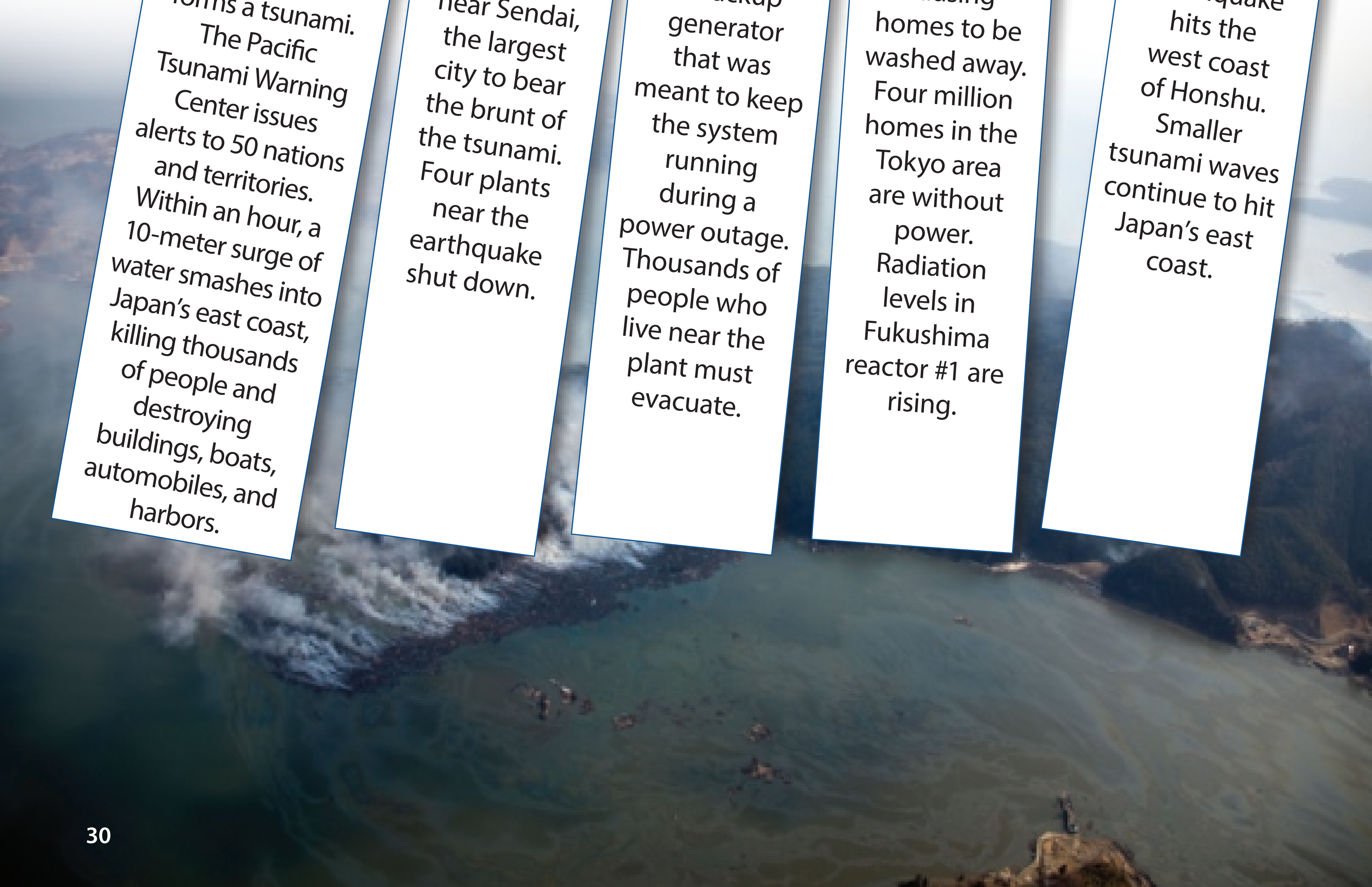
Friday, March 11, 2011, 2:46 p.m.: A magnitude-9.0 earthquake occurs in Earth's crust below the Pacific Ocean off Honshu, Japan's main island. A large area of the seafloor moves horizontally by 50 meters and vertically by 16 meters. The displaced water forms a tsunami. The Pacific Tsunami Warning Center issues alerts to 50 nations and territories. Within an hour, a 10-meter surge of water smashes into Japan's east coast, killing thousands of people and destroying buildings, boats, automobiles, and harbors.

8:15–9:35 p.m.: The Japanese government declares an emergency at a nuclear power plant near Sendai, the largest city to bear the brunt of the tsunami. Four plants near the earthquake shut down.

10:29 p.m.: At the Fukushima Daiichi Nuclear Power Plant, the cooling system fails for four reactors. The tsunami's waves destroyed a backup generator that was meant to keep the system running during a power outage. Thousands of people who live near the plant must evacuate.

Saturday, March 12, early a.m.: Fires triggered by the tsunami are reported in multiple areas. A dam in Fukushima breaks, causing homes to be washed away. Four million homes in the Tokyo area are without power. Radiation levels in Fukushima reactor #1 are rising.

5–6 a.m.: Nuclear emergency declared at the Fukushima plant. Another, smaller earthquake hits the west coast of Honshu. Smaller tsunami waves continue to hit Japan's east coast.



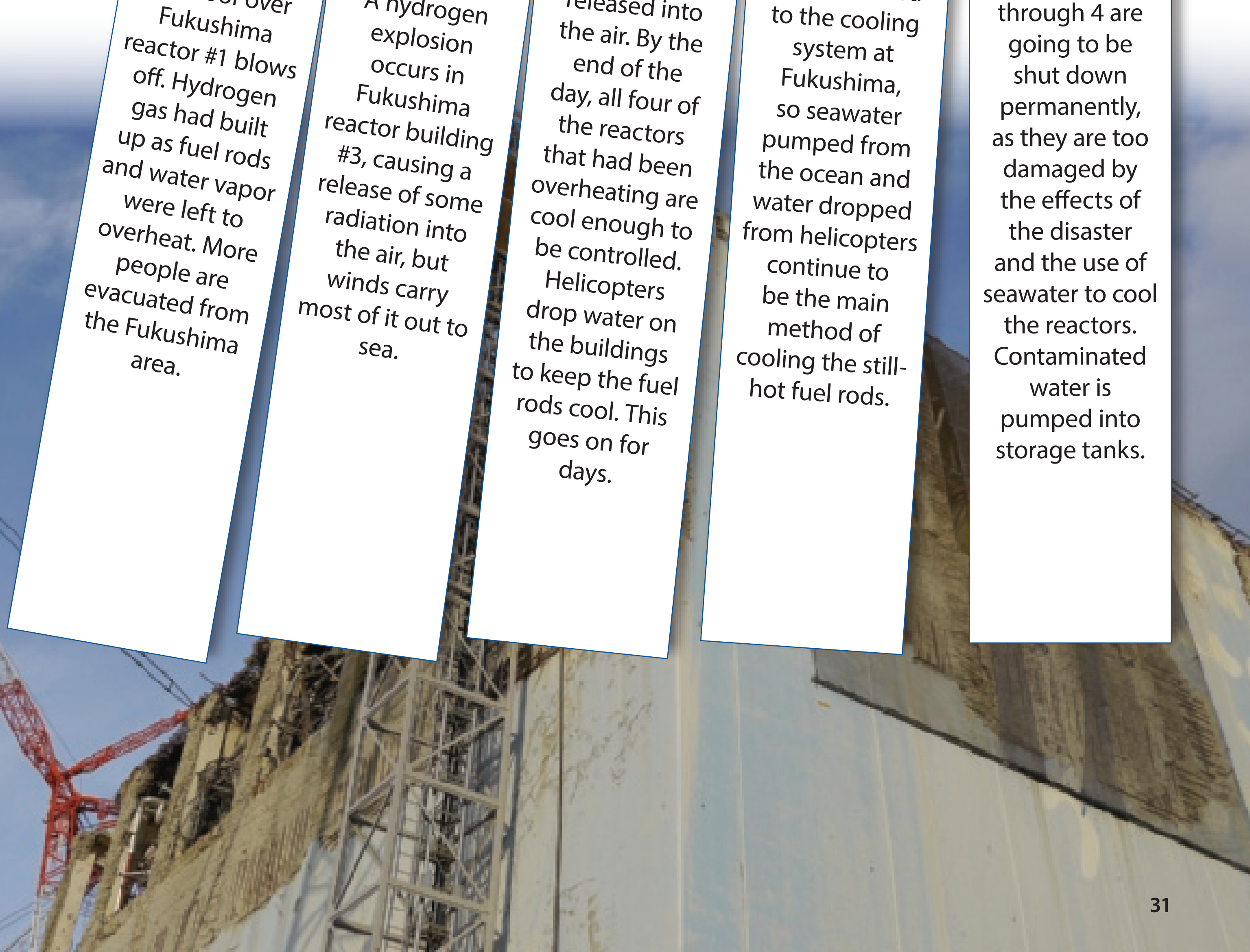
6:22 p.m.: The roof over Fukushima reactor #1 blows off. Hydrogen gas had built up as fuel rods and water vapor were left to overheat. More people are evacuated from the Fukushima area.

March 14: A hydrogen explosion occurs in Fukushima reactor building #3, causing a release of some radiation into the air, but winds carry most of it out to sea.

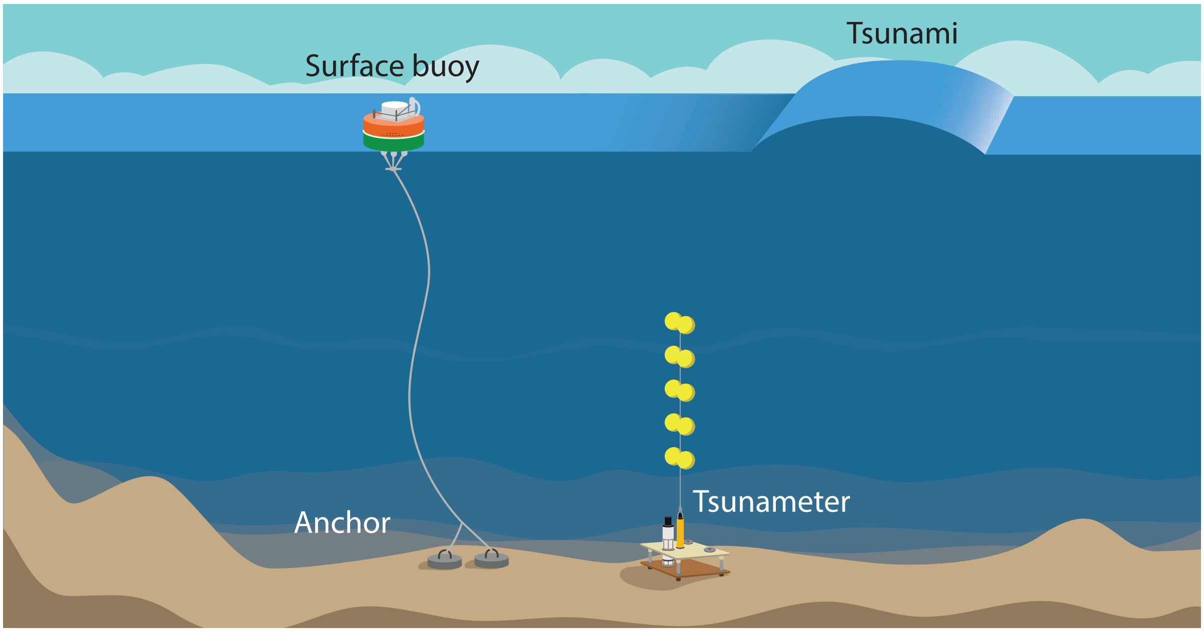
March 15: Nuclear fuel rods in reactor #4 catch fire. Radiation is released into the air. By the end of the day, all four of the reactors that had been overheating are cool enough to be controlled. Helicopters drop water on the buildings to keep the fuel rods cool. This goes on for days.

March 24: Power has not been restored to the cooling system at Fukushima, so seawater pumped from the ocean and water dropped from helicopters continue to be the main method of cooling the still-hot fuel rods.

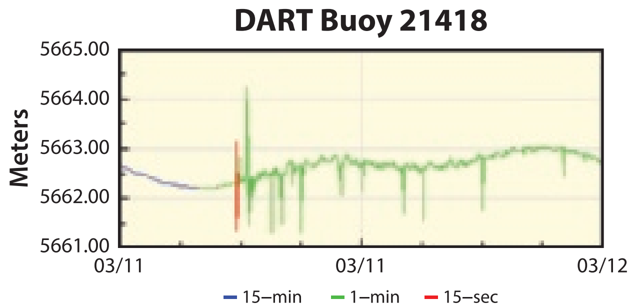
March 30: It is announced that Fukushima Daiichi's reactors 1 through 4 are going to be shut down permanently, as they are too damaged by the effects of the disaster and the use of seawater to cool the reactors. Contaminated water is pumped into storage tanks.



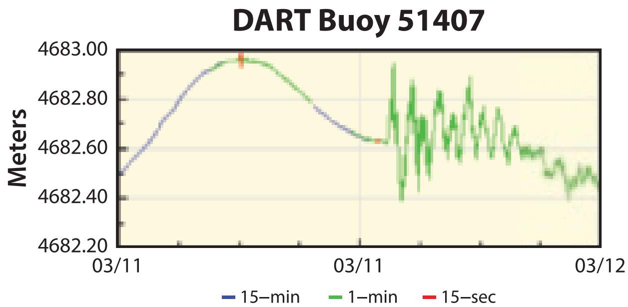
Tsunami Measurements



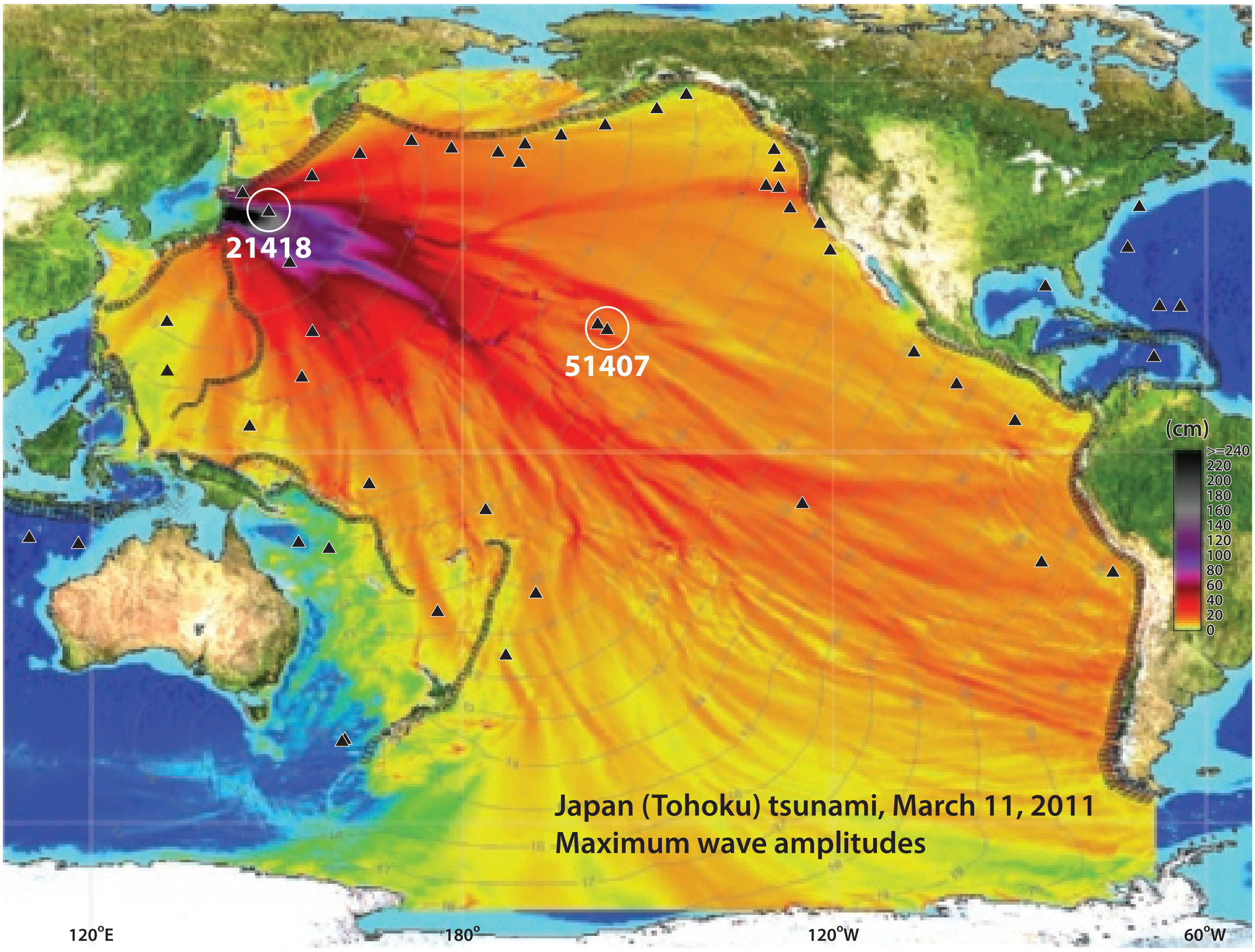
The tsunameter network in the Pacific consists of buoys anchored to the seafloor. These are DART buoys, which stands for Deep-ocean Assessment and Reporting of Tsunamis. Pressure-detecting devices near the anchors work with satellite transmitters on the buoys to detect changes in the ocean's depth and pressure and send data to the network around the Pacific. A slow change in ocean depth represents the rising or falling of the tide. A sudden change represents a large wave, such as a tsunami.



Here is a graph of data from a DART buoy on March 11, 2011. Buoy 21418 was near the start of the tsunami. The graph begins at midnight in Greenwich Mean Time (GMT). The earthquake struck just before 3 p.m. local time in Japan, or just before 6 a.m. GMT. The tsunameter detected a wave with an amplitude of about 2 meters, and numerous 1-meter drops in sea level, after the earthquake struck.



Buoy 51407 was thousands of miles to the east, in the Hawaiian Islands. The graph begins at midnight in Greenwich Mean Time (GMT). The earthquake struck just before 3 p.m. local time in Japan, or just before 6 a.m. GMT. This tsunameter registered small tsunami waves hours after the earthquake occurred and tsunami waves had already struck Japan.



The actual wave amplitudes measured by DART buoys 21418 and 51407 were similar to the amplitudes that were predicted by the NOAA Center for Tsunami Research.

Dig into Data

DART Buoy 21418 detected numerous 1-meter drops in sea level after the earthquake. What do you think this data set suggests?

Words to Know

A *tsunameter* is a device system for detecting and measuring tsunamis. *Amplitude* is the height of a wave above or below the midpoint.

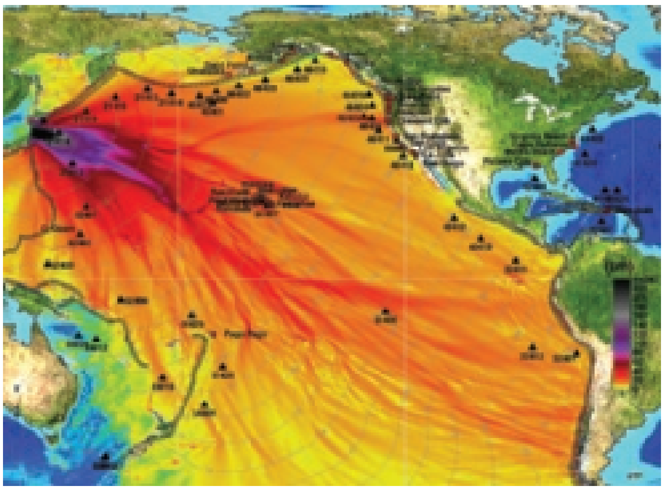
Consider the Source

The NOAA Center for Tsunami Research had fairly accurate predictions regarding the amplitude of the tsunami when compared to the actual data. How might this affect NOAA's credibility as an organization?

Radiation from Fukushima! Or Something Else?

NNN Now or Never for Nature

This is shocking! The image below shows how much radiation has been leaking from the Fukushima nuclear reactors following their meltdowns after the earthquake and tsunami of 2011. You can see how the radiation is carried by the winds and ocean currents from west to east. What's especially troubling is the plume of radiation that goes directly toward California! Of course, our hearts go out to the people of Japan, who suffered the most from this horrible event, but shouldn't we also demand ANSWERS about why we aren't hearing more about this massive radiation leak? Unbelievable! Share this post to get the word out and put some pressure on the politicians who are supposed to be looking out for us—not to mention the poor marine organisms that must be swimming in radiation!



CSP Cora St. Pierre

I have been feeling "off" the last few weeks. And the other day I saw a dead dolphin washed up on the beach in Santa Cruz. Now I know why! I'm sharing this post with everyone I know. Look at all that radiation!

Spot the BS

Heads up! There is some **b**ad **s**cience on this page. Can you detect what kinds of tactics the social media writer is using to influence readers?

Consider the Source

The two posts on this spread use different approaches to make claims related to the Fukushima radiation incident in Japan. Which post do you have more confidence in?

Radiation Leak—NOT

Since early 2011, there have been many misleading social posts about the Fukushima nuclear reactors. Typically, the posts present a colorful map that looks like it's showing the movement of substance from Japan across the Pacific Ocean. The text that goes with the map claims the substance is radioactive air and/or water that is leaking from the Fukushima nuclear power plant. Some posts make claims about dead marine life or plumes of radioactivity reaching the United States.

Whoever started this hoax was clever enough to crop out the National Oceanic and Atmospheric Association (NOAA) logo that was at the top left corner of the original version of the map, along with other NOAA details that were at the bottom. However, they did not bother to crop out the key that sits atop South America. That key has a unit above it, "(cm)." It indicates the colors on the map correspond to measure or length or height. In fact, this map shows the expected amplitudes—basically wave height—from tsunami waves in the aftermath of the earthquake that struck Japan in March 2011. The faint lines throughout the Pacific represent expected wave arrival times in hours after the earthquake. The other clue to the map's actual meaning is the many numbered black triangles. Each of those represents a DART buoy in the Pacific's tsunami warning network. The lines do NOT represent radiation at all.

Some radiation was released into the atmosphere and sea from the Fukushima nuclear power plant after its meltdown, but the levels were not dangerous outside of the immediate area due to the diluting effect of the ocean and atmosphere. The United States food supply, the air over the United States, and the ocean water off the shore of the United States were deemed safe by the Food and Drug Administration (FDA), the Environmental Protection Agency (EPA), and the Woods Hole Oceanographic Institution.

Hazard Map Comparison

Hey. Any luck using the FEMA site to see what kind of flood risk we'd face if we moved to Charleston?

Yes. Downtown Charleston appears to be a major flood zone. See this map. The blue means the properties have a 1% chance of an annual flood hazard. Tan means the chance is just 0.2%. Seems to be a function of elevation above sea level as well as how well the infrastructure is set up to drain water. Hurricanes bring storm surge, as can other storms. Not the most inviting image!

Flood Hazard in Charleston

So, aside from potentially having flooded yards and basements, what does the flooding hazard data mean?

It means it could cost us an arm and a leg to live there. It is risky to buy a home in places like Charleston. Sea levels are rising. Storms are getting more common. If anything were to happen to the new house we buy, we could end up forking out a lot of money to rebuild or fix it.

Argh. I really liked the view of the harbor down there and the salty air. But it makes no sense to pay for that view and that air if it ends up costing us more for the house AND is riskier in general.

This will be a popular place to live if it's not underwater. Not sure it's for us, though. If you take the Charleston job, I think we'd need to live farther from the water in order to be safer. But then you would have a longer drive to work.

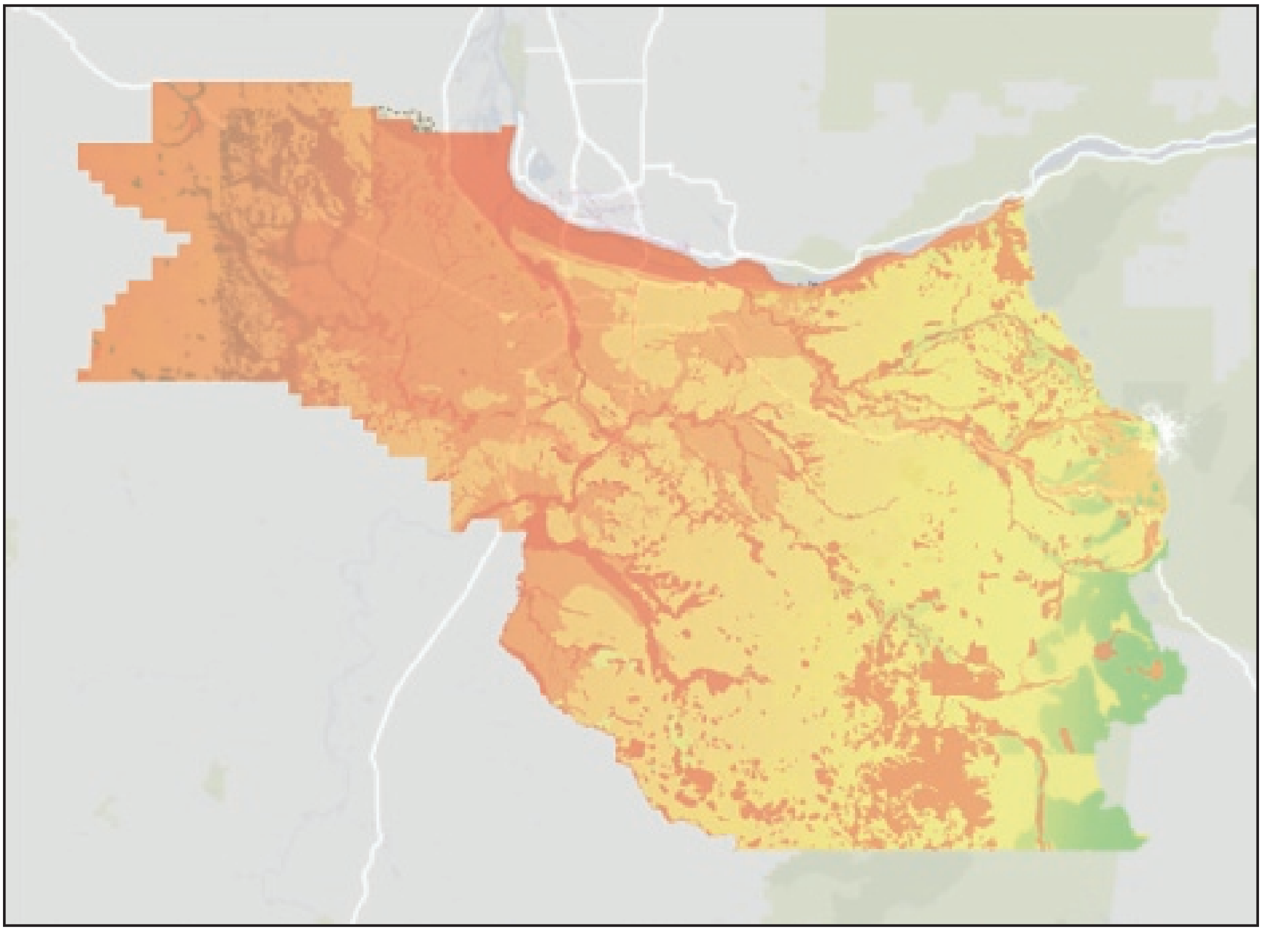
So, how about Portland? I assume there's less risk of flooding there. But what about the disastrous earthquake that the kids keep mentioning?

Dig into Data

The map shown here is from FEMA, the Federal Emergency Management Agency. The map consists of satellite images that are stitched together to make a base layer. Layers to mark other features of the downtown Charleston area, including areas that have a relatively high risk of being flooded, are added on top.

I found an online map for Portland that allows you to look at geological hazards. I clicked on the earthquake layer, and the whole thing turned very orange and red, which basically means a high chance of a severe earthquake.

Earthquake Hazard in Portland



What's going on there? Why such a high risk?

The Pacific Northwest is right next to a major subduction zone, the Cascadia, that gets stuck for centuries and then pops into motion. Earthquakes in the 8.0–9.0 range happen, along with tsunamis. But there's a separate fault in the Portland hills where smaller earthquakes happen, too. In fact, almost all of Oregon gets hit with earthquakes. So, two sources of earthquakes. Take a look at this map. The purple areas are the places where earthquakes happen.

Yikes. The whole thing is reddish orange. What would an earthquake mean for a home there? Does it depend on the construction?

There are 100,000 wood-framed homes that need to be retrofitted to withstand an earthquake. Also, plenty of buildings made of masonry that isn't reinforced. Lots of structures would probably collapse or be heavily damaged in an earthquake. The wood-framed homes are probably less likely to collapse, so the study I read says a nighttime earthquake would be safer because fewer people would be in or near other structures that ARE more likely to collapse. But still, it's definitely risky to buy a home there.

Yeah, sounds like it.

Oh, and one other thing . . . earthquakes can cause landslides. Apparently, landslides are not uncommon in that area. So that is a whole other issue altogether.

I'm starting to think we should live wherever we want to be but rent a home instead of buying.

Agreed!

Katrina's Aftermath

September 25, 2005

The days are getting a bit shorter, but summer lingers on the Gulf Coast, a month after Category-5 Hurricane Katrina wreaked havoc. I'm here on contract with FEMA, surveying the extensive damage to neighborhoods in southern Louisiana and Alabama. It's sad, sobering work. There are entire neighborhoods where the only evidence that homes once stood there are three concrete steps leading up to nothing. Some homes lacked foundations other than a few blocks. With nothing to anchor the frames to the ground, they collapsed, shattered, and simply blew away. Homes with slab foundations—a large block of poured concrete—also suffered extensive damage if the frames were not properly bolted to the slab. Many homes were like sitting ducks, vulnerable to being carried away by wind or storm surge.

Homes built on concrete or brick-and-mortar piers fared better, at least in terms of not being completely blown or washed away, but if the framing was loosely done or the siding and windows were not up to hurricane code, they were still torn apart. Homes with roofs that were connected to the frame with heavy-duty straps and anchors seemed to fare best. Those roofs helped hold the homes together as they were battered by winds. The type of siding made a huge difference, too. Inexpensive vinyl siding, which is installed in long strips, was torn off by strong winds whereas clapboard or cedar shingle siding seemed to hang on better.

Regardless of construction type, the amount of flooding that occurred, especially in the parts of New Orleans that were already below sea level, means that many homes that withstood the winds are still ruined because they sat in water for days or weeks. Their wood frames are rotting. Drywall is moldy and breaking down. Flooring is wet and buckled. The floodwater was also contaminated with bacteria from sewage and heavy metals from the local oil refineries, making things toxic. It will take years to clean up and rebuild here. All of us volunteers have to wear protective gear so we don't inhale spores and bacteria.

Steps to nowhere are like graves for homes destroyed by Katrina.

These brick-and-mortar piers serve as ruins for the structures that survived Katrina's wind and storm surge. The wood-framed house perched above was destroyed. Somehow the computer did not budge from the desktop.

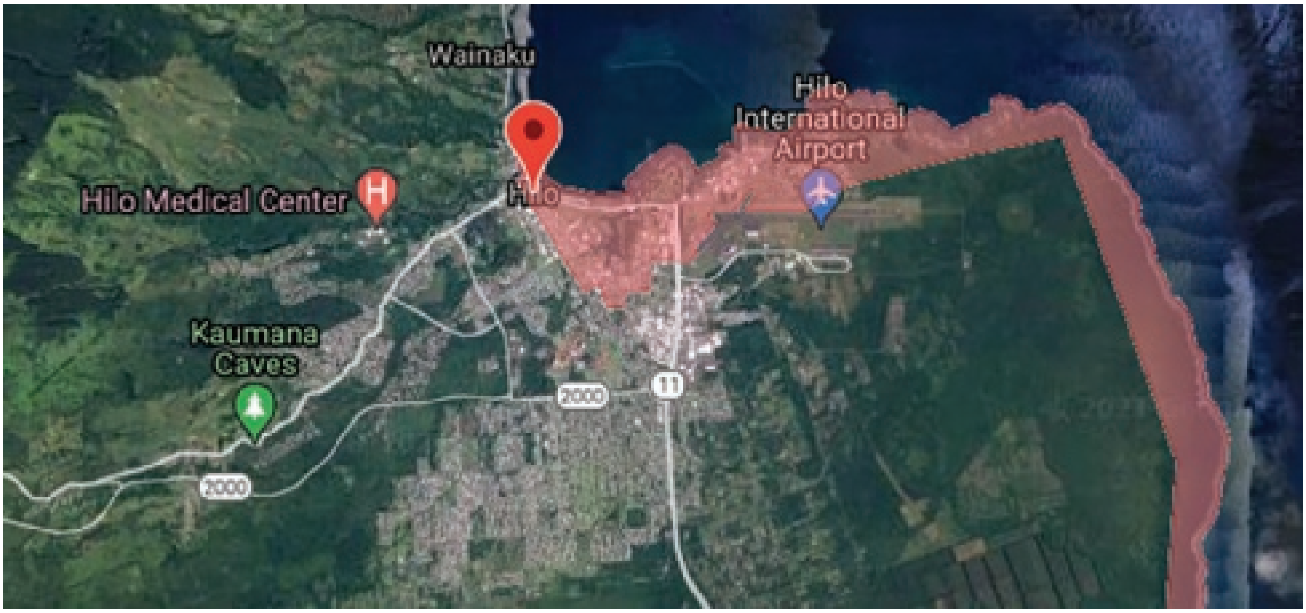
These homes in New Orleans withstood the winds, but the severe flooding means they are most likely uninhabitable due to wood rot, mold, and bacterial growth.

Consider the Source

The voice in this piece is from someone working for FEMA, the Federal Emergency Management Agency, whose mission is "helping people before, during, and after disasters." The agency was established in 1979 by President Jimmy Carter.

Hazards on Hawaii's Islands

Tsunami waves can travel great distances across the ocean. Some tsunami waves generated as far away as Japan have struck the Hawaiian Islands. The Hawaii Emergency Management Agency developed maps that indicate where tsunami waves would likely be the most damaging. The islands are volcanic and have high elevations, so there is plenty of higher ground to head to if a tsunami is incoming. However, getting to higher ground can depend on access to major roadways, as much of the island is covered in forest or rugged volcanic landscapes. To avoid traffic on these roads, public transportation and carpooling could be very helpful in the event of a tsunami.



The evacuation zone for the city of Hilo on the island of Hawaii is shown in red on the map. If word came that the city of Hilo were going to be hit with a tsunami, many people would take routes 11 or 2000 to higher ground. The Hilo Medical Center is outside of the tsunami evacuation zone, so it would be able to help those affected by a tsunami. Note that parts of the international airport are within the evacuation zone.

Word to Know

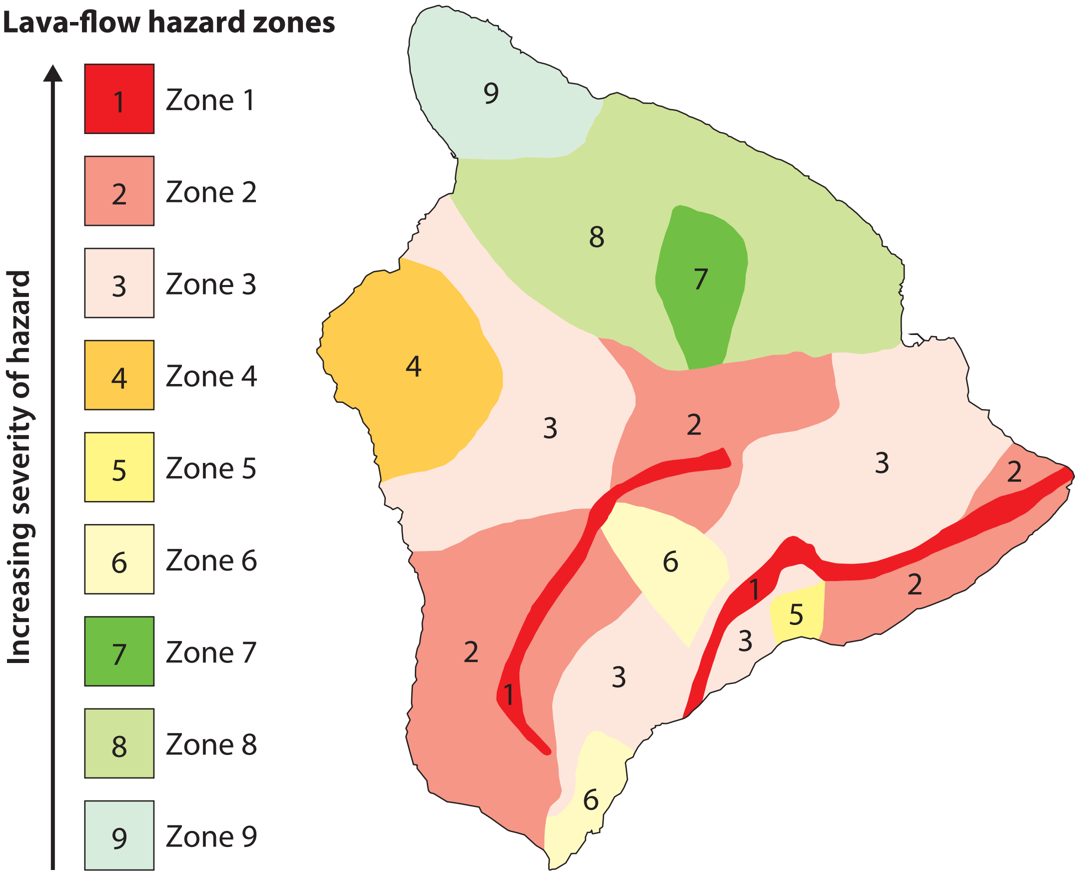
The *topography* of a landmass is its elevations and contours. A topographical map shows these features.

Connection

Look to the right at the map of the island of Hawaii and its legend. Why would it be important to know the lava flow hazard zones on this map if a tsunami is approaching?

The Big Island, which is the island called Hawaii, is "big" because it is the youngest and newest of the Hawaiian Islands. It consists of several active volcanoes that continue to add to the landmass of the island. Other islands in the chain have weathered and eroded over time. Someone on the Big Island who is looking to get away from an incoming tsunami might need to be aware of road closures due to volcanic eruptions, especially the steady eruptions from Mt. Kilauea in the southeastern part of the island. A resident of Hilo or another town might need to pay attention to the tsunami warning network and the eruption alerts.

This zoomed-out map shows the entire island of Hawaii, known as the Big Island, and its tsunami evacuation zones in red. The topography **is dominated by several volcanoes.**



Glossary

accurate, adj. correct, as in a prediction that matches the actual, observed result

amplitude, n. height of a wave above or below the midpoint

analog, adj. relating to a continuously variable signal (as opposed to a digital signal)

anthropology, n. the study of humans and human groups over time

buoy, n. an anchored float

causation, n. the relationship between a factor (cause) and its resulting outcome (effect)

constraint, n. a limitation or restriction

contagious, adj. spread from one organism to another through contact

correlation, n. mutual connection

criteria, n. requirements against which a design or performance is judged

density-dependent, adj. describing an ecological factor that affects organisms in relation to the number of individuals in a given area

digital, adj. relating to intermittent off/on (or 0/1) signals (as opposed to an analog signal)

epicenter, n. the point at Earth's surface directly above the focus of an earthquake

epidemiologist, n. a scientist who studies communicable diseases, how they spread in populations, and how to control them

gale, n. a very strong wind

gradient, n. an increase or decrease of the magnitude of a measurement

index, n. an indicator, sign, or measure of something

infectious, adj. likely to be transmitted and spread infection

landslide, n. rapid movement of earth material down a slope

magnitude, n. size or extent

natural hazard, n. events in Earth's physical environment that are harmful to people but are not directly caused and cannot be controlled by them

pandemic, n. an outbreak of a disease that occurs over multiple continents and affects a large portion of the population

precise, adj. strictly conforming

probability, n. the mathematical likelihood that something will occur

radiation, n. emitted energy in the form of waves or particles

reactor, n. the structure that initiates and controls a nuclear reaction for the purpose of harnessing energy

reliability, n. the extent to which a result is the same in repeat trials

satellite, n. an object or device that orbits a planet or other celestial body

science literacy, n. the ability to read, hear, and comprehend information about scientific topics and demonstrate understanding in discussion and through writing

sea level rise, n. increase of the ocean water level caused by melting of ice

seismometer, n. a device for measuring seismic waves produced by earth movement

social media, n. websites and applications that allow users to participate in sharing content on the internet

sonar, n. a method or device for locating objects using reflected sound waves

stakeholder, n. a person who is involved in or affected by an activity

storm surge, n. an abnormal rise of the water level at a coastline, produced by storm winds

subduction zone, n. a place where two tectonic plates meet and one overlaps the other

subsystem, n. a self-contained system within a larger system

system, n. a set of interconnected parts or factors that function together and mutually affect an outcome or environment

topography, n. the collective elevations and contours of a land area

trade-off, n. a compromise accepted to balance desirable and incompatible features

transmitter, n. a device that transmits signals

tropical storm, n. a large rotating storm system characterized by heavy rain and high wind

tsunameter, n. a system of devices for detection of tsunamis

tsunami, n. a series of higher-than-usual waves produced by displacement of a large volume of water, generally as a result of seismic activity

waterspout, n. a whirling column of air and water mist

wildfire, n. a large, destructive, unplanned, uncontrolled fire that spreads quickly across land

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