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Earth's Resources and Human Impact:

How do changes in the Earth's system impact our communities, and what can we do about it?



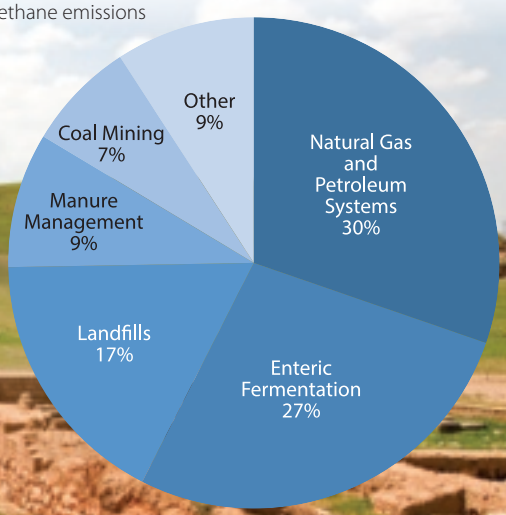
Science Literacy

Science Literacy Student Reader



Coral bleaching

Methane emissions



Effects of changing resources on human life

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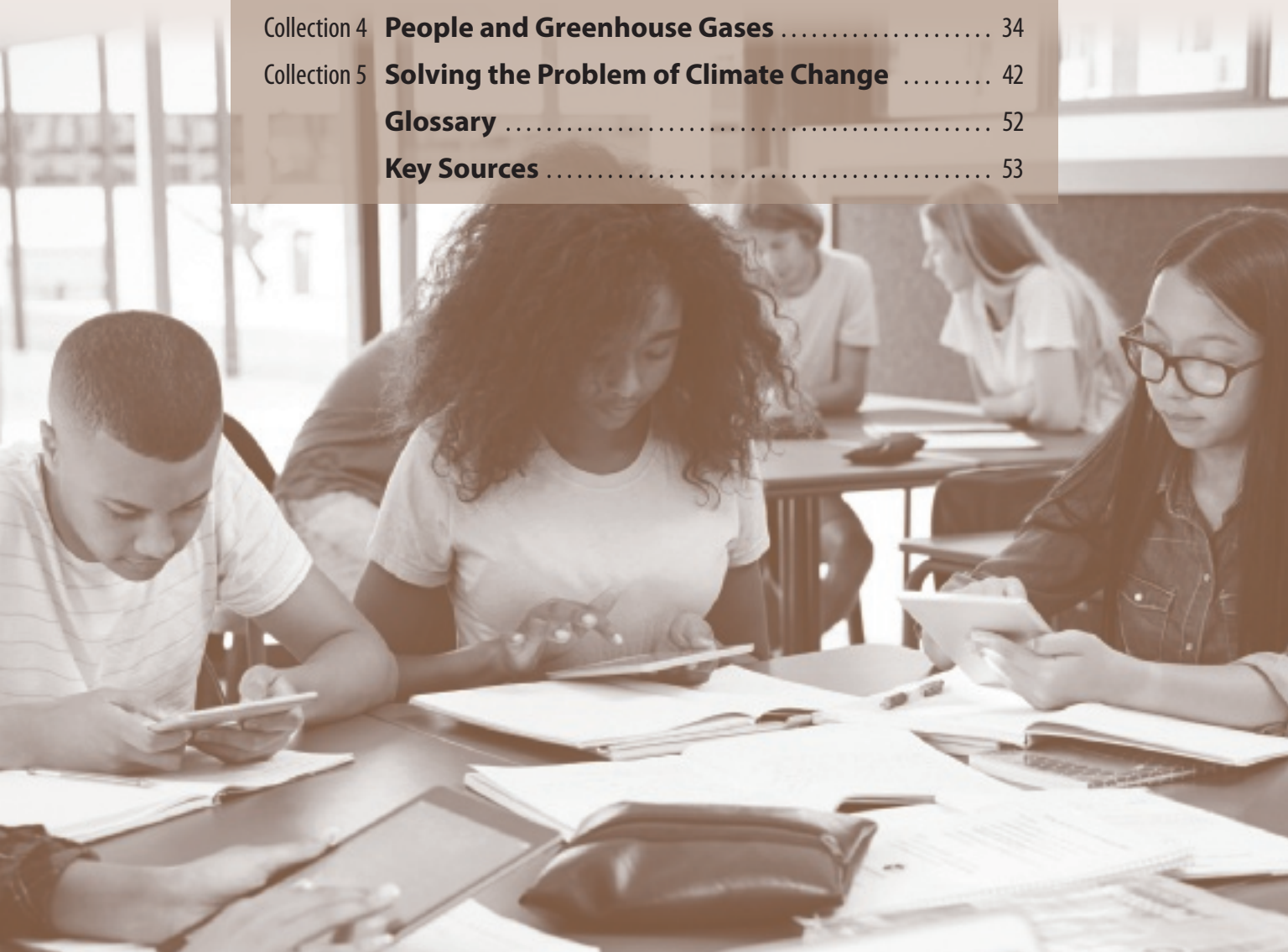
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Earth's Resources and Human Impact

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Put Yourself in This Scene

Elijah is spending a week at his grandparents' house on the coast of Virginia. They bought a seaside house in Virginia in 1975 and have lived there ever since, working on the water. Bill and Edie are telling Elijah that the beach has gotten smaller and that the sea has been rising for decades. "We probably don't have many more years left in this house, Elijah. We hope it's still in the family when you are our age, but that might depend on understanding the causes behind the rising sea levels and what, if anything, we can do about it."

Elijah asks, "Has the sea really risen that much?"

"Sure," Edie replies. "The high-water marks on the piers and where the tide reaches on this beach have all crept higher over the years. The beach used to be much wider, too."

"Grandma's right," Bill says. "I'd say the sea is about a foot higher than it was when we were your age."

"Now, don't go and alarm Elijah," says a familiar voice. It's the next-door neighbor, Mike. Mike and Elijah's grandparents are friends, but they disagree on a lot of things, including sea level rise and its causes.

"Elijah, one of the interesting things about the geological history of Virginia is a thing called subsidence," Mike says. "It's when a coastal area slowly sinks, which can make it seem like the sea is rising. But really, it's the land that's dropping. It's been happening here for a long time. I know this because I'm an engineer, and I've worked on a lot of projects that the state has undertaken to deal with the effects of subsidence. Whatever sea level rise you see here is due to subsidence, not climate change."

Elijah glances at his grandparents while Mike keeps talking.





Bill interrupts. "You say that climate change isn't real, and we disagree. We also disagree on the reason the sea seems to be rising and also about the carbon we've put into the atmosphere, which you say isn't doing anything at all. Now, go get to your fishing, and don't forget to save us a couple of tuna steaks!"

Mike laughs and says, "Elijah, don't worry. If your grandparents run away from the coast, you can come stay with us!"

While Mike keeps chatting away, Grandma Edie quietly says to Elijah, "Don't mind the disagreements, kiddo. Mike's smart and an old friend, but he's held a different position about climate change for decades."

Who's right? Elijah wonders. *This question of climate change seems pretty complicated. How can I find out more about it?*

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.

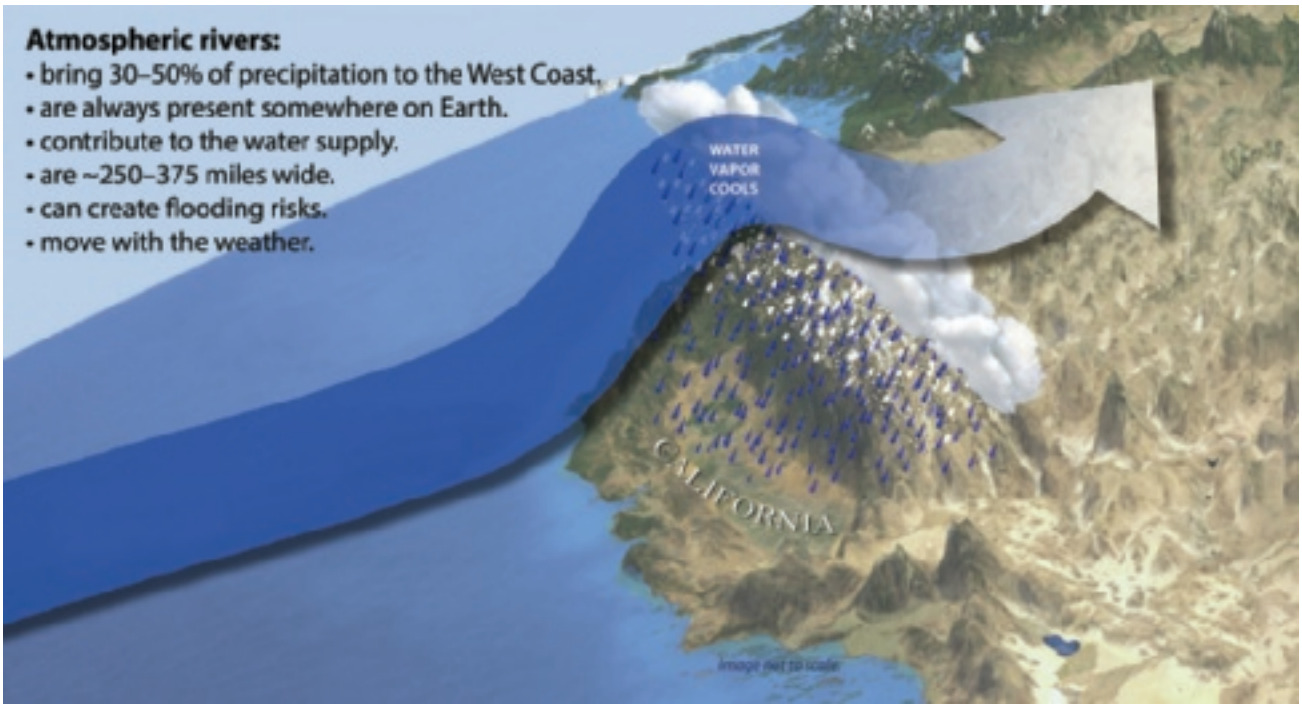
We will make our way back to the topic of climate change by the end of the book. Along the way, the series of reading selections and the writing exercises that go with them will help you flex your mental muscles and sharpen your science literacy skills. The ability to read about science, understand the information, and tell truth from fallacy or misrepresentation is really 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.

Historical Evidence of Climate Events

In the winter of 1861, California experienced 43 straight days of heavy rain. This was caused by what's called an atmospheric river— a **climate event** in which a vast amount of water vapor in the atmosphere, fueled by evaporation from the ocean and a steady breeze carrying the vapor over a continent. There the warm, wet air collides with a cold front and condenses into precipitation. The Central Valley, now home to some of the best farmland in the United States, was turned into an inland sea 300 miles long and 20 miles wide. Rivers that normally trickled from the Sierra Nevada mountains were turned into raging torrents that flooded their banks and swept away mining communities and 800,000 cows. It was an enormous disaster for the state.

Vocabulary

climate event, n. an occasion of extreme values of climate indicators such as temperature, precipitation, or wind



Atmospheric rivers (ARs) are very similar to liquid rivers in terms of how much water they can move. California can be flooded when an atmospheric river that stretches all the way to Hawaii brings warm, moist air from the Central Pacific to the West Coast. Certain conditions in the ocean and atmosphere can produce long-lasting ARs, such as the one that flooded California in 1861.

Historical records of droughts have been pieced together from written documents, stone tablets, archaeological evidence, and soil samples. In the Middle East, evidence suggests that many cities in the region were abandoned around 4,200 years ago, when the Akkadian Empire ruled the region. There is a thick layer of dusty soil that corresponds to that time. Above and below that layer is better soil. Archaeologists think the Akkadian people abandoned their homes to farm the irrigated land around the Tigris and Euphrates Rivers. People moved back to their cities when rainfall returned and the soil was farmable again.

Evidence of droughts can also be gleaned from dendrochronology, the study of growth rings of trees. In years with lots of precipitation, rings are thicker. During a drought, rings are narrow. If tree rings corresponding to a certain year are narrow across a large region, paleoclimatologists have evidence of a major drought event.



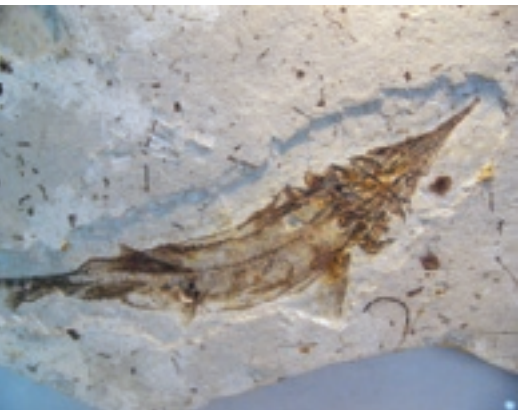
Ruins of ancient cities can provide clues about climates in ancient times.

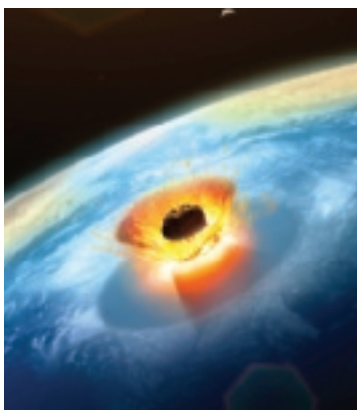


This ancient tree trunk's growth rings are tagged with historical events.

Piecing Together Earth's Climate History

It's not possible to go back in time and record temperatures, rainfall, or other climate data in a direct way. Instead, paleoclimatologists look at fossils, layers of sediment, ice cores, and other types of evidence to infer what climates were like thousands or millions of years ago.





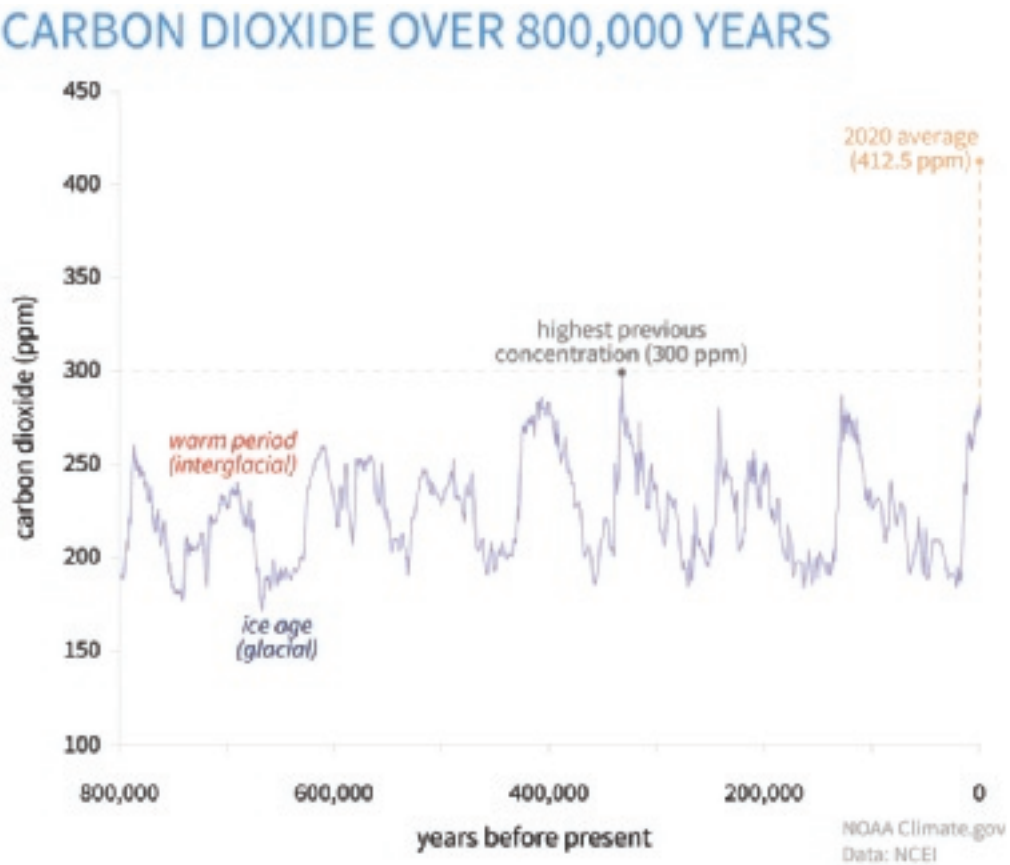
Left: freshwater paddlefish; middle: marine ammonite; right: depiction of asteroid strike

In 1991, a scientific paper announced the discovery of a massive crater in Mexico that represented the impact zone of an asteroid that struck Earth 65 million years ago. The asteroid exploded, filling the atmosphere with dust and debris, including iridium from the asteroid itself, and raining fire down upon the continents. Photosynthesis ground to a halt, and much of Earth was cold after the fires burned out. In 2013, in what is now North Dakota, a paleontologist discovered a snapshot of that terrible day: layer upon layer of stirred-up sediment and fossilized fish, mammals, trees, and marine organisms, all mixed up with tiny fragments of molten material that had exploded out from the asteroid impact. The inland sea that covered part of North America had been hit by massive earthquakes caused by the impact, and the sloshing action of the water acted like a tsunami, killing organisms from the ocean, rivers, and dry land and burying them in a mass grave of mud and sand. A fossilized mammal's burrow dug into the site showed how the few survivors of the disaster tried to survive the cold and darkness.

The thick ice of Antarctica has tiny bubbles of trapped air. By analyzing the bubbles and measuring how deep they are, paleoclimatologists know how much carbon dioxide and other greenhouse gases were in the air hundreds of thousands—or even millions—of years ago. This has helped them make connections between other evidence of climate change—such as the absence or presence of fossilized plants and animals, the surface-shaping work of glaciers, and what greenhouse gases meant for climates in the past—and what they might mean for the future. The graph below indicates a rise in CO_2 recently. Is this a result of human activity? What research data could help answer this question?



Ice core being packed for storage



Straw Men and Logical Fallacies

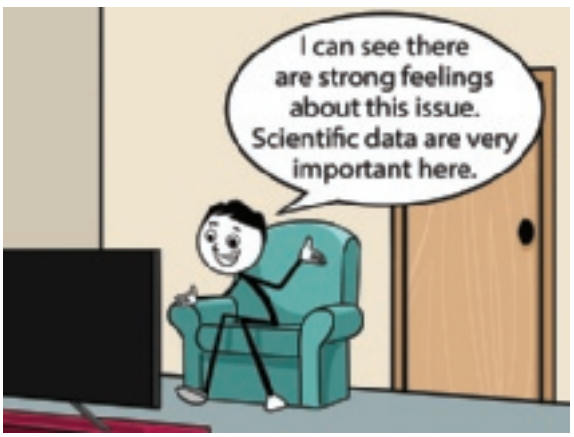
Spot the BS

Heads up! There are some questionable statements being made on these pages. Can you spot the **b**ad **s**cience?





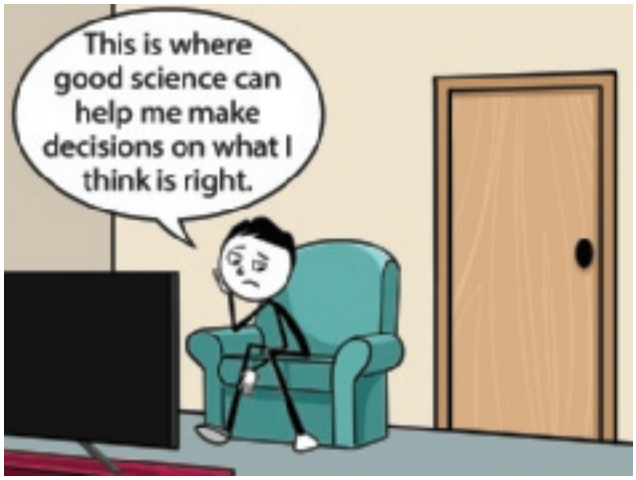




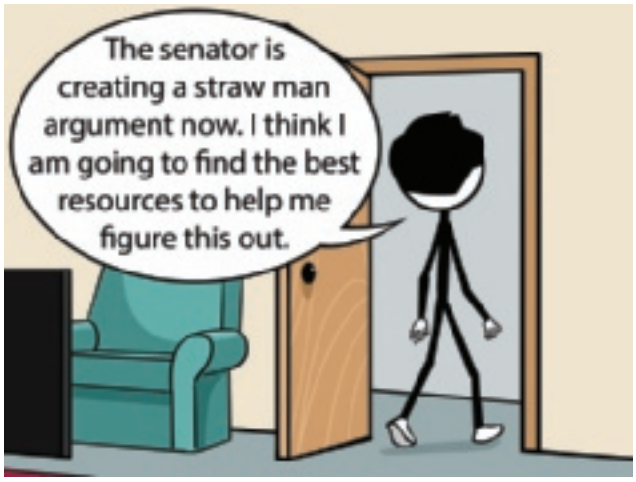












Words to Know

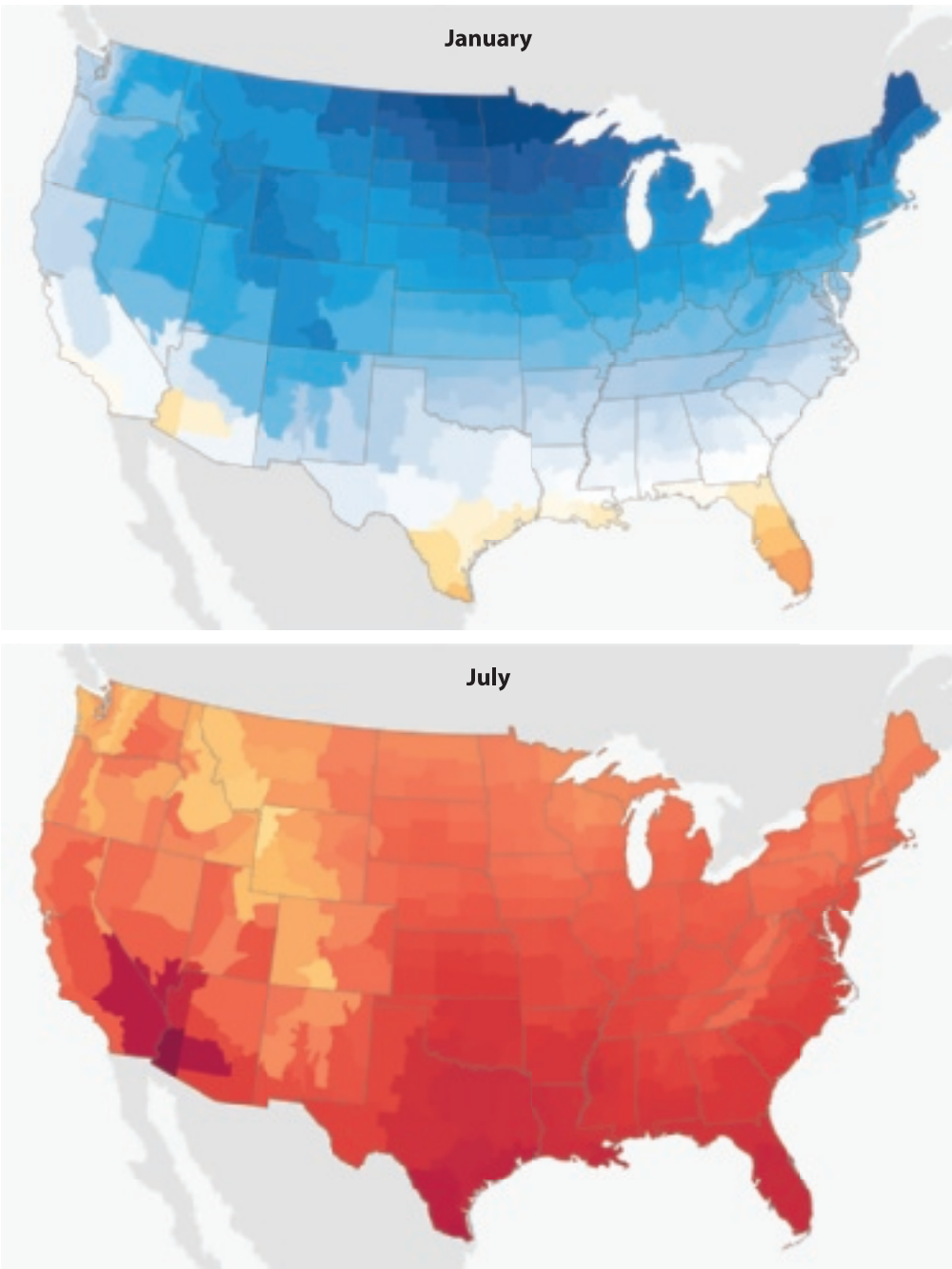
A *logical fallacy* is an argument or line of reasoning that can be disproven or taken apart by further reasoning. For example, if a person claims that something has occurred without human involvement, that does not mean it cannot happen as a result of human activity.

A *straw man* is an argument or point that one side of debate claims is being made by the other side, when in reality it is not. Usually, the straw man consists of exaggerated or distorted claims that the actual opponent has not made. In political arguments, this often involves unnamed people on the other side, because without naming an actual person, the straw man (or woman) can be as bad as its builder wants them to be, and their beliefs can be as scary as the builder needs them to be in order to convince people of something.

Climate Maps

Maps of climate data can help us see patterns. Unlike a weather map, which is a snapshot of a short period of time, a climate map shows data from a longer period. For example, on this page are maps of the United States (minus Alaska and Hawaii) showing the average temperatures for two months, January and July, over a 30-year period. Making these maps required thousands of temperature readings from thousands of weather stations from 30 different Januarys and 30 different Julys, across 48 states. That's a lot of data and a lot of number crunching.

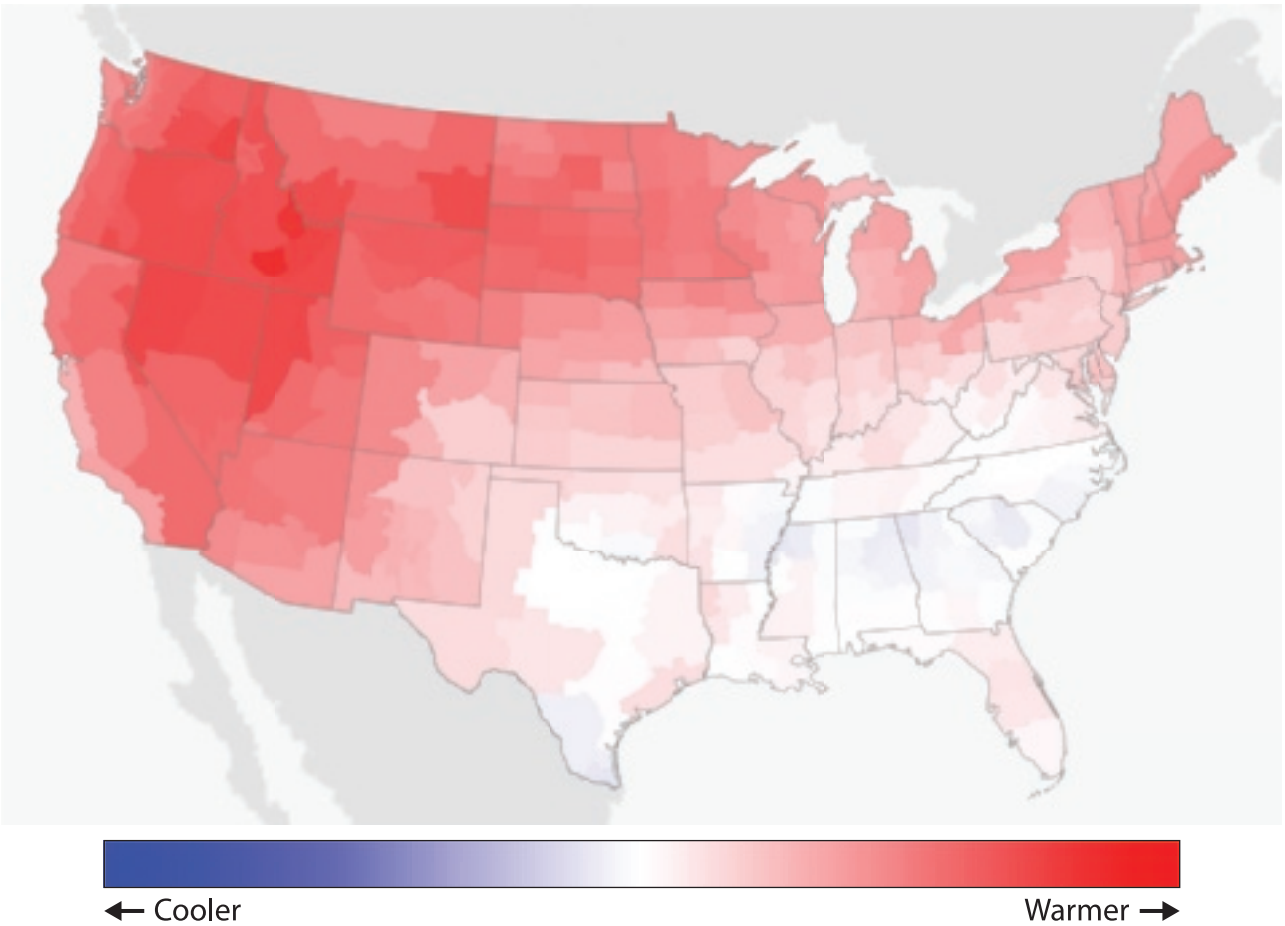
Average Temperatures, 1981–2011



The data in these climate maps show a pretty clear pattern from a 30-year period: temperatures are cold in January and hot in July.

Historical temperatures from a long period of time can be compared to data from a short, more-recent period to assess if climate is changing. The map below shows which parts of the "lower 48" were warmer or cooler than usual in June 2021. In this case, "usual" was defined by the 30-year average for June from 1981 to 2011. The far right end of the scale represents an 11-degree increase in average temperature for the month of June, on the Fahrenheit scale. The far left end represents an 11-degree decrease.

June 2021 vs. June 1981–2011



Now also consider this. By definition, climate is "weather averaged over 30 years." Is it good science to compare one year's values to the 30-year average and make a valid conclusion? What if 2021 were an El Niño or La Niña year? Was there any other cyclical climate event that peaked that year?

Water, Water, Everywhere

Eva, September 3, 2005

Looks like we'll be seeing you a lot sooner than Thanksgiving! Katrina hit New Orleans directly on the 29th, and we've been staying in motels on I-59 since then, slowly heading toward Charlottesville. I'm emailing from the laptop of a former marine who's heading down there to help with search-and-rescue operations.

We knew it was going to be a bad hurricane, maybe the worst of my lifetime, so we had the car packed and the house boarded up a few days earlier, and we hit the road on the 27th. New Orleans is vulnerable to a rising sea, and when a Category-5 hurricane is bearing down on it, it seems like water is coming in from every which way. The storm surge brings in ocean water, and the rain floods the city directly but also indirectly, as the river swells and punches holes through the levees. The canals within the levees flooded all at once, and the levees simply collapsed in some spots. Last we heard, they think at least 75% of the city is flooded, including 95% of St. Bernard Parish—our family's home for as long as anyone can remember.

Like you, we've been watching footage of the damage and chaos on the news. People with nowhere to go but their rooftops, waving helplessly at helicopters. Motorboats in the street instead of cars. People crowded into the Superdome, with nothing but the shirts on their backs. A hundred thousand people just stuck in a flooded city. It's early, but it's hard to imagine how there won't be a lot of fatalities from this thing.

We have no idea what's left of our house and probably won't know for weeks. Our assumption, just based on the footage on TV, is that our house is probably sitting in six to ten feet of water that's going nowhere anytime soon. My dad says the mold that settles in the walls will probably make the home unlivable even if it survived the flood structurally.

Anyhow, it sounds like your parents have offered to take us in, and my mom has already been in touch with your school about enrolling me for the fall. Maybe we'll be classmates? In English we were reading this long poem by Samuel Coleridge called "The Rime of the Ancient Mariner." There's a line in there that's famous: *Water, water, every where, nor any drop to drink*.

I keep thinking about that one line as my city drowns. :(

Love,

Jeanette



Hurricanes are fueled by warm ocean water and conditions in the atmosphere. Climate scientists predict that severe hurricanes will be more frequent and more destructive as Earth gets warmer. What scientific sources would you consult to determine if hurricane frequency is increasing or related to changing climate or not?



Hurricanes and cyclones are damaging (and often deadly) natural disasters that happen every year globally. Our best defense is to improve our landfall predictions and local response. In some parts of New Orleans, the floodwater filled homes, forcing people onto rooftops.

The Difference Between 1.5°C and 2°C

What Does This Difference Mean for You?

In 2021, the Intergovernmental Panel on Climate Change (IPCC) reported that global warming was likely to reach or exceed a number by the year 2040 that the IPCC had been concerned about for years: 1.5°C. The IPCC defines global warming as "an increase in combined surface air and sea surface temperatures averaged over the globe and over a 30-year period." Some climate scientists have stated that the temperature increase is the result of emissions of carbon from coal-burning power plants, engines that power vehicles, and other industrial practices.

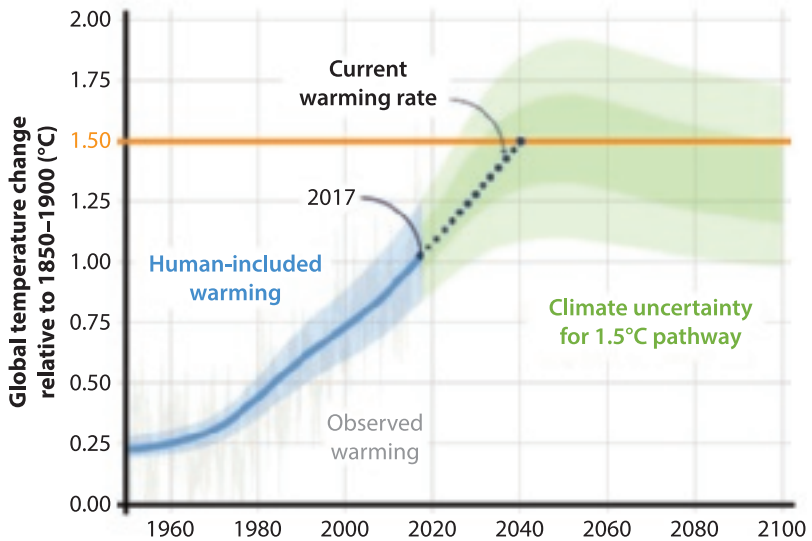
While the 1.5°C increase is almost guaranteed, the IPCC warns that an increase of 2°C would be much worse for ecosystems and human societies. Whether we hit 1.5°C of warming (bad) or 2°C (worse) depends on how much and how quickly we reduce carbon emissions into the atmosphere. The green "pathway" part of the graph below is based on emissions being reduced to zero by 2055. If emissions are not reduced, warming will likely reach 2°C.

Did you know there are ways that any person can help slow the rate of global warming? Easy lifestyle modifications can make a big difference when people around the world make these simple adjustments:

- ✓ Reduce, reuse, and recycle the products that you use.
- ✓ Use public transportation, ride-share, walk, or bike when you need to go somewhere.
- ✓ Turn off lights, computers, and other electronics when you are not using them.
- ✓ Conserve water by taking fewer or shorter showers, using low-flow shower systems, and maintaining landscapes that are drought-resistant and do not require constant watering.
- ✓ Purchase products that have biodegradable or less plastic packaging.

There are also more permanent types of modifications people can make to help address global warming concerns:

- ✓ Make sure homes are well insulated.
- ✓ Install solar panels on rooftops.
- ✓ Seal windows so cool or warm air does not escape your home.
- ✓ Eat fewer meat and dairy products and consume more vegetables, fruits, and grains in your diet.



Dig into Data

The IPCC is concerned about global temperature changes reaching 2°C. The green area is a projection of what might happen, but many events could alter this prediction.

Tough Times in Tuvalu

This is my tenth trip to Tuvalu in the last two decades, and each time I'm here the sea seems to have swallowed up a bit more of this peaceful, lovely place. Tuvalu is one of the smallest nations in the world, both in total land area and population (around 10,000). It is one of the poster children of the climate crisis because the average height of its nine inhabited islands is 1.83 meters above sea level and the islands are just a few hundred meters wide.

I'm part of a seven-year project whose aim is to protect these islands and their people from the rising sea and some of the specific threats it poses. On this trip we are using lidar technology to produce highly detailed images and measurements of the islands, right down to distances from homes to the water. This will help us determine the best locations for concrete sea walls, which will protect the islands from erosion from typical wave action as well as cyclones.



Low-lying islands in the Pacific usually have groundwater that can be tapped for use by people, but when saltwater intrudes, the water can get too salty to be consumed. This has been happening on Tuvalu for years. Cement rainwater catchment tanks are one solution to the lack of potable groundwater, but climate change is making the dry season drier, which means it's tougher to keep those tanks full. What's more, the soil is getting saltier from the tainted groundwater and wash-over from storms. It's a double whammy that's making it harder to grow crops.

Meanwhile, the reefs are suffering from coral bleaching—another effect of global warming—and there are fewer fish and other sources of protein from the marine ecosystem.

I love Tuvalu and its people. My fear is they are running out of time. And as much as I believe in the climate mitigation work we're doing here and elsewhere in the Pacific, I sometimes wonder if we're just putting bandages on wounds that are too big to heal. Many of these people will need to leave Tuvalu and hope for refuge in other nations.



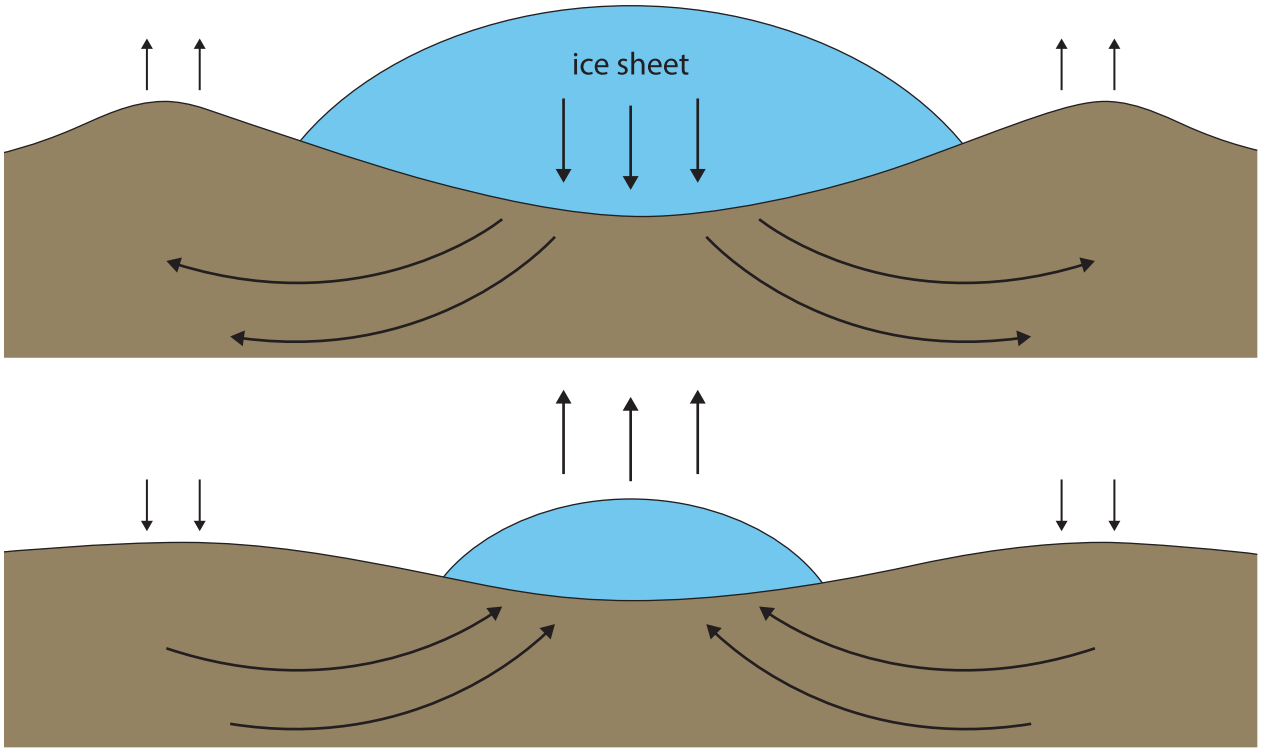
Word to Know

Mitigation means reducing damage or severity of something.

Causes of Sea Level Rise

Subsidence

Earth's crust is solid, but it can behave more like the membrane that contains water in a waterbed. For thousands of years, North America was largely covered by thick, heavy ice. This weight caused the edges of the continent, including the East Coast, to pop up. As ice melted away, much of the continent rebounded, causing the edges to sink back down. This is called subsidence, and the process can continue even long after the ice is gone because the crust flexes slowly. Much of the East Coast is still subsiding for this reason. Subsidence can make it seem like the sea is rising when in reality the land is sinking relative to the **sea level**.



Vocabulary

sea level, n. the height of the ocean's surface, measured via satellite and observable at shorelines

Plate Movement

Earth's crust is broken up into tectonic plates. When the edge of a plate is undercut by the edge of another, it can pop up. Sometimes this occurs very abruptly, as in an earthquake. This can change the relative heights of landmasses and the ocean in an instant. In other cases, the edge of a continent or a set of volcanic islands can rise or fall slowly over time.



This island was lifted about two meters by an earthquake. Dead corals show where the sea level used to be.



This island also was lifted about two meters by an earthquake. Dead corals show where the sea level used to be.

More Liquid Water Means Less Ice

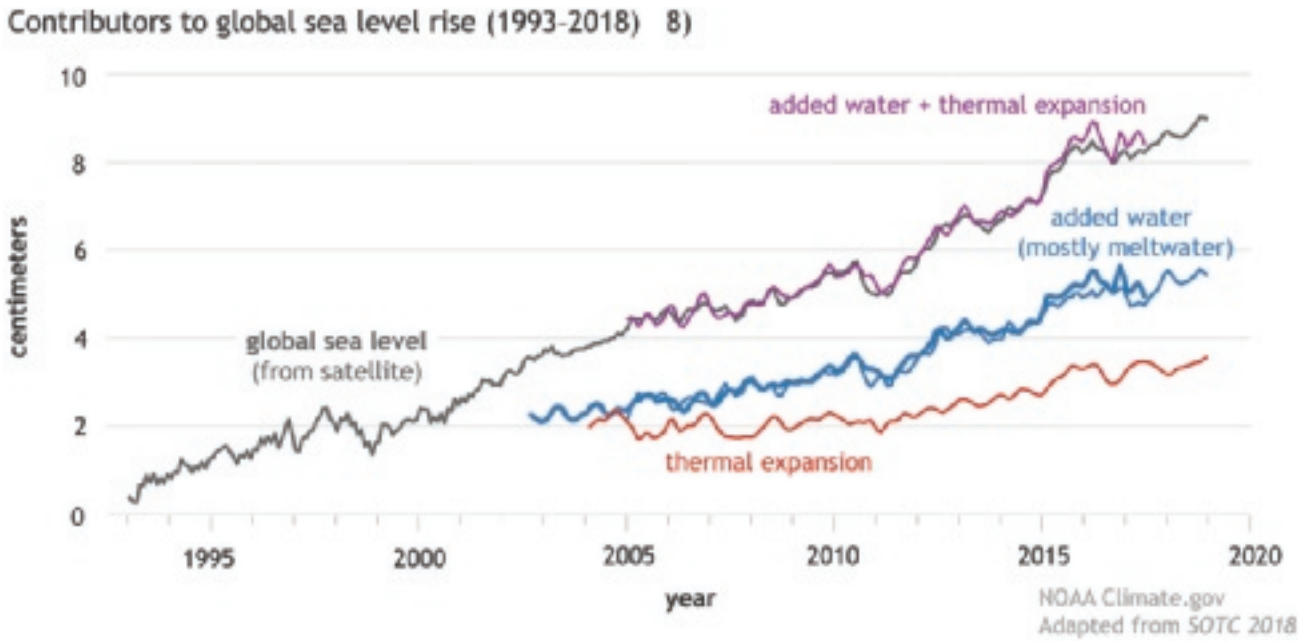
With very minor exceptions, the amount of water on Earth is fixed. What can change is the amount of water that is in solid, liquid, or gaseous states. When there is more ice, there is less liquid water. This means the ocean is shallower and landmasses seem taller relative to sea level. When ice is scarcer, as is the case today, the volume of the ocean gets larger, and sea level rises. The melting of the ice caps of Greenland and Antarctica and the glaciers of the Americas and Europe could cause the ocean to rise many meters over the next century.



These photos, taken from the same location in Glacier Bay, Alaska, one century apart, speak to how much of the world's ice has melted and run into the sea. Consider this: The photos were taken from the same spot one hundred years apart, but were they taken in the same season? Would a seasonal difference in this location account for a substantial difference in this type of glacial ice?

Thermal Expansion

Most substances expand when warmed. While water is somewhat unique in how it is less dense as a solid than as a liquid near the freezing temperature, liquid water does expand as it is warmed. As the ocean gets warmer, the molecules of water get farther apart. This means the volume of the ocean is growing even without the addition of meltwater from landmasses. It also means sea level will continue to rise even after the glaciers and ice caps have melted away.

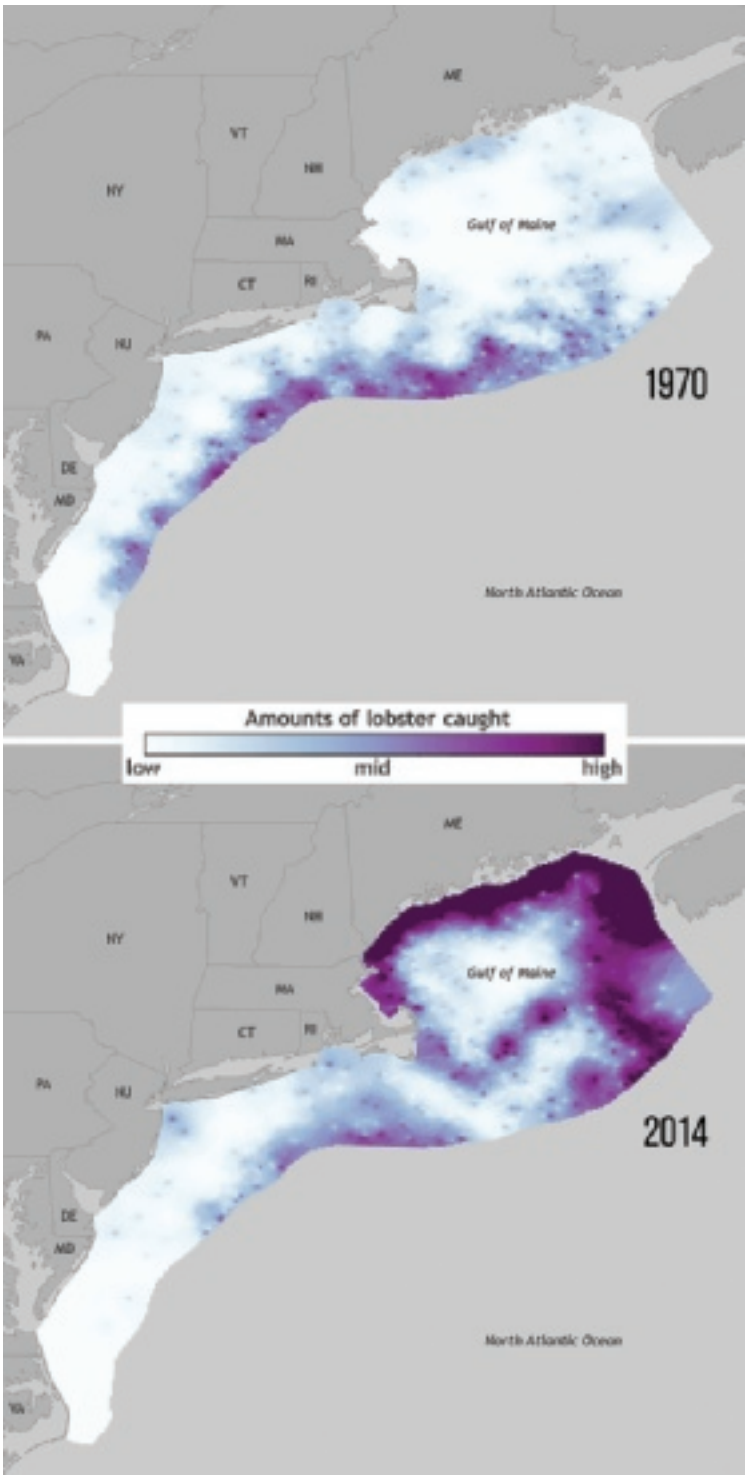


Satellite data show a steady increase in sea level in recent years. Melting ice has been the main contributor so far, but thermal expansion has also played a role. The above graph indicates that the global sea level is rising. Local conditions may vary. Sea level is falling along the Pacific coast of North America due to tectonic uplift and is falling along parts of the Scandinavian coast because of rebound upward due to removal of glacial ice formed during the last ice age.

Effects of Warming Water

Mass Migration

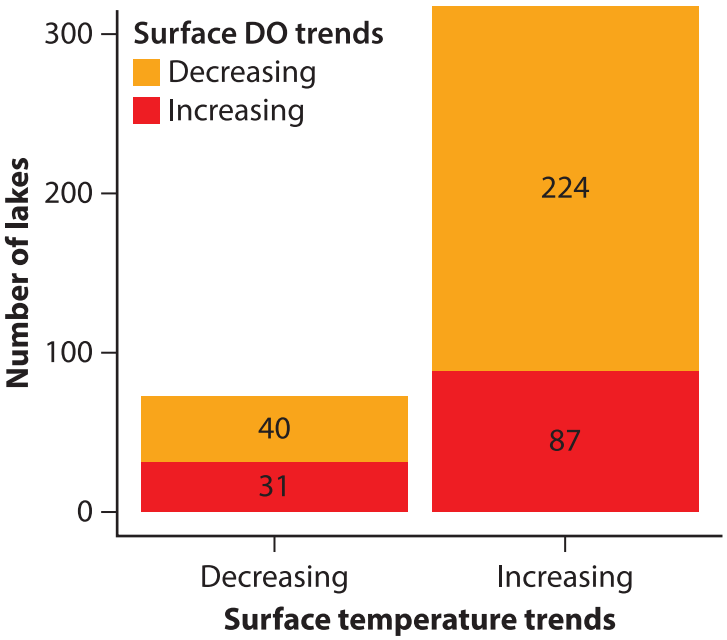
Many aquatic organisms are cold-blooded. They can't regulate their own body temperatures. This means they need to find and be in water that is neither too cold nor too warm. As bodies of water get warmer, some populations are migrating to higher latitudes to find cooler water. The American lobster is an example. Over the last 50 years, lobster have shifted from southern New England, whose waters have warmed, to the Gulf of Maine. This was great for lobster fishers in Maine but bad for those in New York, Connecticut, and Rhode Island. Since 2014, signs have pointed to the lobsters shifting even farther north, to Canadian waters.



Warmer Water, Less O_2

Fish can die in water for many reasons, including toxic chemicals, disease, overcrowding, or prolonged cloudy weather. They can also die from lack of oxygen. Aquatic organisms need oxygen, just like air-breathing organisms. When water is cold, it can hold more dissolved oxygen. When it is warm, it can hold less. When a body of water gets warmer, levels of dissolved oxygen get too low to support fish and other organisms. Low dissolved oxygen can result in sudden die-offs of fish, known as fish kills. This occurs faster in lakes and ponds than in the ocean. Why? Smaller bodies of water heat up faster. In a lake, high air temperatures can cause the surface water to get much warmer than the deep water. The denser, colder water toward the bottom is less likely to mix with the less-dense, warm surface water when their temperatures are very different. Meanwhile, the amount of oxygen dissolving in the surface water is declining because it's too warm.

A study of hundreds of European lakes showed that warming is connected to lower levels of dissolved oxygen. Most lakes with increasing surface temperatures had decreasing dissolved oxygen (DO). This could spell trouble for fish and other aquatic organisms.



Coral Bleaching

Coral reefs are important marine habitats, particularly in the tropics. Warming ocean waters are causing a phenomenon known as coral bleaching. Corals typically have color due to photosynthetic algae that live inside the corals. The algae provide food for the coral in exchange for a relatively safe place to live. This mutualistic relationship ends when the water is too warm and the corals expel the algae. The corals become noticeably whiter and are less capable of surviving. Vast swaths of reefs such as Australia's Great Barrier Reef have died as a result of bleaching. Data seem to indicate the main cause is an increase in water temperature. Other factors, such as increased UV light, sedimentation, pollution, freshwater dilution, and disease, may also contribute to coral bleaching.



The white parts of these hard corals on a reef in Indonesia are bleached.

Cows and Methane

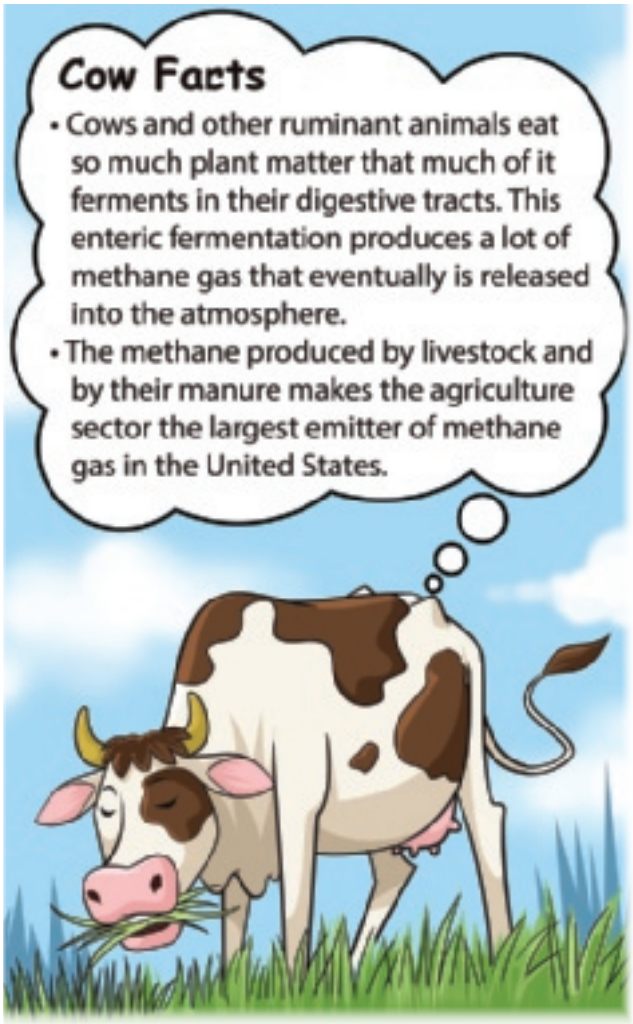
What exactly do cattle have to do with global warming? It turns out the link between cows and the climate has to do with one type of natural gas: methane.

Each time a cow belches or passes gas, methane is released into the atmosphere. Scientists estimate that one cow can belch about 220 pounds of methane in a single year. But what's the problem? Methane is about 25 times more potent than carbon dioxide (CO_2) in being a **greenhouse gas** (GHG).

There are several different gases that account for the greenhouse effect, which is the trapping of heat by Earth's atmosphere. Carbon dioxide is the GHG that is emitted the most by human activities, especially the combustion of fossil fuels such as coal and oil. When a CO_2 molecule is struck by infrared radiation, it vibrates and redirects the energy in all directions. Infrared radiation ends up staying in the atmosphere longer than it would have if CO_2 and other GHGs were not there to absorb it.

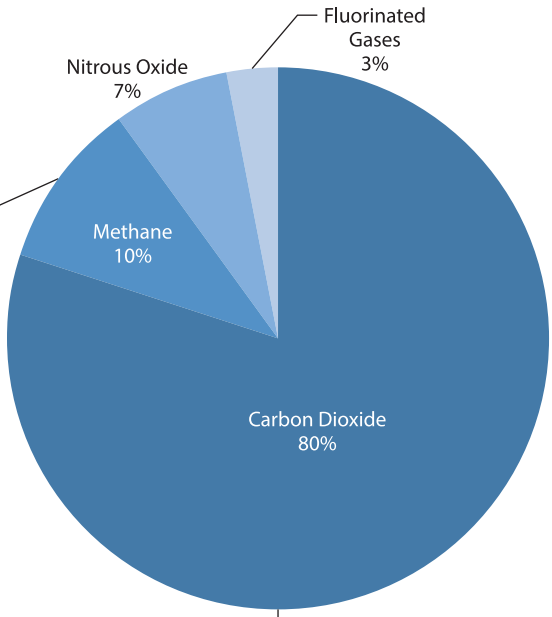
But let's get back to the cows. When methane is burned, it produces water and CO_2. If it does not burn and is released into the air, methane is better than CO_2 at absorbing and redirecting infrared radiation. Methane emissions are believed to be much smaller than CO_2 emissions, but because methane is such a powerful GHG, it is a contributor to climate change.

Methane is a natural product of the breakdown of organic material, such as the remains of plants and animals. This breakdown can occur relatively quickly, as in the digestive system of a cow. It can also occur over the course of centuries in Earth's crust and in peat bogs.

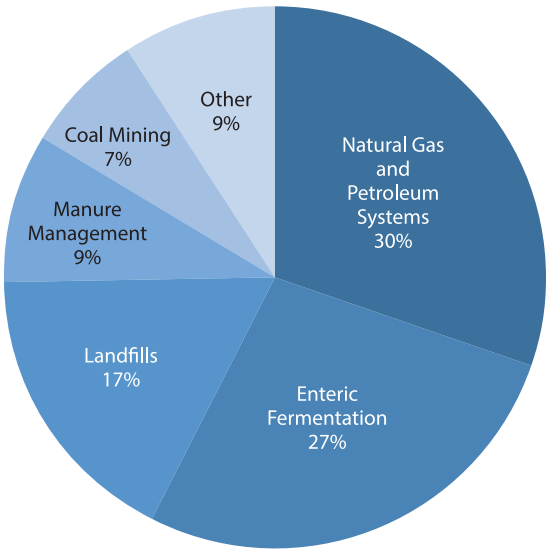


Scientists and agriculture experts around the world are exploring creative strategies for reducing methane emission from cattle. New formulations of cattle feed may reduce methane, and certain chemical additives to food can also help.

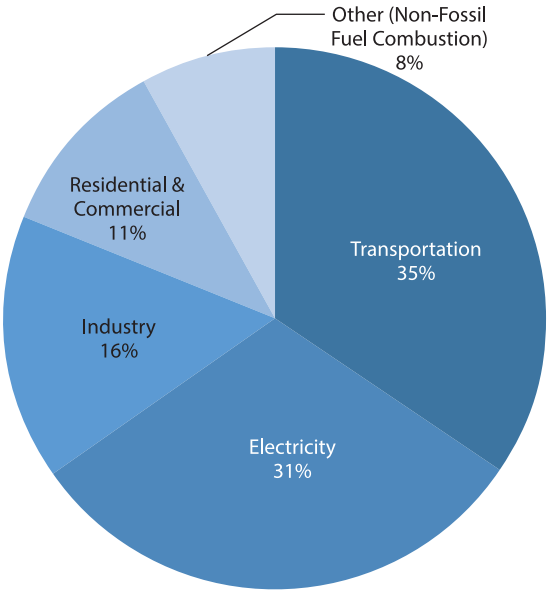
Overview of U.S. Greenhouse Gas Emissions in 2019



2019 U.S. Methane Emissions, by Source



2019 U.S. Carbon Dioxide Emissions, by Source



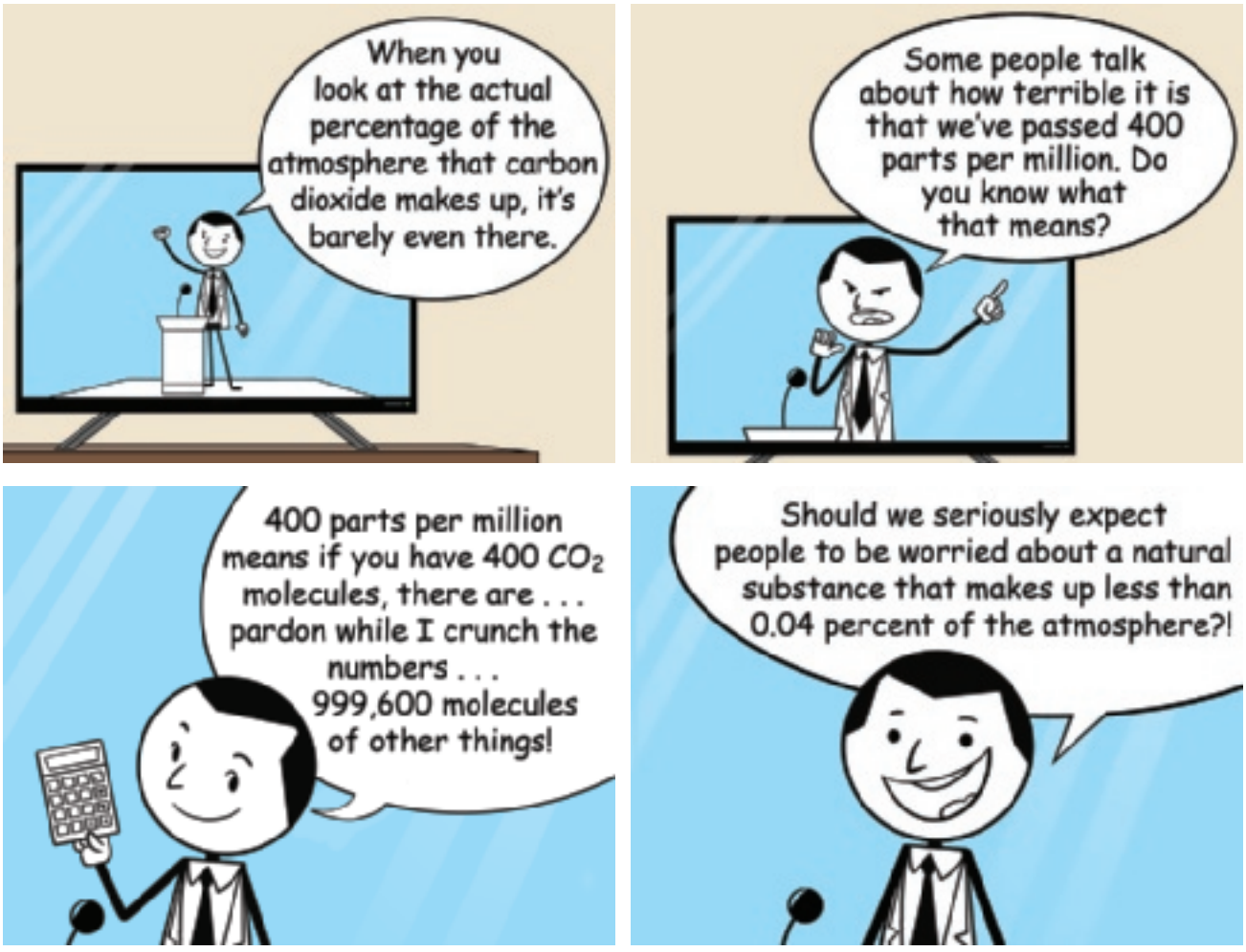
Vocabulary

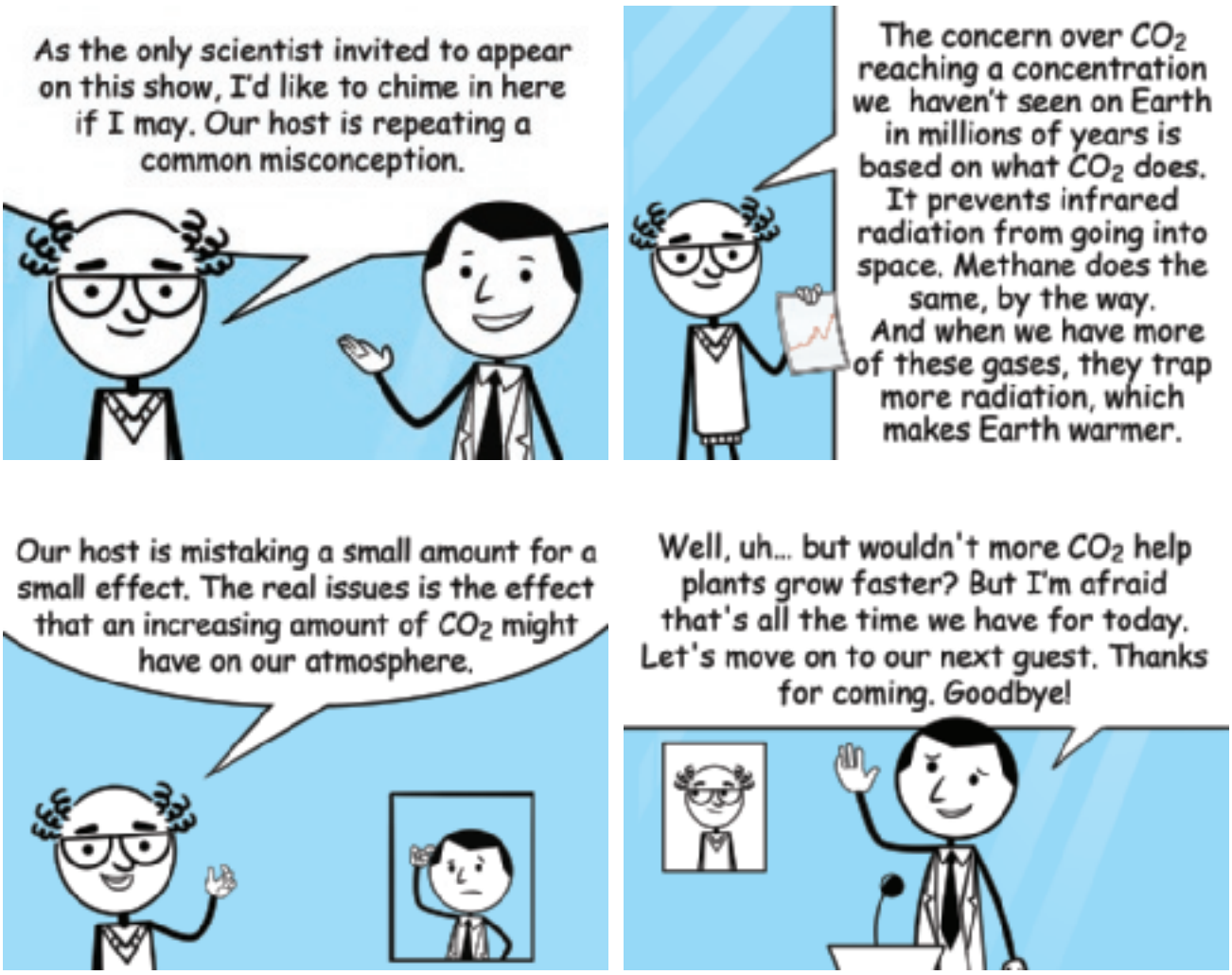
greenhouse gas, n. a gas in Earth's atmosphere that traps heat

Carbon Cartoon

Spot the BS

Heads up! There is some **b**ad **s**cience (and good science) on these pages. Can you spot the questionable talking points?




As the only scientist invited to appear on this show, I'd like to chime in here if I may. Our host is repeating a common misconception.
The concern over CO_2 reaching a concentration we haven't seen on Earth in millions of years is based on what CO_2 does. It prevents infrared radiation from going into space. Methane does the same, by the way. And when we have more of these gases, they trap more radiation, which makes Earth warmer.
Our host is mistaking a small amount for a small effect. The real issues is the effect that an increasing amount of CO_2 might have on our atmosphere.
Well, uh... but wouldn't more CO_2 help plants grow faster? But I'm afraid that's all the time we have for today. Let's move on to our next guest. Thanks for coming. Goodbye!

Volcano Emissions: A Lot of Hot Air?

Spot the BS

Heads up! There are some questionable claims being made on this page. Can you spot the **b**ad **s**cience?

TJ T.J. Walton

Just had to share this! Too funny! This is why I don't feel bad about my gas-guzzling truck.

RS Real Science News

Truth: A volcano can belch out as much carbon dioxide in one year as all of human industry throughout history?



JP Jennifer Perron

Hey, @Melissa. This is an old meme that's been bouncing around for years. Volcanoes emit carbon dioxide, but it's not even in the same ballpark as the amount emitted by automobiles in a year, let alone all human industry. And that's just one year, certainly not all of human history. Take it from me, the only volcanologist in the family!

MP Melissa Perron

I don't know why some people think anything we can do can compete with what nature does. SMH!

A number of social media posts have circulated in recent years with a version of the claim made on the previous page: a volcano can emit as much carbon dioxide as all of the cars that have ever existed or all human sources of emissions. Consider the following:

- The annual emissions of carbon dioxide from vehicles and industrial activity is 24 *billion* tons. According to the United States Geological Survey (USGS), the world's volcanoes emit 200 million tons of carbon dioxide in a year. That's all of the volcanoes combined, including the ones that are underwater.
- If volcanic eruptions were major sources of carbon dioxide in modern times, they would cause blips in the graphs of CO_2 concentration in the atmosphere. Instead, such graphs are relatively smooth and with a clear upward trend.

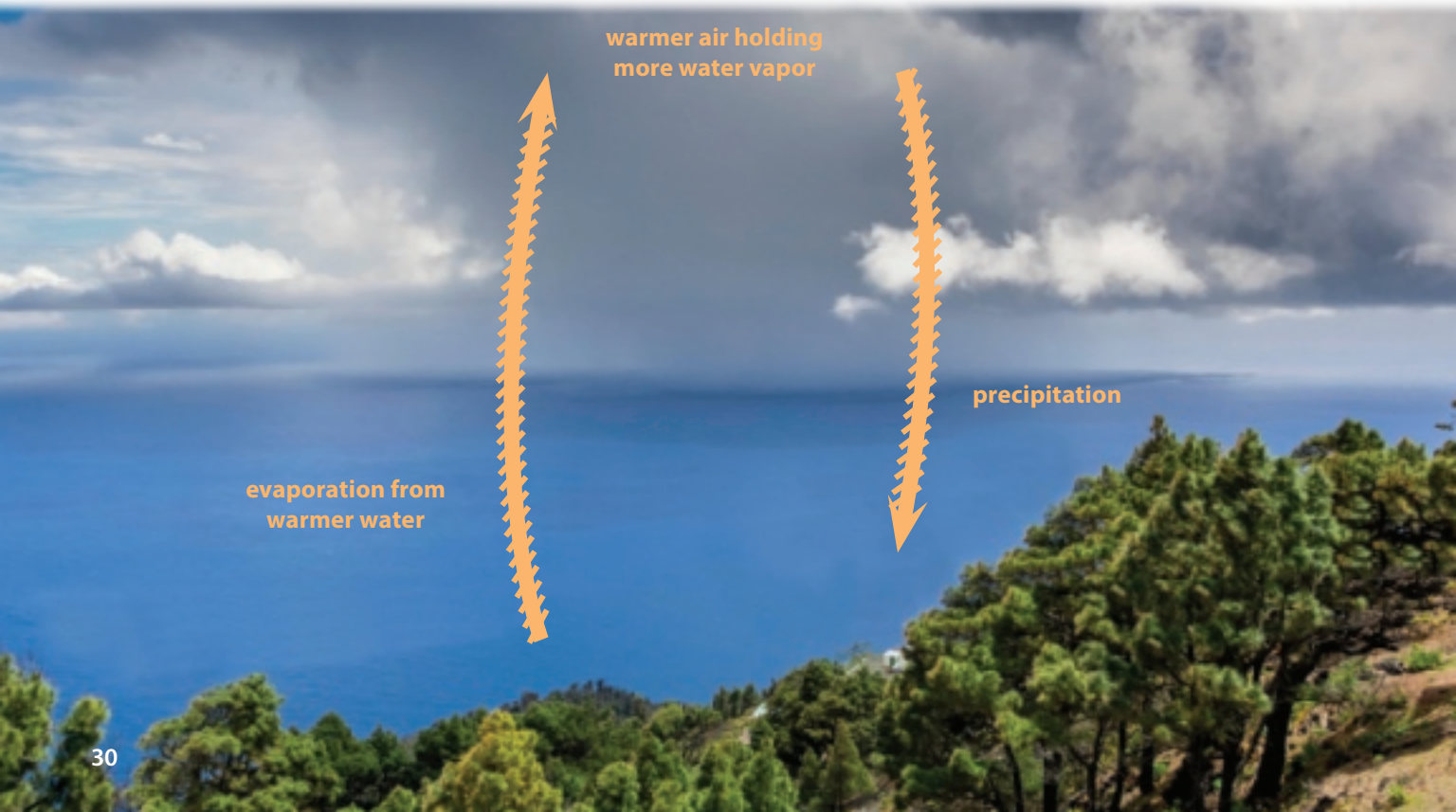
In reality, major volcanic eruptions tend to have cooling effects on the climate. In addition to emitting carbon dioxide, volcanoes emit sulfur dioxide as well as ash that rises into the stratosphere and provides a shading effect by blocking some of the sun's energy from reaching Earth's surface. After Mt. Pinatubo erupted in the Philippines in 1991, Earth's surface was about 0.5°C cooler on average, despite the overall warming trend.

Climate and the Water Cycle

Of the greenhouse gases, water is the only one that condenses in the atmosphere at certain temperatures. Several major processes involving water are amplified by the warming trend.

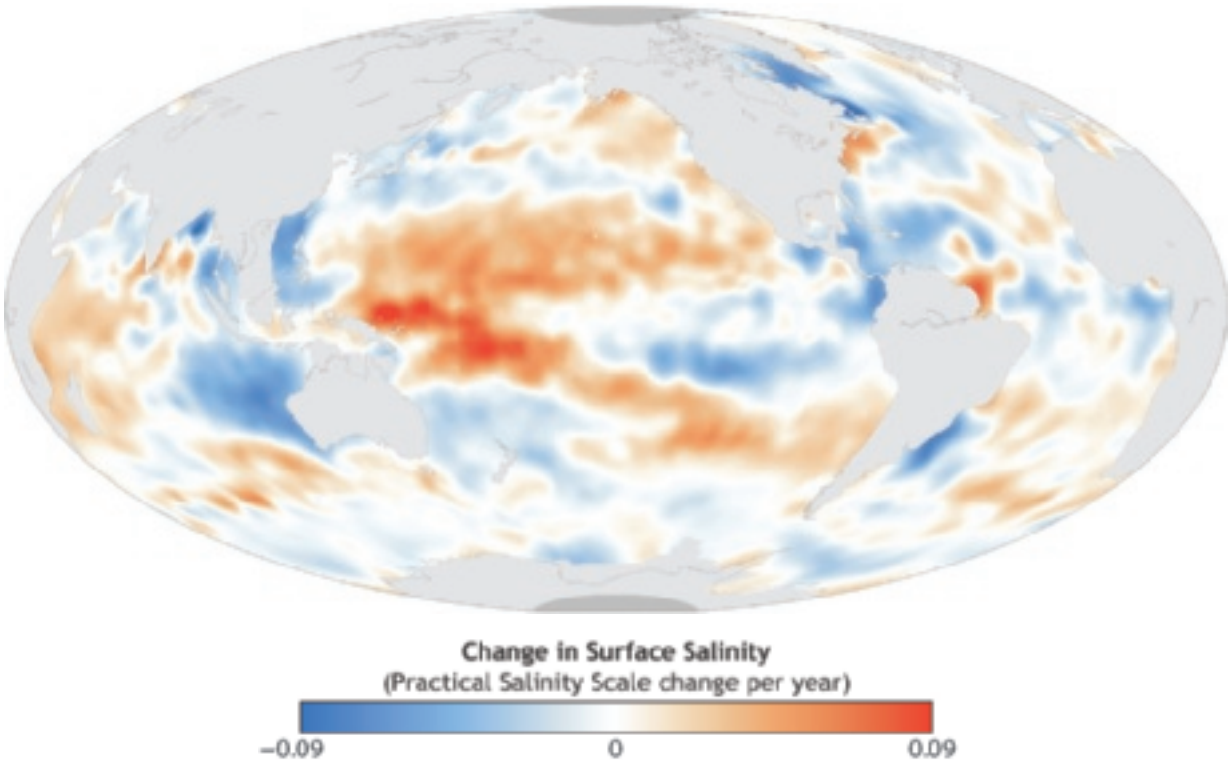
Feedback Loops

A warming planet means the atmosphere and bodies of water are warmer. Warmer seas and lakes mean more evaporation. This puts more water into the atmosphere, which is also warming. A warmer atmosphere holds more water, which in turn absorbs more heat. This is a positive feedback loop that is changing the water cycle. There is also a negative feedback loop involved here. As temperature increases, so does the amount of cloud cover formed by increased evaporation. The increased cloud cover reduces incoming solar radiation and limits warming. Scientific data can give an indication of how these two loops work together.



Saltier Tropics, Wetter Poles

Evaporation rates in warmer areas are increasing as Earth gets hotter, and the warmer atmosphere means that water vapor is slightly less likely to condense into rain clouds in the tropics. As a result, the water cycle is amplified but is also shifting more of Earth's water away from the tropics and toward the poles. Ocean water is getting saltier near the equator due to the higher rate of evaporation and the decline in precipitation there, while more precipitation is falling at higher latitudes. There, the precipitation dilutes the salinity of seawater. In the North Atlantic, for example, the ocean receives fresh meltwater from Greenland's ice cap and precipitation from the atmosphere, causing a decline in salinity. Scientists are keeping track of these issues. And science informs decision-making. If these changes in ocean salinity and a shift in the distribution of water are real, they would present a disadvantage to some regions and an advantage to other regions. What should the response of governments be to such possible changes?



The Hurricane Blogger

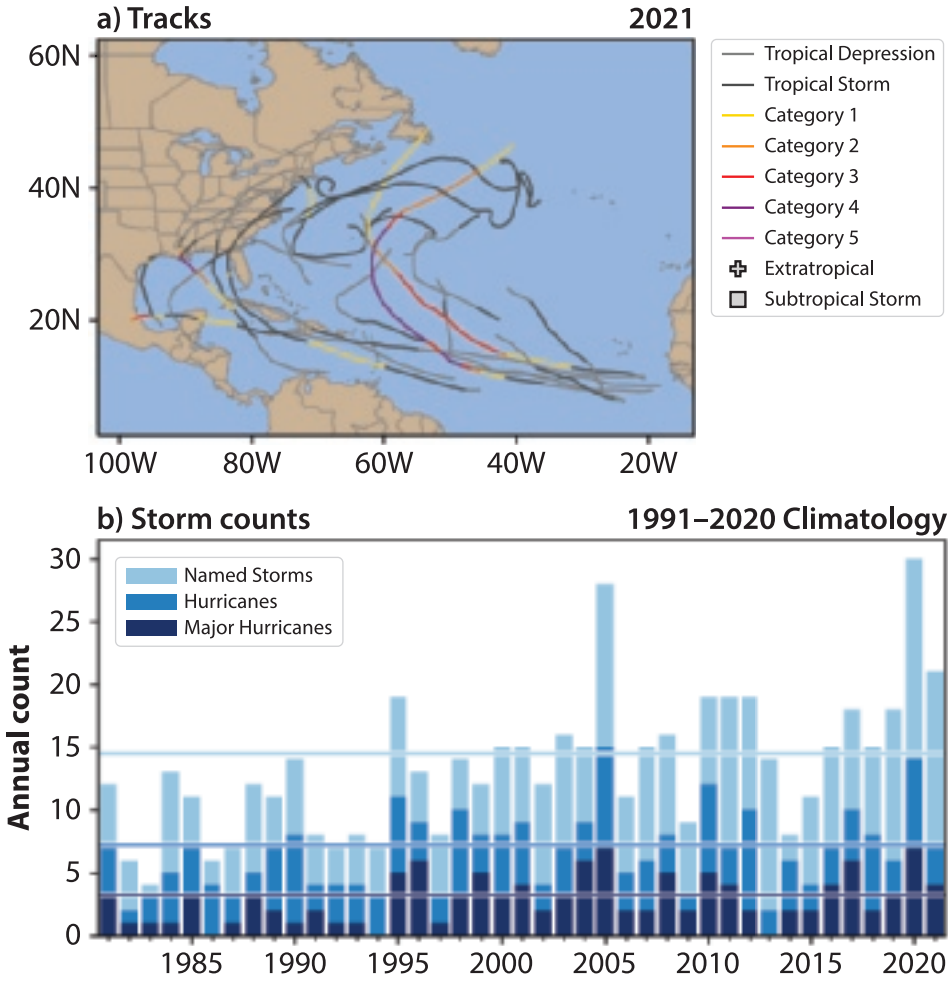
As I spend yet another summer in the Dominican Republic, it's becoming harder and harder for me to imagine how an island with beaches this beautiful could be prone to so much natural destruction. One of Mother Nature's cruel jokes, perhaps. My family and friends don't understand how I could possibly want to be out in the middle of an island that is known for its hurricanes—and in peak season, no less. But for me, it's a matter of research. Tracking weather patterns and studying their causes and effects are what I do best. Unfortunately, the data I'm collecting while I'm here are grim. In working with the Intergovernmental Panel on Climate Change (IPCC), we can now safely say that the world should expect hurricanes to be more intense and wetter in the coming centuries as Earth warms.

Specifically:

- Hurricanes will cause more coastal flooding thanks to sea level rise, a product of global warming.
- Hurricane rainfall rates are projected to increase due to more moisture in the atmosphere.
- More hurricanes will reach Category 4 or 5 status, which is a measure of sustained wind speed.
- The overall number of hurricanes per year is expected to decrease or change very little.



IPCC observations show that since 1980, the intensity of hurricanes has increased, with a larger proportion of powerful hurricanes and an increase in how fast they intensify. It's a matter of looking at the numbers. The 2021 hurricane season in the North Atlantic, for example, had both a high number of named storms and a high number of intense hurricanes, with six storms in Category 3 to 5.
I wish I had better news to report from the Dominican. I'm not sure where I will be off to next. Maybe we'll see where the hurricane winds take me.



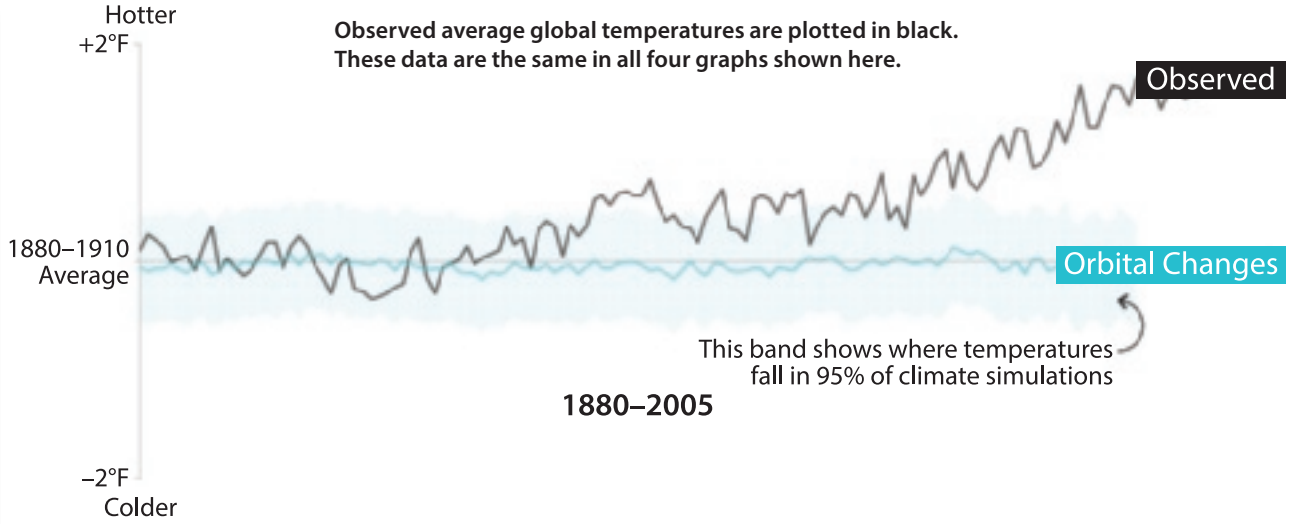
According to NOAA, in 2021 the North Atlantic had a high number of named storms, meaning tropical storms or hurricanes that were given names by the World Meteorological Organization. Only 2005 and 2020 had larger numbers of named storms in the North Atlantic basin.

Consider the Source

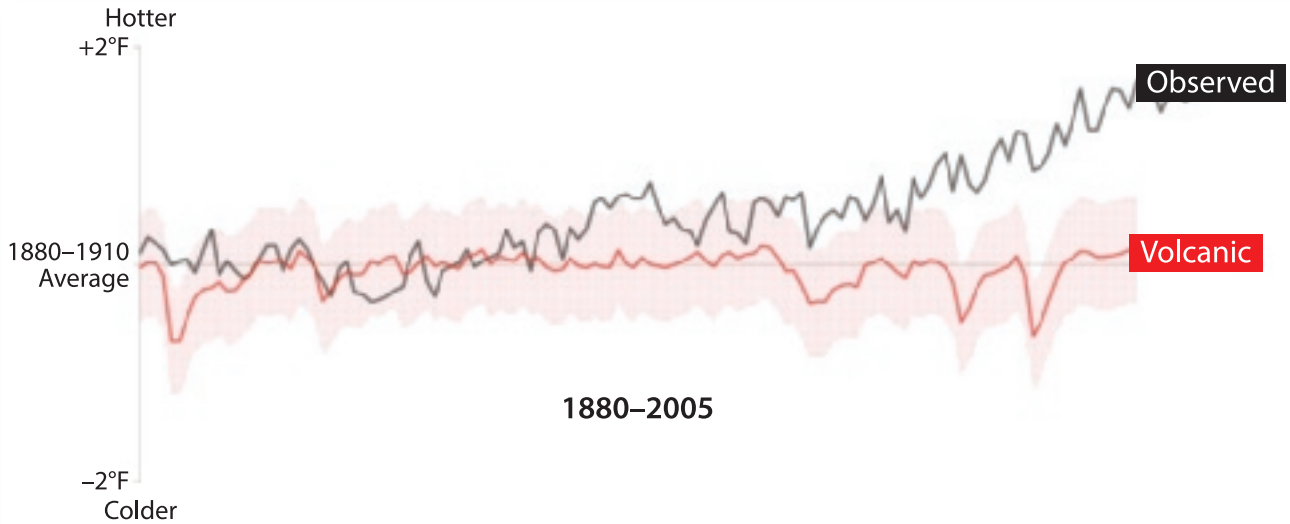
The scientist in this blog cites the IPCC, which is the world's leading body studying climate change. The NOAA is the U.S agency for studying weather and climate, including connections between severe weather events and long-term patterns in climate.

Potential Causes of Changing Climate

Some people say the climate is changing. Some people don't think the climate is changing at all. Others concede that it is changing, but they suggest factors other than human activities. Are there potential cause-and-effect relationships between human factors and the rise in yearly average temperatures? As you study these data, remember that observed temperature changes are constructed based on a staggeringly complicated system. Factors such as heat island effect and changes in data collection technology make all data like this worthy of careful examination.



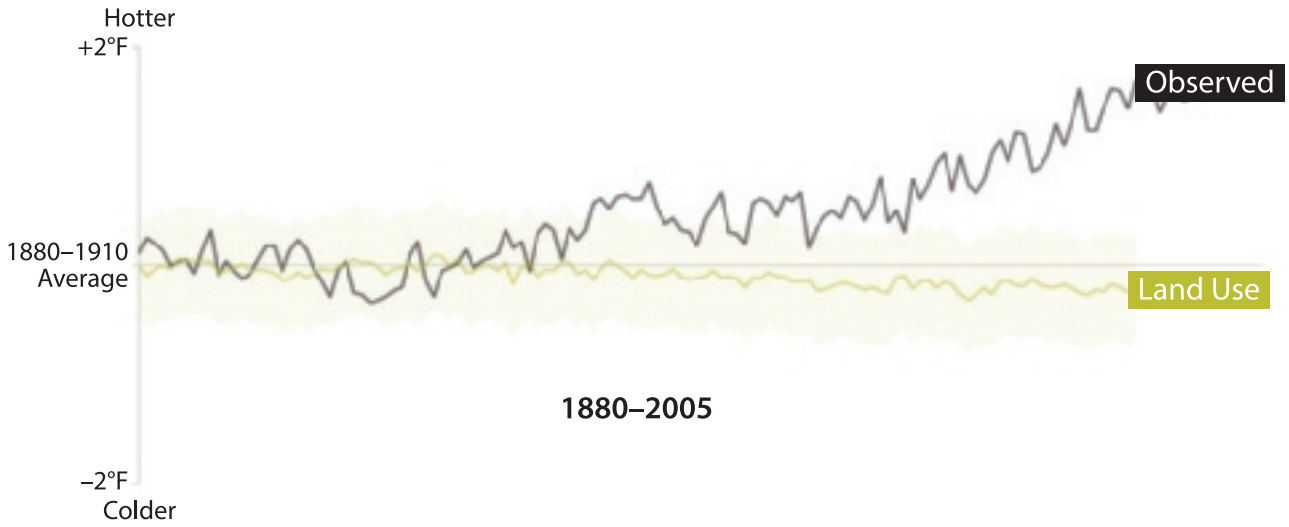
The blue line shows how temperatures should have changed based on changes in Earth's orbit around the sun, including its tilt. The lighter blue band around the blue line shows the upper and lower ranges of where temperatures could be based on orbital factors.



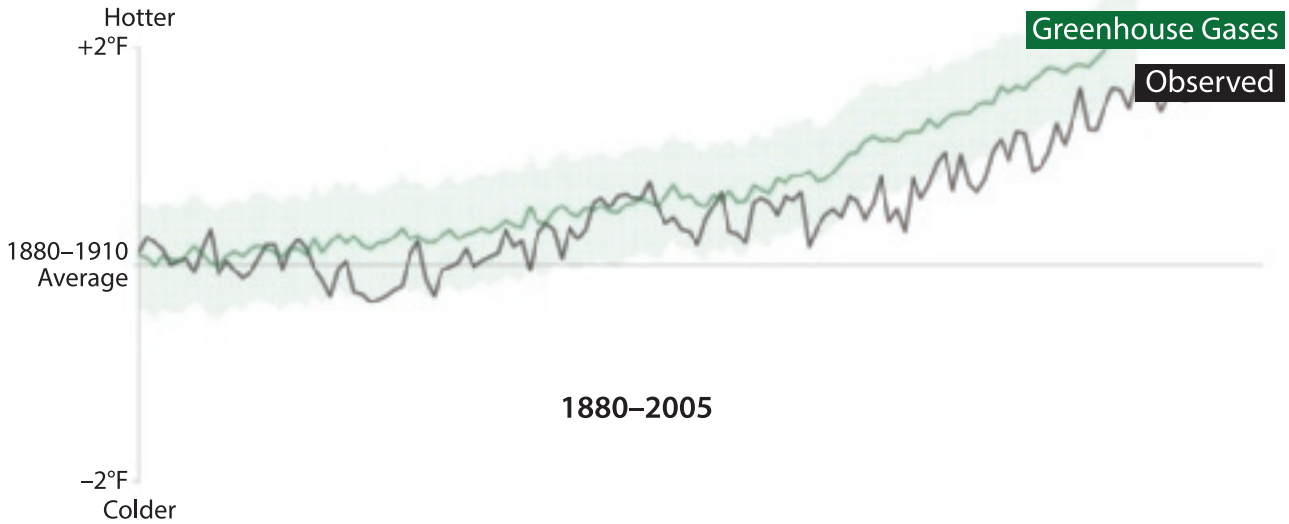
Temperatures that should have been experienced due to volcanic activity are plotted in red.

Vocabulary

climate change, n. long-term shifts in temperature and weather patterns



Humans have remade about half of Earth's land to support farming, roads, cities, and other human structures.



The expected influence on temperature of greenhouse gases is graphed in green. It tracks very closely with the observed change. These two data sets show correlation, but ask this: Does a correlation mean one causes the other? What kind of research would be needed show cause and effect?

Ocean Acidification

Not all of the carbon dioxide that's been emitted into the atmosphere has stayed there. The ocean absorbs gas molecules from the air. Marine photosynthetic organisms need carbon dioxide, but the excess is causing problems as the seawater, which is naturally alkaline, becomes more acidic.

In water, carbon dioxide forms carbonic acid, which quickly dissociates into hydrogen ions and bicarbonate ions. This is what's lowering the pH of the ocean.

$$\underset{\text{Carbon dioxide}}{CO_2} + \overset{\text{Water}}{H_2O} \rightleftharpoons \underset{\text{Carbonic acid}}{H_2CO_3} \rightleftharpoons \overset{\text{Hydrogen ion}}{H^+} + \underset{\text{bicarbonate ion}}{HCO_3}$$

Corals and many other marine organisms form their hard exoskeletons by absorbing carbonate ions from seawater and putting them together with calcium ions to form calcium carbonate. But with many carbonate ions instead meeting hydrogen ions and forming bicarbonate, there's less free carbonate for these "calcifiers" to use.

This pteropod is a small marine snail. Its shell is being dissolved because the seawater it lives in has become more acidic. Corals, oysters, clams, and other calcifiers are also projected to have a much harder time forming and maintaining their exoskeletons in the future.



Overlooked Sources of GHGs

Send

From: Ilah Hart

To: Lane Dysinski

Subject: Carbon Emissions for Novel

Dear Dr. Dysinsky,

I am a novice writer trying to outline my new novel on the topic of climate change. I am writing to you today because I have studied your immense work on global warming and wondered if you might have some time to share your knowledge with me. Not only would I be honored to hear what you have to say but will credit you in the intro of the book!

I would like to know more about the other, less obvious sources of carbon emissions. It seems that these days so many books are focused on the more apparent sources, like fossil fuels from vehicles. But we are trying to make our story more authentic and bring awareness of new information to readers around the world.

Any information that you might share with me would be greatly appreciated. Thank you so much in advance, and thank you for taking the time to consider my request.

Warm regards,
Ilah Hart

Send

From: Lane Dysinski

To: Ilah Hart

Subject: Re: Carbon Emissions for Novel

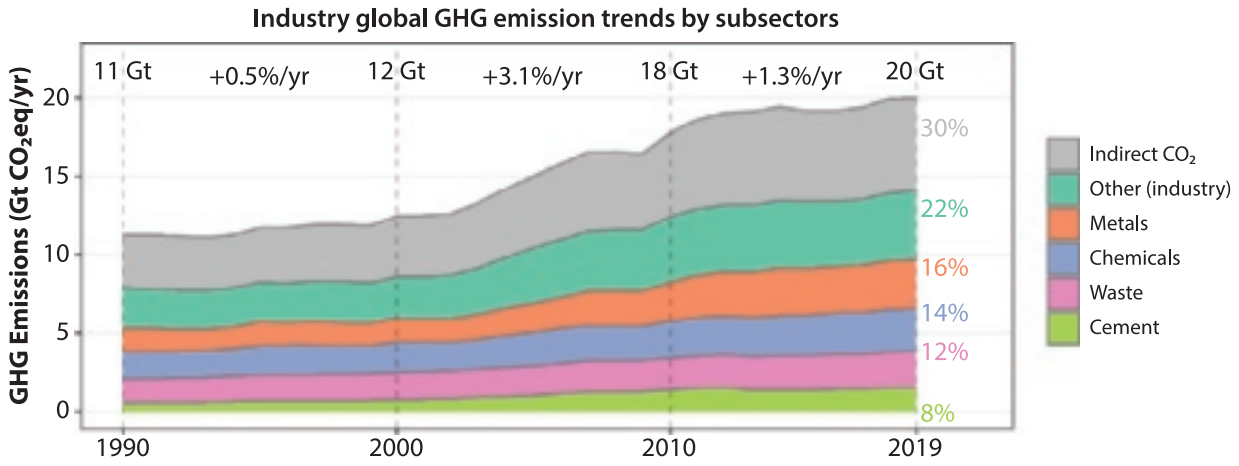
Good day, Ms. Hart.

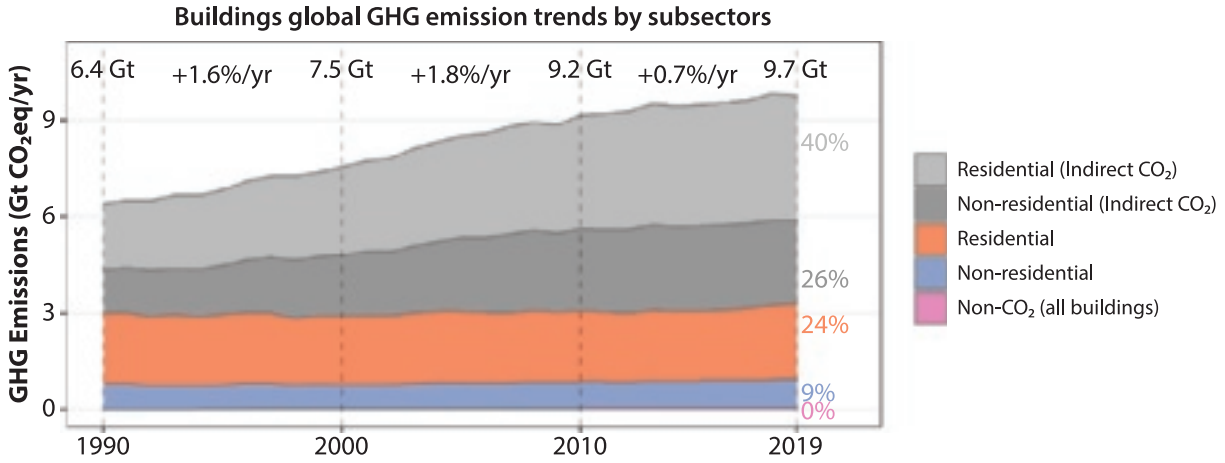
It is a pleasure to receive this email from you, and I am delighted that you are reaching out to better support the facts in your book. Being retired from my 40-year career as a climatologist, I enjoy receiving these types of requests and putting my knowledge to good use. I am happy to share some information with you that I hope you will find helpful.

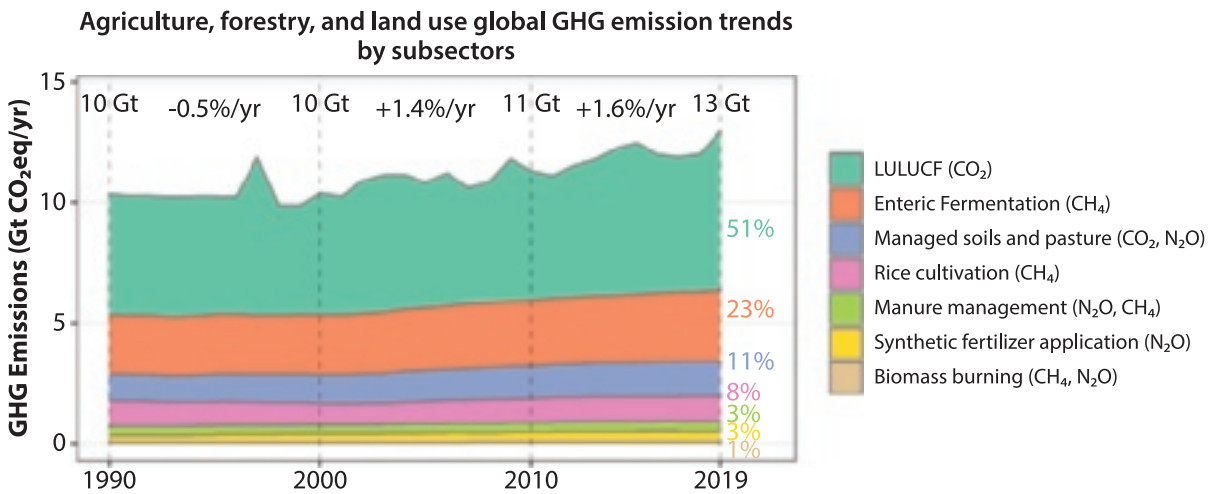
As you must already know, greenhouse gases are not only emitted from the most obvious sources, like vehicles and manufacturing plant smokestacks. There are other players that contribute to atmospheric carbon dioxide. Many things that we make or use in our day-to-day lives can be linked back to a source that originally produced greenhouse gases.

I am attaching some graphs that you can take a look at, and I will walk you through each of them so you get an assortment of data. I hope you find some of this useful, and please reach out to me again for any other questions!

Best,
Dr. Lane Dysinksi


Industry global GHG emission trends by subsectors
GHG Emissions (Gt CO2eq/yr)
11 Gt
+0.5%/yr
12 Gt
+3.1%/yr
18 Gt
+1.3%/yr
20 Gt
30%
22%
16%
14%
12%
8%
Indirect CO2
Other (industry)
Metals
Chemicals
Waste
Cement
1990
2000
2010
2019


Buildings global GHG emission trends by subsectors
GHG Emissions (Gt CO2eq/yr)
6.4 Gt
+1.6%/yr
7.5 Gt
+1.8%/yr
9.2 Gt
+0.7%/yr
9.7 Gt
40%
26%
24%
9%
0%
Residential (Indirect CO2)
Non-residential (Indirect CO2)
Residential
Non-residential
Non-CO2 (all buildings)
1990
2000
2010
2019


Agriculture, forestry, and land use global GHG emission trends by subsectors
GHG Emissions (Gt CO2eq/yr)
10 Gt
-0.5%/yr
10 Gt
+1.4%/yr
11 Gt
+1.6%/yr
13 Gt
51%
23%
11%
8%
3%
3%
1%
LULUCF (CO2)
Enteric Fermentation (CH4)
Managed soils and pasture (CO2, N2O)
Rice cultivation (CH4)
Manure management (N2O, CH4)
Synthetic fertilizer application (N2O)
Biomass burning (CH4, N2O)
1990
2000
2010
2019

This IPCC graph shows which industrial subsectors have shown the most growth in greenhouse gas (GHG) emissions over the last 30 years. By industry, the IPCC means things that produce physical products, not transportation or the burning of fossil fuels to generate electricity. The wider each colored band is, the larger its share of the overall emissions. The production of cement and metals, for example, has grown as demand for these building materials has spread. These subsectors emit a lot of GHGs, but not everyone knows this. People don't often think of cement when they think about sources that are polluting the atmosphere. Overall, industry accounts for 34% of GHGs as of 2021.

The maintenance of buildings, including homes and offices, accounts for 16% of GHG emissions. As more people have moved into homes that use fossil fuels either directly or indirectly for heating, cooking, and cooling, the carbon footprint of home occupants has risen. The trend toward larger-sized homes has also contributed to this rise. When people lived in smaller apartments or living spaces, emissions in this category were also lower.

Agriculture, forestry, and land use sources make up 22% of emissions. In this graph, LULUCF stands for "land use, land use change, and forestry." Clearing forests to plant crops can turn a carbon sink into a carbon source. Enteric fermentation is what happens in the digestive systems of cows and other livestock, which produces methane (a GHG). As a side note, I have contributed information to other books and movies that focus on the importance of people maintaining a "greener" diet (one that involves eating fewer meat products), as this can help slow the rate of atmospheric emissions.

A Climate Refugee

I was born in The Bahamas on September 1, 2005. My parents were from Haiti, a very poor island nation not far from The Bahamas, and they settled in a Haitian neighborhood on the island of Abaco called The Mudd. It got its name from the fact that it was basically built on mud that was dredged out of the harbors and from the muddy roads—if you can even call them that—between the homes. Everyone lived in little shanties made of spare materials from construction projects in the nicer parts of Great Abaco Island. We were poor, but my parents said Haiti was worse, and they managed to make a living along with a lot of other Haitians. My mom was a housekeeper for the wealthy. My dad worked construction.

Close to my fourteenth birthday, September 1, 2019, Hurricane Dorian hit Abaco. It was the fifth Category 5 hurricane in the Atlantic in a four-year



Hurricane Dorian flattened The Mudd, a settlement in Marsh Harbour, Bahamas, on September 1, 2019.

period, and it was one of the most intense storms on record. People who could leave the island did, but a lot of us didn't have time or money or anywhere else to go. Some fled to the church, which was made of cinderblocks and could withstand the winds. Others stayed in their shanties. The wind and storm surge flattened The Mudd, killing thousands. We didn't even try to look for any of our belongings. We knew they were either washed out to sea or buried in mud.

For a few days, we were allowed to stay in the church. Then the Bahamian government told us to head to Nassau, where we were supposed to get "help." Instead, the government demanded our papers. My dad had a visa, but my mom didn't. My dad stayed, but my mom and I went to Haiti, a place I'd never been and one that my mom did not want to see again. I guess this is what the prime minister meant when he campaigned with the slogan "Bahamas First."

My dad is trying to find work so he can send us some money every month. There's very little work here in Haiti, so my mom is trying to figure out a way for us to get back to Nassau even though we could get deported right back to Haiti. Supposedly the people on Abaco whose homes survived—including some of the wealthy—are struggling to find workers to fix and maintain their homes because the hurricane displaced so many of us from the island. But the Bahamian government doesn't want us there.



Satellite view of Hurricane Dorian bearing down on The Bahamas.

What Does It Cost?

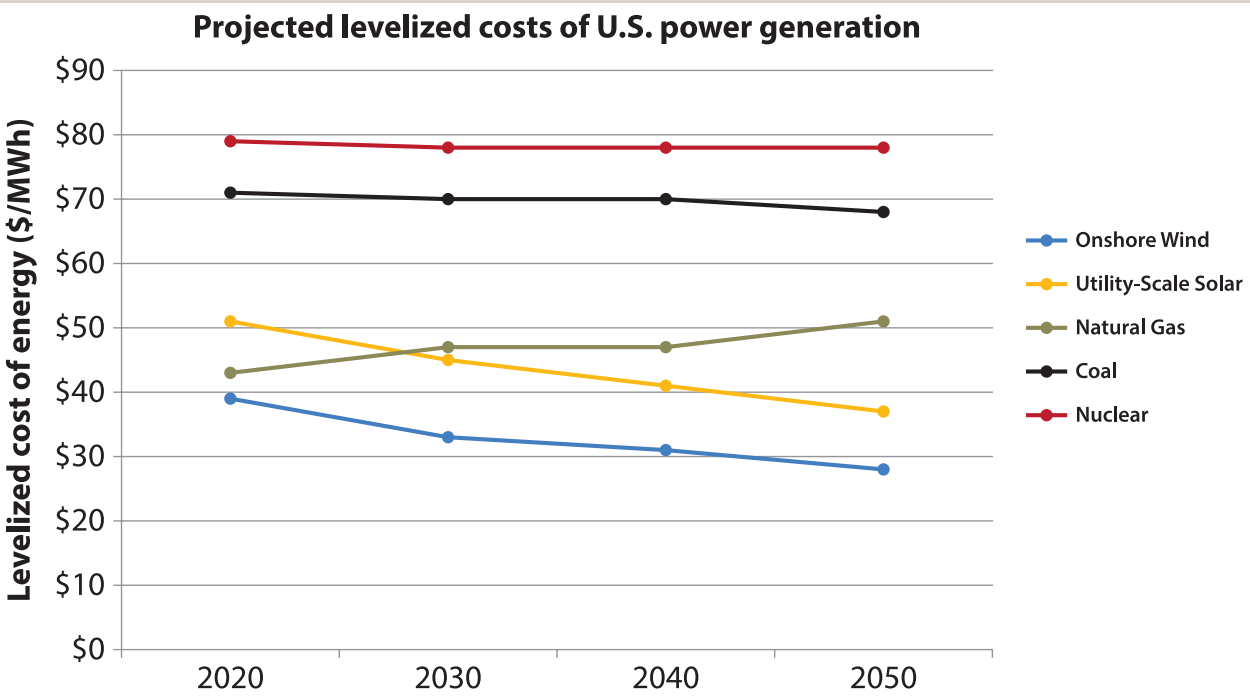
When it comes to the topic of climate change, there are some people who fully support the idea of transitioning away from traditional sources of energy in order to use renewable ones. These people would like to see solutions like solar energy and wind power replace fossil fuels that emit carbon into the atmosphere. They argue that there are costs associated with inaction—specifically, it will be expensive to address the issues that come from climate change, such as increased severe storms, more frequent wildfires, and other problems.

They also argue that the costs of utility-scale solar and onshore wind power are declining. Both are already cheaper than coal, and with natural gas predicted to get more expensive, solar and wind will be cheaper than gas by 2030, according to the National Renewable Energy Laboratory.

There are other people who believe that if we make a choice to modify climate change, it will be expensive because it costs a lot of money to transition from old sources of energy to new ones. Humans have been reliant on coal, natural gas, oil, and other forms of fossil fuels for so long that there's just a tremendous amount of infrastructure that is set up to use those fuels, not to mention billions of small-scale devices (lawnmowers, leaf blowers), vehicles, and appliances that use them also. Switching from nonrenewable energy sources to renewables, such as solar and wind, will require significant investment by governments and individuals. Turbines, transmission lines, and other machinery necessary to make renewable energy possible will need to be built. Building and establishing this equipment will be costly. Some estimates suggest the cost to combat climate change might be as high as $4 trillion per year.

- **An economic analysis by the U.S. Office of Budget and Management and the Network for Greening the Financial System found that the annual costs of climate inaction in America would be $2 trillion by the end of the century.**

- **Federal crop insurance subsidies**—what the United States pays farmers when crops fail—will cost between **$330 million and $2.1 billion** per year.
- Costs of responding to **coastal disasters** such as hurricanes will **increase by $22 billion to $94 billion**.
- Costs of dealing with **wildfires** could **increase by 78 to 480 percent**.
- More than **12,000 federal buildings** and structures could be flooded by a ten-foot increase in sea level, at a **replacement cost of $43.7 billion**.



The graph compares the levelized costs of power generation of five sources. "Levelized costs" means the total costs of generating power per source, including power plant construction, their operation and maintenance, and the costs of any fuels. Because sunlight and wind are "free," the levelized costs of these renewables have declined and will continue to decline through 2050. Keep in mind that all of these technologies are changing and that some are quite new. Many factors go into total cost, such as transportation and storage.

Although supporters of renewable energy claim that wind, hydro, and solar power are cheaper than nonrenewable sources (and thus will offset these manufacturing costs), others argue that renewable energy sources are only less expensive in the beginning phases of the transition and that the prices for these energies will surge once they become the more dominant form of power. So will they really be less expensive for the average household in the long run? There are also a lot of risks associated with transitioning to a new primary power source, especially when those sources are dependent on natural elements—elements that humans cannot control. There are questions as to whether or not renewable energy is as reliable and predictable as nonrenewable energy. If it's not, this can become costly for a country that has made the switch but suddenly faces problems with getting stable and consistent streams of energy to its citizens. When people look at the costs of transitioning away from fossil fuels, are they considering how much money would be spent if things go awry and communities suddenly need financial assistance from their governments?

There are always financial costs in any decision.

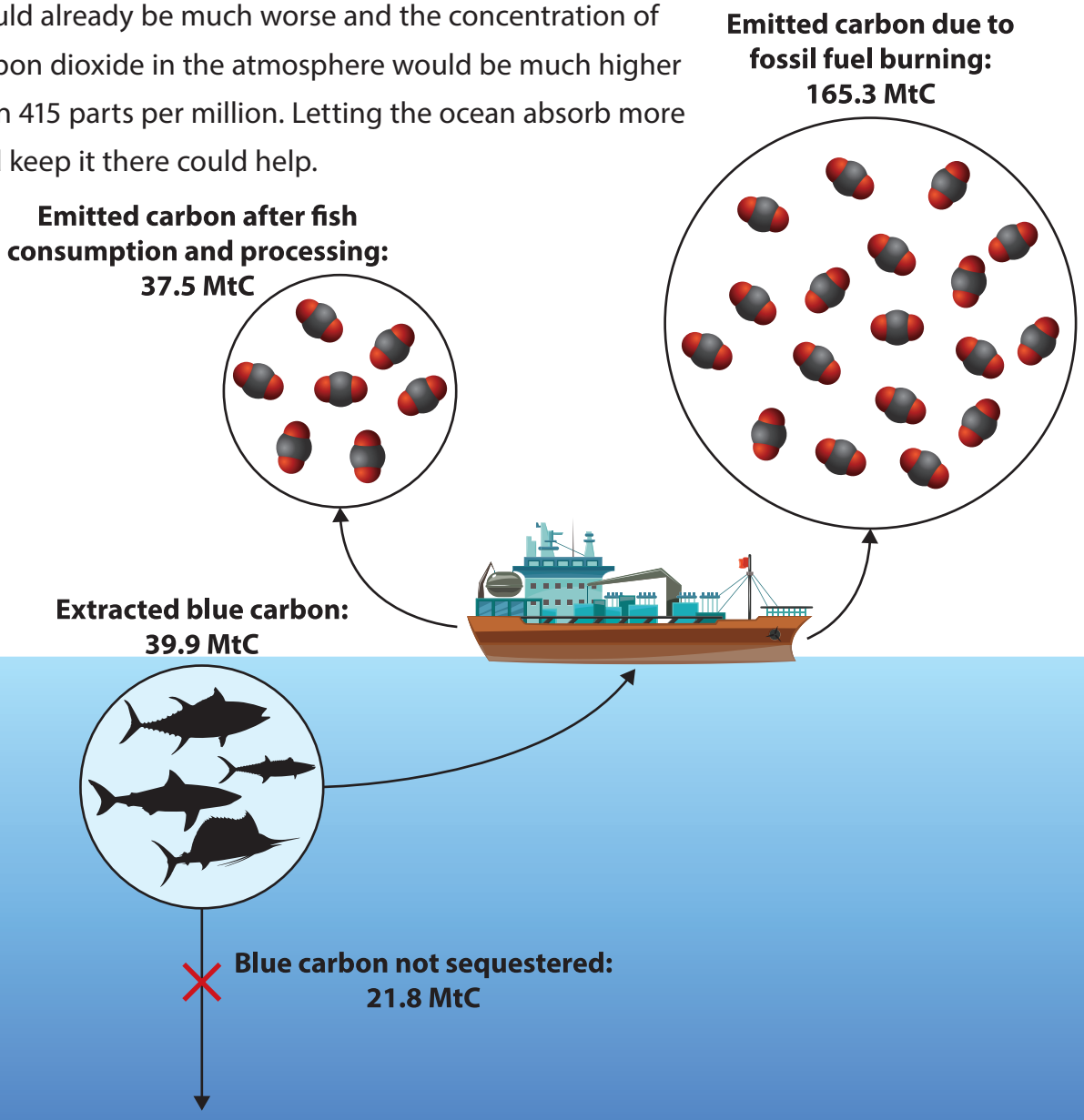
When it comes to climate change and the use of resources, who is right?

Dig into Data

What trends do you notice in the data on the graph?

Letting the Ocean Be a Better Carbon Sink

The ocean has already absorbed a great deal of the carbon that humans have moved from Earth's crust to the atmosphere. If it had not, warming of the atmosphere would already be much worse and the concentration of carbon dioxide in the atmosphere would be much higher than 415 parts per million. Letting the ocean absorb more and keep it there could help.



When fish and other organisms are removed from the ocean, the impact on the carbon cycle is twofold: 1) Instead of organisms and their waste cycling into the deep ocean where large stores of carbon could be sequestered, millions of metric tons of carbon (MtC) in the form of organisms have been taken ashore and turned into food. That carbon ends up cycling mainly into the atmosphere as people digest the food and their cells respire. 2) Fishing vessels, which run mainly on diesel fuel, emit many tons of carbon dioxide directly into the atmosphere. Shipping seafood products adds to the overall emissions of the extraction of carbon from the ocean. Consuming less seafood could restore the carbon cycle in the ocean and enhance the ocean's ability to act as a sink for "blue carbon." The more carbon that's allowed to sink to the ocean floor in the form of remains or waste, the less will enter the atmosphere.

One way to do this is to not take much carbon out of the ocean in the form of fish and other organisms we call "seafood." Instead, if we let marine organisms go through their natural life cycles and allow their remains—and their poop—to drift to the ocean floor, more carbon will remain sequestered there instead of ending up in the atmosphere.









Electric vs. Gas Cars

DB Diana Baird

I'm so tired of being lectured by the Greenies about how much better electric cars are for the environment! Those huge lithium-ion batteries are made of stuff that needs to be mined from the ground, and making the cars sucks up plenty of fossil fuels, too. Picture all the diesel trucks that must drive down into the mine to get the cobalt for the electric car's battery cathode! I'll stick with my gas car, thanks!



SB Stephen Baird

You make a valid point about the manufacture of electric vehicles and the reality that they, too, have a carbon footprint due to the sourcing of materials. But for an apples-to-apples comparison, more "stuff" gets dug out of the ground to make and run a gasoline-powered vehicle than an electric one.

DB Diana Baird

But what if the EV's electricity is generated by burning coal or natural gas? Isn't that basically as bad for the atmosphere as burning gasoline in an internal-combustion engine? Carbon is carbon, yes? And isn't being limited to about 350 miles on a charge a problem? Currently batteries can only be recharged about 200–300 times before the battery stops working. That can be an issue.

SB Stephen Baird

It is important to look at how the EV's battery gets charged. The Argonne National Laboratory did a study on all of this. It found that the break-even points for an EV and a gas-powered car in terms of the lifetime carbon footprint are as follows:

- If 100% of the juice for the battery comes from a renewable source of energy such as hydroelectric (a dam), the EV is cleaner than the gas car after 8,400 miles.
- If the current U.S. average energy mix (23% renewable, 77% nonrenewable) is in play, then the break-even point moves out to 13,500 miles.
- If the battery is charged by electricity generated only by burning coal, it moves to 78,700 miles.

All of the break-even points move out if you are looking at SUV-size cars.

DB Diana Baird

So it takes about a year for an average new EV owner to get "green" by way of the EV? I still don't like that we need all this mining to make the batteries.

AB Aly Baird

Hey, guys! I just came here to say that there's another option: keep using the car you already have, or buy a used car, whether it's an EV or a gas car. The energy that goes into getting the metals and other materials for a brand-new car is substantial. If someone has a relatively fuel-efficient gas car, they're probably doing more for the planet by keeping that car on the road for another few years than scrapping it while it's still good and buying a new one. You guys have covered the "upstream" issues, but when you get to the end of a car's life, there are issues with disposing of those materials, and it often isn't pretty.

SB Stephen Baird

I wouldn't disagree with that, but I do think the true gas guzzlers should probably be retired as soon as possible. And for your next vehicle purchase, it's definitely better to go electric, especially if you can plug in to a source of electricity that is powered by wind, solar, or hydro.

AB Aly Baird

Yup. Before I shop for an EV, I'm going to make sure one of these is either on my property or around the corner:



DB Diana Baird

Good call! I guess I'm on board with what you guys are saying.

Consider the Source

Do you consider the people in this post a credible source for discussing the pros and cons of electric and gas vehicles? What do they write that makes them credible or not credible?

Green or Greenwashing?

Methane is a greenhouse gas that cows produce in abundance all over the world. As has been mentioned earlier, new feeding methods to reduce cattle methane are already being researched and put into use. Additionally, to reduce the release of methane into the atmosphere, some farmers are implementing a process called methane capture.

Methane capture is something more farms are utilizing to reduce their carbon footprints and, in some cases, make money. In California, oil-and-gas companies have partnered with dairy farmers to help finance methane capture equipment. The oil-and-gas companies can buy credits that the dairy farm receives for reducing methane pollution. Those credits cancel out some of the pollution that the oil-and-gas companies are responsible for.

Critics have pointed out that this could create an incentive for other farms to raise more cows just to produce more methane, to then sell on the carbon credit market, which would in effect mean more methane gets produced. And even if most or all that methane gets burned, it still means the carbon footprint of the farm could end up getting bigger rather than smaller. If the methane ends up being worth more than milk or cheese, then farmers could aim to produce more methane. Therefore, some environmentalists call this kind of thing "greenwashing"—giving the appearance of being good for the planet when in fact it's either of little benefit or it's actually a step in the wrong direction.



The heart of methane capture on a dairy farm is a methane digester. Cow manure gets stored inside, and bacteria work on the manure to produce methane gas that is piped out of the digester to be used as fuel.

Spot the BS

The two ads make claims about their commitment to being "green." Knowing what you know about greenwashing and **b**ad **s**cience, can you detect which brand is helping the environment more?



Clem & Nadine's Guilt-Free Dairy

Clem and Nadine met on an organic farm in Europe, where they learned how animals that are well cared for from birth through harvest yield dairy products that are exceptional in quality. Given the reality of climate change, they have married the traditional dairy farming techniques from the old country with modern methane-capture technology. This has allowed their farm to capture 75% of the methane produced by their dairy cows and even the cows' manure. The methane is burned on site to produce electricity for the farm. What's left over is sold to the local utility, keeping Clem and Nadine's products more affordable. They use only organic feed for their cows, and their goal is to eventually achieve carbon neutrality.



Green Pastures Dairy

Why pay more for less? At Green Pastures Dairy, we honor the livelihood of our livestock and give our customers the very best. Fed only the finest organic feed since birth, our dairy cows produce milk without the use of growth hormones, steroids, or additives. When you drink Green Pastures Dairy, you are drinking a silky milk from farms that care the most about our environment. With our methane-capture technology on all of our farms, we can remove carbon from the atmosphere when it is emitted from our cows. We can then offset the cost of raising cows by selling that harvested methane to utility companies. In turn, we can afford to raise more cows and feed them quality ingredients. That's just another reason to feel good when you purchase Green Pastures Dairy.

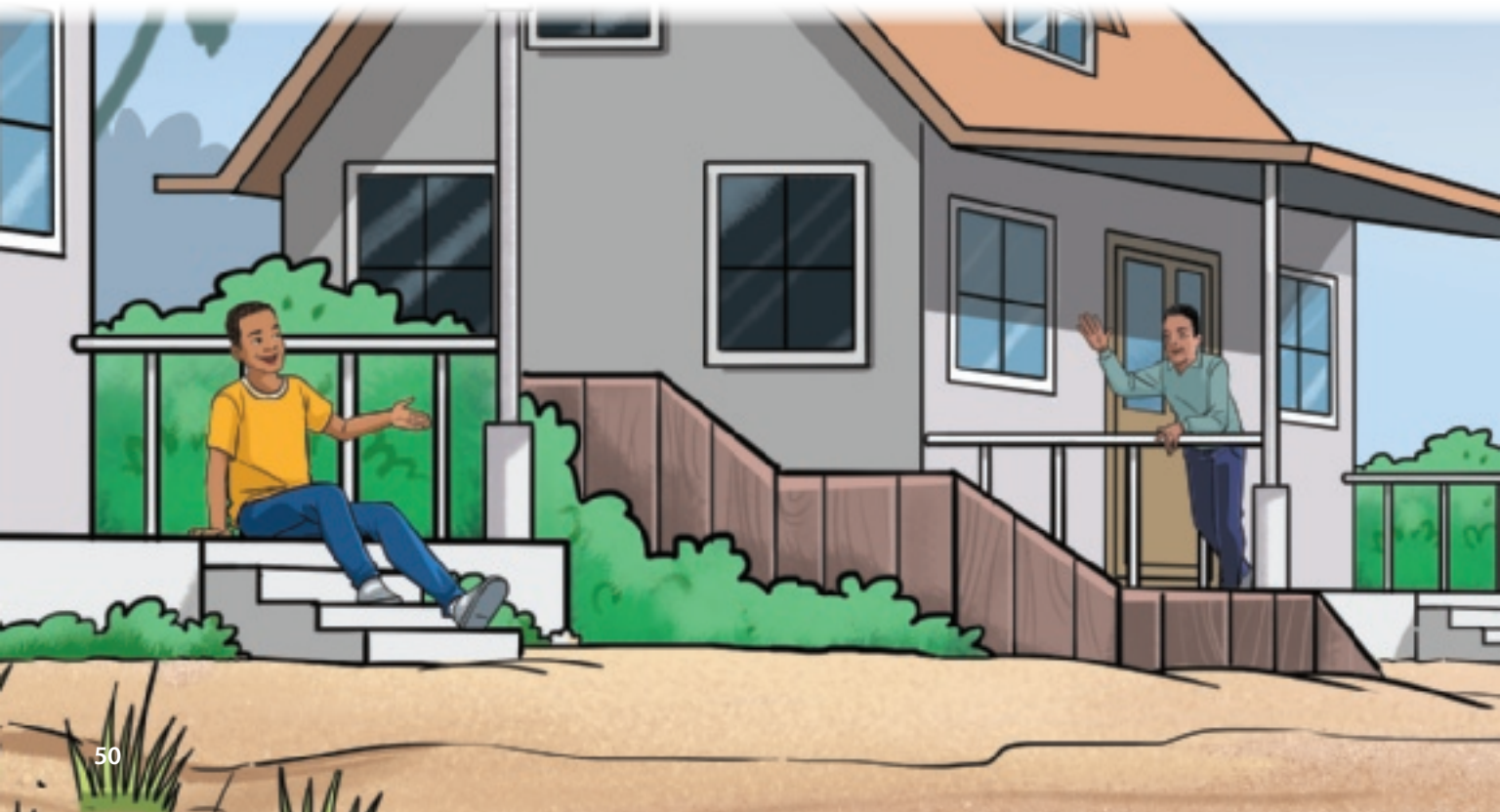
Consensus?

Elijah is back at his grandparents' beach house, eight years later. He's spending the summer with his grandma Edie. Grandpa Bill has passed away. Elijah is now a college student studying marine science. He's studying how oysters lay down their shells and what the acidification of the ocean could mean for oyster stocks on the East Coast and elsewhere. His grandparents' oyster farm is a valuable source of data for his research, which Elijah hopes to continue in graduate school.

"Hey, kiddo! I saw you pull into the driveway last night while I was cleaning fish down on the beach." It's Mike, the neighbor. "How's the research going?"

"Good to see you, Mike! It's going well. Grandma let me set up a few study plots in the farm, and I get to spend the summer here so I can collect data as often as I want."

"That's great. I'm sure Edie loves having you here. It's been tough without Bill. He was such a good friend. I still look over at your porch and expect to see him there." Mike turns away for a moment and uses a forearm to wipe his eyes. Elijah thinks back to the long-running argument that Mike and Bill had about climate change. It never got ugly, and he knows Mike and his grandparents were dear friends. But he wonders if Mike still holds the opinions he had earlier about climate and sea level rise.



Almost as if he can read Elijah's mind, Mike says, "You know, your grandparents had a few solid points."

Elijah isn't sure if Mike is talking about what he was thinking, so he asks, "About what?"

"The changes they'd noticed here. I guess you could say I'm 'warming up' to the idea."

Elijah is surprised but pleased. "What changed your mind? Was it my grandpa?"

"Ha! Well, he did try, didn't he? What finally resonated with me was the level of detail in the IPCC reports. Your grandpa printed them out for me and left them in my mailbox. Hundreds of pages! Must've cost him a ton in printer ink. But I read them. There's just so much detail in there and so many people involved. Thousands of experts in the field. Evidence in so many forms. It swayed me. How could it not?"

"So, you've changed your mind?"

"Well, I still have a lot of questions. I think the the science is very complex, a lot of data gets misinterpreted, a lot of what you read seems very one-sided, on adamantly opposing sides of the question."

"My research is likely going to focus on how oysters will cope with seawater that has a lower pH."

"That's important stuff. I'm sure Edie is super proud of you, and I know Bill was too."

"So, how about you, Mike? You're an engineer, and you're retired. Lots of time on your hands. What are you working on these days?"

"Learning more every day! Talking to everybody I can and trying to listen as much as I talk," Mike replies with a wink and a smile. "How about I take you out on the boat later? The stripers and blues have been biting lately."

"I'm in!"

Glossary

acidification, n. the process or act of containing more acid

basic, adj. describing chemical substances that react with acids to form salts

carbon footprint, n. the amount of greenhouse gas emitted by a specific activity or the activities of a person or group

carbon sink, n. a structure that absorbs more carbon from the atmosphere than it emits

climate change, n. long-term shifts in temperature and weather patterns

climate event, n. an occasion of extreme values of climate indicators such as temperature, precipitation, or wind

combustion, n. the rapid chemical combination of a substance with oxygen, resulting in the production of heat and light; burning

consensus, n. general agreement

dissolved oxygen, n. the amount of oxygen present in water (that is not bound in the water molecules)

emissions, n. the discharge of gases into the atmosphere

erosion, n. the action of gradual removal of surface material

global warming, n. the increase in the overall, average temperature of Earth's atmosphere

greenhouse gas, n. a gas in Earth's atmosphere that traps heat

greenwashing, n. the portrayal of an environmentally responsible public image by individuals or agencies whose actions are of little benefit or environmentally detrimental in actuality

ice core, n. a long rod of ice obtained by drilling through a glacier or ice sheet

logical fallacy, n. a flawed or deceptive argument that can be disproven with reasoning

mitigation, n. the reduction of damage or severity of harm

mold, n. any of several types of fungus that grow fine filaments and often form a layer on damp or decaying material

nonrenewable, adj. not capable of being naturally replaced as quickly as it is used

orbit, n. the elliptical path around something

paleoclimatologist, n. a scientist who studies the climate conditions of Earth's distant past through geologic evidence

pH, n. "potential of hydrogen"; the scale used to measure how acidic or basic a solution is

photosynthetic organisms, n. living things that use sunlight to produce nutrients from carbon dioxide and water

positive feedback loop, n. a process in which the product of a reaction leads to an increase in that reaction

potable, adj. safe to drink

refugee, n. a person who has been forced to leave their home region to escape danger

renewable, adj. capable of being naturally replaced as quickly as it is used

salinity, n. saltiness; the level of dissolved salt content in water

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

sea level, n. the height of the ocean's surface, measured via satellite and observable at shorelines

skepticism, n. doubt about the truth of something

straw man, n. an intentionally misrepresented point in an argument set up because it is easier to dispute than an opponent's real argument

subsidence, n. gradual sinking of an area of land

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