Climate Change

About the Lessons

The five lessons in this unit are designed to introduce students to climate change concepts. Each lesson lasts about 45 minutes.

We recommend teaching the Climate Change Overview lesson first to provide students with background knowledge about the causes and effects of climate change. (If your students are already familiar with these concepts, you can skip this lesson.)

You can then teach one or more of the lessons on specific phenomena:

- Extreme Temperatures
- Extreme Precipitation
- Wildfires and Drought
- Rising Sea Level

Local relevance is key to student engagement with climate change concepts, so we recommend prioritizing lessons about events that affect your community most directly.

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EiE® teamed up with Pear Deck™ to create interactive versions of these lessons. Pear Deck makes it easy for educators to connect with every student by engaging them through discussion and interactive prompts.

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Climate Change Overview

Overview

Students examine data about the causes and effects of climate change. Brief videos clarify terms and concepts. Students then create models of climate change in order to predict additional effects.

A simpler version of this lesson is available in Climate Change, Gr 3-5.

Guiding Question

How and why is Earth's climate changing?

Objectives

Students will be able to

- explain the relationship between weather and climate.
- analyze and interpret information about the causes and consequences of climate change.
- create a model of climate change and use it to make predictions.

Background

The use of coal-powered steam engines in the 1700s began a process known as the Industrial Revolution. As part of this process, over the past several centuries, humans have used increasing amounts of energy from burning coal, oil, and gas. These fuels are called "fossil fuels" because they form from dead organic matter over hundreds of millions of years, just as fossils re traces of organisms from long ago.

Time

- 20 minutes to explore data
- 5 minutes to watch videos
- 20 minutes to create models

Grade Level: 6–8

Vocabulary

- **Climate**
- **Climate Change**
- **Greenhouse Gas**
- **Model**
- **Weather**
- **Weather Patterns**

Standards

NGSS SEP: Analyzing and Interpreting Data. Use graphical displays (e.g., maps, charts, graphs, and/or tables) of large data sets to identify temporal and spatial relationships.

NGSS SEP: Developing and Using Models. Develop and/or revise a model to show the relationships among variables, including those that are not observable but predict observable phenomena.

NGSS MS-ESS3-5.
CCSS.ELA-Literacy.RST.6-8.7.
CCSS.Math.Content.8.SP.A.2.

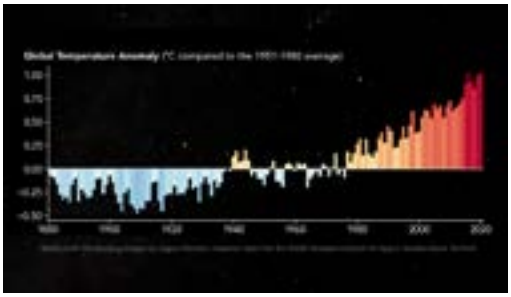
As humans burn fossil fuels to power engines, produce electricity, and engage in industrial processes such as making cement, those fuels release carbon dioxide, methane, and other gases. These gases are also emitted by other human activities, including cutting down forests, raising livestock, and using fertilizers.

Carbon dioxide, methane, and other gases such as nitrous oxide are called "greenhouse gases" because they function like the insulating panes of glass in a greenhouse, trapping heat inside Earth's atmosphere. Sunlight mostly reaches Earth as thermal energy, some of which is absorbed and some of which is radiated back into the atmosphere. Greenhouse gases in the atmosphere reduce the amount of thermal energy that escapes back into space.

An increase in the levels of greenhouse gases in the atmosphere has multiple consequences. The most direct one is an increase in the planet's average temperature, which has risen more than 1°C since the beginning of the Industrial Revolution in the 1700s. This temperature increase has led to a variety of other changes, such as an increase in extreme precipitation, more intense wildfires, and rising sea levels.

Preparation

For this activity, the educator will need the following:



- Video: Climate vs. Weather (0:28)
- Video: Greenhouse Gas (0:32)
- Video: Climate Change Definition (0:31)
- A way to show the videos to students
- Whiteboard or chart paper

For this activity, each group of students will need the following:

- 1 copy of Climate Change Data (English | Spanish)
- 1 or more copies of Climate Change Model (English | Spanish | Answer Key) (optional)
- Pens or pencils

Access the interactive version of this lesson, powered by Pear Deck™

EiE Connections

Learn more about the Engineering Design Process in the EiE Video Library.

Continue your classroom activities with this unit:

Engineering Everywhere®

- Engineering Remote Sensing Devices

Museum of Science Connections

Watch the video What Can Arctic Ice Teach Us About Climate History? (English | Spanish) or teach the associated lesson.

Listen to the Pulsar podcast episode "Climate Change Resilience in Boston."

Family Connections

Continue the learning at home with EiE Families and STEM Events or Family STEM Activities from MOS at Home.

Credits

MOS at School programs are offered at no cost, thanks to the generosity of the Akamai Foundation, Bloomberg Philanthropies, BNY Mellon, Gordon Foundation, Hood, Lincoln and Therese Filene Foundation, Lowell Institute, Mabel Louise Riley Foundation, MathWorks, Richard K. Lubin Family Foundation, Sanofi, and TJX.

Activity Instructions

These steps offer support for implementing the Climate vs. Weather, Greenhouse Gas, and Climate Change Definition videos and associated activities with students.

If your students are already familiar with the basics of climate change, consider beginning with one of the lessons on Extreme Temperatures, Extreme Precipitation, Wildfires and Drought, or Rising Sea Level.

1. Explain to students that today they will be considering something that is a problem for people and living things: climate change. They will examine evidence to learn more about climate change and to learn about ways to reduce the harm it causes

2. Begin by considering climate. Ask:

> **Q: What do you already know about climate?**
>
> *A: Responses will vary. Students may know that climate refers to the trends in an area's temperatures and conditions over long time scales. They may give examples of different features of climate, such as average temperature or average precipitation, or different climates around the world, such as tropical, dry, temperate, or polar.*

Record students' ideas on a whiteboard or chart paper.

Climate	
• Trends in an area's temperatures and conditions over long time scales • Includes features such as average temperature and average precipitation • Types include tropical, dry, temperate, and polar	

3. Have students think about the difference between climate and weather. Ask

> **Q: What is the difference between climate and weather?**
>
> *A: Responses will vary. Students may know that weather refers to an area's short-term temperatures and conditions, such as air pressure, moisture, and precipitation.*

Record students' ideas on a whiteboard or chart paper.

Climate	Weather
• Trends in an area's temperatures and conditions over long time scales • Includes features such as average temperature and average precipitation • Types include tropical, dry, temperate, and polar	• An area's short-term temperatures and conditions • Includes features such as temperature and precipitation • Types include sunny, cloudy, rainy, and snowy

To clarify the difference between weather and climate, you can show the video Climate vs. Weather (0:28).

watch video

4. Explain that recently, climates around the world have been changing from what they used to be. Sometimes, these changes mean there are more extreme weather events. Ask:

> **Q: What are some changes in climate you have learned about or experienced?**
>
> *A: Accept all responses. Possible responses include higher average temperatures and more extreme high and low temperatures, increased intensity of precipitation events, such as rainstorms, hurricanes, blizzards, and floods, as well as increased intensity of droughts and extent of wildfires, reductions in glaciers and sea ice, and increasing sea levels.*

Activity Tip

Local relevance is key to student engagement with climate change concepts, so discussing extreme weather events where you live is a powerful way to get students interested. Indeed, a single recent local extreme weather event can serve as an anchoring phenomenon for your discussion of climate change. However, students may have experienced loss in such events. Think carefully about how to guide the discussion in a way that is respectful of and sensitive to students' experiences.

Record students' ideas on a whiteboard or chart paper.

Climate	Weather
• Trends in an area's temperatures and conditions over long time scales • Includes features such as average temperature and average precipitation • Types include tropical, dry, temperate, and polar	• An area's short-term temperatures and conditions • Includes features such as temperature and precipitation • Types include sunny, cloudy, rainy, and snowy
Climate Change	
• Higher average temperatures, more extreme high and low temperatures • Increased intensity of precipitation events (rainstorms, hurricanes, blizzards) • Increased intensity of drought and wildfires • Melting ice, rising sea levels	

5. Tell students that today, they will be working to make a model of climate change. Their model will help them discover ways to protect people and other living things from climate change in the future.

6. Tell students that they will start by exploring different sets of data to look for patterns. Have students work in groups and provide each group with a copy of *Climate Change Data* (English | Spanish). Give students 10–15 minutes to discuss the data and the patterns they find.

Activity Tips

You can have each group examine one plot, several plots, or all ten plots. Choose the approach that is most appropriate for your students.

Note that the Sea Level Rise plot is cumulative, meaning it shows the total rise since 1900. For example, global average sea level was about 10 centimeters higher in 1970 than in 1900.

Much of the information in the plots comes from the Environmental Protection Agency (EPA), the National Aeronautics and Space Administration (NASA), the National Oceanic and Atmospheric Administration (NOAA), and the United Nations (UN). You can use information from these organizations to create additional plots on topics relevant to your students, such as precipitation, flooding, or drought.

Material Tips

Climate Change Data contains ten scatter plots. Each plot focuses on a particular cause or consequence of climate change. Before having students examine the plots, you may want to review how to read a scatter plot or demonstrate with an example. As appropriate, you can have students draw approximate lines of best fit on the plots.

For plots of length, area, and temperature, metric units appear on the left side and imperial units on the right. Have your students focus on whichever unit type is appropriate.

7. Once students have had a chance to examine the data, discuss their findings as a class. Ask:

Q: What patterns did you notice in these plots?

A: Responses will vary. Possible responses include decreases in forests and ice and increases in power plants, cows, cars, carbon dioxide and methane in the atmosphere, the average temperature of Earth's surface, sea level, and the area burned by wildfires.

Activity Tips

Activity Tips

Students may wonder how we know so much about the climate long ago. One valuable type of evidence is ice cores, which are cross-sections of ice cut from a glacier. Each layer of ice corresponds to a year in the past, and scientists can study the air trapped in those layers to learn what the atmosphere was like hundreds, thousands, or even hundreds of thousands of years ago. If students want to learn more about this evidence, show the video What Can Arctic Ice Teach Us About Climate History? (2:30) (English | Spanish) or teach the associated lesson.

For this lesson, the qualitative trends in the plots are more important than the specific numbers. However, you can use the plots to practice grade-appropriate math skills by posing questions such as "Is the function describing this plot linear or nonlinear?" or "What linear function would describe this line of best fit?"

8. Students may be unfamiliar with the heat-trapping properties of greenhouse gases. Show the video Greenhouse Gas (0:32) to introduce students to greenhouse gases, gases in the atmosphere that trap heat from the Sun and prevent it from radiating back out into space. As necessary, explain that burning fossil fuels (mentioned at 0:26) often releases carbon dioxide, while cow farts (mentioned at 0:30) release methane.

Activity Tips

Activity Tip

Students may have misconceptions about the causes of climate change; provide information as necessary to help correct them. Below are details about three of the most common misconceptions:

1) Climate change has natural causes. While some natural processes release greenhouse gases, they are balanced by other processes that absorb the gases. For example, during the carbon cycle, carbon dioxide is released into the atmosphere as part of cellular respiration and then incorporated into sugars as part of photosynthesis. As a result, the carbon cycle was largely balanced for the past 10,000 years, resulting in a stable climate. Human activity during the past few centuries has upset this balance by releasing far more greenhouse gases than have been reabsorbed, leading to the increased retention of heat from sunlight.

2) Climate change is caused by heat from machines. Human machines that burn fossil fuels do release some heat, and, in addition, the greenhouse gases released by this burning trap additional heat over decades or centuries in the atmosphere. However, the latter effect is tens of thousands of times larger than the former, meaning that heat from the greenhouse effect is a far, far more significant cause of climate change than heat from fossil fuel combustion.

3) The hole in the ozone layer causes climate change. In the early 1900s, humans began to use chlorofluorocarbons (CFCs). These chemicals are nontoxic and inert on Earth's surface, making them seemingly ideal choices for tasks such as refrigeration and air conditioning. However, when they reach the upper atmosphere, CFCs provoke a chemical reaction that destroys ozone molecules. This destruction led to a significant thinning of the ozone layer over Antarctica, which was confirmed in 1985. Since the ozone layer minimizes the amount of harmful UV radiation that reaches Earth's surface, the thinning presented a major threat to living things. The 1987 Montreal Protocol reduced and ultimately banned the production of CFCs. In the decades since its adoption, the ozone layer has stopped thinning.

Although the depletion of the ozone layer and climate change are both caused by human activities and both result in threats to living things, the two processes are not the same. The ozone hole does not "let in" more heat from the Sun; instead, greenhouse gases in the atmosphere trap more of the heat from sunlight.

watch video

9. If students need more time, give them one or two more minutes to examine the plots. Then ask:

> **Q: Using the information in the video and what you already know, how do you think the patterns in the plots might be connected to each other?**
>
> *A: Responses will vary. A possible response is that human activities such as cutting down forests, burning coal for electricity, raising cows, and driving cars release gases such as carbon dioxide and methane, increasing the amount of those gases in the atmosphere. Those gases trap heat from sunlight, increasing the temperature of Earth's surface. The warmer temperature melts ice, raises sea levels, and causes more land to be burned by fires.*

10. Explain that students have been describing the causes and effects of **climate change**, the changes from the rapid rise in global temperatures seen in the last 150 years. Show the video *Climate Change Definition* (0:31) to further define the term.

watch video

As necessary, explain that the Industrial Revolution (mentioned at 0:18) is the period when humans began burning fuels such as coal, oil, and gas to power machines. Ask:

> **Q: In the video, the narrator says that "Earth is getting hotter faster than at any point in its several-billion-year history. When you're setting records, that's not the kind you want to set." Why are high temperatures not a good thing?**
>
> *A: Accept all responses. A possible response is that organisms maintain homeostasis, a stable set of internal conditions that allow physiological processes to occur most effectively. Keeping the inside of the body within an optimum temperature range is one component of homeostasis. Organisms tend to live in habitats where they can stay in their optimum temperature ranges. For example, animals that live in cold places tend to have adaptations such as fur or blubber to keep them warm. If organisms are in unusually hot conditions, they can have trouble maintaining homeostasis, making it difficult for their bodies to keep functioning. Some organisms also rely on habitat features, such as rivers and ice sheets, that exist only within certain temperature ranges, and high temperatures can cause dangerous events, such as extreme storms and wildfires.*

11. Explain to students that to protect people and other living things from climate change, we need to understand and be able to predict the things that cause it and the dangers it produces. One way to do this is to make a **model,** a representation of an object, system, or process.

12. Have each group decide what type of model they want to make. Possible types of modelling include writing a description, drawing a diagram, or performing a physical activity. If it is useful, you can give each group one or more copies of Climate Change Model (English | Spanish).

13. Give groups time to develop their models. Students can incorporate data from the plots as well as information recorded on the weather and climate chart from earlier in the lesson.
14. Discuss students' models. Ask:

Q: What method of representation did you use for your model?

A: Accept all responses. Students may have written a description, drawn pictures, created a diagram or flowchart, or taken some other approach.

Q: How does your model explain the changes we talked about? What other effects can it predict from climate change?

A: Responses will vary. Students may be able to predict how a warmer climate leads to changes in the water cycle, which can cause droughts, extreme precipitation, and floods.

Q: Can your model predict any other causes of climate change?

A: Responses will vary. Students may be able to predict that any activity that releases greenhouse gases is a cause of climate change. These activities include burning fuel to heat buildings, to move vehicles, and to power other machines. People also burn fossil fuels to produce the intense heat needed to manufacture certain materials, such as cement.

Activity Tips

Students' models may show feedback loops: chains of events in which the effects of climate change become causes of further climate change. For example, when people burn forests to clear land, this burning releases carbon dioxide. This carbon dioxide contributes to trapping thermal energy from sunlight, raising Earth's average surface temperature. This increased temperature contributes to more widespread fires, which, by burning trees, release more carbon dioxide, continuing the cycle. If students are interested, you can discuss such loops in their models and attempt to think of others. (For example, melting sea ice leads to the absorption of more heat by dark seawater, melting more ice; melting permafrost releases methane, which ultimately leads to more heat that melts more permafrost).

If time permits, allow students to add to or revise their models using information from the class discussion.

15. Conclude by thinking about the benefits of knowing about climate change. Ask:

Q: How can we use our models to help protect people and other living things from climate change?

A: Responses will vary. A possible response is that the models can predict changes people should make to reduce the intensity of climate change in the future (for example, burning fewer fossil fuels). Another response is that the models can predict effects of climate change that people should prepare for (for example, building structures that can withstand extreme temperatures, extreme precipitation, or sea level rise).

Activity Tips

Human action that limits the concentration of greenhouse gases in the atmosphere is known as *mitigation*, while human action that limits the harm caused by climate change is known as adaptation. Students can explore both concepts in detail in the Extreme Temperatures, Extreme Precipitation, Wildfires and Drought, and Rising Sea Level lessons.

Extreme Temperatures

Overview

Students examine temperature data to draw conclusions about the changes in Earth's climate since the mid-20th century. A video introduction discusses how greenhouse gas emissions have caused more extreme temperatures. Students then explore their local environments to suggest methods for mitigation of greenhouse gas emissions and adaptation to extreme temperatures.

A simpler version of this lesson is available in *Climate Change, Gr 3-5.*

Guiding Question

How and why have temperatures changed since the mid-20th century, and how should we respond?

Objectives

Students will be able to

- calculate and interpret average temperature data from the 1960s and the 2010s.
- explain how human-caused greenhouse gas emissions have caused the rise in global temperatures over the past century.
- explain how increased average temperatures can cause both high and low extreme temperatures.
- propose local solutions for climate change mitigation and adaptation to extreme temperatures.

Background

Humans cause climate change in several ways. Some of the most significant include burning fossil fuels to power engines, generate electricity, heat buildings, and produce materials such as cement; cutting down forests; raising livestock; and using fertilizers.

Time

- 20 minutes to explore data
- 5 minutes to watch video
- 20 minutes to suggest solutions

Grade Level: 6–8

Vocabulary

- **Adaptation**
- **Average**
- **Climate**
- **Climate Change**
- **Greenhouse Gas**
- **Median**
- **Mitigation**
- **Remote Sensing**
- **Weather**
- **Weather Patterns**

Standards

NGSS SEP: Analyzing and Interpreting Data. Apply concepts of statistics and probability (including mean, median, mode, and variability) to analyze and characterize data, using digital tools when feasible.

NGSS MS-ESS3-5. Ask questions to clarify evidence of the factors that have caused the rise in global temperatures over the past century.

NGSS MS-ESS3-3.

NGSS CCC: Patterns.

CCSS.Math.Content.6.SP.B.5.C.

All of these activities release gases such as carbon dioxide, methane, and nitrous oxide. When sunlight reaches Earth, much of the energy is converted to thermal energy. Some of the energy is absorbed and some is radiated back into the atmosphere. Carbon dioxide, methane, and nitrous oxide in the atmosphere reduce the amount of thermal energy that escapes back into space. These gases are called "greenhouse gases" because they function like the insulating panes of glass in a greenhouse.

An increase in the levels of greenhouse gases in the atmosphere has multiple consequences. The most direct one is an increase in the planet's average temperature, which has risen more than 1°C since the beginning of the Industrial Revolution in the 1700s. By destabilizing climate systems such as oceanic and atmospheric currents, this overall increase can cause both high and low extreme temperatures.

Preparation

For this activity, the educator will need the following:

- Video: *Sensing Our Climate: Extreme Temperatures* (4:30) (English | Spanish)
- A way to show the video to students
- Whiteboard or chart paper

For this activity, each student will need the following:

- 1 copy of *City Temperatures* (English | Spanish | Answer Key)
- 1 copy of *Mitigation Strategies* (English | Spanish | Answer Key)
- 1 copy of *Adaptation Strategies* (English | Spanish | Answer Key)
- 1 pen or pencil

Access the interactive version of this lesson, powered by Pear Deck™

EiE Connections

Learn more about the Engineering Design Process in the EiE Video Library.

Continue your classroom activities with these units:

Engineering Everywhere®

- Engineering Insulated Homes
-
- Engineering Remote Sensing Devices

Museum of Science Connections

Listen to the Pulsar podcast episode "Measuring Urban Heat Islands."

Check out the Museum's Wicked Hot Boston and Wicked Hot Mystic citizen science initiatives.

Family Connections

Continue the engineering at home with these activities:

- Building in the Heat
- PLANETS: Remote Sensing Investigation

Credits

MOS at School programs are offered at no cost, thanks to the generosity of the Akamai Foundation, Bloomberg Philanthropies, BNY Mellon, Gordon Foundation, Hood, Lincoln and Therese Filene Foundation, Lowell Institute, Mabel Louise Riley Foundation, MathWorks, Richard K. Lubin Family Foundation, Sanofi, and TJX.

Activity Instructions

These steps offer support for implementing the Sensing Our Climate: Extreme Temperatures video and associated activities with students.

If your students need additional background about the basics of climate change, consider teaching the Climate Change Overview lesson first.

1. Explain to students that today they will be thinking about something they experience every day: temperature. Ask:

> **Q: What is temperature?**
>
> *A: Accept all responses. Students may know that temperature is a measure of the average kinetic energy of the particles in matter. Humans experience temperature as how hot or cold something is or how hot or cold it is outside. Temperature is one part of* ***weather****, the short-term atmospheric conditions in an area, along with factors such as pressure and precipitation.*

Material Tips

If your students have already learned about temperature, show or describe some of the work they did or phenomena they studied in order to activate their prior knowledge.

Q: Why is being at the right temperature important for people and other living things?

A: Accept all responses. A possible response is that organisms maintain homeostasis, a stable set of internal conditions that allow physiological processes to occur most effectively. Keeping the inside of the body within an optimum temperature range is one component of homeostasis.
Organisms tend to live in habitats where they can stay in their optimum temperature ranges; for example, animals that live in cold places tend to have adaptations such as fur or blubber to keep them warm. If organisms are in very hot or very cold conditions, they can have trouble maintaining homeostasis, making it difficult for their bodies to keep functioning. Some organisms also rely on habitat features, such as rivers and ice sheets, that only exist at certain temperature ranges.

Activity Tips

Consider providing your students with examples of local organisms that require a specific temperature range. Have them share observations they have made about those organisms when temperatures are hotter or colder than their ideal ranges. (For example, what happens to trees when it is very hot outside?)

2. Explain to students that while the temperature changes depending on the time of day and time of year, any given location will have an average temperature. Ask:

Q: What is an average?

*A: Students may know that an **average**, or mean, is a measure of center in a set of numerical data, computed by adding the values in a list and then dividing by the number of values in the list. Explain that scientists can measure average temperatures in different ways, including during the daytime, during the nighttime, at different times of year, and from one year to the next.*

Activity Tips

If your students are familiar with other measures of center in numerical data, such as median, you can discuss the definition of those terms as well.

Q: What do you know about climate?

A: Accept all responses. A possible response is that climate is the usual temperature and weather conditions in a place. Average temperature is one factor used in describing climate.

Q: What are some places with warm climates?

A: Responses will vary. Possible responses include tropical places, places near the equator, or specific regions, states, or cities.

Q: What are some places with cold climates?

A: Responses will vary. Possible responses include places in the Arctic and Antarctic, places far north or south, high-elevation places, or specific regions, states, or cities.

3. Tell students that they are going to do something that scientists who study climate do: analyze how the average temperatures in different places have changed over time. Distribute *City Temperatures* (English | Spanish) to students. Explain that they will be calculating the average temperature for different cities in the 1960s and 2010s. They will then look for changes in the average temperature between the two decades. The information they find could be important for protecting people and other living things.

Activity Tips

The temperature data set comes in both Fahrenheit and Celsius. Use the temperature scale that is appropriate for your students.

Local relevance is key to student engagement with climate change concepts. Before the lesson, look up the average temperatures in each year of the 1960s and 2010s for one or two local areas. (For the United States, easy-to-access data is available from the National Oceanic and Atmospheric Administration Regional Climate Centers.) Add those areas and temperatures to the bottom of City Temperatures and have students calculate temperature changes for them as well. Students may also share their prior knowledge about climate and weather in those areas.

Students may have experienced loss in extreme weather events. Think carefully about how to guide the discussion in a way that is respectful of and sensitive to students' experiences.

This lesson uses data from the 1960s because students may know people (such as family members or teachers) who were alive at that time, making the comparison to the present more engaging. Although this range does not capture the entirety of human greenhouse gas emissions, it includes most of them: approximately three-quarters of all human greenhouse gas emissions before 2020 occurred in the period after 1960.

4. Give students time to calculate temperature averages and changes. You can allow them to work individually, in groups, or in some combination of the two. (For example, you can have students calculate changes on their own and then discuss their results in groups.)

Activity Tips

Depending on your students' familiarity with calculating averages, it may be useful to start by calculating the average temperatures for one city together as a class.

If your time is limited, you can shorten the activity by assigning particular cities to particular students or groups, then having them share their findings with the class.

For an additional challenge once they are finished with the initial calculations, students can calculate measures of center for all cities together. For example, they can calculate the average or median temperature for all cities in the 1960s or the 2010s, or the average or median temperature change for all cities.

5. Have students interpret their findings. Ask:

Q: What do you notice about the temperature changes?

A: Responses will vary. A possible response is that all the temperature changes are positive.

Q: What do the temperature changes tell us about temperature change in these cities?

A: The fact the temperature changes are positive means that the cities listed got warmer between the 1960s and the 2010s.

Material Tips

Displaying information in various formats can help scientists interpret it. Consider having students graph some of the data by hand or digitally in order to discover patterns. If time permits, have them draw a line of best fit for each city in each decade, making observations about both year-to-year variations and overall trends.

6. Explain to students that the change was not just in these cities. The entire planet got warmer between 1960 and 2020, part of a process called **climate change**. Ask:

Q: Do you have any ideas about why Earth might have higher temperatures now than it did in the 1960s?

A: Responses will vary. Students may know that the atmosphere now contains more greenhouse gases, gases that trap heat from the Sun and prevent it from radiating back out into space. They may have heard of different kinds of greenhouse gases, including carbon dioxide, methane, and nitrous oxide.

Q: What are some ways these higher temperatures might be affecting people or other living things?

A: Responses will vary. Possible responses include that people can get sick if it is too hot, and that other living things might no longer have the right habitats to live in.

Activity Tips

More information on the sources and effects of greenhouse gases is available in the Climate Change Overview lesson. More information about other consequences of the increase in global average temperature is available in the Extreme Precipitation, Wildfires and Drought, and Rising Sea Level lessons.

An increase in atmospheric greenhouse gases is only one reason cities became hotter between the 1960s and the 2010s. The urban heat island effect is another. Reduced plant cover and widespread dark, impermeable surfaces cause cities to trap thermal energy and restrict water flow, making them warmer than surrounding suburban and rural areas. Often, poor people and people of color face the greatest exposure to the urban heat island effect. This is an example of environmental injustice, a situation in which disadvantaged groups suffer the greatest harms from environmental conditions. If time permits, discuss this concept with students or play the video Redlining and Rising Temperatures: The Inequalities of Extreme Heat (English | Spanish). Have students consider other situations in which environmental injustice occurs and possible ways to combat it.

7. Tell students that although greenhouse gases increase Earth's overall average temperature, they can cause other changes to temperatures at specific places and times. Play the video Sensing Our Climate: Extreme Temperatures (4:30).

watch video

Discuss the video. Ask:

Q: What else did you learn about temperature changes from the video?

*A: Responses will vary. Possible responses include that climate change can also cause extreme cold temperatures and that scientists can use **remote sensing**, the science of scanning Earth from a distance using technology like satellites and high-flying airplanes, to gather information about climate change.*

Q: Do you notice any extreme temperatures in the data we explored?

A: Responses will vary. Students may notice that although the 2010s were warm, the years 2013 and 2014 were unusually cold in many cities. As necessary, explain that the extreme cold temperatures in those years were due in part to the disruption of the polar vortex, one of the phenomena described in the video.

Q: What does the video say about how humans can respond to climate change?

A: Humans can use satellites to predict future changes, and they can invent new technologies, such as electric cars, that do not release greenhouse gases.

8. Explain that electric cars and remote sensing are examples of strategies for responding to climate change. Mitigation is human action that limits the concentration of greenhouse gases in the atmosphere, such as using electric cars instead of cars that burn gas. Adaptation is human action that limits the harm caused by climate change, such as predicting what areas will get hotter or colder and putting in air conditioning or heaters so people can stay safe.

On a whiteboard or chart paper, make a table with the headings "Mitigation" and "Adaptation." Have students brainstorm other examples of each strategy and add them to the chart.

Mitigation *human action that limits the concentration of greenhouse gases in the atmosphere*	**Adaptation** *human action that limits the harm caused by climate change*
• Using electric cars that do not burn fossil fuels	• Putting in air conditioning or heaters

Activity Tips

To avoid confusion, you can explain to students that mitigation and adaptation have different definitions outside the context of climate change. Students may be familiar with other uses of the terms; for example, in biology, adaptation means "a characteristic that allows a living thing to survive in its environment."

9. Tell students that while it can be hard to protect other parts of the country or the world from climate change, there's a lot they can do to protect the people, animals, plants, and environment around them. Today, they will suggest ideas for mitigation and adaptation in their community. Distribute *Mitigation Strategies* (English | Spanish) and explain that they will use it to record sources of greenhouse gas emissions at or caused by their school. Distribute *Adaptation Strategies* (English | Spanish) and explain that they will use it to record ways that their school might be affected by extreme temperatures.

Activity Tips

Depending on time, your school environment, and other lessons you have already completed, you may choose to focus only on mitigation or adaptation. (The mitigation activity in this lesson also appears in the Extreme Precipitation, Wildfires and Drought, and Rising Sea Level lessons.) Distribute only the appropriate sheet to students and use only the relevant discussion questions later in the activity.

If your in-class time is limited, students can complete the investigation and brainstorming of mitigation and adaptation strategies without leaving the classroom, or they can do so outside of class time.

10. Travel around the school and school grounds; possible places to visit include a cafeteria, heating or cooling equipment, dumpsters or other waste disposal, a garden or other green space, and vehicles or parking. Have students work individually or in small groups to record sources of greenhouse gases on the left side of *Mitigation Strategies* and vulnerabilities to extreme temperatures on the left side of *Adaptation Strategies*. Draw student attention to relevant features of the school environment as necessary.

Activity Tips

Although mitigation is often discussed in terms of reducing the sources that emit greenhouse gases into the atmosphere, enhancing the sinks that absorb greenhouse gases from the atmosphere is also a mitigation strategy. Examples of important sinks include the ocean and plants. It may be appropriate to discuss the idea of greenhouse gas sinks with students (or they may bring it up themselves), especially if your school grounds contain plants.

It may benefit student understanding to distinguish between direct and indirect greenhouse gas emissions. In the case of a school, direct emissions are those that happen on the school grounds, such as burning fuels for heat or in the engine of an idling school bus. Indirect emissions happen off the school grounds, such as at a power plant, in a factory, at a landfill, or on a farm, but nevertheless occur for the sake of the school. Students can research locations that are responsible for your school's indirect emissions; in some cases, those locations may be in another city, state, or country!

As you travel around the school, it may also be appropriate for students to ask individuals (other students, teachers, workers, and administrators) about their knowledge of the school's greenhouse gas emissions and vulnerability to extreme temperatures. Make sure to arrange any interviews ahead of time. You could also have individuals come to visit your classroom.

11. Return to the classroom. In small groups or as a class, have students share the greenhouse gas sources they recorded on Mitigation Strategies. Ask:

> **Q: What sources of greenhouse gases did you notice?**
>
> *A: Responses will vary. Possible responses include vehicles, such as school buses or garbage trucks; devices that use electricity, such as lights or air conditioners; objects whose manufacture releases greenhouse gases, such as paper or cement; food whose production releases greenhouse gases, such as beef and milk; garbage, which can release greenhouse gases in a landfill; heating devices, such as furnaces; and the removal of plants or green space.*

12. Explain that students can use their knowledge about climate change to plan ways to reduce the school's greenhouse gas emissions. Ask:

> **Q: What changes can we make here to mitigate climate change?**
>
> *A: Responses will vary. Possible responses include reducing activities that produce greenhouse gases (such as idling cars outside the school), making activities more efficient (such as using efficient light bulbs), and doing them in ways that do not require fossil fuels (such as using cars and school buses powered by electricity from a non-carbon source).*

Have students fill in the right column of Mitigation Strategies with the ideas they discuss.

13. Explain that although mitigation is extremely important for reducing the future effects of climate change, some effects, such as extreme temperatures, are already happening. In small groups or as a class, have students share the ways that the school might be affected by extreme temperatures that they recorded on Adaptation Strategies. Ask:

> **Q: How might our school be affected by extreme temperatures?**
>
> *A: Responses will vary. Possible responses include being too hot or cold inside, having pipes freeze and burst, losing electricity because wires are affected by extreme heat or cold, and having plants or animals die.*

14. Explain that students can use their knowledge about climate change to plan ways to adapt the school for extreme temperatures. Ask:

Q: How could our school adapt to extreme temperatures?

A: Responses will vary. Possible responses include planting trees and other plants around the school (or on its roof), making sure the school is well-insulated, reducing the amount of dark pavement around the school, ensuring the school has appropriate heaters or air conditioning, ensuring the school has a backup source of electricity (ideally not from burning fossil fuels), getting a weather forecast each day, checking on school animals in extreme temperatures, and setting up cooling stations with water on hot days.

Have students fill in the right column of Adaptation Strategies with the ideas they discuss.

15. Discuss how to put these ideas into action. Ask:

Q: Now that we have brainstormed ideas for mitigation and adaptation at our school, how can we put these ideas into action?

A: Responses will vary. Some actions, such as reducing paper and electricity use, can be implemented in your classroom (and encouraged in other classrooms). Other ideas may need to be implemented by the school administration.

Q: Where else could you use these strategies to mitigate and adapt to climate change?

A: Responses will vary. Possible responses include at home and at local community organizations. Encourage students to investigate the specific circumstances in those places and share their knowledge about ways to mitigate and adapt to climate change.

Activity Tips

Mitigation and adaptation strategies are related in several ways. The more effectively humans mitigate greenhouse gas emissions in the near term, the less adaptation we will need in the long term. Although institutions must sometimes choose between devoting resources to mitigation and to adaptation, certain strategies contribute to both goals. For example, insulating buildings reduces their vulnerability to extreme temperatures (adaptation) and means fewer fossil fuels are required to heat or cool them (mitigation).

16. Q: How and why have temperatures changed since the mid-20th century, and how should we respond?

> **Q: How and why have temperatures changed since the mid-20th century, and how should we respond?**
>
> *A: Temperatures have changed because humans have put more greenhouse gases into the atmosphere. These gases trap heat, increasing the average temperature of the planet and causing both high and low temperature extremes. We can respond by reducing how many greenhouse gases are emitted and by adapting to protect ourselves, other living things, and the environment from more extreme temperatures.*

Extension Activity

Use the following activity after the lesson to extend student mastery of this Grades 6–8 Science and Engineering Practice.

Constructing Explanations and Designing Solutions.

- Undertake a design project, engaging in the design cycle, to construct and/or implement a solution that meets specific design criteria and constraints.

In the days, weeks, or months following this lesson, you can extend student understanding and engagement by working to implement one or more of the mitigation or adaptation ideas generated by the class.

Many of the changes needed to mitigate and adapt to climate change cannot be effectively implemented by individuals working alone. Rather, they require collective action at the local, state, national, and international levels. Likewise, there may be some changes that students in your class cannot implement without the support of school administration. Have students consider how they can advocate for those changes. For example, students may write letters, meet with school officials, or organize an event. It may be useful for students to gather information about other benefits of the proposed strategy; for example, eliminating direct sources of greenhouse gas emissions often improves air quality.

Consider collecting data both before and after a change is implemented to understand its effects and whether it should be replicated elsewhere. For example, you could collect data about the number and types of vehicles idling outside the school both before and after the implementation of a no-idling policy, then calculate the approximate reduction in greenhouse gas emissions as a result of the change.

Extreme Precipitation

Overview

Students examine precipitation data to draw conclusions about the changes in Earth's climate since the mid-20th century. A video introduction discusses how increased temperatures have caused more extreme precipitation. Students then explore their local environments to suggest methods for mitigation of greenhouse gas emissions and adaptation to extreme precipitation.

A simpler version of this lesson is available in *Climate Change*, Gr 3-5.

Guiding Question

How and why have precipitation patterns changed since the mid-20th century, and how should we respond?

Objectives

Students will be able to

- calculate and interpret average precipitation data from the 1960s and the 2010s.
- explain how human-caused greenhouse gas emissions have caused an increase in global precipitation over the past century.
- explain how increased average temperatures can cause both rainstorms and snowstorms.
- propose local solutions for climate change mitigation and adaptation to extreme precipitation.

Background

Humans cause climate change in several ways. Some of the most significant include burning fossil fuels to power engines, generate electricity, heat buildings, and produce materials such as cement; cutting down forests; raising livestock; and using fertilizers.

Time

- 20 minutes to explore data
- 5 minutes to watch video
- 20 minutes to suggest solutions

Grade Level: 6–8

Vocabulary

- **Adaptation**
- **Climate**
- **Climate Change**
- **Greenhouse Gas**
- **Mitigation**
- **Precipitation**
- **Remote Sensing**
- **Weather**
- **Weather Patterns**

Standards

NGSS SEP: **Analyzing and Interpreting Data.** Apply concepts of statistics and probability (including mean, median, mode, and variability) to analyze and characterize data, using digital tools when feasible.

NGSS MS-ESS3-5. Ask questions to clarify evidence of the factors that have caused the rise in global temperatures over the past century.

NGSS MS-ESS3-3.

NGSS CCC: Patterns.

CCSS.Math.Content.6.SP.B.5.C.

All of these activities release gases such as carbon dioxide, methane, and nitrous oxide. When sunlight reaches Earth, much of the energy is converted to thermal energy. Some of the energy is absorbed and some is radiated back into the atmosphere. Carbon dioxide, methane, and nitrous oxide in the atmosphere reduce the amount of thermal energy that escapes back into space. These gases are called "greenhouse gases" because they function like the insulating panes of glass in a greenhouse.

An increase in the levels of greenhouse gases in the atmosphere has multiple consequences. The most direct one is an increase in the planet's average temperature, which has risen more than 1°C since the beginning of the Industrial Revolution in the 1700s. As the ocean warms, more moisture evaporates, leading to larger and more energetic storms such as hurricanes and blizzards. Many of the world's regions have experienced an increase in heavy precipitation since the mid-20th century as a result of this phenomenon.

Preparation

For this activity, the educator will need the following:

- Video: *Sensing Our Climate: Extreme Precipitation* (3:52) (English | Spanish)
- A way to show the video to students
- Whiteboard or chart paper

For this activity, each student will need the following:

- 1 copy of *City Precipitation* (English | Spanish | Answer Key)
- 1 copy of *Mitigation Strategies* (English | Spanish | Answer Key)
- 1 copy of *Adaptation Strategies* (English | Spanish | Answer Key)
- 1 pen or pencil

Access the interactive version of this lesson, powered by Pear Deck™

EiE Connections

Learn more about the Engineering Design Process in the EiE Video Library.

Continue your classroom activities with these units:

Engineering Everywhere®

- Engineering Remote Sensing Devices
- Engineering an Urban Landscape

Museum of Science Connections

Listen to the Pulsar podcast episode "Climate Change Resilience in Boston."

Family Connections

Continue the engineering at home with these activities:

- Engineer a Floating House
-
- PLANETS: Remote Sensing Investigation

Credits

MOS at School programs are offered at no cost, thanks to the generosity of the Akamai Foundation, Bloomberg Philanthropies, BNY Mellon, Gordon Foundation, Hood, Lincoln and Therese Filene Foundation, Lowell Institute, Mabel Louise Riley Foundation, MathWorks, Richard K. Lubin Family Foundation, Sanofi, and TJX.

Activity Instructions

These steps offer support for implementing the Sensing Our Climate: Extreme Precipitation video and associated activities with students.

If your students need additional background about the basics of climate change, consider teaching the Climate Change Overview lesson first.

1. Explain to students that today they will be thinking about something they have probably experienced before: precipitation. Ask:

Q: What is precipitation?

A: Accept all responses. Students may know that ***precipitation*** *is the phase of the water cycle in which water that has condensed in the atmosphere returns to Earth's surface as rain, snow, sleet, hail, or a related phenomenon. Precipitation is one part of* **weather***, the short-term atmospheric conditions in an area, along with factors such as pressure and temperature.*

Material Tips

If your students have already learned about precipitation, show or describe some of the work they did or phenomena they studied in order to activate their prior knowledge.

Q: Why is getting the right amount of precipitation important for people, other animals, and plants?

A: Accept all responses. A possible response is that living things need water in order to function. For example, producers need water in order to conduct photosynthesis, while humans need it to maintain proper chemical balances throughout their bodies and to regulate their temperature by sweating. Some animals need precipitation so that their habitats have the right features, such as snow on the ground or water in a river. However, too much precipitation, especially over a brief period, can cause habitat destruction through mechanisms such as erosion and flooding.

Activity Tips

Consider providing your students with examples of local organisms that require an amount of precipitation within a specific range. Have them share observations they have made about those organisms when they get too much or too little precipitation. (For example, what happens to trees when there is lots of rain or no rain at all?)

2. Explain to students that while the precipitation changes from day to day and month to month, any given location will have an average amount of precipitation. Ask:

Q: What is an average?

A: Students may know that an average, or mean, is a measure of center in a set of numerical data, computed by adding the values in a list and then dividing by the number of values in the list. Explain that scientists can measure average precipitation in different ways, including per day, at different times of year, and from one year to the next.

Q: What do you know about climate?

A: Accept all responses. A possible response is that climate is the usual temperature and weather conditions in a place. Average precipitation is one factor used in describing climate.

Q: What are some places with wet climates?

A: Responses will vary. Possible responses include tropical places, places near the equator, or specific regions, states, or cities.

3. Tell students that they are going to do something that scientists who study climate do: analyze how the average precipitation in different places has changed over time. Distribute *City Precipitation* (English | Spanish) to students. Explain that they will be calculating the average precipitation for different cities in the 1960s and 2010s. They will then look for changes in the average precipitation between the two decades. The information they find could be important for protecting people and other living things.

Activity Tips

The precipitation data set comes in both centimeters and inches. Use the unit that is appropriate for your students.

Local relevance is key to student engagement with climate change concepts. Before the lesson, look up the total precipitation in each year of the 1960s and 2010s for one or two local areas. (For the United States, easy-to-access data is available from the National Oceanic and Atmospheric Administration Regional Climate Centers.) Add those areas and amounts to the bottom of City Precipitation and have students calculate precipitation changes for them as well. Students may also share their prior knowledge about climate and weather in those areas.

Students may have experienced loss in extreme weather events. Think carefully about how to guide the discussion in a way that is respectful of and sensitive to students' experiences.

This lesson uses data from the 1960s because students may know people (such as family members or teachers) who were alive at that time, making the comparison to the present more engaging. Although this range does not capture the entirety of human greenhouse gas emissions, it includes most of them: approximately three-quarters of all human greenhouse gas emissions before 2020 occurred in the period after 1960.

4. Give students time to calculate precipitation averages and changes. You can allow them to work individually, in groups, or in some combination of the two. (For example, you can have students calculate changes on their own and then discuss their results in groups.)

Activity Tips

Depending on your students' familiarity with calculating averages, it may be useful to start by calculating the average precipitation amounts for one city together as a class.

If your time is limited, you can shorten the activity by assigning particular cities to particular students or groups, then having them share their findings with the class.

For an additional challenge once they are finished with the initial calculations, students can calculate measures of center for all cities together. For example, they can calculate the average or median precipitation for all cities in the 1960s or the 2010s, or the average or median precipitation change for all cities.

5. Have students interpret their findings. Ask:

Q: What do you notice about the precipitation changes?

A: Responses will vary. A possible response is most of the precipitation changes are positive, although a few are negative.

Q: What do the precipitation changes tell us about the change in precipitation in these cities?

A: The fact that the precipitation changes are mostly positive means that most of the cities listed received more precipitation in the 2010s than in the 1960s. Only two of the cities, Jacksonville and Los Angeles, received less precipitation.

Activity Tips

Average precipitation numbers alone do not capture all the changes in precipitation. For example, some areas have experienced an increase in amounts of precipitation in brief periods of time in recent decades. These intense events can cause serious damage even if total precipitation amounts remain unchanged.

Although precipitation is increasing in many places, some places are becoming drier as a result of changed precipitation patterns. Consider discussing the impacts of drought with your students, especially if they live in an area affected by decreased precipitation.

Material Tips

Displaying information in various formats can help scientists interpret it. Consider having students graph some of the data by hand or digitally in order to discover patterns. If time permits, have them draw a line of best fit for each city in each decade, making observations about both year-to-year variations and overall trends.

6. Explain to students that the change was not just in these cities. Precipitation amounts changed in many places around the planet between 1960 and 2020, part of a process called **climate change.** Ask:

Q: Do you have any ideas about why Earth might have different precipitation patterns now than it did fifty years ago?

A: Responses will vary. Students may know that the atmosphere now contains more greenhouse gases, gases that trap heat from the Sun and prevent it from radiating back out into space. They may have heard of different kinds of greenhouse gases, including carbon dioxide, methane, and nitrous oxide. These gases increase the planet's average surface temperature, causing more water to evaporate and storms to become more intense.

Q: What are some ways changes in precipitation might be affecting people, animals, or plants?

A: Responses will vary. A possible response is that extreme precipitation can drown living things or wash away their habitats. If living things don't get enough precipitation, they cannot perform physiological tasks necessary for survival.

Activity Tips

More information on the sources and effects of greenhouse gases is available in the Climate Change Overview and Extreme Temperatures lessons. More information about other consequences of the increase in global average temperature is available in the Wildfires and Drought and Rising Sea Levels lessons.

Students may need help to understand the connection between increased temperatures and extreme precipitation. It may be useful to remind them about previous work they have done with the water cycle and to discuss how increased temperatures affect the different phases of the cycle.

Although an increase in extreme precipitation events is one reason floods became more extreme between the 1960s and the 2010s, there are other reasons as well. One is an increase in impermeable pavement, which, unlike soil, cannot absorb water and so leads to increased flood levels during rainfall. Sea level rise also increases the likelihood of flooding during storms. Often, poor people and people of color face the greatest exposure to flood risk. This is an example of environmental injustice, a situation in which disadvantaged groups suffer the greatest harms from environmental conditions. If time permits, discuss this concept with students. Have students consider other situations in which environmental injustice occurs and possible ways to combat it.

7. Tell students that scientists are interested in the ways that extreme precipitation events are occurring. Play the video Sensing *Our Climate: Extreme Precipitation* (3:52).

watch video

Activity Tips

Although the precipitation data used in this unit were collected at Earth's surface, the video mentions using remote sensing for data collection. If students are interested, you can consider possible benefits and drawbacks of collecting data from the ground, from the atmosphere, or from space. For example, weather measurements on the ground are easy and cheap to make and can capture small differences between nearby locations. Remote sensing measurements require expensive equipment, can be blocked by clouds, and do not always have high resolution, but they can cover large areas and observe places difficult or impossible to reach on the ground.

If students are interested in how higher temperatures can cause more snowstorms, you can play the video Snowstorms (0:28) to provide further information.

Discuss the video. Ask:

Q: What are some ways changes in precipitation might be affecting people, animals, or plants?

A: Responses will vary. Possible responses include that extreme precipitation can take the form of both hurricanes and blizzards and that scientists can use **remote sensing**, *the science of scanning Earth from a distance using technology like satellites and high-flying airplanes, to gather information about climate change.*

Q: Did you notice evidence of extreme precipitation in the data we explored?

A: Responses will vary. Students may notice years in which precipitation totals were especially high. For example, Houston had an especially high rainfall total for 2017 because Hurricane Harvey dropped 75–125 cm (30–50") of rain on the city over the course of a week. In 2018, many cities on the East Coast received large amounts of snowfall over the course of several winter storms.

Q: What does the video say about how humans can respond to climate change?

A: Humans can use airplanes and satellites to observe when storms form, see where they go, and predict how people should prepare for them.

8. Call students' attention to the line at the end of the video that "Humans are incredibly innovative and resilient, and our development and utilization of new technology will allow us to be prepared." Explain that there are different ways to use technology in response to climate change. **Mitigation** is human action that limits the concentration of greenhouse gases in the atmosphere, such as using electric cars instead of cars that burn gas. **Adaptation** is human action that limits the harm caused by climate change, such as using satellites to observe where storms will hit.

On a whiteboard or chart paper, make a table with the headings "Mitigation" and "Adaptation." Have students brainstorm other examples of each strategy and add them to the chart.

Mitigation *human action that limits the concentration of greenhouse gases in the atmosphere*	**Adaptation** *human action that limits the harm caused by climate change*
• Using electric cars that do not burn fossil fuels	• Putting in air conditioning or heaters

Activity Tips

To avoid confusion, you can explain to students that mitigation and adaptation have different definitions outside the context of climate change. Students may be familiar with other uses of the terms; for example, in biology, adaptation means "a characteristic that allows a living thing to survive in its environment."

9. Tell students that while it can be hard to protect other parts of the country or the world from climate change, there's a lot they can do to protect the people, animals, plants, and environment around them. Today, they will suggest ideas for mitigation and adaptation in their community. Distribute *Mitigation Strategies* (English | Spanish) and explain that they will use it to record sources of greenhouse gas emissions at or caused by their school. Distribute *Adaptation Strategies* (English | Spanish) and explain that they will use it to record ways that their school might be affected by extreme precipitation.

Activity Tips

Depending on time, your school environment, and other lessons you have already completed, you may choose to focus only on mitigation or adaptation. (The mitigation activity in this lesson also appears in the Extreme Temperatures, Wildfires and Drought, and Rising Sea Level lessons.) Distribute only the appropriate sheet to students and use only the relevant discussion questions later in the activity.

If your in-class time is limited, students can complete the investigation and brainstorming of mitigation and adaptation strategies without leaving the classroom, or they can do so outside of class time.

10. Travel around the school and school grounds; possible places to visit include a cafeteria, heating or cooling equipment, dumpsters or other waste disposal, a garden or other green space, a blacktop or playground, drainage canals and grates, and vehicles or parking. Have students work individually or in small groups to record sources of greenhouse gases on the left side of *Mitigation Strategies* and vulnerabilities to extreme precipitation on the left side of *Adaptation Strategies*. Draw student attention to relevant features of the school environment as necessary.

Activity Tips

Although mitigation is often discussed in terms of reducing the sources that emit greenhouse gases into the atmosphere, enhancing the sinks that absorb greenhouse gases from the atmosphere is also a mitigation strategy. Examples of important sinks include the ocean and plants. It may be appropriate to discuss the idea of greenhouse gas sinks with students (or they may bring it up themselves), especially if your school grounds contain plants.

It may benefit student understanding to distinguish between direct and indirect greenhouse gas emissions. In the case of a school, direct emissions are those that happen on the school grounds, such as burning fuels for heat or in the engine of an idling school bus. Indirect emissions happen off the school grounds, such as at a power plant, in a factory, at a landfill, or on a farm, but nevertheless occur for the sake of the school. Students can research locations that are responsible for your school's indirect emissions; in some cases, those locations may be in another city, state, or country!

As you travel around the school, it may also be appropriate for students to ask individuals (other students, teachers, workers, and administrators) about their knowledge of the school's greenhouse gas emissions and vulnerability to extreme precipitation. Make sure to arrange any interviews ahead of time. You could also have individuals come to visit your classroom.

11. Return to the classroom. In small groups or as a class, have students share the greenhouse gas sources they recorded on Mitigation Strategies. Ask:

Q: What sources of greenhouse gases did you notice?

A: Responses will vary. Possible responses include vehicles, such as school buses or garbage trucks; devices that use electricity, such as lights or air conditioners; objects whose manufacture releases greenhouse gases, such as paper or cement; food whose production releases greenhouse gases, such as beef and milk; garbage, which can release greenhouse gases in a landfill; heating devices, such as furnaces; and the removal of plants or green space.

12. Explain that students can use their knowledge about climate change to plan ways to reduce the school's greenhouse gas emissions. Ask:

Q: What changes can we make here to mitigate climate change?

A: Responses will vary. Possible responses include reducing activities that produce greenhouse gases (such as idling cars outside the school), making activities more efficient (such as using efficient light bulbs), and doing them in ways that do not require fossil fuels (such as using cars and school buses powered by electricity from a non-carbon source).

Have students fill in the right column of Mitigation Strategies with the ideas they discuss.

13. Explain that although mitigation is extremely important for reducing the future effects of climate change, some effects, such as extreme precipitation, are already happening. In small groups or as a class, have students share the ways that the school might be affected by extreme precipitation that they recorded on Adaptation Strategies. Ask:

Q: How might our school be affected by extreme precipitation?

A: Responses will vary. Possible responses include getting wet or snowy, having pavement flood, having mudslides or avalanches on hills, or having roofs leak or break. Students may also know that runoff can wash pollution into nearby bodies of water, which is bad for the health of people and other living things in the area.

14. Explain that students can use their knowledge about climate change to plan ways to adapt the school for extreme temperatures. Ask:

> **Q: How could our school adapt to extreme precipitation?**
>
> *A: Responses will vary. Possible responses include monitoring weather forecasts and warning people of impending extreme precipitation, having extra umbrellas and shovels available, replacing pavement with plants to improve drainage and pollution filtration, adding plants or barriers on hillsides to prevent erosion, having sloped roofs, and cleaning gutters regularly.*

Have students fill in the right column of Adaptation Strategies with the ideas they discuss.

15. Discuss how to put these ideas into action. Ask:

> **Q: Now that we have brainstormed ideas for mitigation and adaptation at our school, how can we put these ideas into action?**
>
> *A: Responses will vary. Some actions, such as reducing paper and electricity use, can be implemented in your classroom (and encouraged in other classrooms). Other ideas may need to be implemented by the school administration.*

> **Q: Where else could you use these strategies to mitigate and adapt to climate change?**
>
> *A: Responses will vary. Possible responses include at home and at local community organizations. Encourage students to investigate the specific circumstances in those places and share their knowledge about ways to mitigate and adapt to climate change.*

16. Wrap up by returning to the Guiding Question:

> **Q: How and why have precipitation patterns changed since the mid-20th century, and how should we respond?**
>
> *A: Temperatures have changed because humans have put more greenhouse gases into the atmosphere. These gases trap heat, increasing the temperature of the planet. This increased temperature warms water, causing more evaporation and more energetic storms. We can respond by reducing how many greenhouse gases are emitted and by adapting to protect ourselves, other living things, and the environment from more extreme precipitation.*

Extension Activity

Use the following activity after the lesson to extend student mastery of this Grades 6–8 Science and Engineering Practice.

Constructing Explanations and Designing Solutions.

- Undertake a design project, engaging in the design cycle, to construct and/or implement a solution that meets specific design criteria and constraints.

In the days, weeks, or months following this lesson, you can extend student understanding and engagement by working to implement one or more of the mitigation or adaptation ideas generated by the class.

Many of the changes needed to mitigate and adapt to climate change cannot be effectively implemented by individuals working alone. Rather, they require collective action at the local, state, national, and international levels. Likewise, there may be some changes that students in your class cannot implement without the support of school administration. Have students consider how they can advocate for those changes. For example, students may write letters, meet with school officials, or organize an event. It may be useful for students to gather information about other benefits of the proposed strategy; for example, eliminating direct sources of greenhouse gas emissions often improves air quality.

Consider collecting data both before and after a change is implemented to understand its effects and whether it should be replicated elsewhere. For example, you could collect data about the number and types of vehicles idling outside the school both before and after the implementation of a no-idling policy, then calculate the approximate reduction in greenhouse gas emissions as a result of the change.

Wildfires and Drought

Overview

Students examine data on the area burned by wildfire to draw conclusions about the changes in Earth's climate since 2000. A video introduction discusses how increased temperatures have caused more extensive wildfires. Students then explore their local environments to suggest methods for mitigation of greenhouse gas emissions and adaptation to wildfires.

A simpler version of this lesson is available in *Climate Change*, Gr 3-5.

Guiding Question

How and why have wildfires changed since the 2000s, and how should we respond?

Objectives

Students will be able to

- analyze and interpret wildfire data from the 2000s and the 2010s.
- explain how human-caused greenhouse gas emissions have caused an increase in the total area burned by wildfire.
- propose local solutions for climate change mitigation and adaptation to wildfires.

Background

Humans cause climate change in several ways. Some of the most significant include burning fossil fuels to power engines, generate electricity, heat buildings, and produce materials such as cement; cutting down forests; raising livestock; and using fertilizers.

All of these activities release gases such as carbon dioxide, methane, and nitrous oxide. When sunlight reaches Earth, much of the energy is converted to thermal energy. Some of the energy

Time

- 20 minutes to explore data
- 5 minutes to watch video
- 20 minutes to suggest solutions

Grade Level: 6–8

Vocabulary

- **Adaptation**
- **Climate**
- **Climate Change**
- **Greenhouse Gas**
- **Mitigation**
- **Precipitation**
- **Remote Sensing**
- **Weather**
- **Weather Patterns**

Standards

NGSS SEP: **Analyzing and Interpreting Data.** Apply concepts of statistics and probability (including mean, median, mode, and variability) to analyze and characterize data, using digital tools when feasible.

NGSS MS-ESS3-5. Ask questions to clarify evidence of the factors that have caused the rise in global temperatures over the past century.

NGSS MS-ESS3-3.

NGSS CCC: Patterns.

CCSS.Math.Content.6.SP.B.5.C.

is absorbed and some is radiated back into the atmosphere. Carbon dioxide, methane, and nitrous oxide in the atmosphere reduce the amount of thermal energy that escapes back into space. These gases are called "greenhouse gases" because they function like the insulating panes of glass in a greenhouse.

An increase in the levels of greenhouse gases in the atmosphere has multiple consequences. The most direct one is an increase in the planet's average temperature, which has risen more than 1°C since the beginning of the Industrial Revolution in the 1700s. Increased temperatures can increase evaporation from bodies of water such as lakes and reservoirs, as well as faster melting of spring snowpack, leading to longer and more intense droughts in some areas. Increased temperatures and droughts together lead to more extensive wildfires.

Preparation

For this activity, the educator will need the following:

- Video: *Sensing Our Climate: Wildfires and Drought* (3:37) (English | Spanish)
- A way to show the video to students
- Whiteboard or chart paper

For this activity, each student will need the following:

- 1 copy of Area Burned (English | Spanish | Answer Key)
- 1 copy of Mitigation Strategies (English | Spanish | Answer Key)
- 1 copy of Adaptation Strategies (English | Spanish | Answer Key)
- 1 pen or pencil

Access the interactive version of this lesson, powered by Pear Deck™

EiE Connections

Learn more about the Engineering Design Process in the EiE Video Library.

- Continue your classroom activities with this unit:
- **Engineering Everywhere®**
- Engineering Remote Sensing Devices
-

Museum of Science Connections

Listen to the Pulsar podcast episode "Staying Safe in a Lightning Storm."

Family Connections

Continue the engineering at home with these activities:

- Keep It Watered!
- PLANETS: Remote Sensing Investigation

Credits

MOS at School programs are offered at no cost, thanks to the generosity of the Akamai Foundation, Bloomberg Philanthropies, BNY Mellon, Gordon Foundation, Hood, Lincoln and Therese Filene Foundation, Lowell Institute, Mabel Louise Riley Foundation, MathWorks, Richard K. Lubin Family Foundation, Sanofi, and TJX.

Activity Instructions

These steps offer support for implementing the Sensing Our Climate: Wildfires and Drought video and associated activities with students.

If your students need additional background about the basics of climate change, consider teaching the Climate Change Overview lesson first.

1. Explain to students that today they will be thinking about something they likely know about: fire. Ask:

> **Q: What is fire?**
>
> *A: Accept all responses. Students may know that fire is a chemical reaction in which a fuel source (such as wood, coal, oil, or gas) reacts with oxygen in the air. This reaction gives off heat (is exothermic) and light, as well as products such as carbon dioxide or water. Students may also give examples of how people use fire, such as to cook, heat buildings, or boil water for electricity generation.*

> **Q: What is a wildfire?**
>
> *A: Accept all responses. Students may know that a **wildfire** is an uncontrolled fire in an outdoor area. They may give examples of wildfires they have heard about or experienced.*

Q: Why are wildfires dangerous for people, other animals, and plants?

A: Accept all responses. Possible responses that fires can kill living things, make smoke that kills or hurts them, or destroy their habitats.

Material Tips

If your students have already learned about fire, show or describe some of the work they did or phenomena they studied in order to activate their prior knowledge.

Q: Why are wildfires useful for animals and plants?

A: Accept all responses. Students may know that wildfires can help nutrients cycle through an ecosystem. Wildfires can also prevent the buildup of dry plant matter, preventing much larger fires in the future. Some living things rely on fire for their life cycle. For example, certain trees sprout only after being exposed to fire.

Activity Tips

Students may have experienced loss in wildfires. Think carefully about how to guide the discussion in a way that is respectful of and sensitive to students' experiences.

Consider providing your students with examples of local organisms that are affected by wildfires. Discuss the ways in which these organisms have been affected. You may want to have them share observations they have made about those organisms after wildfires (for example, what happens to trees after a wildfire?).

2. Explain to students that the size, speed, and intensity of wildfires in a region depends on its climate. Ask:

Q: What do you know about climate?

*A: Accept all responses. A possible response is that **climate** is the usual temperature and weather conditions in a place.*

Q: In places with large wildfires, what is the climate like?

*A: Responses will vary. A possible response is that places with large wildfires often have warm, dry climates. Students may also know that places experiencing **drought**, or an extended period of abnormally dry weather, tend to have an increased risk of wildfire.*

3. Tell students that they are going to do something that scientists who study climate do: analyze how fire seasons have changed over time. Distribute *Area Burned* (English | Spanish) to students. Explain that they will be calculating the ratio of area burned in certain states and provinces to the total area of those states and provinces during both the 2000s and 2010s. The information they find could be important for protecting people and other living things.

Activity Tips

The wildfire data set comes in both square kilometers and square miles. Use the unit that is appropriate for your students.

Local relevance is key to student engagement with climate change concepts. Before the lesson, if you live in a wildfire-prone area, you can look up wildfire statistics for where you live and have students perform calculations with them as well. (For the United States, yearly state-by-state data is available from the National Interagency Fire Center.) If you live in an area not as prone to wildfires, you can create local relevance by having students determine how the size of burned areas compares to that of local regions. For example, about 30,000 square km burned in California in the 2010s, an area slightly larger than the entire state of Massachusetts.

This lesson uses data from the 2000s because that is the earliest period for which many precise wildfire statistics are reported. This fact is partly due to the availability of remote sensing technologies. For example, NASA's Terra and Aqua—the satellites mentioned in the video—launched in 1999 and 2002, respectively. These satellites provide detailed images of fires around the world.

4. Give students time to calculate ratios for each area and decade. You can allow them to work individually, in groups, or in some combination of the two. (For example, you can have students calculate ratios on their own and then discuss their results in groups.)

Activity Tips

Depending on your students' familiarity with calculating ratios, it may be useful to start by calculating the ratios for one state or province together as a class.

If your time is limited, you can shorten the activity by assigning particular states or provinces to particular students or groups, then having them share their findings with the class.

For an additional challenge once they are finished with the initial calculations, students can answer questions about the data, such as which state or province had the most area burned (California in the 2000s, British Columbia in the 2010s), the largest portion of its area burned (California in the 2000s, Oregon in the 2010s), or the largest increase in portion of area burned between the two decades (British Columbia).

5. Have students interpret their findings. Ask:

Q: What do you notice about the changes in ratios?

A: Responses will vary. A possible response is that all the ratios became larger in the 2010s.

Q: What do the changes in area burned tell us about the change in fire in these states and provinces?

A: The fact that the all the ratios became larger means that more of each state and province burned in the 2010s than in the 2000s.

Material Tips

Displaying information in various formats can help scientists interpret it. Consider having students graph some of the data by hand or digitally in order to discover patterns.

Activity Tips

The area burned alone does not capture all the changes in wildfire patterns. For example, in the 2010s, many wildfires also spread more quickly, making it more difficult for people to respond by evacuating or firefighting.

6. Explain to students that the change was not just in these states and provinces. Wildfires have burned increasingly large areas in many places around the planet since 2000, part of a process called **climate change.** Ask:

Q: Do you have any ideas about why wildfires might be burning more area now than in the 2000s?

A: Responses will vary. Students may know that the atmosphere now contains more greenhouse gases, gases that trap heat from the Sun and prevent it from radiating back out into space. They may have heard of different kinds of ***greenhouse gases,*** *especially carbon dioxide. These gases increase the planet's average surface temperature, causing drought. The resulting dry, hot conditions make it easier for wildfires to start and to spread.*

Q: What are some ways changes in wildfires might be affecting people, animals, or plants?

A: Responses will vary. A possible response is that frequent, large, intense wildfires can destroy people's homes and the habitats of other living things. They can also kill people and other living things or hurt them through pollution such as smoke.

Activity Tips

More information on the sources and effects of greenhouse gases is available in the Climate Change Overview and Extreme Temperatures lessons. More information about other consequences of the increase in global average temperature is available in the Extreme Precipitation and Rising Sea Level lessons.

Students may need help to understand the connection between increased temperatures and drought. It may be useful to remind them about previous work they have done with the water cycle and to discuss how increased temperatures affect the different phases of the cycle. For example, increased temperatures can increase evaporation, drying the ground. They can also melt spring snowpack more quickly, meaning runoff from that snowpack is not available later in the year.

A climate feedback loop is a situation in which an effect of climate change contributes to additional climate change in the future. For example, a hot, dry climate leads to wildfires, which release greenhouse gases, which make the climate hotter and drier, leading to even more wildfires. This lesson does not require an understanding of feedback loops, but you may want to discuss them if students bring them up.

Although an increase in area is one reason wildfires became more destructive between 2000 and 2019, there are other reasons as well. One is an increase in the extent of the wildland-urban interface (WUI), the area where buildings intermingle with wild vegetation. Wildfires in this area, which previously would not have damaged buildings, now harm more people as more buildings are present. If students are interested, you can discuss this concept and the ways in which it may appear in your local area.

7. Tell students that scientists are interested in the ways that extreme wildfires are occurring. Play the video Sensing Our Climate: Wildfires and Drought (3:37).

watch video

Activity Tips

The video mentions using remote sensing for data collection. If students are interested, you can consider possible benefits and drawbacks of collecting data from the ground, from the atmosphere, or from space. For example, wildfires can often be spotted remotely before they are observed on the ground. However, remote sensing measurements require expensive equipment, can be blocked by clouds, and do not always have high resolution.

Discuss the video. Ask:

Q: What else did you learn about wildfires from the video?

A: Responses will vary. Possible responses include that drought contributes to wildfires and that scientists can use remote sensing, the science of scanning Earth from a distance using technology like satellites and high-flying airplanes, to gather information about climate change.

Q: What does the video say about how humans can respond to climate change?

A: Humans can use airplanes and satellites to observe when wildfires start, to see where they go and the path of their smoke, and to predict how people should prepare for them.

8. Call students' attention to the line at the end of the video that says "Humans are incredibly innovative and resilient, and our development and utilization of new technology will allow us to be prepared." Explain that there are different ways to use technology in response to climate change. Mitigation is human action that limits the concentration of greenhouse gases in the atmosphere, such as using electric cars instead of cars that burn gas. Adaptation is human action that limits the harm caused by climate change, such as using satellites to observe the location of wildfires and smoke.

On a whiteboard or chart paper, make a table with the headings "**Mitigation**" and "**Adaptation**." Have students brainstorm other examples of each strategy and add them to the chart.

Mitigation *human action that limits the concentration of greenhouse gases in the atmosphere*	**Adaptation** *human action that limits the harm caused by climate change*
• Using electric cars that do not burn fossil fuels	• Predicting where wildfires and smoke will go and warning people

9. Tell students that while it can be hard to protect other parts of the country or the world from climate change, there's a lot they can do to protect the people, animals, plants, and environment around them. Today, they will suggest ideas for mitigation and adaptation in their community. Distribute *Mitigation Strategies* (English | Spanish) and explain that they will use it to record sources of greenhouse gas emissions at their school. Distribute *Adaptation Strategies* (English | Spanish) and explain that they will use it to record ways that their school might be affected by wildfires.

Activity Tips

Depending on time, your school environment, and other lessons you have already completed, you may choose to focus only on mitigation or adaptation. (The mitigation activity in this lesson also appears in the Extreme Temperatures, Extreme Precipitation, and Rising Sea Level lessons.) Distribute only the appropriate sheet to students and use only the relevant discussion questions later in the activity.

If your in-class time is limited, students can complete the investigation and brainstorming of mitigation and adaptation strategies without leaving the classroom, or they can do so outside of class time.

10. Travel around the school and school grounds; possible places to visit include a cafeteria, heating/cooling or air-filtration equipment, dumpsters or other waste disposal, a garden or other green space, a blacktop or playground, and vehicles or parking. Have students work individually or in small groups to record sources of greenhouse gases on the left side of *Mitigation Strategies* and vulnerabilities to wildfires on the left side of *Adaptation Strategies*. Draw student attention to relevant features of the school environment as necessary.

Activity Tips

Although mitigation is often discussed in terms of reducing the sources that emit greenhouse gases into the atmosphere, enhancing the sinks that absorb greenhouse gases from the atmosphere is also a mitigation strategy. Examples of important sinks include the ocean and plants. It may be appropriate to discuss the idea of greenhouse gas sinks with students (or they may bring it up themselves), especially if your school grounds contain plants.

It may benefit student understanding to distinguish between direct and indirect greenhouse gas emissions. In the case of a school, direct emissions are those that happen on the school grounds, such as burning fuels for heat or in the engine of an idling school bus. Indirect emissions happen off the school grounds, such as at a power plant, in a factory, at a landfill, or on a farm, but nevertheless occur for the sake of the school. Students can research locations that are responsible for your school's indirect emissions; in some cases, those locations may be in another city, state, or country!

As you travel around the school, it may also be appropriate for students to ask individuals (other students, teachers, workers, and administrators) about their knowledge of the school's greenhouse gas emissions and vulnerability to wildfire. Make sure to arrange any interviews ahead of time. You could also have individuals come to visit your classroom.

11. Return to the classroom. Have students work in small groups or as a class to share the greenhouse gas sources they recorded on *Mitigation Strategies*. Ask:

Q: What sources of greenhouse gases did you notice?

A: Responses will vary. Possible responses include vehicles, such as school buses or garbage trucks; devices that use electricity, such as lights or air conditioners; objects whose manufacture releases greenhouse gases, such as paper or cement; food whose production releases greenhouse gases, such as beef and milk; garbage, which can release greenhouse gases in a landfill; heating devices, such as furnaces; and the removal of plants or green space.

12. Explain that students can use their knowledge about climate change to plan ways to reduce the school's greenhouse gas emissions. Ask:

> **Q: What changes can we make here to mitigate climate change?**
>
> *A: Responses will vary. Possible responses include reducing activities that produce greenhouse gases (such as idling cars outside the school), making activities more efficient (such as using efficient light bulbs), and doing them in ways that do not require fossil fuels (such as using cars and school buses powered by electricity from a non-carbon source).*

Have students fill in the right column of *Mitigation Strategies* with the ideas they discuss.

13. Explain that although mitigation is extremely important for reducing the future effects of climate change, some effects, such as larger and more intense wildfires, are already happening. Have students work in small groups or as a class to share the ways that the school might be affected by wildfires that they recorded on Adaptation Strategies. Ask:

> **Q: How might our school be affected by wildfires?**
>
> *A: Responses will vary. Possible responses include having people or animals exposed to smoke, having plants near the school catch fire, or having parts of the school itself catch fire.*

14. Explain that students can use their knowledge about climate change to plan ways to adapt the school for wildfires. Ask:

> **Q: How could our school adapt to wildfires?**
>
> *A: Responses will vary. Possible responses include monitoring remote sensing data and warning people of nearby smoke or fire, having effective air filtration systems for when it is smoky, keeping plants well-watered and spaced away from the school, using fire-resistant materials in the school, and having evacuation plans.*

Have students fill in the right column of *Adaptation Strategies* with the ideas they discuss.

15. Discuss how to put these ideas into action. Ask:

> **Q: Now that we have brainstormed ideas for mitigation and adaptation at our school, how can we put these ideas into action?**
>
> *A: Responses will vary. Some actions, such as reducing paper and electricity use, can be implemented in your classroom (and encouraged in other classrooms). Other ideas may need to be implemented by the school administration.*

Q: Where else could you use these strategies to mitigate and adapt to climate change?

A: Responses will vary. Possible responses include at home and at local community organizations. Encourage students to investigate the specific circumstances in those places and share their knowledge about ways to mitigate and adapt to climate change.

Activity Tips

Mitigation and adaptation strategies are related in several ways. The more effectively humans mitigate greenhouse gas emissions in the near term, the less adaptation we will need in the long term. Although institutions must sometimes choose between devoting resources to mitigation and to adaptation, certain strategies contribute to both goals. For example, refraining from clearing forest for new buildings prevents carbon dioxide emission from deforestation (mitigation) while also keeping structures out of the wildfire-prone wildland-urban interface (adaptation).

16. Wrap up by returning to the Guiding Question:

Q: How and why have wildfires changed since the 2000s, and how should we respond?

A: Temperatures have changed because humans have put more greenhouse gases into the atmosphere. These gases trap heat, increasing the temperature of the planet. This increased temperature warms water, causing more evaporation and faster snowmelt. Together, increased temperatures and drought contribute to faster-spreading, larger, and more intense wildfires. We can respond by reducing how many greenhouse gases are emitted and by adapting to protect ourselves, animals, plants, and the environment from wildfires.

Extension Activity

Use the following activity after the lesson to extend student mastery of this Grades 6–8 Science and Engineering Practice.

Constructing Explanations and Designing Solutions.

- Undertake a design project, engaging in the design cycle, to construct and/or implement a solution that meets specific design criteria and constraints.

In the days, weeks, or months following this lesson, you can extend student understanding and engagement by working to implement one or more of the mitigation or adaptation ideas generated by the class.

Many of the changes needed to mitigate and adapt to climate change cannot be effectively implemented by individuals working alone. Rather, they require collective action at the local, state, national, and international levels. Likewise, there may be some changes that students in your class cannot implement without the support of school administration. Have students consider how they can advocate for those changes. For example, students may write letters, meet with school officials,

or organize an event. It may be useful for students to gather information about other benefits of the proposed strategy; for example, eliminating direct sources of greenhouse gas emissions often improves air quality.

Consider collecting data both before and after a change is implemented to understand its effects and whether it should be replicated elsewhere. For example, you could collect data about the number and types of vehicles idling outside the school both before and after the implementation of a no-idling policy, then calculate the approximate reduction in greenhouse gas emissions as a result of the change.

Rising Sea Level

Overview

Students examine sea level data to draw conclusions about the changes in Earth's climate since 1920. A video introduction discusses how increased temperatures have caused sea level rise. Students then explore their local environments to suggest methods for mitigation of greenhouse gas emissions and adaptation to sea level rise.

A simpler version of this lesson is available in *Climate Change*, Gr 3-5.

Guiding Question

How and why have sea levels changed since the 1920s, and how should we respond?

Objectives

Students will be able to

- analyze and interpret sea level data from 1920 to 2020.
- explain how human-caused greenhouse gas emissions have caused a rise in sea levels over the past century.
- propose local solutions for climate change mitigation and adaptation to sea level rise.

Background

Humans cause climate change in several ways. Some of the most significant include burning fossil fuels to power engines, generate electricity, heat buildings, and produce materials such as cement; cutting down forests; raising livestock; and using fertilizers.

All of these activities release gases such as carbon dioxide, methane, and nitrous oxide. When sunlight reaches Earth, much of the energy is converted to thermal energy. Some of the energy is absorbed and some is radiated back into the atmosphere. Carbon dioxide, methane, and nitrous oxide in the atmosphere

Time

- 20 minutes to explore data
- 5 minutes to watch video
- 20 minutes to suggest solutions

Grade Level: 6–8

Vocabulary

- **Adaptation**
- **Climate**
- **Climate Change**
- **Greenhouse Gas**
- **Mitigation**
- **Remote Sensing**
- **Weather**
- **Weather Patterns**

Standards

NGSS SEP: **Analyzing and Interpreting Data.** Apply concepts of statistics and probability (including mean, median, mode, and variability) to analyze and characterize data, using digital tools when feasible.

NGSS MS-ESS3-5. Ask questions to clarify evidence of the factors that have caused the rise in global temperatures over the past century.

NGSS MS-ESS3-3.

NGSS CCC: Patterns.

CCSS.Math.Content.6.SP.B.5.C.

reduce the amount of thermal energy that escapes back into space. These gases are called "greenhouse gases" because they function like the insulating panes of glass in a greenhouse.

An increase in the levels of greenhouse gases in the atmosphere has multiple consequences. The most direct one is an increase in the planet's average temperature, which has risen more than 1°C since the beginning of the Industrial Revolution in the 1700s. This increased temperature melts glaciers and ice sheets in places such as Greenland and Antarctica. It also causes ocean water to warm and expand. Both phenomena cause sea levels to rise.

Preparation

For this activity, the educator will need the following:

- Video: *Sensing Our Climate: Rising Sea Level* (3:32) (English | Spanish)
- A way to show the video to students
- Whiteboard or chart paper

For this activity, each student will need the following:

- 1 copy of Global Sea Level Change (English | Spanish | Answer Key)
- 1 copy of Mitigation Strategies (English | Spanish | Answer Key)
- 1 copy of Adaptation Strategies (English | Spanish | Answer Key)
- 1 pen or pencil

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EiE Connections

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Continue your classroom activities with these units:

Engineering Everywhere®

- Engineering Remote Sensing Devices
- Engineering an Urban Landscape
- Engineering a Water Reuse Process

Museum of Science Connections

Listen to the Pulsar podcast episodes "Climate Change Resilience in Boston," "Glaciers: Tortoise or Hare?", and "Preserving Our Heritage with Technology."

Watch the video *Places in Peril: Cities Facing the Climate Crisis.*

Check out the Museum's Wicked High Tides citizen science initiative.

Family Connections

Continue the engineering at home with these activities:

Engineer a Floating House

PLANETS: Remote Sensing Investigation

Credits

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Activity Instructions

These steps offer support for implementing the Sensing Our Climate: Rising Sea Level video and associated activities with students.

If your students need additional background about the basics of climate change, consider teaching the Climate Change Overview lesson first.

1. Explain to students that today they will be thinking about the sea. Ask:

> **Q: What is the sea?**
>
> *A: Accept all responses. Students may know that the sea or ocean is the location of most water on Earth. Although most seas are part of a single body of water, people use different names to refer to different parts, such as the Atlantic Ocean, Pacific Ocean, Indian Ocean, and Caribbean Sea.*

Q: Why is the sea important for people and other living things?

A: Accept all responses. Possible responses include that many organisms live in or near the sea or depend on it for food. People use the sea in different ways, such as for food and transportation. Ocean currents also affect the temperature of coastal areas, making them warmer or cooler than they would otherwise be.

Activity Tips

If you live near the sea, consider providing your students with examples of local organisms that live in or near it. Have them share observations about those organisms when the sea level is higher or lower. (For example, what do organisms on the beach do at high tide? At low tide?) If you don't live near the sea, students can share any experiences they have had if they have visited it.

Material Tips

If your students have already learned about the sea, show or describe some of the work they did or phenomena they studied in order to activate their prior knowledge.

2. Have students consider sea level. Ask:

Q: What affects the level of the sea?

A: Accept all responses. Students may know that the level of the sea is affected by gravity from the Moon and (to a lesser extent) the Sun. When a location faces directly toward or away from the Moon, it experiences high tide; otherwise, it experiences low tide. At the New Moon and Full Moon, when the Sun and Moon are on the same or opposite sides of Earth, tides are more extreme (and are called "spring tides"). At quarter Moons, when the Sun and Moon are at a right angle to one another relative to Earth, tides are less extreme (and are called "neap tides"). The ***weather****, short-term temperatures and conditions such as wind, air pressure, and precipitation, also affects sea level.*

Explain to students that while the sea level changes depending on the time of day, month, and year (and varies in multi-year cycles), scientists average values over time to calculate a Mean Sea Level (MSL) for a given location.

3. Tell students that they are going to do something that scientists who study the sea do: analyze how Earth's Mean Sea Level has changed over time. Distribute *Global Sea Level Change* (English | Spanish) to students. Explain that they will be plotting the change in global Mean Sea Level for various years relative to 1920. This information could be important for protecting people and other living things.

Activity Tips

The sea level data comes in both centimeters and inches. Use the units that are appropriate for your students.

Local relevance is key to student engagement with climate change concepts. If you live near the sea, before the lesson, look up sea level change for a nearby location between 1920 and 2020. (Easy-to-access data is available from the National Oceanic and Atmospheric Administration.) Consider having students plot changes in sea level for that location as well. Students may also share their prior knowledge about sea level and weather in that location.

Students may have experienced loss due to sea level rise or extreme weather events. Think carefully about how to guide the discussion in a way that is respectful of and sensitive to students' experiences.

4. Give students time to plot the sea level changes. You can allow them to work individually, in groups, or in some combination of the two. (For example, you can have students graph changes on their own and then discuss their results in groups.)

Activity Tips

For an additional challenge once they are finished plotting the data, students can attempt to draw a line or curve of best fit and write an equation describing it.

5. Have students interpret their findings. Ask:

Q: What does your graph show about the sea level changes?

A: Responses will vary. A possible response is that global Mean Sea Level has risen almost every decade since 1920.

Q: Is the relationship between time and sea level linear or nonlinear?

A: The relationship is nonlinear. Global Mean Sea Level has been increasing faster as time goes on. For example, it increased just 1 cm in the 1920s but 5 cm in the 2010s.

6. Explain to students that rising sea levels are part of a process called climate change. Ask:

Q: Do you have any ideas about why Earth might have higher sea levels now than it did in the early 1900s?

A: Responses will vary. Students may know that the atmosphere now contains more greenhouse

gases, gases that trap heat from the Sun and prevent it from radiating back out into space. They may have heard of different kinds of greenhouse gases, especially carbon dioxide. These gases increase the planet's average surface temperature, causing ice to melt in places such as Greenland and Antarctica.

Q: What are some ways these higher sea levels might be affecting people and other living things?

A: Responses will vary. Possible responses include that people's homes can flood if the sea level is too high and that other living things might no longer have the right habitats to live in. For example, some migratory birds depend on seashore organisms for food; as rising sea levels make beaches inaccessible, those birds cannot find enough to eat.

Activity Tips

More information on the sources and effects of greenhouse gases is available in the Climate Change Overview and Extreme Temperatures lessons. More information about other consequences of the increase in global average temperature is available in the Extreme Precipitation and Wildfires and Drought lessons.

Although sea levels have increased in many places since the early 1900s, they have not increased everywhere. In locations such as Alaska and Scandinavia, the land is also rising, due to tectonic processes and the removal of weight as ice melts. If students are interested in this phenomenon, it may be useful to distinguish between absolute sea level (the level of the sea above the center of the Earth, which is increasing everywhere) and relative sea level (the level of the sea compared to the coast nearby, which is increasing in most places but decreasing in some).

Although sea level rise is one reason for increased coastal flooding, there are other reasons as well. One is an increase in impermeable pavement, which, unlike soil or wetlands, cannot absorb water and so leads to increased flood levels during rainfall. Extreme precipitation also increases the likelihood of flooding during storms. Often, poor people and people of color face the greatest exposure to flood risk. This is an example of environmental injustice, a situation in which disadvantaged groups suffer the greatest harms from environmental conditions. If time permits, discuss this concept with students. Have students consider other situations in which environmental injustice occurs and possible ways to combat it.

Rising sea level is not the only climatic threat to marine organisms. Much of the carbon dioxide released by human activities is absorbed by the ocean. This absorption of carbon dioxide leads to a series of chemical reactions that reduces the pH of the water. Before the Industrial Revolution, the pH of the ocean was 8.2; in 2020, it was 8.1, meaning its acidity had increased by about a third. This increased acidity makes it difficult for organisms to build shells and other structures. If students are interested, have them consider how this change might affect individual organisms and the food webs of which they are a part.

7. Tell students that an increase in Earth's average temperature increases sea level in several ways. Play the video *Sensing Our Climate: Rising Sea Level* (3:32).

watch video

Activity Tips

If students are interested in the thermal expansion of water, show the video *Thermal Expansion* (0:31). This video gives another example of the same phenomenon: the air in a balloon expanding when exposed to the heat of a light. Students can attempt to list other examples of this phenomenon in order to develop a model explaining why it occurs.

Sea level data can be collected either directly at Earth's surface or by remote sensing from above. If students are interested, you can consider possible benefits and drawbacks of collecting data from the ground, from the atmosphere, or from space. For example, remote sensing measurements require expensive equipment, can be blocked by clouds, and do not always have high resolution, but they can cover large areas and observe places difficult or impossible to reach on the ground.

Aqua, the NASA satellite mentioned in the video, was launched in 2002. Its name (Latin for *water*) comes from its primary mission to learn more about the water cycle.

A possible student misconception is that melting sea ice contributes to sea level rise. In fact, sea ice such as that in the Arctic is already displacing water, so it does not substantially change the sea level when it melts; the melt that affects sea level is from land ice in places such as Greenland and Antarctica. However, melting sea ice still has consequences for the climate, as it can affect ocean currents. It also exposes more seawater to sunlight. Since dark seawater absorbs more heat from sunlight than bright ice, this change causes increased warming.

Discuss the video. Ask:

Q: What else did you learn about sea level rise from the video?

A: Responses will vary. A possible response is that increased temperature causes sea level rise both by melting ice and by causing the thermal expansion of water. Students may also discuss how scientists can use remote sensing, the science of scanning Earth from a distance using technology like satellites and high-flying airplanes, to gather information about climate change.

Q: What does the video say about how humans can respond to climate change?

A: Humans can use satellites to monitor changes, and they can use technologies such as coastal barriers to limit the impacts of sea level rise.

8. Explain to students that there are different ways to use technology in response to climate change. Mitigation is human action that limits the concentration of greenhouse gases in the atmosphere, such as using electric cars instead of cars that burn gas. Adaptation is human action that limits the harm caused by climate change, such as building barriers to prevent flooding.

On a whiteboard or chart paper, make a table with the headings "Mitigation" and "Adaptation." Have students brainstorm other examples of each strategy and add them to the chart.

Mitigation *human action that limits the concentration of greenhouse gases in the atmosphere*	**Adaptation** *human action that limits the harm caused by climate change*
• Using electric cars that do not burn fossil fuels	• Building barriers to prevent flooding

Activity Tips

To avoid confusion, you can explain to students that mitigation and adaptation have different definitions outside the context of climate change. Students may be familiar with other uses of the terms; for example, in biology, adaptation means "a characteristic that allows a living thing to survive in its environment."

9. Tell students that while it can be hard to protect other parts of the country or the world from climate change, there's a lot they can do to protect the people, animals, plants, and environment around them. Today, they will suggest ideas for mitigation and adaptation in their community. Distribute *Mitigation Strategies* (English | Spanish) and explain that they will use it to record sources of greenhouse gas emissions at their school. Distribute *Adaptation Strategies* (English | Spanish) and explain that they will use it to record ways that their school might be affected by sea level rise.

Activity Tips

Depending on time, your school environment, and other lessons you have already completed, you may choose to focus only on mitigation or adaptation. (The mitigation activity in this lesson also appears in the Extreme Temperatures, Extreme Precipitation, and Wildfires and Drought lessons.) Distribute only the appropriate sheet to students and use only the relevant discussion questions later in the activity.

If your in-class time is limited, students can complete the investigation and brainstorming of mitigation and adaptation strategies without leaving the classroom, or they can do so outside of class time.

10. Travel around the school and school grounds; possible places to visit include a cafeteria, heating or cooling equipment, dumpsters or other waste disposal, a garden or other green space, and vehicles or parking. Have students work individually or in small groups to record sources of greenhouse gases on the left side of Mitigation Strategies and vulnerabilities to sea level rise on the left side of Adaptation Strategies. Draw student attention to relevant features of the school environment as necessary.

Activity Tips

Although mitigation is often discussed in terms of reducing the sources that emit greenhouse gases into the atmosphere, enhancing the sinks that absorb greenhouse gases from the atmosphere is also a mitigation strategy. Examples of important sinks include the ocean and plants. It may be appropriate to discuss the idea of greenhouse gas sinks with students (or they may bring it up themselves), especially if your school grounds contain plants.

It may benefit student understanding to distinguish between direct and indirect greenhouse gas emissions. In the case of a school, direct emissions are those that happen on the school grounds, such as burning fuels for heat or in the engine of an idling school bus. Indirect emissions happen off the school grounds, such as at a power plant, in a factory, at a landfill, or on a farm, but nevertheless occur for the sake of the school. Students can research locations that are responsible for your school's indirect emissions; in some cases, those locations may be in another city, state, or country!

As you travel around the school, it may also be appropriate for students to ask individuals (other students, teachers, workers, and administrators) about their knowledge of the school's greenhouse gas emissions and vulnerability to sea level rise. Make sure to arrange any interviews ahead of time. You could also have individuals come to visit your classroom.

The National Oceanic and Atmospheric Administration has tools for visualizing future sea level rise in a variety of climate scenarios. Consider sharing projected rise amounts for given years or scenarios. Your state or community may also have an amount of sea level rise that it uses for infrastructure planning.

11. Return to the classroom. In small groups or as a class, have students share the greenhouse gas sources they recorded on Mitigation Strategies. Ask:

Q: What sources of greenhouse gases did you notice?

A: Responses will vary. Possible responses include vehicles, such as school buses or garbage trucks; devices that use electricity, such as lights or air conditioners; objects whose manufacture releases greenhouse gases, such as paper or cement; food whose production releases greenhouse gases, such as beef and milk; garbage, which can release greenhouse gases in a landfill; heating devices, such as furnaces; and the removal of plants or green space.

12. Explain that students can use their knowledge about climate change to plan ways to reduce the school's greenhouse gas emissions. Ask:

Q: What changes can we make here to mitigate climate change?

A: Responses will vary. Possible responses include reducing activities that produce greenhouse gases (such as idling cars outside the school), making activities more efficient (such as using efficient light bulbs), and doing them in ways that do not require fossil fuels (such as using cars and school buses powered by electricity from a non-carbon source).

Have students fill in the right column of Mitigation Strategies with the ideas they discuss.

13. Explain that although mitigation is extremely important for reducing the future effects of climate change, some effects, such as sea level rise, are already happening. In small groups or as a class, have students share the ways that the school might be affected by sea level rise that they recorded on Adaptation Strategies. Ask:

> **Q: How might our school be affected by sea level rise?**
>
> *A: Responses will vary. Possible responses include buildings and other infrastructure flooding, having water become polluted and unsuitable for drinking or other uses, and having people and animals get wet.*

14. Explain that students can use their knowledge about climate change to plan ways to adapt the school for sea level rise. Ask:

> **Q: How could our school adapt to sea level rise?**
>
> *A: Responses will vary. Possible responses include elevating infrastructure, constructing hard barriers such as levees or soft barriers such as plants, checking groundwater quality, monitoring floods and storms, and having evacuation plans in place.*

Have students fill in the right column of Adaptation Strategies with the ideas they discuss.

15. Discuss how to put these ideas into action. Ask:

> **Q: Now that we have brainstormed ideas for mitigation and adaptation at our school, how can we put these ideas into action?**
>
> *A: Responses will vary. Some actions, such as reducing paper and electricity use, can be implemented in your classroom (and encouraged in other classrooms). Other ideas may need to be implemented by the school administration.*

> **Q: Where else could you use these strategies to mitigate and adapt to climate change?**
>
> *A: Responses will vary. Possible responses include at home and at local community organizations. Encourage students to investigate the specific circumstances in those places and share their knowledge about ways to mitigate and adapt to climate change.*

Activity Tips

Mitigation and adaptation strategies are related in several ways. The more effectively humans mitigate greenhouse gas emissions in the near term, the less adaptation we will need in the long term. Although institutions must sometimes choose between devoting resources to mitigation and to adaptation, certain strategies contribute to both goals. For example, regrowing wetlands both removes carbon dioxide from the atmosphere (mitigation) and makes flooding less severe (adaptation).

16. Wrap up by returning to the Guiding Question:

> **Q: How and why have sea levels changed since the 1920s, and how should we respond?**
>
> *A: Temperatures have changed because humans have put more greenhouse gases into the atmosphere. These gases trap heat, increasing the temperature of the planet. This increased temperature melts ice and causes the thermal expansion of water, raising sea levels. We can respond by reducing how many greenhouse gases are emitted and by adapting to protect ourselves, other living things, and the environment from sea level rise.*

Extension Activity

Use the following activity after the lesson to extend student mastery of this Grades 6–8 Science and Engineering Practice.

Constructing Explanations and Designing Solutions.

- Undertake a design project, engaging in the design cycle, to construct and/or implement a solution that meets specific design criteria and constraints.

In the days, weeks, or months following this lesson, you can extend student understanding and engagement by working to implement one or more of the mitigation or adaptation ideas generated by the class.

Many of the changes needed to mitigate and adapt to climate change cannot be effectively implemented by individuals working alone. Rather, they require collective action at the local, state, national, and international levels. Likewise, there may be some changes that students in your class cannot implement without the support of school administration. Have students consider how they can advocate for those changes. For example, students may write letters, meet with school officials, or organize an event. It may be useful for students to gather information about other benefits of the proposed strategy; for example, eliminating direct sources of greenhouse gas emissions often improves air quality.

Consider collecting data both before and after a change is implemented to understand its effects and whether it should be replicated elsewhere. For example, you could collect data about the number and types of vehicles idling outside the school both before and after the implementation of a no-idling policy, then calculate the approximate reduction in greenhouse gas emissions as a result of the change.

Glossary

Adaptation
human action that limits the harm caused by climate change

Average
a measure of center in a set of numerical data, computed by adding the values in a list and then dividing by the number of values in the list; also called a mean

Climate
trends in temperatures and conditions over long time scales

Climate Change
a long-term change in weather patterns for a given area, especially changes from the rapid rise in global temperatures seen in the last 150 years

Drought
an extended period of abnormally dry weather

Greenhouse Gas
a gas in the atmosphere that traps heat from the Sun and prevents it from radiating back out into space

Median
a measure of center in a set of numerical data: the value appearing at the center of a sorted version of a list of numerical values

Mitigation
human action that limits the concentration of greenhouse gases in the atmosphere

Model
a representation of an object, system, or process

Precipitation
rain or snow

Remote Sensing
the science of scanning Earth from a distance using technology like satellites and high-flying airplanes

Weather
short-term temperatures and conditions

Weather Patterns
typical temperatures and conditions

Wildfire
an uncontrolled fire in an outdoor area