MODULE 5

Air & Climate Change

Rising Temperatures, Rising Tides

Module Overview

In 2006, former Vice President Al Gore went on tour with the new film “An Inconvenient Truth” to educate Americans about the dangers of climate change. Since then, people in this country and around the world have awakened to the new reality of a warming planet and all the consequences that go with it. In this module, students use the phenomenon of rising sea levels and “sunny day flooding” to investigate the causes and effects of climate change including melting polar ice, the greenhouse effect, atmospheric carbon dioxide levels, and burning fossil fuels. By the end of the unit, students will have developed a cause and effect chain that leads from power plants to flooded coastlines. They will also learn how they can fight climate change through individual action, group effort, and building climate resilience into their communities.

Anchor phenomenon: A city that is flooding on a sunny day.

Pacing

- 8 activities (+2 optional) and summative assessment
- Approximately 9-13 class periods + summative assessment

Module Contents

When to Teach This Module

Finding the right place within a science scope and sequence to investigate air pollution with students can be tricky. Below you will find some information about the module that can help you decide where this it might fit into your own plans for student leaning:

- **Connection to Ecology:** Studying climate change fits well within a life science course during a unit on ecology. If you are studying ecosystems – and in particular the carbon cycle – teaching this module afterwards to see how ecosystems are affected by climate change is a natural progression. It will also allow students to dive more deeply into human impacts on ecosystems and the planet.

- **Connection to Natural Resource Usage:** If you are teaching an earth science unit on natural resource use, this module would fit well afterwards as a way to investigate the environmental consquences of using certain kinds of natural resources such as fossil fuels. Students may not make that connection until later in the unit, but the anchor phenomenon will set the stage well for students to have the eventual aha! realization of how natural resources and global climate are inextricably intertwined.

Standards Overview

Middle School NGSS standards alignment:

Performance Expectations

Focus PE:

MS-ESS3-5. Ask questions to clarify evidence of the factors that have caused the rise in global temperatures over the past century. [Clarification Statement: Examples of factors include human activities (such as fossil fuel combustion, cement production, and agricultural activity) and natural processes (such as changes in incoming solar radiation or volcanic activity). Examples of evidence can include tables, graphs, and maps of global and regional temperatures, atmospheric levels of gases such as carbon dioxide and methane, and the rates of human activities. Emphasis is on the major role that human activities play in causing the rise in global temperatures.]

Background PEs:

MS-ESS3-3. Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment.* [Clarification Statement: Examples of the design process include examining human environmental impacts, assessing the kinds of solutions that are feasible, and designing and evaluating solutions that could reduce that impact. Examples of human impacts can include water usage (such as the withdrawal of water from streams and aquifers or the construction of dams and levees), land usage (such as urban development, agriculture, or the removal of wetlands), and pollution (such as of the air, water, or land).]

MS-ESS3-4. Construct an argument supported by evidence for how increases in human population and per-capita consumption of natural resources impact Earth's systems. [Clarification Statement: Examples of evidence include grade-appropriate databases on human populations and the rates of consumption of food and natural resources (such as freshwater, mineral, and energy). Examples of impacts can include changes to the appearance, composition, and structure of Earth's systems as well as the rates at which they change. The consequences of increases in human populations and consumption of natural resources are described by science, but science does not make the decisions for the actions society takes.]

Science & Engineering Practices

Focus SEP: Analyzing data
Analyzing data in 6–8 builds on K–5 experiences and progresses to extending quantitative analysis to investigations, distinguishing between correlation and causation, and basic statistical techniques of data and error analysis.

- Construct, analyze, and/or interpret graphical displays of data and/or large data sets to identify linear and nonlinear relationships.
- Use graphical displays (e.g., maps, charts, graphs, and/or tables) of large data sets to identify temporal and spatial relationships.
- Distinguish between causal and correlational relationships in data.
- Analyze and interpret to provide evidence for phenomena.
- Consider limitations of data analysis (e.g., measurement error), and/or seek to improve precision and accuracy of data with better technological tools and methods (e.g., multiple trials).

Background SEP: Planning and carrying out investigations
Planning and carrying out investigations in 6-8 builds on K-5 experiences and progresses to include investigations that use multiple variables and provide evidence to support explanations or solutions.

- Plan an investigation individually and collaboratively, and in the design: identify independent and dependent variables and controls, what tools are needed to do the gathering, how measurements will be recorded, and how many data are needed to support a claim.
- Conduct an investigation and/or evaluate and/or revise the experimental design to produce data to serve as the basis for evidence that meet the goals of the investigation.
- Evaluate the accuracy of various methods for collecting data.
- Collect data to produce data to serve as the basis for evidence to answer scientific questions or test design solutions under a range of conditions.

Background SEP: Asking questions and defining problems
Asking questions and defining problems in 6–8 builds on K–5 experiences and progresses to specifying relationships between variables, and clarifying arguments and models. Ask questions…

- that arise from careful observation of phenomena, models, or unexpected results, to clarify and/or seek additional information.
- to determine relationships between independent and dependent variables and relationships in models.
- to clarify and/or refine a model, an explanation, or an engineering problem.
- that can be investigated within the scope of the classroom, outdoor environment, and museums and other public facilities with available resources and, when appropriate, frame a hypothesis based on observations and scientific principles.

Background SEP: **Using mathematics and computational thinking**
Using mathematics and computational thinking in 6–8 builds on K–5 experiences and progresses to identifying patterns in large data sets and using mathematical concepts to support explanations and arguments.

- Use mathematical representations to describe and/or support scientific conclusions and design solutions.
- Apply mathematical concepts and/or processes (e.g., ratio, rate, percent, basic operations, simple algebra) to scientific and engineering questions and problems.

Disciplinary Core Ideas

Focus DCI: ESS3.D: Global Climate Change
Human activities, such as the release of greenhouse gases from burning fossil fuels, are major factors in the current rise in Earth's mean surface temperature (global warming). Reducing the level of climate change and reducing human vulnerability to whatever climate changes do occur depend on the understanding of climate science, engineering capabilities, and other kinds of knowledge, such as understanding of human behavior and on applying that knowledge wisely in decisions and activities.

Background DCI: ESS3.C: Human Impacts on Earth Systems
Typically as human populations and per-capita consumption of natural resources increase, so do the negative impacts on Earth unless the activities and technologies involved are engineered otherwise.

Crosscutting Concepts

Focus CCC: Cause and Effect: Mechanism and Prediction – Events have causes, sometimes simple, sometimes multifaceted. Deciphering causal relationships, and the mechanisms by which they are mediated, is a major activity of science and engineering.

- Relationships can be classified as causal or correlational, and correlation does not necessarily imply causation.
- Cause and effect relationships may be used to predict phenomena in natural or designed systems.
- Phenomena may have more than one cause, and some cause and effect relationships in systems can only be described using probability

Background CCC: Patterns – Observed patterns in nature guide organization and classification and prompt questions about relationships and causes underlying them.

- Patterns in rates of change and other numerical relationships can provide information about natural and human designed systems.
- Patterns can be used to identify cause and effect relationships.
- Graphs, charts, and images can be used to identify patterns in data.

Scale, Proportion, and Quantity – In considering phenomena, it is critical to recognize what is relevant at different size, time, and energy scales, and to recognize proportional relationships between different quantities as scales change.

- Proportional relationships (e.g., speed as the ratio of distance traveled to time taken) among different types of quantities provide information about the magnitude of properties and processes.

Connections to Engineering, Technology, and Applications of Science
Influence of Science, Engineering, and Technology on Society and the Natural World

All human activity draws on natural resources and has both short and long-term consequences, positive as well as negative, for the health of people and the natural environment.

NGSS 5th Grade Standards alignment

Performance Expectations:

Focus PE:
5-ESS3-1. Obtain and combine information about ways individual communities use science ideas to protect the Earth's resources and environment.

Background PE:
5-ESS2-1. Develop a model using an example to describe ways the geosphere, biosphere, hydrosphere, and/or atmosphere interact. [Clarification Statement: Examples could include the influence of the ocean on ecosystems, landform shape, and climate; the influence of the atmosphere on landforms and ecosystems through weather and climate; and the influence of mountain ranges on winds and clouds in the atmosphere. The geosphere, hydrosphere, atmosphere, and biosphere are each a system.] [Assessment Boundary: Assessment is limited to the interactions of two systems at a time.]

Science & Engineering Practices

Focus SEP: Analyzing Data
Analyzing data in 3–5 builds on K–2 experiences and progresses to introducing quantitative approaches to collecting data and conducting multiple trials of qualitative observations. When possible and feasible, digital tools should be used.

- Represent data in tables and/or various graphical displays (bar graphs, pictographs and/or pie charts) to reveal patterns that indicate relationships.
- Analyze and interpret data to make sense of phenomena, using logical reasoning, mathematics, and/or computation.
- Compare and contrast data collected by different groups in order to discuss similarities and differences in their findings.
- Analyze data to refine a problem statement or the design of a proposed object, tool, or process.

Background SEP: Planning and carrying out investigations
Planning and carrying out investigations to answer questions or test solutions to problems in 3–5 builds on K–2 experiences and progresses to include investigations that control variables and provide evidence to support explanations or design solutions.

- Plan and conduct an investigation collaboratively to produce data to serve as the basis for evidence, using fair tests in which variables are controlled and the number of trials considered.
- Make observations and/or measurements to produce data to serve as the basis for evidence for an explanation of a phenomenon or test a design solution.

Background SEP: Asking questions and defining problems
Asking questions and defining problems in 3–5 builds on K–2 experiences and progresses to specifying qualitative relationships.

- Ask questions that can be investigated and predict reasonable outcomes based on patterns such as cause and effect relationships.

Background SEP: Using mathematics and computational thinking
Mathematical and computational thinking in 3–5 builds on K–2 experiences and progresses to extending quantitative measurements to a variety of physical properties and using computation and mathematics to analyze data and compare alternative design solutions.

- Describe, measure, estimate, and/or graph quantities (e.g., area, volume, weight, time) to address scientific and engineering questions and problems.

Disciplinary Core Ideas

Focus DCI: ESS3.C: Human Impacts on Earth Systems
Human activities in agriculture, industry, and everyday life have had major effects on the land, vegetation, streams, ocean, air, and even outer space. But individuals and communities are doing things to help protect Earth's resources and environments.

Background DCI: ESS2.A: Earth Materials and Systems
Earth's major systems are the geosphere (solid and molten rock, soil, and sediments), the hydrosphere (water and ice), the atmosphere (air), and the biosphere (living things, including humans). These systems interact in multiple ways to affect Earth's surface materials and processes. The ocean supports a variety of ecosystems and organisms, shapes landforms, and influences climate. Winds and clouds in the atmosphere interact with the landforms to determine patterns of weather.

Crosscutting Concepts

Focus CCC: Cause and Effect: Mechanism and Prediction – Events have causes, sometimes simple, sometimes multifaceted. Deciphering causal relationships, and the mechanisms by which they are mediated, is a major activity of science and engineering.

- Cause and effect relationships are routinely identified, tested, and used to explain change.
- Events that occur together with regularity might or might not be a cause and effect relationship.

Background CCC: **Patterns** – Observed patterns in nature guide organization and classification and prompt questions about relationships and causes underlying them.

- Patterns of change can be used to make predictions.
- Patterns can be used as evidence to support an explanation.

Connections to Engineering, Technology, and Applications of Science Influence of Science, Engineering, and Technology on Society and the Natural World

All human activity draws on natural resources and has both short and long-term consequences, positive as well as negative, for the health of people and the natural environment.

The uses of technologies and limitations on their use are driven by people's needs, desires, and values; by the findings of scientific research; and by differences in such factors as climate, natural resources, and economic conditions. Thus technology use varies from region to region and over time.

Virginia Standards of Learning (SOLs) alignment

Science & Engineering Practices	
Earth Science ES.1 (a)	Asking questions and defining problems. The student will... • ask questions that arise from careful observation of phenomena, examination of a model or theory, or unexpected results, and/or to seek additional information • generate hypotheses based on research and scientific principles • make hypotheses that specify what happens to a dependent variable when an independent variable is manipulated
Earth Science ES.1 (b)	Planning and carrying out investigations. The student will… • individually and collaboratively plan and conduct observational and experimental investigations • select and use appropriate tools and technology to collect, record, analyze, and evaluate data
Earth Science ES.1 (c)	Interpreting, analyzing, and evaluating data. The student will… • construct and interpret data tables showing independent and dependent variables, repeated trials, and means • construct, analyze, and interpret graphical displays of data and consider limitations of data analysis • apply mathematical concepts and processes to scientific questions • use data in building and revising models, supporting explanations of phenomena, or testing solutions to problems • analyze data using tools, technologies, and/or models in order to make valid and reliable scientific claims or determine an optimal design solution
Content Standards	
Earth Science ES.6	The student will investigate and understand that resource use is complex. Key ideas include… a) global resource use has environmental liabilities and benefits
Earth Science ES.11	The student will investigate and understand that the atmosphere is a complex, dynamic system and is subject to long-and short-term variations. Key ideas include… c) natural events and human actions may stress atmospheric regulation mechanisms; and d) human actions, including economic and policy decisions, affect the atmosphere.
Earth Science ES.12	The student will investigate and understand that Earth's weather and climate are the result of the interaction of the sun's energy with the atmosphere, oceans, and the land. Key ideas include… e) changes in the atmosphere and the oceans due to natural and human activity affect global climate.

Common Core State Standards alignment

Literacy Standards	
RST.6-8.3	Follow precisely a multistep procedure when carrying out experiments, taking measurements, or performing technical tasks.
RST.6-8.4	Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to grades 6-8 texts and topics.
RST.6-8.7	Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually (e.g., in a flowchart, diagram, model, graph, or table).
WHST.6-8.2	Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes.
SL.8.1	Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grade 8 topics, texts, and issues, building on others' ideas and expressing their own clearly.
Math Standards	
MP.1	Make sense of problems and persevere in solving them.
MP.2	Reason abstractly and quantitatively.
6.RP.A.1	Understand the concept of a ratio and use ratio language to describe a ratio relationship between two quantities.
6.RP.A.3	Use ratio and rate reasoning to solve real-world and mathematical problems, e.g., by reasoning about tables of equivalent ratios, tape diagrams, double number line diagrams, or equations.
7.EE.B.3	Solve multi-step real-life and mathematical problems posed with positive and negative rational numbers in any form (whole numbers, fractions, and decimals), using tools strategically. Apply properties of operations to calculate with numbers in any form; convert between forms as appropriate; and assess the reasonableness of answers using mental computation and estimation strategies.
7.RP.A.3	Use proportional relationships to solve multistep ratio and percent problems. Examples: simple interest, tax, markups and markdowns, gratuities and commissions, fees, percent increase and decrease, percent error.

5E Module Flow

Activity 1 (Engage): Under Water
Timing: 45 minutes
Purpose: Introducing the anchor phenomenon and developing questions and methods to investigate them

- ✓ Students will make observations and ask questions to better understand the phenomenon of “sunny day flooding”
- ✓ Students will generate ideas for how to answer their questions about the phenomenon

Activity 2 (Explore): Where Does Sunny Day Flooding Happen?
Timing: 60 minutes
Purpose: Making a cause-effect connection between sunny day flooding and sea level rise in coastal communities

- ✓ Students will use maps to determine the location of sunny day floods in order to investigate the cause of the phenomenon.
- ✓ Students will understand how sea level rise affects coastal communities

Activity 3 (Explore): Why Are Sea Levels Rising?
Timing: 1-2 class periods (60-90 minutes)
Purpose: Planning and conducting experiments to show a cause-effect connection between sea level rise and melting land ice

- ✓ Students will design and conduct experiments to determine the effect of melting land and sea ice on sea level change.

Activity 4 (Explain): Rising Temperatures, Rising Tides
Timing: 60 minutes
Purpose: Connecting global temperature increases to rising carbon dioxide levels and the greenhouse effect.

- ✓ Students will analyze graphs to identify the correlation between carbon dioxide concentrations in the atmosphere and global temperature increases
- ✓ Students will be able to explain the greenhouse effect in order to show how carbon dioxide is causing global temperature increases

Activity 5 (Explore/Explain): The Urban Heat Island Effect (optional)
Timing: 1-2 class periods (60-90 minutes)
Purpose: Demonstrating how the greenhouse effect and urban heat islands work

- ✓ Students will perform experiments to simulate how the greenhouse effect works
- ✓ Students will perform experiments to explain one cause of the urban heat island effect

Activity 6 (Explore): Atmosphere in a Jar
Timing: 45-60 minutes
Purpose: Understanding the composition of Earth’s atmosphere

- ✓ Students will know what gases make up Earth’s atmosphere and in what proportions
- ✓ Students will use sampling and quantitative analysis to estimate the composition of a mixture

Activity 7 (Elaborate): How Must is a PPM? (optional)
Timing: 30-45 minutes
Purpose: Building understanding of the unit "part-per-million"
- ✓ Students will develop an intuitive and mathematical sense of the unit parts-per-million
- ✓ Students will understand that very small amounts of pollution can have a big effect on the atmosphere

Activity 8 (Elaborate): Climate Change and Resilience
Timing: 60 minutes
Purpose: Understanding the effects of rising global temperatures (climate change) and what communities can do to protect themselves from these effects
- ✓ Students will understand the concept of climate change and how it is tied to atmospheric CO_2 concentration
- ✓ Students will understand the concept of climate resilience and how it applies to sea level rise

Activity 9 (Elaborate): CO_2 Sources & Solutions
Timing: 45 minutes
Purpose: Understanding the where greenhouse gases come from and how to minimize those sources
- ✓ Students will understand where fossil fuels come from
- ✓ Students will understand how carbon dioxide gets into the atmosphere from fossil fuels
- ✓ Students will identify local sources of greenhouse gas emissions
- ✓ Students will brainstorm ideas for keeping carbon dioxide out of the atmosphere

Activity 10 (Elaborate): Doing Our Part
Timing: 2 or more class periods (120+ minutes)
Purpose: Provoding an opportunity to students to take an active role in preventing climate change through both individual and group efforts
- ✓ Students will use what they have learned in the module to create individual and group action plans to address climate change.
- ✓ Students will advocate for climate change in their communities by completing a group action project.

Activity 11 (Evaluate): Earth in 2050
Timing: 30 minutes
Purpose: Assessing students' mastery of key module learning objectives and skills
- ✓ Students will demonstrate their understanding of key climate change ideas related to greenhouse gases, sea level rise, and climate resilience.
- ✓ Students will interpret graphs to draw conclusions about climate change scenarios

Module Materials

Activity 1 (Engage): Under Water

- ❐ Handouts: Phenomenon I See I Wonder
- ❐ Materials needed: Computer & projector, Sticky notes (enough for all students to have a few)
- ❐ Optional materials: Plain paper, Air Quality Champion interview (optional) – see end of module

Activity 2 (Explore): Where Does Sunny Day Flooding Happen?

- ❐ Handouts: Sunny Day Floods
- ❐ Materials needed: Computer & projector
- ❐ Optional materials: Student computers (highly recommended)

Activity 3 (Explore): Why Are Sea Levels Rising?

- ❐ Handouts: What is Causing the Ocean to Rise?
- ❐ Materials needed: Computer & projector, Ice, Water, Measuring cups, Containers, Rulers, Clay or other materials to make "land" (see activity for details on these materials)
- ❐ Optional materials: Scale (optional to weigh ice), Heat lamp

Activity 4 (Explain): Rising Temperatures, Rising Tides

- ❐ Handouts: Rising Temperatures, Rising Tides
- ❐ Materials needed: Computer & Projector, Speakers for video
- ❐ Optional materials: None

Activity 5 (Explore/Explain): The Urban Heat Island Effect

- ❐ Handouts: The Urban Heat Island Effect
- ❐ Materials needed: Computer & projector, Glass jars with a whole punched in the lid for a thermometer, Thermometers, Black and white construction paper, Other "surface" materials: soil, grass, rocks, sticks, sand, roof shingle, water, etc., Stopwatch (at least one),
- ❐ Optional materials: Clipboards (for recording data outside), Graph paper

Activity 6 (Explore): Atmosphere in a Jar

- ❐ Handouts: Atmosphere in a Jar activity sheet, Atmosphere in a Jar summary questions (optional)
- ❐ Materials needed: Computer & projector, One apple (any kind), Beans for Atmosphere in a Jar (see teacher handout), One large clear container, Small cups – enough for one per student group, Calculators,
- ❐ Optional materials: Apple peeler, Chart paper & markers

Activity 7 (Elaborate): How Much is a PPM? (optional)

- ❒ Handouts: How Much is a PPM?
- ❒ Materials needed: Atmosphere in a Jar (from previous activity)
- ❒ Optional materials: none

Activity 8 (Elaborate): Climate Change & Resilience

- ❒ Handouts: What is Climate Change?, Climate Resilience and Sea Level Rise
- ❒ Materials needed: Computer & Projector, Speakers (for video)
- ❒ Optional materials: none

Activity 9 (Elaborate): CO_2 Sources & Solutions

- ❒ Handouts: Carbon dioxide and Fossil Fuels graphic organizer
- ❒ Materials needed: Computer & projector, Speakers (for video), Plain paper
- ❒ Optional materials: Student computers

Activity 10 (Elaborate): Doing Our Part

- ❒ Handouts: My carbon footprint, What I Can Do, What We Can Do
- ❒ Materials needed: Computer & projector, Speakers (for video and podcast), Make A Pledge!
- ❒ Optional materials: Student computers

Activity 11 (Evaluate): Earth in 2050

- ❒ Handouts: Earth in 2050 assessment
- ❒ Materials needed: Computer & projector
- ❒ Optional materials: none

Teacher Background Information

Climate Change Basics

How is the climate changing in the U.S.?

Observations across the United States and world provide multiple, independent lines of evidence that climate change is happening now.

Our Earth is warming. Earth's average temperature has risen by 1.5°F over the past century, and is projected to rise another 0.5 to 8.6°F over the next hundred years. Small changes in the average temperature of the planet can translate to large and potentially dangerous shifts in climate and weather.

The evidence is clear. Rising global temperatures have been accompanied by changes in weather and climate. Many places have seen changes in rainfall, resulting in more floods, droughts, or intense rain, as well as more frequent and severe heat waves.

The planet's oceans and glaciers have also experienced some big changes – oceans are warming and becoming more acidic, ice caps are melting, and sea levels are rising. As these and other changes become more pronounced in the coming decades, they will likely present challenges to our society and our environment.

What is the difference between climate change and global warming?

Global warming refers to the recent and ongoing rise in global average temperature near Earth's surface. It is caused mostly by increasing concentrations of greenhouse gases in the atmosphere. Global warming is causing climate patterns to change. However, global warming itself represents only one aspect of climate change.

Climate change refers to any significant change in the measures of climate lasting for an extended period of time. In other words, climate change includes major changes in temperature, precipitation, or wind patterns, among other effects, that occur over several decades or longer.

Humans are largely responsible for recent climate change

Over the past century, human activities have released large amounts of carbon dioxide and other greenhouse gases into the atmosphere. The majority of greenhouse gases come from burning fossil fuels to produce energy, although deforestation, industrial processes, and some agricultural practices also emit gases into the atmosphere.

Greenhouse gases act like a blanket around Earth, trapping energy in the atmosphere and causing it to warm. This phenomenon is called the greenhouse effect and is natural and necessary to support life on Earth. However, the buildup of greenhouse gases can change Earth's climate and result in dangerous effects to human health and welfare and to ecosystems.

Climate change affects everyone

Our lives are connected to the climate. Human societies have adapted to the relatively stable climate we have enjoyed since the last ice age which ended several thousand years ago. A warming climate will bring changes that can affect our water supplies, agriculture, power and transportation systems, the natural environment, and even our own health and safety.

Some changes to the climate are unavoidable. Carbon dioxide can stay in the atmosphere for nearly a century, so Earth will continue to warm in the coming decades. The warmer it gets, the greater the risk for more severe changes to the climate and Earth's system. Although it's difficult to predict the exact impacts of climate change, what's clear is that the climate we are accustomed to is no longer a reliable guide for what to expect in the future.

We can reduce the risks we will face from climate change. By making choices that reduce greenhouse gas pollution, and preparing for the changes that are already underway, we can reduce risks from climate change. Our decisions today will shape the world our children and grandchildren will live in.

You can take action. You can take steps at home, on the road, and in your office to reduce greenhouse gas emissions and the risks associated with climate change. Many of these steps can save you money; some, such as walking or biking to work, can even improve your health! You can also get involved on a local or state level to support energy efficiency, clean energy programs, or other climate programs.

Source: Climate Change Basic Information. US EPA
https://19january2017snapshot.epa.gov/climatechange/climate-change-basic-information_.html

Additional Climate Change Resources

There are many, many resources available online to provide deeper understanding of climate change, including several great videos. Because climate change can be a controversial topic, make sure to get additional information from reputable sources.

Here are a few additional resources to check out:

- **Global Climate Change: Vital Signs of the Planet.** This is an excellent website from NASA that includes up-to-date data, evidence, news, interactive simulations, and more about climate change: https://climate.nasa.gov/

- **Climate Change Basics**. This is a short, but useful video about climate change from the US EPA: https://www.youtube.com/watch?v=ScX29WBJI3w#at%3D81

- **NOAA's Climate Portal:** This website isn't as fancy as NASA's, but it has a lot of data, teaching resources, images, and other information about climate change. Also, it's an easy address to remember: https://climate.gov/

Is Sea Level Rising?

Yes, sea level is rising at an increasing rate.

Global sea level has been rising over the past century, and the rate has increased in recent decades. In 2014, global sea level was 2.6 inches above the 1993 average—the highest annual average in the satellite record (1993-present). Sea level continues to rise at a rate of about one-eighth of an inch per year.

Higher sea levels mean that deadly and destructive storm surges push farther inland than they once did, which also means more frequent nuisance flooding. Disruptive and expensive, nuisance flooding is estimated to be from 300 percent to 900 percent more frequent within U.S. coastal communities than it was just 50 years ago.

The two major causes of global sea level rise are thermal expansion caused by warming of the ocean (since water expands as it warms) and increased melting of land-based ice, such as glaciers and ice sheets. The oceans are absorbing more than 90 percent of the increased atmospheric heat associated with emissions from human activity.

With continued ocean and atmospheric warming, sea levels will likely rise for many centuries at rates higher than that of the current century. In the United States, almost 40 percent of the population lives in relatively high-population-density coastal areas, where sea level plays a role in flooding, shoreline erosion, and hazards from storms. Globally, eight of the world's 10 largest cities are near a coast, according to the U.N. Atlas of the Oceans.

Sea level rise at specific locations may be more or less than the global average due to local factors such as land subsidence from natural processes and withdrawal of groundwater and fossil fuels, changes in regional ocean currents, and whether the land is still rebounding from the compressive weight of Ice Age glaciers. In urban settings, rising seas threaten infrastructure necessary for local jobs and regional industries. Roads, bridges, subways, water supplies, oil and gas wells, power plants, sewage treatment plants, landfills—virtually all human infrastructure—is at risk from sea level rise.

What's the difference between global and local sea level?

Global sea level trends and relative sea level trends are different measurements. Just as the surface of the Earth is not flat, the surface of the ocean is also not flat—in other words, the sea surface is not changing at the same rate globally. Sea level rise at specific locations may be more or less than the global average due to many local factors: subsidence, upstream flood control, erosion, regional ocean currents, variations in land height, and whether the land is still rebounding from the compressive weight of Ice Age glaciers.

Sea level is primarily measured using tide stations and satellite laser altimeters. Tide stations around the globe tell us what is happening at a local level—the height of the water as measured along the coast relative to a specific point on land. Satellite measurements provide us with the average height of the entire ocean. Taken together, these tools tell us how our ocean sea levels are changing over time.

Source: Is sea level rising? National Ocean Service, National Oceanic and Atmospheric Administration: https://oceanservice.noaa.gov/facts/sealevel.html

Additional Resources

- **Sea-level rise projections for Maryland 2018**. This is a very informative and detailed report from the University of Maryland Center for Environmental Science (UMCES) about how sea-level is expected to rise in Maryland https://www.umces.edu/sea-level-rise-projections

- **Climate Resilience Portal**. This website is a great primer on climate resilience from the Center for Climate and Energy Solutions. As we work to help students develop proactive attitudes about addressing climate change, climate resilience is an important concept for them to understand: https://www.c2es.org/content/climate-resilience-overview/

- **Baltimore Climate Action Plan.** Baltimore's Climate Action plan has been lauded for its inclusive approach of working directly with residents to build a plant to tackle climate change. The plan is extensive, but you can also read a summary on their webpage, and also check out a cute animated video that goes with it here: https://www.baltimoresustainability.org/plans/climate-action-plan/

Quantities and units used in this module

Air pollutants, including carbon dioxide, may be harmful at very small amounts. To describe these very small amounts of gases, scientists use the measures parts per million (ppm) and parts per billion (ppb). One percent is equal to one part per hundred or 10,000 parts per million. Similarly, one part per million equals 0.0001%.

$$1\% = \frac{1}{100} \times \frac{10{,}000}{10{,}000} = \frac{10{,}000}{1{,}000{,}000}$$

1% = 10,000 ppm

$$\frac{1}{1{,}000{,}000} \times \frac{0.0001}{0.0001} = \frac{0.0001}{100} = 0.0001\%$$

1 ppm = 0.0001%

Expressed using ppm, the major components of Earth's atmosphere are:

- Nitrogen: 780,800 ppm (78.08%)
- Oxygen: 209,500 ppm (20.95%)
- Argon: 9,340 ppm (0.93%)
- Water vapor: ~10,000 ppm (~1%)
- Carbon dioxide: 410 ppm (0.041%)

Activity 1 (Engage): Under Water

ACTIVITY DETAILS

Time: 45 minutes

Objectives

- ✓ Students will make observations and ask questions to better understand the phenomenon of "sunny day flooding"
- ✓ Students will generate ideas for how to answer their questions about the phenomenon

Materials

- ✓ Sticky notes (enough for all students to have a few)
- ✓ Plain paper (optional)

Handouts

- ✓ Phenomenon I See I Wonder
- ✓ Air Quality Champion interview (optional) – see end of module

Alternative media

- ✓ Instead of showing students the pictures, you can show them this video without sound from 0:32 to 1:20: https://youtu.be/h-BSJXMkeqg
- ✓ Leaving the sound off will prevent "giving away" the explanation

Activity summary: In this introductory activity, students look at pictures or watch a video of "sunny day flooding" which occurs due to high tides and rising sea level as opposed to rainfall. From these images, they generate and organize questions for their new investigation, and brainstorm ways that they can answer those questions.

Standards Connection
DCI: ESS3.C: Human Impacts on Earth Systems
SEP: Asking Questions and Defining Problems
CCC: Cause & Effect

Warmup: Have you ever had a flood in your neighborhood or home? What was the weather like before and during the flood?

- The purpose of this warmup is for students to make a connection with flooding, and to setup a contrast between flooding they are likely used to (during/after a storm) and flooding due to sea-level rise.

1. **Frame the activity:** Tell students that today they are starting a new investigation. For this investigation they are going to be looking at a major global phenomenon from the perspectives of many different people: including scientists, business owners, and themselves.

2. **Introduce the Phenomenon:** Pass out the Phenomenon I See I Wonder handout to students. Then show them pictures of sunny-day flooding (flooding that occurs without a storm), or put up pictures and have them do a gallery walk. Have students write down what they see and what they wonder about the pictures. Sample pictures:

Photo by Amy McGovern

Once students have had a chance to look at all the pictures, have them what they notice. Possible answers:

- It's not raining in any of these pictures
- The sky is blue in some of the pictures
- The water level is high

Tell students that this type of flood has a special name called, a "sunny day flood." Ask students why they think it's called a sunny day flood (because the flood happens when there's no rain).

3. **Generating questions:** Make sure students have written down some wonderings (ex. where is this? or what happened before the flood?) If they haven't, give them a moment to write down any wonderings that they have. Tell students that they are now going to generate some questions from their wonderings to use during their investigation. Pass out a few sticky notes to each student, and tell them to write one question that they have per sticky note. The questions should be things they want to know about what they see in the pictures. They can come directly from their wonderings or they can be totally different questions. For example: Where did the water come from? Did the water stay like that or did it go back down? What time of year did the flooding happen? Was it raining a lot before the flooding happened? How often does this flooding happen? What caused this flood?

   If students struggle to come up with questions, have them think about what they see to help them make up questions.

4. **Organizing questions**. Have students start by sharing their questions with one another in a small group. If two people have the same (or very similar) questions, they should put the sticky notes together. Next, have each group share one of their questions with the whole group, and put that question up on the wall or a piece of chart paper. Rotate from group to group, sharing questions. If one group has a similar question, put the sticky notes together. Once all the questions are up, have students organize the questions around particular topics. For example: questions that have to do with weather (did it rain before the picture?), location (where are these pictures from?), time (what time of year was this?).

5. **Create big guiding questions:** Using the groups of questions, see if students can come up with one question that summarizes all of the questions in the group. Ex: Does this kind of flooding happen in particular places? or What is the weather like when this flooding happens? Do this together as a whole group to support students in generating good questions.

6. **How to investigate?:** Ask students how scientists answer questions. Write their responses on the board: ex. they ask other scientists, they look things up, they conduct experiments.

TEACHER NOTES

Modifications

- ✓ If students have a lot of questions, consider having them choose the top 3 questions from their group to share out loud, and put the rest up on the board at the end.
- ✓ To help organizing the questions, you may want to write them in large print on pieces of paper so students can see more easily.

TEACHER NOTES

Teacher Tip

- ✓ Some of the questions that students come up with will be ones that you will answer during the module, and others will go beyond what you have planned. The same is true of their ideas for investigation. Consider ways you can either modify upcoming activities to address their questions, or ways that you can incorporate some of their ideas for investigation into your plan. Ultimately, you will not be able to answer all students' questions through the module activities, or follow all of their suggestions. Think about other ways to make sure students recognize their ideas are valid: ex. a suggested experiment might be good for science fair or an extra credit project. Unanswered questions may be divided up and answered as a homework assignment.

Recommended

- ✓ Have students read the interview with the module's Air Quality Champion to get them into the frame of mind of what they'll be investigating

Next, ask students how they can investigate their own questions. Can they look up the answers? Do they need to perform an experiment?

Assign one big guiding question to each group of students and have them create a list of ways they could find out the answers to their big question. Make sure they are specific (ex: "Look up places that have sunny day flooding" vs. "look it up") If they get stuck, have them use the little questions to help them figure out how they might answer the big question.

Once groups are finished, have each group share out their suggestions for how to investigate the answers to their questions. Record these on chart paper to put up with the questions. When each group is done sharing, allow other students to ask them questions, or add additional ideas.

7. **Next steps:** Tell students that they have made a great start in figuring out this strange phenomenon of the sunny day flood. During the course of the investigation, they'll do some of the suggested investigations in order to answer their questions, and maybe even figure out some ways to address it. Put the questions and the suggested investigations up on the wall for future reference.

8. **Formative assessment**: Have students answer the prompt: What question is the most interesting one that you want to answer? Why?

Air Quality Champion

Vernon Morris is an atmospheric researcher with NOAA, and a university professor. Learn more about Vernon's work and his journey to where he is now at the end of the module.

Name ______________________________

STUDENT HANDOUT

Phenomenon: I See I Wonder

I see	I wonder

Activity 2 (Explore): Where Does Sunny Day Flooding Happen?

ACTIVITY DETAILS

Time: 60 minutes

Objectives

- ✓ Students will use maps to determine the location of sunny day floods in order to investigate the cause of the phenomenon.
- ✓ Students will understand how sea level rise affects coastal communities

Materials

- ✓ Computer & projector
- ✓ Student computers (highly recommended)

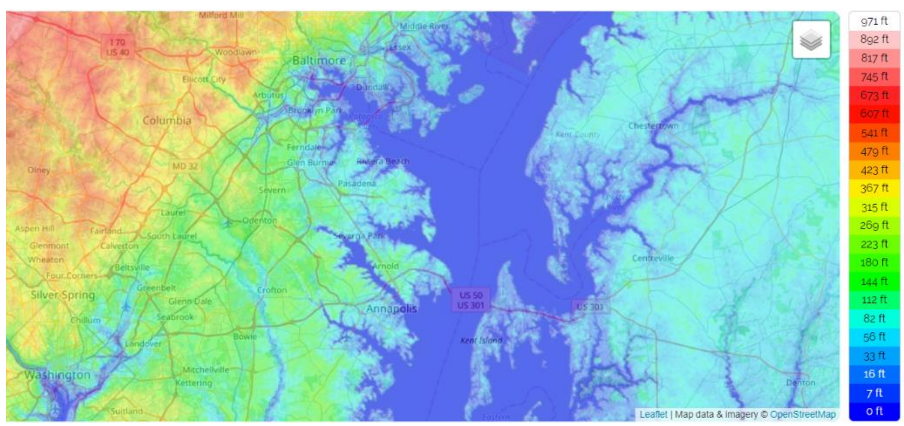
Handouts

- ✓ Sunny Day Floods

Activity summary: In this activity, students investigate the phenomenon of sunny day floods by looking at elevation and flooding maps, and then by using NOAA's online Sea Level Rise viewer. Through their research, students learn where sunny day flooding occurs, and how different sea level rise scenarios affect different communities, including their own.

<u>Standards Connection</u>
DCI: ESS 3.C: Human Impacts on Earth Systems
SEP: Analyzing data
CCC: Cause & Effect, Patterns

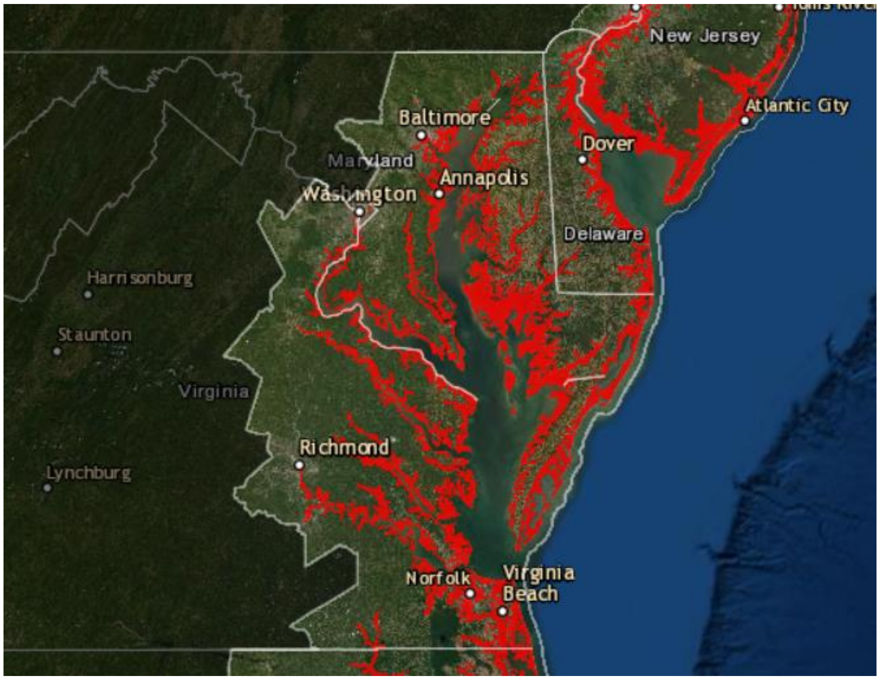
Warmup: Show students the map below, and tell them that this map shows the elevation (height) of land above sea level. The height is shown on the scale on the right. Have them use the scale to see about how high Annapolis, MD is above sea level (they can provide a range). If they are on the map, have them find how high the school is above sea level. Note: You can also go to this map at https://en-au.topographic-map.com/maps/kh4d/Severn-River/ and move it around, zoom in, or click to see the elevation in a particular location. Use the dropdown menu at the top to select English (United States) for measurements in feet.



Answer: Annapolis ranges from about 1' to 64' above sea level in different places.

1. **Frame the activity:** Look at the big guiding questions that students came up with in Activity 1. Find a question that relates to the location of the flooding, as well as an idea for investigation (if there is one). Tell students that today they are going to investigate where sunny day flooding occurs to help answer their question. If possible, make a connection to their idea for investigation as well.

2. **Where does sunny day flooding happen?** Show students the map below which shows areas of the region (in red) that currently experience sunny day flooding.



Ask students what they notice about what areas are red (they are all along the coast or along rivers). Ask students what would cause the areas along the coast to flood more often. Have them turn to a partner to discuss, and then hear answers. Use questions if necessary to help students come to the conclusion that if the sea level of the ocean is rising, then areas that are along the ocean or near it will experience more flooding.

3. **Annapolis under water:** Ask students where they think the pictures came from that they saw during Activity 1. They will likely say that they came from somewhere in the red area. Two of the pictures came from Annapolis, MD:

And one from Cambridge, MD on the Eastern Shore:

TEACHER NOTES

Map sources

- ✓ The maps for this part of the activity come from the National Oceanic and Atmospheric Administration (NOAA). Go to coast.noaa.gov/slr to access them.

Tech Tip

- ✓ If student computers are not available for the Sea Level Rise Viewer part of the activity, then it is best for the class to do the activity together using a computer connected to a projector, so they can all see as the maps change.

TEACHER NOTES

Why Annapolis?

✓ The student handout is based around Annapolis, MD because it experiences sunny day floods on an increasingly regular basis. You can also have students look at other cities nearby. There are high tide flood scenarios and local scenarios for Washington DC, Baltimore, Richmond (local scenario only), and other cities nearby.

Additional data

✓ The National Environmental Modeling and Analysis Center has graphs and other data including predicted number of flood days in the DC/ Baltimore Region. Use the link below and click on one of the blue dots on the map to access their flood days graphs for that location: https://tinyurl.com/flooddays

Tell students that they are going to look more closely at what happens when the sea level rises in places like Annapolis and Cambridge using a computer simulation.

4. **Sea level rise viewer:** Pass out the Sunny Day Floods sheet to students. If they are using student computers for the activity, pass out the computers now and have students go to http://coast.noaa.gov/slr. If student computers are not available, it is best to lead them through the activity together as a whole group using a computer connected to a projector.

   Even if students are using computers, you should walk them through the first few steps of the directions to make sure they are able to use the NOAA Sea Level Rise Viewer.

   While students are working on the activity, circulate and support as necessary. Sometimes finding the right button to click on the map may be difficult. Zooming out can often help with this, although sometimes you may need to refresh the page and go back to the location.

   When students are done with the viewer (up to the summary portion), collect student computers and lead the discussion below before having students complete the summary.

5. **Sensemaking discussion**: Ask students what they learned from using the sea level rise viewer. Use questions to help drive the conversation if these key points don't come up naturally:
   - Sea level rise affects low elevation coastal communities and those near rivers the most
   - Sunny day floods are caused by sea level rise
   - The number of sunny day floods will continue to rise if the sea level continues to rise
   - Vulnerable communities may end up completely underwater
   - People who live in vulnerable communities will have difficulty going about their lives and work if sea level continues to rise. They may have to move somewhere else.

   Close the discussion by asking students if they know what is causing the sea level to rise (don't give them any answers, this is a teaser for the next activity).

6. **Formative assessment**: Have students complete the summary section of their Sunny Day Floods sheet.

Name ____

STUDENT HANDOUT

Sunny Day Floods

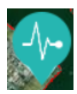
1. Using your computer, go to http://coast.noaa.gov/slr. This is the National Oceanic and Atmospheric Administration (NOAA) website for sea level rise. Click "Get started" to begin.

2. At the top of the page, where it says, "Enter an address or city" type in Annapolis, MD and click on it when it pops up.

   Look at where Annapolis is. What is the area around Annapolis like? ____________________

   ____

High Tide Flooding

3. On the left side of the map, click "High Tide Flooding." A little heartbeat icon will pop up next to Annapolis that looks like this:  Click on the icon to learn more about how much flooding happens in Annapolis. If you move your cursor over the graph, you can get information for specific years.

4. What year had the most flood days in Annapolis? ______________How many? ____________

5. What is the greatest number of flood days in Annapolis in one year before 1983? __________

6. Look at the years 2010-2017. What is the range of the number of flood days per year (the range is the lowest amount to the highest amount) (lowest) _____ - ______ (highest)

7. What is the mean (average) number of flood days per year from 2010-2017? To find the mean, add up the total number of flood days from 2010-2017 and divide by the number of years. The average number of flood days from 2010-2017 is: ____________________________

8. Do you think flooding in Annapolis is getting worse or not? Explain your answer using information from the graph. ____

   ____

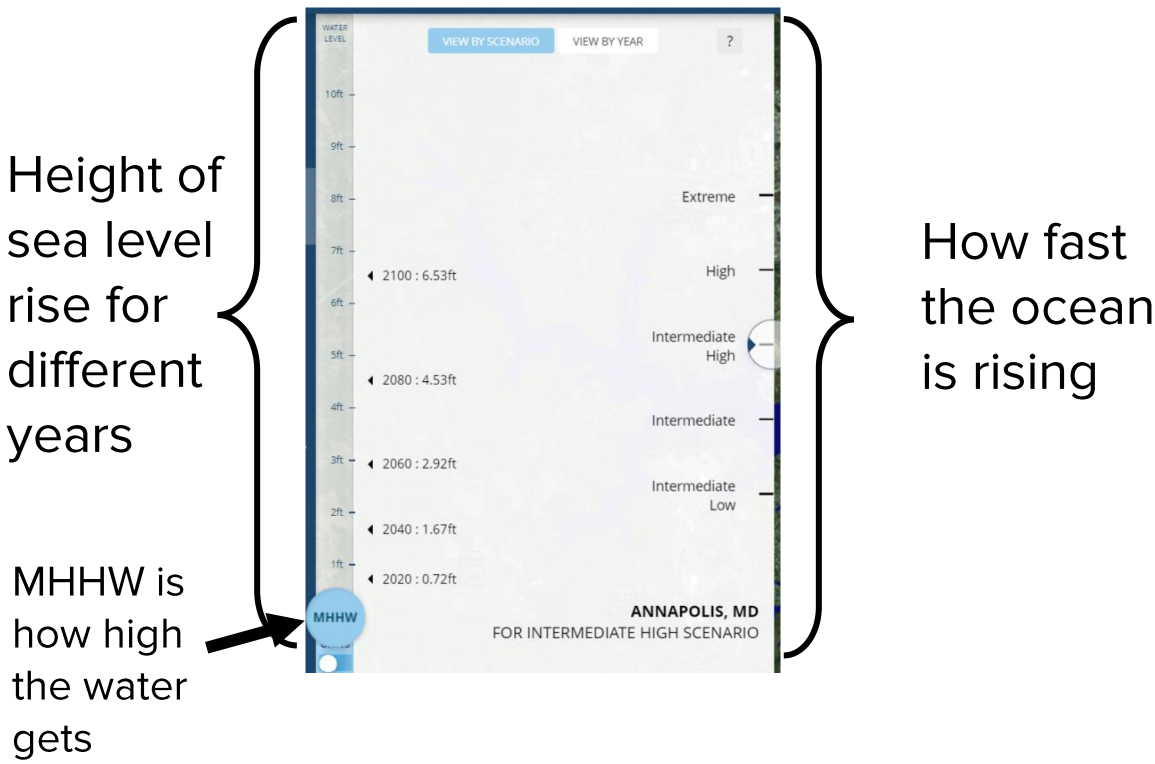
   ____

   ____

Local Scenario

9. On the left side of the map, click “Local Scenarios.” A little house icon will pop up next to Annapolis that looks like this:  Click on the icon to start the local scenario.

10. A box like the one below will pop up on the left. You can move the sliders on either side of
the box to change how high and how fast the ocean is rising. Zoom in using the + button in the bottom right to see Annapolis up close. Then try moving the sliders and seeing how the map of Annapolis changes.



11. What happens to Annapolis if you raise the sea level up to 10 feet? (what do you think the light blue means?) ____

____

12. Move the slider on the right to “Intermediate High.” This means that the ocean is rising a medium amount. Now look at the left side of the box. In what year will the ocean be 2.92 feet higher? ____________________
Move the left slide to 3 feet. How bad is the flooding in Annapolis in this scenario? __________

____

13. Now move the slider on the right to “Extreme.” This means the ocean is rising a lot. Now how high will the water be in 2060? ________________________

    Move the slider on the left to 5 feet. How bad is the flooding in Annapolis in this extreme scenario in 2060? ____

    ____

Vulnerable Places

Vulnerable places are those places that are in the most danger from sea level rise. Choose one or more of the vulnerable places below to investigate and circle the location on your paper. Use the search bar above the map to find the location.

Tangier, VA Ocean City, MD Toddville, MD Lewes, DE

14. When you are centered on the location, click on the “Sea Level Rise” button on the left and set the water level to “Current MHHW.”

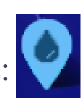
    Where is your location (ex: Is it an island? Is it at the beach? Is it on the coast?)______________

    ____

15. What does your location look like (is it flooded or dry land)? ____________________________

    ____

    Move the slider up to raise the sea level. How far do you have to go before the area is mostly underwater? ____________________________

16. Find the nearest picture by clicking on a water drop that looks like this:  You may need to zoom out to find it. When you click on it, set the water level to MHHW. What do you see? ____

    ____

    Try moving the slider up to 3 feet, 7 feet, and 10 feet. What does the location look like now? What would it be like if you were there?____

    ____

    ____

17. Do you think the people in your vulnerable area should be worried about sea level rise? Why or why not? ____
____
____

My Home

18. Put your town into the bar above the map and use the tools you have learned about today to see if your community will be directly affected.

    Will your community be flooded by sea level rise? ______________________________

    Why might you care about sea level rise even if your community is not directly flooded? _____
____
____
____
____

Summary

1. What is causing the sunny day floods? ______________________________
2. What areas are most affected by sea level rise? ______________________________
____
3. What do you expect will happen to the number of sunny day floods if sea levels continue to rise? ____
____
4. Imagine you are a business owner on a street near the harbor in Annapolis. How do you think your business will be affected by sunny day floods? ______________________________
____
____
____
____

Activity 3 (Explore): Why Are Sea Levels Rising?

Activity summary: In this activity, students design and run experiments to determine whether sea ice or land ice is having a bigger effect on sea level rise. They then use this information to draw conclusions about which is more responsible for the sunny day flooding from their original phenomenon.

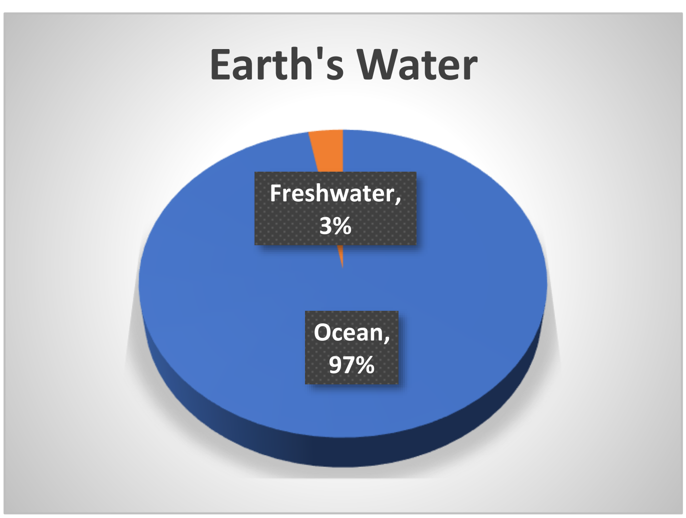
Standards Connection
DCI: ESS 3.C: Human Impacts on Earth Systems
SEP: Planning & Carrying Out Investigations
CCC: Cause & Effect

Warmup: Name as many places as you can think of where there is water (in any form) on Earth.

- Possible answers: lakes, rivers, the ocean, the atmosphere, ice, snow, the ground, etc.
- Have students share when they are done with their lists, but don't discuss further (they will use these lists shortly)

1. **Frame the Activity:** During our last activity, we learned that sea level rise is causing the sunny day flooding. The next question we have to answer then, is what is causing the sea level rise? During today's activity, we're going to do an experiment to help figure out why the ocean is rising. If students asked any questions in Activity 1 related to sea level rise (or where the water is coming from), tell students they they'll be investigating this question today.

2. **Where is the water coming from?** Have students consider the lists they made during their warmup, and ask what percentage of the world's water is in the ocean. They will likely know that most of the water is in the ocean, but they may be surprised how high the percentage is (97%). Show them the pie chart below:



ACTIVITY DETAILS

Time: 1-2 class periods (60-90 minutes)

Objective
- ✓ Students will design and conduct experiments to determine the effect of melting land and sea ice on sea level change.

Materials
(see activity for details on these materials)
- ✓ Ice, Water, Measuring cups, Containers, Rulers, Clay or other materials to make "land"
- ✓ Scale (optional to weigh ice)
- ✓ Heat lamp (optional)
- ✓ Computer & projector

Handouts
- ✓ What is Causing the Ocean to Rise?

Source
- ✓ This activity is based on NASA's *What's Causing Sea-Level Rise? Land Ice vs. Sea Ice*: https://www.jpl.nasa.gov/edu/teach/activity/whats-causing-sea-level-rise-land-ice-vs-sea-ice/ For additional photos and tips on the experiment, check out their website.

TEACHER NOTES

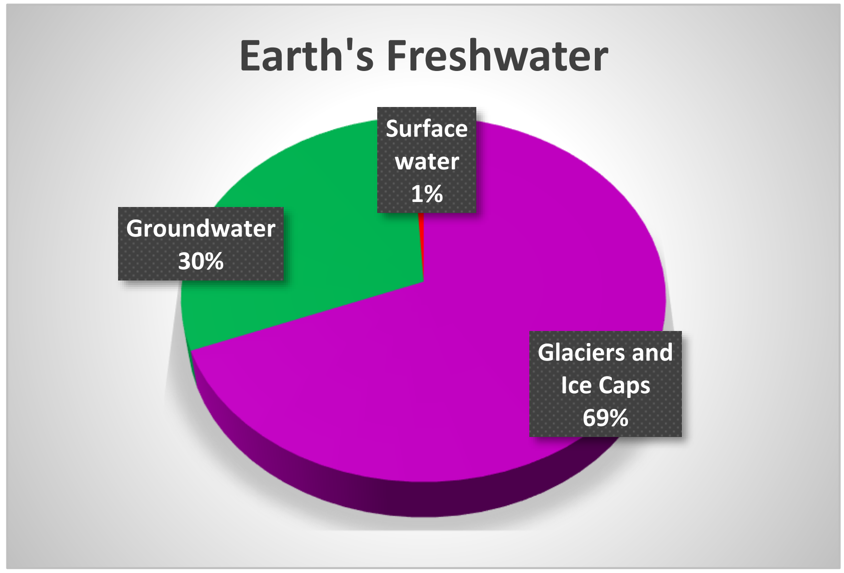
Melting ice vs. thermal expansion

- ✓ In this activity, students learn about how melting land ice affect sea level rise. Thermal expansion (when water expands as it is heated) also plays a major role in causing sea level rise. How much each of these factors affects sea level rise is still debated today. While there is not space in this activity to introduce students to thermal expansion in detail, it is worth bringing it up when time permits. See the article below for more information on the debate: https://www.carbonbrief.org/extra-water-or-more-heat-whats-driving-sea-level-rise and see this graph for additional information on how much each contributes to sea level rise: https://www.climate.gov/sites/default/files/sealevel_contributors_graph_SOTC2018_lrg.jpg

Materials

- ✓ This activity can be done in small groups (recommended) or as a whole group. If it is done as a whole group, use a larger container to make it easier for all students to see.

Next ask them where the 3% is. They will likely say things like the lakes, rivers, the air, etc. If they don't mention it, ask about water in another form. See if students recognize that some water is frozen. What percentage of the 3% is frozen as ice? Show students the pie chart below, which breaks up the 3%:



Students may be surprised to find that more than 2/3 of the freshwater on the planet (2% of the total) is frozen as ice in glaciers and ice caps (make sure students know what a glacier is). 1% of the total is in the ground, and only a tiny fraction (about 0.007%) is in lakes, rivers, and swamps.

Ask students: if the sea level is rising, where do they think the water is coming from? They will likely say it is coming from the melting ice. Tell them that during their experiment today, they are going to investigate how melting ice can affect sea levels.

3. **Land ice vs. sea ice:** Hand out the "What is Causing the Ocean to Rise?" sheet to students. Show students these two pictures and ask them what the difference is in what they see (the pictures are also on their sheets)

There are several differences, but the important one to help students see is that in the picture on the left, the ice is on land, and the picture on the right, the ice is floating in the ocean. Once picture (on the left) is Antarctica, and the other is the Arctic Ocean. Have students label the left picture "land ice" and the right picture "sea ice." Ask them where land ice is found (mountains and Antarctica) and sea ice (the Arctic Ocean). Ask students if they think land ice melting or sea ice melting is doing more to cause sea level rise. Have them write this research question on their sheets.

4. **Design the experiment:** This experiment requires a very simple setup, so rather than tell students what to do, have them design their own experiments given the materials you have. In general, student groups will need:
   - ❒ 2 identical containers (one each for sea and land ice) approximately 6" x 6"
   - ❒ Ice
   - ❒ Water
   - ❒ Something to make land out of (blocks of wood, clay, a jar, etc.
   - ❒ Something to measure height (ex. a ruler)
   - ❒ Heat lamp (optional – see timing tip on the next page)

   Tell students what materials you have available (having additional materials will give them more flexibility in their designs).

   Form students into groups and have them brainstorm ways they could test whether sea ice or land ice will make the ocean level rise higher. When they have an idea, they should share it with you for approval. You may also choose to have students share ideas as a whole group. If students are stuck, consider asking questions such as:
   - What will you need in order to *compare* sea ice vs. land ice?
   - How can you simulate land ice?
   - How can you simulate the ocean?
   - How will you measure sea level rise?

   Have students write down the materials they will use for their experiments, and draw their designs in the boxes at the bottom of their data sheets.

TEACHER NOTES

Differentiation

- ✓ Depending on students' level of experience designing their own experiments, they may have an easier or harder time getting started. You may want to brainstorm together as a class before having student groups work on their own.

Teacher Tip

- ✓ The amount of ice in each container needs to be the same. If you don't have ice cubes that you can count, suggest to students that they use a scale to weight out equal amounts of ice.

TEACHER NOTES

Teacher Tip

✓ If you are short on materials, pair up groups that have similar designs so that one builds the sea ice setup and one builds the land ice. Just make sure they work together to ensure the amount of ice and water is the same.

Timing Tip

✓ It is possible to do this experiment in a shorter time period if you set up a heat lamp or put experiments in a sunny location where the ice will melt more quickly. This will also prevent evaporation from being a variable.

5. **Variables, controls, and data gathering:** On the back of their sheets, have students consider what they are changing between the two setups (independent variable), what they are measuring (dependent variable) and what needs to be the same for both of their setups (controls). In general, these will be the same for all groups:
    - Independent variable: ice on land vs. ice in water
    - Dependent variable: the height of the water
    - Controls: same container, same amount of ice, same amount of water

   Also have students describe how they will measure the water rise, and what units they will use.

6. **Write a hypothesis:** Have students write a hypothesis about whether they think the land ice or the sea ice will make the water rise more. Encourage them to think about why the land or sea ice will make the water rise more.

7. **Build the setups:** When you are confident that students understand what they are doing, have them build their setups. As they are building, make sure they are measuring the amounts of ice and water they put into each container to be sure they are equal. Also check that the ice in the "sea ice" container is floating (not sitting on the bottom), and the land ice is above the water level.

   As groups finish building, make sure they measure the height of the water as quickly as possible before the ice starts melting.

8. **Run the experiment:** If you are having students leave the experiment overnight, then make sure you have at least 1-2 measurements before they leave class. If you are using a heat lamp, you may want students to take measurements at regular intervals. The data sheet on their handout is flexible to accommodate various methods.

9. **Data analysis:** When students have collected all their data, have them analyze the data by determining which water level rose more and by how much. You may choose to have students graph their data (especially if they took data at multiple points), but since the most consequential data is the beginning and ending points, it is not necessary.

10. **Sensemaking discussion:** As a whole group, have student groups share their results. Did everyone get the same result? Why or why not? Use discussion techniques to have students consider why the water level rose more in the "land ice" than the "sea ice." While they do not need to understand the physics of buoyancy, they should understand that the ice on land was added to the water level, making it go up. The ice in the water was already there, so when it melted, it didn't make the water go up at all.

11. **Check in with questions:** Go back to students' question board from Activity 1. Are they able to answer any of the questions they asked? If so, take a moment to acknowledge this and make note of what they've figured out.

12. **Conclusions (formative assessment):** Have students complete the conclusions section of their experiment handout, including why the water rose more in one container than the other, and which kind of ice melting they think is causing the sunny day flooding from their original phenomenon.

TEACHER NOTES

Experiment Reflection

✓ If you have time, have students reflect on their experience of designing and running their own experiments. What did they like? What was frustrating? What would they do differently next time? This opportunity to reflect on the process of science is useful in helping students learn to think like scientists.

Group Names____

STUDENT EXPERIMENT

What is Causing the Ocean to Rise?

Type of ice: ______________________________

Found in: ________________________________

Type of Ice: ______________________________

Found in: ________________________________

Research question: ____

____

Materials

-
-
-
-
-
-

Experimental Design

In the space, draw a picture of what your land ice setup will look like, and what your sea ice setup will look like:

Land ice	Sea ice

Variables & Controls

What is your independent variable? (What are you changing between your two setups?)________

____

What is your dependent variable (What are you measuring?)________________________________

What are you controlling (What needs to be the same in both of your setups?) ________________

____

Data

How will you measure your sea level rise? ____

____

What units will you use? ____

Hypothesis

Do you think the land ice or sea ice will make the water rise higher? (you can also say they will rise the same amount)

____

____

Use the table below to record your data:

	Land Ice	Sea Ice

Analysis

What does your data show? (how much did each water level change? which rose more? By how much?) ____

____

____

____

Conclusion

Was your hypothesis correct? ______________________________

Why did the water rise more in one container than the other? _________________________________

____

____

____

____

____

____

What kind of ice melting is causing sunny day flooding? Explain how you know using the result of your experiment:

____

____

____

____

____

____

____

____

____

Activity 4 (Explain): Rising Temperatures, Rising Tides

Activity summary: In this activity, students look at a series of graphs showing global temperature and carbon dioxide levels to make the connection that the two are correlated. Then they watch a video about the greenhouse effect to see how carbon dioxide is causing global temperature increases. Finally, students fill in a cause & effect graphic organizer that traces each step from greenhouse gases to the sunny day floods in their phenomenon.

Standards Connection
DCI: ESS 3.D: Global Climate Change
SEP: Analyzing Data; Constructing Explanations
CCC: Cause & Effect; Patterns

Warmup: Show students this video from NASA showing how global temperatures have risen from 1880-2018: https://www.youtube.com/watch?v=gXXOkhoki8s. Try to keep the title of the video off the screen, and at the end, have students guess what they think the video is showing. Don't tell students whether they are wrong or right: you will come back to this video later, so use this video as an opportunity to spark students' curiosity about what they will be learning today.

1. **Frame the activity:** Remind students that in their last activity, they learned that one of the causes of sea level rise is melting land ice (Antarctic ice and glaciers, largely in Greenland). But why is the ice melting in the first place? In today's activity, they are going to study why the ice is melting. If any students posted a question about climate change or global warming in Activity 1, tell them they will investigate the answers to those questions today.

2. **Global temperature change:** Ask students what could cause the ice in Antarctica to melt. Students should say something about the temperature (ex. that it is too hot). Tell them that the first piece of evidence they should look at then is the temperature. Since ice is melting all over the planet, they will look at a graph of global temperature first.

   Hand out the Rising Temperatures, Rising Tides sheet to students and have them look at the graph on the first page. You can also display the graph on the projector so they can see it in color.

ACTIVITY DETAILS

Time: 60 minutes

Objectives
- ✓ Students will analyze graphs to identify the correlation between carbon dioxide concentrations in the atmosphere and global temperature increases
- ✓ Students will be able to explain the greenhouse effect in order to show how carbon dioxide is causing global temperature increases

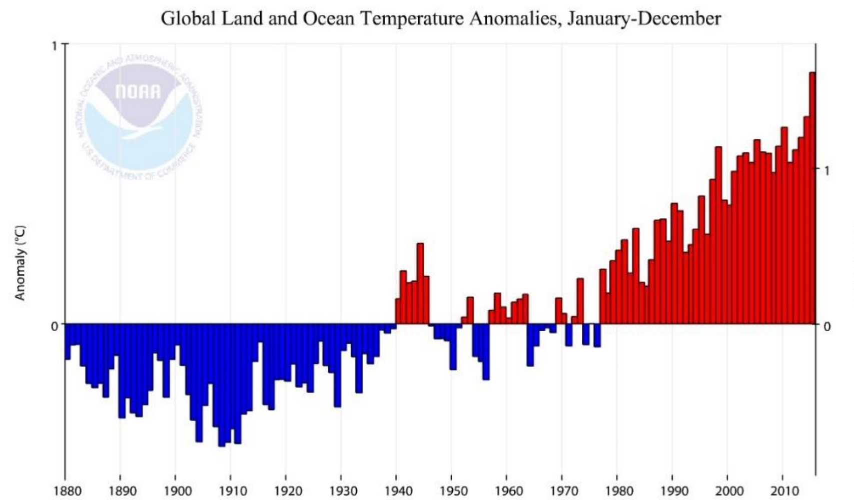
Materials
- ✓ Computer & projector
- ✓ Speakers for video

Handouts
- ✓ Rising Temperatures, Rising Tides

TEACHER NOTES

Data Sources

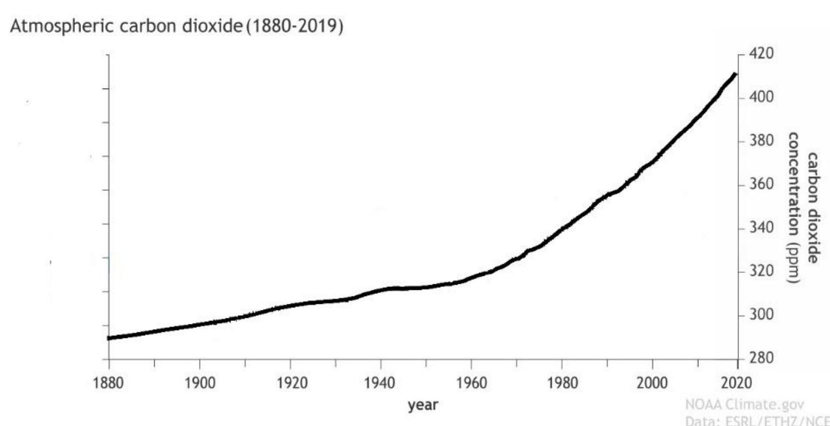
- ✓ Most of the graphs in this activity come from the National Oceanic and Atmospheric Administration (NOAA). See individual graphs for specific sources.



Take a moment to help students understand what the graph is showing, then have them answer the questions below the graph.

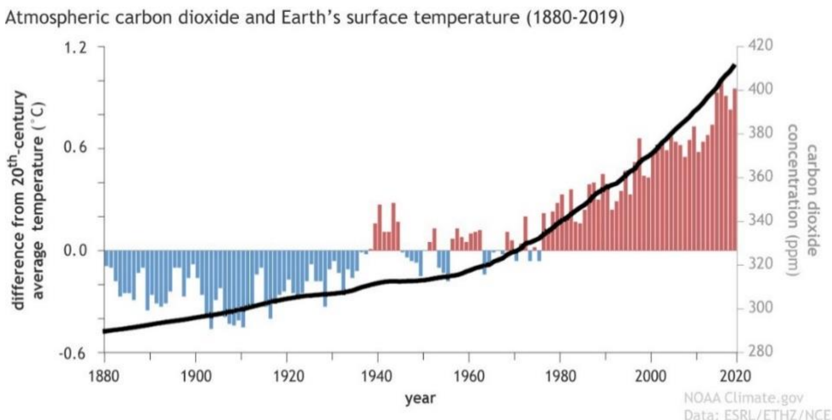
Review just the final question with students to make sure they understand that global temperatures are rising. Then go back to the NASA visualization video and make sure students see the title and the scale in the top left. Show the video again so students see the two different ways to display similar data.

3. **Carbon dioxide levels:** Have students look at the next graph and project it:



Have students answer the questions below the graph. Students will study the idea of parts per million in a later activity, but it is a good idea to mention to them that parts per million is a measurement that is similar to percent (parts per hundred). One part per million is the same as 0.0001%.

4. **Global temperatures & carbon dioxide levels:** Have students look at the third graph and project it:



Have them answer the question below it. You can review quickly afterwards, but students should have a good sense at this point that carbon dioxide levels and global temperature are correlated.

5. **Reading: correlation vs. causation:** Have students read the short passage on correlation vs. causation. This topic is always tricky for students to grasp, so take the time to review it with students afterwards. The key point in this reading for students to take away is that the data looks like carbon dioxide might be causing the global temperature to go up, but as scientists we need an explanation of why.

6. **The Greenhouse effect video:** Show this video on the greenhouse effect from the US EPA: https://www.youtube.com/watch?v=VYMjSule0Bw. Afterwards, have students turn to the next page in their handout so they can fill in the graphic. You can show the video a second time (it is short) to help students with the graphic. When they are done, discuss what they learned about the greenhouse effect. Key takeaways:
   - The greenhouse effect is necessary to keep Earth warm enough for us to live
   - The greenhouse effect works by trapping heat in Earth's atmosphere
   - Carbon dioxide is a greenhouse gas
   - Humans produce extra carbon dioxide by driving cars and using energy
   - Too many greenhouse gases are causing the Earth's temperature to rise

TEACHER NOTES

Human Population and Carbon Dioxide Emissions

✓ Rising carbon dioxide concentrations are due to increasing amounts of carbon dioxide emissions. Why emissions are rising is a more complicated story. In many places (including the US) *per capita* emissions are going down, but the *population* is going up, thus leading to higher emissions. If you have time, consider showing students this graph: https://tinyurl.com/populationCO2emissions as a way to talk about correlation, causation, and why CO2 levels are rising.

Alternative Media

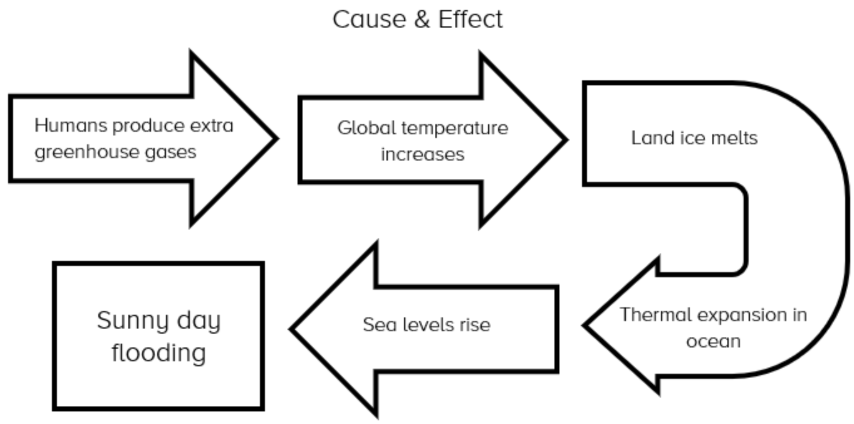
✓ There are many good videos available that explain the greenhouse effect. The one listed here is accurate and straightforward, but if you are interested in providing further detail, you may want to show one or more additional videos.

TEACHER NOTES

Modification

- ✓ Since this formative assessment is rather complex, you may choose to use the cause and effect organizer as your formative assessment and save this writing piece for later in the module.

7. **Cause & effect:** Now that the class has made connections among sunny day flooding, rising ocean levels, melting ice, rising global temperatures, rising carbon dioxide levels, and the greenhouse effect, see if students can fill in the cause and effect organizer. Make sure students understand that the arrows mean one thing *causes* the following effect, which then causes the next effect. There are a variety of ways that students can fill it in; the key is to help students internalize the cause effect relationship from one step to another. A sample cause-effect organizer is below:



Make sure to return to the causation/correlation discussion to ask students if they think carbon dioxide concentrations and global temperature are only correlated, or if one is actually causing the other.

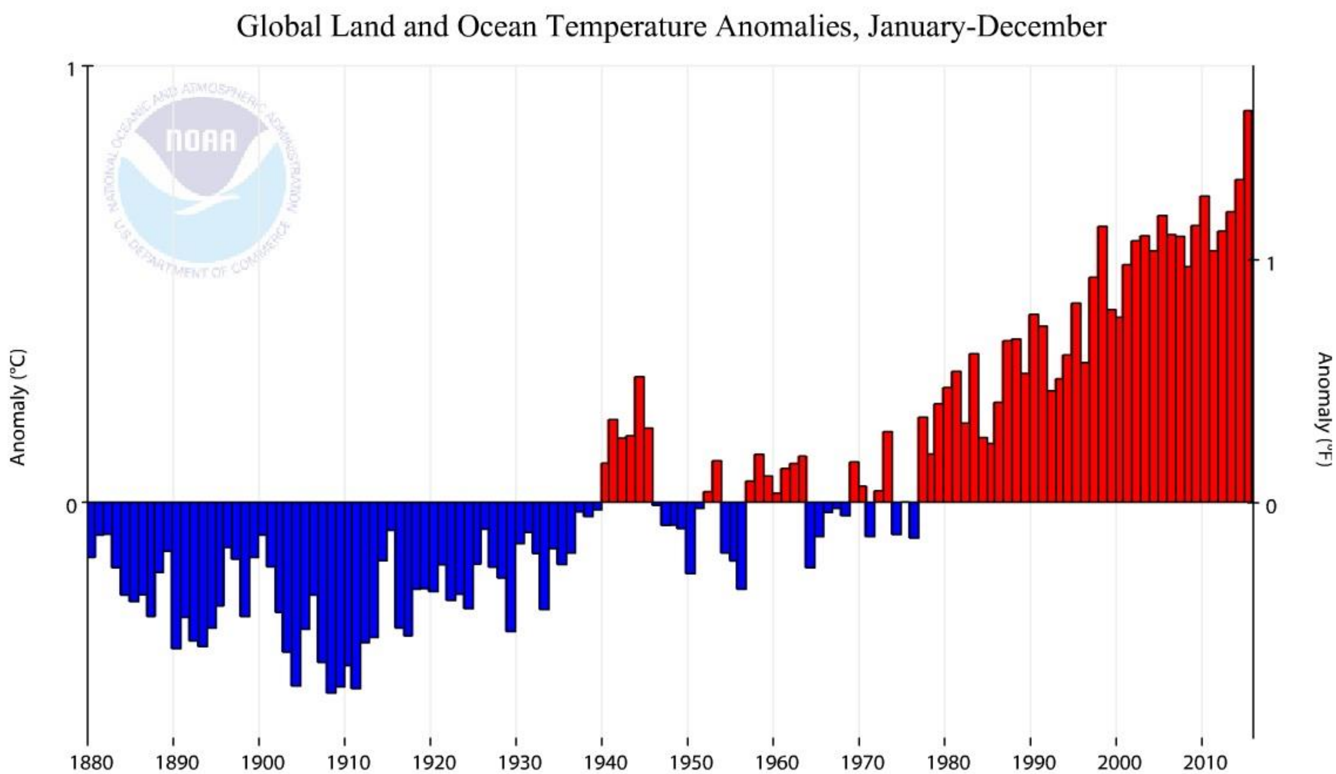
This cause and effect organizer helps to answer a lot of questions that students may have had during Activity 1, so go back to the questions board to see if there are any big questions you can answer now. If so, you may want to have students answer the question in place of the formative assessment below.

8. **Formative assessment:** Using your cause and effect organizer, and what you've learned so far in this investigation, explain how extra greenhouse gases like carbon dioxide are causing the sunny day flooding in Annapolis.

Name____

STUDENT HANDOUT

Rising Temperatures, Rising Tides



This graph shows whether the temperature in each year is hotter than average or colder than average. If a year is at 0, then it means the temperature is exactly at the average.

1. Look at 1880-1940. Is the temperature above or below average for these years? _________

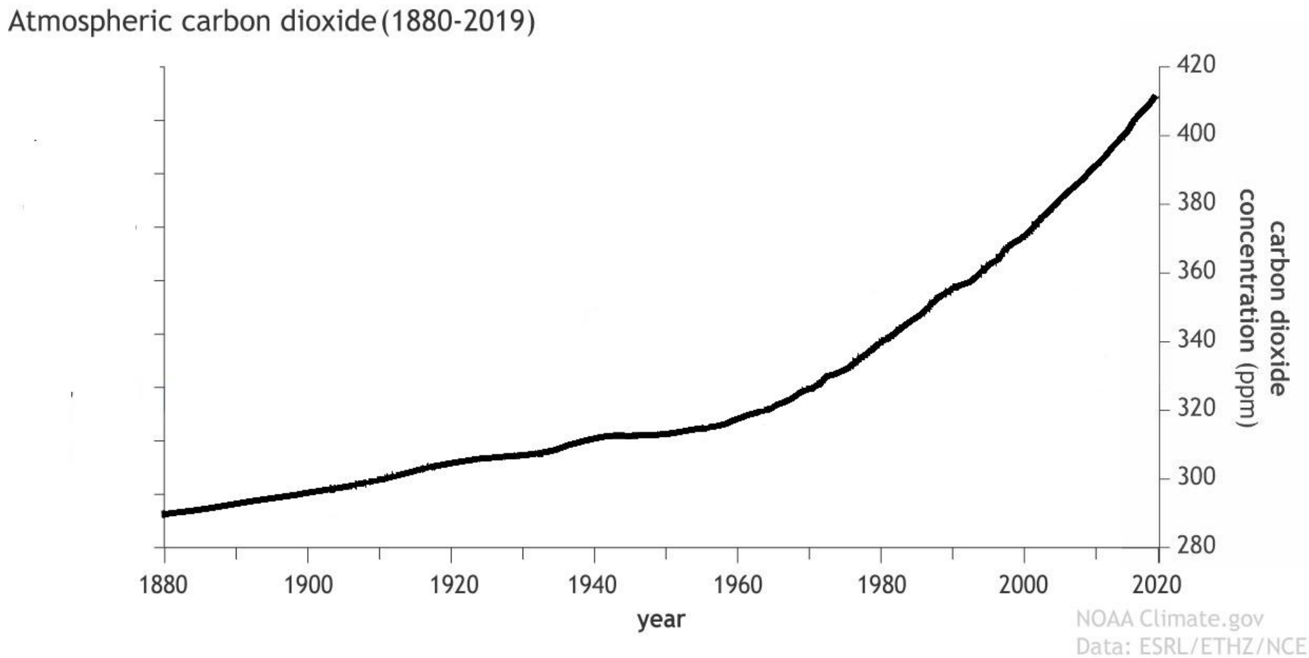
   ____

2. Look at 1980-2015. Is the temperature above or below average for these years? _________

   ____

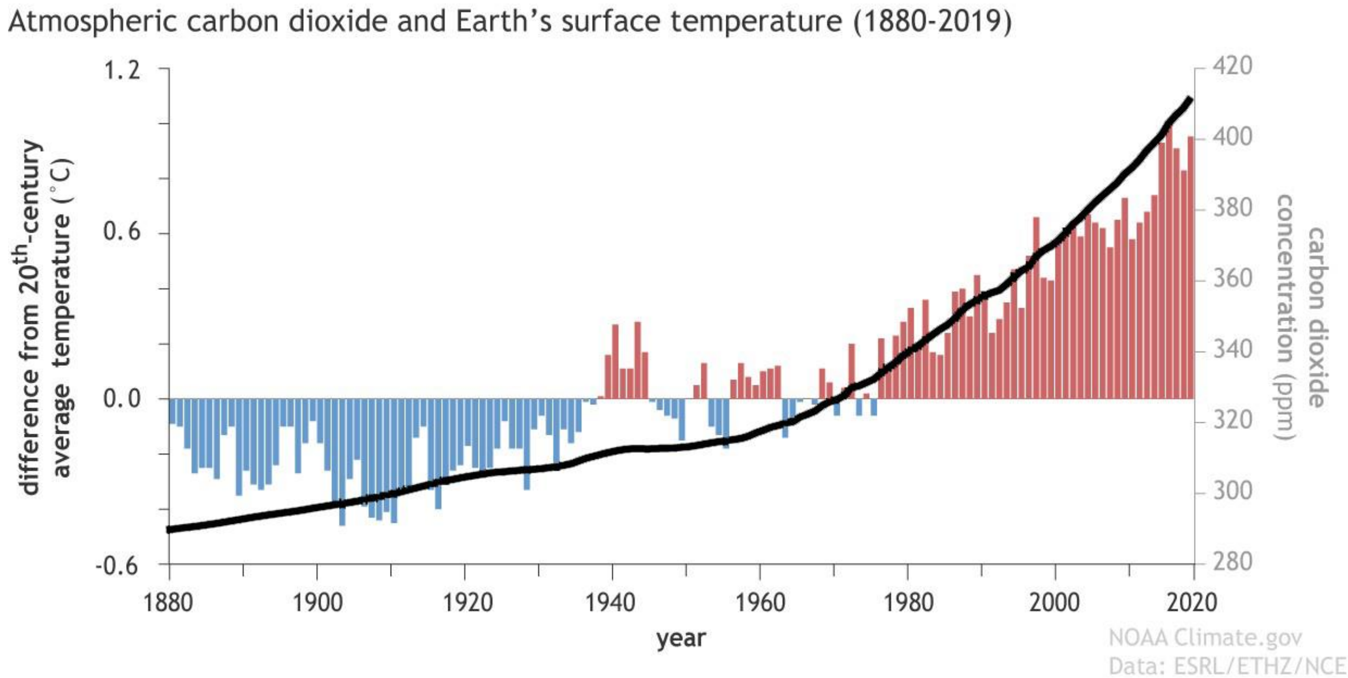
3. What is the hottest year you can see? ____
4. How far above average is that year? ____
5. Based on this information, what would you say is happening to the global temperature? __

   ____



This graph shows the concentration of carbon dioxide in the atmosphere during the same time period.

1. How does the concentration of carbon dioxide in the atmosphere change? ______________
   ____
2. Carbon dioxide concentration is measured in parts per million. What is the lowest concentration in the graph? ___________________ What is the highest? ___________________
3. Using your answers from the last question, how much has the concentration of carbon dioxide gone up from 1880-2020? ____



This graph shows the concentration of carbon dioxide in the atmosphere and the temperature at the same time.

1. What pattern do you notice in the amount of carbon dioxide in the atmosphere compared to the temperature change? ____

____

Reading: Correlation vs. Causation

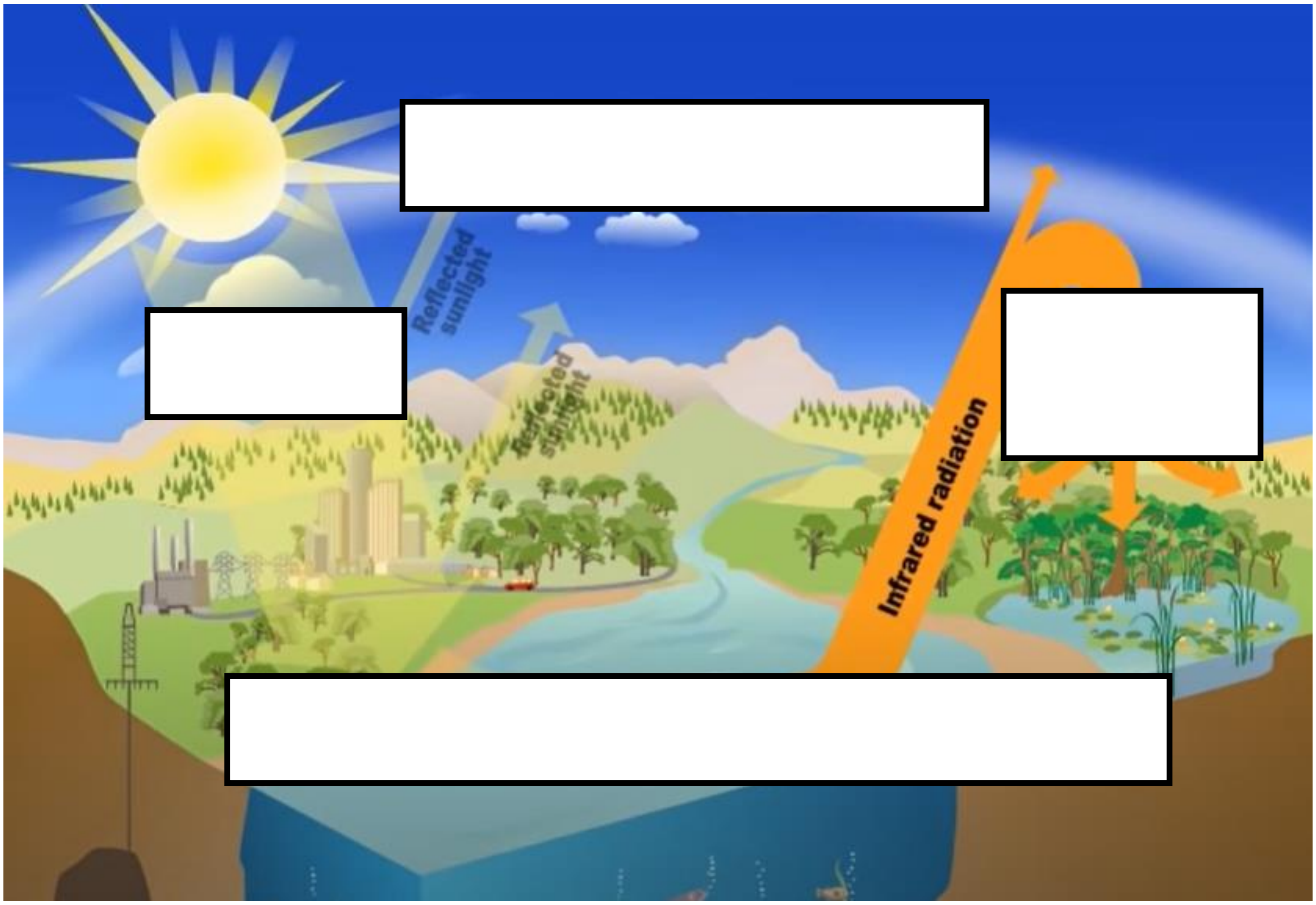
Scientists noticed that the concentration of carbon dioxide in the atmosphere and the global temperature seem to go together. As one went up, the other went up. When two things seem to go together like this, scientists say that they are correlated. The prefix “co-" means together as in cooperate and copilot. When things are correlated they are related together. If scientists see that things are correlated, they often try to figure out if one thing is causing the other thing.

Just because two things are correlated doesn't mean one thing is causing the other. For example, students who are in higher grades are also taller. Does that mean that being in a higher grade **causes** you to be taller? Of course not. There is another factor – your age – that is related to being taller and being in a higher grade.

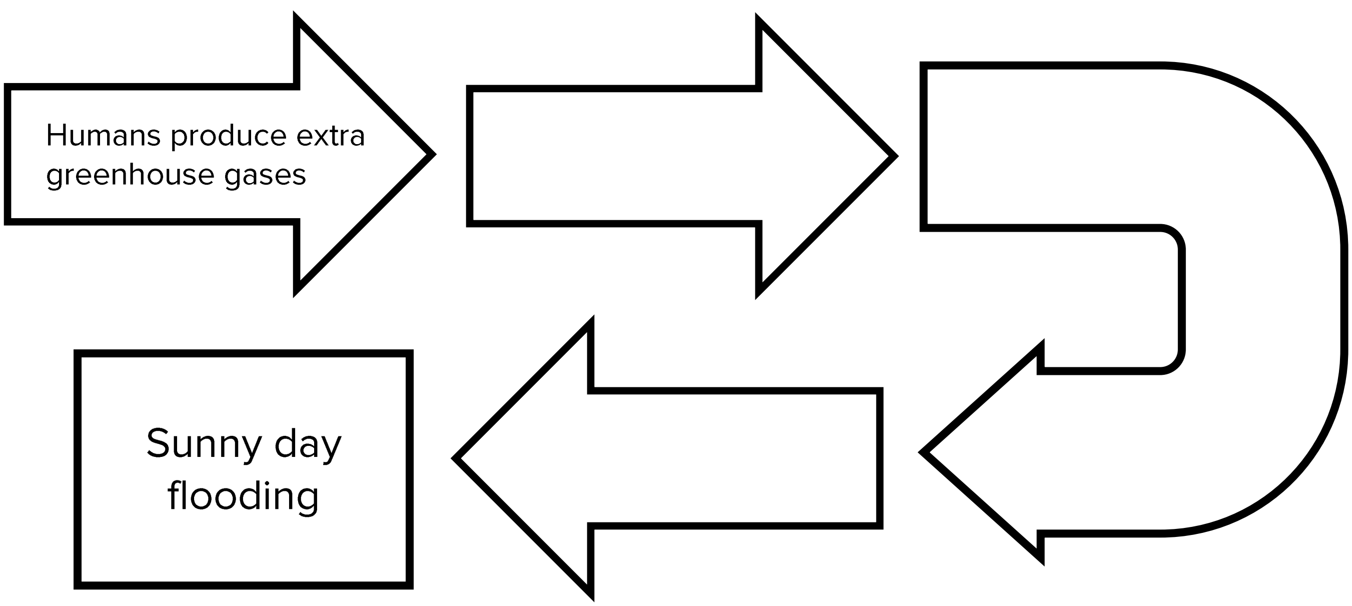
Can higher carbon dioxide concentrations **cause** temperatures to rise? That's a great question to ask. We will learn about that now!

Video: The Greenhouse Effect

Watch the greenhouse effect video and fill in the spaces with the correct information.



Cause & Effect



Activity 5 (Explore/Explain): The Urban Heat Island Effect (optional)

Activity summary: In this activity, students perform a series of experiments that show how different surfaces affect how much heat is absorbed by the Earth, which contributes to the urban heat island effect. While the urban heat island effect does not directly contribute to climate change or sea level rise, temperatures in urban areas are affected by both urban heat islands and climate change, resulting in dangerously high temperatures. Consider adding this activity if your school is in an urban area or your students live in an urban environment.

Standards Connection
DCI: ESS 3.D: Global Climate Change
SEP: Planning & Carrying Out Investigations
CCC: Cause & Effect

Warmup: Have you ever walked barefoot on hot pavement during the summer? What was it like? What other surfaces get very hot in the summer? What surfaces stay cooler?

- Hot surfaces: sand, rocks
- Cool surfaces: grass, dirt

1. **Frame the activity:** Ask students if they think the surfaces they talked about in their warmup have any effect on the temperature of the atmosphere. Tell them that today they're going to design experiments to test their answers.

2. **The urban heat island effect:** Go to the climate.gov website for the DC/Baltimore heat island effect (https://www.climate.gov/news-features/features/detailed-maps-urban-heat-island-effects-washington-dc-and-baltimore) and show students one of the maps (see example on the next page). You may want to zoom out so students can see the whole map. Make sure they understand the temperature scale at the bottom, and move the slider back and forth. Ask students what they notice about where the temperature seems to be hotter or cooler. It should be relatively easy for students to recognize that the temperature is hotter where there is pavement, and cooler where there is grass and trees.

   Tell students that scientists call this the "Urban heat island" effect. It is called a heat island because the high temperature air is like an island surrounded by cooler air. They are urban because they are mostly found in cities. Ask students why they think they are mostly found in cities (because cities have a lot of pavement).

   Ask students why they think urban heat islands can be harmful (temperatures can get well over 100° in the summer).

ACTIVITY DETAILS

Time: 2 class periods (90-120 minutes)

Objectives

- ✓ Students will be able to explain the Urban Heat Island effect
- ✓ Students will perform experiments to explain one cause of the urban heat island effect

Materials

- ✓ Computer & projector
- ✓ Thermometers
- ✓ Black and white construction paper
- ✓ Other "surface" materials: soil, grass, rocks, sticks, sand, roof shingle, water, etc.
- ✓ Stopwatch (at least one)
- ✓ Clipboards (optional, for recording data outside)
- ✓ Graph paper (optional)

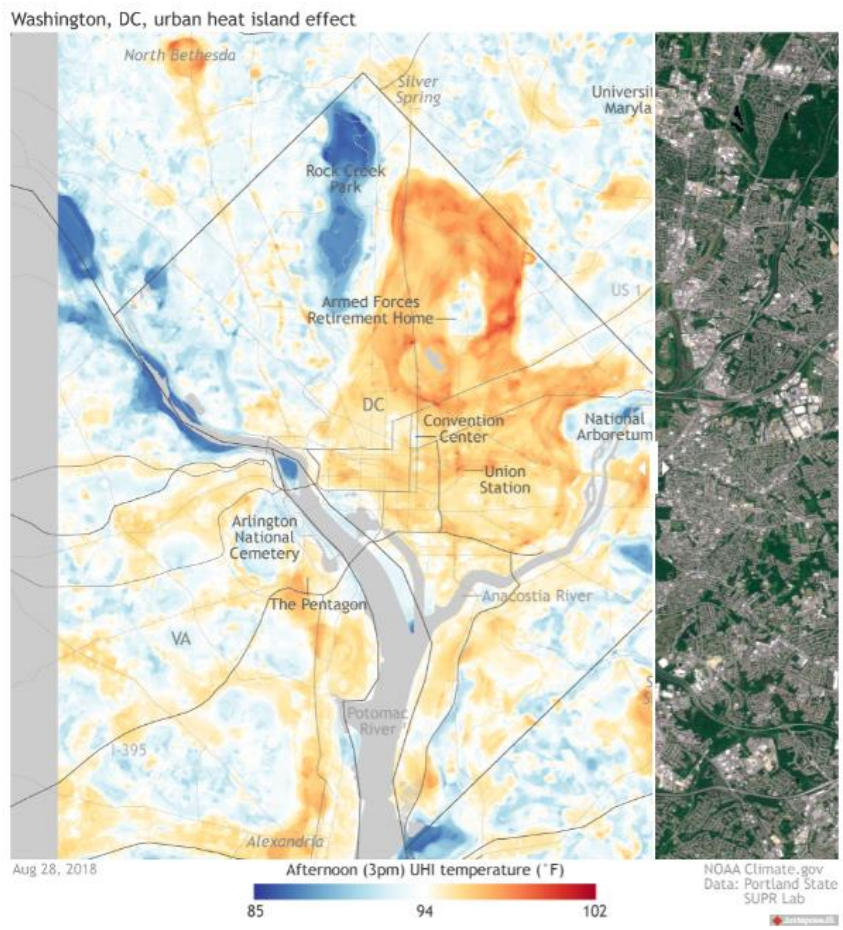
Handouts

- ✓ The Urban Heat Island Effect

TEACHER NOTES

Source

- ✓ This activity is based on the activity “Greenhouse Effect) from the “Protect Your Climate” curriculum published by the Bay Area Air Quality Management District: https://www.baaqmd.gov/~/media/Files/Planning%20and%20Research/Climate%20Protection%20Program/protectyourclimate.ashx



3. **Introduce the experiment:** Tell students that to test their ideas about what causes the urban heat island effect, they are going to do a series of experiments. Each group of students will do a different version of the experiment so that they can compare their results. Pass out the Urban Heat Island Effect sheet to students.

   For their experiments, they will measure the air temperature near different surfaces to see if they have different temperatures. Ask students what kinds of things they could use to act as different surfaces. If they get stuck, remind them of the surfaces they talked about during their warmup. As students share ideas, write them down on chart paper or on the board. You can also ask about how they could represent specific things such as a roof or the ocean.

4. **Writing research questions:** Form students into groups, and have each group choose a surface that they will test. It is best if they all choose different surfaces so they can compare their results. From here, have students write a research question based on comparing their material to another material. For example, if students are using the black paper to represent pavement: “Does a dark surface cause the temperature to get higher than a light surface?” If students are new to writing research questions, you may want to write one together and then have them write their own questions in groups.

5. **Materials:** Review the materials list with students, and have them add any additional materials that they are going to use such as soil, grass, or black paper.

6. **Procedure:** In order for students to be able to compare results from their tests, they all need to agree on the same procedure. This experiment is relatively simple, so their procedure should consist of a few steps:
   - Put “surface” materials in a sunny area.
   - Hold the thermometer a given distance above the surface (ex. 1 inch)
   - Leave the surfaces outside 10-20 minutes (have students decide on a time)
   - Record the temperature of the air every 1-2 minutes (have students decide on a time)

   Have students write their procedure on their handout, including any additional steps. If it appears to be windy outside, consider how you will modify the procedure to prevent the wind from affecting the results.

7. **Variables and controls:** Have students fill in the variables and controls for their experiment. The independent variable is their surface, the dependent variable is the temperature, and the controls are the location of the surfaces.

8. **Write a hypothesis:** Have students write a hypothesis about how the temperature near their surface will change compared to one or more of the other surfaces. Their hypothesis should be an answer to their research question. Make sure students are thinking about their hypotheses so they are logical. For example, ask them if they think dark surfaces heat up more than light surfaces?

9. **Build the setups:** Have students gather their materials. You may want to have them use trays or other containers to make the materials easier to carry. As they work, check to make sure the setups are the same except for the material that will act as the surface.

TEACHER NOTES

Modification

✓ If there are different surfaces near the school that have the same sun exposure, students can measure the air temperature near these. Just make sure there are no other variables (ex. shade, wind, etc.) that may affect the results.

Modification: Showing the Greenhouse Effect

✓ To simulate the greenhouse effect, you can also run the experiment using a jar with the thermometer inside. Because the air is trapped inside the jar (the “greenhouse”) the temperature will likely be significantly higher than their surface measurements. If you do this variation, be sure to clarify for students the difference between the greenhouse effect and urban heat islands, and how the jar is only simulates the greenhouse effect.

TEACHER NOTES

Teacher tip

- ✓ Students sometimes struggle to make accurate thermometer readings if you are using alcohol thermometers. It is a good idea to practice reading a thermometer before going outside to collect data, and checking on students' measurements if you think they will have difficulty.

10. **Run the experiment:** Take the setups outside (or put them in a sunny location if you cannot go outside. Make sure to have students record the temperature at the exact intervals they have determined in their procedure. You can give each group a stopwatch, or use one stopwatch for the whole class and have them all take the temperature at the same time. Students should record their data in the Surface 1 space on their data table.

11. **Data sharing:** Have students share data with groups that they have chosen to compare with. For example, if one group used a light surface and other group used a dark surface, or sand vs. grass, have them share data with the group that is using their comparison material. You may also want students to compare data from all the surfaces. If so, put all the data into a computer spreadsheet or on the board for students to copy. Have them write their comparison group data into the Surface 2 space on their data table.

12. **Data analysis:** When students have collected all their data, return inside to have them do their analysis. They should start by finding the difference between the final and ending temperatures to see how much the temperature changed. You can also have them graph their data in a variety of ways: ex. bar graphs with the temperature change for each surface, or time vs. temperature line graphs. Make sure the graphical representation you choose is meaningful for the analysis.

13. **Sensemaking discussion:** Have students share what they learned from their experiments. Use some or all of the questions below to help drive student thinking, but make sure that students are doing most of the talking, and make sure they are referencing their data. It will help for this if the data is visible somewhere in the classroom:
    - Which surface seemed to cause the temperature to rise the most? The least?
    - Were you right or wrong in your hypotheses?
    - Are the surfaces that caused the temperature to rise the most similar or different in any way?
    - What do your results help you understand about the urban heat island effect?

14. Return to causation vs. correlation: urban heat islands and global temperature: Ask students if they think urban heat islands are raising the global temperature (is one *causing* the other?). Students can make logical arguments on both sides (ex. if more heat is absorbed, more will be trapped, and that will raise temperatures). However, in reality, global heat islands do not trap nearly enough heat to raise global temperatures. They are *correlated* because as global temperatures increase, urban heat island temperatures also go up, but the *cause* of global temperature increases is the greenhouse effect, and the *cause* of urban heat islands is related to the types of surfaces in urban environments (as well as other factors). The only cause-effect relationship present is that when temperatures get hot in cities due to urban heat islands, people in those cities tend to use more electricity to cool the air, which does cause higher global temperatures (due to increased greenhouse gases being emitted to produce the electricity).

15. Conclusion (formative assessment): Have students complete the conclusions section of their experiment handout. The second question asks students why the air in some jars heated up more than others. After their discussion, students should be able to explain that some surfaces absorb more heat than others, and therefore heat up the jar more than others.

The final question asks students to explain the urban heat island effect using their results. Students should be able to explain that there are more surfaces in urban areas that absorb a lot of heat, and therefore they raise the temperature in urban areas more.

Urban heat islands are complex

Urban heat islands are caused by more than just differences in surfaces. Large numbers of tall buildings can trap heat by slowing wind and acting as large heat sinks. Larger populations also add more heat to the air through the use of cars, air conditioning, and other machinery.

The effects of urban heat islands also go beyond higher temperatures. With higher temperatures come increase ozone levels (see the sidebar), and increased electricity demand for things like air conditioner. This increased electricity demand often results in additional greenhouses gases being released to the atmosphere, which accelerate climate change.

TEACHER NOTES

The Urban Heat Island Effect & Ozone Formation

- ✓ Ground-level ozone, an air pollutant that can irritate lungs and make breathing difficult, is formed by a chemical reaction that occurs in the presence of hot weather and sunlight. Another effect of the urban heat islands is an increase in ozone production due to increased temperatures.

Name ________________________________

STUDENT HANDOUT

The Urban Heat Island Effect

Research question: ________________________________

____

____

Materials

- ❒ Thermometer
- ❒
- ❒
- ❒
- ❒
- ❒

Procedure

1. ________________________________
2. ________________________________
3. ________________________________
4. ________________________________
5. ________________________________

Variables and controls

What is your independent variable? (What are you changing between your two setups?)________

____

What is your dependent variable? (What are you measuring?)______________________________

What are you controlling? (What needs to be the same in both of your setups?) ________________

____

Hypothesis

Your hypothesis should be a logical answer to your research question based upon what you know about surfaces:

____

____

Data

Time	Surface 1:	Surface 2:
0 min		

Analysis

How much did the temperature change near Surface 1? ______________________________

How much did the temperature change near Surface 2? ___________________________________

Conclusion

Was your hypothesis correct? ____________________________

Why did the air heat up more in some places than others? _________________________________

____

____

____

____

Based upon your results, explain what causes the urban heat island effect.

____

____

____

____

____

____

____

____

____

Activity 6 (Explore): Atmosphere in a Jar

Activity summary: In this activity, students investigate what the most common elements and compounds in the atmosphere are by digging into an atmospheric "soup" of molecules. They use ratios and proportional reasoning to relate the finding from their investigation to the atmosphere as a whole.

Standards Connection
SEP: Analyzing Data; Using Mathematics & Computational Thinking
CCC: Patterns; Scale, Proportion, and Quantity

In advance: Gather the materials and setup the "Atmosphere in a Jar" activity. See teacher handout for additional details.

Warmup: Show students the apple, and tell them to imagine that the apple is the Earth. If so, how big would the atmosphere be? (ex. would it extend out for 1", ½", etc.)

1. Answer: the atmosphere is the thickness of the apple's skin (you may choose to peel a piece of skin to show how thin it is)
2. When reviewing the answer with students, show them a photograph of Earth from space (such as the one below) to highlight how thin the atmosphere is.

1. **Frame the activity:** Remind students that the greenhouse effect is caused carbon dioxide and other gases in the atmosphere. In order for them to understand the problem of having too much carbon dioxide, they need to know more about what gases are in the atmosphere. Today they're going to study the atmosphere so they can understand how carbon dioxide affects the planet.

ACTIVITY DETAILS

Time: 45-60 minutes

Objectives

- ✓ Students will know what gases make up Earth's atmosphere and in what proportions
- ✓ Students will use sampling and quantitative analysis to estimate the composition of a mixture

Materials

- ✓ One apple (any kind)
- ✓ Apple peeler (optional)
- ✓ Beans for Atmosphere in a Jar (see teacher handout)
- ✓ Chart paper & markers (optional)
- ✓ One large, clear container
- ✓ Small cups – enough for one per student group
- ✓ Calculators
- ✓ Atmosphere in a Jar Teacher Guide
- ✓ Computer & projector

Handouts

- ✓ Atmosphere in a Jar activity sheet
- ✓ Atmosphere in a Jar summary questions (optional)

TEACHER NOTES

Differentiation

✓ If students are reluctant to share ideas in front of peers, have them write their answers on sticky notes or note cards. Make sure to get at least one answer from each student to support participation. You can also have students brainstorm first in groups, or have them write out a list before sharing.

Modification

✓ The follow-up questions for this activity also work well as a homework assignment.

Next steps

✓ If you plan to do the “How Much is a PPM” activity next, make sure to have students return their samples and keep the Atmosphere in a Jar nearby.

2. **Fact or Fiction: Gathering students’ ideas**: Prepare a piece of chart paper (or a place on the board) to record student responses. Then ask them: what do we already know about the atmosphere of Earth? Record each answer on the board where all students can see. If students get stuck, prompt them with questions such as: “What do you think the atmosphere is made of?”, “Is the atmosphere clean or polluted?”, or “Where do the gases in our atmosphere come from?”
    - Don’t tell students which statements are accurate or inaccurate, just focus on letting them share

    When students are finished sharing, tell them that you will come back to this list later as a class to see which statements we made about the atmosphere are actually facts and which are fiction.

3. **Atmosphere in a Jar:** Follow the directions in the Atmosphere in a Jar teacher guide (see below).

4. **Atmosphere in a Jar follow-up questions (optional):** Use the Atmosphere in a Jar follow up question handout to help students think more about the process of sampling, the importance of using multiple samples, and why percentage is useful measurement when considering composition of a mixture.

5. **Formative assessment**: Let each student choose one fact or fiction from the list that has been decided. Have them write a short answer telling whether it is a fact or fiction, and supporting their answer using evidence from the activity. For example, if the “fiction” is “Our atmosphere is mostly oxygen” a student might write “Our atmosphere is mostly oxygen is fiction. Our atmosphere is only 21% oxygen. It is mostly made of nitrogen (78%).

Atmosphere in a Jar

TEACHER GUIDE

In this activity, students take samples of different beans and peas from a jar which represent the different molecules in Earth's atmosphere. By counting the numbers of each bean in their sample, and using proportional reasoning, they can determine what the different gases are in the atmosphere, and in what proportions.

Materials:

- Digital scale for measuring materials
- A large clear container big enough to hold all of the beans and peas required for an entire class, preferably one with a lid
- Different kinds of dried beans and peas[1]. See "preparation" below for approximate amounts and weights of different beans. You will likely need a whole bag of two different beans (ex. black beans and black-eyed peas) and a bag of mixed beans for the rest.
- Small sample cups for students (approx. 2 oz) – 1 per student group

Background information:
The vast majority of Earth's atmosphere is made up of just two gases: nitrogen or N_2 (78.09%) and oxygen or O_2 (20.95%). Trace gases such as argon (0.93%), carbon dioxide (0.04%), and others are also present in very small amounts. Air also contains a variable amount of water vapor, on average around 1% at sea level and 0.4% across the entire atmosphere.

Nitrogen: While nitrogen is important to human life, we cannot use the nitrogen in form it takes in the atmosphere. Bacteria take this nitrogen out of the air and "fix" it into a form that plants use. We therefore get the nitrogen that we need from the food that we eat.

Oxygen: The Earth did not always have so much oxygen in its atmosphere. It was not until about 2.7 billion years ago that blue-green algae (cyanobacteria) evolved the process of photosynthesis which began producing oxygen. Today, the majority of our oxygen is made by phytoplankton and other plants in the ocean.

Argon: Argon is a colorless, odorless, non-toxic, inert gas. Today, argon is commonly used in light bulbs. Argon is a great insulator used in double pane windows minimizes transfer of heat.

Water vapor: The amount of water vapor in the atmosphere is highly variable, based on different weather conditions. At low humidity, water vapor may only make up 0.2% of the atmosphere, but at high humidity, that percentage can get over 4%.

Carbon dioxide: Even though most animals produce carbon dioxide from cell respiration, and carbon dioxide is released by many human activities, this gas still makes up only a very small proportion of Earth's atmosphere (0.04%). However, even this small percentage can have large consequences for Earth's climate.

[1] Beans and peas are suggested because they are inexpensive, easy to handle and clean up, and easy to distinguish from one another. Small Lego blocks, rice grains, beads, and popcorn kernels work equally well.

Preparation:

- Determine which beans will represent which gases in your "atmosphere". You will need 5 different beans, with the majority being the beans representing nitrogen and oxygen.
- Create your "atmosphere." These directions are based on the chart below which will provide a large enough atmosphere for a full class of students[2].
  - Count out and weigh 100 of your "nitrogen" beans
  - Multiply the weight by 39 (because you need 3900 beans) and record
  - Weigh out the recorded amount and add to your atmosphere container
  - Count out and weigh 100 of your "oxygen" beans
  - Multiply the weight by 10.5 (because you need 1050 beans) and record
  - Weigh out the recorded amount and add to your atmosphere container
  - Count and add 50 "argon" beans to the container
  - Count and add 50 "water vapor" beans to the container
  - Count and add 2 "carbon dioxide" beans to the container

Bean	Gas	Percentage	Number	Approximate Weight
Black bean	Nitrogen	78%	3,900	858g
Black-eyed pea	Oxygen	21%	1,050	220g
Pinto bean	Argon	1%	50	n/a
White bean	Water vapor	1%	50	n/a
Kidney bean	Carbon dioxide	0.04%	2	n/a
Total			**5,052**	

*Note: The percentages do not add up to 100% due to rounding and variability with respect to water vapor. See NASA's website for more information about Earth's atmosphere: https://nssdc.gsfc.nasa.gov/planetary/factsheet/earthfact.html

- Put a lid on your atmosphere container, and mix thoroughly. The atmosphere should look uniform when you are finished.

[2] If for any reason you choose to use different amounts based on the same proportions, be sure to mark down how many of each material (bean) you include in your "atmosphere" to use in later activities.

Leading the Activity:

- Show students the atmosphere jar and tell them that the materials in the jar represent the molecules that make up our atmosphere. In this activity, they are going learn about what gases make up out atmosphere by studying what's in the jar.

- Have students look at the jar and jot down (on their lab sheets) initial observations of what they see.

- Remind students that during their warm up, they mentioned some different gases that they think are in Earth's atmosphere. Tell them that each bean (or other material) in this jar represents one molecule of a gas in our atmosphere. Note: If this is the first time you have used the word "molecule" with students, take a moment to discuss what this word means.

- Tell students that the amount of each bean in the jar is proportional to the amount of the actual gas it represents in the atmosphere. In other words, if there is a gas that makes up 10% of the gases our atmosphere, that bean makes up 10% of the beans in the jar. We are going to use this information to figure out what gas each bean in the jar represents.

- Ask students if they would like to take the rest of the week to count all the beans in the jar so they can find out how many of each bean there is. When they (hopefully) reject this idea, tell them that scientists use a technique called "sampling" to count things when there are a lot of things to count. Instead of counting all the beans, we will take "samples" from the jar and count those instead. As long as the samples are similar to the whole jar, we can use our samples to calculate what percentage of each bean there is in the jar.

- Go over the sampling and counting procedure that students will do in groups. You may want to do one as an example:
    - Take a sample cup and scoop a full cup of beans from the jar
    - With your group, separate all the different types of beans
    - Count the number of beans of each type and record the names and numbers on your data sheet.
    - Make sure to hold up each bean for students and tell them what it is called so they can aggregate data together with the class.

- Break students into groups and have them collect their samples and count their beans.
    - Teacher tip: when counting, have students make groups of 10 with their beans so that they don't lose count.
    - Teacher tip: Because there are so few carbon dioxide beans, try to ensure that at least one group gets one.

- Once all students have finished counting their beans, have them total the number of beans in their sample and write the total on their data sheet. They should also fill in the column for ratio of number to total.

- Discuss with students how to calculate the percent of each bean that is in their sample compared to the whole (molecule total/overall total x 100). Once students understand the procedure, have them calculate the percentage of each bean in their sample and write it on their data sheet.
  - Teacher tip: Calculating percentages is a 7th grade standard in many states, so students may or may not have learned how to do this already.

- Have groups share aloud what percentages they got for each bean. There will be differences, so ask them why they think their numbers are different. Use this opportunity to discuss that sampling does not give us a "correct" number. It is like an estimate of the percentage. Scientists use sampling because it is much faster than trying to count all the beans in the jar. Because each group had a slightly different sample, they got different percentages. Ask students if they think counting more means or less beans would give them a more accurate sample. Use discussion to build student understanding that larger samples provide better estimates of the "real" number they are trying to estimate.

- Ask students how they can use their data to get the best estimate of the actual percentages. Use discussion to help them realize that if they combine their data, they will have a better estimate than if they use just their own group's data. Have them pool their data (using a spreadsheet on a computer, a whiteboard, etc.). Just pool the raw numbers (not the percentages). Have students record this information in the "class data" portion of their data sheet.

- Have students write the ratio of each number of beans to the total using the class data. They should then calculate the percentage of each bean, and record their percentages on their data sheets. Take a moment when students are finished to have them compare the class data with their own data. Some things will likely be higher, and others will be lower.

- Once all the data has been calculated, share the list of gases in the atmosphere with students. See if they can guess which material goes with which gas in the space on their data sheets.

- Share the correct answers about which material goes with which gas. Have students share whether they were surprised or not. Most students will likely be surprised that nitrogen (a gas they are not very familiar with) makes up the largest part of Earth's atmosphere, while carbon dioxide and water vapor (gases they are likely more familiar with) make up such a small part.

- Optional: Have students complete one or more of the follow-up tasks related to this activity:
  - Answer the summary questions (see handout below)
  - Create a bar graph or pie chart showing the make-up of Earth's atmosphere
  - Calculate the volume of each gas we breathe each day (see handout below)

STUDENT HANDOUT

Name ____________________________________

Atmosphere in a Jar Data Sheet

Initial observations: what do you notice about the materials in the jar?

Group directions:

1. Take a sample from the “atmosphere” jar using your sample cup
2. Separate all the different types of beans in your sample
3. Count the number of each type of bean
4. Record the name of the bean and the number in the data table
5. Add up the total number of beans in your sample, and write it on your data table
6. Write the ratio of the number of beans in each sample to the total
7. Calculate the percentage of each bean in your sample using the formula below:

$$Percent\ of\ total = \frac{number\ in\ sample}{total} \times 100\%$$

My group’s sample data:

Material (bean)	**Number in sample**	**Ratio of number to total**	**Percent of total**
Total			

Class data:

Material (bean)	Number in sample	Ratio of number to total	Percent of total
Total			

What gas do you think each bean represents?

Material (bean)	My guess	Actual gas	Percentage of Earth's atmosphere

Name ______________________________

STUDENT HANDOUT

Atmosphere in a Jar Follow-Up Questions

Answer the questions below based on the Atmosphere in a Jar activity.

1. Which estimate of the gases in the atmosphere do you thinks more accurate?

My group's estimate   The class data estimate

Why do you think your choice is more accurate?

____
____
____
____

2. If the beans in the jar were not mixed up before you took your sample, do you think you could make a good estimate of the gases in the atmosphere? Why or why not?

____
____
____
____

3. Why is it more useful to know the percentage of each gas in the atmosphere instead of the amount of each gas? Hint: When you take a quiz, it is more useful to know how many questions you got right, or the percentage of questions you got right?

____
____
____
____

Activity 7 (Elaborate): How Much is a PPM? (optional)

ACTIVITY DETAILS

Time: 30-45 minutes

Objectives

- ✓ Students will develop an intuitive and mathematical sense of the unit parts-per-million
- ✓ Students will understand that very small amounts of pollution can have a big effect on the atmosphere

Materials

- ✓ Atmosphere in a Jar (from previous activity)

Handouts

- ✓ How Much is a PPM?

Math integration

- ✓ For the warmup, have students do the calculation on their own before going over it.
- ✓ This activity provides many opportunities to incorporate math. Feel free to take advantage of this fact by building in additional problems that relate to the math students are currently learning.

Activity summary: In this optional activity, students learn about the concept of parts-per-million (ppm) in order to understand how small amounts of pollution can have a large effect on the environment. They do this by returning to their Pollution in a Jar activity and using mathematical reasoning skills.

Standards Connection
DCI: ESS3.C – Human Impacts on Earth Systems
SEP: Using Mathematics & Computational Thinking
CCC: Scale, Proportion, and Quantity

Warmup: How long would it take you to count to a million?

- Some students may try to calculate, others may guess. Both methods are fine because the goal of this lesson is to help students develop both a mathematical *and* an intuitive sense of large numbers.
- After students have reached their answers, go over how to find out the answer (assuming one counted number per second):

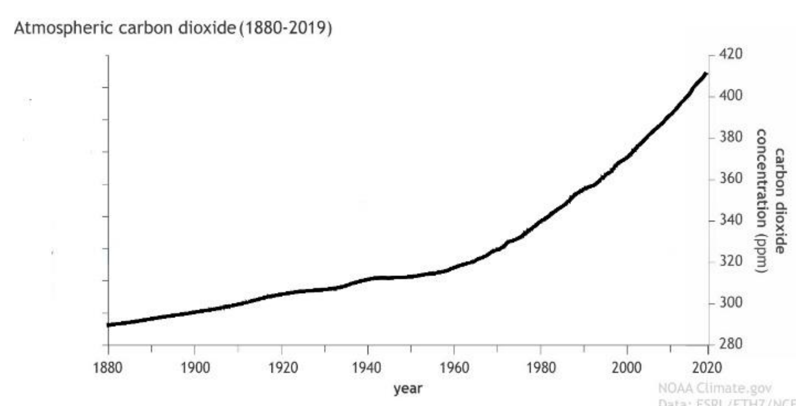
$$1{,}000{,}000 \text{ seconds} \times \frac{1 \text{ minute}}{60 \text{ seconds}} = 16{,}666 \text{ minutes}$$

$$16{,}666 \text{ minutes} \times \frac{1 \text{ hour}}{60 \text{ minutes}} = 277 \text{ hours}$$

$$277 \text{ hours} \times \frac{1 \text{ day}}{24 \text{ hours}} = 11.6 \text{ days}$$

- See how this compares with students' estimates/calculations. Use this to start reinforcing for students how large 1 million is.

1. **Frame the Activity**. Show students the graph from Activity 4 (below) that shows the amount of carbon dioxide levels in the atmosphere:



Point out that the scale for carbon dioxide on the right side is in parts-per-million. Ask them if they've ever seen this unit before. It is unlikely – this is a pretty unusual unit! Tell students that today they're going to think about how much carbon dioxide is too much, and how low it needs to be to slow down or stop the global temperature from rising.

2. **Pollution in a Jar:** Take out the atmosphere in a jar from the previous activity, and remind students of what it represents. Hold up one bean of carbon dioxide (whatever bean you chose to represent it), and remind students that this bean represents carbon dioxide. Return to the graph of carbon dioxide levels and point out to students that the current level of carbon dioxide in the atmosphere is about 414 parts per million (for current levels visit https://www.co2.earth/). That would mean that there would be 414 beans in a jar that had a million beans in it. Ask students how many beans that would be in their jar that has far fewer beans. Have students record their guesses for later.

3. **Understanding parts-per-million:** Hand out the "How Much is a PPM?" sheet to students, and have them read the first section. Use a reading strategy to help students focus on key points and questions they have about of the reading. When students are done, have them share key points, and use peer discussion to help answer any questions they have.

4. **Animated Part-per-million (optional):** Show students the animated video "How to Visualize One Part Per Million" found at: https://www.youtube.com/watch?v=aa-m8a-jZ0k

5. **Return to Pollution in a Jar.** Take out the atmosphere jar and remind students of their guesses from earlier in class about how many "beans" of carbon dioxide would need to go into their jar to make it equal to 414 parts per million. See if the students want to revise their estimates based on the reading.

   Read the next section of the handout together ("How much carbon dioxide is in our jar?"). Have students write the fraction for the amount of carbon dioxide in the atmosphere on their papers in the box.

   Note: You will need to adjust the fractions in the next section if you used a different amount of beans than the suggested amount.

TEACHER NOTES

Modifications

- ✓ There are many different mathematical terms used in this lesson which can be interchanged (ex. fraction, ratio, proportion). If students are new to any these terms, make sure students understand them well enough that they do not interfere with their understanding of the lesson.

Teacher Tip

- ✓ The jar actually has about 5,052 beans in it (if you used the amounts listed). This is rounded to 5,000 for this activity to simplify the math somewhat. The result will ultimately be the same.

TEACHER NOTES

Teacher Tip

- ✓ The goal of this part of the activity is to help students understand the idea of air pollution from a proportional perspective, and to realize how a very little amount of air pollution can make a huge difference in air quality.

Next, ask students how they could figure out what the fraction would be if they put one bean of carbon dioxide in their jar. Ask students to write the fraction representing the ratio of pollution to air in the jar in the box on their paper next to the carbon dioxide amount like this:

$$\frac{414}{1{,}000{,}000} \qquad \frac{1}{5{,}000}$$

Have students turn to a partner to determine which fraction is larger. If they get stuck on this, suggest that they multiply the second fraction by 414/414 to make equivalent numerators.

After a few moments, have them share their findings. When they agree that the "jar" fraction is smaller (414 out of 2,070,000 is less than 414 out of 1 million), have them write an inequality symbol between the fractions to show this.

$$\frac{414}{1{,}000{,}000} > \frac{1}{5{,}000}$$

6. **Making sense of the fractions:** With their partners, have students determine what this means. Does one bean of carbon dioxide in the jar mean it is more or less than the amount in the atmosphere? Bring the class back together, and let them discuss until they agree that one bean in the jar is not enough because it is still less than the amount in the atmosphere.

7. **Finding equivalent ratios/fractions:** Tell students that they know they need more than one bean, but how many do they need? To figure it out they need to make equivalent fractions. Write this on the board and have them add it to their papers (if they are familiar with variables, you can use "x" instead of the "?"

$$\frac{414}{1{,}000{,}000} = \frac{?}{5{,}000}$$

Ask how they can figure out what goes in the space with the question mark. There are many different ways to solve this (ex. cross multiply and divide). To continue with finding equivalent fractions, you can suggest that they can divide the top and bottom by the same number to get an equivalent fraction. What number do you need to divide 1,000,000 by to get 5,000? They can solve this with guess-and-check, or by dividing. Give partners time to figure out what the answer is. When they figure it out that it is 200, ask them what the numerator in the equivalent fraction should be (2.07). Have them write 2.07 into the space where the question mark is.

Ask students how many carbon dioxide beans this means they should put into their jar (2). Ga back to students' guesses from earlier in the class to see if anyone was right (or close).

8. **Reflection: such a small amount:** Ask students if they are surprised that such a small amount of carbon dioxide can have such a big effect on the environment. Take a moment to have students consider this effect. You may want to have them make an analogy to their own lives or to their experience (has one day in their life been very important? Can one person make a difference in the lives of millions of others?)

9. **Formative assessment:** Tell students that the carbon dioxide level in the atmosphere 100 years ago was 303 ppm. Have them write this as a fraction, and see if they can figure out how many beans (or parts of beans) they would need in their jar if it was 100 years ago.

$$\frac{303}{1{,}000{,}000} = \frac{1.5}{5{,}000}$$

There would be about 1.5 beans of carbon dioxide in the jar 100 years ago.

Name ______________________________________

STUDENT HANDOUT

How Much is a PPM?

The current amount of carbon dioxide in the atmosphere is about 414 parts-per-million (ppm). That means that there are 414 molecules of carbon dioxide for every million molecules of gas in the air. Parts-per-million is a unit just like inches or miles or meters.

We can also write parts-per-million as a fraction. Look at the three fractions below:

$$1 \text{ percent } (1\%) = \frac{1}{100} \qquad 1 \text{ ppm} = \frac{1}{1{,}000{,}000} \qquad 414 \text{ ppm} = \frac{414}{1{,}000{,}000}$$

One percent pollution would mean 1 molecule of pollution for every 100 molecules of air. 1 ppm is 1 molecule of pollution for every 1,000,000 molecules of air, so 414 ppm is 414 molecules of pollution for every million molecules of air.

414 ppm seems like a big number, but parts-per-million is a pretty small unit. How small is it really? Think how long one day is. One day in a million is the same as one day in 2,737 years, so 414 parts per million is like 1 year in 2,413 years!

<u>How much carbon dioxide is in our jar?</u>

Think about our atmosphere in a jar. If we want to show how much carbon dioxide is in our atmosphere, we would need to put 414 beans in a jar with a million beans. But our jar has far fewer than a million beans in it! In fact, our jar only has about 5,000 beans. So how many beans of carbon dioxide do we need to put in our jar?

How many carbon dioxide beans should go in our jar?

Activity 8 (Elaborate): Climate Change & Resilience

Activity summary: In this activity, students learn about how the greenhouse effect connects to climate change. They also interpret graphs of predicted CO_2 levels and sea-levels to make the connection between different possible climate change scenarios. Finally, they learn about climate resilience, and watch a video about New Orleans to learn about how they can build flood resilience into their own community.

Standards Connection
DCI: ESS 3.D: Global Climate Change
DCI: ESS 3.C: Human Impacts on Earth Systems
SEP: Analyzing Data
CCC: Patterns

Warmup: When you hear the words climate change, what do you think of? What do you already know about climate change?

- The purpose of this warm up is to activate students' prior knowledge about climate change, and provide some information to the teacher about what students already know. Because students will be learning more about climate change during the activity, don't spend too much time diving into students' prior knowledge.
- If students asked any questions in Activity 1 related to climate change, be sure to point them out before continuing.

1. **Frame the Activity**: Remind students of the sunny day flooding activity (Activity 2) where they looked at how different amounts of sea level rise would result in different amounts of flooding. You may want to go back to the website quickly to show them: http://coast.noaa.gov/slr. Tell students that scientists don't know how much sea level will rise in the future, because humans have the ability to prevent changes like this. Today they are going to think about different sea-level rise scenarios to see how they connect with different amounts of greenhouse gases like carbon dioxide, and what they can do to protect their community from climate change.

2. **Reading: Climate change:** Hand out the What is Climate Change? reading to students. Have them read the passage and answer the questions. When they are done, lead a short discussion about the difference between the greenhouse effect and climate change. The key takeaway is that the greenhouse effect is a natural process, while climate change is the result of humans increasing the greenhouse effect by adding additional greenhouse gases to the atmosphere.

ACTIVITY DETAILS

Time: 60 minutes

Objectives
- ✓ Students will understand the concept of climate change and how it is tied to atmospheric CO_2 concentration
- ✓ Students will understand the concept of climate resilience and how it applies to sea level rise

Materials
- ✓ Computer & Projector
- ✓ Speakers (for video)

Handouts
- ✓ What is Climate Change?
- ✓ Climate Resilience and Sea Level Rise

TEACHER NOTES

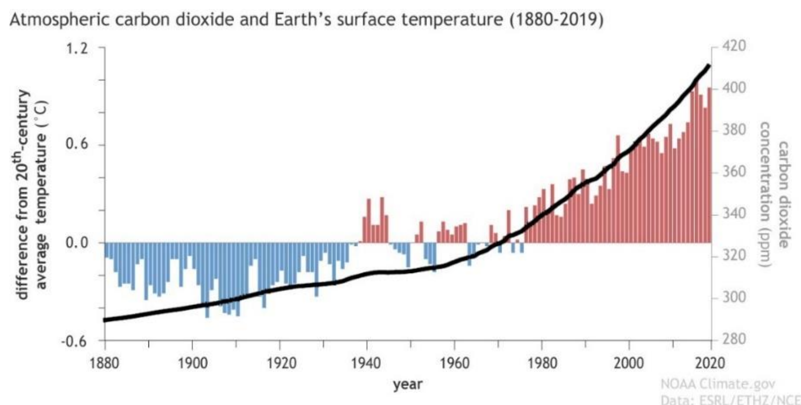
Climate Change Data Source

✓ A huge quantity of data, analysis, and predictions about climate change come from the UN's Intergovernmental Panel on Climate Change (IPCC) which is the foremost authority on climate change. Their most recent major report is the 2014 Synthesis Report (AR5). Their next reports (AR6) are expected in 2021-2022.

Teacher Tip

✓ The RCPs in these graphs refer to "representative concentration pathways" which provide a few possible scenarios from among the many possible outcomes.

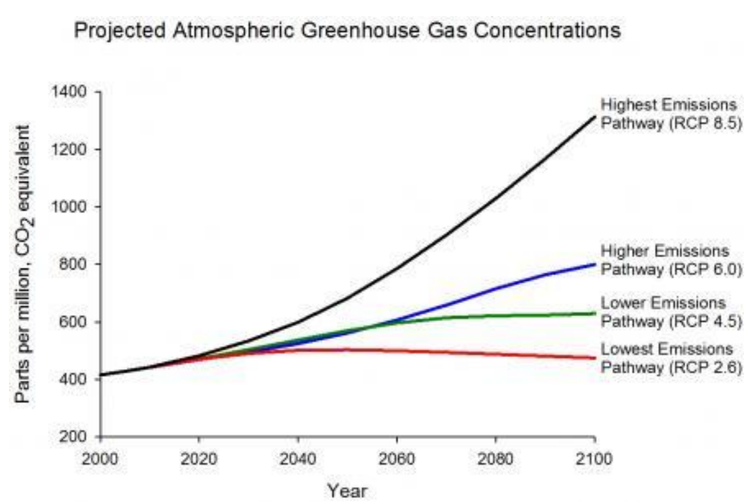
3. **How much is too much?** Show students the graph of the carbon dioxide concentration and global temperature:



Ask students what they think will happen to the temperature if the carbon dioxide levels continue to go up? (It will continue to get hotter). That might be an easy question, but what about if the carbon dioxide level goes down? For example, what if it goes down to 400 ppm? Will the temperature still go up? It might, because 400 ppm is still much higher than the concentration of CO_2 used to be. What scientists right now are trying to figure out is, how much carbon dioxide is too much? How far do we have to make it go down to get the temperature back to normal?

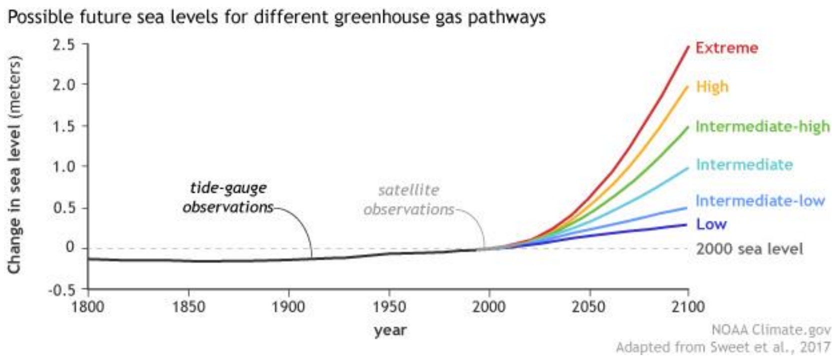
Tell students that in the next part of their activity, they are going to look at different climate change scenarios based on how much the greenhouse gas level goes up or down.

4. **Introduce the climate change scenarios:** Have students turn to the back of their reading to look at the graph, and project it so students can see it in color.



Tell students that scientists create models to predict how the climate will change based upon how much greenhouse gas is in the atmosphere. However, the scientists don't know how much greenhouse gas there will be, so they make different predictions for different amounts of gas. This graph above shows the amount of greenhouse gas (in ppm) for each scenario. Have students mark on their graphs the worst-case scenario (RCP 8.5), the mid-case scenarios (RCP 4.5 & RCP 6.0) and the best-case scenario (RCP 2.6). Ask students why they think we have these different scenarios (it is based on what decisions we make to stop polluting the air with CO_2 and other greenhouse gases).

5. **Sea level rise scenarios:** Have students look at the graph that shows "Possible futures sea levels for different greenhouse gas pathways" and project it so they can see the colors:



Ask them what similarities they see in this graph compared to the last one they looked at (it is line graph, it shows a similar time period, it has a few different lines that split apart as you go into the future). Ask students why there are different scenarios for sea level rise. (it also depends on what decisions we make to stop emitting greenhouse gases). Ask which greenhouse gas level goes with which scenario (note that there is not an exact match, but the scenarios are similar).

Have students use the graph to determine what the sea level rise prediction is for three different greenhouse gas levels. Make sure they change from meters to feet for their answers.

6. **Introduce resilience:** Write the word "resilient" on the board and ask if anyone know what the word resilient means. Have students share what they know about the word resilient. Use what students know to introduce the definition of community climate resilience: "the ability of communities to prepare for, respond to, and recover from hazardous events and adversity related to climate change."

TEACHER NOTES

Extension

- ✓ The Urban Sustainability Directors Network has created a series of "games" designed to teach people about how to build climate resiliency into their community plans. You can check out their three scenarios (Game of Floods, Game of Extremes, and Game of Heat) here: https://www.usdn.org/projects/climate-trainings.html

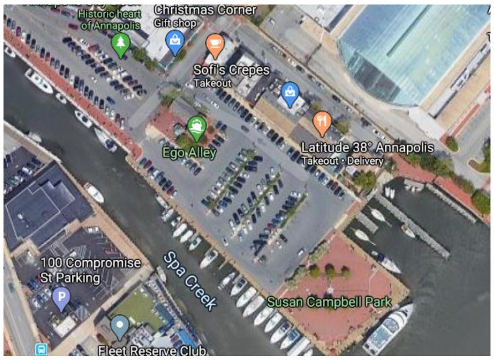
Ask students if they have ever recovered from adversity. Have a few students share their experiences if they are interested (as appropriate). Use this to begin making a connection between personal resilience and community climate resilience.

7. **Resilience example:** Hand out the Climate Resilience and Sea Level Rise sheet to students. Tell students that communities that are facing rising sea levels can prepare to deal with the changes. In just a moment, they are going to watch a video about a city that is dealing with flooding from rising sea levels and also extreme weather. During the video, they should take notes on their handouts about what the people in the city are doing to build resilience from flooding.

   Show the video: Sea Level Rising: Living With Water from 0:48 to 7:09. The video can be found at: https://www.pbs.org/video/sea-level-rising-living-with-water-inv0lp/. Some solutions for resilience seen or mentioned in the video:
   - ✓ Elevation (building houses up off the ground)
   - ✓ Plant rain gardens
   - ✓ Plant orchards
   - ✓ Build canals to circulate water around the city
   - ✓ Plant specific plants in low areas that will help the ground absorb water
   - ✓ Build "blue ways" to channel water

   After the video, have students share some of the things they wrote down that New Orleans is doing to build climate resilience.

8. **Formative assessment:** Have students complete the prompt on making their community more resilient to flooding from climate change. You can also show them Google Street View pictures of this community to give them a better sense of what it is like. Much of this area will be under water given the intermediate sea level rise scenario:



Possible student answers:

- Build a wall along the water to keep out the rising water level
- Replace some of the pavement with grassy areas that can absorb water from flooding
- Elevate the building (if possible) or raise the floor level to keep water out in case of a flood
- Move these stores to a different part of the city that is less prone to flooding and use this space for something else

TEACHER NOTES

Modification

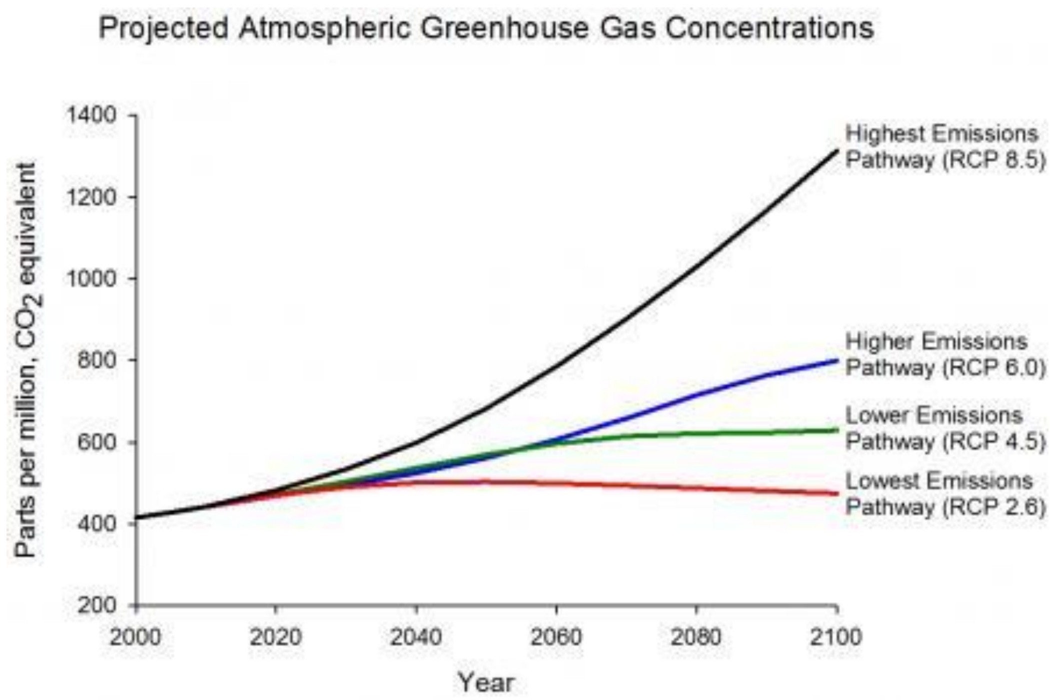
- ✓ If the school community is in an area that is at risk from flooding due to climate change, feel free to change the formative assessment scenario to be about the school community. In Activity 10, students will directly address how to address climate change, including through changes in their personal lives and by building community resiliency.

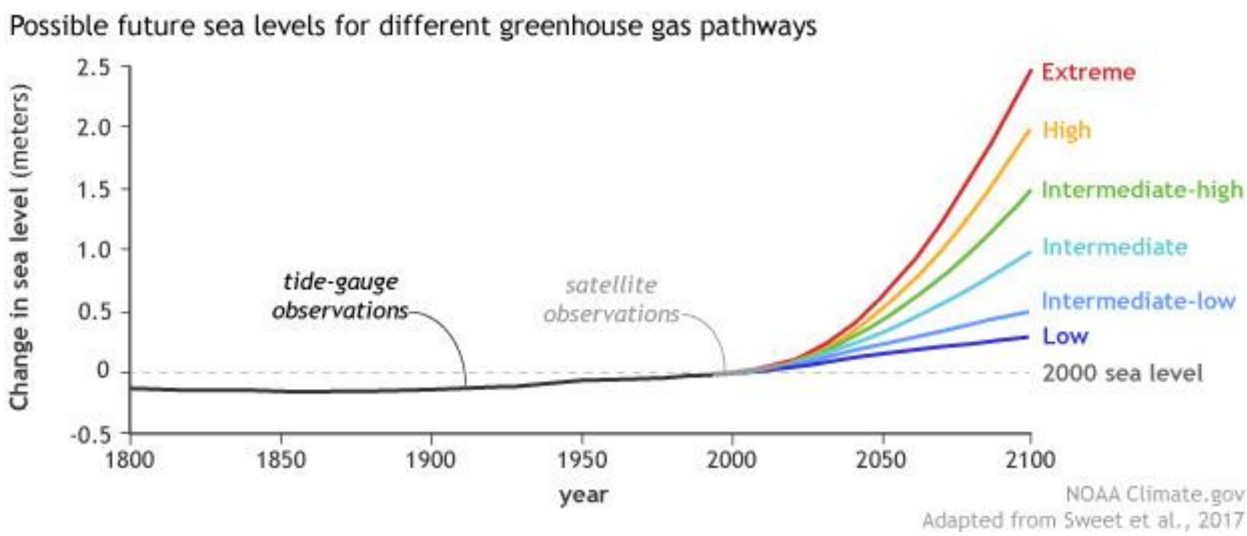
Name ______________________________

STUDENT READING

What is Climate Change?

The greenhouse effect is a process that occurs when certain gases in the Earth's atmosphere trap heat and cause the planet to get warmer. Carbon dioxide (CO_2) is the most important greenhouse gas, but there are other greenhouse gases in the atmosphere such as water vapor, methane, and nitrous oxide.	What are the major greenhouse gases?
When the temperature on the planet goes up, it causes more than just hotter days. There are a lot of different effects that are caused by a warmer Earth. Climates across the planet will be different, so we call these effects "climate change." Climate change involves changes in long-term weather patterns including temperature, rainfall, and storm activities.	What is climate change?
There are many effects from climate change. Rising sea levels are one example. Melting polar ice in both the Arctic and Antarctic is another. As temperatures rise, we expect there will be more droughts and heat waves, which can lead to wildfires. Many places in the United States will get more rain, although some will get less. Hurricanes are also expected to get stronger.	Name three effects of climate change:
Even though the effects of climate change can feel frightening, there is reason to be hopeful! Millions of people around the world are working to help stop climate change by reducing the amount of carbon dioxide in the atmosphere. Because greenhouse gases are often produced in power plants and vehicles, we can all do our part to reduce climate change by using less electricity, and riding or driving less in cars and trucks.	Name two ways that you can help stop climate change:





Note: 1 meter is about 3 feet.

What is the predicted change in sea level in feet for the extreme scenario?	
What is the predicted change in sea level in feet for the intermediate scenario?	
What is the predicted change in sea level in feet for the low scenario?	

STUDENT HANDOUT

Name ___________________________

Climate Resilience & Sea Level Rise

Community climate resilience: the ability of communities to prepare for, respond to, and recover from hazardous events and adversity related to climate change.

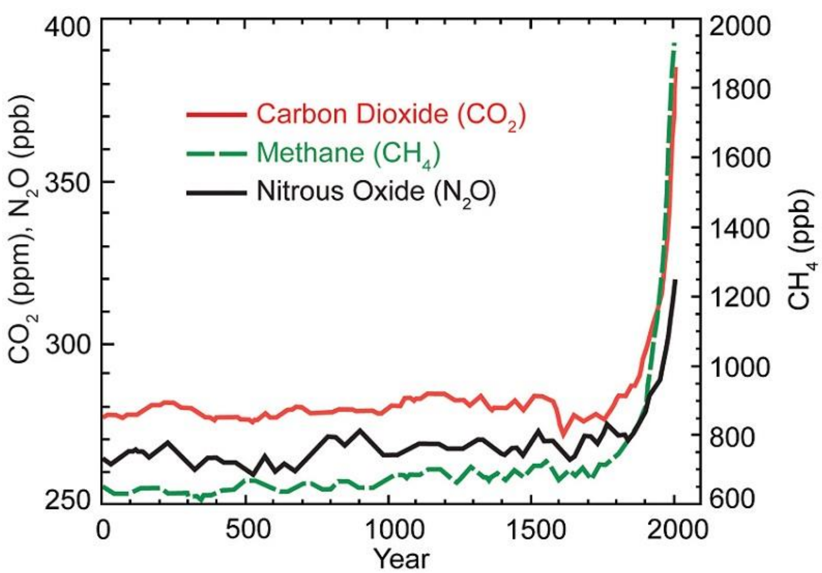
What kinds of things do the people in the video do to prepare for flooding?
Think back to the sea-level rise scenarios we studied in Annapolis. Imagine that you are a business owner with a store that is in the light blue zone. You want to prepare for the “intermediate” climate change scenario. What kinds of things can you do to make your community more resilient to climate change? 

Activity 9 (Elaborate): CO_2 Sources & Solutions

Activity summary: In this activity, students learn about where fossil fuels come from, and they make the connection that burning fossil fuels (largely in power plants and vehicles) is what is increasing the amount of carbon dioxide and other greenhouse gases in the atmosphere. They research local sources of greenhouse gases, and discover that sources of greenhouse gases are also the sources for other air pollutants. Finally, students start brainstorming ways that they can reduce the amount of carbon dioxide they put in the atmosphere.

Standards Connection
DCI: ESS 3.D: Global Climate Change
DCI: ESS 3.C: Human Impacts on Earth Systems
SEP: Analyzing Data
CCC: Cause & Effect

Warmup: Show students this graph of greenhouse gas concentrations over the last 2000 years:



At this point, they should be relatively familiar with graphs showing greenhouse gas concentrations, but make sure they understand what the graph is showing. Then ask them what they think happened to make the graph go up so much in the last 200 years.

- Use this warmup to gauge students' familiarity with things like the industrial revolution and human activities like combustion engines, power plants and factories that produce greenhouse gases. These are all topics they'll explore during this activity. If these ideas are new to them, then use the warmup as a way to frame what they'll be learning about today. They will come back to this graph in their formative assessment, so don't take the time now to go into a deep explanation.

ACTIVITY DETAILS

Time: 45 minutes

Objectives

- ✓ Students will understand where fossil fuels come from
- ✓ Students will understand how carbon dioxide gets into the atmosphere from fossil fuels
- ✓ Students will identify local sources of greenhouse gas emissions
- ✓ Students will brainstorm ideas for keeping carbon dioxide out of the atmosphere

Materials

- ✓ Computer & projector
- ✓ Speakers (for video)
- ✓ Student computers (optional)
- ✓ Plain paper

Handouts

- ✓ Carbon dioxide and Fossil Fuels graphic organizer

TEACHER NOTES

Teacher Tip

- ✓ Students learned a little bit about where greenhouse gases come from in Activity 2, so try to tie in anything they remember from that activity (or previous modules) about where pollution comes from.

Teacher Tip

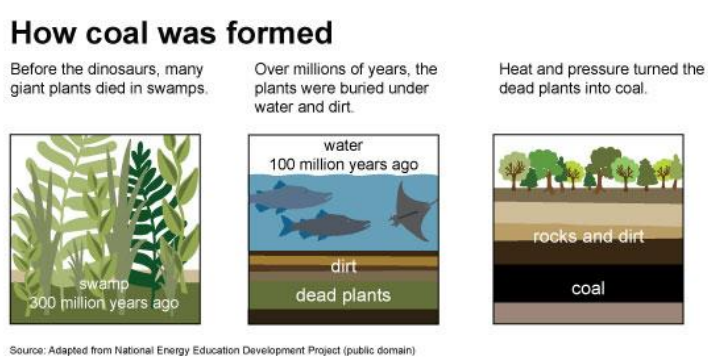
- ✓ If you have previously studied the carbon cycle with students, this would be a great opportunity to make a connection back to it.

1. **Frame the Activity**: Tell students that as humans, we can deal with climate change in two big ways: we can plan for resilient communities that can decrease the effects of climate change, and we can slow down the rate of climate change by limiting the amount of greenhouse gases we put in the air. During the last activity, they focused on resilience, so today they are going to learn about how to limit greenhouse gas emissions.

2. **Introduction to fossil fuels:** Have students turn to a partner and discuss for a brief moment if they (personally) can create carbon dioxide. When you come back together as a class, have them share what they decided. At least some students should remember that we as humans breathe out carbon dioxide all the time. Each person exhales over 800 pounds of carbon dioxide every year! Tell students that carbon – part of carbon dioxide – is an element that is a very important part of living things. Every living thing on the planet is made of carbon and other elements. So where is all this carbon dioxide coming from that is causing climate change?

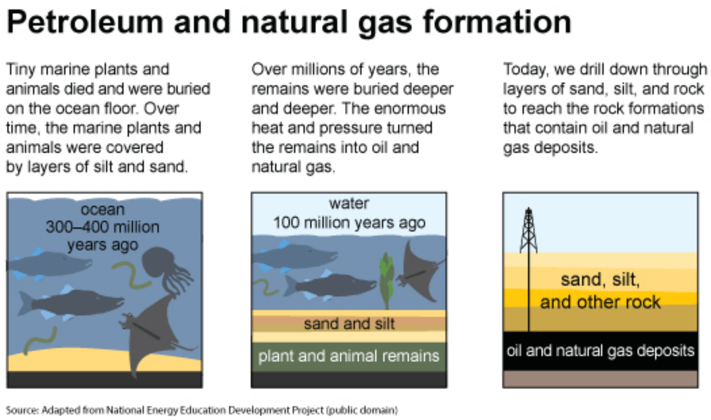
   Pass out the Carbon Dioxide and Fossil Fuels graphic organizer, and ask students what goes in the first box (carbon) and have them fill it in.

   Show students the graphic below and have them read through it.



   Use questioning to help students understand that coal is mostly made of carbon. For example:
   - Based on this graphic, what coal is made from? (dead plants).
   - What element did we say is a big part of plants? (carbon)
   - What element do you think coal is mostly made of? (carbon). The carbon content of coal varies, but coal commonly has a carbon content of 75%.

Next, show students this graphic that shows how oil and natural gas are formed. The processes are very similar except that oil and natural gas formation mostly involves marine animals and plants.



Ask students what should go in the second line (plants & animals) and third line (coal, oil, and natural gas) in their graphic organizers and have them fill it in.

3. **What do we do with fossil fuels?** Ask students what we do with things like coal, oil, and natural gas to get the energy out of them? (We burn them). Show students the picture below, which shows burning coal:

Tell students that we burn fossil fuels in power plants to generate electricity and to power things like cars and trucks. But when we burn fossil fuels, the carbon in the fuel combines with oxygen to make carbon dioxide. That is the carbon dioxide that is causing climate change.

Ask students what should go in the fourth line (burn them) and fifth line (carbon dioxide) of their graphic organizers, and have them fill it in.

TEACHER NOTES

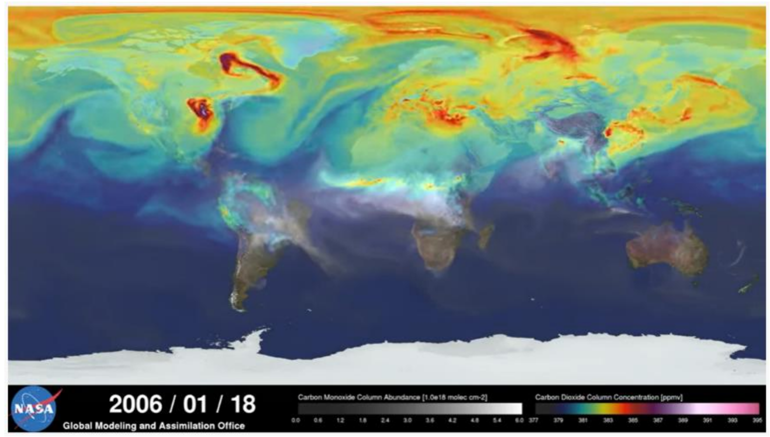
Additional Media

- ✓ This video from California Academy of Sciences has a great youth-led explanation of how fossil fuels and made and what problems they pose: https://www.calacademy.org/educators/whats-the-deal-with-fossil-fuels
- ✓ Vox produced an alternative version of NASA's Earth and CO_2 video which highlights some important details. You may wish to show that video instead of NASA's original: https://www.youtube.com/watch?v=fJ0o2E4d8Ts

Modification

- ✓ If student computers are available, have students use them to look up the information in the spreadsheet themselves.

4. **Earth and carbon dioxide:** To give students a sense of what carbon dioxide in the atmosphere looks like, show them this very cool short video from NASA which models carbon dioxide emissions and dispersion during the course of a year: https://www.youtube.com/watch?v=x1SgmFa0r04. Before playing the video, asks students to keep an eye out for where the most carbon dioxide emissions are coming from (North America, Europe, and Asia)



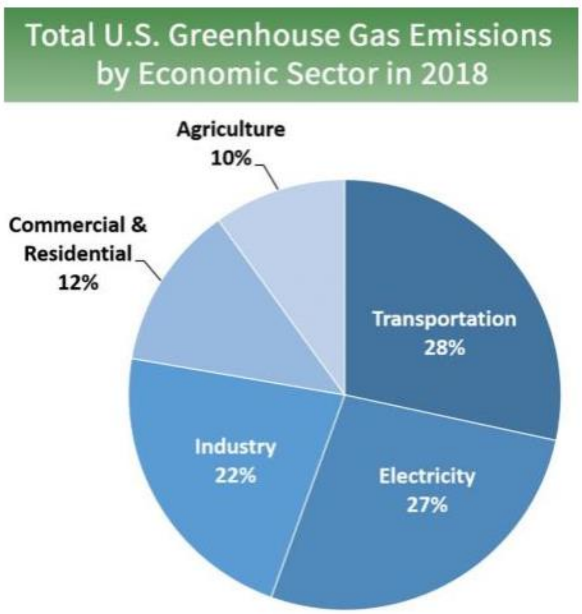
If you have already studied photosynthesis, this video also provides an opportunity to talk about why CO_2 levels drop in the summer (in the Northern Hemisphere) and go up in the winter.

5. **Local sources of greenhouse gases:** Ask students if they think there are any sources of greenhouse gases like power plants and factories in the area. After they have had a chance to think about it, go to the local sources of air pollution spreadsheet: https://tinyurl.com/DCMetroAirPollution and display it for students to see. Go to the tab for greenhouse gases and sort the total emissions column Z→A. This will bring up a list of the largest greenhouse gas emitters in the DC, MD, VA, WV area. Have students turn to the back side of their handout, and answer the first two questions together:
    - The top 10 sources of greenhouse gases in the area are all power plants (electricity generation)
    - Other sources in the top 30 are factories/mills (pulp & paper, cement, and chemical manufacturing)

    Next, look up local sources of greenhouse gases. You can do this by filtering the list for a particular county or zip code. To filter, click the little triangle at the top of the column you want to filter, click "clear", then click on the individual county or zip code to add it to the list. You can also sort the column and search for your county or zip code. Have students identify the top local sources of greenhouse gases and them to their papers. Ask students if they've ever heard of these sources.

6. **Greenhouse gases and other air pollutants:** Switch over to the "Criteria pollutants" tab and sort the total emissions column by Z→A. Click the emissions units filter and uncheck the "tons" option so the list is sorted by the highest emissions sources. Tell students that this is a list of different kinds of air pollutants that are called criteria pollutants. Some criteria pollutants are also greenhouse gases, and some are not. Have students look at the list of the top emissions sources. Do they notice any similarities? You may want to go back to the original greenhouse gas emissions list (not the local list) so students can compare. What do they see? (the top sources are mostly the same). Ask them what this tells them about how different kinds of air pollution are related (many different kinds of air pollution come from the same sources). Have students answer questions 4 and 5 on their handouts.

7. **What can we do?** Show students the infographic below, and ask them which sector they think most of the greenhouse gases *they* add to the atmosphere come from (most likely electricity and transportation).



Total Emissions in 2018 = 6,677 Million Metric Tons of CO_2 equivalent. Percentages may not add up to 100% due to independent rounding.

Now that they know how greenhouse gases get into the atmosphere, they can start thinking about how to slow the rate of climate change.

TEACHER NOTES

Data Source

- ✓ The information for the local pollution source database comes from the National Emissions Inventory published by the US EPA. The database is updated every three years. These data come from the 2017 version of the database. Learn more about the NEI here: https://www.epa.gov/air-emissions-inventories/national-emissions-inventory-nei

Cause & effect connection

- ✓ When students are considering how to slow the rate of climate change, consider having them look back at the cause & effect chain they developed in Activity 4 and thinking about ways that they can "break the chain"

TEACHER NOTES

Looking ahead

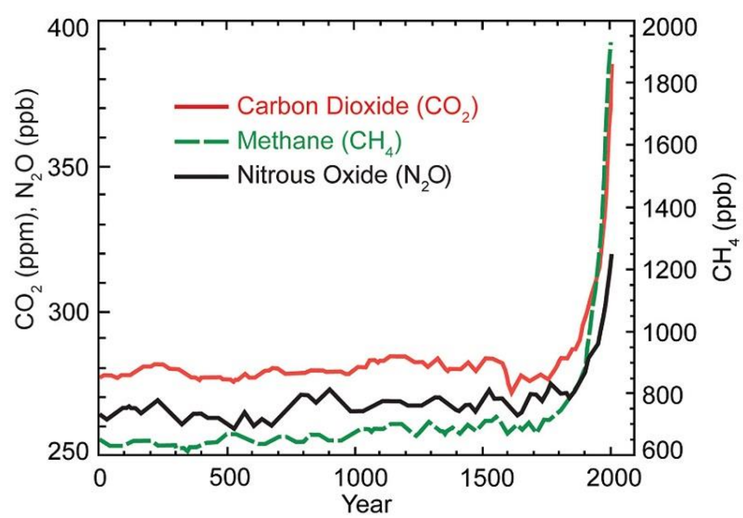
✓ The "Doing our Part" activity in this module (which comes up next) involves students making a plan to reduce their greenhouse gas emissions or build resilience into their community. As soon as you have their brainstorm sheets, begin thinking about how to tie their ideas into this activity. You might want to type up students lists so it is easier to share it with them during the next activity.

Have students start brainstorming on their handout things that they can do to prevent climate change. Encourage them to be as specific as possible (ex. "Turn of my Xbox when I am done playing" vs. "use less electricity").

Once students have had a chance to make a list on their own, have them share their lists with others in a small group. Give each group a sheet of paper so they can make a list for the whole group with all of their ideas.

When students are done, thank them for thinking about ways to protect the Earth. Then collect the lists and tell students that they will come back to these ideas during their next activity.

8. **Formative assessment:** Display the graph up from the warmup so all students can see it:



Have students write a short explanation of why the graph goes up so much towards the end. Their answer should include what they learned about fossil fuels and how humans use them. Even if students haven't learned about the industrial revolution, they should be able to conclude that this was the time we started burning lots of fossil fuels (and discovered others) to make electricity, and around the time that cars were invented that burned fossil fuels. They may also realize that human population has grown a lot during this time period, which also contributes to the big spike in CO_2 levels in the atmosphere.

Name________________________________

STUDENT NOTES SHEET

Carbon Dioxide and Fossil Fuels

How are fossil fuels connected to climate change?

Living things are made of		and other elements
Millions of years ago, dead		were buried underground
Over time, they were formed into		called fossil fuels, because they are old like fossils
Humans dig these resources out of the ground and		to produce electricity in power plants and power cars and trucks
Burning fossil fuels releases		which causes climate change

Sources of greenhouse gases

1. What do the top 10 sources of greenhouse gases in the area have in common?

____

2. Look at the top 30 sources of greenhouse gases. Besides electricity generation, what other kinds of sources are there? ____

3. What are the top three local sources of greenhouse gas emissions and what type of sources are they (ex. electricity generation, institutional, etc.)?

____

____

____

4. What do you notice about the top sources of criteria pollutants compared to the top sources of greenhouse gases?

____

5. What does this tell you about the how different kinds of air pollution are related?

____

____

6. What can <u>you</u> do to keep carbon dioxide out of the atmosphere?

- ____
- ____
- ____
- ____
- ____

Activity 10 (Elaborate): Doing Our Part

Activity summary: In this action-oriented activity, students think about individual and group actions they can take to fight climate change. They also engage with stories that show the power that young people have to make a difference in the fight against climate change. Using this information, students create individual pledges and develop a group action project to address climate change in their community.

Standards Connection
DCI: ESS 3.C: Human Impacts on Earth Systems
DCI: ESS 3.D: Global Climate Change
CCC: Cause & Effect

Timing and other thoughts on this activity

Climate change can be disheartening for students, especially if they have routinely been presented with "doom and gloom" scenarios about the future of the planet. Providing an opportunity for them to make small changes for themselves and their communities is an important way to build their sense of empowerment, and to learn to live the "think globally, act locally" philosophy. This activity presents a variety of options that take different amounts of time, resources, and effort to achieve. Choose those that fit within your constraints, and provide students with the opportunities to make a real difference. If the project goes on for multiple days, you may choose to give students the assessment (Activity 11) when students need a break from the project.

Warmup: Display the photo collage below, and ask students what all these things have in common.

ACTIVITY DETAILS

Time: 2 or more class periods (120+ minutes)

Objectives
- ✓ Students will use what they have learned in the module to create individual and group action plans to address climate change.
- ✓ Students will advocate for climate change in their communities by completing a group action project.

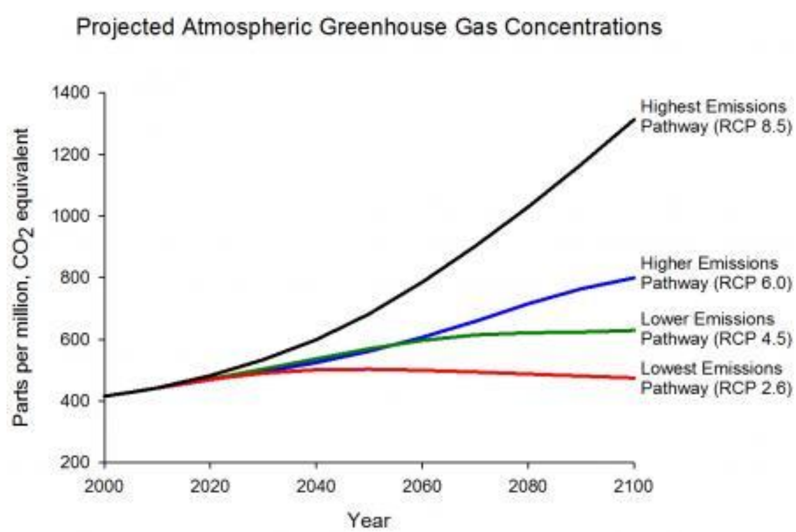
Materials
- ✓ Computer & projector
- ✓ Speakers (for video)
- ✓ Student computers (optional)
- ✓ Make A Pledge!

Handouts
- ✓ My carbon footprint
- ✓ What I Can Do, What We Can Do

TEACHER NOTES

- Each of these pictures represents a way to reduce greenhouse gas emissions to prevent climate change: bicycling (instead of taking a car), turning off the lights when not in use, using energy from solar panels instead of fossil fuels, and eating a plant-based diet.

1. **Frame the activity:** Show students the greenhouse gas concentration graph from Activity 8 (below) and remind them that we as humans can do a lot to prevent climate change. If we change the cause of climate change, we can change the effects. Our goal is to get this greenhouse gas graph to stop going up and start going down. And we all have the power to do our part to make it happen. During the last activity, students brainstormed ways that they can help protect the Earth from climate change. Today they are going to develop ways to put those ideas into action.



2. **Carbon footprints (optional):** Pass out the “My Carbon Footprint” sheet to students. Tell them that a good way to figure out what they can do to prevent climate change is to calculate their carbon footprint. A carbon footprint is the amount of greenhouse gases you put into the atmosphere through your actions (including how much electricity you use) during a whole year. Have students add this definition to their sheets. Share that your carbon footprint is based on where you live, how you get around, what you eat, and how you use electricity.

   If student computers are available, pass them out, and have students complete one of the carbon footprint calculators below. If not, you may choose to do one for the whole class together. There are many different carbon footprint calculators to choose from that take different amounts of time and require different amounts of knowledge. On the next page there are links to a few that are student-friendly:

Teacher Tip

- ✓ The “My Carbon Footprint” sheet is generic and can be used with any of the footprint calculators, although it is closely patterned after the first one on the list. For the others, you may need to help students decide on things they can do to help lower their carbon footprints.

- Zero Footprint Youth Calculator (https://calc.zerofootprint.net/): simpler, and includes details on how to decrease your footprint
- Lehigh University Carbon Emissions Calculator (https://ei.lehigh.edu/learners/cc/carboncalc.html): more detailed, but no suggestions for decreasing footprint
- International Student Carbon Footprint Challenge (https://depts.washington.edu/i2sea/iscfc/fpcalc.php?version=ms): very detailed, but no suggestions for decreasing footprint

3. **What can we do?** Ask students if they feel like they have the power to fight climate change in their communities. Lead them in a short discussion about why they do or don't feel like they have that power. Then share some stories of young people who are working to make a difference in their communities and for the world. Students may have heard of Greta Thunberg. This video about Greta is a great way to help students see the power that they can have: https://www.youtube.com/watch?v=uRgJ-22S_Rs. Students should also have a chance to see other young people who look like them who are fighting for climate change. Consider having students read about one of these other young climate activists who come from a diverse variety of backgrounds: https://www.cnn.com/2019/09/28/world/youth-environment-activists-greta-thunberg-trnd/index.html

   You can also share this episode of the Flossy podcast, which is an award-winning climate change podcast developed by a group of Black high school students in Canarsie, NY.
   - Podcast: https://soundcloud.com/canarsiestudios/climate-change-environmental-racism
   - Their story: https://www.npr.org/2020/06/03/867842394/the-winners-of-the-npr-student-podcast-challenge

   Afterwards, revisit the conversation about whether they have the power to fight climate change in their communities, and see if their opinions have changed.

4. **Make an individual plan:** Hand out the "What I Can Do, What We Can Do" sheet, and read through the top part together. Then share the lists that students brainstormed in the last activity about what they can do to fight climate change, either by giving back their papers, or by sharing a summary of their ideas. There are some additional ideas on the back of their handouts. Have students make an individual commitment for what they want to do at the top of the page based on their lists.

TEACHER NOTES

Climate Change and Equity

- ✓ Many suggestions for how to lower your carbon footprint are closely related to standards of living and living conditions. For example, riding a bicycle to school may be safe in some neighborhoods but not others. Buying locally-sourced fruits and vegetables depends on having access to these resources. Be mindful of inequities that make some changes difficult for some students. Also consider how you can help students advocate for things like a school-based farmers market that can challenge these inequities.

Modification

- ✓ There are many different ways to help students take action. Focus on what students want to do and use what they are passionate about to drive the decision-making.

TEACHER NOTES

Other Resources

- ✓ Project Drawdown has numerous ideas for how to reduce your carbon footprint. Students and schools can also form teams and make pledges online. The Project Drawdown Ecochallenge is a good way to start. It takes some time to learn how to navigate the site, but the resources are well worthwhile. Check it out here: https://drawdown.ecochallenge.org/

Pledge Drive

- ✓ A great way to involve the school community and teach students about advocacy is to hold a pledge drive. Have students take a copy of the Make A Pledge! sheet and go to their families, friends, teachers, and neighbors asking them to pledge to make a change. Students can record pledges on paper cutouts of Earth or other shapes. Make a classroom collage of all the shapes and total up the pledges to celebrate success.

5. **Choose a group project:** Have students think about what they can do as a class to help fight climate change. They may already have some ideas from thinking about their individual action. The back of their sheet has some additional ideas. Discuss with students what they would like to do. Be sure to guide the conversation to keep student ideas within budgetary and time constraints. It will only take a class period to make signs to put up around the school reminding people to turn off the lights, but it might take several days to plan a fundraiser, make a video, or plan a school rally. Help students select a plan that they can be successful with.

   If some students want to do a larger project, consider starting an environmental club that can work on longer-term projects.

6. **Plan the project**: If students are interested in taking on a project that requires additional planning, have them divide the project up into smaller pieces that groups of students can work on. For a school rally, some students may make posters, while others write a letter for school staff, administration, or parents. You will likely need to do some planning outside of class, but try to include students in planning as much as possible. Once you have a plan developed, make sure to share that plan with students.

7. **Implement the plan**: Follow your plan, and make adjustments along the way as necessary. Be sure to document your students' work along the way with pictures, videos, etc.

8. **Celebrate success**: When the project is complete, take time to reflect on and celebrate what you and your students have accomplished. How much carbon dioxide will stay out of the air if people keep their pledges? Did you hold a rally or present at a school assembly? Write a story about it for the local newspaper or the school website. Share your success with others in the environmental conservation community.

Name___________________________________

STUDENT DATA SHEET

My Carbon Footprint

What is a carbon footprint? ____

____

What is your carbon footprint?_____________________tons/kgs of carbon dioxide.

How does your carbon footprint compare with the United States average? (18 tons or 7,800kg) __

____

____

How does your carbon footprint compare with the world average? (5 tons or 3,800 kg) ________

____

____

What kinds of things make your carbon footprint higher?

- ____
- ____
- ____

To get the carbon dioxide concentration back down to a safer level, we need to get each person's carbon footprint down to 3 tons.

What are 3 things you can do to lower your carbon footprint?

- ____
- ____
- ____

Name________________________________

STUDENT GUIDE

What I Can Do, What We Can Do

There are many different ways that young people can help prevent climate change. You have already taken the first step by learning what climate change is. Use this guide to help you think about ways to work with others to increase your influence. Be a leader! Help your community fight climate change!

What I plan to do to fight climate change:
What we as a class plan to do to fight climate change:

Individual Action Ideas

Participate in a climate change rally	Go grocery shopping with your family and look for locally produced foods, especially fresh fruits and vegetables.	Teach a family member or friend about climate change and help them make a change to lower their carbon footprint
Ride your bike to school or to a friend's house instead of riding in a car.	Eat more plant-based foods and less meat and dairy products.	Create a transportation log that shows how many miles you ride in a car in a month. Pledge to reduce the number next month.

Group Action Ideas

Ask your school leaders to make a change that will reduce the school's carbon footprint. For example, serving more vegetarian food at lunch and turning off buses when they pick up and drop off students.	Run a pledge drive! Ask your friends, family members, neighbors and teachers to pledge to do one thing to reduce their carbon footprint. Keep track of how much CO_2 is reduced by people's pledges.	Make a video to educate others about climate change, then share your video with the community.
Advocate for a bicycle rack at school, or a place to store bikes insides so more students can bike to school.	Organize a climate change rally or assembly for your school or community.	Start a club that meets to talk about climate change and work to reduce the school's carbon footprint. If your school is in Maryland, you can work to make your school a Green School.
Advocate to hold a farmers' market at the school once a week or once a month.	Hold a fundraiser to buy Kill A Watt electricity use monitors for the school, then use them to monitor and lower electricity use	Create signs around the school reminding teachers and students to shut off lights and electronics when they're not being used

Make a Pledge!

Action	Approximate Pounds of CO_2 saved
Take a day (or more!) off from eating meat and dairy products	8 pounds for every day off
Ride a bicycle or walk next time you need to go somewhere nearby instead of driving (or riding) in a car	1 pound for every mile you don't drive
Adjust your thermostat up by 2° in the summer and down by 2° in the winter	5 pounds for every day you use less energy for heating and cooling
Change one light bulb from an incandescent light to a compact fluorescent light	2 pounds for every week with the new bulb
Shorten your shower by 2 minutes	1 pound per shower your take
Recycle cans and bottles	1 pound for every pound of waste you recycle (instead of putting in the trash)
Recycle newspapers and magazines	3 pounds for every week you recycle
Air dry your laundry instead of using a dryer	3 pounds for every load of laundry
Wash your clothes in cold water instead of hot	1 pound for every load of laundry

Sources: https://www.clackamas.us/sustainability/tips.html, https://www3.epa.gov/carbon-footprint-calculator/

Activity 11 (Evaluate): Earth in 2050

ACTIVITY DETAILS

Time: 30 minutes

Objectives

- ✓ Students will demonstrate their understanding of key climate change ideas related to greenhouse gases, sea level rise, and climate resilience.
- ✓ Students will interpret graphs to draw conclusions about climate change scenarios

Materials

- ✓ Computer & projector

Handouts

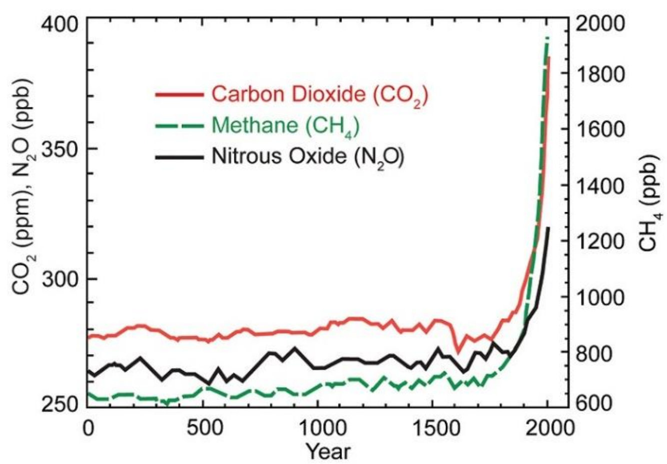
- ✓ Earth in 2050 assessment

Activity summary: This summative assessment is designed to evaluate students' understanding of the big ideas of the module by posing a fictional scenario about the future and having students interpret the effects to determine the causes. Students also share what they learned about climate resilience to provide suggestions to a community in need.

Standards Connection

DCI: ESS 3.D: Global Climate Change
DCI: ESS 3.C: Human Impacts on Earth Systems
SEP: Analyzing Data
CCC: Cause & Effect

Warmup: Consider what topic students might need some additional support with before the assessment, and use it to help provide some additional guidance (without giving away any of the answers on the assessment). For example, have students determine approximately what year carbon dioxide levels were at 300 ppm using the graph below (it was just after 1900).



1. **Frame the activity:** Remind students of how much they have learned during the module, and how many questions from Activity 1 they have answered based on their original phenomenon. Assure them that they are prepared to show what they know.

2. **Provide the assessment.** Give students the assessment (Earth in 2050).

3. **Next steps:** After the assessment, consider if there are any questions left from Activity 1 that you want to address, and finish any action projects that are still ongoing. Be sure to give students feedback on their assessment, and celebrate all that they have learned!

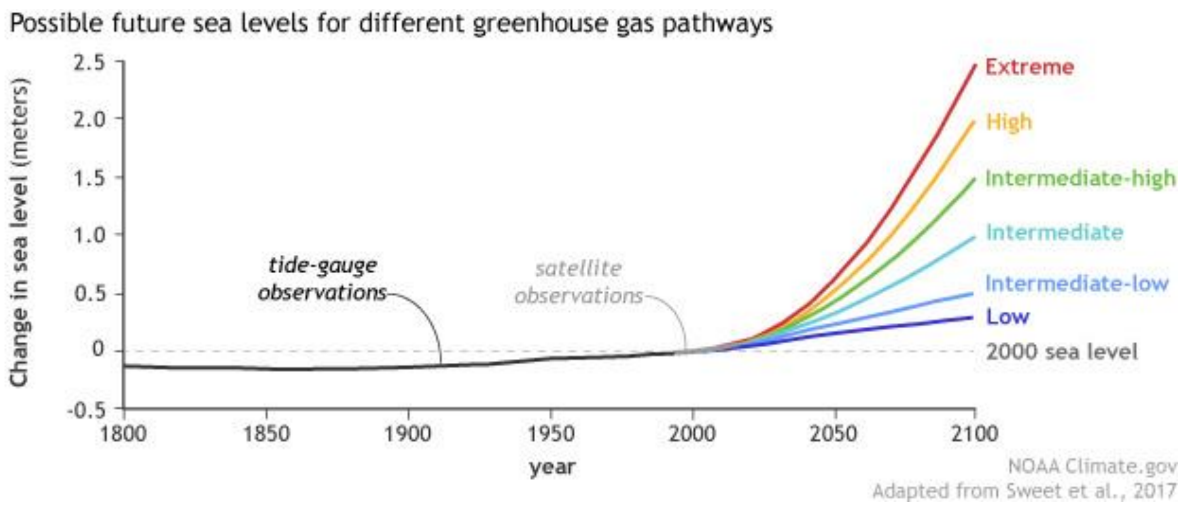
Name ______________________________

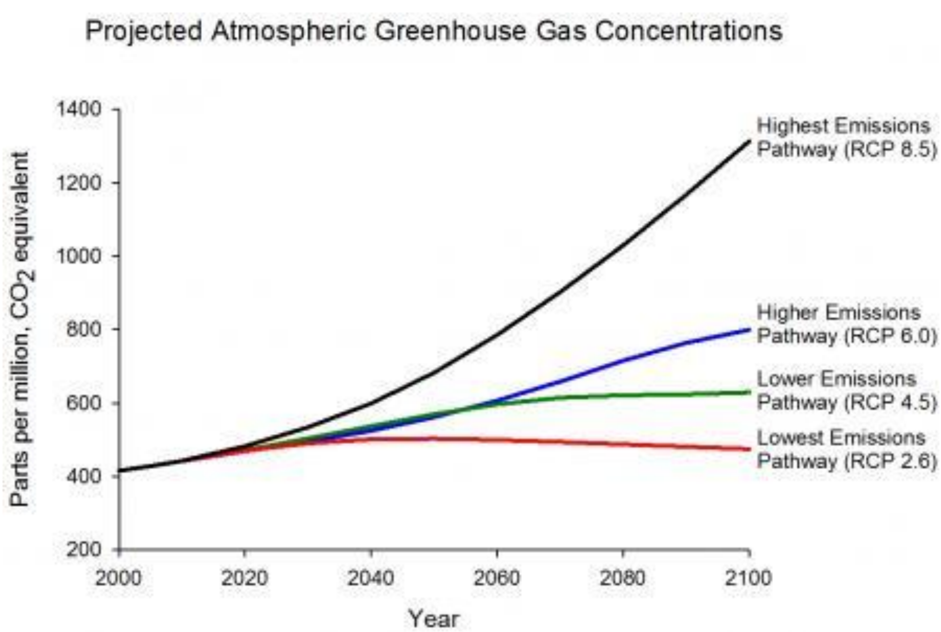
STUDENT ASSESSMENT

Earth in 2050

Imagine that it is the year 2050. You are a professional climate scientist who specializes in studying sea level rise. You have been collecting and analyzing data on how much the ocean has risen since 2000. According to your measurements, the sea level has risen by 0.2 meters since 2000 (8 inches). You would like to use this information to think about how the Earth has changed in the last 50 years, and what humans have been doing to prevent climate change.

Use this information and the graphs below to answer the questions on the following pages.





1. Based on the amount of sea-level rise, what pathway (scenario) for sea level rise do you think happened (extreme, high, intermediate, or low)?

    ____

    How did you find your answer? ______________________________

    ____

    ____

2. Based on the pathway you think happened, what do you think the concentration of greenhouse gases in the atmosphere is in 2050?

    ____

    How did you find your answer? ______________________________

    ____

    ____

3. Sea level rise is an effect that has many causes. Fill in the boxes in the cause-effect chain below to show how human activities have led to rising sea levels.

Human activities like...

produced

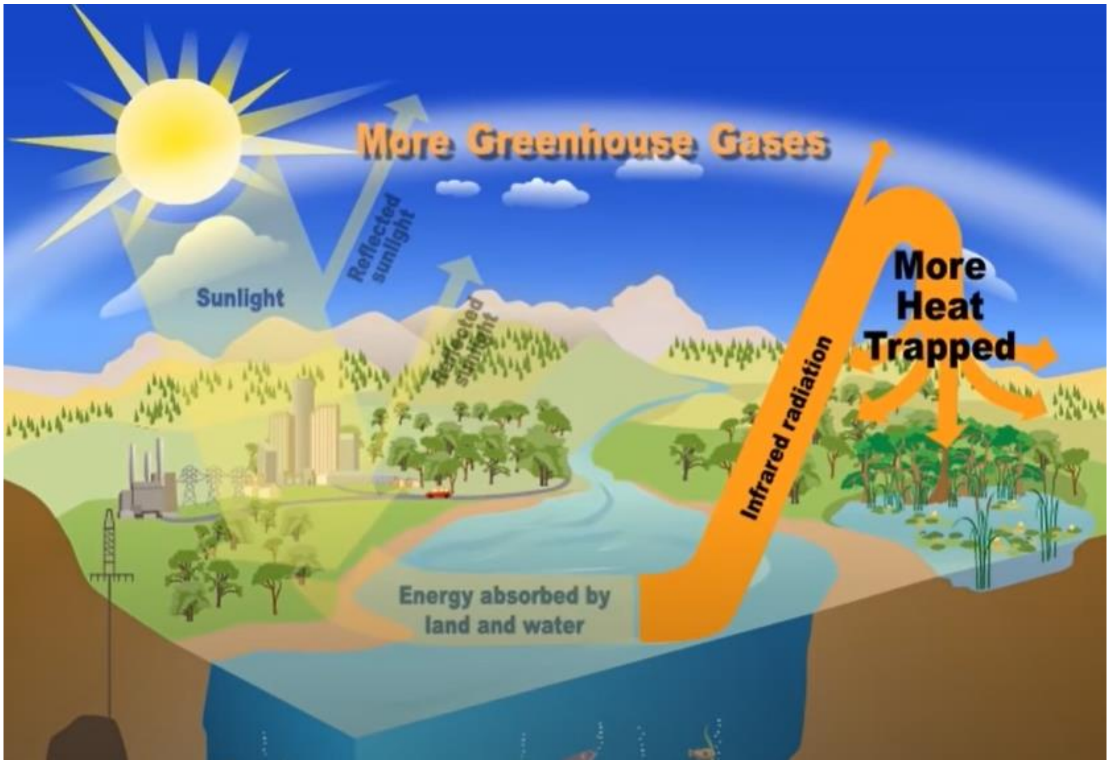
which caused

which caused

which caused

Sea levels to rise

4. The greenhouse effect is closely related to climate change. Use the diagram below to write an explanation of how the greenhouse effect works:



____

____

____

____

____

____

____

____

5. What are humans doing that increases the greenhouse effect? ____________________

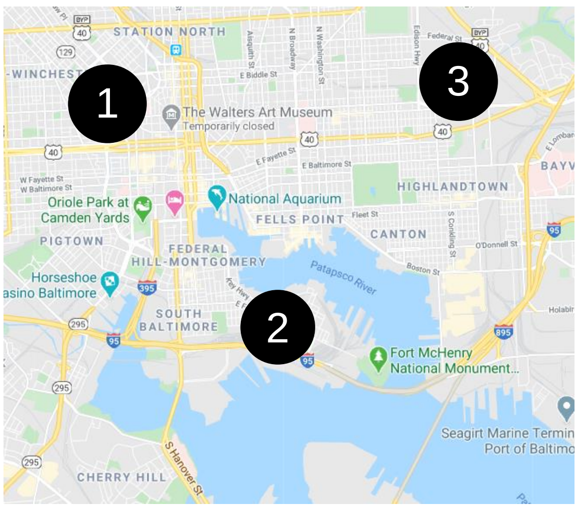
____

____

____

6. Based on the pathway (scenario) that humans followed, what kinds of things do you think humans did to prevent climate change? Include <u>at least three things</u> in your answer.

7. The Baltimore city government calls you to ask if they should be worried about rising sea levels. Look at the map below that shows a section of Baltimore.



Which neighborhood is most at risk for rising sea levels? (1, 2, or 3)?

Why are they most at risk?

8. The community you identified calls you to ask what they can do to make their neighborhood more <u>resilient</u> to rising sea levels. What suggestions would you make to them? Include <u>at least two suggestions</u> in your answer.

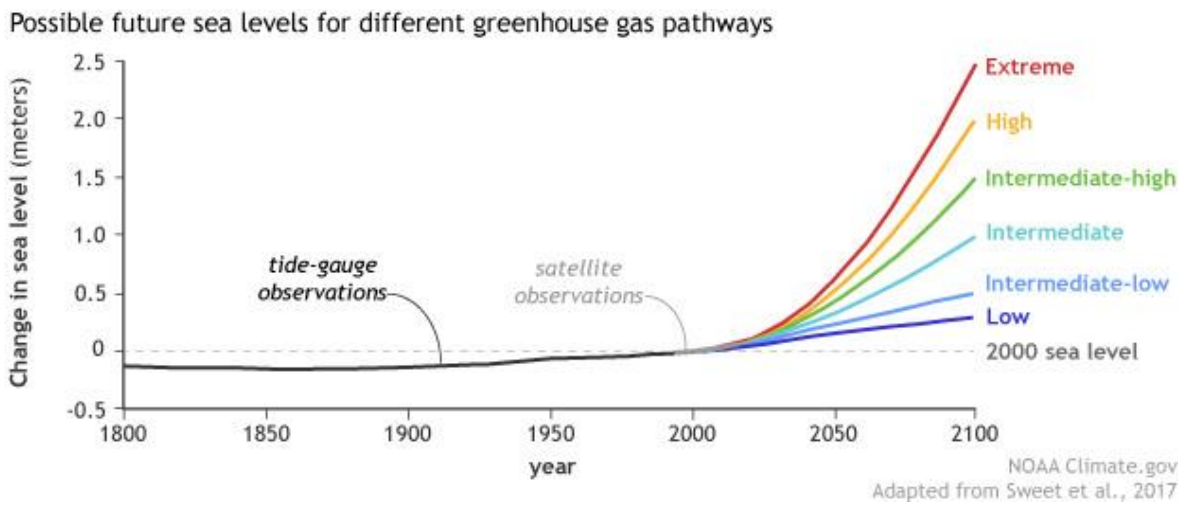
ANSWER GUIDE

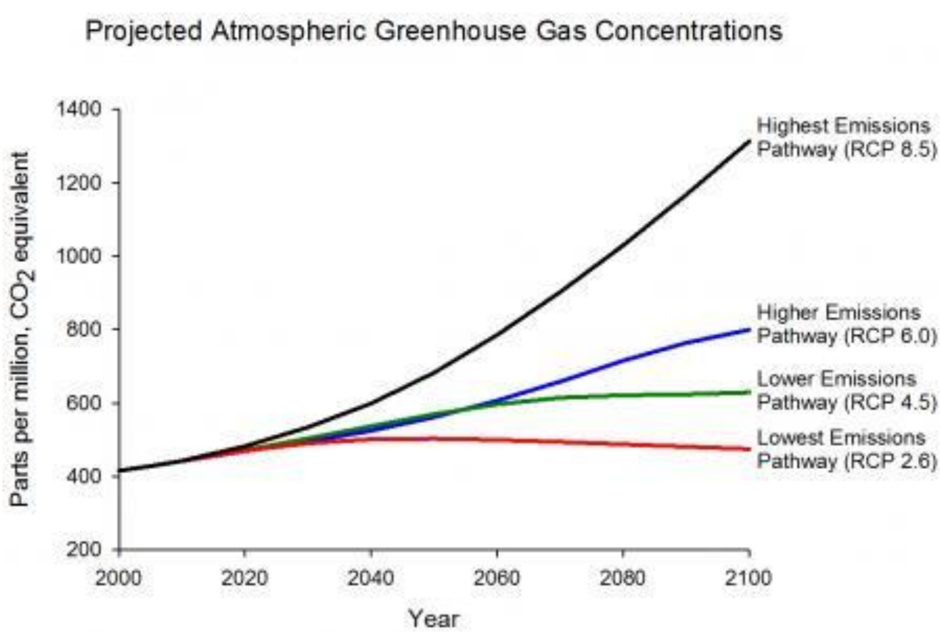
Name ______________________________

Earth in 2050

Imagine that it is the year 2050. You are a professional climate scientist who specializes in studying sea level rise. You have been collecting and analyzing data on how much the ocean has risen since 2000. According to your measurements, the sea level has risen by 0.2 meters since 2000 (8 inches). You would like to use this information to think about how the Earth has changed in the last 50 years, and what humans have been doing to prevent climate change.

Use this information and the graphs below to answer the questions on the following pages.





1. Based on the amount of sea-level rise, what pathway (scenario) for sea level rise do you think happened (extreme, high, intermediate, or low)?

   ____Low____

   How did you find your answer? ______I looked at the first graph and found the sea level rise for 0.2 meters on the y-axis. I went across to 2050, and saw that it intersected with the graph for the low pathway________________________________

2. Based on the pathway you think happened, what do you think the concentration of greenhouse gases in the atmosphere is in 2050?

   ____500 ppm____

   How did you find your answer? ______I looked the bottom graph, and found where 2050 was on the x-axis. I went up to the lowest emissions scenario and then across to the y-axis. It was about in the middle of 400 and 600ppm, so I estimated it was 500 ppm.________________

3. Sea level rise is an effect that has many causes. Fill in the boxes in the cause-effect chain below to show how human activities have led to rising sea levels.

Human activities like…

Burning fossil fuels to make energy
Driving gas-powered cars

produced

Greenhouse gases like carbon dioxide

which caused

Global temperatures to rise (increased the greenhouse effect)

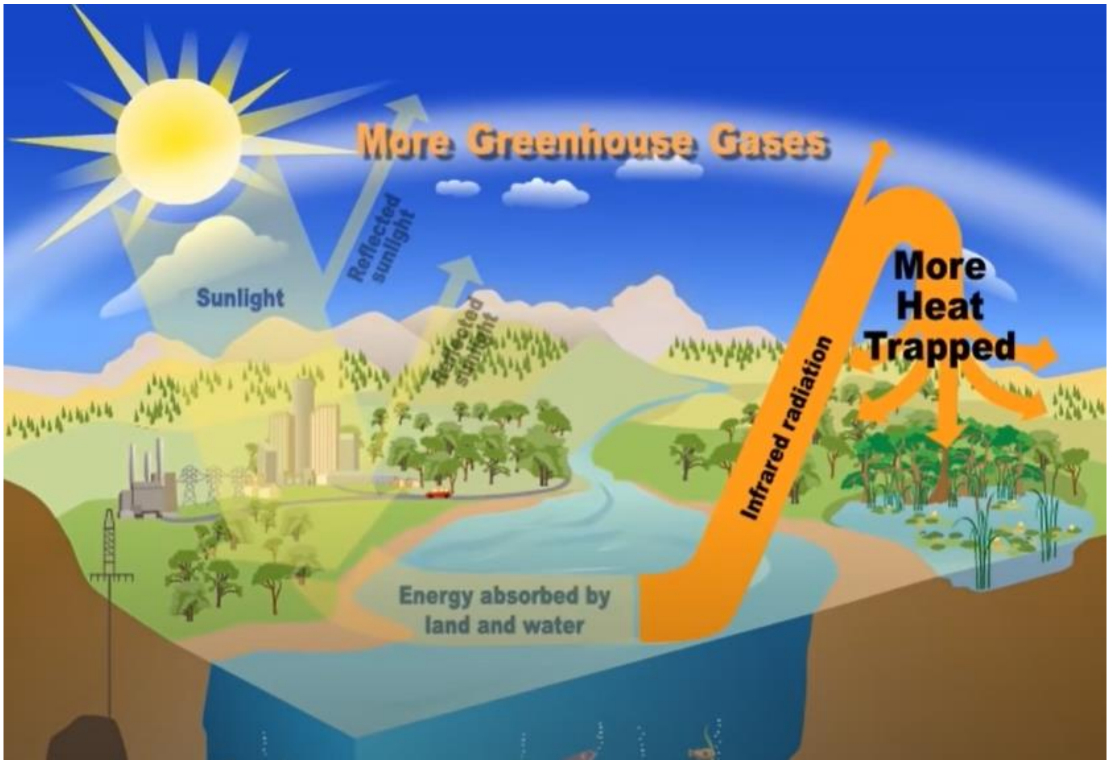
which caused

Land ice to melt (and thermal expansion of ocean water)

which caused

Sea levels to rise

4. The greenhouse effect is closely related to climate change. Use the diagram below to write an explanation of how the greenhouse effect works:



Sunlight from the sun heats up the Earth (land and water). The Earth then sends some of that heat back out into the air. Some of the heat goes back out into space, but some of it is trapped by greenhouse gases, which keeps the Earth warm.

5. What are humans doing that increases the greenhouse effect? Humans produce more greenhouse gases when they burn fossil fuels for energy or transportation. This increases the greenhouse effect.

6. Based on the pathway (scenario) that humans followed, what kinds of things do you think humans did to prevent climate change? Include at least three things in your answer.

Used more clean transportation (electric vehicles, mass transit, bicycles)

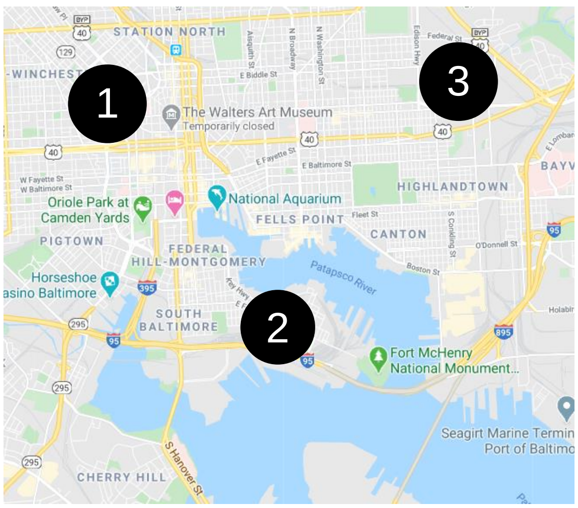
Ate more locally-produced food and less meat

Used energy more efficiently (turned off lights, electronics, etc.)

Used more clean energy sources (wind, solar, geothermal, tidal)

Many other answers possible

7. The Baltimore city government calls you to ask if they should be worried about rising sea levels. Look at the map below that shows a section of Baltimore.



Which neighborhood is most at risk for rising sea levels? (1, 2, or 3)?

2

Why are they most at risk?

It is closest to the water, and likely the lowest in elevation.

8. The community you identified calls you to ask what they can do to make their neighborhood more resilient to rising sea levels. What suggestions would you make to them? Include at least two suggestions in your answer.

build walls at the water's edge to prevent flooding

create low-lying grassy areas with plants that will help to absorb floodwaters

create channels to direct flood water back to the harbor

build new buildings that have a ground floor that is above ground level)

other creative answers are possible

Air Quality Champion in Our Community

Name: Dr. Vernon Morris
Titles: Director of the Cooperative Science Center in Atmospheric Science & Meteorology (NOAA); Emeritus Professor of Chemistry & Atmospheric Sciences (Howard University)
Organizations: NOAA Cooperative Science Center for Atmospheric Sciences and Meteorology (NCAS-M), Howard University

How does your work relate to air quality?
At N-CASM, I lead teams of scientists, university students, and professors to work on problems of air chemistry, weather, and climate. We work on projects to improve predictions about air pollution, develop new ways to measure chemicals in the environment, and study how climate change and air quality affect each other. As a professor, I teach, develop new courses, and support education and career opportunities in environmental science, particularly for students from disadvantaged backgrounds.

What motivates you to come to work every day?

- ✓ <u>Curiosity</u>. I love learning and finding out how and why things in nature work the way they do. My job allows me to uncover the mysteries of the Earth's environment.

- ✓ <u>The possibility of making a difference</u>. Whether I'm providing educational tools and programs or conducting research that will lead to a better quality of life for people all over the world, I feel like the work that I do makes a difference. Sometimes, I even get to see the fruits of my labor when a student becomes a successful professional or my research leads to policy or process changes in an organization or society.

- ✓ <u>Engagement with students</u>. I absolutely love to be around people who want to learn new things. I am fortunate to have a job that continually seeks and shares knowledge. Being around people who love learning is energizing.

What education and career path did you pursue to have the position that you have today?
Growing up, I thought that I would enter the military and travel the world. In high school, I envisioned myself becoming a professional fighter. A dramatic event changed my mind and I literally stumbled into my current career. Shortly after entering Morehouse College, I found myself unable to pay some of my tuition. I was dashing through the chemistry building on my way to find a job and ran smack into a chemistry professor. This professor not only paid my tuition, he found me a part-time campus job and convinced me to major in Chemistry and Mathematics. I went on to become the first African American to earn a PhD in Geophysical Sciences (now Earth and Atmospheric Sciences) at Georgia Tech. After that, I began my research in a mountain monastery in Sicily and have now conducted research on five of the seven continents, three of the five major Oceans, and visited over 30 countries.

What is your workspace like?
On a typical day, I may be in a meeting room in the morning, a classroom in the afternoon, and a rooftop lab after that. My favorite workspace is aboard research ships that sail out into the remote oceans to conduct experiments. On the ships, I launch balloons that carry delicate instruments up in the atmosphere to measure the properties of the air. I also monitor air chemistry on deck, and even send devices into the sea to measure gases.

What accomplishment are you most proud of?
My proudest accomplishment has been my children. I have three intelligent and beautiful daughters and a son on the way. A close second is enabling the success of the 150 students whom I have mentored over the years. Many of these students have gone on to become successful doctors, scientists, engineers, and business owners. I take a lot of pride in opening doors and enabling people to achieve their dreams.

Is there something important that you want to share that we haven't asked?
A little advice: believing in yourself is important but not enough. Hard work is essential but not enough. Combining these two elements and building meaningful professional relationships will take you a long, long way towards achieving your dreams. You have to find people who will fight for you and help open doors for you. You have to be prepared to do your job well when the door is opened. And once you get through the door, make sure that you reach back and help someone else.

Glossary

carbon dioxide (CO_2) – a colorless, odorless gas produced by burning carbon and organic compounds such as fossil fuels, and by cellular respiration. It is naturally present in air (about 0.03 percent) and is absorbed by plants in photosynthesis. Carbon dioxide is also a major greenhouse gas.

carbon footprint – the amount of carbon dioxide and other carbon compounds emitted due to the consumption of fossil fuels by a particular person, group, etc.

causation – a change in one variable directly resulting in the change of another variable through a direct mechanism

climate – the weather conditions in a given area over a long period of time, ex. temperature and rainfall

climate change – any significant change in the measures of climate lasting for an extended period of time. In other words, climate change includes major changes in temperature, precipitation, or wind patterns, among other effects, that occur over several decades or longer.

climate resilience – the ability to anticipate, prepare for, and respond to hazardous events, trends, or disturbances related to climate.

community climate resilience – the ability of communities to prepare for, respond to, and recover from hazardous events and adversity related to climate change

control – a variable which is kept constant across groups in a controlled experiment in order to isolate the effects of the other variables

correlation – a mutual relationship or connection between two or more things. Often shown as a relationship between two variables or quantities in a graph or chart

dependent variable – a variable that is measured by the experimenter in a controlled experiment, and whose value depends upon the independent variable

fossil fuel – a natural fuel such as coal or gas, formed in the geological past from the remains of living organisms.

global warming – recent and ongoing rise in global average temperature near Earth's surface. It is caused mostly by increasing concentrations of greenhouse gases in the atmosphere.

greenhouse effect – the trapping of the sun's warmth in a planet's lower atmosphere by particular gases

greenhouse gas – a gas that contributes to the greenhouse effect by absorbing infrared radiation (heat), e.g., carbon dioxide and chlorofluorocarbons

independent variable – a variable that is changed by the experimenter in a controlled experiment

land ice – frozen water that is on land, including mountain glaciers and **ice** sheets covering Greenland and Antarctica

parts-per-billion (abbreviation ppb) – a unit of measure equal to 1 in 1 billion, or 0.0000001%. 1 ppb is also equivalent to 1 µg/liter.

parts-per-million (abbreviation ppm) – a unit of measure equal to 1 in 1 million, or 0.0001%. 1 ppm is also equivalent to 1 mg/liter.

RCP (Representative Concentration Pathway) – is a greenhouse gas concentration (not emissions) trajectory. The pathways describe different climate futures, all of which are considered possible depending on the volume of greenhouse gases (GHG) emitted in the years to come

sea ice – frozen, floating ocean water

sunny day flooding – temporary flooding of low-lying areas, especially streets, during exceptionally high tide events, such as at full and new moons. Also known as nuisance flooding or tidal flooding.

tide – the alternate rising and falling of the sea, usually twice in each lunar day at a particular place, due to the attraction of the moon and sun.

urban heat island – a phenomenon wherein an urban area or metropolitan area is significantly warmer than its surrounding rural areas due to human activities.

weather – the state of the atmosphere at a given place and time in terms of temperature, humidity, precipitation, wind, etc.