

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

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 consequences 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... <ul style="list-style-type: none"> 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... <ul style="list-style-type: none"> 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... <ul style="list-style-type: none"> 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... <ul style="list-style-type: none"> 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... <ul style="list-style-type: none"> 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... <ul style="list-style-type: none"> 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 CO₂ concentration
- ✓ Students will understand the concept of climate resilience and how it applies to sea level rise

Activity 9 (Elaborate): CO₂ 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: Providing 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): CO₂ 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 plan 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%.

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

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

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%)

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?

- ✓ Curiosity. 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.
- ✓ The possibility of making a difference. 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.
- ✓ Engagement with students. 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 (CO₂) – 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.