GROUNDWORK Hudson Valley

CHANGING PLACES CHANGING LIVES

With Partners:

NOAA

SARAH LAWRENCE COLLEGE

CENTER FOR THE URBAN RIVER AT BECZAK

TEACHER'S GUIDE

DISTANCE LEARNING MODULE

Global, Local, Coastal:

Preparing the Next Generation for a Changing Planet

Preface

In 2016, Groundwork Hudson Valley prepared a comprehensive curriculum on climate change science, impact, and resiliency. Our primary audience was secondary students in Yonkers, New York: a city of three rivers, including the tidal estuary portion of the Hudson River. Yonkers has already felt impacts from severe storms, such as Hurricane Sandy, as well as rising coastal waters. The course set out to provide experiential learning at three sites: The Science Barge, The Center for the Urban River at Beczak, and the EcoHouse. At each site, we engaged students on (1) how scientists study climate, (2) what impacts can be felt already and what we can expect in the future and (3) what we can do to build resiliency from future impacts into our economies, infrastructure, natural resources, food systems, public health, and safety. This Distance Learning Module is intended to translate the educational resources we developed in partnership with the National Oceanic and Atmospheric Administration (NOAA) and the Sarah Lawrence College Center for the Urban River at Beczak (CURB) for classroom use through the use of a web-based app, virtual tours of our sites, classroom activities, and student worksheets.

Guiding Questions

⇒ **What is climate and how is it different than weather?**

⇒ **How is the climate changing and what is driving that change?**

⇒ **What are the impacts of a changing climate?**

⇒ **How can we mitigate what is driving climate change?**

⇒ **How can we adapt and face changes with resiliency?**

Where to Find This Curriculum and Other Resources for Download

This curriculum, and other accompanying resources, are available for download on the Groundwork Hudson Valley website, Sustainability Education tab, under **"Climate Change and Resilience Learning Module."**

You can link directly there, and download the full curriculum or each unit separately, by following this url:

http://www.groundworkhv.org/climate-change-resilience-learning-module/

This "Global, Local, Coastal: Preparing the Next Generation for a Changing Climate" distance learning module booklet was prepared by Groundwork Hudson Valley, Inc. under award NA15SEC0080004 from the Environmental Literacy Grant (ELG) Program of the National Oceanic and Atmospheric Administration (NOAA), U.S. Department of Commerce. The statements, findings, conclusions, and recommendations are those of the author(s) and do not necessarily reflect the views of NOAA or the U.S. Department of Commerce.

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Primary Sources:

NOAA—Climate Literacy packet, Climate Resiliency Toolkit, Teacher Portal
NASA—Global Climate Change Vital Signs of the Planet, Images of Change, Visualization Lab
National Snow and Ice Data Center
U.S. EPA
U.S. Global Change Research Program—National Climate Assessment (2014, 2018)
PBS Learning Media Library

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Follow along with the web-application:

https://nicholasericksen.github.io/GHV-data/

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INTRODUCTION

Core Objectives

◊ To broadly increase climate literacy among teachers, students, and the public.

◊ To introduce students to the many ways scientists unearth our climate history, and track our current climate.

◊ To align our climate literacy curriculum with NGSS so that it can be used to teach many earth science, living environment, environmental studies, and engineering concepts.

◊ To better equip local residents so they can participate in the long-term resiliency decision making process in their own communities.

◊ To explore the utilization of this program to reach vulnerable communities throughout the Hudson River Valley and beyond through new distance-learning technology.

Climate Change Affects Everyone

That isn't just a future-tense thing. The availability of food and freshwater, the costs of goods and services, the security of our loved ones have been fundamentally changed by global warming. Creating personal connections to the material is key to motivating collective action in finding solutions.

◊ To identify best practices for facilitating meaningful conversations around consequence of climate change and how it relates to environmental justice, as well as how to leverage individual and community action into collective impacts.

The following standards will be fully or partially covered in one or more of the learning modules.

"Science is all about discovery. It's about learning how the world works, and why, and connecting empirical data to a better understanding of the world we live in... Students will benefit from a basic understanding of what we believe will be the greatest challenge their generation will ever face." — Rebecca Anderson, Director of the Alliance for Climate Education

National Science Standards Addressed

Ecosystems: Interactions, Energy, and Dynamics

◊ HS-LS2-1. Use mathematical and/or computational representations to support explanations of factors that affect carrying capacity of ecosystems at different scales.

◊ HS-LS2-4. Use mathematical representations to support claims for the cycling of matter and flow of energy among organisms in an ecosystem

◊ HS-LS2-6. Evaluate the claims, evidence, and reasoning that the complex interactions in ecosystems maintain relatively consistent numbers and types of organisms in stable conditions, but changing conditions may result in a new ecosystem

◊ HS-LS2-7. Design, evaluate, and refine a solution for reducing the impacts of human activities on the environment and biodiversity.

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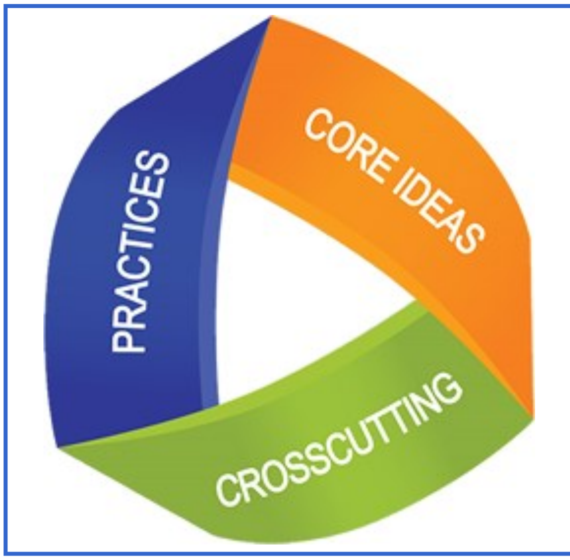


National Science Standards cont'd

From Molecules to Organisms: Structures and Processes

◊ HS-LS2-5. Develop a model to illustrate the role of photosynthesis and cellular respiration in the cycling of carbon among the biosphere, atmosphere, hydrosphere, and geosphere.

Biological Evolution: Unity and Diversity

◊ HS-LS4-5. Evaluate the evidence supporting claims that changes in environmental conditions may result in: (1) increases in the number of individuals of some species, (2) the emergence of new species over time, and (3) the extinction of other species.

Earth's Systems

◊ HS-ESS2-2. Analyze geoscience data to make the claim that one change to Earth's surface can create feedbacks that cause changes to other Earth systems.

◊ HS-ESS2-4. Use a model to describe how variations in the flow of energy into and out of Earth's systems result in changes in climate.

◊ HS-ESS2-6. Develop a quantitative model to describe the cycling of carbon among the hydrosphere, atmosphere, geosphere, and biosphere.

Earth and Human Activity

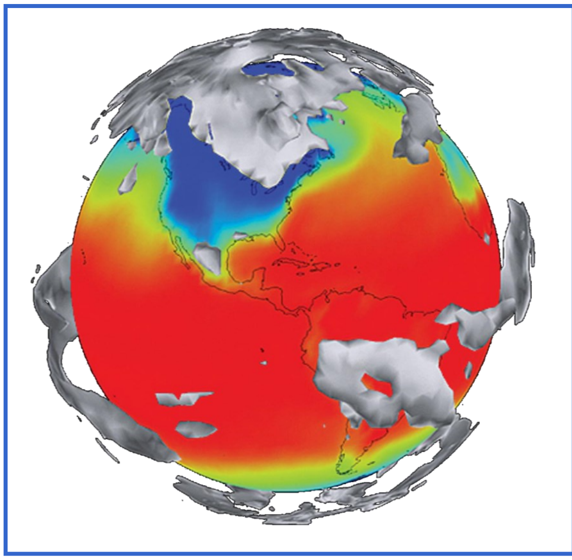
◊ HS-ESS3-1. Construct an explanation based on evidence for how the availability of natural resources, occurrence of natural hazards, and changes in climate have influenced human activity.

◊ HS-ESS3-3. Create a computational simulation to illustrate the relationships among management of natural resources, the sustainability of human populations, and biodiversity.

◊ HS-ESS3-4. Evaluate or refine a technological solution that reduces impacts of human activities on natural systems.

◊ HS-ESS3-5. Analyze geoscience data and the results from global climate models to make an evidence-based forecast of the current rate of global or regional climate change and associated future impacts to Earth systems.

◊ HS-ESS3-6. Use a computational representation to illustrate the relationships among Earth systems and how those relationships are being modified due to human activity.



OVERVIEW

Background information

Climate change presents a global existential crisis. Our youth will inherit a world imperiled by more powerful storms, rising seas, freshwater and food scarcities, and extreme biodiversity loss. While the majority of K-12 teachers want to engage their students on climate change, they face overwhelming obstacles: subject complexity, politicization, and emotional heaviness, in addition to resource and time constraints to dig into the material. A lot of misinformation also exists, causing confusion about how and why accelerated climate change is occurring and why it is such a big concern. In a recent poll of educators conducted by the New York Times, over 70% incorrectly believed that the hole in the ozone was a primary cause for global warming! It is all too easy for teachers to shelve climate lessons in class because they lack confidence in their own knowledge of the subject, do not feel prepared to tackle the emotional repercussions to students, or have trouble selecting a lesson that is relevant enough to tie in with their curriculum while addressing state or federal standards. This curriculum was developed in hopes that it could begin a bridge over those obstacles.

The five **Unit** overviews serve as a primer for teachers to self educate, with individual chapters providing more depth. While the curriculum in its entirety can be used comprehensively, many chapters include lessons, classroom activities, and student worksheets that can be used as stand-alones, a la carte. Many of these lessons utilize educational tools developed by NOAA and a network of partners. There are innumerable of such resources found on NOAA’s teacher portal, PBS Learning Media Library, NASA’s website, and the Climate Literacy and Energy Awareness Network (CLEAN) that are worth combing over, but we acknowledge that doing that is work and takes time. We have begun that work over the past three years while developing three experiential climate resilience programs as recipients of NOAA’s Environmental Literacy Program grant in 2015. We translated those programs into this Teacher’s Guide in order to provide an easier entry-point into both the subject of climate change, and the myriad resources we found online.

NAVIGATING THE WEB-APP

Videos, graphs, slideshows, maps, and widgets to assist in teaching each unit.

This web-app was developed with the help of Nicholas Ericksen, formerly of IAC Applications. Originally intended to be used on the Science Barge’s touchscreens for public interface and to aid in our Global, Local, Coastal programs, we have adapted it into a host of teacher resources for teaching climate change. These resources fall into three key areas presented on the web-app: (1) climate science, (2) climate change impact, and (3) adaptation and resiliency. By clicking through the tabs, you will find video segments, graphs, slide-shows, and even interactive computer labs that have been hand-selected by Groundwork Hudson Valley to complement this curriculum. These resources have been sourced from a number of reputable organizations, including NOAA, the EPA, FEMA, the 2014 & 2018 National Climate Assessments, and CLEAN (Climate Literacy and Awareness Network—also syndicated to NOAA’s climate.gov portal). Whenever possible, this curriculum also provides a direct link to these videos, images, and webpages to allow you to find supplementary resources and to ensure access to these resources even if our web-app does not load.

Throughout this curriculum, teachers have the option of either using the web-app in the front of the classroom as an instructional tool, or letting students navigate to its different functions in a computer lab setting or at home (for homework). Here we provide a few helpful tips for each use:

If using for instructional purposes:

◊ Most shared images can be saved for printing purposes by right-clicking. The captions will not save with the image however.

◊ If a particular lab or widget does not load, your **browser** may be blocking it. This can be usually be fixed by navigating to that tab, and then clicking the pop-up notification or shield icon at the right of the web-address box and selecting “load unsafe scripts.” This will return you to the home menu, so you will have to navigate back to the tab you are trying to use. You only need to do this once while this web-app is still open.

◊ If a particular video does not play, you may be blocked by your **network** to play YouTube links, or missing Windows Media Player software. Whenever possible, we have sourced videos that could be downloaded and streamed straight through the web-app. However, some files were not available anywhere but YouTube or simply too large to include.

If letting students navigate in a computer lab setting:

◊ To eliminate the web-browser buttons during use, so students do not accidentally or purposely navigate off the web-app, you can use F-11 to go to full-screen mode. Be sure to permit all “unsafe scripts” in the app to load first, for each computer.

Note: This application is open source, which means other web-app developers can help to shape its look and content in the future. We will try to preserve the navigational order of resources, but in future years, you may expect some content to be added and other content replaced. **If you need to find the most current web-address for the app or version of this curriculum, you can find them at: http://www.groundworkhv.org/climate-change-resilience-learning-module/**

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GLOSSARY

Key vocabulary used in this curriculum

Adaptation
Albedo Effect
Aquifer
Atmosphere
Biodiversity
Biomass
Biome
Bioremediation
Carbon Cycle
Carbon Footprint
Carbon Sequestration
Carbon Sink
Carbon Source
Climate
Climate Change
Climate States (Hothouse and Icehouse)
Conservation
Deforestation
Dendrichronology
Drought
Drought-resistant
Ecosystem
Epidemic
Essential Climate Variables (ECVs)
Estuary
Flood
Fossil Fuels
Glacial Period
Greenhouse Gases
Greenhouse Effect
Green Roof
Habitat
Hybridization
Hydroponics
Ice Core
Integrated Pest Management
Interglacial Period
Milankovitch Cycles
Mitigation
Ocean Acidification
Paleoclimatology
Renewable Energy
Resiliency
Reverse Osmosis
Sea Level Rise (SLR)
Sediment Core
Solar Insolation/Irradiance
Species (Native/Invasive)
Species Ranges
Storm Surge
Stormwater Management
USDA Plant Hardiness Zones
Vector Species
Watershed
Weather
Wetland/Marsh

Adaptation: Initiatives by species to reduce the vulnerability of natural and human systems against actual or expected climate change effects.

Albedo Effect: Albedo is a measure of the reflectivity of a surface. Ice is more reflective than dark ocean.
The albedo effect when applied to the Earth is a measure of how much of the Sun's energy is reflected back into space.

Atmosphere: The gaseous envelope surrounding the Earth consisting almost entirely of nitrogen and oxygen, together with a number of trace gases. In addition the atmosphere contains water vapor, and contains clouds and aerosols.

Biodiversity: The variety of life on Earth at all its levels, from genes to ecosystems, and the ecological and evolutionary processes that sustain it.

Biomass: Organic non-fossil material of biological origin constituting a renewable energy source.

Biome: A complex biotic community characterized by distinctive plant and animal species and maintained
under the climatic conditions of the region

Bioremediation: The use of naturally occurring or introduced organisms to consume of break down environmental pollutants.

Carbon Cycle: Circulation of carbon atoms through the different reservoirs in our biosphere.

Carbon Footprint: The total amount of greenhouse gases that are emitted into the atmosphere each year by a person

In partnership with:

GLOSSARY

Key vocabulary used in this curriculum

or household from producing the goods or services that the individual uses. (EPA)

Carbon Sequestration: The processes by which trees and plants absorb carbon dioxide, release the oxygen, and store the carbon.

Carbon Sink: A reservoir that absorbs carbon from another part of the carbon cycle. Ex: forests, oceans and freshwater bodies.

Carbon Source: CO2 molecules released into our atmosphere by natural sources, like fires or decomposition, or anthropogenic sources, through the burning of fossil fuels. (CLC)

Climate: The long-term average of conditions in the atmosphere, ocean, and ice sheets and sea ice described by statistics, such as means and extremes. (NOAA)

Climate Change: A significant and persistent change in the average state of the climate or its variability. Climate change occurs in response to changes in some aspect of Earth's environment such as changes in Earth's orbit about the sun, re-arrangement of continents through plate tectonic motions, or anthropogenic modification of the atmosphere. (NOAA)

Climate State (Hothouse and Icehouse): A state of climate on Earth based on a thermal energy budget, such as the hothouse or icehouse climate states. Hothouse=no prevailing ice sheets. Icehouse=expansive and prevailing ice sheets.

Conservation: A reduction in consumption that corresponds with a reduction in service demand.

Deforestation: Those practices or processes that result in the conversion of forested lands for non-forest uses, contributing to increasing carbon dioxide concentrations through the burning of wood and removal of a carbon sink.

Dendrichronology: The study of tree rings to date trees and get historical climate condition data. Tree rings are the cross sections of the stem of a woody plant.

Drought-resistant: The ability of a plant to maintain a favorable water balance even when exposed to drought conditions.

Ecosystem: A community of interacting organisms and their physical environment.

Epidemic: The spreading of an infectious disease over a wide range of a human population that historically leads to a dramatic loss of life.

Essential Climate Variables (ECVs): An ECV is a physical, chemical or biological variable or a group of linked variables that critically contributes to the characterization of Earth' s climate.

Estuary: The mouth or water passage of a large river where the tide meets a river current.

Flood: An overflowing of water beyond its natural confines, especially over what is normally dry land.

Fossil Fuels: Energy sources such as petroleum, coal, or natural gas, which are derived from living matter that existed during a previous geologic time period.

Glacial Period: An interval of time (thousands of years) within an ice age that is marked by colder temperatures and glacier advances.

Greenhouse Gases: Gases, such as water vapor (H2O (g)), nitrous oxide (N2O), carbon dioxide (CO2), and methane (CH4) that allow solar radiation through but not long-wave radiation that is emitted from the earth after solar radiation

GLOSSARY

Key vocabulary used in this curriculum

is absorbed. This causes the Greenhouse Effect.

Greenhouse Effect: Greenhouse gases in the atmosphere trap infrared energy re-radiated from absorbed solar radiation, resulting in warming of the earth's surface, much like the glass roof and walls of a greenhouse traps solar gain inside.

Green Roof: The roof of a building that is partially or completely covered with vegetation.

Habitat: The natural home or environment of an animal, plant, or organism.
Hybridization: The process of mating between two different organisms to create a new organism in hopes that the offspring will adapt the best genetics.

Hydroponics: The use of use of nutrients and organic and inorganic materials, to grow plants without soil, in with water.

Ice Core: A cylindrical section of ice removed from a glacier or an ice sheet in order to study climate patterns of the past.

Integrated Pest Management (IPM): Reduces the need for chemical pesticides by using predator insects to handle infestations.

Interglacial Period: Geological interval of warmer global average temperature lasting thousands of years that separates consecutive glacial periods within an ice age.

Milankovitch Cycles: The collective effects of changes in the Earth's movements and position in relation to the sun on its climate over thousands of years.

Mitigation: Interventions to reduce the sources of greenhouse gases or enhance the sinks that remove them from the atmosphere.

Ocean Acidification: A change in the chemistry of the ocean in which carbon dioxide gas is absorbed by the ocean and reacts with the seawater to produce acid.

Renewable Energy: Energy resources that are naturally but limited in the amount of energy that is available per unit of time.

Resiliency: The ability to prepare for, respond to, and recover from significant multi-hazard threats with minimum damage to social well-being, the economy, and the environment.

Reverse Osmosis: The process by which a solvent passes through a porous membrane in the direction opposite to that for natural osmosis when subjected to a hydrostatic pressure greater than the osmotic pressure. This process is often used to filter water.

Sea level rise: An increase in global sea level due to a rise in the volume of water in the world's oceans.

Sediment Core: A cylindrical section of soil removed from land in order to study climate patterns of the past. Analysis of sediment can provide clues about conditions in past oceans and sedimentary processes.

Shoreline Stabilization: A practice of modifying shorelines so as to control erosion and protect natural resources.

Solar Insolation/Irradiance: The amount of electromagnetic radiation received from the sun per unit area (usually square meters).

GLOSSARY

Key vocabulary used in this curriculum

Species (Native/Invasive): A group of living organisms with similar traits who share genes and breed with one another. An invasive species is one whose introduction to a natural ecosystem causes environmental harm.

Species Ranges: The area where a particular species can be found during its lifetime. Species range includes areas where individuals or communities may migrate or hibernate.

Storm surge: An abnormal rise in seawater level during a storm as a result of atmospheric pressure or wind change.

Storm-water Management: Controlling runoff from rain or snowmelt over impermeable surfaces, heavily found in urbanized areas.

Watershed: An area of land that separates waters flowing to different rivers, basins, or seas.

Wetland/ Marsh: An area of soft, wet land covered with tall grasses. It typically remains water-logged at all times.

Tides/ Intertidal zone: The alternate rising and falling of the sea due to the attraction of the moon and the sun. Tides change about every 12 and leave an area between the foreshore and the seabed.

USDA Zones: Geographically-defined zone in which a specific category of plant life is capable of growing.

Weather: The specific conditions of the atmosphere at a particular place and time, measured in temperature, precipitation, cloudiness, humidity, air pressure, and wind. (NOAA)

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CLIMATE SCIENCE

Unit I: What is "climate" and how do scientists study it?

Earth's climate system is complex. A combination of cosmic, atmospheric, biologic, and geologic systems and forces all contribute to our regional temperatures, seasonal changes, and annual precipitation. Generally, our climate represents at least a 30-year average of the seasonal weather for that region. Typically, short-term changes in our climate are cyclical and influenced by changes in the sun's intensity, trade winds, and the ocean currents. El Niño and La Niña events are examples of short term climate fluctuations that affect precipitation and temperatures around the globe. Smoke from volcanic eruptions can also have a short-term effect on regional or even global temperatures by blocking out sunlight in the upper atmosphere. Long-term climate change is driven by major shifts in our planet's energy balance due to variations in our orbit around the sun, the precise tilt of Earth's axis, tectonic movement affecting land masses and ocean circulation, and large-scale changes in our atmosphere's composition. These may either be cyclical, as is the case with the Milankovitch Cycle, or from a catastrophic event. The mass extinction of dinosaurs during the Cretaceous Period (65 m.y.a.) is theorized to be a result of a catastrophic energy shift from a large meteor impact that resulted in a pervasive dust cloud that blocked the sun and cooled the Earth rapidly.

Unit I: Climate Science explores the difference between climate and weather and the tools of the trade that scientists use to study Earth's climate system in real-time. In the lessons, students will have an opportunity to interact with monitoring equipment and assess climate data. This unit is also meant to broadly introduce the concept of Earth's energy balance, beginning with the primary source of energy: the sun. In the next unit, we will elaborate on climate cycles (i.e.: glacial and interglacial periods), the natural and anthropogenic forcings of climate change with special attention to the role that Earth's atmosphere plays in our energy balance.

Pre-requisite Next Generation Science Standards:

MS—ESS1.A: **The Universe and Its Stars**

Patterns of the apparent motion of the sun, the moon, and stars in the sky can be observed, described, predicted, and explained with models.

MS—ESS1.B: Earth and the Solar System

This model of the solar system can explain eclipses of the sun and the moon. Earth's spin axis is fixed in direction over the short-term but tilted relative to its orbit around the sun. The seasons are a result of that tilt and are caused by the differential intensity of sunlight on different areas of Earth across the year.

I.A: Weather versus Climate—Overview

Key Concepts and Web-app Resources:

Every day, we dress for the weather. One day to the next, our outfits reflect if we expect mild, cold, or hot conditions, or if it is supposed to be clear, windy, or rainy outside. Weather is changeable from day to day, and sometimes a bit unpredictable, because it is shaped by even the smallest energy shifts in our atmosphere, oceans, and land masses. Our daily outfit choices are representative of the ***weather***. Still, we are unlikely to go from wearing a bathing suit on the beach to a heavy coat within a week's time. Instead, we might expect to swap out our closets on a seasonal basis. Our year's wardrobe is akin to the local range of weather conditions averaged out throughout the seasons, or in a word—***climate***. Scientists use weather averages for a period of 30 years or more to determine climate conditions, and climates *can* change over time, with variations of vegetation, ice cover, or atmospheric composition. However, these shifts are typically subtle and slow.

Earth's climate interacts with the regional landscape to create ***biomes*** of flora and fauna that are well-adapted to the annual temperature ranges and amount of precipitation that is expected there. When the local climate changes slowly, plants and animals either adapt or move their ranges to more suitable conditions over time. Because the climate system on Earth is so complex, it usually takes thousands or millions of years to show meaningful change. Still, ***Earth's climate has changed many times in its 4.6 billion year history***, and it has had enormous consequences to life, as evidenced by the fossil record. What would happen if Earth's climate system changed rapidly? Life as we know it depends on climate stability—from our farmlands to our coastlines, to our cities and roads. Humans can adapt, but only if given access to meaningful and accurate data, and the time and means necessary. ***Climate science*** is integral to adapting to a changing planet.

The way scientists study Earth's climate system is also changing with technology. Now, sophisticated measuring instruments are sent into our atmosphere via weather balloons, into orbit via satellites, and into the oceans on ships and buoys. Then, computers can use that real-time data to perform complex calculations, run simulations with input variables, and map out recent past, present, and predicted future conditions.

Unit 1A. Web-app Resources:

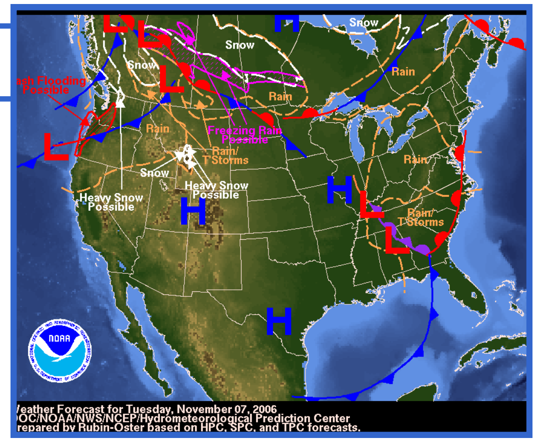
>Climate Science

>>Climate vs. Weather

>>>Trend and Variation (video)

>>>What is Climate? (UEN video)

I.A: Weather versus Climate—Classroom Activity



Lesson: What is the Difference Between Weather and Climate

Subject / grade level: 6th-9th grade, Earth Science

Materials: Mini “fun-size” bags of M&Ms, worksheets, computer for web-app content. Alternatively, bags with different color beads can be prepared ahead of time. Optional: special event M&M packs with different, or limited colors to represent different climate regions.

NGSS Standards:

ESS2.C: The Roles of Water in Earth's Surface Processes

- The complex patterns of the changes and the movement of water in the atmosphere, determined by winds, landforms, and ocean temperatures and currents, are major determinants of local weather patterns. (MS-ESS2-5)

ESS2.D: Weather and Climate

- Weather and climate are influenced by interactions involving sunlight, the ocean, the atmosphere, ice, landforms, and living things. These interactions vary with latitude, altitude, and local and regional geography, all of which can affect oceanic and atmospheric flow patterns.
- Because these patterns are so complex, weather can only be predicted probabilistically.
- The ocean exerts a major influence on weather and climate by absorbing energy from the sun, releasing it over time, and globally redistributing it through ocean currents.

Lesson objective(s): Students will understand the difference between weather and climate as well as how they are related. Students will learn the difference between trend and variation. Students will be able to graph the changes of weather over time and see if there is a trend within the variation. Students will be able to identify at least 3 distinct climates found around the world.

ENGAGEMENT (5 minutes)

- Ask students to describe the current, local *weather*. Do they know what it’ll be like tomorrow or the coming weekend? Are they as are sure about the forecast next week, or next month, as they are about tomorrow’s?
- How much is the weather likely to change from day to day? Though it might go from rain to sun, will it go from snow to a scorcher?
- How would they define their *climate?* Are they in a temperate zone with four distinct seasons? Are they semi-tropical with plenty of rainfall, but very mild winters? Are they in an arid region, with hot summers and without much precipitation? Does their climate change from day to day or even year to year?

EXPLORATION (20 minutes)

- Depending on your supply of M&M bags, have students work individually or group them into teams.
- Make sure each student has a worksheet with the reference key and table to chart their results.
- Ask the class as a whole to identify the colors expected in the typical M&M bags. Tell them to imagine that each color represents a different weather expectation. Have them define each color’s weather (e.g.: yellow is sunny and mild, orange is warm and dry, red is hot and humid, brown is thunderstorms, green is cool and rainy, blue is cold and windy). If using any special-holiday packs to represent different climate regions, you may need to assist with those. Do not tell them how they might define their climate pack just yet.

I.A: Weather versus Climate—Classroom Activity Page 2

EXPLORATION (continued)

- Distribute the M&M bags. Optionally, you can have a few individuals or teams get a special-event pack. These can be purchased seasonally in grocery stores, on amazon.com, or from the M&M online store. (Fall Harvest pack is good for representing either arid or tropical climates, Baby Boy pack is good for representing tundra).
- Following the worksheet directions, students should pull one M&M at a time out of the bag, and record the associated weather condition as a new day each time, until they have completed 10 days on the table.
- Students can continue using the worksheet, answering questions about percentage and what climate their bag/selections may represent. They may use the **Köppen Climate Classification** map on the back of the worksheet provided for reference.

EXPLANATION (15 minutes)

- Have students present their conclusions to the classroom about the difference between weather and climate and what particular climate they had based on the 10 M&M's they drew.
- Using the web-application, show them the following video on **Trend and Variation**:
  >Climate Science>>Climate vs. Weather>>>Trend and Variation
  (also found here: https://youtu.be/e0vj-0imOLw)
- The *dog* represents the *weather* and the *owner* represents the *climate*. The dog is tethered to the owner via a leash, so while his one movement to the next may vary, his range is fixed by the leash, and his general direction over time is the same as the owner. Ask students if they can provide any additional analogies to describe weather vs. climate? E.G.: outfit vs. wardrobe; a play during the Superbowl vs. the team's entire football season averages; seashells washing onto shore vs. the whole beach.
- **Ask**: How many years of weather data do you think is necessary to reliably determine a region's climate? Hint: We need to find a trend emerging from the day to day or season to season variations. **A: 30+ years.**

ELABORATION (10+ minutes)

- Though day to day weather is somewhat unpredictable, climate IS typically predictable. Why is climate predictability so important? If they don't offer, give them leading suggestions:
  - Agriculture: it helps farmers determine what they can grow year to year.
  - Seasonal Weather Extremes: It helps governments, communities, and emergency responders anticipate and prepare for extreme weather, like hurricanes, tornadoes, and heat waves.
  - Economy: tourism/hobby industries rely upon this for their businesses, like skiing, beach resorts, etc.
- Using the web-application, show them the following video on Weather vs. Climate:
  >Climate Science>>>Climate vs. Weather>>>What is Climate? (UEN Climate Science Series)
  (also found here as Episode 2: https://www.uen.org/climate/videos.shtml)
- Re-state the complexity of our climate system: **"When energy from the Sun interacts with the atmosphere, oceans, land, ice, clouds, and living things on earth, it creates the climate."**
- **Ask:** How do you think scientists know the global climate is changing? How do you think scientists can track global changes given our climate system's complexity? Why is rapid climate change a concern?

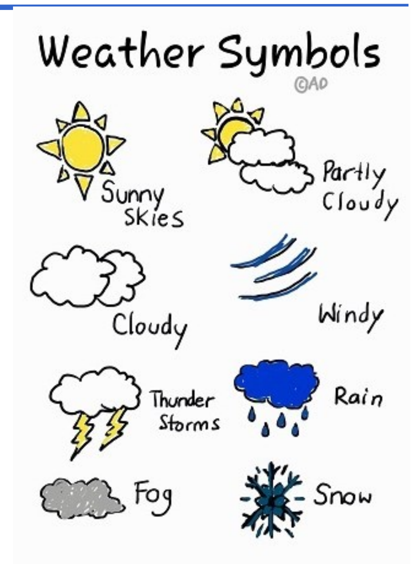
Name:______________________ **I.A: Weather versus Climate—Worksheet**

Experiment (adapted from activity by Westerville School in Ohio)

1) As a class, define different type of weather for each M&M candy color.

Brown- ______________________
Yellow- ______________________
Blue- ______________________
Green- ______________________
Orange- ______________________
Red- ______________________

Optional Colors (Op):
1________-________________
2________-________________
3________-________________



2) *Each person or group will get a small bag of M&M's. (DO NOT EAT THEM… *yet*). This bag represents the different weather we can see on a daily basis.

*Each person or group will, without looking, pick one M&M from their bag and place it in front of them. That M&M current weather conditions.

The weather today, according to your M&M is ______________________________________.

3) Continue drawing M&M's one at a time and record the corresponding weather in the table below.
This represents weather… the unpredictable daily happenings of what is going on outside.

Day	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Weather										

If you look at the weather over a longer period of time, (for example, each M&M represents a different day patterns start to emerge. You are starting to pin down the climate....

4) Next, pour out all your M&M's on the table and compute a percentage for each color for your tab (Remember… color divided by total number multiplied by 100) This is **climate**.

Conclusion:

Color/Weather	**Percentage**
Brown:________________	
Yellow:________________	
Blue:________________	
Green:________________	
Orange:______________	
Red:________________	
Op1_______:___________	
Op2_______:___________	
Op3_______:___________	

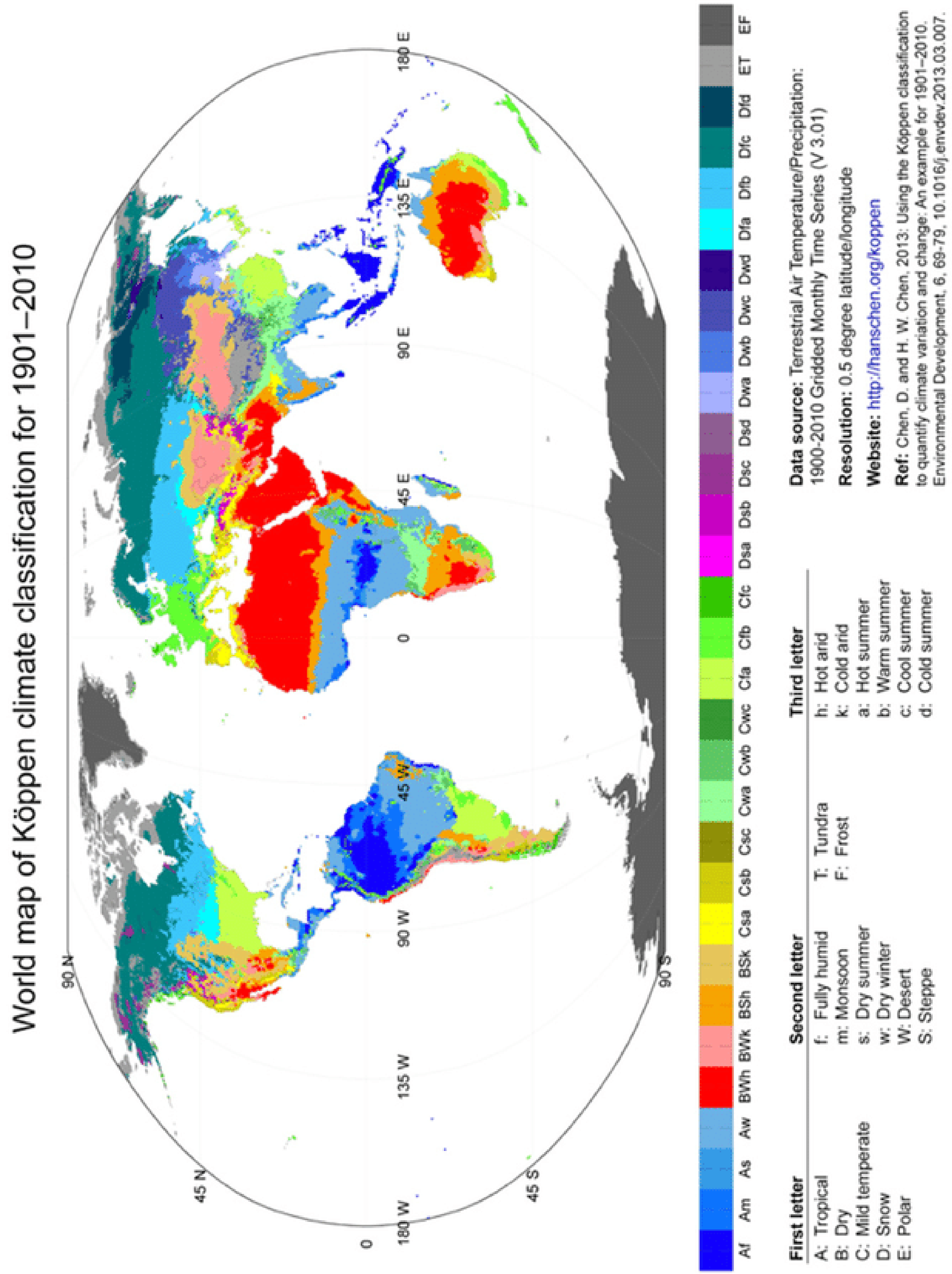
If you give someone a fresh bag of M&M's, you can't predict the weather—whether the next candy out of the bag will be blue or orange—but you can predict trends in the weather. You can say, with confidence, that there won't be 100% orange candies in the cup. That would be very unlikely!

5) So… The difference between weather and climate is:
____
____
____
____

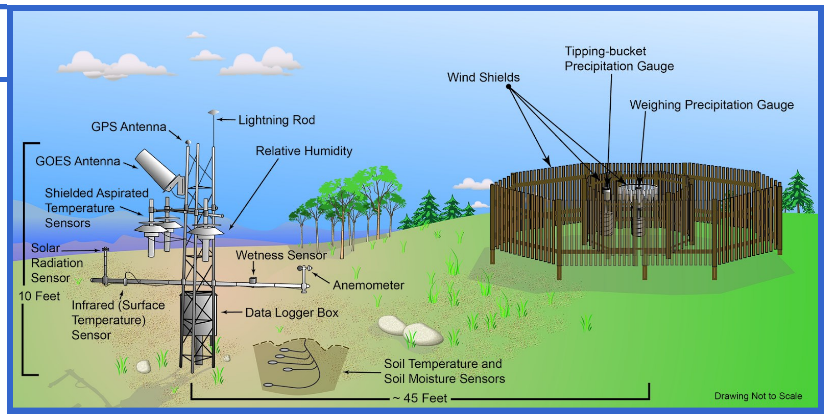
6) How would you describe your local *climate* based on the results from your particular bag of M&M's*?

If some individuals/groups were given alternatives to the classic M&M bag (ie: Harvest Bag or Baby Boy) their colors will be different—and thus the range of weather conditions and climate would be different!

Name:______________________ **I.A: Weather versus Climate—Worksheet**



I.B: Real Time Climate Monitoring



Source: NOAA

Key Concepts and Web-app Resources:

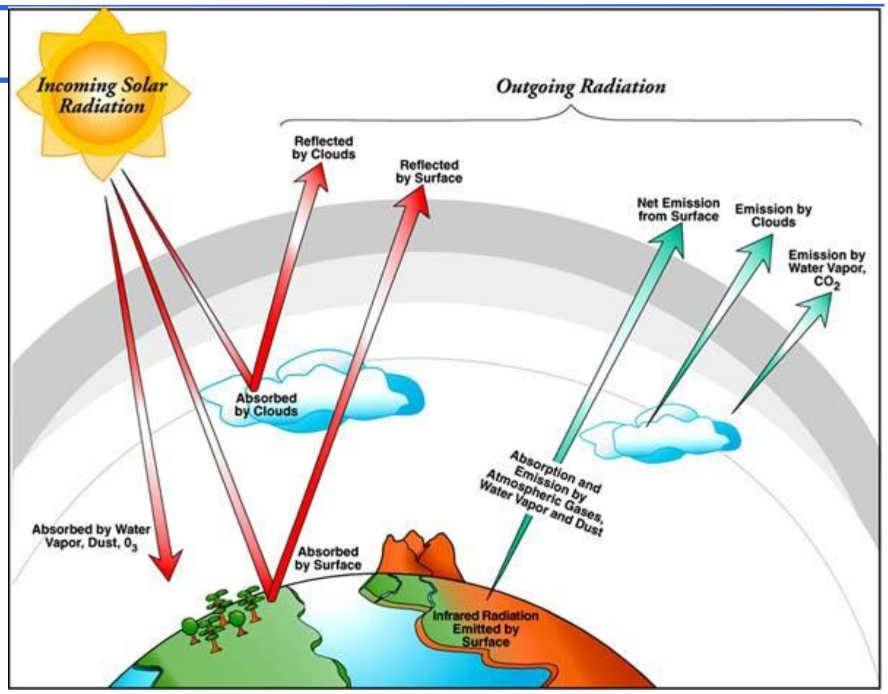
Data is a resource, much like water, food, and even money. Having timely and reliable climate data helps farmers, policy makers, public health workers, and business owners make critical decisions about how best to invest their time, money, land, and human resources each year. Modern scientific instruments allow scientists to monitor the climate and collect data in real time. Then, supercomputers compile and analyze this data to project out the seasonal expectations of different regions. For instance, they might predict a wetter summer than normal in the Northeast, or a hotter summer than normal in the Midwest. Founded in 1970, The National Oceanic and Atmospheric Administration (NOAA) is a U.S. government agency that employs over 6,500 engineers and scientists to monitor the weather, oceans, and climate and manage fisheries and coastal restoration, and convey climate and weather information to the public and private sectors. Some of the equipment NOAA scientists use is highlighted in the table below. You can discuss with students why each of these is an important parameter to understanding our climate system (see more on next page).

Air Temperature	Three platinum resistance thermometers housed in fan aspirated solar radiation shields.
Precipitation	An inlet-heated, wind-shielded weighing rain gauge (configured with three load cell sensors), precipitation (wetness) detector, and an auxiliary tipping bucket gauge.
Wind Speed	A 3-cup anemometer at the same height as the air temperature shield intakes.
Solar Radiation	A silicon pyranometer.
Surface Temperature	A precision infrared temperature sensor pointed at the ground surface.
Relative Humidity	A capacitive thin-film polymer humidity sensor providing accurate and stable measurement even in environments with high humidity.
Soil Moisture	Moisture sensors with built-in thermistors installed at specific depths: 5, 10 20, 50 and 100 cm.

NOAA is one agency of many that studies our planet. Together, along with volunteer observers, universities, and other organizations around the world, they form a network. This network has determined a list of **essential climate variables** (EVC's) that create a standard to track changes regardless of location. These EVCs are grouped in three categories depending on where they track the remote information: atmospheric, terrestrial, and oceanic. The National Center for Environmental Information (NCEI), formed in 1951, catalogs and stores this data for historical reference. By comparing real-time climate data to historical data, we get a better idea of how our climate is changing.

In this chapter, students will interact with weather and climate monitoring equipment, such as the Hudson River Environmental Conditions Observation Station (HRECOS). HRECOS equipment helps us to report weather and river conditions in real time. Students will learn about the tools of the trade, data collection and analysis, and weather anomalies and trends. Students will also gain an appreciation of why and how *accurate* climate monitoring must synthesize data from the atmosphere, geosphere, biosphere, and more.

I.B: continued



Source: U.S. Department of Energy Office of Scientific and Technical Information (OSTI)

The reason climatologists study properties of the atmosphere, land, and oceans has to do with Earth's energy budget. The sun is the primary source of energy for our climate. As solar radiation reaches the Earth, about 30% is reflected off the atmosphere and clouds, while 20% is absorbed there. Of the remaining, most is absorbed by the Earth's surface, though ice cover reflects some back through our atmosphere. As the Earth rotates, one half of the planet is gaining solar radiation, while the other half is emitting heat and losing radiation through our atmosphere.

Earth's heat gain is dependent not only on the amount of radiation we get from the sun, but also how that energy is transferred when it interacts with molecules in our atmosphere, land and ocean, as well as plants. It may be reflected, refracted, have its speed changed, or absorbed. Absorbed solar energy may also be emitted as long-frequency waves and interact with the atmosphere yet again. The heat gained can then be circulated around the globe through convection and conduction by our air and water. If this energy budget is unfamiliar to your students, you may introduce the topics through this lab, developed by NSTA teacher Jerry Roth, in partnership with NOAA: https://oceanservice.noaa.gov/education/lessons/earth_energy_budget_lesson.html

Unit 1A. Web-app Resources:

>Climate Science

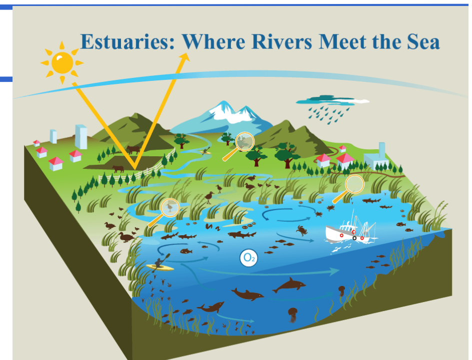
>>>Why Data Matters (International Research Institute Video)

>>Real Time Climate Monitoring

>>>NASA Climate Time Machine: Vital Signs of the Planet

>>>HRECOS Local Weather and River Conditions

I.B: Monitoring Coastal Climate Data—Classroom Activity 1



Source: NOAA

Lesson: How can we monitor water quality parameters to track climate change?

Subject / grade level: 6th – 12th grade, Chemistry, Environmental Science

Materials: thermometers, hydrometers, turbidity tube, bucket, funnel, dissolved oxygen test kit (Salifert or LaMotte), access to Internet and computers

NGSS Standards: MS-LS2-1. Analyze and interpret data to provide evidence for the effects of resource availability on organisms and populations of organisms in an ecosystem.

MS-LS2-4. Construct an argument supported by empirical evidence that changes to physical or biological components of an ecosystem affect populations.

HS-ESS3-5. Analyze geoscience data and the results from global climate models to make an evidence-based forecast of the current rate of global or regional climate change and associated future impacts to Earth's systems.

Lesson objective(s): Students will learn estuarine literacy, water quality field testing methods, and Hudson River water quality changes over time relating to climate change.

ENGAGEMENT

- What is an estuary? Why is it important?
- Ask students what they know about where they live and the type of water inside. Why is it important to keep testing the water in an estuary?

EXPLORATION

- Estuaries are dynamic water bodies that are in constant flux. Their water quality parameters will continuously shift so it's unusual that two measurements taken day after day, or even within a few hours, will be exactly alike.
- Using the web-application, show them the following video by CURB on estuaries:

  >Climate Adaptation and Resilience>>Coastal Resilience>>>Estuary Model & Coastal Resilience
  (also found here: https://youtu.be/jCKYg1NtBnI)

  - This video explores the natural and man-made aspects that affect estuary health. Students should be familiar with estuarine vocabulary words listed on the worksheet below.

EXPLANATION

- **Ask:** What kinds of water quality tests do we need to do to measure the health of an estuary? What does the water have to do with the health of animals in the habitat? How might they change over time?
- Let's think about why each parameter is important and the best way to measure it.
  What does temperature measure? What is the best unit for us to use? How about the tool?
  - Temperature is the amount of heat in a substance. Using a thermometer, we measure the amount of heat in a substance in degrees Celsius or Farenheit. The Celsius scale allows us to compare to the rest of the world, while Fahrenheit, which is more familiar, can be used so we know what we're talking about relative to our own experience!

I.B: Monitoring Coastal Climate Data—Classroom Activity page 2

- Will the temperature of the water be warmer, colder, or the same as the air around it? Why?
  - The water temperature depends on the season. Water has a high **specific heat** so it takes a lot longer to warm and cool than the air (also the air is a gas and water is a liquid, so the density of the state of matter will affect how quickly heat can pass through).
- What does salinity measure? What is the unit we use? What does that mean? What is full ocean salinity and what might we expect to find here in our estuary? What might affect the salinity? Can tides make a difference? How about seasons? Weather?
  - Salinity is how many dissolved salt ions are in the water in parts per thousand (ppt). In other words, if you had one thousand molecules of water, the salinity would represent how many molecules are actually dissolved salt ions. We can measure salinity with a hydrometer or refractometer.
  - Ocean salinity is between 34 and 36 ppt and the brackish Hudson River estuary is usually under 32ppt. We see higher levels closer to the ocean. High tide will increase salinity as ocean water flows into the river; low tide will reduce it, as the river "flushes out" into the ocean. Temperature and precipitation rates can affect salinity as well. We also observe higher salinity in warmer weather due to evaporation changing the salt concentrations. Summer therefore has higher salinity; spring lower because of all the rainfall and snowmelt from the mountains running down.
- How does the hydrometer work? What do you know about the density of saltwater versus freshwater? Would that cause the arrow to become buoyant at the level of salinity?
  - Saltwater is more dense than freshwater so it sinks to the bottom of the hydrometer, causing the plastic arrow to become buoyant in the hydrometer. We are looking at the numbers on the left, not the specific gravity (though that can also measure salinity in its own way).
- What does turbidity measure? What does it really mean to measure turbidity, and why is it important for our ecosystem? How does the turbidity tube work?
  - Turbidity is a measurement of suspended particles in the water, so we're measuring how far you could see in centimeters if you opened your eyes underwater. When we talk about turbidity in our region, we're really talking about plankton and suspended particles like sediment. If we see high levels of turbidity, that may be good for our animals because it means they have lots of food to eat. Why might turbidity change? The amount of sunlight can increase or decrease phytoplankton presence, big storms can move sediment around, tides can bring it in or out. Turbidity is a good example of how different ecosystems can look very different, but does not necessarily mean one is healthier than the other. For instance, turbidity is very low in the Caribbean, which people often confuse with thinking that means the water is cleaner. However, it really just means the water is *clearer* – there are not nearly as many plankton living in the tropics.
- Why can we see the disk from the side, but not from the top with all the water in it?
  - All the water molecules piled on top of each other allow less light through than just the side of the tube.

I.B: Monitoring Coastal Climate Data—Classroom Activity page 3

- What does dissolved oxygen measure? Why is it important? What unit do we use?
    - Aquatic organisms still need to breathe oxygen, through their gills rather than lungs. There is less oxygen available underwater than in the open air. Dissolved oxygen measures the availability of oxygen dissolved in a sample of water in parts per million (ppm). A healthy amount is anything over 6-7ppm, though many organisms in the estuary can survive with less, especially if they don’t move around much or live in the sediment/low oxygen conditions.
    - The Winkler Titration is a complex yet easy-to-use method to find the amount of dissolved oxygen in water. There are easier test kits that are less accurate, but this is the most precise.

ELABORATION

- Students will actually test water quality themselves! Get a sample from the river or local waterway. Have students practice taking all the parameter tests. If they get different answers, have them take the averages. Then talk about what the data means, and how you can’t tell that much from one specific point in time, but looking at datasets over time can give a much more extensive picture.
- Which parameters would we expect to change over time that would reflect a changing climate? What resources do we have to explore that?
- Technology incorporation: have students explore the HRECOS data. Use this lesson plan and instructions to graph temperature changes over time.

http://www.hrecos.org/index.php?option=com_content&view=article&id=126:using-real-time-data-temperatures-impact-on-sea-level-rise&catid=36:lesson-plans&Itemid=59

EVALUATION

- Students should be able to define all vocabulary in their own words on the worksheet attached.
- Students should be able to answer the changes that might affect different parameters, and why.
- Students will graph the water quality changes over time.

Vocabulary—Define the following terms:

Estuary ____

Brackish Water ____

Temperature ____

Salinity ____

Turbidity ____

Dissolved Oxygen ____

Marshland ____

Questions:

1) Why is it important to track temperature of the estuary over time?____________________

____

2) In an estuary, what factors influence salinity on a daily basis? Which season usually has the highest salinity? Why? The lowest? Why? _______________________________________

____

____

3) What would it mean if one day, turbidity in the Hudson measured 400cm? What would that mean for the ecosystem?____

____

____

4) What might affect the amount of dissolved oxygen (DO) in the water?

____

____

5) Which water quality parameters would we expect to change over time that would reflect climate change? How would climate change influence them? __________________________

____

____

Monitoring Coastal Climate Data—Teacher Answer Sheet

Vocabulary

Estuary – a place on the coast, partially enclosed, where freshwater rivers meet and interact with saltwater oceans.

Brackish Water – a mixture of saltwater and freshwater, found in estuaries.

Temperature – the amount of heat in a substance.

Salinity – the amount of dissolved salt ions in water.

Turbidity – the unclarity of the water (also described as how far you could see if you opened your eyes underwater).

Dissolved Oxygen – the amount of oxygen dissolved in water available for marine life.

Marshland – an area of wetland plants on a water's coast that provides habitat and resources for coastal inhabitants.

Answers to exploration questions:

Why is it important to track temperature of the estuary over time?
Temperature measures the amount of heat in a substance. Temperature can fluctuate daily, but can demonstrate long-term changes over time. The Hudson River has actually risen 2 degrees Fahrenheit since the beginning of the 20th century.

What influences salinity on a daily basis? Which season usually has the highest salinity? Why? The lowest? Why?
Salinity measures how many dissolved salt ions are in a water sample. Tides change salinity in the estuary about every 6 hours. Summer has the highest salinity, because fresh water evaporates in the heat and leaves the salt behind. Spring tends to have the lowest, because of all the rain and snowmelt from the Adirondacks.

What are we really looking at when measuring turbidity in the estuary? What would it mean if one day, turbidity in the Hudson measured 400cm? What would that mean for the ecosystem?
Turbidity measures the amount of suspended particles in the water. We are really measuring the amount of plankton and suspended sediment in the water sample. If the turbidity measurement in the Hudson suddenly jumped to 400cm (meaning it was much lower turbidity than usual), that would indicate a lack of plankton. This would be bad for the ecosystem because plankton are the base of the food web of the Hudson so without them, many other organisms would not be able to survive.

What might affect the amount of dissolved oxygen (DO) in the water?
Dissolved oxygen measures how much oxygen is available for animals in the water. The amount of plankton can increase DO, while too much plankton (from eutrophication or an algal bloom) can lower DO because once the plankton die they are eaten by bacteria which use up available oxygen. Also, the warmer the water is, the less oxygen it is able to hold. Therefore, there is generally a higher level of DO in the winter and less DO in the summer.

Which water quality parameters would we expect to change over time that would reflect climate change? How would climate change influence them?
Water temperature will probably rise as the climate warms. This would also cause a rise in salinity, as more evaporation occurs from the surface. Warmer water would also reduce available oxygen for animals living in it, because warm water can't hold as much oxygen as cooler water. All of this could have severe effects on the types of animals and plants living in the water, their range, and the ability for native species to compete in evolving environments.

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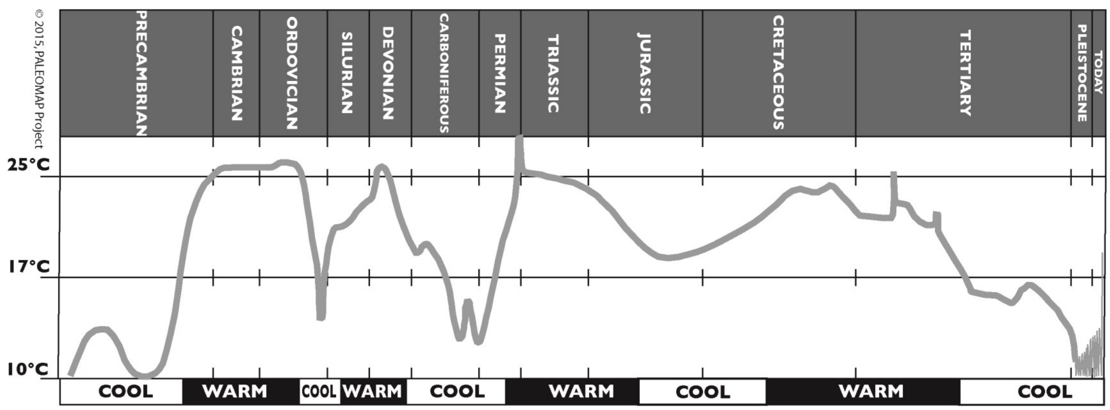
CLIMATE CHANGE

Unit II: What are the natural and anthropogenic forces that change Earth's climate?

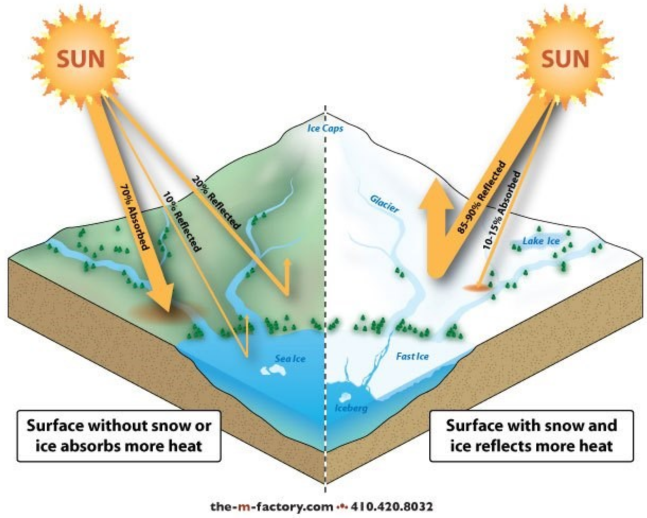
Though Earth's climate system is complex and seeks equilibrium, it *is* subject to change when Earth's energy budget is fundamentally altered. In the last unit, we learned how the different "spheres" (atmosphere, geosphere, hydrosphere, biosphere) interact with incoming solar radiation and shape our climate. Even small cyclical fluctuations to our climate have major consequences for life on Earth, perhaps especially for human civilization, which fares better with stability and predictability in our climate. For any large-scale, or long-term changes in Earth's climate to take place, an event must drastically alter either the amount of incoming solar radiation or the properties of one or more of the "spheres." Though scientists have many instruments to study climate and weather in real-time today, how do they know about Earth's climate history when it predates human records, or even human existence? The answer is **paleoclimatology**. Paleoclimatology uses information from natural climate "proxies," such as tree rings, ice cores, corals, and ocean and lake sediment cores to garner knowledge of Earth's past climate variability.



The evidence from paleoclimatology points to two major **climate states** in Earth's 4.6 billion year history: Icehouse and Hothouse. The **Hothouse** (or Greenhouse) state was marked by a total lack continental ice, desert or tropical conditions on nearly all the land surfaces, high concentrations of methane and carbon dioxide in the atmosphere, and sea temperatures ranging from 28°C at the equator to 0°C at the poles. The explosion of species during the Cambrian Period (540 million years ago) and the proliferation of dinosaurs during the Mesozoic Era took place in a Hothouse Earth state. By contrast, the **Icehouse** state is characterized by large continental ice sheets near the poles, mostly temperate to tundra conditions on land, reduced concentrations of greenhouse gases in the atmosphere, and fluctuations between **glacial and interglacial periods**. On one extreme of an Icehouse Earth is the Cryogenic Ice Age, over 635 million years ago, when glaciations reached the equator (known as "Snowball Earth"). On the opposite side is *right now*. Currently, the Earth is in an *Icehouse state* but an *interglacial period* (Holocene Epoch), demonstrated by the presence of both large sheets of ice at the poles and tropical conditions near the equator.

Fossil records and ocean sediment cores show that these climate states last for *millions of years.* They also point to **greenhouse gas** concentrations such as carbon dioxide and methane being the main forces for the heating and cooling—tectonic activity causing either up-swells in CO_2 release through increased volcanic activity or reductions in atmospheric carbon through sequestration in new soils formed when continental plates collide and form mountains.

Unit II: Introduction Page 2/3

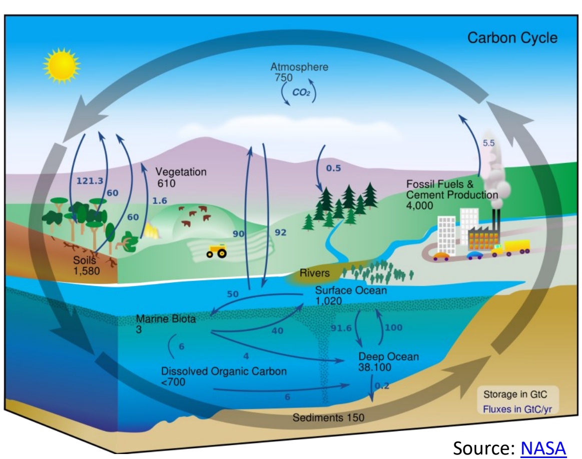


Tectonic plate movement also affects ocean distribution. It is likely that this also has a large role in the changes between Icehouse and Hothouse periods. Continental rifts from diverging tectonic plates can cause new ocean pathways to form, while continental collisions from converging tectonic plates can close pathways. Scientists hypothesize that these major geologic shifts could either circulate warm ocean currents and melt reflective ice, or allow colder deep water to move around and aid in ice sheet formation. This causes a positive feedback loop.

The extent of ice cover on Earth changes its surface reflectivity. This is known as the **albedo effect**. Increased ice cover from cooler ocean conditions reflect more light from the sun back through the atmosphere, thus reducing heat gain. Alternatively, as ice melts from warmer conditions and is replaced by darker earth and ocean, more solar radiation is absorbed, instead of reflected, and the Earth warms more.

Finally, the biosphere, all the living things on Earth, has also been a large factor in Earth’s climate history—primarily due to its relationship to carbon dioxide, methane, and other greenhouse gases. Beginning approximately 3 billion years ago, cyanobacteria, or blue-green algae, began to *photosynthesize*. That is, they began using light energy from the sun (photons) to convert atmospheric carbon dioxide and liquid water into cellular energy (glucose)! They also released oxygen gas as a byproduct. Here is where all three “spheres” interconnect: geosphere changes weathered more rock, releasing minerals into the ocean; ocean currents distributed minerals around the world and fed the biosphere, including cyanobacteria; thriving cyanobacteria rapidly pulled CO_2 out of the atmosphere, allowing more heat to escape into outer-space, cooling the planet; dying cyanobacteria fell to the ocean floor, creating a lasting carbon sink.

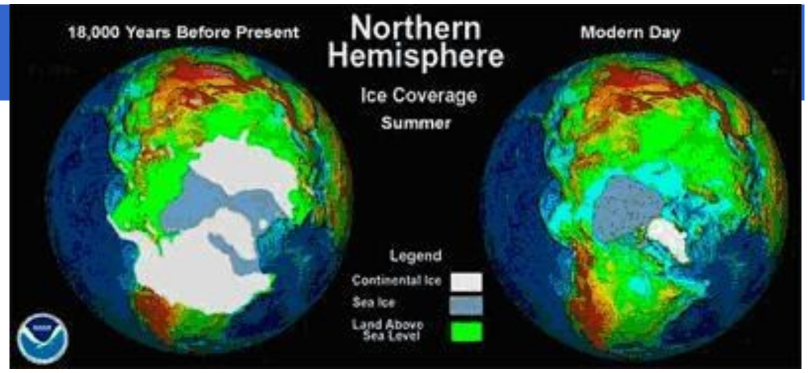
As Earth’s biosphere became more complex, so did the **carbon cycle**. Previously driven by volcanic activity and weatherization, living things introduced *organic* carbon to the mix. The first *heterotrophs* (animals) emerged 620 million years ago, consuming algae and metabolizing it through oxidation, thereby releasing carbon dioxide. The evolution of land-based plants with vascular tissue 430 million years ago gave rise to trees (370 m.y.a.) that could sequester and store carbon in woody roots and trunks. By the late Carboniferous Period 300 million years ago, *detrivores* (invertebrates, fungi, and aerobic bacteria) had populated the globe, turning carbon over more rapidly from dead organisms back to the soil for new producers. In many ways, the added complexity of the carbon cycle may buffer the Earth from larger climate swings. For instance, as carbon dioxide in the atmosphere increases, so does the rate of tree growth and hence, carbon sequestration. Perhaps **biodiversity** today is what has contributed to a relatively stable climate period.



Source: NASA

In partnership with:

Unit II: Introduction Page 3/3



As stated before, the Earth is currently in an Icehouse State—and has been for the approximately the last 34 million years—but we are on the warmer end of the spectrum. A little more than 10,000 years ago, Earth emerged from the last glacial period, and is now in an interglacial period named the Holocene Epoch. Human civilization has developed in leaps and bounds during this milder, more stable climate period, beginning with the advent of agriculture. Farming replaced hunting and gathering as the primary method for food production, and allowed people to settle in larger groups, rather than roaming to follow herds as they migrated. Furthermore, by breeding storage crops and grains and domesticating livestock, settlements could thrive even through winter, and surpluses could be traded with neighboring settlements. Better safety and nutrition contributed to longer lifespans, allowing elders to share wisdom with their children and grandchildren. Without ice sheets covering much of the northern hemisphere, civilization could spread to all reaches of the planet. Human population started to increase exponentially.

Today, more than 8 million *species* of plant, fungus, animal, and bacteria share planet Earth with nearly 8 billion human beings. Life as it exists, in all of its forms, is best adapted for Earth's current climate state. The cycling between glacial and interglacial periods has caused innumerous extinctions in the past few million years, and yet we are now experiencing an extinction event 100 to 1,000 times greater than the background rate (based on historical averages due to natural selection). Rapid global climate change is one powerful driver of mass extinctions. Clearly both human and nonhuman life has a lot at stake if the climate is changing. How do we know if the climate change we are experiencing today is normal or accelerated? And can natural forces alone explain these changes?

Unit II: Climate Change outlines the difference between natural and anthropogenic climate forcings, and explains how human activity is affecting the carbon cycle. Students will learn more about the Milankovitch cycles and how they affect solar insolation, or the amount of solar energy that reaches the Earth over time. The lessons will highlight the carbon cycle, identify **carbon sources** and **carbon sinks**, and explore the greenhouse effect. This unit will also allow students to explore paleoclimatology methods, by using simulated tree cores and ice cores. Finally, we will look at the current rate of change and how it compares to past warming or cooling periods.

Pre-requisite Next Generation Science Standards:

MS—PS1.A: Structure and Properties of Matter
MS—PS3.A: Definitions of Energy
MS—PS1.B: Chemical Reactions
MS—PS3.B: Conservation of Energy and Energy Transfer
MS—PS4.B: Electromagnetic Radiation

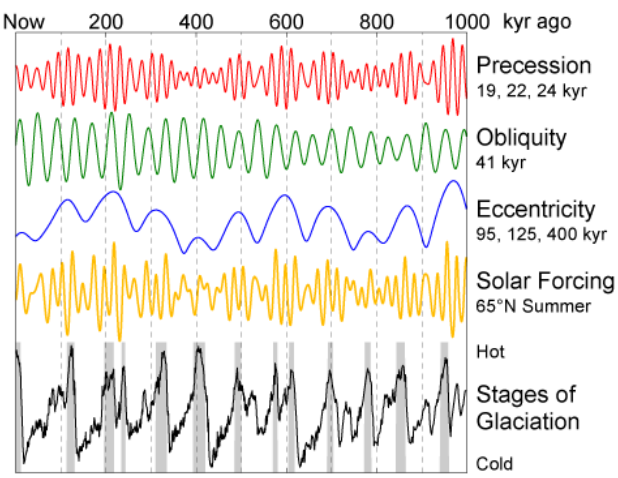
MS—LS1.C: Organization for Matter and Energy Flow in Organisms

II.A: Natural Forces—volcanoes, sunspots, & wobbles

Key Concepts and Web-app Resources:

Earth’s climate has hardly been consistent. Over the past 4.6 billion years, Earth has modulated between a Hothouse state (70% of the time), and an Icehouse state (30% of the time). Its current Icehouse state has lasted for several million years, but in-flux with cycling glacial and interglacial periods. What drives those ice age cycles?

In 1920, Serbian mathematician, astronomer, and climatologist Milutin Milanković published his astronomical theory of climate. This theory calculated a curve of solar **insolation** , the amount of heat energy a particular spot on Earth receives from the sun for any period of time, and correlated the oscillating pattern to the cycle of ice ages. Today, the term “**Milankovitch Cycle**” is used to describe the prevailing pattern of the last 800,000 years. Three cosmic factors play a role in this cycle: 1) the *eccentricity* of Earth’s orbit around the sun varies over a *100,000 year* time period from nearly circular to mildly elliptical; 2) the angle of Earth’s axial *tilt* which affects the length of our seasons, cycles from 22.1° to 24.5° over the course of *41,000 years*; and 3) Earth wobbles like a top as its axial *precession* changes with respect to the stars in a *25,700 year cycle*.



Source: Azimuth Project

Though paleoclimatological data supports the Milankovitch Cycle as a leading driver for long-term ice age cycles within the last 800,000 years, it does not account for the full extent of heating or cooling trends. Even shorter intervals, such as the 11-year change of solar activity as observed by a rise and fall in the number of sunspots, cannot explain the current changes in global temperatures. In fact, solar energy is on a downward trend while global temperatures are moving markedly upward. Though the sun is the primary source of energy on Earth, feedback mechanisms, like the **albedo effect**, **greenhouse gas** concentrations, and dust from **volcanic activity** have clearly factored as well.

In this chapter, students will interact with past and present climate data to discern how natural climate forcings, including volcanic activity, ice cover, and El Niño/La Niña events affect global temperature and precipitation patterns.

Unit IIA. Web-app Resources:

>Climate Science

>>Natural Forces: Volcanoes, Sunspots, and Meteors, Oh My!

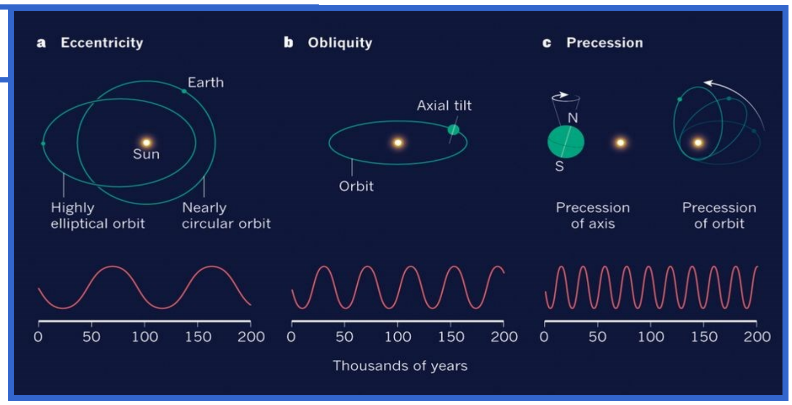
>>>Natural Cycles: Evidence of Change

>>>Natural Climate Forces

>>>NASA Video Comparing Natural and Human Factors

In partnership with:

II.A: Milankovitch Cycle Lab



Source: NASA

Lesson: In what three ways does Earth's orbit change? How do these cycles affect Earth's solar heat gain, and thus climate?

**Adapted from [NOAA reviewed resource] that uses applet by Tom Whittaker - University of Wisconsin*

Subjects / grade levels: 6th-12th grade, Earth Science, Physics.

Materials: Computer access, copies of student worksheet, and homework reference graph.

NGSS Standards:

MS—ESS2-6: Weather and Climate

- ESS2.D: Weather and Climate—Weather and climate are influenced by interactions involving sunlight, the ocean, the atmosphere, ice, landforms, and living things. These interactions vary with latitude, altitude, and local and regional geography, all of which can affect oceanic and atmospheric flow patterns.
- The ocean exerts a major influence on weather and climate by absorbing energy from the sun, releasing it over time, and globally redistributing it through ocean currents.

MS—PS2-5: Motion and Stability: Forces and Interactions

- Forces that act at a distance (electric, magnetic, and gravitational) can be explained by fields that extend through space and can be mapped by their effect on a test object.

MS—PS3-3: Energy

- PS3.A: Definitions of Energy—Temperature is a measure of the average kinetic energy of particles of matter. The relationship between the temperature and the total energy of a system depends on the types, states, and amounts of matter present.

MS—ESS1-1: Earth's Place in the Universe

- ESS1.A: The Universe and Its Stars—Patterns of the apparent motion of the sun, the moon, and stars in the sky can be observed, described, predicted, and explained with models.
- ESS1.B: Earth and the Solar System—This model of the solar system can explain eclipses of the sun and the moon. Earth's spin axis is fixed in direction over the short-term but tilted relative to its orbit around the sun. The seasons are a result of that tilt and are caused by the differential intensity of sunlight on different areas of Earth across the year.

HS—ESS1-1-4: Earth's Place in the Universe

- ESS1.B: Earth and the Solar System—Kepler's laws describe common features of the motions of orbiting objects, including their elliptical paths around the sun. Orbits may change due to the gravitational effects from, or collisions with, other objects in the solar system.

Lesson objective(s): Students will gain a better understanding of how long-term changes is Earth's orbit, known as Milankovitch Cycles, affect solar insolation and therefore Earth's global temperature average. They will also begin to connect an 8°C temperature fluctuation with the difference between an ice age and a temperate climate.

ENGAGEMENT (5 minutes)

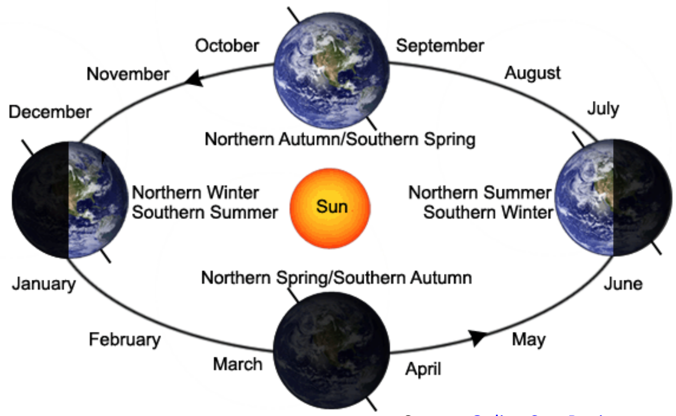
- Ask students: why does Earth experience different seasons? How do our seasons relate to the tilt of Earth's axis and its orbit around the Sun? **A:** When Earth's axis points away from the sun in orbit, we experience winter in the Northern Hemisphere and summer in the Southern Hemisphere. When it points towards the sun, the opposite is true.
- Is Earth's tilt at a fixed angle? Is our orbit always the same shape? **A: No**, the Earth's bulge at the equator makes it wobble on it's axis. Gravitational forces from other planetary bodies also alter the shape of its orbit.

EXPLORATION (20 minutes)

- Load the **Vostok Core and Milankovíc Cycles Climate Applet** found here: http://itg1.meteor.wisc.edu/wxwise/climate/earthorbit.html *This can be done on individual computers in a lab or alternatively on a shared computer and Smartboard.
- Orient students to the Vostok Ice Core temperature data on the right-hand side. It graphs lower atmosphere temperature anomalies from modern times (over Antarctica) for the past 400,000 years that range from approximately –9°C to 3°C.
    - Explain that this temperature variation also represents the difference between an ice age, where mile high ice sheets covered the New York Hudson Valley, and temperate conditions, like we experience today, where pervasive ice exists only on the poles and at high altitudes.
- Next, tell students to start the **time slider** along the temperature graph on the right at "**Now**" - found at the top. Later, students will view changes in Earth's tilt and orbital eccentricity over time by sliding that timer down. For now, we want students just to learn about the current relationship between Earth's tilt, its orbit and seasonal differences.
    - Have students toggle between the "Top View" and "Side View" button and the "Rotation," "Orbit," and "Faster Orbit" Checkboxes to see the differences.
- *From the applet instructions at the bottom:*
    - The view button toggles between showing a projection which is above the orbital plane and one which is more sideways.
    - The Label checkbox which toggles the seasonal labels on/off. The default is on.
    - The "rotation" checkbox which (when enabled) shows the Earth in its daily rotation about the axis.
    - The "orbit" checkbox which (when enabled) causes the orbital motion of the Earth to be in correct proportion to the rotation.
    - The "faster orbit" checkbox accelerates the orbital motion.
- After a few orbits (with seasonal labels on), students should be able to answer the first few questions about seasons on their worksheet.
- Next, students should explore each of the three main variations on the applet and define what each is in their own terms on the worksheet. To get clues on what each variation means, students will have to manipulate the Time Slider on the right. These variations are:
    - **Eccentricity—**sliding the time scale back and forth while on Top View shows that eccentricity refers to how elliptical Earth's orbit is over time. Sometimes, it looks like almost perfectly circular, and sometimes it is a bit oblong. The eccentricity curve displayed is a combination of the **95 yr, 125 yr, and 140K yr cycles.**
    - **Precession—**sliding the time scale back and forth while on Top View or Side View and toggling only precession on shows that Earth spins like a top, with its axis wobbling to point toward a different direction over time. The precession curve displayed is a combination of the **19 yr and 24K yr cycles.**
    - **Tilt**—sliding the time scale back and forth while on Side View and toggling only tilt on shows that the degree of Earth's axial tilt has changed with respect to the sun (how much it would point toward the sun during summer, or away from the sun during winter). The tilt curve displayed is the **41K yr cycle.**

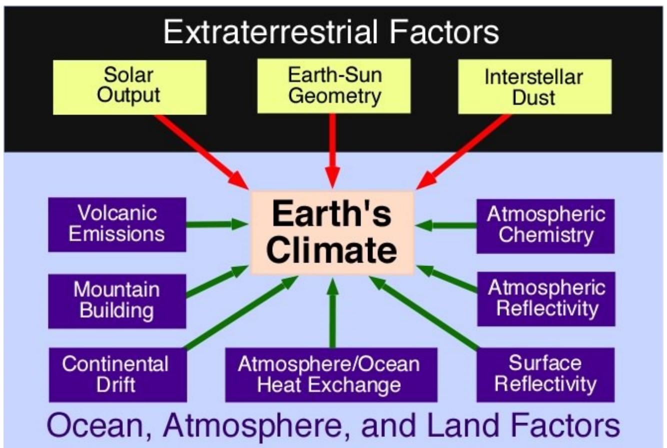
EXPLORATION continued

- Students can proceed to toggle each Checkbox to answer questions on their worksheet regarding the length of each type of cycle. How would variations in each affect the amount of direct sunlight the Earth receives in, let's say, the Northern Hemisphere on the Summer Solstice?
  - **A:** An increase in **tilt** would put more of the Northern Hemisphere in line with direct sunlight at the Summer Solstice, when it points towards the sun, increasing heat gain. Changes in **precession** would alter the timeline for our seasons over millennia—sometimes the Summer Solstice for the Northern Hemisphere would be in June, as it does now (because the Earth is tilted toward the sun); other times the Summer Solstice for the Northern Hemisphere would take place in September, in a hypothetical calendar year, as only then would the tilt point toward the sun. Now for the trickiest one: eccentricity. Changes in **eccentricity** would modulate the combined seasonal effects of tilt and precession. In other words, when eccentricity is *minimized* (a more circular orbit), the Summer Solstice in the Northern Hemisphere might feel relatively hotter than when eccentricity is greater. If the Northern Hemisphere's Summer Solstice takes place on the "far end" of an elliptical orbit, as it does today, its increased distance from the sun would mitigate the increase in direct sunlight Earth receives.



Source: Online Star Registry

- Finally, students should combine all three Checkboxes to see the resultant graph on solar insolation against temperature anomalies. Does the Milankovitch Cycle graphed (in magenta), illustrating the amount of sunlight Earth receives over time, correlate with temperature changes? *Remember, the two graphs do not have to fit together perfectly—as they are different scales. Do the increases in direct sunlight generally match up with increases in temperature?* **A:** Yes, but not always perfectly.



Source: United Nations University

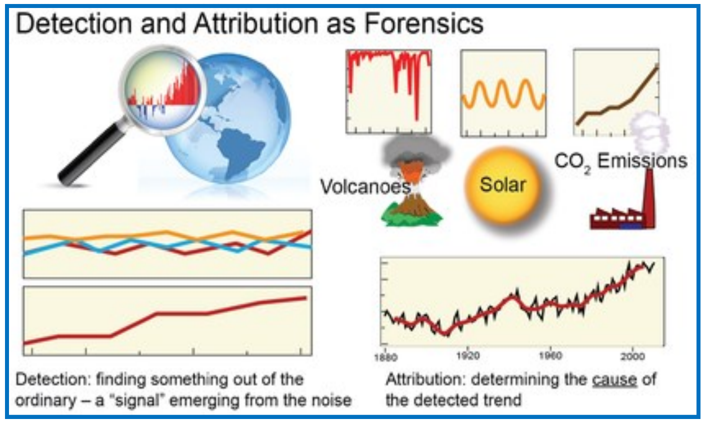
EXPLANATION (10 minutes)

- Now that we understand how the angle of tilt, the axial precession, and the eccentricity of Earth's orbit contribute to glacial and interglacial climate cycles, what other natural forces may either exacerbate or modulate the Milankovitch cycle, or create briefer, less drastic climate cycles within each period?
- After giving students an opportunity to provide their own ideas, use the Web-based application to pull up the graphic on Natural Climate Factors:
  >Climate Science>>>Natural Forces: Volcanoes, Sunspots, & Wobbles, Oh My!>>>Natural Climate Forces
- Use this Unit's introduction to lead a discussion on how each of the terrestrial factors listed (ocean,

II.A: Milankovitch Cycle Lab—continued 4/4

ELABORATION (homework—this page can be printed and provided to students for reference/instruction)

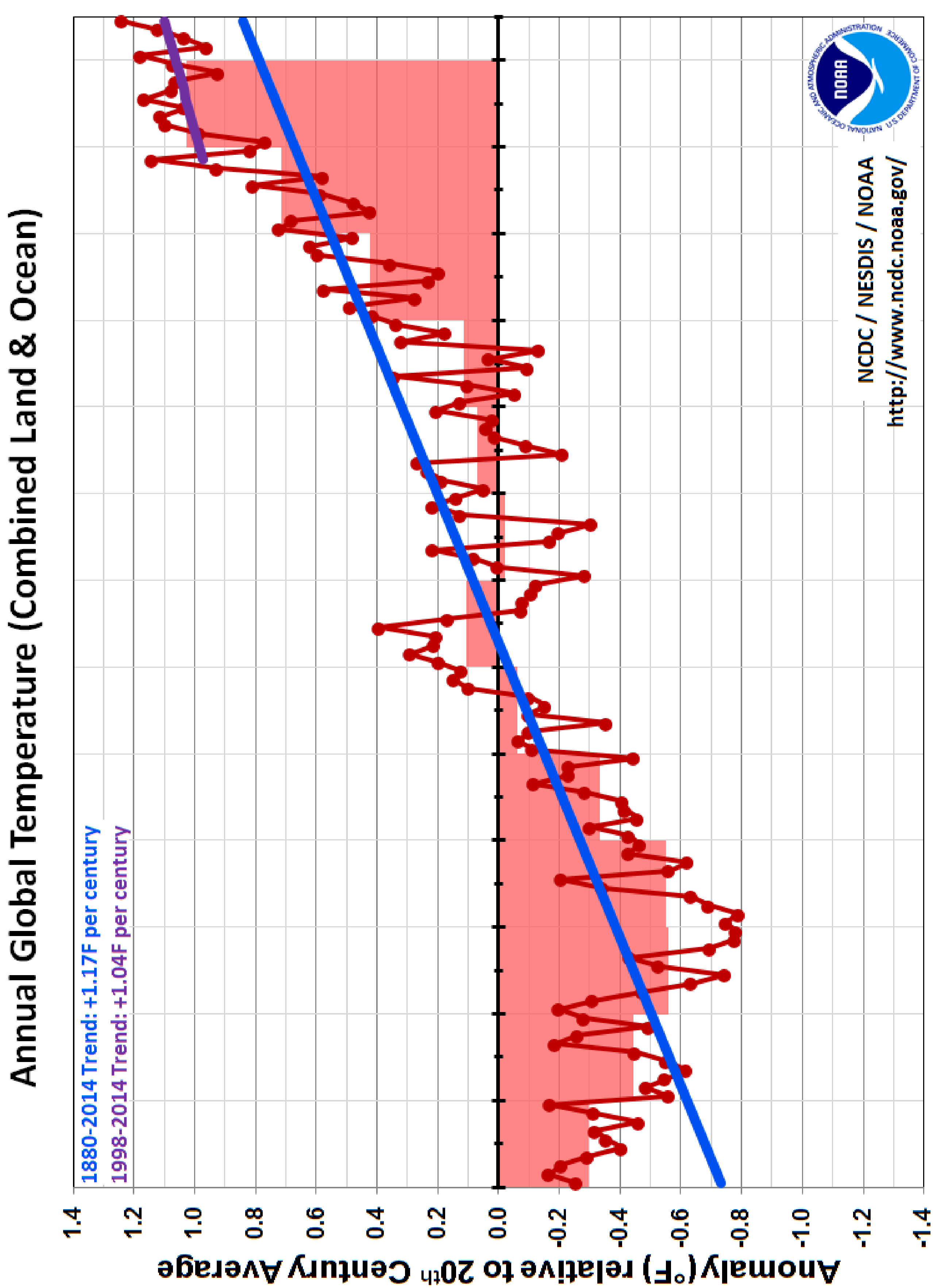
- Now that students have charted Milankovitch Cycles, can they apply the same learned concepts of natural climate forcings to track the effects of volcanic activity, ocean-atmosphere interactions and sunspots on climate?
- Break the class up into three team: **volcanoes, ENSO, and sunspots.**
    - Powerful volcanoes, with a VEI of 5 or greater, expel large quantities of particulates into the upper atmosphere, which can reflect light. They also expel some CO_2 which is a heat-trapping gas.
    - ENSO stands for El Niño Southern Oscillation, which is a repeating pattern of interaction between trade winds and seas, resulting in a predictable, though irregular fluctuation of sea surface temperatures (SST). El Niño means higher SST and La Niña means lower SST.



Source: Detection and Attribution as Forensics (source: NOAA NCDC), in: Walsh, J., et al. (11 January 2013), "Appendix II: The Science of Climate Change", in FEDERAL ADVISORY COMMITTEE DRAFT CLIMATE ASSESSMENT. A report by the National Climate Assessment Development Advisory Committee.

    - Sunspots are used as a way of measuring solar activity. Generally, more sunspots mean an increase of solar output energy and fewer sunspots mean reduced solar output energy.
- Using the NOAA graph on the back of the worksheet, entitled **Annual Global Temperature Anomaly (Combined Land and Ocean)**, students should use data related to their assigned team and plot years of high VEI, ENSO events, or peak sunspot activity onto the Temperature graph from 1880-2015.
    - **Significant Volcanic Eruption** data can be found at NOAA's National Center for Environmental Information database by plugging in the timeline (1880 to 2015) and VEI parameters (5 minimum to 8 maximum) here: https://www.ngdc.noaa.gov/nndc/servlet/ShowDatasets?dataset=102557&search_look=50&display_look=50
    - **ENSO events** can be found at the bar on the right, here: https://www.esrl.noaa.gov/psd/enso/
      Students should track El Niño events in RED and La Niña Events in BLUE
    - Sunspot data collected from the Zurich Observatory since 1849 and corroborated by NASA can be found here: https://solarscience.msfc.nasa.gov/images/Zurich_Color_Small.jpg
      Students should only track years of peak activity (the apex of the curve).
- Once the assignment is completed, ask students to report with their teams if their natural climate factor was usually a good predictor of changes in the climate *from year to year* and in what way (warmer or cooler?).
- Do any of these factors account for the warming trend of the last century, particularly over the last 2 decades?
- To recap—use the Web-based application to show the video on **>Climate Science>>>Natural Forces: Volcanoes, Sunspots, & Wobbles, Oh My!>>>Natural Cycles: Evidence of Change**, also found here: https://youtu.be/2_10jtPCjQw

Name: ______________________________　　**II.A: Milankovitch Cycle Lab—Homework**



Name: ___________________________ II.A: Milankovitch Cycle Lab—Student Worksheet

This worksheet accompanies the Milankovitch Cycle applet found at http://itg1.meteor.wisc.edu/wxwise/climate/earthorbit.html. First, with the time slider set to "Now" allow the slow orbit and rotation to complete a cycle and answer the questions below. Switch between Top view and Side view to change the perspective.

1) What causes the temperature difference between the winter and summer solstices for the Northern Hemisphere?

____

____

2) What is the difference between the Perihelion Aphelion points in the Earth's revolution around the sun?

____

____

3) *Next, use the applet to learn more about variations to Earth's tilt, axial precession, and elliptical orbit that affect climate cycles.* ***After manipulating each variation alone, try to define them your own words.***

Tilt:____

Precession:____

____

Eccentricity: ____

____

4) *Using the applet, see how <u>each</u> variable graph (in* ***magenta****) compares to the Vostok Ice Core Temperature graph (in* *green*). ***What is the full length of each cycle? Hint: you can drag the Time slider from one peak or valley to the next on the graphs and read the number of years on the Timer slider.***

a) An axial tilt cycle takes approximately __________________ years.

b) An axial precession cycle takes approximately __________________________ years.

c) An orbital eccentricity cycle takes approximately _______________________________ years.

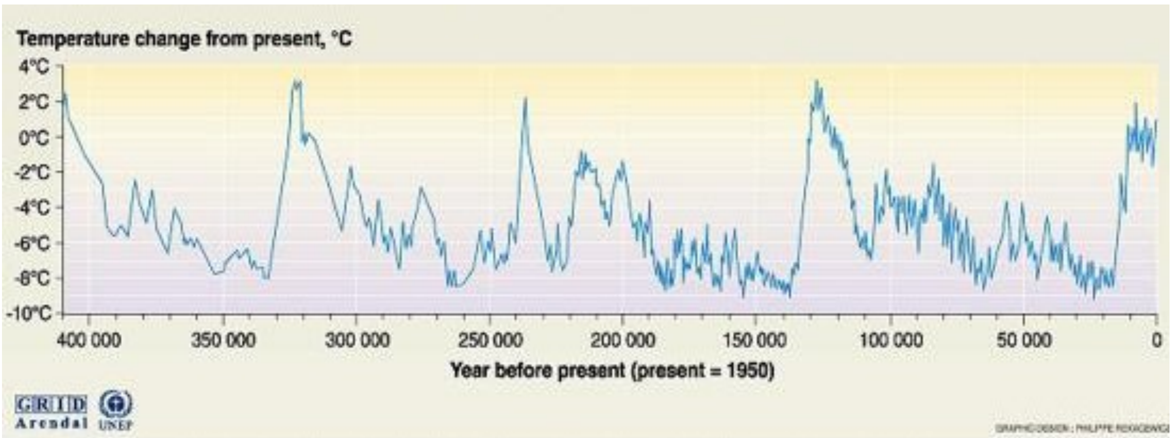
5) ***Consider how each cycle might affect the amount of direct sunlight the Earth receives in the Northern Hemisphere at the Summer Solstice. Record your thoughts here:*** ____

____

____

6) *Finally, combine all three variations by making sure all the boxes are checked. This represents the true amount of insolation the Earth received over the last 400,000 years, accounting for these variations to tilt, precession, and eccentricity.*

The graph below is the same Vostok Ice Core graph on the applet, showing temperature anomalies for the past 400,000 years, only presented horizontally and inverted for clarity. Peaks correspond to temperate climates, whereas valleys are ice ages. ***Bonus: Try to recreate the total insolation graph by plotting it onto the Temperature graph below.***



Source: J.R. Petit, J. Jouzel, et al. Climate and atmospheric history of the past 420 000 years from the Vostok ice core in Antarctica, Nature 399 (3JUne), pp 429-436, 1999.

7) How well does the *total* insolation graph correlate to the temperature graph? Do the increases in direct sunlight *generally* match up with increases in temperature? Are there any glaring contradictions or lags?

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____

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II.B: Paleoclimatology: Clues in Trees & Ice

Key Concepts and Web-app Resources:

Direct climate measurements date back only to the 1880s, which provides very little perspective to compare current climate change to Earth's long history. Scientists therefore use **climate proxies**, or preserved physical characteristics of the past environment, as substitutes for direct measurements. Climate proxies include ice cores, fossilized pollen grains, tree rings, ocean sediment cores, and layers of sedimentary rock. Scientists that gather climate proxy data and reconstruct it to learn about Earth's past climate conditions are called paleoclimatologists.

Ice cores have been particularly helpful in extracting fairly precise information on the atmospheric conditions stretching back for hundreds of thousands of years. That is because, in the Earth's current Icehouse state, some areas of polar ice have never melted. Year after year, precipitation (snow, hail, freezing rain) that accumulated formed annual rings through seasonal changes, much like a tree. Scientists drill into the ice-sheets and extract cores containing trapped gases in the layers. The further they drill down, the further back into history they can see. These ice cores are brought to frozen laboratories where the trapped gases can be extracted and assessed in a vacuum chamber to determine the amount of carbon dioxide present each year in parts per million (ppm). Oxygen isotopes in the frozen water can also be used to estimate relative annual temperatures at the surface. The Vostok Cores from Antarctica give paleoclimatologists workable data on Earth's temperatures that stretch back to 400,000 years ago!

Tree cores and cookies also provide annual proxy data. Climate conditions affect the rate of tree growth—wider annual rings are indicative of favorable climate conditions, whereas more narrow rings mean poorer climate conditions for growth. Depending on the region and the species of tree, the relative size of the tree rings and cell size within each ring provide evidence of either warmer/cooler periods, or wetter/drier periods. Living trees can be cored with an increment borer and compared to cores, cookies, or even lumber from dead trees and the data can be cross-dated to construct a longer time-line. Given that some trees can live and grow for thousands of years, a lot can be learned by studying tree-rings The study of tree-rings is called **dendrochronology**.

Unit IIB. Web-app Resources

>Climate Science

>>Historical Climate Change: Clues in Trees and Ice

>>>Dendrochronology: What tree cores tell about local climate history

>>>Climate History in Ice Cores (NOVA Video Segment: Extreme Ice)

>>The Greenhouse Effect and Anthropogenic Warming

>>>CO_2 and Temperature Correlation (past 800,000 years)

In partnership with:

II.B: Dendrochronology Lab

**This lesson is intended to be used with the Lab-Aids Dendrochronology kit, available for purchase here:* *https://www.nature-watch.com/dendrochronology-tree-ring-dating-kit-p-1785.html*
The kit contains two sets of 12 simulated tree cores—each representing a different sample, student worksheets, and a teacher's manual.

Lesson: How do scientists read annual growth rings from tree cores and cookies to determine past climate history? How can cores from multiple samples be cross-dated to create extended timelines of paleoclimate data?

Subjects / grade levels: 4th-9th grade, Earth Science, Living Science

Materials: Several tree cookies for comparison (can be cut from local fallen branches, or purchased at local craft stores or Nature-Watch.com; Lab-Aids #52: Dendrochronology—Tree Ring Dating Kit (available for purchase through several online retailers); student worksheets, rulers, computer(s) to view Web-application video.

NGSS Standards:
5-PS3-1 Energy
5-LS1-1 From Molecules to Organisms: Structures and Processes
5-LS2-1 Ecosystems: Interactions, Energy, and Dynamics
5-ESS2-1 Earth's Systems
MS-LS1-1 From Molecules to Organisms: Structures and Processes
MS-LS1-7 From Molecules to Organisms: Structures and Processes

Source: Michigan Weather Center

ENGAGEMENT: (5-8 minutes)

- Ask students: How would you describe your regional climate? Was it always like that?
- How do scientists know about Earth's climate history—such as temperature or amount of precipitation thousands of years ago? **A:** Climate *proxies*. Scientists measure trapped gases in ice cores, study fossilized pollen in sediment cores, and measure growth rings in tree cores because they can be dated and indicate relative markers about the climate at that time.
- Tell students that today, they will become **Dendrochronologists**! Can they figure out what that means?
- Using the web-application, show students the following video on Dendrochronology:
  >Climate Science>>>Historical Climate Change: Clues in Trees and Ice>>>Dendrochronology: Tree Ring Dating (also found here: https://youtu.be/-Vfg4GieRTc)
- **Review:**
  - What is the study of past climates using proxies called? **A:** Paleoclimatology.
  - How does paleoclimatology data help scientists predict future climate changes? **A:** Collected data allows scientists to test the accuracy of Climate Models (simulated by computers)
  - What kind of climate data can be attained by looking at tree rings? **A:** Cloud cover, precipitation, temperatures

EXPLORATION: (10 minutes)

- Pass out Dendrochronology worksheets and tree cookies to each student.
- Have students use the diagram on their worksheet to help them find the first annual growth ring. How about the last? Note, not the bark!

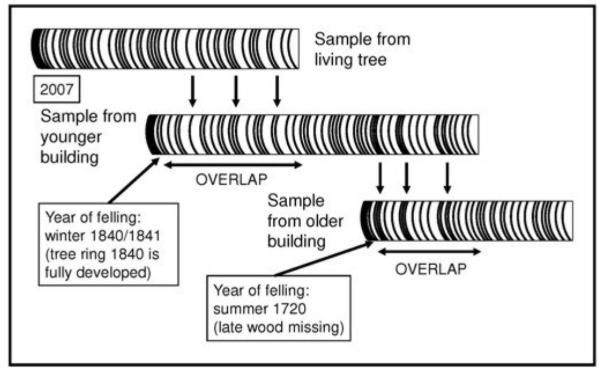
II.B: Dendrochronology Lab 2/2

EXPLORATION (continued)

- Students should continue using their tree cookie to answer questions on the worksheet.
- Ask students to sum up what they learned about their tree cookies and what it tells them about the climate their tree grew in.

EXPLANATION (25 minutes)

- Tell students that these tree cross-sections, or cookies, were made from felled trees. Can they think of any other places where tree rings can be found and counted? How about lumber/furniture?

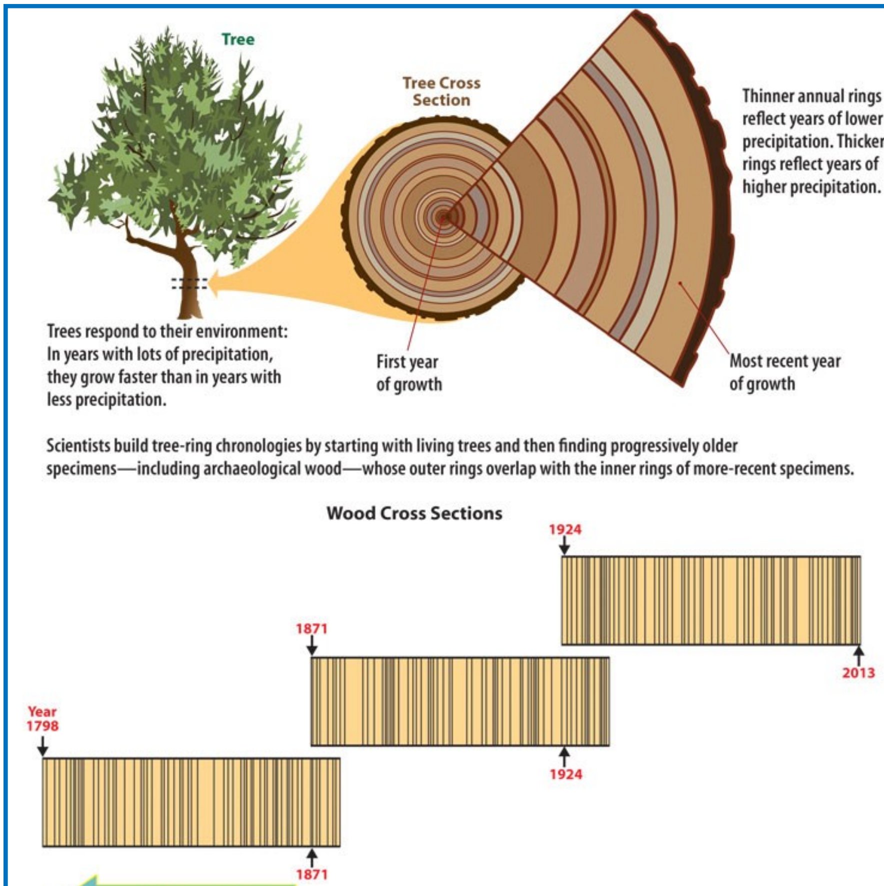


Source: [Oxford Tree Ring Laboratory - Washington County Historical Trust]

- Ask students if they can guess the age of the oldest living tree? **A:** It is a bristlecone pine—over 5,200 years old. That's a lot of climate data! These trees are hardly the biggest, but there are many narrow rings, as bristlecone pines grow in arid areas. The largest trees in the world, the coastal redwoods and giant sequoias, can live to be thousands of years old as well, and grow in temperate climates. But how do we get data from living trees without cutting them down? **A:** Dendrochronologists use an **increment borer** to drill to the center growth ring of the living tree and get a core.
- Follow the directions on the Lab-Aids 52: Tree Ring Dating to learn more about tree cores and cross-dating techniques that dendrochronologists use to get proxy data.

ELABORATION (10 minutes)

- While tree rings can tell us a lot about precipitation rates, temperature, or even about wildfires, the data at best stretches back about 13,000 years. What other climate proxies can scientists use that might provide information about Earth's climate hundreds of thousands of years in the past?
- Using the web-application, show students the following video on Ice Cores: **>Climate Science>>>Historical Climate Change: Clues in Trees and Ice>>>Climate History in Ice Cores (NOVA Video Segment: Extreme Ice)** (also found here: [https://ny.pbslearningmedia.org/resource/nvei.sci.earth.climate/ice-core-record-of-climate/])
- If there is time, discuss what new information is gained from ice core data.



Source: [Crow Canyon Archaeological Center]

In partnership with:

Name: ________________________________ **II.B: Dendrochronology Lab**

Dendrochronologists study tree rings, to determine the growth rate and age of trees. This provides insight into past climate in the region where the tree grew, such as annual precipitation and relative temperatures. Tree cores from living trees can be used to contrast and compare with tree slices, or "cookies" from preserved, dead trees. Every band represents a year of growth.

1) Look at your tree cookie sample and count the rings to determine how old it is.

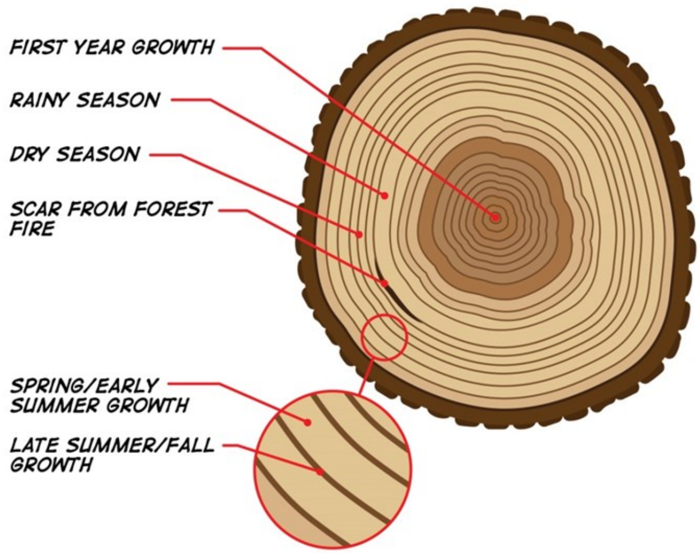
A: ____

2) Use the chart to the right to identify the first and last annual growth rings. If the tree came down *this year*, in what year did it begin growing?

A: ____

3) What year did the tree grow the fastest? How do you know?

A: ____



Source: NASA - Climate Kids

____

4) What does rapid growth probably mean for the weather conditions that year? ____________________________

____

5) Record any other notable observations from your tree cookie that may provide climate proxy data (ie: fire scar, all the rings are narrow, all the rings are wide, a knot in the wood, etc.)

____

____

____

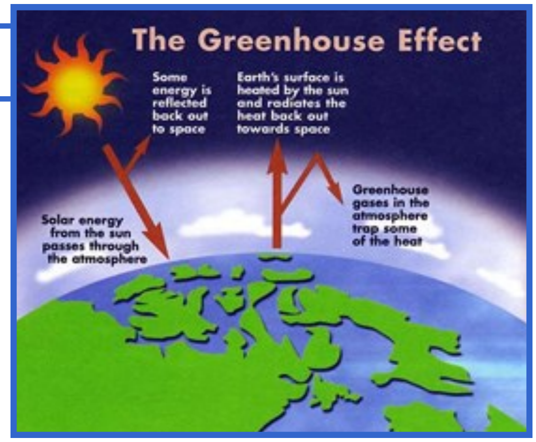
6) How does your tree cookie compare to your neighbor's? To the class? Do you think they all grew in the same climate?

____

____

GROUNDWORK Hudson Valley — In partnership with: NOAA — Sarah Lawrence College Center for the Urban River at Beczak

II.C: Our Atmosphere and the Greenhouse Effect



Key Concepts and Web-app Resources:

Earth's atmosphere consists of a mixture of gases separated into layers by their density, and bound to Earth by gravity. Though incredibly thin, the atmosphere has a potent affect on Earth's climate system. In fact, it is our atmosphere that allows Earth to sustain life at all. It contains the air that we breathe, and gases that protect us from harmful cosmic rays, and gases that trap heat and keep Earth full of liquid water—a key component of life. According to NOAA, the chemical composition of our atmosphere is: Nitrogen — 78.09%; Oxygen — 20.95%; Argon — 0.93%; Water vapor—.39%; Carbon dioxide — 0.04%; trace amounts of neon, helium, methane, krypton, hydrogen, nitrous oxide, sulfur hexaflouride, and ozone.

The composition, temperature, and pressure of this mixture of gases forms five distinct layers in our atmosphere: the troposphere—which hugs Earth's surface and contains the air we breathe, the stratosphere—where you can find commercial aircrafts flying, the mesosphere—which despite it being frigidly cold is where meteors burn up upon entry, the thermosphere—which reflects and absorbs the most harmful incoming radiation, and the exosphere—which fades into outer space where satellites can orbit Earth.

Although Nitrogen, Oxygen, and Argon make up over 99.5% of the Atmosphere, they absorb almost no incoming solar radiation nor outgoing infrared radiation. Instead, the other .5% of the atmosphere which contains water vapor, carbon dioxide, nitrous oxide, and methane are responsible for trapping most of the Earth's outgoing infrared radiation and heating the planet. Because of this thermal ability, we refer to them as **greenhouse gases**. The process by which incoming high-frequency light waves from the sun—absorbed at Earth's surface and reradiated as low-frequency infrared waves—are then absorbed by greenhouse gases and turned into heat energy, is called the **greenhouse effect**. These trace gases act just as the glass on a greenhouse ceiling do. The greenhouse effect is natural and quite beneficial to life on Earth. Without it, we'd be a frigid planet! According to NOAA, "the global average temperature is 14°C (57°F), which is approximately 33°C (59°F) warmer than temperatures would be without an atmosphere and GHGs."

Though methane and sulfur hexaflouride are the most potent greenhouse gases, carbon dioxide molecules are much more abundant, and they stay in the atmosphere for far longer. The feedback effect of carbon dioxide in the atmosphere on global temperatures is well documented in both the paleoclimate record and in real-time climate data.

Unit IIC. Web-app Resources:

>Climate Science

>>The Greenhouse Effect and Anthropogenic Warming

>>>The Greenhouse Effect (slideshow with captions)

>>>Global Temperature Time-lapse 1884-2012 (NASA visualization)

>>>CO_2 and Temperature Correlation (Past 800,000 years)

>>> Post-Industrial CO_2 and Temperature (1850-2015)

II.C: Our Atmosphere and the Greenhouse Effect—Rate of Change Activity

Lesson: How do global temperature averages and atmospheric carbon dioxide concentrations correlate in the past 130+ years?

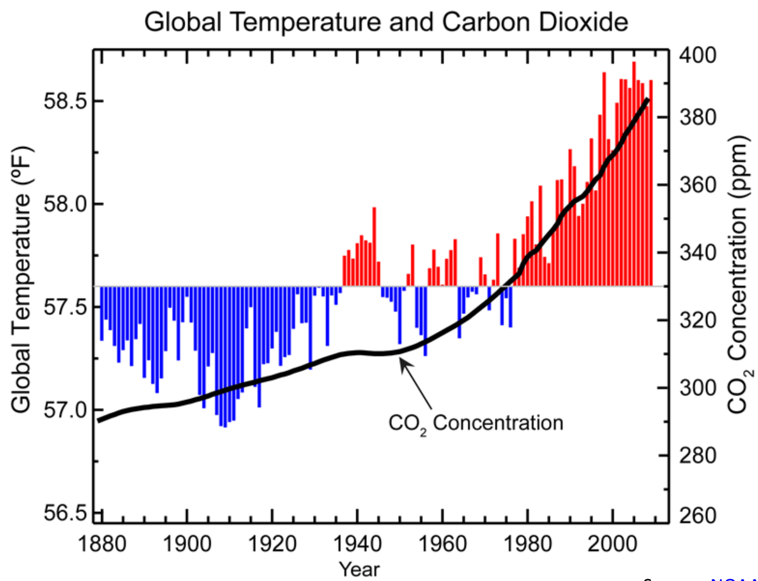
Subject / grade level: 6th-12th grade, Earth Science

Materials: Copies of the student worksheets and NOAA graph charting **Global Temperature and Carbon Dioxide from 1880-2010**; Earth Science reference book; rulers; calculators; Web-based application.

NGSS Standards:

SS2.D: Weather and Climate

- Weather and climate are influenced by interactions involving sunlight, the ocean, the atmosphere, ice, landforms, and living things. These interactions vary with latitude, altitude, and local and regional geography, all of which can affect oceanic and atmospheric



Source: NOAA

Lesson objective(s): Students will calculate rate of change to determine if the 20th century temperature increase is significant. They will also determine the relationship between the two graphs.

ENGAGEMENT (5 minutes)

- Ask students to define global warming in their own terms? If we are in an interglacial period, some degree of warming would be expected. Ask: how do you think current "global warming" compares to past warming?

EXPLORATION (15-20 minutes)

- Pass out worksheets and NOAA graphs to each student (or group of students). If you would like to display the graph on a smart board, you can find it on the web-based application by going to: >**Climate Science>>The Greenhouse Effect and Anthropogenic Warming>>>Post-Industrial CO2 and Temperature (1880—2010)**
- Orient students to the Y axis on the *left**. This charts Global Temperature in degrees Fahrenheit (°*F)*. **Blue** bars represent temperatures that are *colder* than the 20th century average; **red** bars are *warmer* than the 20th century average. (The horizontal "line" that runs between the blue and red bars represents the 20th century average).
    - Students should use rulers to match up the year 1900 on the graph to the corresponding blue bar. To get the global temperature for blue bar years, such as 1900, they need to use their rulers to then line up the ***bottom*** of that bar with the scale on the Y axis at left. To measure the temperature for red bar years, they need to trace the ***top*** of those bars to the Y axis on the left. **Some students may have trouble estimating points between the given marked temperature intervals. It may be preferable to mark more intervals on that axis, such as .25°F or even .125°F.*
- Next orient students to the Y axis on the *right*. This charts CO_2 Concentration in parts per million (ppm). This means there are *X* many molecules of carbon dioxide for every million other gas molecules in the atmosphere. The bold **black** line graphed represents the measured CO_2.

GROUNDWORK Hudson Valley CHANGING PLACES CHANGING LIVES In partnership with: NOAA SARAH LAWRENCE COLLEGE CENTER FOR THE URBAN RIVER AT BECZAK

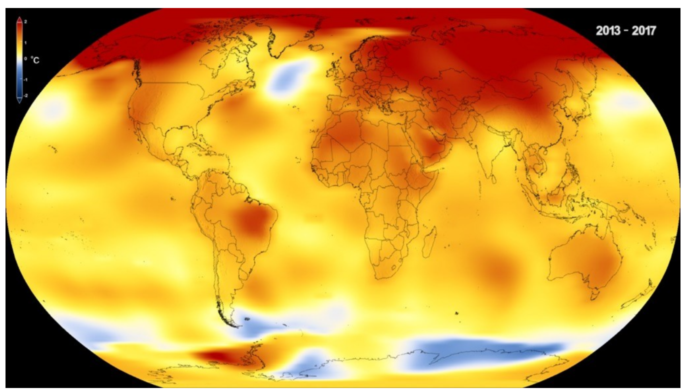
II.C: Our Atmosphere and the Greenhouse Effect—Rate of Change Activity

EXPLORATION (continued)

- Have students work independently or in groups with their Earth Science Reference books (or provide them the formula for rate of change). They should be able to answer questions 1-4.

EXPLANATION (10 minutes)

- Ask them to share their answers for questions 2 & 4. **A:** Temperature and carbon dioxide concentrations have a *direct* relationship. In other words, as one goes up, so does the other. The rate of change for 1950-2010 is about 10 times greater than the rate of change for 1900-1950. Earth is warming more rapidly and CO_2 increases are accelerating.
- Before they answer Part B on their worksheets, discuss the meaning of a 1-2 degree Fahrenheit increase in global temperatures. It does NOT mean that a New York summer day may be one degree warmer. Instead, these values are the land and water temperatures averaged out for the *whole globe* over the *entire year.*
  - Earth's average temperature is much like our internal temperature—a 1-2°F increase in 100 years or less is significant. For a human, it would mean getting a fever. When a human gets sick with a fever, they may get a headache, start sweating, get lethargic, or break out in a rash. When Earth's temperature increases rapidly, we notice deadly heat waves, more powerful storms, and rapid ice melt.
- Using the web-based application, watch the NASA Visualization Studio video on Global Temperature Timelapse: **>Climate Science>>The Greenhouse Effect and Anthropogenic Warming>>>Global Temperature Time-lapse 1884-2012 (NASA Scientific Visualization Studio** (can also be found here: https://svs.gsfc.nasa.gov/4609)
  - Tell students that this will show how the annual temperature averages look when mapped out over the globe. White would represent average temperatures over land or ocean. **Deep blue** are –4°F from the average whereas **deep red** are +4°F from the average temperatures.
- Students should now answer part B on their worksheets.



Source: [NASA Scientific Visualization Studio]

ELABORATION (5 minutes)

- Use your Teacher Answer Sheet to discuss their answers.
- What do they think may be the consequence of an accelerated rate of change for both CO_2 and Temperature on our climate system? What sort of effects do they expect to see around the world from introducing a quick change of entropy? **A:** Unpredictability in ice cover, atmospheric conditions, ocean currents, etc.

In partnership with:

Name:___________________________ II.C: Climate and Rate of Change Student Worksheet

PART A: *Use the graph provided , Global Temperature and Carbon Dioxide, to answer the following questions.*

1) **Look at the graph. Record the Temperature and CO_2 below for the following years. Be sure to include the right unit of measurement! The average temperature in this timeline is ______________________**

A: **1900**— Temp: ______________________________ CO_2: ___________________________

A: **1950—** Temp: ______________________________ CO_2: ___________________________

A: **2010**— Temp: - ______________________________ CO_2: ___________________________

2) What is the relationship between the graphed data? (direct or inverse?) ________________________________

3) Use your Reference Book to look up the formula for *Rate of Change.* Next, calculate the rate of change for temperature and carbon dioxide over the following time intervals.

…from 1900-1950? # of years: ___________ Temp: ____________________ CO_2: _________________________

…from 1950-2010? # of years: ___________ Temp: ____________________ CO_2: _________________________

4) To what degree do they differ? Temp: __________________________ CO_2: __________________________

PART B: *Watch the NASA Visualization on Global Temperature Time-lapse 1884-2012 before answering the following questions.*

5) Why do you think the Northern Hemisphere seems to heat up much faster than the Southern Hemisphere?
Hint: Think about ice cover and albedo effect; also look up the specific heat values in your Reference book.

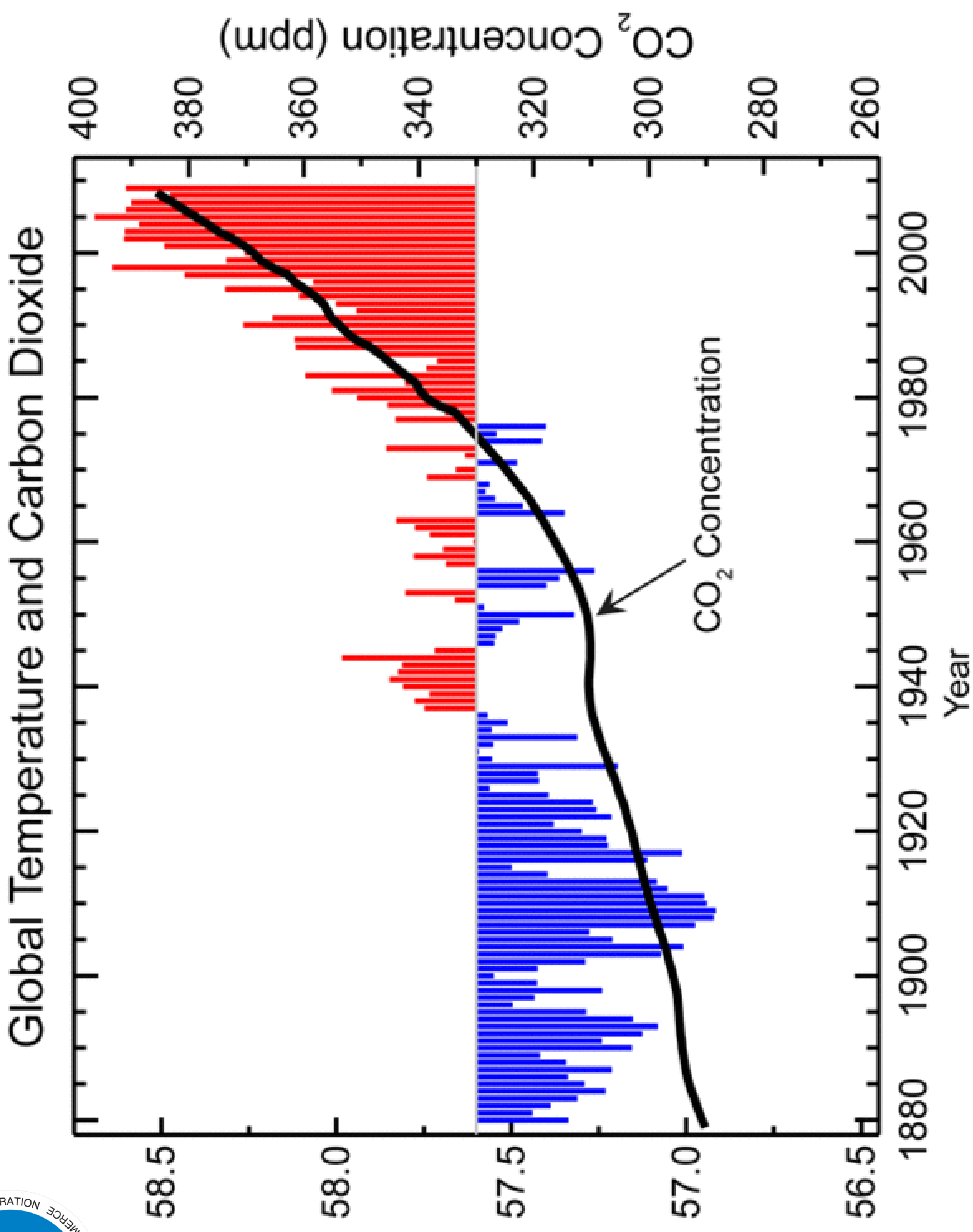
____

____

***6*) Describe in your words what this average global temperature increase looks like when mapped out over the globe.**

A: ____

____



Global Temperature and Carbon Dioxide
CO_2 Concentration (ppm)
Global Temperature (°F)
Year
CO_2 Concentration

II.C: Climate and Rate of Change Teacher Answer Sheet

Use the graph provided , Global Temperature and Carbon Dioxide, to answer the following questions.

1) Look at the graph. Record the Temperature and CO_2 below for the following years. Be sure to include the right unit of measurement! The average temperature in this timeline is ___**~57.6°F**_____________

a: **1900**— Temp: ~**57.6°F**____________________ CO_2:______**~295ppm**__________

b: **1950—** Temp: ~**57.3°F**____________________ CO_2:__________~**310ppm**__________

c: **2010**— Temp: ~**58.6°F**____________________ CO_2:_________~**390ppm**___________

2) What is the relationship between the graphed data? (direct or inverse?) ___Direct______________________

3) Use your Reference Book to look up the formula for *Rate of Change*. Next, calculate the rate of change for temperature and carbon dioxide over the following time intervals.

A) …from 1900-1950? # of years: 50________ Temp: **-.006°F/year**_ CO_2:_____**.3ppm/year**___________

B) …from 1950-2010? # of years: 60________ Temp: **.022°F/year**_ CO_2:______**1.33ppm/year**_________

4) To what degree do they differ? Temp:__**B is 35.7 times fasters than A**_ CO_2:__**B is 3.4 times faster than A**

Watch the NASA Visualization on Global Temperature Time-lapse 1884-2012 before answering the following questions.

5) Why do you think the Northern Hemisphere seems to heat up much faster than the Southern Hemisphere?
Hint: Think about ice cover and albedo effect; also look up the specific heat values in your Reference book.

There is more land mass in the northern hemisphere. Land heats up faster than water because water has a high specific heat value. As ice melts in the north pole and Greenland, less solar reflection creates a positive feedback to further increase warming.

***6*) Describe in your words what this average global temperature increase looks like when mapped out over the globe.**

A: It looks like pockets of extreme warming on land some years, and slow warming of our entire oceans. The planet on the whole seems to have changed significantly in just the past 130 years.

II.D: Anthropogenic Warming

Key Concepts and Web-app Resources:

Humans have long-altered our planet’s resources, often to the detriment of other species, but could we really fundamentally change our global climate system? Throughout this unit, we have learned about the ways in which the atmosphere, geosphere, hydrosphere, and biosphere interact with Earth’s energy budget. We have also learned about the unique role that carbon dioxide, as a heat trapping gas in the atmosphere, has had in past changes to our climate. Anthropogenic warming refers to the change in global temperatures that cannot be accounted for by natural processes alone. Human influence, particularly on the atmosphere and biosphere, is the primary driver to climate change today.

When humans began repopulating the globe after the last ice age., a stable climate allowed for settlements to form and agriculture to become the predominant method of food production. To clear forests and grow crops, trees and brush were slashed and burned, releasing their stored carbon. The ground was plowed, turning up roots and mixing in oxygen. The disturbance to the soil increased decomposition rates and released more carbon dioxide and methane into the atmosphere as well. This uptick in CO_2 was remediated by other forests, still in abundance, and the oceans, still cold and able to dissolve more gases. However, by the 1800’s, the Industrial Revolution was in full swing, and manufacturing plants brought coal-fires for steel production, fuel-driven steam engines, and clear-cutting of forests to make room for roads, trains, farms, mining, and more factories. In the late 1800’s the invention of the steam -powered generator to produce electricity was introduced. More fuel was needed to meet increased consumption. Fuel is burned to boil water, which creates steam, which expands and pushes pistons in a generator, which spin powerful electromagnets, which provide a current of electricity. To meet demand, humans turned to new fuel sources and new methods of extraction. Coal, oil, and natural gas soon became our fuels of choice, as they seemed almost unlimited in their quantity deep in the Earth’s crust.

In the last lesson (II.C), we learned how greenhouse gases work to trap solar gain and convert it to heat energy. Scientists know from paleoclimate data in ice cores, field experiments, and computer models, that increases in the greenhouse gas, carbon dioxide, have been the greatest predictor of increases in global temperatures. Today, the amount of carbon dioxide in the atmosphere is over 400 parts per million—a level not seen in the last 400,000 years. Predictably, global temperatures are also on a marked increase. Human activity is the main climate forcing today.

Unit IID. Web-app Resources:

>Climate Science

>>The Greenhouse Effect and Anthropogenic Warming

>>>Separating Natural and Human Factors

>>>Post Industrial CO2 and Temperature (1850-2015)

>>Natural Forces: Volcanoes, Sunspots, and Meteors, Oh My!

>>>NASA Video Comparing Natural and Human Factors

II.D: Anthropogenic Warming—Carbon Cycle Activity

**This activity was adapted from the Nitrogen Cycle Game, developed for the National Earth Science Teachers Association by Lisa Gardiner of the UCAR Center. It was modified by Groundwork to teach about the Carbon Cycle in 2016 after partnering with NOAA. Tokens were introduced to replace dice as a way of showing forces of change.*

Lesson: What are the natural and anthropogenic sources of carbon? Where are the biggest carbon sinks? How is human activity “loading the dice” for atmospheric and oceanic carbon dioxide concentrations?

Subjects / grade levels: 5th-9th grade, Earth Science, Living Science

Materials: 7 Envelopes; Carbon Cycle Game printouts (Student Passports for each student, 7 Stations: Sources and Sinks, and Tokens), available for download here:
Tokens should be cut out ahead of time and placed in corresponding 6 Station envelopes. (Laminating tokens and station sheets makes them more durable). Be sure that each station has at least one of the tokens listed.

NGSS Standards:
MS—PS1-1: Matter and Its Interactions
PS1.A: Structure and Properties of Matter—Each pure substance has characteristic physical and chemical properties (for any bulk quantity under given conditions) that can be used to identify it.
PS1.B: Chemical Reactions—Substances react chemically in characteristic ways. In a chemical process, the atoms that make up the original substances are regrouped into different molecules, and these new substances have different properties from those of the reactants.
MS—ESS3-3: Earth and Human Activity
ESS3.C: Human Impacts on Earth Systems—Human activities have significantly altered the biosphere, sometimes damaging or destroying natural habitats and causing the extinction of other species. But changes to Earth’s environments can have different impacts (negative and positive) for different living things.
MS—ESS3-5: Earth and Human Activity
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.

ENGAGEMENT

- Ask students to name all of the carbon molecules they can think of. (ex: carbon dioxide, carbon monoxide, methane (CH_4) , glucose ($C_6H_{12}O_6$), calcium carbonate ($CaCO_3$) found in seashells…) Where can you find carbon in the ***atmosphere***? **A:** As trace carbon dioxide and methane. The ***biosphere***? **A:** Stored in plants and other trees, in living cells of animals (proteins, carbohydrates, lipids). The ***hydrosphere***? **A:** Dissolved in the oceans and lakes. The ***geosphere***? **A:** In the sunken remnants of dead marine organisms and buried deep in the Earth’s crust as coal, oil, or methane.
- Tell students that the same fixed amount of carbon, used as a building block of life, has been in cycle since Earth’s beginning over 4 billion years ago. How does this carbon get moved from one organism to the next, or even one sphere to the next?
    - The movement of carbon atoms from oceans, to atmosphere, to plants, to animals, to Earth’s crust is called the **Carbon Cycle**.

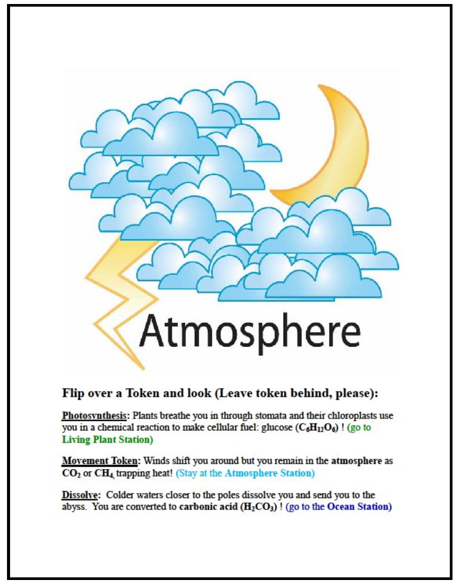
II.D: Anthropogenic Warming—Carbon Cycle Activity 2/3

ENGAGEMENT continued

- Photosynthesis, consumption, assimilation, and decomposition all transform and move organic carbon, while geologic forces (tectonic movement, weathering, volcanoes), and physical forces such as dissolving, diffusion, and burning, can transform and move inorganic carbon.
- Some of these processes happen in a geologic instant! For instance, plants convert atmospheric carbon dioxide to glucose in their leaves every day. Other processes take millions of years, such as the layering of ocean sediment containing carbon from dead marine organisms being heated and compressed by the weight of the crust and turned into "**fossil fuels**."

- Can humans alter the carbon activity? If so, how? **A:** We disturb soil and rock through agriculture, mining, and construction—changing the rates of weathering. We have clear-cut forests through slash-and-burn techniques, releasing the carbon stored in trees. We burn trees and fossil fuels for heat and electricity production.

EXPLORATION (15-20 minutes)

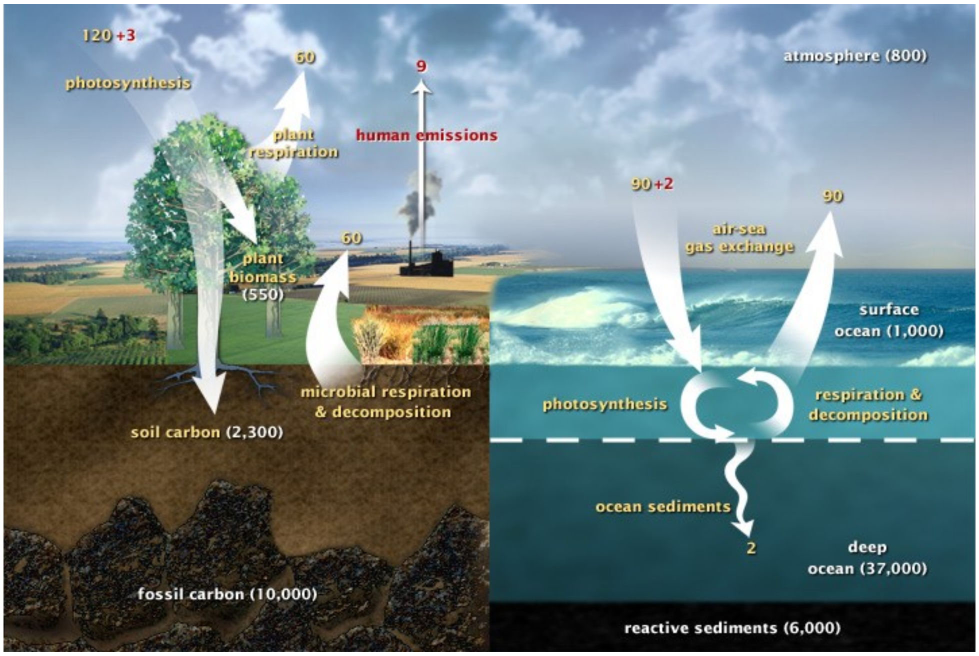


- Set up the room to space out the 7 Carbon Cycle Stations—Atmosphere, Oceans, Soils, Living Animals, Living Plants, Dead Plants & Animals, Fossil Fuels. Make sure each station has its associated envelope containing its tokens. ***For now, leave the fuel token out of the Fossil Fuel station envelope.***
- Pass out the Student Passports to students. Make sure everyone has a pencil.
- Ask students to position themselves at a station. ***Start at least one student at the Fossil Fuel station.***
  - Read over the directions at the top of the passport out loud with students and have them fill in the correct information for their starting station. Keeping track of their particular carbon molecule at each station is optional—but you can offer bonus points for doing so. Explain that the way they fill out remaining stations changes a bit.
  - Also, it is important that students RETURN the token to its envelope after they record it on their passport. The tokens are station-specific. They should <u>not</u> take tokens with them to the next station.
  - Explain that it is quite possible to draw the same token multiple times in a row. This represents longer stays at each station in geologic time. Students should record each draw as a new trip on their passports.
- Allow the students 10 minutes to move through the Carbon Cycle Stations and populate their passports. After the first few minutes, the student(s) at the Fossil Fuel station will begin to get frustrated. They are stuck—round after round, millennium after millennium. They represent the ultimate carbon sink… for now. After they have filled in at least 4 stations, announce to the class that you are going to introduce **anthropogenic** forces: FUELS.
  - At least 2 Fuel tokens should be placed in the Fossil Fuel station envelope. The remaining can be divided between the Living Plants and the Dead Plants & Animals station envelopes. (After all, we do burn biomass other than coal, oil, and gas for fuel).
  - Students should return to their seats after completing their passport.

II.D: Anthropogenic Warming—Carbon Cycle Activity 3/3

EXPLANATION

- Ask students to share what they learned from this activity. As a carbon atom, would their journey ever truly end? Was every person's journey the same? Why not?
    - At which stations were they most likely to repeat consecutively? These are **carbon sinks**. Where were they least likely to repeat? These are **carbon sources**. Which carbon sink have humans converted to a carbon source? Where did carbon from burned fuels end up? **A:** The Atmosphere as carbon dioxide.



Source: Diagram adapted from U.S. DOE, Biological and Environmental Research Information System. -http://earthobservatory.nasa.gov/Features/CarbonCycle/

ELABORATION

- Show students the above diagram of the carbon cycle to review. The sizes of the arrows are approximately proportional to the amount of flow of carbon atoms. (Also found here: https://scied.ucar.edu/carbon-cycle-diagram-doe)
- Ask students to create a diagram like this but documenting only their journey.
- Ask a few students to come to the front of the room to compare their diagrams. Be sure to include at least one person that started at the fossil fuel station.
    - How do the diagrams differ? How does human activity disrupt the natural balance of the carbon cycle?
- Connect this lesson back to what we know about the atmosphere and historical climate change. Why might disruptions to the carbon cycle (by humans) cause global warming?
- Using the web-application, show students the following NASA video comparing natural and anthropogenic forcings:
  >Climate Science>>>Natural Forces: Volcanoes, Sunspots, and Wobbles, Oh My!>>>NASA Video Comparing Natural and Human Factors
  (also found here: https://climate.nasa.gov/climate_resources/144/video-how-global-warming-stacks-up/)
- What must we conclude is the primary cause for our current warming trend?

CARBON CYCLE GAME: PASSPORT

1) Mark your starting station on your passport
2) Pick a starting nitrogen molecule from the possibilities at that station (read token descriptions on Destination Sheet and look for the first boldface carbon molecules listed).
3) Select a token from the bag. Mark it on your passport under "Mode of Travel."
4) Find the corresponding directions depending on your selected token and mark your next destination on your passport. Travel now to this destination. Congrats, you've just become part of the N cycle!

Starting Station:	**Mode of travel (token):**
Starting Carbon Molecule:	**1st New Destination:**

5) Repeat steps 3-4 for each new station, always marking your Mode of Travel (token), your new form (nitrogen molecule) and next destination on your Passport for 8 total trips.
6) Return to your seat to discuss how this conceptual experiment worked!

Trip 1:

Mode of travel (Token):	**Next Destination:**
New Carbon **Molecule form**	

Trip 2:

Mode of travel (Token):	**Next Destination:**
New Carbon **Molecule form**	

Trip 3:

Mode of travel (Token):	**Next Destination:**
New Carbon **Molecule form**	

Trip 4:

Mode of travel (Token):	**Next Destination:**
New Carbon **Molecule form**	

Trip 5:

Mode of travel (Token):	**Next Destination:**
New Carbon **Molecule form**	

Trip 6:

Mode of travel (Token):	**Next Destination:**
New Carbon **Molecule form**	

Trip 7:

Mode of travel (Token):	**Next Destination:**
New Carbon **Molecule form**	

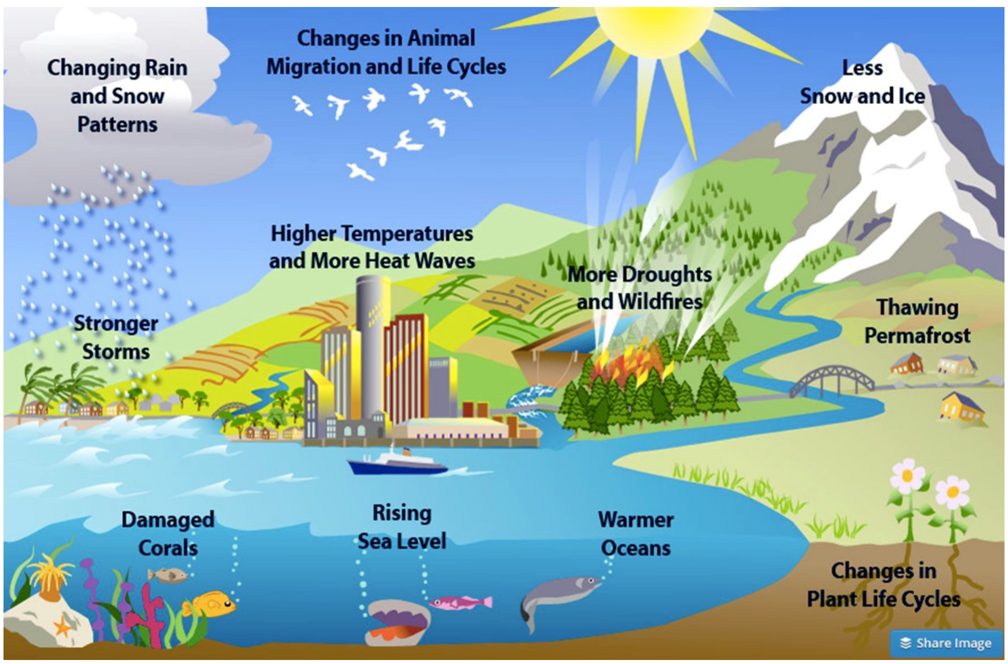
Trip 8:

Mode of travel (Token):	**Next Destination:**
New Carbon **Molecule form**	

CLIMATE CHANGE IMPACT

UNIT III: How will climate change affect life on Earth?

Climate change has been readily observable around the planet for the past century. Global temperature averages have increased over 1.04°C (or 1.5°F), creating a chain reaction on the rest of our climate system. Polar ice melt and thermal expansion have caused sea levels to rise, warmer oceans have propelled more powerful storm events, hotter, drier conditions inland have caused wildfires to spread faster, and increased air temperatures have given rise to more issues with air pollution and health effects. Scientists forecast that the planet will continue to warm another 2.5—10°F by the year 2100. This rapid change could bring dire circumstances for vulnerable biological communities and coastal populations. Knowing what the impacts have been and what they will be in the future can aid ecologists, farmers, policy makers, industry, and urban planners in formulating adaptation strategies.



Source: EPA

In **Unit III: Climate Change Impact**, we explore in detail the impacts of climate change on different sectors: ice cover, the water cycle and weather, oceans and coasts, agriculture, forest cover, wildlife, and human health. In 2014, a team of 300 expert scientists from NOAA's Climatic Data Center, NASA, and other ocean and climate research institutes around the world put together the Third National Climate Assessment.* This report documents twelve key findings of their research on our changing climate. This unit and the associated web-based application resources draw heavily from this National Climate Assessment. Additional scientific data comes from the National Snow and Ice Data Center, NASA, NOAA, USDA, and National Geographic.

* This report is updated periodically. The Fourth National Climate Assessment, released on November 23, 2018, can be found here: https://www.globalchange.gov/nca4

III.A: Polar and Glacial Ice Melt

Key Concepts and Web-app Resources:

Polar bears became the early "poster child" for climate change impact. In the 1970s, our improving understanding of global warming converged with a decades-long study on polar bear population decline due to habitat loss and over-hunting.* Cue images of stranded polar bear families on floating ice or starving polar bears in a frozen desert landscape. While polar bears *do* rely upon arctic sea ice for hunting and resting, they are just one of countless species imperiled by diminishing sea ice. Seals and walruses use sea ice as breeding grounds, narwhals hide in sea ice from predators, and sea birds rest on the floating platforms.

Sea ice formation at Earth's poles creates microscopic spaces between the crystals where algae can grow in brine channels. Recent studies, like the one conducted by the Alfred Wegener Institute, Helmholtz Centre for Polar and Marine Research, show that this sea ice algae feeds a far reaching community of zooplankton and other arctic animals. "Ice-associated animals derive between 60 and 90 percent of their carbon from the ice [algae]," including animal life at great depths below the ice. The extent of sea ice in the Arctic has declined by about 2.8% per decade since 1978. Moreover, studies indicate a sharp decrease in the ice thickness. Continued arctic ice melt may have far-reaching consequences on the food web of the oceans.

Though sea ice melt can have consequences for the ocean current circulation, it does not affect sea *levels.* Melting glacial and Antarctic *land ice*, however, *does* cause global ocean rise. Since reliable records began, the oceans have risen 8 inches (.2 meters) due to a combination of **thermal expansion** and land ice melt, primarily from Greenland. According to the National Snow and Ice Data Center (NSIDC), if all of Greenland's ice sheet were to melt, the ocean would rise 6 meters, or 20 feet. Luckily, Antarctica is buffered from extreme ice melt by the Albedo Effect and by being surrounded by frigid waters, because melting those ice sheets would cause a 200 foot rise in sea levels! Finally, two thirds of the Earth's freshwater is found in land ice. Winter snow pack in the mountains of northern California is what primarily recharges their reservoirs each spring. Melting glaciers means a loss of freshwater supplies.

*Polar bear populations are up since the 1972 passage of the Marine Mammal Protection Act (MMPA).

Unit IIIA. Web-app Resources:

>Climate Change Impact

>>Polar and Glacial Ice

>>>NASA Images of Change: Glacier Melt

>>>Antarctic & Greenland Land Ice

>>>National Snow and Ice Data Center (NSIDC)

>>>Arctic Sea Ice and Albedo Effect

>Oceans and Coasts

>>>If Antarctica Melted

In partnership with:

III.A: Polar and Glacial Ice Melt—Classroom Activity

Lesson: How is climate change impacting ice cover at the poles? How does variation in sea or land ice affect the ecosystem?

Subject / grade level: 6th-12th grade, Earth Science, Living Environment

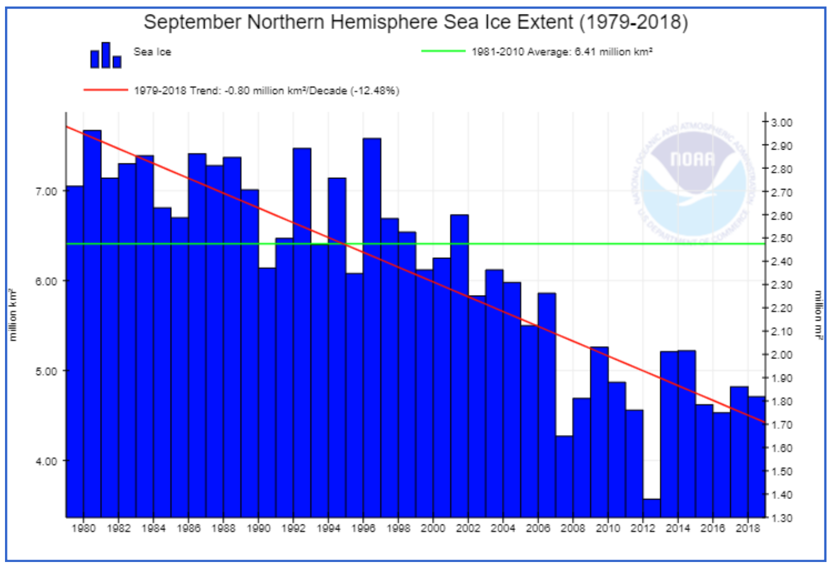
Materials: Web based Application, Copies of Student Worksheets. Optional: EcoChains—Arctic Life Card Game found here: http://ecochainsgame.com/

NGSS Standards:

- 5-ESS2-2 Earth's Systems
- 5-LS2-1 Ecosystems: Interactions, Energy, and Dynamics
- MS-LS2-1 Ecosystems: Interactions, Energy, and Dynamics
- MS-LS2-3 Ecosystems: Interactions, Energy, and Dynamics
- MS-LS2-4 Ecosystems: Interactions, Energy, and Dynamics
- HS-ESS2-2 Earth's Systems

ENGAGEMENT

- Ask students: Do you know what the **cryosphere** is? **A:** It is the part of the geosphere that includes all the land and sea ice sheets. The amount of ice cover at the poles fluctuates with seasons. These ebbs and flows have been studied for their impact on weather systems, ocean currents, marine food chains, and feedback to the climate system.
    - Introduce or review the idea of the **Albedo Effect**, if you haven't covered it recently.

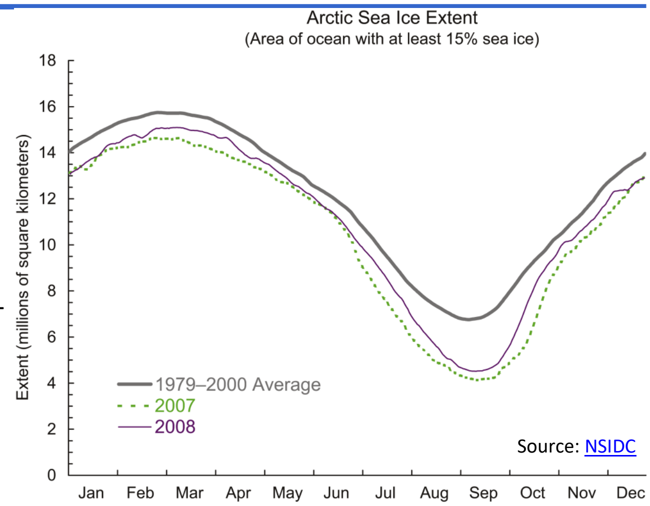


- **Optional**: Use the NSIDC Imaging tool to show them the seasonal changes of arctic sea ice extent for an earlier year (e.g: 1980) by putting in the desired parameters. Found here: https://nsidc.org/data/seaice_index/archives/image_select
- Recent warming of our planet has had an effect on the cryosphere and everything that goes with it. Ask students to name wildlife that live in the Arctic. They will likely name polar bears and seals. What about zooplankton and krill? What is there relationship to the ice? **A:** They feed on the ice algae that live in sea ice channels.

EXPLORATION

- Using the web-based application, load the Ch*arctic* Interactive Sea Ice Graph by following: **>Climate Change Impact>> Polar and Glacial Ice >>>National Snow and Ice Data Center** (also found here: https://nsidc.org/arcticseaicenews/charctic-interactive-sea-ice-graph)
    - You can either manipulate the data from the front of the room, or if students have access to a computer lab, have students navigate to this graph themselves. ***NOTE:*** *If the graph does not load, check your browser permissions at the top of the page. You may need to allow the app to "load unsafe scripts" first. That will reset you to the home-screen. If you navigate to the graph again, it should now work. Doing this once allows all other scripts on the app to load without a problem while the app is still open.*
- Have students begin by defining sea ice and land ice on their worksheet.

III.A: Polar and Glacial Ice Melt—Classroom Activity



Source: NSIDC

EXPLORATION (continued)

- Using the Ch*arctic* Interactive Graph:
  - Start by selecting "Hide All" on the right-hand bar.
  - Toggle on the **1981-2010 Average**—it will display as a **dark grey** line; and **Standard Deviation**—it will display as a **light gray** shaded region around the average. This represents degree of certainty from natural fluctuations, and measuring errors . The standard deviation given is +/- 2 million kilometers squared.
  - Orient students to the graph. The Y-Axis is "Extent of Arctic Sea Ice," measured in millions of square kilometers. The X-Axis is "Time," specifically the calendar year from January 1 through December 31. When students select a year (let's say **1980**) from the right-hand bar to display, it will chart that year's daily ice data in a colored line.
    - Show students that they can even see what that amount of ice would look like for a specific date, by clicking on the year-line at any point. A grey circle on the satellite image representation means no data.
    - They can look at the difference between winter and summer ice, visually. The orange line in the map represents the Median for that particular date.
  - Notice that Arctic Sea Ice extent grows in the winter months and shrinks in the summer months, following the pattern of temperatures in the Northern Hemisphere.
- Have students begin working on question 2 on their worksheets by looking at the pattern of ice extent for the past 10 years. They should be recording any year where the curve of the line falls below standard deviation for the summer months. If it rides the lower edge of the light gray shaded area, they **should** record that year.
- Next, we will look at changes in land ice over time. Climate data can come in a variety of forms. Surveyors and nature photographers returning to the same location decades later can provide a unique look into our changing planet. Satellite images can now also provide remarkable aerial perspectives of even difficult to reach locations. Using the web-based application, view the NASA image of Muir Glacier:
  >Climate Change Impact>>Polar and Glacial Ice>>>Images of Change NASA Glacier Melt
  (also found here: https://climate.nasa.gov/images-of-change?id=376#376-muir-glacier-melt-alaska)
  - Use the slider to see the difference between Muir Glacier, in Alaska, from 1941 to 2004.
  - Caption (Source—NASA): "The 1941 photograph shows the lower reaches of Muir Glacier and its tributary, Riggs Glacier. The two glaciers filled Muir Inlet. In the 2004 photograph, Muir Glacier, continuing a retreat nearly two centuries long, is located about 4 miles (7 kilometers) to the northwest, out of the field of view. Riggs Glacier has retreated some 0.4 miles (0.6 kilometers). Both glaciers have thinned substantially."
  - Glaciers either advance or retreat in response to slight, but prolonged changes to climate. The current rate of glacial retreat is faster than it has been in 5,000 years, doubling in the past 25 years.
  - If there is time, you can allow students to explore other areas of the map, by clicking the "location" pointer button at the top right of the NASA widget. Have students answer question 3 and 4 on their worksheets in their own words.

EXPLANATION

- Review their answers using the Teacher Answer Sheet. By comparing past decades with the current one on the Ch*arctic* Sea Ice Interactive Map, it starts to become more clear how abnormal the recent pattern of summer ice loss

III.A: Polar and Glacial Ice Melt—Classroom Activity

is, and why it may be a cause for concern to climate scientists... and lovers of polar bears.

- If students struggle to understand why sea ice melt does not contributes to sea level rise whereas land ice melt does, consider setting up the following demonstration:
    - Get 2 clear glasses, a small but rigid piece of mesh or chicken wire, and some ice.
    - Fill the first glass up with ice and water together until the level is to the brim of the glass. The ice in this glass represents sea ice.
    - Fill the second glass up to the top with water alone. Place the mesh over the second glass carefully and put approximately the same quantity of ice as the first glass onto the mesh over the second glass. The ice over this glass represents land ice.
    - Let the ice for both glasses melt…. Do they both spill over? No, only the land ice glass floods.
    - Explain that ice in the first glass—sea ice—is already displacing water in the glass. Because ice actually expands as it freezes, melting could even perceivable lower the level of water in the glass. The ice over the second glass melts from the “land” into the “sea”, raising its level.
- Why be concerned with sea level rise from ice sheet melt? **A:** We might not be in an ice age but we are in an Icehouse State. In other words, there’s still a lot of ice on Earth! If large quantities of ice melt, it would drastically change our geography. Most of the world’s population live on the coasts. Sea level rise of even a few feet could completely flood out cities like Miami, New Orleans, and even parts of Boston!
- Use the web-based application to explore maps of a world without ice:
  >Climate Change Impact>> Oceans and Coasts>>> If Antarctica Melted Maps
  (also found here: https://climate.nasa.gov/images-of-change?id=376#376-muir-glacier-melt-alaska)
    - As stated in this chapters overview, if all the Antarctic ice sheets melted, the oceans would rise 200 feet higher than they are today! These images, while perhaps disturbing, are luckily still only an extreme of a distant future (a thousand years or more) if warming is unchecked. However, a 6-10 foot rise in sea-levels is still possible in our lifetime if we do not mitigate our carbon footprint.

ELABORATION

- Extend this lesson into the effects on polar animals and the arctic ecosystem by showing the PBS video on the web-based application and/or buying copies of the EcoChains—Arctic Life Card Game and having students play each other.
- **>Climate Change Impact>> Wildlife>>> A Warmer World for Arctic Animals**
  (also found here: https://ny.pbslearningmedia.org/resource/kqedcl11.sci.ess.warmerworldforarcticanimals/a-warmer-world-for-arctic-animals/# =)

Name: ___________________________III.A: Polar and Glacial Ice Melt—Student Worksheet

1) Define the following terms:
a) Sea Ice:____

b) Land Ice:____

Use the web-based application to load the interactive graph on Arctic Sea Ice Extent:
>Climate Change Impact>>Polar and Glacial Ice>>>National Snow and Ice Data Center

2) Look at the graph comparing arctic ice cover from the past few decades and determine which years the data suggests that we are *losing arctic sea ice in summer months* beyond what can be accounted for by measuring errors (standard deviation). Record each year in the last decade where this is true.
A: ____

Next, use the web-based application to load the NASA Images of Change Widget:
>Climate Change Impact>>Polar and Glacial Ice>>>Images of Change NASA Glacier Melt

3) Look at the images of Muir Glacier in August 1941 and August 2004. Describe the difference between the two images below:
A: ____

____

4) Describe the relationship (if any) of sea ice melt and land ice melt to each of the following:

Impact of: → / Impact on: ↓	Sea Ice Melt	Land Ice Melt
Polar Animals		
Freshwater Availability		
Sea Levels		

In partnership with:

III.A: Polar and Glacial Ice Melt—Teacher Answer Sheet

1) Define the following terms:

a) Sea Ice:______Frozen ocean water that grows and melts in the ocean at the poles, depending on the season._

b) Land Ice: Ice sheets that form on land when winter snows never melt and get compressed into ice over years.

Use the web-based application to load the interactive graph on Arctic Sea Ice Extent:
>Climate Change Impact>>Polar and Glacial Ice>>>National Snow and Ice Data Center

2) Look at the graph comparing arctic ice cover from the past few decades and determine which years the data suggests that we are *losing arctic sea ice in summer months* beyond what can be accounted for by measuring errors (standard deviation) Record each year in the last decade where this is true.
A: **__2008, 2010, 2011, 2012, 2013, 2014, 2015, 2016, 2017, 2018 (10 of the past 11 years) ________**______

Next, use the web-based application to load the NASA Images of Change Widget:
>Climate Change Impact>>Polar and Glacial Ice>>>Images of Change NASA Glacier Melt

3) Look at the images of Muir Glacier in August 1941 and August 2004. Describe the difference between the two images below:
A: **Frozen rivers are replaced with a temperate looking climate and flowing water. In other words, the glaciers are__**

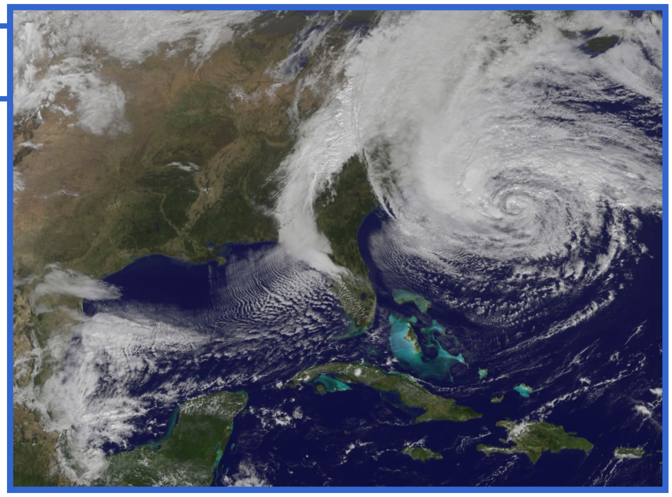
receding or retreating._______________________________________

4) Describe the relationship (if any) of sea ice melt and land ice melt to each of the following:

Impact of: → / Impact on: ↓	Sea Ice Melt	Land Ice Melt
Polar Animals	Loss of habitat, possible starvation or drowning in summer without normal sea ice to rest on/hunt on. Migration into new areas for food?	Loss of habitat. Changes to food availability. Possible phenology changes.
Freshwater Availability	Not really, new ice still has saltwater brine channels in it, making it undrinkable.	Rapid snow pack and glacial ice melt depletes an important freshwater sources for downhill.
Sea Levels	No change. Sea ice is already in the sea—no displacement takes place.	Yes, land ice melts into the ocean, raising sea levels over time.

GROUNDWORK Hudson Valley CHANGING PLACES CHANGING LIVES In partnership with: SARAH LAWRENCE COLLEGE CENTER FOR THE URBAN RIVER AT BECZAK

III.B: Water Cycle & Extreme Weather



Key Concepts and Web-app Resources:

The water cycle guides the movement of water molecules from land and oceans surfaces to the atmosphere where is condenses into clouds. Air movement circulates the atmospheric moisture and once it reaches a saturation point, we experience precipitation. Sometimes the rain can go on for days, slowly passing over the continents and recharging reservoirs and groundwater. This cycle is essential to life on land. Without adequate rain, grasslands become deserts, food production uses up our aquifers, and animal life must migrate or face local extinction. In recent decades, rapid climate change has fundamentally altered the water cycle as we know it. While year-to-year rainfall may still be as erratic as the weather, and different regions may experience more or less precipitation than they did historically, one overall trend is emerging: downpours are more intense and more frequent, but the total area of Earth's land surfaces getting adequate rainfall in any given year is shrinking! In other words, **deluge** or **drought** extremes are becoming the new normal. Why is this?

A warmer hydrosphere, geosphere, and biosphere means higher rates of evaporation/evapotranspiration. A warmer atmosphere can hold more water before saturation. That means once it rains, it is more likely to pour. However, a warmer atmosphere also takes longer to recharge between storm events, which can lead to **drought** conditions— extensive periods of time without much rain, causing water shortages. Drought conditions can actually compound the consequences of heavy downpours because dry earth is less absorbent than moderately moist soils. Flooding and erosion occurs when heavy rains meet dry-cracked earth or over-saturated soils; the rain either sits on the surface causing flood contamination, or runs off, eroding topsoil.

The moisture that fuels extreme weather like typhoons and hurricanes originates over the ocean. As the ocean warms, it is capable of generating more powerful storms. Paired with rising sea-levels, hurricanes are causing unprecedented damage at our coasts.

Unit IIIB. Web-app Resources:

>Climate Change Impact

>>Water Cycle and Extreme Weather

>>>**Deluge**

>>>**Drought**

>>>**Freshwater Availability and Consumption**

>>>**Extreme Precipitation (slideshow with captions)**

>>>**NOAA State of the Climate (Drought Monitor)**

>>>**Cost of Extreme Weather**

III.B: Water Cycle & Extreme Weather—Classroom Activity

Lesson: How is extreme weather connected to climate change? What are the true costs of storms, like hurricanes, or extensive droughts to the economy and to human health and wellness?

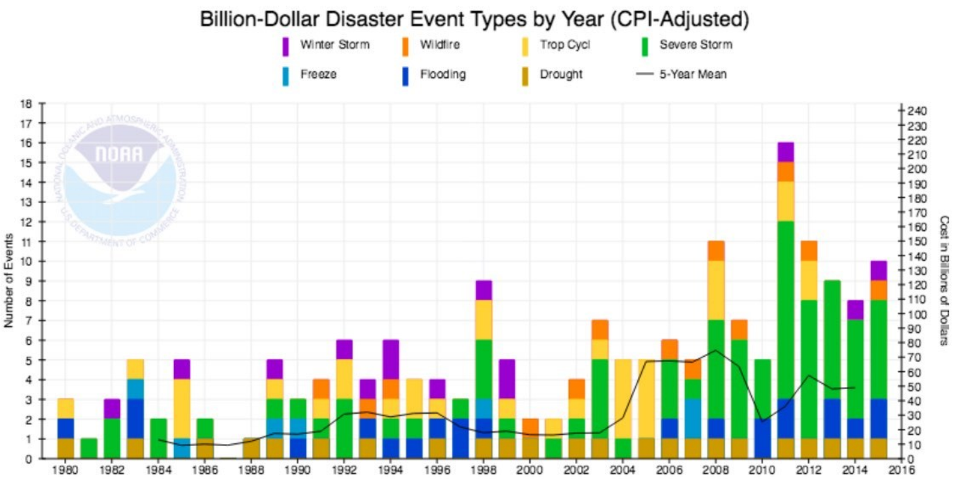
Subject / grade level: 6th-12th grade, Earth Science

Materials: Web-based climate app, prepared fact sheets about Billion Dollar Weather Disasters or computer access, student worksheets.

NGSS Standards:

MS.Weather and Climate

HS-ESS2-2 Earth's Systems



ENGAGEMENT (5-8 minutes)

- Ask students: What causes droughts and floods?
- Use the web-based application to watch the following videos on flood and drought events:
  >Climate Change Impact>> Water Cycle and Extreme Weather>>> Deluge
  >Climate Change Impact>> Water Cycle and Extreme Weather>>> Drought
  (also found as a set, here: https://ny.pbslearningmedia.org/resource/dce5a696-4f0c-47c5-a2ba-5e517c779089/water-cycle-animation)
- Ask: what do you think are some of the consequences of each?

EXPLORATION (20 minutes)

- Before class, prepare copies of this list U.S. Billion Dollar Weather and Climate Disasters 1980-2018. (https://www.ncdc.noaa.gov/billions/events.pdf) You can either pre-select a few key storms/hurricanes or drought periods and create individual sheets, or ask students to choose either a severe storm, hurricane, or drought to profile themselves.
- Alternatively, if your students have computer access, they can use the following website to key into their home state. By clicking on their state on the map, a table listing billion dollar disasters from 1980-2018 for that state will load. https://www.ncdc.noaa.gov/billions/mapping
- Have students work in teams to research one extreme weather event of their choice and record the relevant data onto their student worksheets.
- Students will then take turns briefly summarizing their weather event data to the rest of the class.
- What are the long-term consequences of more frequent and more costly extreme weather disasters? Where are we most vulnerable?

EXPLANATION (20 minute slide-show with discussion)

- Use the web-based application to present a slideshow on the cost of extreme weather:
  >Climate Change Impact>> Water Cycle and Extreme Weather>>> The Cost of Extreme Weather

III.B: Water Cycle & Extreme Weather—Classroom Activity

- **Captions for Slide-show:**
  - (1/9): As extreme precipitation events become more common, so does extreme flooding. Our stormwater infrastructure was not designed for our rapidly changing climate. This slideshow shows the many effects that extreme rain and wind can cause.
  - (2/9) The map above shows the number of times between 1980 and August 2011 that a U.S. state has been involved in a weather or climate disaster whose region-wide damage totals were at least one billion dollars at the time they occurred. The maps are based on records of economic losses kept by NOAA's National Climatic Data Center.
  - (3/9): It's official: 2017 was the costliest year on record for the United States when it comes to natural disasters. According to NOAA, the disasters caused $306 billion in total damage in 2017, with 16 events that caused more than $1 billion in damage each. The bulk of the damage, at $265 billion, came from hurricanes Harvey, Irma, and Maria, as well as wildfires on the west coast.
  - (4/9): Once considered 500-year events, storms like Hurricane Katrina (2005) now occur decades apart or less. Hurricane Katrina destroyed much of the Gulf Coast, especially the city of New Orleans. Severe flooding and inadequate response left many without drinking water, food, or proper first aid for days, if not weeks. Over 1,200 deaths are attributed to Katrina and $161 billion in losses.
  - (5/9) Flooding in Louisiana has become more common in recent years, even in the absence of a hurricane. In August 2016, prolonged rainfall resulted in catastrophic flooding in the state. Thousands of houses and businesses were submerged.
  - (6/9) Hurricanes and heavy rain events have different impact depending on where they hit and when. Hurricane Irene (2011) brought 16 inches of rain to upstate New York after an already unseasonably wet August. Saturated soils gave out to erosion and roads and bridges were washed out. It is now considered the most costly Category 1 storm in history.
  - (7/9) Some storms bring surges along the coast from high winds, instead of heavy rain. This was the case for Superstorm Sandy (2012). Winds swept the peak tide into highly developed areas with great population densities. As a result of the salt-water flooding, economic losses topped $65 billion.
  - (8/9) As the number of billion dollar weather events continues to rise, what do you think that will mean for the cost of goods and services? For taxes and insurance rates? For equitable access to basic needs?
  - (9/9) Knowing how vulnerable a location is to costly weather disasters is important to the people who live there, and to emergency planners and insurers. Ultimately, records like this should help scientists figure out if, in addition to the known influence of population growth and development, long-term climate change is contributing to the cost of weather-related disasters.

ELABORATION (10 minutes + homework)

- Studies show that people are more likely to respond to news about climate change and extreme weather when it is personal to them. Most of us have experiences extreme weather in our lives, or have family members who have. For some, the losses may be more devastating than others. Try to be mindful that some students may have had to move due to extreme weather, or even lost loved ones.
- To encourage students to share their personal experiences, you can show one or more Youth Climate Story videos from the Alliance for Climate Education (ACE), found here: https://ourclimateourfuture.org/map).
- For homework, ask students to write a 1-2 page essay about their own extreme weather experience. For students who claim no personal experience to draw from, or for students who are uncomfortable sharing their story, they can choose another ACE Youth Climate Story to watch and write an essay about.

III.B: Water Cycle & Extreme Weather—Classroom Activity

Use the provided data source of billion dollar weather disasters to profile either a drought, severe storm, or hurricane of your choosing.

Record the reported human and economic losses from one of these super storms.

A. Event Choice/Name: ____

B. Event Type: ____

i. If it was a hurricane, what category storm was it? __________________________________

C. State(s) or region affected: ____

D. When did this event take place? ____

E. Any important details that made this weather event particularly costly? (e.g.: slow moving, coinciding with high tides, size or range)

____

____

F. Sectors most affected?: (e.g.: agriculture, forests, infrastructure, utilities, properties, natural resources)

____

G. Total estimated economic losses? ____

H. Number of estimated deaths attributed directly or indirectly to event? __________________________________

In partnership with:

III.C: Oceans and Coasts—Overview

Key Concepts and Web-app Resources:

We live on a blue planet. Seventy-five percent of the Earth's surface is covered in saltwater. The vastness and depths of the oceans have buffered us against more severe changes to our climate. Ocean water heats much more slowly than land masses, meaning it absorbs much of our excess heat without large temperature changes. Our ocean is also a carbon sink because it can dissolve carbon dioxide from the atmosphere, mitigating the greenhouse effect from our additional carbon emissions. Still, we have learned from the previous chapters, that ocean ecosystems are threatened by sea-ice melt and that more powerful storms are being powered by warmer ocean temperatures. A marine ecosystem compromised by overfishing, pollution, coral and mangrove destruction (important fish nurseries), and now climate change, in turn impacts life on land—including us. Over one billion people around the world use the ocean as their primary source of food. According to NOAA's Fisheries Economics of the U.S., commercial and recreational fishing generated over $208 billion in sales in 2017, contributing $97 billion to the gross domestic product. Additionally, the industry employed over 1.8 million people. Coastal tourism and recreation is another large economic driver that depends upon more stability. All over the world, people are still intrinsically linked to the ocean.

While warming has its own adverse consequences to our oceans, excess carbon dioxide emissions from burning fossil fuels for energy poses another unique threat: **ocean acidification**. In just 200 years, the Earth's oceans have absorbed more than 150 *billion* metric tons of carbon from human activities. Dissolved CO_2 reacts with water to create carbonic acid molecules, which ionizes to form a mix of bicarbonate, carbonate and hydrogen ions. An excess of dissolved CO_2 causes an imbalance of reactants and leads to extra hydrogen ions which acidifies the ocean. Zooplankton and other marine organisms require carbonate ions to create their exoskeletons in a process called **calcification**. As the ocean dissolves more CO_2, it produces more hydrogen ions which also bond with carbonate ions to form bicarbonate, impeding the calcification process. Because ocean acidification impacts lower trophic level consumers, it affects the whole ocean food web.

Unit IIIC. Web-app Resources:

>Climate Change Impacts

>>Oceans and Coasts

>>>Ocean Acidification (ACE video)

>>>NOVA Impact of Ocean Acidification

>>>NOAA Digital Coast Mapping Tool

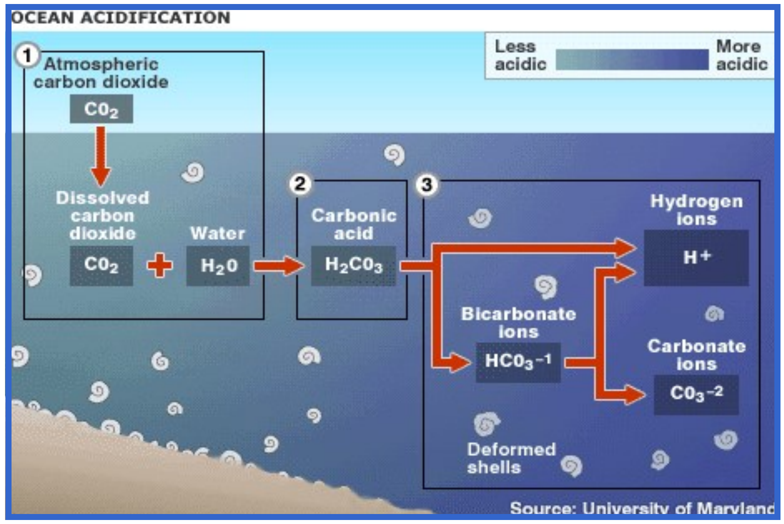
>>>If Antarctica Melted

In partnership with:

III.C: Oceans and Coasts — Acidification Classroom Activity

Lesson: What Impact Will Climate Change Have on Marine Ecosystems?

App Resources: >Climate Change Impacts>>Oceans and Coasts



Subject / grade level: Chemistry, Environmental Science/ 9th – 11th grade

NGSS Standards:

HS-LS2-6. Evaluate claims, evidence, and reasoning that the complex interactions in ecosystems maintain relatively consistent numbers and types of organisms in stable conditions, but changing conditions may result in a new ecosystem.

HS-LS2-7. Design, evaluate, and refine a solution for reducing the impacts of human activities on the environment and biodiversity.

HS-ESS3-5. Analyze geoscience data and the results from global climate models to make an evidence-based forecast of the current rate of global or regional climate change and associated future impacts to Earth's systems.

ESS3.C: Human Impacts on Earth Systems

ESS3.D: Global Climate Change

Materials:

Jars with different types of seashells: **(make at least one week in advance)**

2 jars with lids

Seashells – snail, oyster, mussel

Vinegar

Water

To prepare: Put some shells in a jar and fill with water. Fill the other with shells in white vinegar. If done at least a week in advance, shells in vinegar will have started to disintegrate.

Phenol Red Experiment: **(Prep samples ahead of time)**

Phenol red indicator

Glass jars with one-way valve tops

Straws (can cut in half to reduce waste)

pH Test strips or test kit

To prepare (can be done up to 2 days in advance): make a solution with 1:10 phenol red and water in each jar. Color should still be a deep red. Tightly screw in lids with one-way valves on top.

Lesson objective(s): Through a video and hands-on lab activity, students will understand the chemical process of ocean acidification and its effect on the marine ecosystem.

ENGAGEMENT

Ask students what kinds of impacts climate change may have on the marine environment. If they don't offer it, ask if they've heard of warming water conditions, mass coral bleaching, or ocean acidification. Will this affect the animals that live in the oceans and rivers in our area? What change do they think may stem from these two issues?
Web-app Resource: Climate Change Impacts>>Oceans and Coasts>>Ocean Acidification (ACE Video)

III.C: Oceans and Coasts — Acidification (page 2)

EXPLORATION

- Ask students to explain in their own words what ocean acidification is. Show them the two jars of shells in different media. Ask which they think is the one with a higher level of acidity. Ask if they recognize any of the animals that built those shells. Do they think that would have an impact on any other organisms in the environment? Do any of these organisms provide habitat for other plants or animals? Would they impact the food web? Could it affect humans?

EXPLANATION

- What is going on chemically when we talk about ocean acidification? What is carbonic acid and how is it made?
- Students may not remember from the video, so prompt them:
    - ♦ When carbon dioxide enters the water, it combines with water molecules to make carbonic acid. Carbonic acid disassociates into bicarbonate and hydrogen ions.
    - ♦ There are also carbonate ions floating around in the water, which animals such as mollusks/bivalves (clams, mussels, oysters, scallops etc.) need to make their shells.
    - ♦ The extra free hydrogen ions (from the carbonic acid) "steal" the carbonate floating around and make bicarbonate which is not useful for mollusk-shell building.
    - ♦ Since there are fewer carbonate ions, the shells of mollusks become weaker. Crustaceans (crabs, lobsters, shrimp etc.) use chitin for their shell, not carbonate. But if their food sources die out that could impact the rest of the food webs in the environment. These cascading reactions harm the ocean but also harm people.

ELABORATION

- Students will do this lab activity to produce carbonic acid – they can measure the change in acidity both by sight and by testing the pH. They will learn how excess carbon dioxide can physically alter the water.

- Lab activity: Review the pH scale as logarithmic and remind students that each jump on the scale represents a tenfold change, rather than only 1 degree (like temperature).

- Take out the phenol red jar solutions. Split students into groups and have them test the pH of the solution before starting the experiment on datasheet. Now, have students use straws to take turns blowing air bubbles into the jar. After only 30 seconds to a minute they will start to see a change in color from deep red to orange. If they continue blowing air into the solution the color will continue to change. Have the students test and record the pH again at the end of the activity. The pH should have shifted slightly to be more acidic. Review the logarithmic scale again and have the class figure out how much more acidic the solution became.

EVALUATION

- By the end of the lesson, students should know:
    - ♦ The definition of ocean acidification.
    - ♦ How carbonic acid is made.
    - ♦ What effect ocean acidification will have on mollusks.
    - ♦ How that will affect the rest of the marine food web and ecosystem.
    - ♦ Students should fill out the attached worksheet for evaluation.

EXTENSION

- Further resources for students:
    - ♦ Ocean Acidification http://www.noaa.gov/resource-collections/ocean-acidification
    - ♦ Earth's Acid Test: https://www.nature.com/news/2011/110309/pdf/471154a.pdf
    - ♦ Ocean Acidification's impact on oysters and other shellfish: https://www.pmel.noaa.gov/co2/story/Ocean+Acidification%27s+impact+on+oysters+and+other+shellfish

III.D: The Future of Farming

Key Concepts and Web-app Resources:

There is perhaps no human activity more critical to civilization than modern agriculture. Our food system means by and large, our meals come to us. In the United States, less than 2% of the population are farmers, with each farm feeding 165 citizens. The ability to dependably produce crops is integrally linked to climate conditions. The Dust Bowl of the 1930s is a prime example of this. Severe drought and poor soil management turned over 75% of the once fertile topsoil in the Midwest states to a cloud of dust that swept over the nation. Today, climate change threatens farmland across the globe with drought, heat-stress, and soil fertility loss through heavy rain events. Warmer climates also tend to favor pest species and fungal diseases that bring heavy crop losses, or even total failures. Still, some regions, typically too cold for major agricultural production, may become more productive as winters become more mild and growing seasons lengthen.

Use the web app resources below to explore some of the noticeable impacts that climate change has had on agriculture on a regional or even global scale.

Unit IIID. Web-app Resources:

>Climate Change Impact

>>Agriculture

>>>Climate Change & Agriculture (NASA: Science for a Hungry World)

>>>USDA Plant Hardiness Zone Map

>>>Projected Crop Yields 2050 (World Resource Institute)

>>>NOAA Drought Monitor (Animated Maps)

>>Wildlife

>>>Bees are Feeling the Sting of Climate Change

In partnership with:

Name: ______________________________ III.D—The Future of Farming—Student Worksheet

On the climate app, navigate from the homepage to :

>Climate Change Impact>>Agriculture>>>USDA Plant Hardiness Zone Map

(adjust the page zoom if necessary to improve visibility, or just print the image)

1) What is zone hardiness?

____

____

2) What plant hardiness zone do you live in? ____

3) How are plant zones shifting according to the maps from 1990 and 2015?

____

Now, **use the climate app to navigate from the homepage to :**

>Climate Change Impact>>Agriculture>>>Projected Crop Yields 2050

(adjust the page zoom if necessary to improve visibility, or just print the image)

Deep green means crops produce twice as much yield, whereas deep red means half as much yield from current conditions.

4) a. If the global warming trend continues, what regions may experience better conditions for agriculture and improved yields? b. Which regions will experience worse conditions and reduced yields?

a. ____

____

b. ____

____

5) Currently the top four food producing countries are China, India, United States, and Brazil. These countries also require the most food to feed their large populations. If projected crop yield estimates for 2050 are accurate, what effect will the new agricultural landscape have on trade, population, and world hunger? Why?

____

____

____

III.E: Threats to our Forests

Key Concepts and Web-app Resources:

Approximately 30% of the world is covered in forest. Forests are the lungs of world, absorbing CO_2 from the atmosphere and releasing oxygen gas as they photosynthesize. While forests alone cannot provide enough oxygen to sustain the world of consumers (algae, diatoms also assist in this), they do provide a home to over 80% of terrestrial organisms, sequester over 13% of human carbon emissions, and provide food and shelter resources for billions of people.

Climate change poses a threat to Earth's forest cover in a number of ways. First, warming conditions often favor a select few species, especially invasive species, that outperform and choke out biodiversity. In the next few decades, we may see shifting forest types in our wild spaces. Secondly, warming conditions also favor pest species, such as insects and fungal disease, which can then spread more quickly and damage or even kill trees in urban, managed, and natural forests. Finally, long-term droughts paired with higher temperatures dry out the wood of trees, turning them into fuel for forest fires. Burning forests release stored carbon back into the atmosphere, contributing to the greenhouse effect for decades to come.

Use the web-app resources below to explore these threats to our forests, and the repercussions of forest loss to other plants, animals, and people around the world.

Unit IIIE. Web-app Resources:

>Climate Change Impact

>>Agriculture

>>>**NOAA Drought Monitor** (Animated Maps)

>>Forests

>>>**Increase in Wildfires** (slideshow)

>>>**Global Deforestation** (slideshow)

>>>**Forest Pests** (Associated Press Video)

>>>**Projected Shifts in Forest Types** (slideshow)

>>>**Forests: Lungs of the Planet** (NASA Visualization)

III.F: Impacts on Wildlife

Key Concepts and Web-app Resources:

Animals have a key advantage over forests when it comes to a changing planet: they can move! Around the globe, on land and in the oceans, animal species have been shifting their ranges towards the poles an average rate of 10.5 miles per decade. Still, diminished food and water availability as well as habitat loss (caused by forest fire, pests, and invasives) due to climate change put immense environmental pressure on animal life. When change happens slowly, more species of plants and animals have to migrate or adapt. Accelerated climate change is making that difficult. When population numbers decline rapidly, ecologists at the U.S. Fish and Wildlife Service can place a species on a federal list of “threatened or endangered wildlife” for protection. According the USFWS, protective measures include “restrictions on taking, transporting, or selling a species; authority for us to develop and carry out recovery plans; authority to purchase important habitat; and Federal aid to State and Commonwealth wildlife agencies that have cooperative agreements with us.” While this has helped to prevent extinction in many keystone species, it may not be enough to prevent regional ecological collapse in a rapidly changing environment.

Use the web app resources below to explore the different ways wildlife is responding to increasing environmental pressures from climate change.

Unit IIIF. Web-app Resources:

>Climate Change Impact

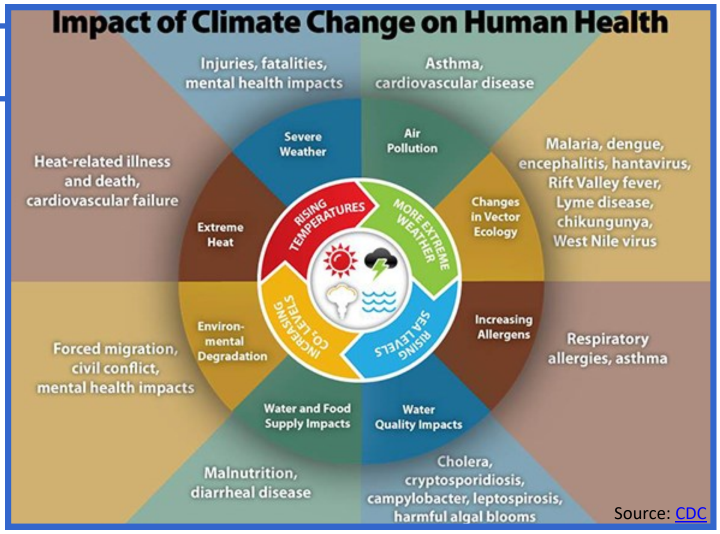
>>Wildlife

>>>A Warmer World for Arctic Animals

>>>Species Ranges Map

>>>Bees are Feeling the Sting of Climate Change

III.G: Human Health and Disease



Source: CDC

Key Concepts and Web-app Resources:

Climate change impacts human health and wellness in myriad ways. For instance, some areas that are more prone to natural disasters could see an increase in physical injury, while others that are vulnerable to high heat or poor air quality, such as our urban areas, could see a spike in respiratory or cardiovascular issues. Certainly, around the world, the strain of climate change on our environment, industry, freshwater and food availability, and stress levels contributes to mental health issues. Public health officials use information about regional vulnerabilities, vector species populations, and nutritional health to create proactive prevention and response plans. Such plans can mitigate the human losses due to disease and minimize their spread.

Understanding the transmission of pathogens to humans is crucial in disease prevention. This requires not only medical professionals, but also city planners, resource management officials, and biologists. That is because many diseases are spread through vector species or contaminated water. Climate change impacts on the water cycle and temperature affects the reproduction rates of both the vector species and the virus/bacteria they transmit. A **vector species** is any organism that can carry and transmit infectious pathogens from one organism to the next. Mosquitoes breed in stagnant waters, often left behind from flooding rains. More flood events mean more places for mosquitoes to lay eggs, leading to an increase in mosquito population. Warmer temperatures also allows mosquitoes and other vector species ranges to expand, as well as the number of reproductive cycles possible in a year. Each spring, newly hatched ticks look for a new host to feed from. They jump from host to host throughout their life-cycle. Shorter winters and warmer springs aid in earlier hatching and more time for reproductive cycles between winters. In recent years, the incidence of West-Nile and Lyme disease in the U.S. has gone up dramatically.

Use the web app resources below and the student worksheets to explore how climate change and extreme weather is already impacting human health and the spread of disease from one region to the next.

Unit IIIG. Web-app Resources:

>Climate Change Impact

>>Human Health and Disease

>>>Climate Change & Human Health

>>>Pathways and Regional Vulnerabilities

>>>Extreme Heat Waves

>>>Climate Change and Air Quality Mapping Tool

>>>Water Contamination

Name:________________________ III.G—Human Health and Disease—Student Worksheet

Use the climate web-app to navigate from the homepage to:

Climate Change Impact>>Human Health and Disease>>Climate Change & Human Health and look at the image.

1) Starting in the center circle, choose a pathway and follow it outward. Each step is part of a pathway that a changing climate affects human health and wellness. Choose two to document below, drawing arrows from one step to the next.

a:____

____

b. ____

____

2) Next, navigate to: Climate Change Impact>>Human Health and Disease>>Regional Vulnerabilities and look at the map. Why do health concerns from climate change vary from region to region?

____

____

3) Using the images to the right, give two reasons why climate change may contribute to the spread of disease. Hint: It has to do with the proliferation of vector species (like mosquitos and ticks).

a) ______________________________________

____

____

____

____

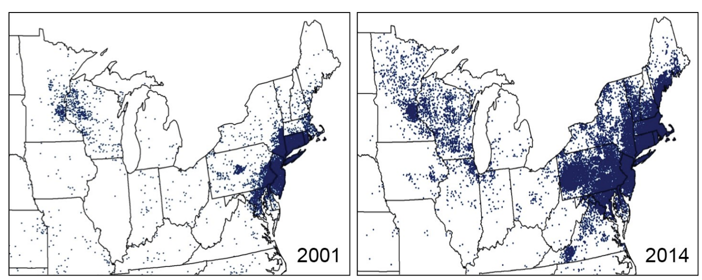
____

____

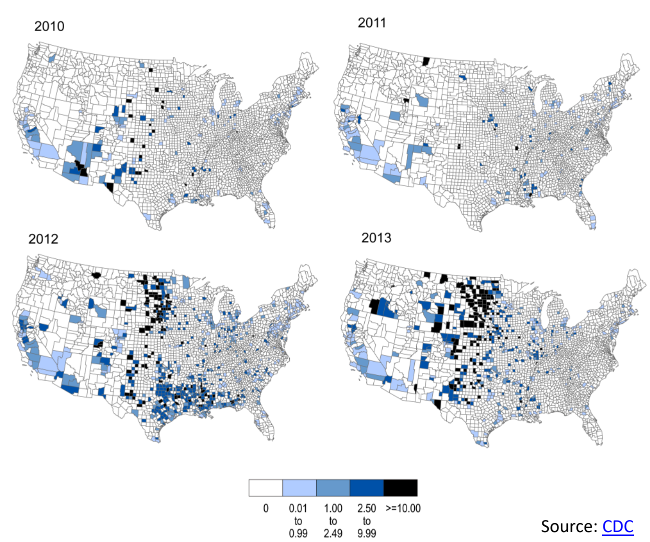
____

____

Changes in Lyme Disease Case Report Distribution



Incidence of West Nile Neuroinvasive Disease in the United States



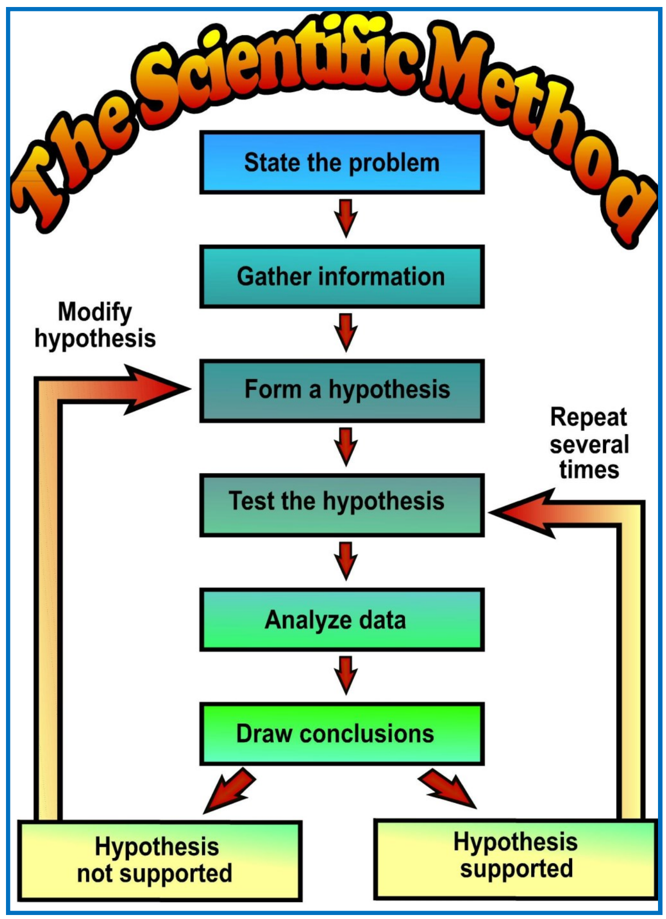
Source: CDC

MITIGATION

Unit IV: How can we reduce our carbon footprint and reverse climate change?

According to the Intercontinental Panel on Climate Change (IPCC—established in 1988), there has been a consensus among scientists for at least the past two decades that the primary factor for observed climate change today is human activity. In their 2001 assessment, the panel stated, "Human activities … are modifying the concentration of atmospheric constituents … that absorb or scatter radiant energy. Most of the observed warming over the last 50 years is likely to have been due to the increase in greenhouse gas concentrations." Today, over 97% of published scientists and institutes—including 13 U.S. government agencies and nearly 200 worldwide scientific organizations—agree that we are experiencing anthropogenic warming due to our carbon emissions. This, of course, was not always the case. Even among climatologists, there was skepticism that such a vast and complex system as Earth's climate could be altered by humans. This is partly due to that very complexity and partly due to the iterative nature of the **scientific method**. Skepticism is a cornerstone of the process!

The scientific method is a defined series of steps to investigate a question or solve a problem. An **observation** gives rise to a question. The investigator researches the question until they can make an educated **hypothesis** about the nature or mechanisms driving the observed phenomenon. An **experiment** is constructed to control variables (or "controls") and test a limited scope of dependent variables to determine their effect. The results of the experiment are **analyzed** and a **conclusion** will either support the hypothesis or reject it. Either way, uncertainty in the controls and variables is used to reconfigure the experiment and retest the original hypothesis or a new one. The scientific community is encouraged by the principles of the scientific method to look to falsify the hypothesis in **peer review**—that is, they try to scrutinize the experimental procedure and the analysis to look for issues in the original experiment that might cause ambiguity in the conclusions. The experiment should be repeatable, and often in retesting (either by the original investigator or their peers), the procedure is refined and improved to limit uncertainty. Over time, the retested hypothesis will gain strength only if it has it has some level of veracity. The fact that 97% of scientists from around the world are in consensus that we are causing the current warming with carbon emissions is substantial, and should not be dismissed.



Source: tes.com

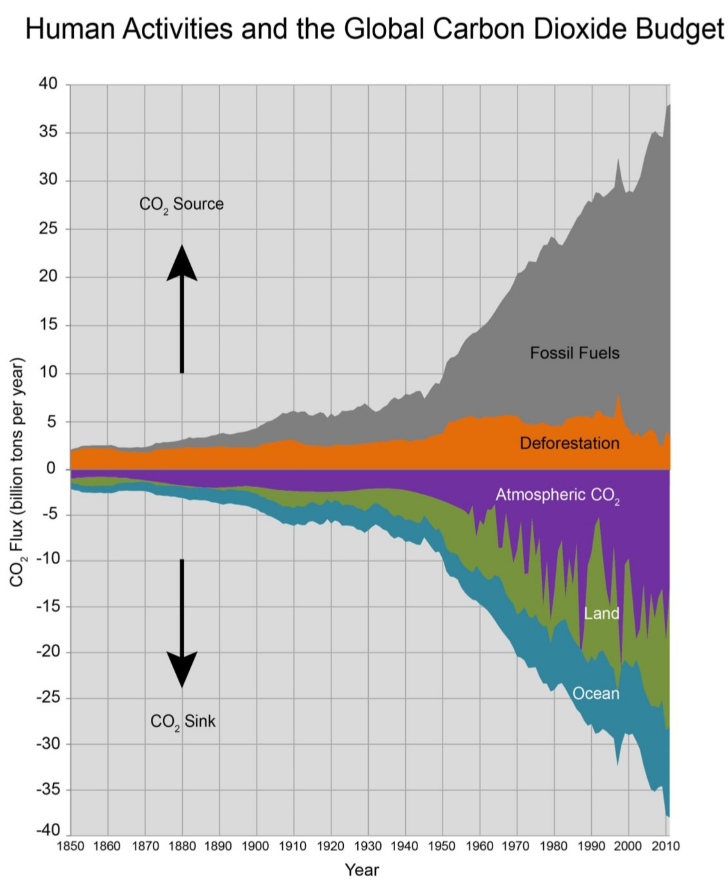
So if human activity is at the root of the problem, and the consequences are global in scope and dire in significance, what can be done? The answer is more hopeful than it might seem. In just over 50 years, human innovation has put satellites into orbit and rovers onto the surface of Mars. We have developed ways to reduce our

Unit IV: Introduction Page 2/2

carbon emissions through practical photovoltaics (solar panels), rechargeable batteries, and electric cars, as well as ways to sequester carbon emissions through geological carbon capture and storage (CCS) technologies. What is needed, now, is a *consensus of global citizens* from all sectors—agriculture, manufacturing, energy, transportation, science, public service, government, and education— that we *can and will* reduce our carbon footprint worldwide.

As highlighted in the last unit, we now know that even small increases in global air and ocean temperatures have had widespread implications for coastlines, marine habitat, storm intensity, freshwater resources, food production, forest cover, species ranges, and human health. Scientists warn that we must **limit** global warming to 2°C (3.6°F) above pre-industrial temperatures or face catastrophic and potentially irreversible consequences. According to NOAA, researchers predict that this would mean limiting our atmospheric carbon dioxide to 450 parts per million (ppm). We first exceeded 400 ppm in 2014 and the trend is still upwards, so there is work to be done! In **Unit IV: Mitigation**, we will explore what is being done on a global scale to curb emissions and ultimately prevent global warming from reaching the 2°C threshold, as well as what individuals can do at a local level to reduce energy demands.

Mitigation involves both *reducing* emissions and *enhancing* **carbon sinks** to remove CO_2 from the atmosphere. Carbon dioxide has a long lifespan in the atmosphere, so the CO_2 we emit today could have impacts for decades to come. As population increases, so does our total energy demand. That is why energy **efficiency** and **conservation** is critical to curbing future emissions. Even so, the true effect of past greenhouse gases will still be felt for years to come, due to the [thermal inertia of the oceans] (water's high specific heat value means it takes longer for its temperature to increase in response to an increase in heat energy). Therefore, it is essential that we enhance carbon sinks and create a resiliency plan for the future. Often, mitigation and adaptation strategies overlap. In the next unit, we will dive deeper into identifying and managing climate change risks.



From the 2014 National Climate Assessment

In partnership with:

IV.A: A Global Effort: The Paris Agreement

Key Concepts and Web-app Resources:

Climate change is a global crisis and therefore requires a global effort to remedy. However, industrialized countries, like the United States, are responsible for far greater emissions per capita than developing countries. The wealthiest countries represent only 20% of the world's population, but account for over 70% of cumulative CO_2 emissions since the Industrial Revolution. Still, if densely populated countries like India and China (each with populations over 1 billion people) continue to rapidly industrialize, they will quickly dwarf U.S. in future emissions. This very debate has stalled international negotiations on mitigating climate change for decades.

In 1992, the UN Earth Summit in Rio, Brazil adopted the United Nations Framework Convention on Climate Change (UNFCCC). With nearly global membership, it helped to create more dialogue between nations about monitoring and reducing human impact on the climate system. In 1997, UNFCCC parties met again in Kyoto, Japan to map out the first legally binding global treaty to curb carbon emissions. Though 150 nations were represented, it mandated the U.S. and European Union to cut emissions to 5% below 1990 levels in the next 15 years, while exempting China and India, and asked merely for voluntary commitment by other developing countries. Ultimately, despite thirty six developed nations succeeding in the 5% reduction goal, the United States failed to ever ratify the Kyoto Protocol and Canada withdrew from the agreement. Meanwhile, China and India doubled their greenhouse gases released in the past 20 years, pushing atmospheric CO_2 past 400 parts per million, a threshold scientists warned against.

In the period since the UNFCCC was first established in the early 1990's, the impact of the global warming on Earth's oceans, weather system, and living things has become hard to ignore. Guided by the recommendations of the 2014 report made by the International Panel on Climate Change (IPCC), the world came together in 2015 to sign a bold new treaty, committing all of its signers to specific actions (or "nationally determined contributions") to prevent a 2°C rise in global average temperature, with regular reporting on carbon mitigation. Furthermore, the "Paris Agreement" obligates wealthy nations to provide financial support to developing countries to create cleaner energy technology as well as to vulnerable countries to improve resiliency efforts. Though critics believe the Paris Agreement falls short of necessary goals, it is remarkable in being the first international treaty of the sort to receive *unanimous* support. By December 2017, every country in the world had signed the Agreement. (Though the Trump Administration has stated the U.S. intends to withdraw from the agreement, it cannot legally do so until Nov. 2019, 2 years after its ratification.)

Unit IVA. Web-app Resources:

>Adaptation and Resiliency

>>The Global Effort

>>>The Benefits of Global Action (EPA Video)

>>>Paris Agreement Interactive (CAIT Climate Data Explorer)

>>>Meeting World Energy Lab (The Habitable Planet)

IV.B: Your Carbon Footprint

What Is A Carbon Footprint?

A **carbon footprint** is a measure of the impact our activities have on the environment, and in particular climate change. It relates to the amount of greenhouse gases produced in our day-to-day lives through burning fossil fuels for electricity, heating and transportation etc.

Key Concepts and Web-app Resources:

Everything we purchase, use, eat, throw away, or transport can be associated with an ecological footprint—that is the amount of land required to sustain each actions use of natural resources. While a large factory, company, or power plant may utilize far more natural resources and put out far more pollution than the average person, as consumers of those goods, we are responsible for our own piece of the pie. When it comes to stemming climate change, we can attribute the size of our individual piece based on our energy **efficiency**, our energy/resource use or **conservation**, and our **lifestyle**. For instance, a newer car may have better fuel efficiency, a larger home likely costs more to heat, and a vegetarian diet requires fewer natural resources to support. Together, these choices make up a person's **carbon footprint**—a quantifiable estimate of the *number of tons of carbon dioxide per year* emitted as a result of that person's unique day to day life choices.

According to the World Bank, the average human on Earth has a carbon footprint of 5.4 tons (4.9 metric tonnes) of CO_2/year. Compare that to the United States, where the average American has a footprint of approximately 18 tons (16.4 metric tonnes) of CO_2/year! Americans live in larger homes, drive larger, gas-guzzling vehicles, and consume more meat than people in any other country in the world! Clearly, our carbon footprint matters—and it matters *more*. Small lifestyle changes and a few home investments can save a lot of energy and therefore carbon.

Many carbon footprint calculators exist online to help you begin to audit your individual or home energy consumption. A little research and math may be necessary, but once the work is done, you can determine which areas of your life could stand to improve in sustainability the most. Generally, you can think of lowering your carbon footprint in three categories: improve **efficiency** (work smarter, not harder!), increase **conservation** efforts (waste not, want not), and simplify your **lifestyle** needs (go green). To improve energy efficiency in your home, add insulation to your home ceiling, walls, and floors, weatherize your windows and doors, switch to a car with better gas mileage (like a hybrid), replace lightbulbs, appliances, and utilities with Energy-Star rated ones, and make sure the refrigerator has a strong seal and clean coils. To save energy through conservation efforts, try using public transportation or carpooling, turn off lights and unplug electronics when they aren't in use, reduce—reuse—recycle to create less waste, and get a programmable thermostat and set it to be 2°-10°F cooler. In the winter and warmer in the summer when you aren't home. Finally, shifting larger lifestyle choices can require some bigger commitments, but can really shrink your footprint considerably. Some greener lifestyle choices include reducing meat consumption, shopping for local goods, buying second-hand, walking/biking more, and composting food waste.

Unit IVB. Web-app Resources:

>Adaptation and Resiliency

>>Thinking Globally, Acting Locally

>>>Carbon Mitigation

>>>>Your Carbon Footprint Calculator

IV.C: Thinking Globally, Acting Locally

Key Concepts and Web-app Resources:

Climate change, though global in its impact, will mean different things for different populations around the planet. Some areas may experience extensive drought, while others may experience more heavy rain events. Each population must adapt to their specific regional concerns. Similarly, carbon mitigation strategies can differ depending on the needs, resources, and share of the responsibility of each community. The key is to think globally and act locally. Community organizations and local governments of highly populated cities and states can have a collective impact that rivals smaller nations. Even large corporations can have tremendous reach in coordinated efforts to lower their carbon footprint. By adopting the **Paris Agreement** at a city-level, 407 U.S. mayors could help the U.S. meet its climate mitigation goals even if the U.S. withdraws at a national level.

For some communities, states, or countries, enhancing their forest cover to sequester more carbon may be the most effective effort. For others, creating better emission standards might make more sense. Developing areas could try to build more sustainably with renewable energy sources, recycled materials, and energy efficient designs. Rural areas could improve land use thereby preventing the need for more deforestation whilst retaining healthy soils that can hold more carbon. As the productivity of farmland increases and more people move into urban environments, suburban and rural zones can also encourage *reforestation*.

Human population is still growing exponentially, so our dependence on fossil fuels is unlikely to disappear overnight. Each community can and should reconsider its power-grid and create plans to divest from coal and oil, looking toward clean, renewable energy sources like solar, wind, geothermal, hydro, and tidal power more and more. These technologies have improved significantly in the past few decades and have become much more affordable. Using a mapping tool like the NREL Renewable Energy Atlas, we can not only track national *progress*, but see untapped *potential* for energy grid changes. Another helpful resource, the U.S. Climate Resilience Toolkit was developed by NOAA to help determine your city’s risks and readiness in addressing climate change. One of the tools is the Climate Explorer app which can chart or map your local climate observations as well as climate predictions in a higher or lower emission scenario. By linking mitigation and adaptation directly to *your* hometown or region, you begin to think about personal connections to climate change and you become more involved.

Unit IVC. Web-app Resources:

>Adaptation and Resiliency

>>Thinking Globally, Acting Locally

>>>Carbon Mitigation

>>>>Reforestation for Carbon Sequestration

>>>Tracking National Progress

>>>>National Renewable Energy Sources (NREL RE Atlas)

>>>NOAA Resilience Toolkit: Climate Explorer

In partnership with:

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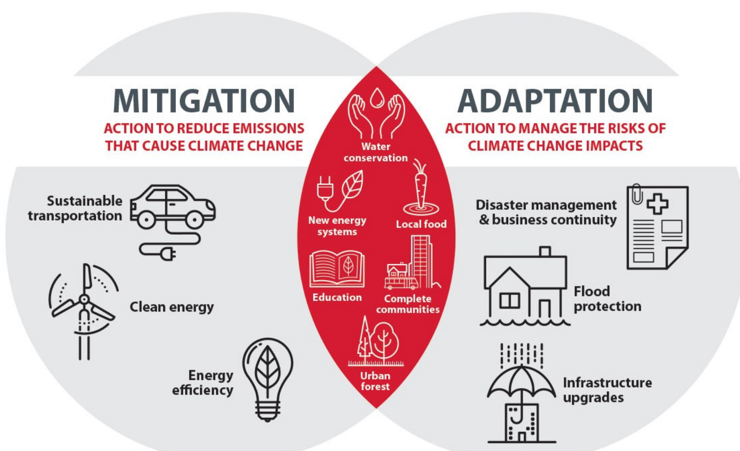
ADAPTATION & RESILIENCY

Unit V: How can humans adapt to climate change in an equitable way?

Our planet is already experiencing the impacts of accelerated climate change, and will continue to for some time even after we begin our best mitigation efforts. Though we may each experience climate change differently, every person, community, state, and country must assess local risks and vulnerabilities and adapt to projected impacts. We live in an interdependent world, however, so it serves our own best interests to help protect the infrastructure and resources of other populations around the globe as well. There is also a moral imperative to do so. Often the populations that are *least* responsible for our current level of heat-trapping greenhouse gases are the ones most affected. Small, island nations are being swallowed up by rising seas, impoverished populations are seeing their homes and farms devastated by more powerful storms, indigenous peoples are losing access to traditional foods and homelands due to habitat loss and species range changes, and the very young, elderly, and sick are most vulnerable to resulting air pollution and heatwaves.

In this unit, we will examine myriad adaptation responses to the types of climate change impacts described in Unit III. Sometimes, adaptation planning can coincide with carbon mitigation efforts, as it does when we plant more trees. Where mitigation and adaptation meet can be called resilience. **Resilience** is defined as the ability to withstand or bounce back from challenging conditions or disturbances to our natural and built environment. The ultimate goal is to build a more resilient and sustainable world. Urban spaces may have to respond to challenges that are dissimilar to rural environments and will have to react accordingly, just as the marine organisms will adapt differently to climate change than land-dwellers.

Building Climate Resilience



Source: Official website of the City of Calgary, Alberta, Canada

While some strategies can be developed and adopted across the globe, others will need tailoring to hyper-local circumstances. For instance, Yonkers has a built waterfront along the tidal estuary portion of the Hudson River. Rising sea-levels combined with storm surge events, like Hurricane Sandy, make the developing waterfront vulnerable to coastal flooding, while heavy rain events cause frequent flooding on the highways and erosion along the smaller Saw Mill and Bronx Rivers. To address these and projected issues, Groundwork Hudson Valley has worked with partners such as the New York Department of Environmental Conservation and the City of Yonkers to (1) plant native willows

Unit V: Adaptation and Resilience—continued

along the Saw Mill River while removing invasive species to stabilize the shoreline and alleviate flooding on roadways; (2) develop a “Greenway” path along an abandoned train line to promote more biking and walking, thus reducing traffic and vehicle emissions; (3) promote local agricultural production through the Science Barge hydroponic farm and community gardens; and (4) reduce or eliminate combined sewage overflow from flooding/surge events by “daylighting” buried portions of Saw Mill River, diverting excess storm water into the old culverts, and installing **bioswales** in the adjacent parks. There is still more work to be done, but it is a good start.

Source: Groundwork Hudson Valley

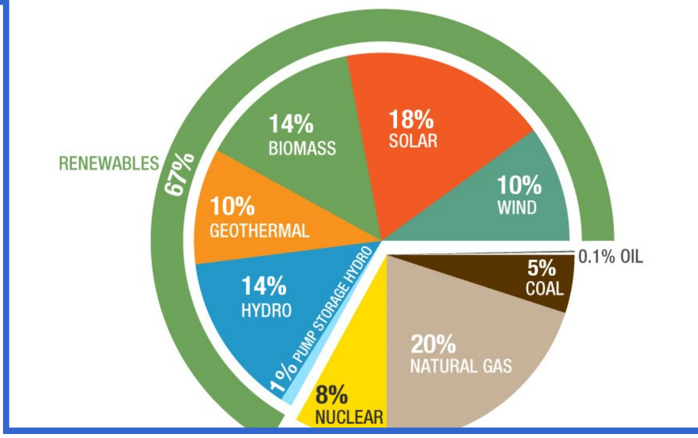
Generally, our most vital areas of focus are: infrastructure, coasts, food systems, emergency preparedness and crisis response, local energy backups, water and natural resource management, and public health.   Woven through all of these is the need for information. Only through research, reporting, and public education can communities gain true resilience. Climate education can save lives, too. The more knowledgeable citizens are about their individual risks, the better they can prepare and respond during disasters. Local and federal governments can also use data to predict, prepare for, and respond to climate change related hazards more efficiently.

> “Statistics on the occurrence of these extreme events and the people and infrastructure at risk are essential for disaster risk management and saving lives. When an extreme event results in a significant disruption of the functioning of society we call it a disaster. What kind of information is vital to save lives when a disaster strikes?
>
> At first glance, the first questions that come to mind are: How many people are affected? How many are at risk? How many impaired or elderly live there? What relief means are available or can be rapidly mobilized? Immediate action is required and being efficient relies on accurate, up-to-date, ready-to-be-used information.
>
> After facing the first impact, new challenges need to be evaluated: Will the food, water and electricity production and supply be affected? How many houses or roads need to be reconstructed? What are the social and economic impacts?” —UN Economic Commission for Europe

The National Oceanic and Atmospheric Administration (NOAA) is committed to not only gathering useful climate change and impact data, but also disseminating it to create a more resilient public. They have compiled a list of information and education resources (some by NOAA and others external) to better inform communities at all levels. You can find it here: https://www.noaa.gov/office-education/elp/resilience-assets.

V.A: Global: Energy, Food, and Water

Shift to renewable energy by 2050 as proposed by the Institute for Sustainable Energy Policies



Key Concepts and Web-app Resources:

Resilience for the future of humanity hinges on the management of energy, food, and water. We learned in **UNIT III: Climate Change Impact** how each would be affected as the planet continues to warm in the coming decades. Practice budgeting for these key resources while accounting for fringe expenses or increased demand after disasters like heat, drought, and flood-contamination will help us meet our needs and save resources for a more sustainable future. Cutting out fossil fuel production tomorrow is not an option, given increasing energy demand around the world, as well as oil’s use in plastic production and coal’s role in steel production. However, if we budget for immediate-but-gradual shifts to clean energy technology, while improving efficiency and conservation efforts, we can meet or surpass our carbon mitigation commitments to the Paris Agreement worldwide. By using the web-app resources listed below, especially the **Meeting World Energy Lab** (also found here: http://www.learner.org/courses/envsci/interactives/energy/energy.html), **Climate Smart Agriculture** video (also found here: https://youtu.be/lUdNMsVDIZ0), and **Be Water Wise** images (right click to save or print), you can foster meaningful dialogue with students about practical solutions.

> *“We have to understand the ubiquity of energy in everything we do. Energy is core to our economy and it brings with it environmental challenges, and it’s core to our security challenges.”*
>
> - Ernest Moniz, former secretary of the US Department of Energy

Unit VA. Web-app Resources:

>Adaptation and Resiliency

>>The Global Effort

>>>Benefits of Global Action (EPA Video)

>>>Climate Smart Agriculture

>>>Breeding Resilience Into our Forests (American Chestnut Foundation)

>>>Meeting World Energy Lab (by The Habitable Planet)

>>>Our Future Starts NOW (UN Markers on Sustainable Development)

>>Think Globally, Act Locally

>>>Be Water Wise

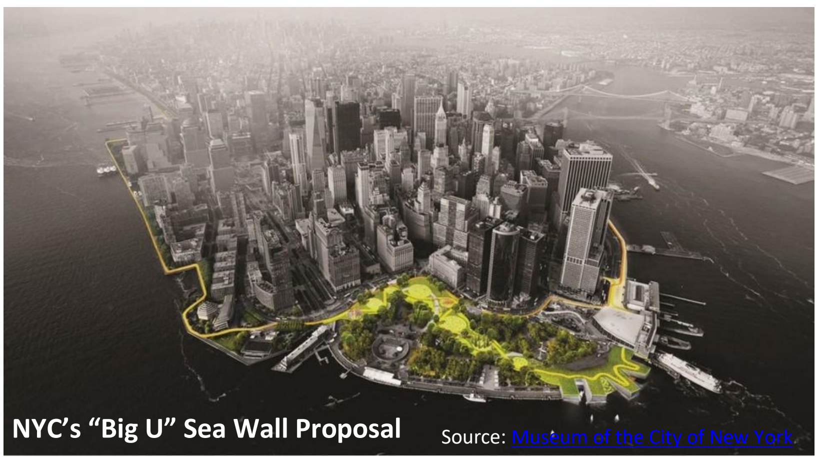
GROUNDWORK Hudson Valley — CHANGING PLACES CHANGING LIVES

In partnership with: NOAA; SARAH LAWRENCE COLLEGE CENTER FOR THE URBAN RIVER AT BECZAK

V.B: Coastal Communities: Rising Above the Tide

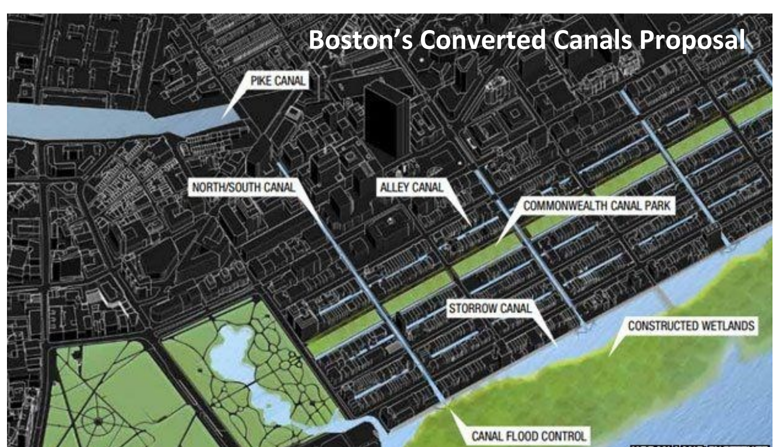
Key Concepts and Web-app Resources:

The coastlines of our oceans and rivers have connected us since the very beginnings of civilization. Floodplains around rivers contained fertile soils and rafting heavy building stones and logs for buildings, forts, and monuments did not require advanced technology. The oceans and estuaries provided an abundant food source. As settlements sprung up around the world, our waterways served as the backbone for trade routes and emigration. Today, over 40% of the world's population live within 60 miles from the ocean, according to the UN, and 75% of "**megacities**" like Singapore, Tokyo, Delhi, Lagos, New York, and Los Angeles are located on a coastline. Furthermore, those percentages are still increasing. NOAA reported that by 2020, roughly *half* of Americans will be living along the coasts. Coastlines have always been dynamic environments, offering as many challenges as they do benefits. The rising tides of climate change only serve to exacerbate this. The primary concerns are storm surge, erosion, saltwater encroachment [of freshwater aquifers], and degrading fisheries, but cities with little elevation gain above sea level are at even greater and more immediate risk.



NYC's "Big U" Sea Wall Proposal Source: Museum of the City of New York

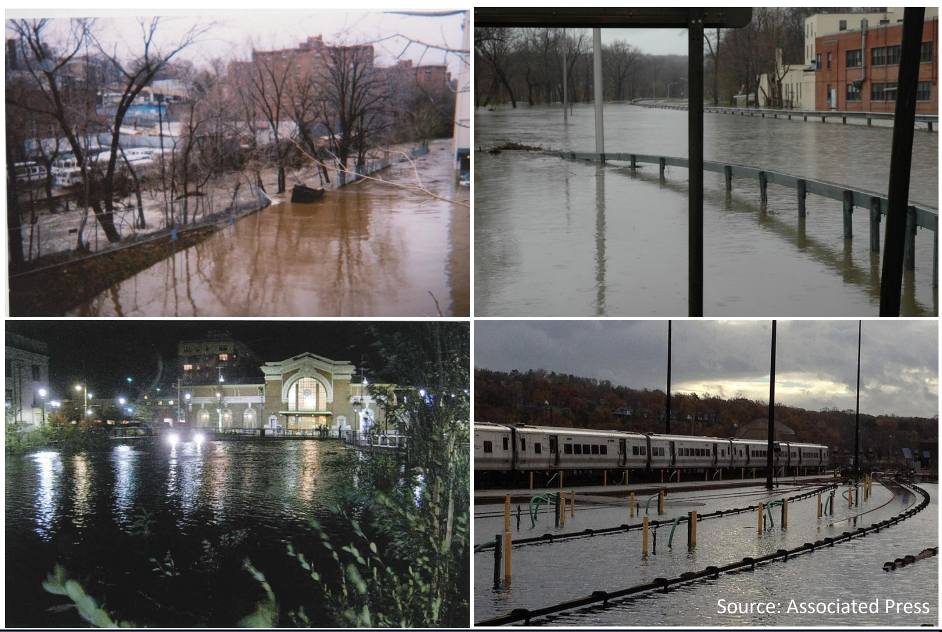
The densely populated coastal cities of Miami, Boston, and New York City are racing against time to strategize how best to confront both the imminent and future impacts of rising sea levels and more powerful storms. From water pumps to sea walls, adaptation plans vary depending on the needs and financial resources of each municipality. Often projects that combine efforts to restore and enhance natural buffers while also building new barriers and levees is deemed the best approach—provided public will, capital, and other necessary resources exist to support it! In Miami, where sunny-day flooding during high tide has become an increasingly common phenomenon, mangroves, reefs and wetlands are getting new protections, while engineers work on raising roads, utilities, and installing new pumps to return rising tidewater back to the bay. For New York City—devastated by $19 billion dollars worth of damages by 2012's Hurricane Sandy— $335 million dollars has been allocated to develop plans for a barrier wall and park space to stem future flooding in the "big U" of lower Manhattan. The project, if completed, will cost over $1 billion dollars. In Boston, the city was built on a marsh at the mouth of the Charles River and is therefore *doubly* vulnerable to flooding from increased precipitation *and* sea level rise. One of their most recent proposals to confront the issue is to accommodate rising waters by converting low-lying roads into canals, essentially turning Boston into the "Venice of New England."



Boston's Converted Canals Proposal

V.B: Coastal Communities: Rising Above the Tide page 2/2

In Yonkers, New York, there are *storm surge* risks from the Hudson River Estuary as well as *stormwater overflow* risks from the Saw Mill and Bronx Rivers. During Hurricane Sandy, the Yonkers' waterfront was flooded by a six foot surge, including the Metro North train station that brings thousands of commuters into the city, the public library, a school bus depot, riverside apartment buildings, some manufacturing plants, and the wastewater treatment plant. The damages to the wastewater system alone topped $14 million. The small portion of the waterfront adjacent to the wastewater plant was buffered by a natural tidal marsh ecosystem. The Center for the Urban River at Beczak (CURB) building was not flooded because the greenspace around it acted like a sponge, absorbing the rising Hudson. Future projections of sea level will raise the baseline height of the Hudson tidal estuary to the Hurricane Sandy storm surge level—6 ft higher by the year 2100. Raising sea walls in the Yonkers' waterfront may not be sufficient for future storm events. More wetland areas like the marsh by CURB may be warranted, with added benefits to the river's water quality and its fisheries.



Top left of page: Yonkers Water Treatment Plant (Associated Press)
Right, going clockwise: Flooding by the Bronx River (); flooded highways bordering the Saw Mill River (), along the Metro North Hudson line south of Yonkers (Associated Press), and at Yonkers Station where the Saw Mill meets the Hudson river (Donna Davis)

Unit 1A. Web-app Resources:

>Adaptation and Resilience

>>Coastal Resilience

>>>**Estuary Model & Coastal Resilience** (SLC CURB Video)

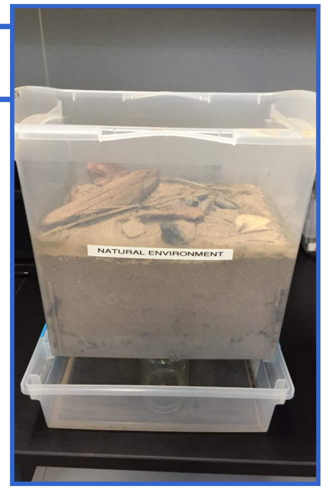
>>>**Coastal Resilience** (The Nature Conservancy Video)

>>>**NOAA Digital Coast Mapping Tool**

GROUNDWORK Hudson Valley — CHANGING PLACES CHANGING LIVES

In partnership with: NOAA — SARAH LAWRENCE COLLEGE CENTER FOR THE URBAN RIVER AT BECZAK

V.B: Coastal Communities— Storm Surge



Lesson: How will climate change affect the built environments on our coasts?

Subject / grade level: 9-12th grade, Environmental science

Materials:

- Internet access and computers for the online mappers
- For marsh/built environment demo:
  - Two plastic bins with holes drilled into the bottom to let water out, two more bins to let water drip into, wooden blocks or wide jars to hold up the models
    - For marsh environment: collect sand, rocks, dried grasses, seashells, etc. and pile up into bin
    - For built environment: collect larger rocks, Lego or other houses, toy cars, etc.

NGSS Standards

HS-ESS3-5. Analyze geoscience data and the results from global climate models to make an evidence-based forecast of the current rate of global or regional climate change and associated future impacts to Earth's systems.
ESS2.D: Weather and Climate
ESS3.C: Human Impacts on Earth Systems
ESS3.D: Global Climate Change

Lesson objective(s): Students will understand how climate change impacts their coastal surroundings, and evaluate ideas for combating these detrimental effects using physical investigation and mapping models.

ENGAGEMENT

- Ask students if they remember any major recent storms (Superstorm Sandy, Hurricane Irene, the blizzard on Halloween, Hurricanes in Texas, Florida, or Puerto Rico from 2017). What effect did these storms have on their houses or communities? Did they lose power? Could they go trick-or-treating? Were their family members in other states or cities affected? Did their houses or cars get damaged?
- What impact will a changing climate have on storm intensity and frequency?
- What other impact will climate change have on our oceans and coastal areas around the world?

EXPLORATION

Why was Superstorm Sandy so devastating to the coastal community? There wasn't actually that much rain, yet flooding was a huge issue throughout the lower Hudson. What is storm surge?

Web-app Resources:
Climate Change Impacts
>Oceans and Coasts>
Storm Surge Video

- Storm surges tear up shorelines, redistribute sand, and remove sediment and mud from the local ecosystem.
- Strong winds drive storm surges and crashing waves into land, damaging habitats.
- Floods alter salinity levels, cause higher tides, and redistribute organisms.
- Erosion of shorelines and sediment displacement due to wave action and stronger currents.

V.B: Coastal Communities— Storm Surge (page 2)

EXPLANATION

- How far does storm surge (and sea level rise) actually travel up the coast? What does a 6 foot storm surge actually mean? (6 feet is also the worst-case scenario prediction for sea level rise in Yonkers by the year 2100)
- If you have access to a coastal park or beach (must be a soft shoreline, not a pier or bulkhead), teachers can take students to explore the area and find out just how far the water would move up the land in their community with this extension lesson/activity: http://www.seagrant.sunysb.edu/hriver/pdfs/climatechange/HRCC_Lesson9.pdf
- If no coastal access, have students explore on the Internet. In the Hudson Valley, use this website: http://www.scenichudson.org/slr/mapper
  - If anywhere else in the country, use NOAA's website: https://coast.noaa.gov/digitalcoast/tools/slr.html
- Students can increase the amount of sea level rise and watch how it will increase flooding in their local community.
- Have students fill out worksheet attached at the end of this lesson plan.

ELABORATION

Ask students what we can do to prevent the devastating impact of sea level rise and storm surge from more frequent extreme weather. If we can't stem the tide of climate change, what might we be able to do on our coasts?

Web-app Resources:

>Adaptation and Resiliency

>>Coastal Resilience

>>>Estuary Model & Coastal Resilience (SLC CURB Video)

>Adaptation and Resiliency

>>Coastal Resilience

>>>NOAA Digital Coast Mapping Tool

- If they don't offer, introduce marshes and wetlands:
  - Vital role in regulating water quality and chemistry
  - Removing pollutants
  - Sequestering carbon
  - Oxygenating the water
  - Storm surge buffers and flood control
  - Dissipating wave energy
  - Increasing the resilience of the uplands and waterfront communities

- Either set up built environment/wetland environment models beforehand, or have students create their own as an extension activity. Ask students which they think will absorb more water, and if/how that would help their local environment.
  - Have students pour water through their models and evaluate the results on worksheet.
- Now, have students explore real-world wetland models to see how they will be affected by sea level rise in the Hudson Valley: https://scenichudson.maps.arcgis.com/apps/MapSeries/index.html?appid=9190b7560a574ad69cd91b43e383b203

V.C: Local—Emergency Preparedness

Key Concepts and Web-app Resources:

According to the Red Cross, the frequency of reported weather-related disasters has doubled in the past two decades. Though proactive national and city adaptation strategies can broadly safeguard citizens from flooding, wildfire, heat waves, intense storms, and other natural disasters, they cannot usually protect *every* household. When disaster strikes, *individual readiness* is the only way to ensure your personal protection. Disaster preparedness includes the activities and measures taken in advance to effectively respond to the impact of hazards, such as the construction of early warning systems or building a 72-hour emergency kit. This can also include the planning of a possible evacuation of people and property from threatened locations. Individual readiness means being educated about risks, having provisions and a plan, and acting accordingly to the severity and locality of the threat.

NOAA’s “Weather Ready Nation” is a national program that includes brochures, videos, checklists, and other information about weather-related impacts to stay informed and up-to-date on preparedness measures.

Unit VC. Web-app Resources:

>Adaptation and Resiliency

>>Think Globally, Act Locally

>>>Emergency Preparedness

>>>Weather Ready Nation (NOAA Videos)

>>>Simulated Hurricane Video

>>>Make and Emergency Plan & Kit (FEMA video)

>>>Designing Cities for Resilience

>>>The EcoHouse example (Groundwork Hudson Valley video)

>>>NOAA Resilience Toolkit: Climate Explorer

V.C: Local Emergency Preparedness—Classroom Activity

Lesson: Individual Readiness for Weather-Related Emergencies

Source: FEMA

Subject / grade level: 6th-9th grade, all subjects

Materials: Computer lab & Web-app OR Choose your own adventure Book download & Prep tokens; 72-hour Emergency Prep Kit; Checklist and Evacuation Plan worksheets

Lesson objective(s): Students will be able to identify and state the local extreme weather risks (e.g.: flash flood, hurricane or high winds, and heat waves) and individual/home vulnerabilities to address. Students will know what items should be included in every 72-hour emergency prep kit and have a contact list and evacuation plan.

ENGAGEMENT (Discussion based—10 minutes)

- Ask students if they can share an experience they have had in their lives with extreme weather. If they were personally affected, how? Did they ever *feel* in danger? Did they know how to respond if things became critical?
- How would they define “emergency preparedness?” What information is necessary to be prepared in their community? How/where would you obtain that information?
- How does climate change the likelihood of extreme weather events? Which extreme weather events do they think their community or home is most vulnerable to?

EXPLORATION (20 minutes)

- Using the Web-app, navigate to the NOAA Climate Explorer:
  >Adaptation and Resiliency>>Think Globally, Act Locally>>>NOAA Resiliece Toolkit: Climate Explorer
  (also found here: https://crt-climate-explorer.nemac.org/)
  - Note: Teacher’s should have some experience with this site ahead of the class as familiarity with the tools will ease their use in the classroom.
  - Enter in your zip code at the top to generate temperature and precipitation data and maps closest to your hometown.
  - Starting with **temperature**, look at the risk of extreme heat and heat waves. First, open **“Average Daily Max Temperatures (°F),”** and select “**Monthly**.” Use the red button below the chart to select the “**30-Years Centered in 2050.**” You can choose either a lower or higher emission scenario.
    - How does the average temperatures for July change for your hometown in the future? What might this mean for your hometown’s vulnerability to extreme heat events?
    - You can also map this out by clicking “**Maps”** on the right. The curtain tool allows you to toggle between historical data and whichever decade you select on the time slider at the bottom.
    - Optional: Next, choose the “**Days with Max > 90°F**” option and compare the current number with the year 2020, 2030, 2040…
    - Ask students, how do they cope with summer heat waves? How might an increase in days with extreme heat impact their hobbies, vacation plans, homes cooling costs, etc.?

V.C: Local Emergency Preparedness—Classroom Activity (page 2/3)

- Next, scroll down to **Precipitation**, look at the risk of heavy rain events. First, open **“Days with > 1 in.”** Use the blue buttons on the year-slider below to shrink the chart to the years 1985-2065 for better visibility. Be sure to chart **historical** information.

- How has the number of heavy rain events changed in your area over the past few decades, if at all? (Remember, every location could be different). If they have increased, what does this mean for potential flash flood events? Do the same for “**Days with >3 in**.” This represents deluge conditions that are typically uncommon.
- Select the Mapping tool and move the curtain slider back and forth from past records to future projections. Shifts in color represent an increase (or decrease) of heavy rain events as it is mapped out over your city and region.
    - Climate change means that the warmer atmosphere can hold more water. As storm systems cool moving over the land, especially hills and mountains, the potential for much heavier downpours could increase in some areas, whereas neighboring cities may experience drought. An increased likelihood from year to year could spell hazardous road conditions, infrastructure damage, and property loss.
- Finally, in addition to heat waves or flash floods, ask students to identify any other region-specific risks, such as forest fires, hurricanes, tornadoes, heavy snow, etc.

EXPLANATION (20-40 minutes depending on number of modules covered).

- Using the Web-app, navigate to the NOAA Climate Explorer:
  >Adaptation and Resiliency>>Think Globally, Act Locally>>>Emergency Preparedness>>>>Weather Ready Nation Videos
  (also found here: https://www.meted.ucar.edu/emgmt/wxreadynation/launch.htm*)
    - * This interactive teaching module was developed by Raytheon in partnership with NOAA’s Weather Ready Nation program. Getting into the *interactive module* will require setting up an account and logging in. Then, you can select a grade-level and state to get the “required” and “elective” lessons. Each lesson takes about 8-10 minutes to play through.
        - Alternatively, the videos in the lessons can be downloaded and saved to play in the future without a login required.
    - Each scenario will explain what to do BEFORE, DURING, and AFTER the severe weather event, and then test the student’s retention of the information. This is an engaging way to communicate live-saving information. By connecting it to Climate Explorer and other locally relevant climate change impact information, it helps students to think critically about building community and individual resilience.
- Another way to teach this material without computer access is to download our Choose Your Own Misadventure activity, written by Groundwork Hudson Valley to facilitate conversation and critical thinking about hurricane winds, flash floods, and heat waves. The packet works like the choose-your-own-adventure books , requiring the reader to make decisions that will sometimes lead to dire outcomes for their character. This should be used only for audiences

V.C: Local Emergency Preparedness—Classroom Activity (page 3/3)

that are in Middle School and up. The "Choose Your Own Misadventure" activity packet can be found and downloaded at the bottom of this : http://www.groundworkhv.org/climate-change-resilience-learning-module/

- Once the students have finished either activity, they should be able to list three rules to follow BEFORE, DURING, and AFTER a natural disaster to ensure their safety. One such rule is to prepare an evacuation plan or an emergency kit.
- **Optional**:

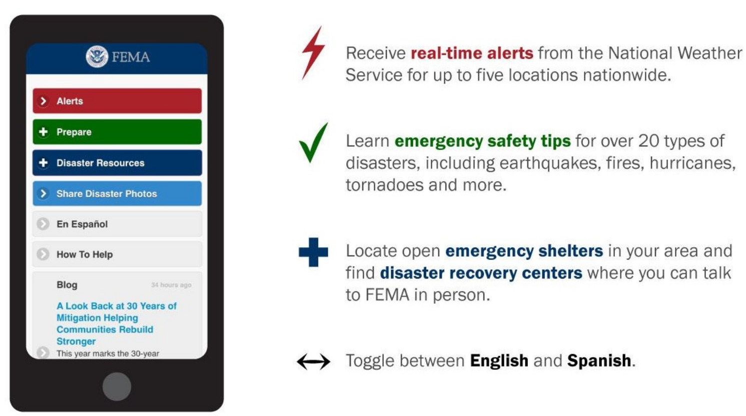
ELABORATION (10-15 minutes plus set-up time)

- Using the Web-app, navigate to the following prep videos:

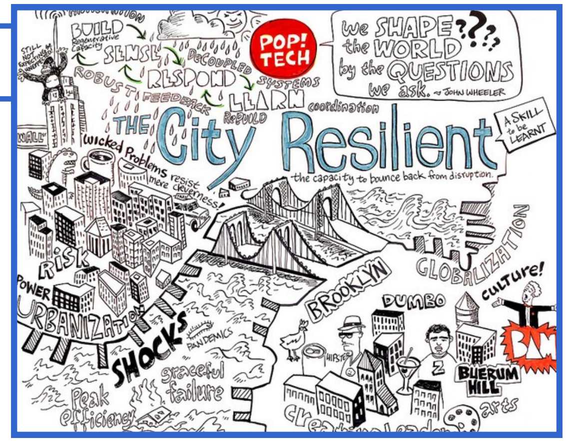
  >Adaptation and Resiliency>>Think Globally, Act Locally>>>Emergency Preparedness>>>>Simulated Hurricane Video
  (also found here: https://youtu.be/WXB1DQzvfxU)

  >Adaptation and Resiliency>>Think Globally, Act Locally>>>Emergency Preparedness>>>>Make an Emergency Plan & Kit (FEMA)
  (also found here: https://youtu.be/LviZ4pZrqu8)

- You can use the Simulated Hurricane Video as an opportunity to have students narrate the increasing intensity of the storm, the hazards that may face at each stage, and what choices the person should have made. For example:
  - **BEFORE**: Secure items outdoors, board up windows, protect vulnerable areas with sand-bag barrier walls or similar, garage your vehicle, raise utilities and valuable possessions if possible, have an evacuation plan and a 72-hour kit, evacuate if instructed to.
  - **DURING**: Stay indoors! (even when it gets calm suddenly—you are in the eye of the storm). Avoid windows and doors and electrical hazards. Shelter in a small room with more walls and possibly under a sturdy table. Avoid the basement if heavy rains and avoid the top floor if possible unless flooded out.
  - **AFTER**: Avoid flooded areas, electrical hazards, listen to NOAA hand-crank radio to get updates about conditions outside, have contact info and go-bag ready, a whistle and flashlight for signaling emergency responders.
- Download and print an emergency checklist, found on www.ready.gov, or here: https://www.fema.gov/media-library-data/1390846764394-dc08e309debe561d866b05ac84daf1ee/checklist_2014.pdf
  - You can assign a home scavenger hunt of these checklist items for homework (without students being obliged to find them all, as they might not yet own them)
  - OR you can buy most items from a dollar store and set them out ahead of time around the classroom, rec center, or other facility and give students a time-limit to find them all and mark where they were found and why they are necessary/useful.
  - Follow up with questions about family contacts and evacuation plans. Why is it much better to prepare these far in advance of any potential hazard?
  - Show them how to download and use the **FEMA app** for mobile devices, which features a buildable checklist, reminders for replenishing your kit or checking fire alarms, a natural disaster guide, local weather alerts, etc.



V.D: Local—Designing Resilient Cities



Key Concepts and Web-app Resources:

In the past, the chance of disaster arising from a 500 year or 1,000 year storm event was a risk we were willing to take because the cost-benefit ratio was too great. Now, the mounting expenses from increasingly frequent “billion dollar disasters,” coupled with human-driven climate change make inaction irresponsible and perilous. Disasters leave a trail of devastation that can lead to public health crises, disrupt business and everyday life, and limit social and economic growth. But, the new reality also presents an opportunity! Resilience planning and development can build a new, ***green*** economy—requiring city planners, scientists, hydrologists, farmers, architects, contractors, landscapers, energy companies, advertisers, public health workers, educators, media, industry, and government to work in concert with each other toward a sustainable goal! Great strides can be made by improving building and vehicle energy efficiency, reducing waste by finding ways to reuse and recycle consumer goods, construction materials, and organic scraps locally, and increasing greenspace in our cities.

According to the UN Department of Economic and Social Affairs, the world is continually urbanizing, challenging both aging infrastructure in *old* cities, and poorly planned layouts of rapidly developed *new* cities. By the year 2050, one third of human population will have moved out of rural areas and into the city over the course of a century. Our cities have the most at stake to gain **or** lose when it comes to adaptation and carbon mitigation efforts. Resilience planning necessitates serious investment of people-hours and capital but studies show that sustainable development can actually have economic benefits too, saving money in resource management, utilities, liability insurance, public health, and emergency response, while generating new jobs. Ultimately, each city will have to weigh its various stake-holders’ interests and available capital against their particular vulnerabilities to determine the best resiliency plans.

Unit VD. Web-app Resources:

>Adaptation and Resiliency

>>Coastal Resilience

>>>**Coastal Resilience** (Nature Conservancy Video)

>>Think Globally, Act Locally

>>>Designing Cities for Resilience

>>>>The Science Barge example (Groundwork HV video)

>>>>The EcoHouse example (Groundwork HV video)

>>>> Be Water Wise

>>>NOAA Resilience Toolkit: Climate Explorer

In partnership with:

V.D: Local—Designing Resilient Cities—Classroom Activity (page 1/8)

Lesson: Weighing stake-holder interests while planning for city resilience

*****_This lesson is adapted from the activity, Beat the Uncertainty, developed by NOAA and the Max Planck Institute for Human Development, found here: https://games.noaa.gov/beat-the-uncertainty/beat-the-uncertainty-instructions.pdf_

Subject / grade level: 6th-9th grade, all subjects

Materials: 4 copies of the Climate Change Resiliency Game packet, 4 pairs of dice, 4 pennies, bingo chip or similar size figurines (as game pieces).

Lesson objective(s): Students will understand the complexity of city resilience planning. By following a process, students will also develop critical thinking skills, learn how to assess community risks and prioritize stakeholder needs, and improve communication skills.

ENGAGEMENT (5 minutes)

- Ask students: What are the necessary steps a city must take towards a resiliency plan? They can shout out their ideas while you record them on a blackboard or over-sized notepad.
  - Examples: form a planning team, identify risk and vulnerabilities including social vulnerabilities, determine community stakeholder’s needs, research solutions, set the goals, create a plan, budget, and timeline, gain public approval, implement and evaluate the plan, maintain and modify as needed.

EXPLORATION (40 minutes)

- SET UP: Print four copies of the Climate Change Resiliency Planning activity packet. Each should include a (1) Gameboard, (2) The map and background information for “Rivertown,” (3) the Stakeholder’s Perspectives Page, (4) the Resiliency Measures checklist, and (5) the double-sided Climate Cause and Effect page.
  - Highlight a different Stakeholder’s Perspective for each packet so that each team will have a different approach to resiliency.
- Break the class into four teams. Give each team an activity packet, a game piece, and a pair of dice.
- Each team represents residents from “Rivertown”—a coastal city that is vulnerable to climate change. Collectively among the four teams, the players are the citizens, policymakers, business-owners, public-health workers or researchers—who together are responsible for making their city resilient to climate change. Each group, however, will be approaching resiliency from their own stakeholder perspective needs.
- First have a student read the background information on the map aloud to the class. Together, they should identify key vulnerabilities for Rivertown in three categories: SOCIAL, INFRASTRUCTURE, COMMUNITY RESOURCES.
  - **Social:** low-income families, aging homeowners, retirement home, immigrants with language barriers
  - **Infrastructure:** high percentage of impervious surfaces (roads, buildings, parking lots), Rivertown Train Station and tracks, water treatment plant, aging roads, culverts, and sewer system (combined sewage overflows), limited greenspace, retaining walls along Main Estuary, few evacuation routes out of the city can cause traffic in emergencies, energy lines
  - **Community Resources to Safeguard:** Public library, Hospital, supermarkets and other food hubs, Community Center, shelters, hydration stations, cooling centers

V.D: Local—Designing Resilient Cities—Classroom Activity (page 2/8)

- **Next**, tell each team to assign a leader to be the tie-breaker for any resilience planning decisions. They can now begin to read their team's highlighted shakeholder perspective. This is the approach they will be taking when they determine which resiliency measures to enact.
    - This part is designed to help understand different points of view. While some students may find one stakeholder more justified or important, it is important to keep in mind that every stakeholder has an objectively valid perspective—and that they all want to help build resiliency in their community. For the purpose of this activity, at least, no stakeholder is suggesting that climate resiliency planning be ignored.
- Tell the teams they have 7 minutes to discuss and decide how to spend their Rivertown resiliency planning budget of 70M credits, seeking to fulfill their stakeholder needs. (Students should be working off the Resiliency Measures sheet). They can record their Letter Codes for their chosen resiliency measures on the top of the Game Board page for easy reference.
- **GAME PLAY:** How resilient is your city?
    - Roll the dice, and then find the climate threat on the "Climate Cause and Effect" page that corresponds to the number rolled. For instance, if you rolled two fours, you would look for number eight: "Extreme Flooding."
        - Read the Climate Cause and Effect. First move your game piece FORWARD according to the directions for that hazard. (For instance: Extreme Weather—high winds take out power lines: FIRST ADD 2).
        - Next, see if your chosen resiliency measures spared you the full impact. Move BACKWARD on the game board accordingly.
        - Mark Round 1 at the top of your Game Board with a CHECK.
        - Continue rolling the die and seeing how Rivertown is impacted by future climate uncertainty. Be sure to mark each round with a check before rolling the dice again. The game ends when either time is up, you make it to Round 14, OR your game piece reaches the deep red "Game Over" space by the end of the round.
    - When all the teams are finished playing, ask the team leader for each to recap their stakeholder perspective, their choices, and what their Final Score was. What might the do differently?
- **Discuss**: Why is it important to weigh many stakeholder perspectives when determining the best course of action for a resiliency plan?
    - How important to scientific data and expert consultation to the process?
    - Would they want to spend more or less than their budgeted 70M credits on resiliency planning if they could?
    - What obstacles do the students think city planners and communities face when trying to budget for resilience?

Resiliency Game Board

My approach was: ________________ My resiliency measures included ____________________________________

Rounds: (fill in as you go) See how many you last for! (hint: keep track of resiliency choices by copying letters above)

①	②	③	④	⑤	⑥	⑦	⑧	⑨	⑩	⑪	⑫	⑬	⑭

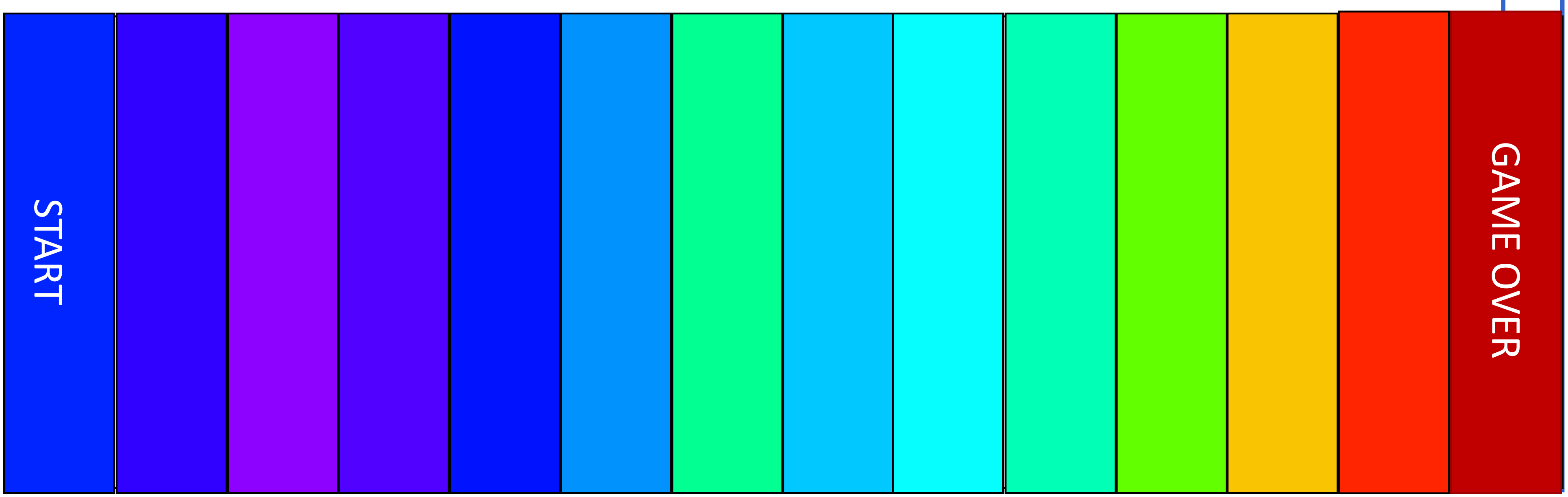
A warming planet, is a more vulnerable planet.

This color chart—based on deviations from global temperature averages every decade for the last 120 years—shows our pattern of accelerated warming since the industrial revolution. Use this as a game board, moving spaces forward with your game piece (to the right) as you ADD points from climate change impacts and moving spaces backward (to the left), as you SUBTRACT points from resiliency and mitigation measures.

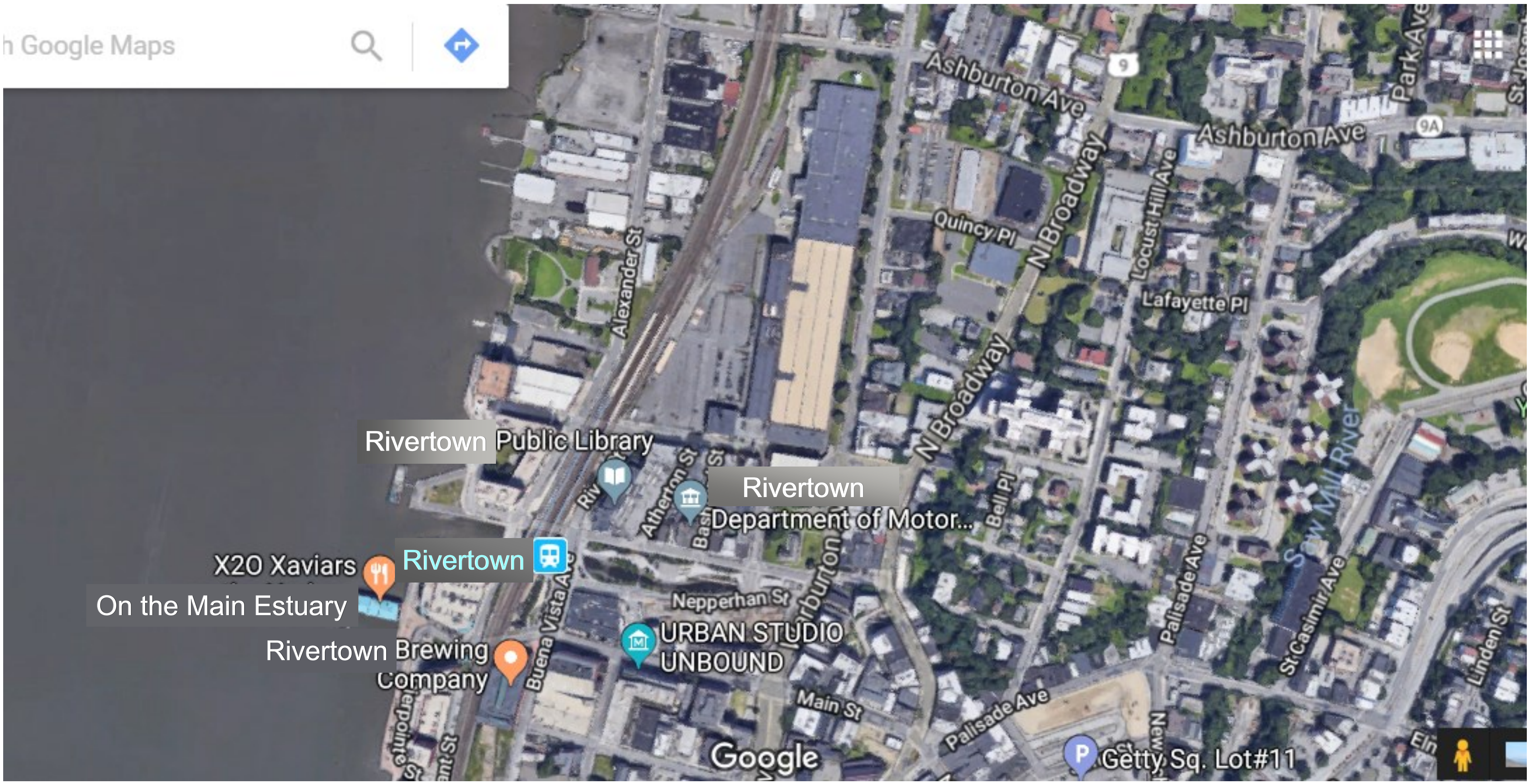
Keep track of how many rounds you last above. Once you hit the deep red…. GAME OVER.

SCORE:

1-4 Rounds—At Risk City 5-10 Rounds—Fairly Resilient, needs additional planning 11-14 Rounds—Climate Smart City



Background: Last year, Hurricane Harold and other heavy rain events have exposed Downtown Rivertown's aging Infrastructure. Harold, a category 3 storm, caused a 6 ft storm surge on the Main Estuary waterfront that flooded into the library, train station, and nearby restaurants and apartment buildings. It also caused many power outages in public housing units. Furthermore, more frequent heavy rain events have caused landslides that severely damaged the Retirement Home on Ashburton Avenue, flooding of the parks, and combined sewage overflows into the Tributary River and Main Estuary. Despite this, development is on the rise, with new high-end apartments and retail spaces being built close to the waterfront. Resources for the aging homeowner population, and lower-income families living in the downtown—such as health centers, affordable/accessible grocery stores, parking, subsidized housing, and affordable transportation are seemingly on the decline. Greenspace is also limited, with most of the shoreline built up and walled in.



Developers:

Rivertown is ripe for development. The Riverline Train station is nearby and with lower taxes than Metropolis, commuters can afford to live on the Rivertown's waterfront and commute into the big city. The fine dining restaurants in Rivertown, like X2O and Dolphin are looking forward to more new customers, and new high-end retail stores are being planned for the strip. Flooding by the waterfront is a big concern for the new apartments.

Homeowners:

Rivertown's waterfront has an aging homeowner population. With rising insurance rates, cost of food and transportation rising, and more frequent heavy storms, many are considering selling to developers and looking for subsidized public housing or retirement homes to live in. Power outages are a big concern, as many are medically dependent on electricity and means of communication. Infrastructure for flood protection might help alleviate cost of damages and insurance rates.

City Government:

With so much spending and development, and more frequent infrastructure damage by severe storms, Rivertown's budget is strapped. Ironically, this means there is limited funds for investing in long-term solutions for sea-level rise and storm surge along the Estuary, or flood protection along the Tributary. The roads are aging poorly from too many harsh winter storms and have many potholes, and trash in the street has clogged storm-drains. The city looks forward to new tax income from new residents in high-end housing units to help rebuild the roads, etc.

Public Housing Residents:

The cost of living in Rivertown is going up, making it harder all the time to afford food, transportation to work, and rising rents. Youth see little future in Rivertown for job training pathways or positions with decent wages after HS or College. There are few social and cultural spaces and limited greenspace access. Utilities in the basements make these buildings very vulnerable to flooding. Emergency preparedness is not widely known or prioritized.

Climate Change Resiliency Game

GROUNDWORK
CHANGING PLACES CHANGING LIVES
GROUNDWORK Hudson Valley
NOAA

	Resiliency Measure	Cost	Your Selection
A OR B	Develop a soft coastline (e.g. using carefully managed wetlands) for protecting against the effects of storms and sea level rise.	25M	
	Build a hard coastline (e.g. using levees) for protecting against the effects of storms and sea level rise.	20M	
C	Require that new city sidewalks and pavements be made from permeable materials, in order to absorb stormwater. Add greenroofs.	5M	
D	Fund a "Youth Green Corps" initiative to develop and maintain green-spaces in the city. Greenspace can serve as (a) heat absorption/ reduction of urban heat island effect, (b) water absorption to reduce flooding (c) carbon sequestration to mitigate our footprint.	10M	
E	Create early warning systems to warn citizens of impending hazards.	10M	
F	Form evacuation plans and run a public preparedness campaign for responding to extreme events. Run drills with emergency responders.	15M	
G	Invest in infrastructure that is more storm resilient. E.g.: raised buildings to let floodwater flow underneath, underground power lines, and outdoor structures resilient to more powerful winds.	25M	
H OR I	Allow building in coastal areas that are rarely affected by floods now but may be in coming decades, in order to strengthen the economy in preparation for climate change impacts.	10M REBATE!	
	Devise policies to discourage building around coastal areas and prevent development in storm surge-prone areas.	5M	
J OR K	Update all storm drains, sewers, and drainage ditches, to add room for unpredictable increases in stormwater runoff.	25M	
	Create Bioswales and Vernal Ponds to absorb and hold water in heavy rain events near roads and building complexes prone to flooding.	15M	
L	Retro-fit vulnerable public housing complexes and municipal buildings (including libraries, hospitals, etc.) to have utilities moved off the basement and first floors and higher up to avoid floodwaters.	20M	
M	Create a more localized power grid that includes rooftop solar panels, geothermal, wind turbines along the Palisades, and biodiesel backup generators to reduce the carbon footprint and ensure power is locally available even after extreme weather events and "brown-outs."	25M	
Do not exceed 70M Credits			

Roll the Dice!	Cause and Effect!
2	**Green Growth** **SUBTRACT 1:** Your community has embraced green infrastructure so resilience policies are easier and cheaper to pass and implement!
3	**Heat Wave—increased heat stroke: <u>FIRST ADD 1</u>** **SUBTRACT 1 if you chose <u>TWO</u> of the following**: **A** (soft coastal barrier), **D** (greencorps), **E** (early warning), **M** (local energy to safeguard against brown-outs).
4	**Favorable Conditions** **SUBTRACT 2:** Your population is less vulnerable to extreme weather. Your government has saved resources to deal with future extremes.
5	**Storm Surge: Extreme Severity—levees fail: <u>FIRST ADD 5</u>** **SUBTRACT 1 for each of the following you implemented:** **A** (soft coastal barrier), **D** (green corps), **E <u>AND</u> F** (early warning and evacuation), **G** (raised buildings), **I** (discourage coastal development), **J OR K** (flood drainage plans), or **L** (retro-fit building utilities). **ADD 1** if you selected **H** (allow coastal development).
6	**Marine Dead-zones from Runoff: <u>FIRST ADD 3</u>** More rain causes nutrient runoff from lawns, farms, and sewage-overflow to deposit into rivers and lakes, causing massive fish die-offs, hurting the economy. **SUBTRACT 1 for each of the following you implemented:** **C** (permeable streets) **D** (green corps), or **J** (margins on drainage) .
7	**Heavy Rains & Storm Surge Cause Flash Flooding: <u>FIRST ADD 2</u>** **SUBTRACT 1 for each of the following you implemented:** **A or B** (coastal barriers), **C** (permeable streets), **D** (green corps), **E** (early warning), **G** (raised buildings), **I** (discourage coastal development), **J or K** (flood drainage plans), L (retrofit buildings). **ADD 1** if you selected **H** (allow coastal development).

Roll the Dice!	Cause and Effect!
8	**Extreme Weather—high winds take out power lines: FIRST ADD 2** Power loss can cause disruption to transportation, commerce, communication, heating/cooling, cooking, and health-care, compromising wellness, safety, and the economy. **SUBTRACT 1 for each of the following you implemented: G** (resilient infrastructure), **M** (localized energy).
9	**Moderate Flooding from Extensive Rain: <u>FIRST ADD 2</u>** **SUBTRACT 1 if you chose <u>TWO</u> of the following**: **A** (soft coastal barrier), **C** (permeable surfaces), **D** (greencorps), **J or K** (flood drainage plans), or **L** (retrofit)
10	**Fewer Coastal Extremes** **NO CHANGE:** Your population is less vulnerable to extreme weather for a few years.
11	**Storm Surge: Normal Severity—levees not breached: <u>FIRST ADD 3</u>** **SUBTRACT 1 for each of the following you implemented:** **A or B** (coastal barrier), **D** (green corps), **E** (early warning), **F** (evacuation), **G** (raised buildings), **I** (discourage coastal development), **J OR K** (flood drainage plans), or **L** (retro-fit building utilities). **ADD 1** if you selected **H** (allow coastal development).
12	**Climate Literacy Improves** Citizens make more informed decisions, helping them to protect the community! **SUBTRACT 2 for each of the following you implemented:** **D** (green corps), **F** (public preparedness campaign), or **I** (smart policies on coastal development).

GROUNDWORK Hudson Valley — CHANGING PLACES CHANGING LIVES — In partnership with: NOAA — SARAH LAWRENCE COLLEGE CENTER FOR THE URBAN RIVER AT BECZAK

