EDUCATOR GUIDE

ATLAS of a Changing Earth

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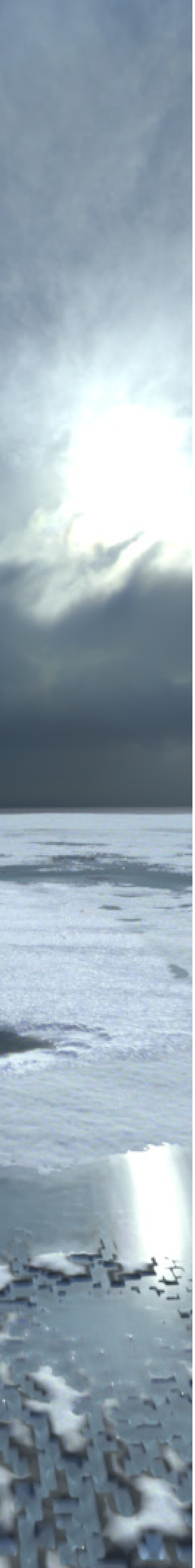


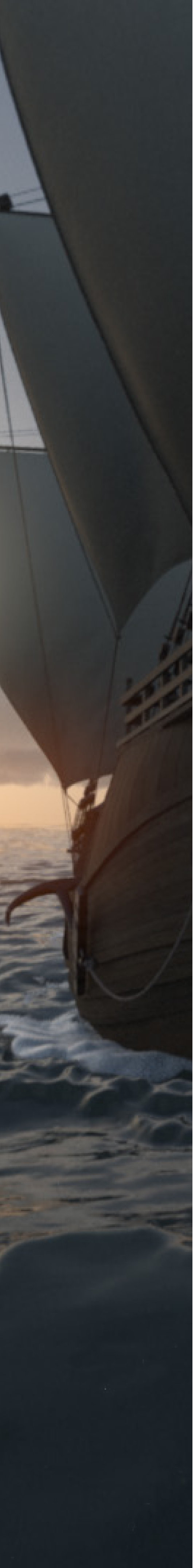
Introduction

The following activities are meant to provide depth and context to the information presented in the fulldome show Atlas of a Changing Earth. They are designed to help viewers delve deeper into the study of climates past and present, and to bring an understanding of how global changes can have a profound local effect. These activities were all developed by educators, including the education and outreach team at the Byrd Polar and Climate Research Center on The Ohio State University main campus.

While Atlas of a Changing Earth is rich in information, it also communicates the sense of urgency that is required for all of us to address the global issue of climate change. One of the show's biggest takeaways is that we are all connected to each other through Earth's environmental systems. No one is isolated. We no longer have the luxury of thinking that the world is too large or too stable for any individual to have a significant impact. One of our jobs as educators is to arm our students with observational, problem-solving, and critical reasoning skills that they can use to help preserve the world which nurtures us all.

Whether you are a teacher in the classroom, an informal educator, or a parent teaching at home, we hope these activities will help your students learn about the world that we live in, how climate science is done, how we are all connected to one another, and how we know what we know.

This guide includes lessons that can be done both in the classroom and at home, using easily available materials. They target a wide range of grade levels, and include concepts that are central to climatology and Earth science. A key goal of these activities is to inspire curiosity in students, as well as to provide them with research tools necessary to answer any questions they may have.



Next Generation Science Standards

Middle School

Earth and Space Science (ESS)

ESS2.A: Earth Materials and Systems

Earth's major systems are the geosphere (solid and molten rock, soil, and sediments), the hydrosphere (water and ice), the atmosphere (air), and the biosphere (living things, including humans). These systems interact in multiple ways to affect Earth's surface materials and processes. The ocean supports a variety of ecosystems and organisms, shapes landforms, and influences climate. Winds and clouds in the atmosphere interact with the landforms to determine patterns of weather. (5-ESS2-1)

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

Nearly all of Earth's available water is in the ocean. Most fresh water is in glaciers or underground; only a tiny fraction is in streams, lakes, wetlands, and the atmosphere. (5-ESS2-2)

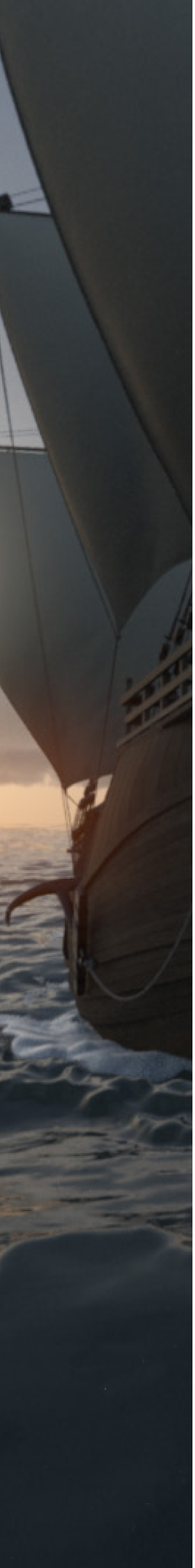
ESS3.C: Human Impacts on Earth Systems

Human activities in agriculture, industry, and everyday life have had major effects on the land, vegetation, streams, ocean, air, and even outer space. But individuals and communities are doing things to help protect Earth's resources and environments. (5-ESS3-1)

ESS2.A: Earth Materials and Systems

The planet's systems interact over scales that range from microscopic to global in size, and they operate over fractions of a second to billions of years. These interactions have shaped Earth's history and will determine its future. (MS-ESS2-2)

Global movements of water and its changes in form are propelled by sunlight and gravity. (MS-ESS2-4)



Middle School (continued)

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)

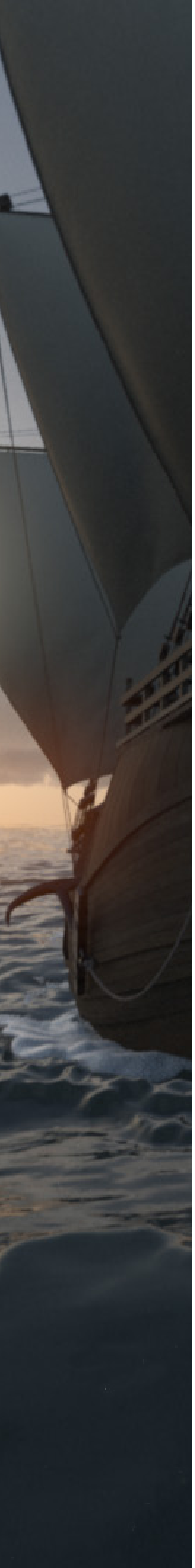
Variations in density due to variations in temperature and salinity drive a global pattern of interconnected ocean currents. (MS-ESS2-6)

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. (MS-ESS2-6)

Because these patterns are so complex, weather can only be predicted probabilistically. (MS-ESS2-5)

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-ESS2-6)

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. (MS-ESS3-5)



Middle School (continued)

ESS3.B: Natural Hazards
Mapping the history of natural hazards in a region, combined with an understanding of related geologic forces can help forecast the locations and likelihoods of future events. (MS-ESS3-2)

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-ESS3-3)

Typically, as human populations and per-capita consumption of natural resources increase, so do the negative impacts on Earth unless the activities and technologies involved are engineered otherwise. (MS-ESS3-3), (MS-ESS3-4)

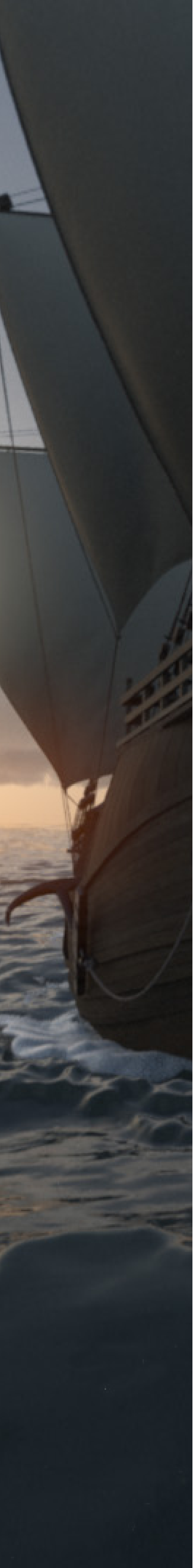
Life Science (LS)

LS2.C: Ecosystem Dynamics, Functioning, and Resilience
Biodiversity describes the variety of species found in Earth's terrestrial and oceanic ecosystems. The completeness or integrity of an ecosystem's biodiversity is often used as a measure of its health. (MS-LS2-5)

LS4.D: Biodiversity and Humans
Changes in biodiversity can influence humans' resources, such as food, energy, and medicines, as well as ecosystem services that humans rely on— for example, water purification and recycling. (secondary to MS-LS2-5)

Crosscutting Concepts: Systems and System Models

A system can be described in terms of its components and their interactions. (5-ESS2-1), (5-ESS3-1)



Middle School (continued)

Models can be used to represent systems and their interactions—such as inputs, processes and outputs—and energy, matter, and information flows within systems. (MS-ESS2-6) (MS-PS3-2)

Patterns

Similarities and differences in patterns can be used to sort, classify, communicate and analyze simple rates of change for natural phenomena. (5-ESS1-2)

Patterns can be used to identify cause-and-effect relationships. (MS-LS2-2)

Stability and Change

Small changes in one part of a system might cause large changes in another part. (MS-LS2-5)

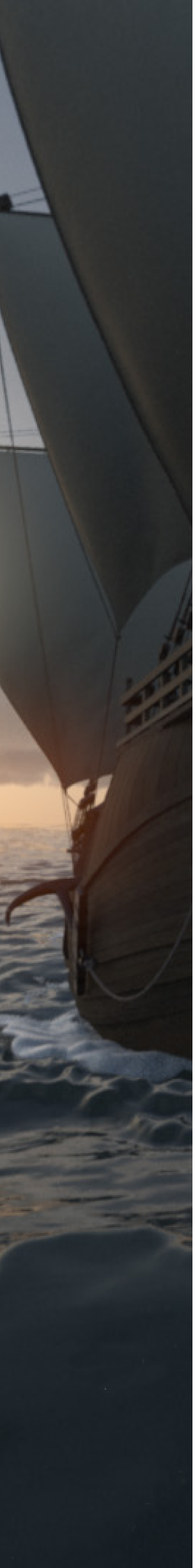
Stability might be disturbed either by sudden events or gradual changes that accumulate over time. (MS-ESS3-5)

Influence of Science, Engineering, & Technology on Society & the Natural World

The uses of technologies and any limitations on their use are driven by individual or societal needs, desires, and values; by the findings of scientific research; and by differences in such factors as climate, natural resources, and economic conditions. Thus, technology use varies from region to region and over time. (MS-LS2-5)

Connections to Nature of Science

All human activity draws on natural resources and has both short and long-term consequences, positive as well as negative, for the health of people and the natural environment. (MS-ESS3-1)



Middle School (continued)

Science Addresses Questions About the Natural and Material World

Science findings are limited to questions that can be answered with empirical evidence. (5-ESS3-1)

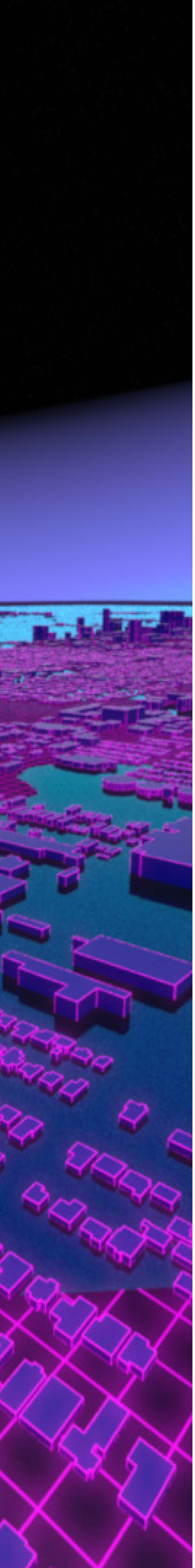
Scientific knowledge can describe the consequences of actions but does not necessarily prescribe the decisions that society takes. (MS-LS2-5)

Energy and Matter

Within a natural or designed system, the transfer of energy drives the motion and/or cycling of matter. (MS-ESS2-4)

Cause and Effect

Cause and effect relationships may be used to predict phenomena in natural or designed systems. (MS-ESS2-5)



Next Generation Science Standards

High School

Earth and Space Science (ESS)

PS1.C: Nuclear Processes

Spontaneous radioactive decays follow a characteristic exponential decay law. Nuclear lifetimes allow radiometric dating to be used to determine the ages of rocks and other materials. (secondary to HS-ESS1-5), (secondary to HS-ESS1-6)

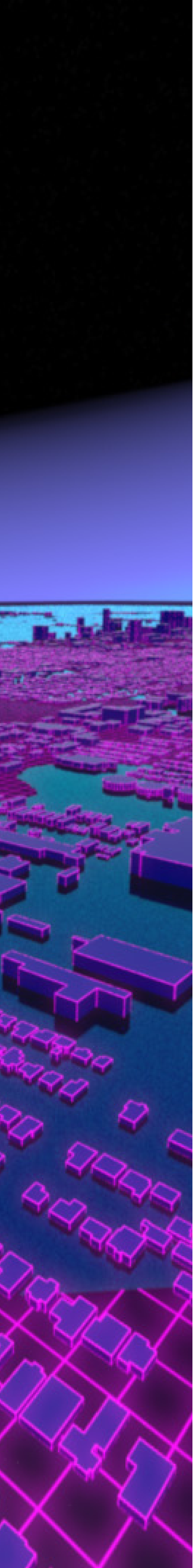
ESS2.A: Earth Materials and Systems

Earth's systems, being dynamic and interacting, cause feedback effects that can increase or decrease the original changes. (HS-ESS2-1) (Note: This Disciplinary Core Idea is also addressed by HS-ESS2-2.)

The geologic record shows that changes to global and regional climate can be caused by interactions among changes in the sun's energy output or Earth's orbit, tectonic events, ocean circulation, volcanic activity, glaciers, vegetation, and human activities. These changes can occur on a variety of time scales from sudden (e.g., volcanic ash clouds) to intermediate (ice ages) to very long-term tectonic cycles. (HS-ESS2-4)

ESS1.B: Earth and the Solar System

Cyclical changes in the shape of Earth's orbit around the sun, together with changes in the tilt of the planet's axis of rotation, both occurring over hundreds of thousands of years, have altered the intensity and distribution of sunlight falling on the earth. These phenomena cause a cycle of ice ages and other gradual climate changes. (secondary to HS-ESS2-4)



High School (continued)

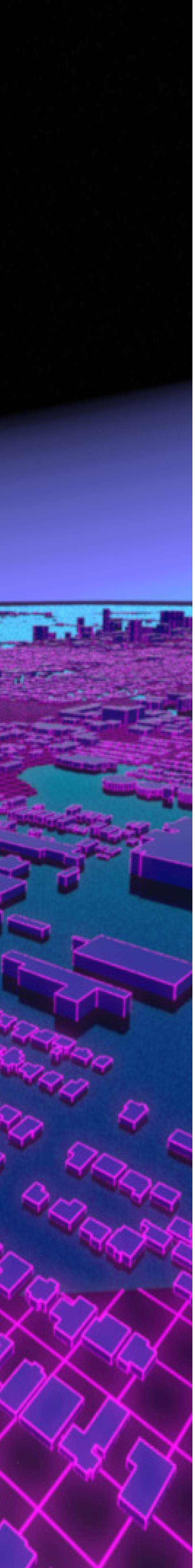
ESS2.C: The Roles of Water in Earth's Surface Processes
The abundance of liquid water on Earth's surface and its unique combination of physical and chemical properties are central to the planet's dynamics. These properties include water's exceptional capacity to absorb, store, and release large amounts of energy, transmit sunlight, expand upon freezing, dissolve and transport materials, and lower the viscosities and melting points of rocks. (HS-ESS2-5)

ESS2.D: Weather and Climate
The foundation for Earth's global climate systems is the electromagnetic radiation from the sun, as well as its reflection, absorption, storage, and redistribution among the atmosphere, ocean, and land systems, and this energy's re-radiation into space. (HS-ESS2-2)

Gradual atmospheric changes were due to plants and other organisms that captured carbon dioxide and released oxygen. (HS-ESS2-6), (HS-ESS2-7)

Changes in the atmosphere due to human activity have increased carbon dioxide concentrations and thus affect climate. (HS-ESS2-6)

Current models predict that, although future regional climate changes will be complex and varied, average global temperatures will continue to rise. The outcomes predicted by global climate models strongly depend on the amounts of human-generated greenhouse gases added to the atmosphere each year and by the ways in which these gases are absorbed by the ocean and biosphere. (secondary to HS-ESS3-6)



High School (continued)

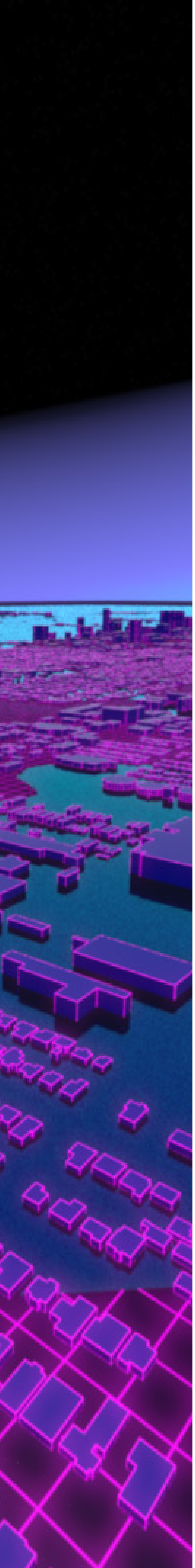
ESS2.E: Biogeology
The many dynamic and delicate feedbacks between the biosphere and other Earth systems cause a continual co-evolution of Earth's surface and the life that exists on it. (HS-ESS2-7)

ESS3.B: Natural Hazards
Natural hazards and other geologic events have shaped the course of human history; [they] have significantly altered the sizes of human populations and have driven human migrations. (HS-ESS3-1) (HS-ESS3-1)

ESS3.C: Human Impacts on Earth Systems
The sustainability of human societies and the biodiversity that supports them requires responsible management of natural resources. (HS-ESS3-3)
Scientists and engineers can make major contributions by developing technologies that produce less pollution and waste and that preclude ecosystem degradation. (HS-ESS3-4)

ESS3.D: Global Climate Change
Though the magnitudes of human impacts are greater than they have ever been, so too are human abilities to model, predict, and manage current and future impacts. (HS-ESS3-5)

Through computer simulations and other studies, important discoveries are still being made about how the ocean, the atmosphere, and the biosphere interact and are modified in response to human activities. (HS-ESS3-6)



High School (continued)

Engineering Design – Climate Change Mitigation and Solutions

ETS1.A: Defining and Delimiting Engineering Problems

Criteria and constraints also include satisfying any requirements set by society, such as taking issues of risk mitigation into account, and they should be quantified to the extent possible and stated in such a way that one can tell if a given design meets them. (HS-ETS1-1)

Humanity faces major global challenges today, such as the need for supplies of clean water and food or for energy sources that minimize pollution, which can be addressed through engineering. These global challenges also may have manifestations in local communities. (HS-ETS1-1)

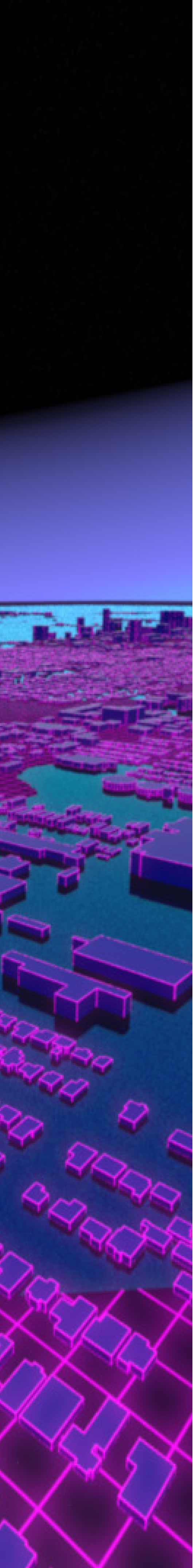
ETS1.B: Developing Possible Solutions

When evaluating solutions, it is important to take into account a range of constraints including cost, safety, reliability and aesthetics and to consider social, cultural and environmental impacts. (HS-ETS1-3)

Both physical models and computers can be used in various ways to aid in the engineering design process. Computers are useful for a variety of purposes, such as running simulations to test different ways of solving a problem or to see which one is most efficient or economical; and in making a persuasive presentation to a client about how a given design will meet his or her needs. (HS-ETS1-4)

ETS1.C: Optimizing the Design Solution

Criteria may need to be broken down into simpler ones that can be approached systematically, and decisions about the priority of certain criteria over others (trade-offs) may be needed. (HS-ETS1-2)



High School (continued)

Crosscutting Concepts: Systems and System Models

Models (e.g., physical, mathematical, computer models) can be used to simulate systems and interactions—including energy, matter, and information flows—within and between systems at different scales. (HS-ETS1-4)

Connections to Engineering, Technology, and Applications of Science

Influence of Science, Engineering, and Technology on Society and the Natural World. New technologies can have deep impacts on society and the environment, including some that were not anticipated. Analysis of costs and benefits is a critical aspect of decisions about technology. (HS-ETS1-1), (HS-ETS1-3)

Patterns

Empirical evidence is needed to identify patterns. (HS-ESS1-5)

Stability and Change

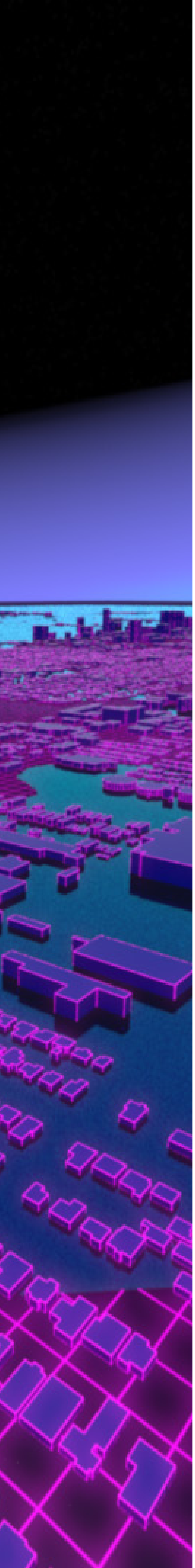
Much of science deals with constructing explanations of how things change and how they remain stable. (HS-ESS1-6)

Change and rates of change can be quantified and modeled over very short or very long periods of time. Some system changes are irreversible. (HS-ESS2-1)

Feedback (negative or positive) can stabilize or destabilize a system. (HS-ESS2-2)

Energy and Matter

Energy drives the cycling of matter within and between systems. (HS-ESS2-3)



High School (continued)

Cause and Effect

Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. (HS-ESS2-4)

Science Is a Human Endeavor

Science is a result of human endeavors, imagination, and creativity. (HS-ESS3-3)

Science Addresses Questions About the Natural and Material World

Science and technology may raise ethical issues for which science, by itself, does not provide answers and solutions. (HS-ESS3-2)

Science knowledge indicates what can happen in natural systems—not what should happen. The latter involves ethics, values, and human decisions about the use of knowledge. (HS-ESS3-2)

Many decisions are not made using science alone, but rely on social and cultural contexts to resolve issues. (HS-ESS3-2)

Key Topics

We can measure that Carbon Dioxide and other greenhouse gases are on the rise in our atmosphere. We measure the past 100,000 years of CO_2 from the ice record. We know that these gases are driving the global climate to warm. Climate affects us all as the global air and water currents distribute heat from the low latitudes to high latitudes and the poles.

There is tremendous water stored in frozen polar ice. Climate change and warming doesn’t make all glaciers shrink; it can melt glaciers from underneath or lubricate their paths causing them to flow rapidly, releasing billions of tons of ice into the ocean every year. All the extra water being added into the oceans contributes to sea level rise. The additional heat stored in the oceans raises the temperature and lowers the density causing additional rise. We can measure the temperature changes in ocean currents and sea levels overtaking dry land from satellites orbiting the Earth.

The models of climate change used to predict the future events show us the many possible events given a lot of inputs. Most of these inputs we do know or can measure. Scientists then use a range of possible values to describe what humanity will choose to do in the next 100 years. We have the power to change and choose the world we want for the future. These models show that the oceans will continue to rise even in the best possible situations which will flood many of the world’s major cities causing a massive human migration. Science tells us what can happen, but we choose what will happen.

The following activities investigate many different aspects of climate, how we measure climate, who does the science, and many related topics for all ages. Thinking critically and understanding how we know what we know are important tools to creating the solutions for all of humanity.

Fluid Earth Viewer: Grades 4+

You can use the Fluid Earth Viewer (https://fluid-earth.byrd.osu.edu/) to learn about the atmosphere and oceans by exploring the daily conditions in places where you live, work, and play or examining whole regions of the planet over years. In particular, Fluid Earth Viewer provides hands-on visualizations of conditions in polar regions, changes they are undergoing, and connections between polar regions and the rest of the planet. Built on an open-source application, Fluid Earth Viewer is a vehicle for modern Earth science communication, making information used by the scientific community accessible and engaging to everyone. Fluid Earth Viewer is explorable 24 hours a day, 7 days a week using your computer, tablet, and smartphone.
Fluid Earth Viewer can look at current and past events and display a tremendous amount of data overlayed on the globe. You can explore the temperatures of both oceans and land surface. You can observe the currents in the air and water. You can see the effects of hurricanes and other severe weather events. Smoke from fires and other aerosols are visible from space thanks to orbiting satellites. We can track land events through dust, carbon monoxide, sulfur dioxide, and ozone. This means both natural and human-caused events are visible, as you learn what datasets can show you.
In addition to the site, the Byrd team has created:

•Fluid Earth Viewer - Blog: A companion website that provides additional project information, including updates, Fluid Earth Viewer's features and expansion of the data sets visualized.
•Fluid Earth Viewer - Educator Resources: A collection of lessons that teachers and informal educators can use in their classrooms and with youth programs.
•Fluid Earth Viewer-Video Resources: A collection of instructional videos that allows you to better understand key phenomena in Earth's atmosphere and oceans, and become better acquainted with Fluid Earth Viewer's features.

This project is sponsored by the U.S. National Science Foundation as an Exploratory Pathways project under the Advancing Informal STEM Learning (AISL) Program

Virtual Reality Tours: Grade 4+

Creating Your Own Tour

Currently, there are seven VR tours available as part of Virtual Ice Explorer. The entire collection can be seen at the Virtual Ice Explorer site https://virtualice.byrd.osu.edu/. Tours were created by Kira Harris, Kasey Krok, Daniel Hamilton, and Adelyn Arens using video, photos, and data collected by field researchers. Field researchers were instrumental in providing guidance so that tours genuinely capture the landscape and research conducted there. Claire Mercer, Pam Theodotou, and Jason Cervenec also contributed to the tours. A resource explaining "how to" create your own immersive tours is available here. There is a small but growing series of virtual field trips to research facilities at The Ohio State University here. The tours can explored on a normal web browser.

Important links:
https://virtualice.byrd.osu.edu/
https://u.osu.edu/virtualice/

Development of these tours was supported by NSF grant #1713537 and a donation to the Byrd Center by Ohio State Energy Partners/ENGIE.

Create an Ice Core: Grade 5+

Ice cores provide scientists with a way to learn about environmental conditions in the past before people were around to write records. The great thing about ice cores is that, once they're extracted and taken to a lab for analysis, each layer of ice provides information about the amount of snow the glacier has received in a given year. These layers also contain materials such as debris from forest fires and volcanoes, dust picked up by winds, and living materials such as pollen and insects. Some of these materials can be seen with a naked eye. Others, such as chemical tracers, require more sophisticated methods of analysis. Ultimately, the more layers scientists can observe, the more years into the past they can investigate.

BPCRC's Education and Outreach team has created and field-tested a comprehensive lesson plan designed to provide students with a simulation of the process that scientists use when analyzing ice cores. Included in the lesson plan are instructions on how to create your own classroom ice cores, as shown to the right.

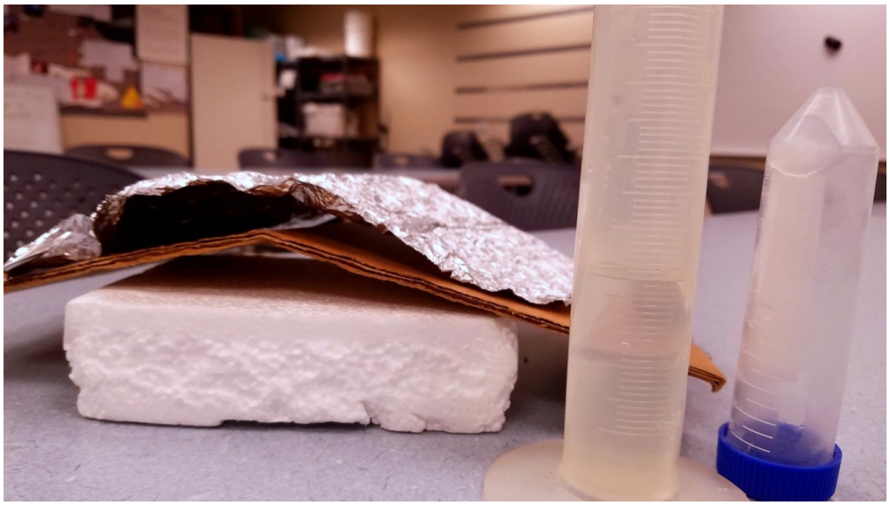
For a complete set of resources and lesson plans, go to:
https://byrd.osu.edu/create-classroom-ice-cores
There you can find:

- High resolution images of the above ice core as well as instructions for making your own.
- Complete lesson plan
- Student worksheet
- Post-exploration assessment
- A long list of videos and Virtual Reality Expeditions

Keep it Cool: Grade 6+

When you put on layers to stay warm in the winter, or use a cooler to keep food cool, have you ever wondered about the science of thermal energy transfer? How does your insulated mug keep the liquid hot and how does your cooler keep food frozen? In fact, did you wonder how both of these devices can actually work to keep objects hot or cold? Many devices are designed to maintain the temperature of an object without being plugged into an electrical outlet, and even those that are plugged in, such as refrigerators, use designs and materials that reduce the effort needed to maintain the temperature, thus saving valuable resources.

Ice cores are an example of a substance that needs to remain frozen when it is being transported. In order to successfully transport an ice core from excavation site to the freezer, scientists need to store it in a device that is lightweight, easy to carry in a backpack, and can maintain a below-freezing temperature for days. Because ice cores often travel inside warm trucks and airplanes, this transporting device is designed to reduce the transfer of thermal energy from the exterior (i.e., the environment) to the interior (i.e., the container where the ice core is stored). Likewise, since ice cores may find themselves in a very bright environment – such as the top of a glacier, surrounded by highly-reflective snow and located above the clouds, - the device needs to limit transformation of light energy into thermal energy.

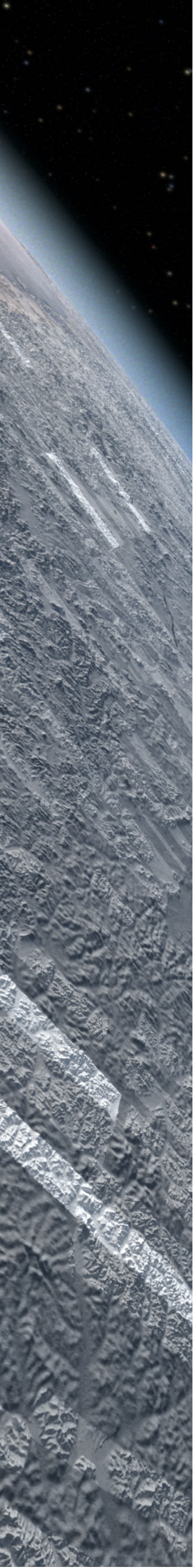


Keep it Cool: Grade 6+ (continued)

BPCRC's Education and Outreach team created a comprehensive lesson plan which challenges students to utilize their understanding of thermal energy transfer and transformation in order to develop a simple, lightweight, and efficient method for storing and transporting ice cores. Included in the lesson plan resources are supplemental photos and instructions on how to make a miniature ice core insulating tube.

For a complete set of resources and lesson plans go to:
https://byrd.osu.edu/keep-it-cool.
There you can find:

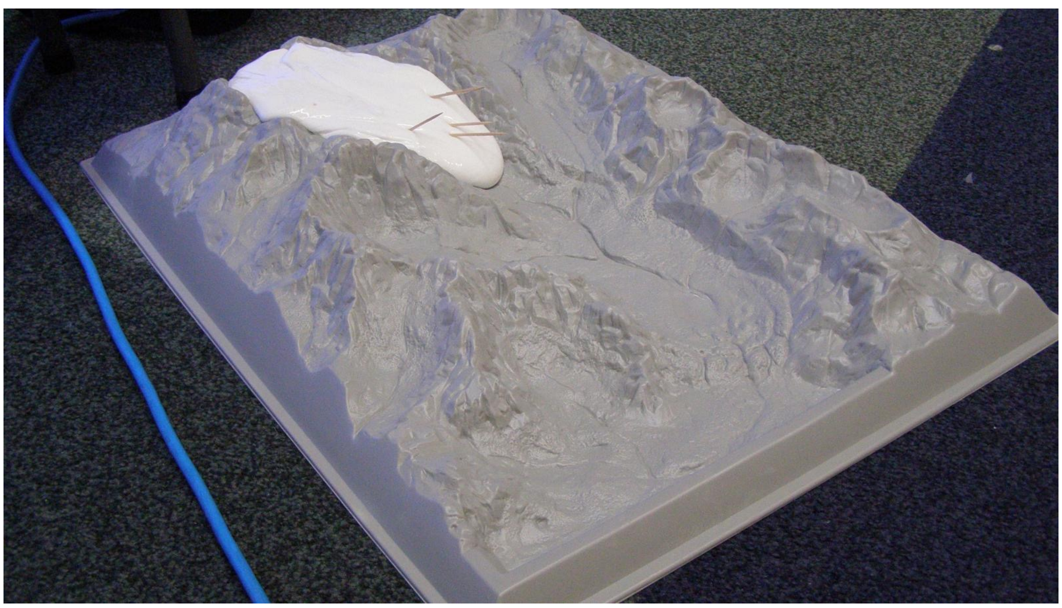
•Keep it Cool Teacher Notes
•Keep it Cool Classroom Handout
•Additional Keep it Cool photos
•Video Instructions

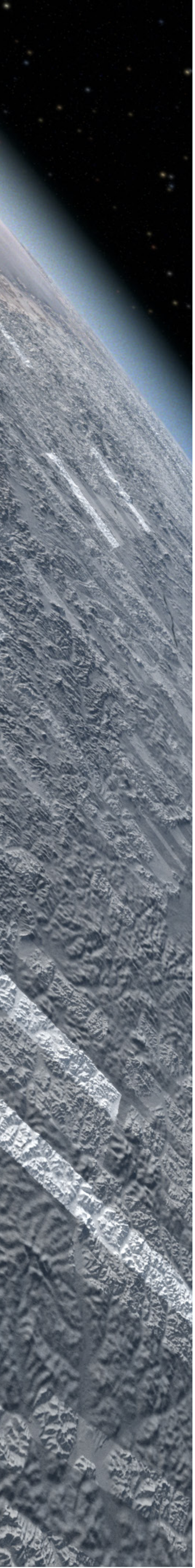


Glacier Flubber: All Ages

Flubber Glacier Flow lessons were designed for two age groups, grades 2-3 and grades 3-5. These are hands-on activities that simulate glacial flow for students. Students use a glacier-modeling compound called “FLUBBER” (which is made from glue, water, and Borax) to predict and observe the flow of ice. The students and teacher discuss how scientists determine the rate and direction of flow of glaciers. The flubber recipe was provided by COSI (https://cosi.org) and is available for download (https://smile.cosi.org/fsq-classiccosi.pdf).

PhET at the University of Colorado at Boulder has a simulation that allows students to explore the advance, retreat, and flow of glaciers and a second simulation that allows students to explore the greenhouse effect. The Flubber lesson provides a tangible experience for students to understand the flow of glaciers before they continue to investigate using PhET simulations. The PhET team consistently produces excellent computer simulations that are scientifically valid and provide students with opportunities to investigate difficult to visualize or experience concepts.

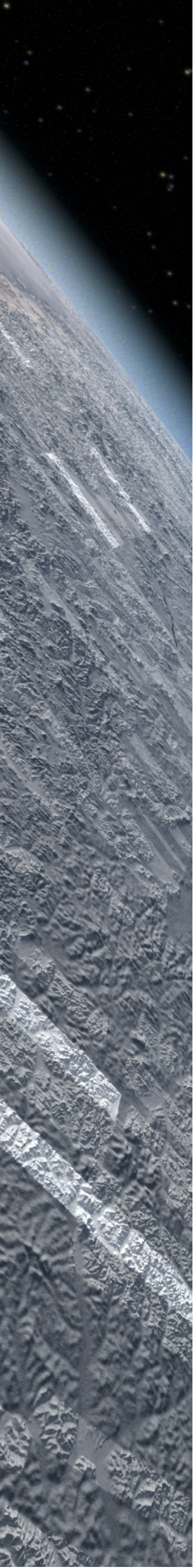




Glacier Flubber: All Ages (continued)

For a complete set of resources and lesson plans go to:
https://byrd.osu.edu/educators/flubber-glacier-flow.
There you can find:

•The Flubber Glacier Flow lessons for grades 2-3:
https://bpcrc.osu.edu/sites/bpcrc.osu.edu/files/flubber_activity_grade_2-3_0.zip
•The Flubber Glacier Flow lessons for grades 3-5:
https://bpcrc.osu.edu/sites/bpcrc.osu.edu/files/flubber_activity_grade_3-5_0.zip
•Links to the University of Colorado Boulder's Phet Simulations:
https://phet.colorado.edu/
•Video Demonstration of Making Flubber

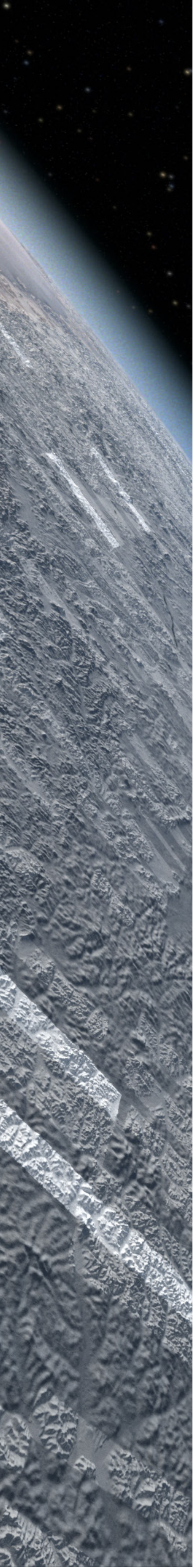


Get Outside! BINGO: All Ages

Venture outside with this bingo card and see what you can find. If you are a true nature sleuth and complete a bingo right away, try to fill the entire card over a weekend. Look but don't disturb animals, specifically the young who are new to the world.

If you want to identify some of the living things you found during bingo but don't have a bunch of plant and animal books laying around, there is an app for that. Download the iNaturalist app www.inaturalist.org to your smart phone or tablet and begin photographing what's living in your corner of the world. In addition to learning more about plants and animals, you can share the photos and locations with a community of scientists who are figuring out where exactly these plants and animals live. See if you can identify five new plants and five animals in a yard, field, or park. Remember, insects are animals too and can often be found in streams, under rocks, and in logs if you can't find any flying around.

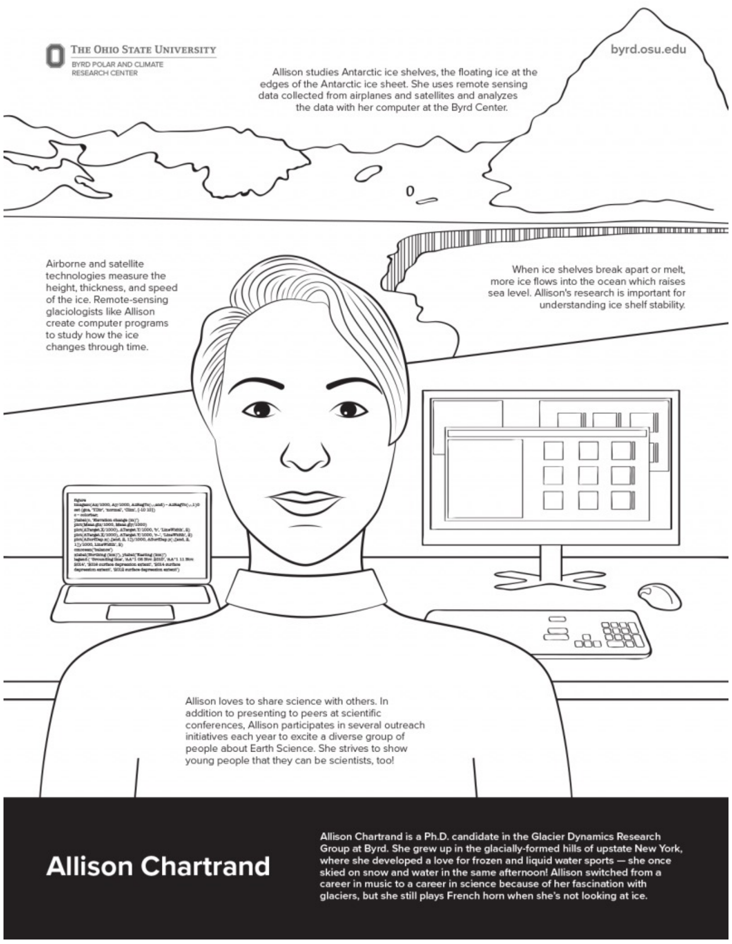
https://byrd.osu.edu/sites/default/files/2020-08/BINGO_Get_Outside.pdf



Coloring Pages: All Ages

Bring a Science Snapshot to life! Download each of the coloring book pages to add color by hand or a computer program. Share your masterpiece with us or view others' masterpieces @ByrdPolar #ScienceSnapShot # ColoringPage. Each of these sheets was created by Maria Burns, an undergraduate student at The Ohio State University, in collaboration with the researcher featured.

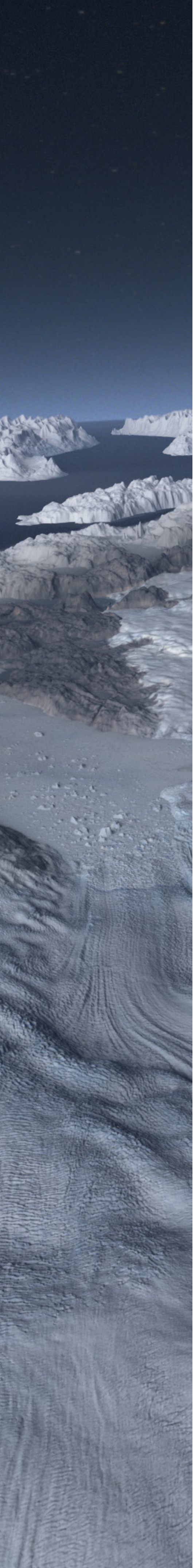
Example of Allison Chartrand



Best Places: Grades 3-12

Best Places was developed by the Byrd Center's Dr. Carol Landis as a mathematics and science lesson for grades 5-12 (modifications necessary for younger grades). The purpose of this lesson is to enhance analytical skills and to apply historic data to everyday decisions using local climatological data summaries from the National Weather Service. This lesson allows students to see temperature and precipitation averages, ranges, and seasonal variability. At the end of the unit, climate data can be examined in terms of geography.

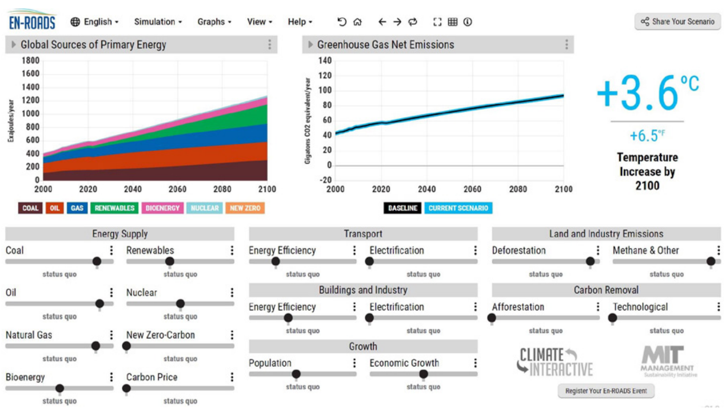
Best Places Activity:
https://byrd.osu.edu/sites/bpcrc.osu.edu/files/best_place.zip



En-ROADS: High School+

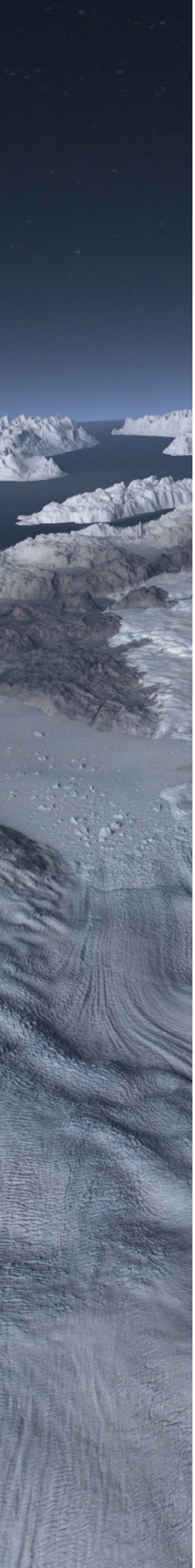
The Climate Action Simulation is a highly interactive, role-playing game. It uses the En-ROADS simulation model to engage a wide range of participants in exploring key technology and policy solutions for addressing global warming. The game is conducted as a simulated emergency climate summit organized by the United Nations that convenes global stakeholders to establish a concrete plan that limits warming to Paris Agreement goals. This game is a fun format for large groups to explore climate change solutions and see what it would really take to address this global challenge.

A recent publication by Dr. Rooney-Varga of UMass Lowell shows that taking part in the Climate Action Simulation improves participants' knowledge on the actions needed to address climate change, boosts both personal and emotional engagement with climate issues, and leaves participants feeling empowered to address climate change.



The website include the following and more:

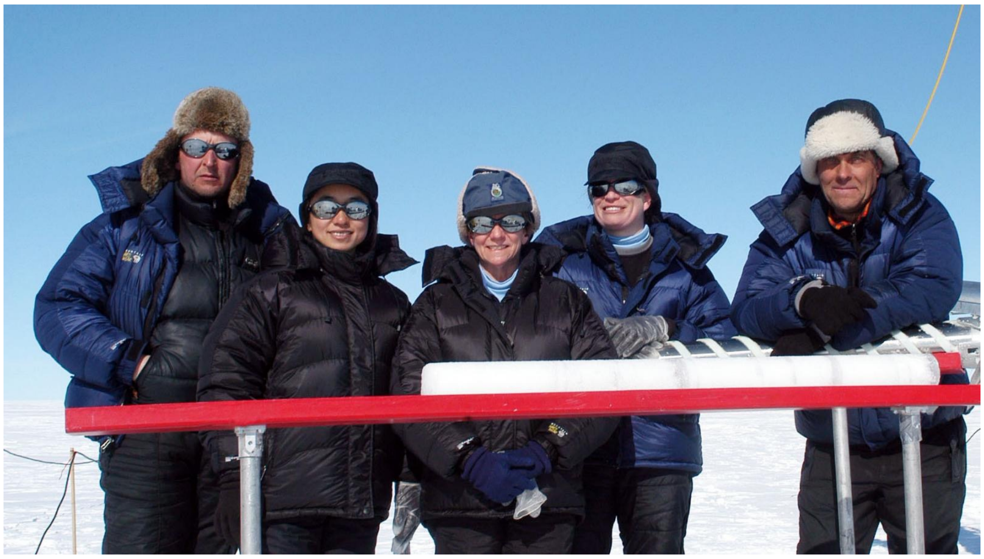
•Go to the En-ROADS simulator: https://en-roads.climateinteractive.org/
•The En-ROADS Training Program: https://learn.climateinteractive.org/
•En-ROADS User Guide:
https://docs.climateinteractive.org/projects/en-roads/en/latest/index.html

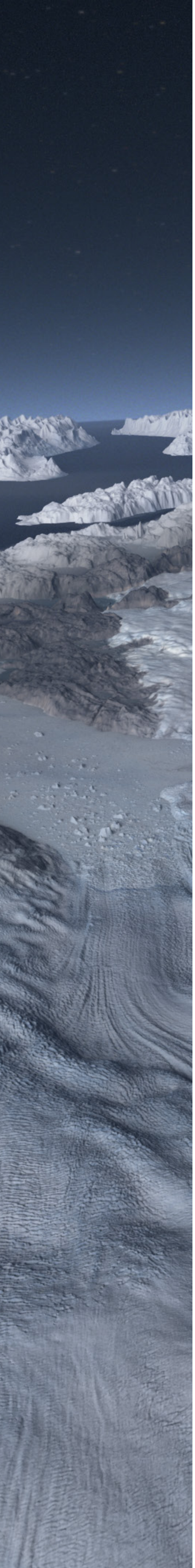


Ice Core Data: High School+

Ice core data allow students to explore a number of patterns (including cyclic patterns) while learning that researchers need to gather and interpret evidence to understand Earth's past. Students will explore core data collected in Western Greenland that document a few decades of Earth's atmosphere. Students are challenged to identify patterns and then use those patterns and background information to determine the year that the core was drilled. In the process, challenges of what to do with inconsistent and missing data must be discussed. The data include measurements of temperature, dust, and atmospheric gases. This activity is developed for upper-level high school and university students and will need instructor support.

Downloadable files are provided on the website (https://byrd.osu.edu/educator/lessons/icecore) for those who intend to run this activity in person. For those running the activity with an online or virtual class, a separate page includes all of the necessary information for students to complete the activity, including an interactive graph and background readings. Click here to visit for the virtual lesson. In addition, there are four videos below, which may be used with in-person classes or embedded in course management systems to support lesson delivery.

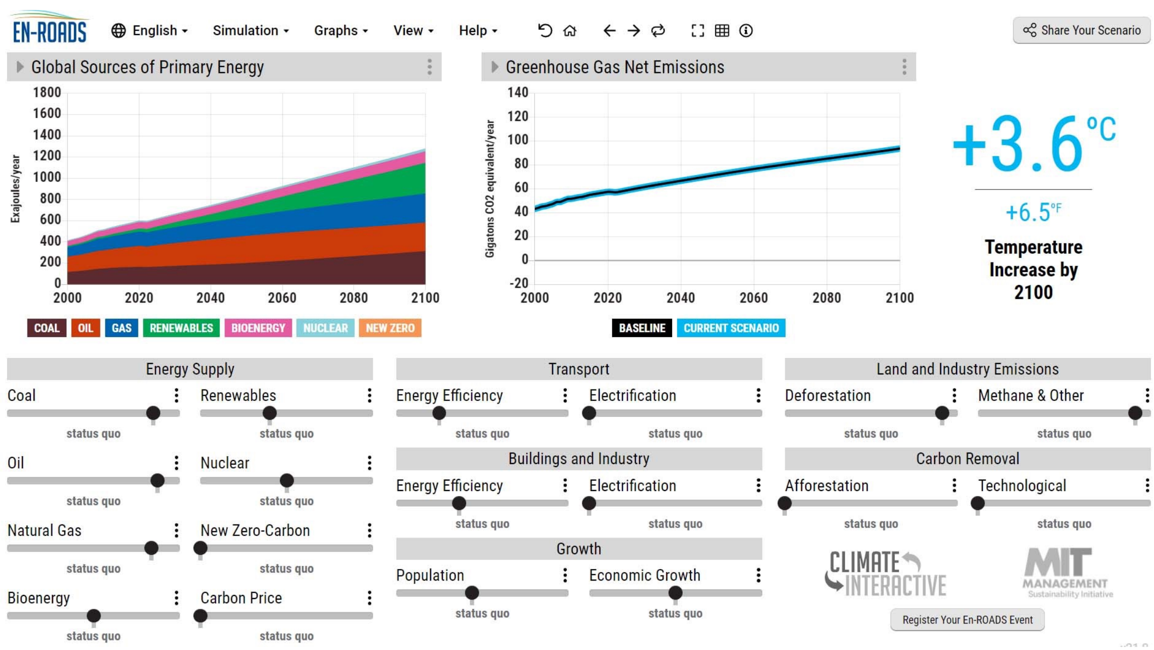




Ice Core Data: High School+ (continued)

For a complete set of resources and lesson plans go to:
https://byrd.osu.edu/educator/lessons/icecore.
There you will find:

•Ice Core Instructor Notes
•Student Handouts
•Background Reading
•Nuclear Weapons Testing History
•Slides for Instructor Presentation
•The Ice Core Virtual Lesson
•Video of Dr. Stacy E Porter explaining how ice cores reveal Earth's climate history
•Virtual Reality Tour of an Ice Core Drilling Expedition



Glossary

Cartography: The science or practice of drawing maps
Climate: average pattern of weather for a particular region
Fossil fuel: a natural fuel such as coal or gas, formed in the geological past from the remains of living organisms.
Glacier: a persistent body of dense ice that is constantly moving under its own weight.
Global warming: a gradual increase in the overall temperature of the earth's atmosphere generally attributed to the greenhouse effect caused by increased levels of carbon dioxide, chlorofluorocarbons, and other pollutants.
Greenhouse gas: a gas that contributes to the greenhouse effect by absorbing sunlight, e.g., carbon dioxide and chlorofluorocarbons.
Iceberg: a piece of freshwater ice more than 15 m long that has broken off a glacier or an ice shelf and is floating freely in open water.
Latitude: latitude is a geographic coordinate that specifies the north–south position of a point on the Earth's surface. Lines of constant latitude, or parallels, run east-west as circles parallel to the equator.
Longitude: a geographic coordinate that specifies the east-west position of a point on the Earth's surface. Longitude is measured by imaginary lines that run around the Earth vertically (up and down) and meet at the North and South Poles. These lines are known as meridian.
Magnetic Field: also known as the geomagnetic field, is the magnetic field that extends from the Earth's interior out into space, where it interacts with the solar wind, a stream of charged particles emanating from the Sun.
Radar: a detection system that uses radio waves to determine the distance, angle, or velocity of objects. It can be used to detect aircraft, ships, spacecraft, guided missiles, motor vehicles, weather formations, and terrain.
Radiation: emission of energy as electromagnetic waves.

Additional Resources

•Science Literature Outside the Textbook:
https://byrd.osu.edu/sites/default/files/ByrdBibliography.pdf
•Understanding Global Climate Change DVD:
https://byrd.osu.edu/educators/climate-change-dvd
•Water Cycles and Watersheds:
https://byrd.osu.edu/educators/watersheds
•Climate Literacy and Energy Awareness Network (CLEAN):
https://cleanet.org/index.html