

Standards and Suggestions



Science Standards and Grade-Banded Exemplar Units

The Next Generation Science Standards (NGSS) (<http://www.nextgenscience.org/>) were completed in April 2013 (with subsequent revisions in June and November, 2013). Some state governments are electing to adopt them.

Shortly after their completion, Frank Niepold and Scott Carley of CLEAN (Climate Literacy & Energy Awareness Network) analyzed the NGSS to identify how their "Performance Expectations" related to the climate science principles and concepts in the Climate Literacy document (<http://www.globalchange.gov/resources/educators/climate-literacy>). Their analysis also included correlations between the climate science principles and concepts and the three dimensions ("Disciplinary Core Ideas", "Science and Engineering Practices" and "Cross-cutting Concepts") of the 2011 National Research Council document, *A Framework for K-12 Education* (http://www.nap.edu/catalog.php?record_id=13165#), which underlies the NGSS. This work is posted online at <http://cleanet.org/clean/community/cln/NGSS.html>.

Since this analysis had already been done, we chose to use it, along with the NGSS website, the Common Core standards, and the CLEAN Collection of reviewed digital resources (at http://cleanet.org/clean/educational_resources/index.html) to construct units for teaching climate change. Each unit ties a series of high quality lessons into a coherent sequence of learning opportunities appropriate for a certain grade band. Those exemplar units can be found below in this section of the POLCA web page.

Next Generation Science Standards and Exemplar Units

By teaching units on climate change, you can cover several of the Next Generation Science Standards (NGSS). These standards were developed by a consortium of the states and are based on the *Framework for K-12 Science Education*, developed by the National Research Council.

This section provides examples of units on climate change that will cover related science standards. Each of four grade bands is covered: K-2, 3-5, 6-8, and 9-12. For each grade band, you will find a chart with relevant standards and a clarification of how each standard is relevant to climate change. The chart is followed by an exemplar unit on climate change that applies those standards. For each unit, you will find:

- Overview
- Goals
- Background information
- Time requirements
- Materials and resources
- Activities for teaching the unit

Grade Band: K-2

Unit Title: Weather, Weather, Everywhere!

| Next Generation Science Standards for K-2 | |
|--|---|
| Standard | Clarification Statement |
| K-ESS2-1. Use and share observations of local weather conditions to describe patterns over time. | Examples of qualitative observations could include descriptions of the weather (such as sunny, cloudy, rainy, and warm). Examples of quantitative observations could include numbers of sunny, windy, and rainy days in a month. Examples of patterns could include the fact that it is usually cooler in the morning than in the afternoon, and the number of sunny days cloudy days varies in different months. Assessment Boundary: The assessment of quantitative observations should be limited to whole numbers and relative measures such as warmer or cooler. |
| K-ESS3-2. Ask questions to obtain information about the purpose of weather forecasting to prepare for, and respond to, severe weather. | The emphasis is on local forms of severe weather. |
| K-ESS3-3. Communicate solutions that will reduce the impact of humans on the land, water, air, and/or other living things in the local environment | Examples of human impact on the land could include cutting trees to produce paper and using resources to produce bottles. Examples of solutions could include reusing paper and recycling cans and bottles. |
| 2-ESS1-1. Make observations from media to construct an evidence-based account that Earth events can occur quickly or slowly. | Examples of events and timescales could include volcanic explosions and earthquakes, which happen quickly, and erosion of rocks, which occurs slowly. |

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| | Assessment Boundary: The assessment of quantitative observations should be limited to whole numbers and relative measures such as warmer or cooler. |
| 2-ESS2-3. Obtain information to identify where water is found on Earth and that it can be solid or liquid. | |

Unit Overview

The first step to understanding climate change is to develop an understanding of weather and how weather impacts our day-to-day lives in our own communities. Students then have a strong foundation to begin to understand weather in other parts of the world and can begin to distinguish between weather and climate. In this unit, students will use and create instruments to make and record weather observations and data. Students will collect data over time and analyze for patterns associated with time of year and compared to data in other parts of the world. This analysis of data will begin to build preliminary understandings of climate.

Unit Goals

- Students will create and use weather measurement technology to collect data on wind speed, barometric pressure, wind direction, temperature, and precipitation.
- Students will collect data over time and will analyze patterns associated with time of year and compare local weather data to weather data in other parts of the world.
- Students will develop a preliminary understanding of the relationship between weather and climate.

Background Information:

THE DIFFERENCE BETWEEN WEATHER AND CLIMATE

<http://beyondpenguins.ehe.osu.edu/issue/weather-and-climate-from-home-to-the-poles/weather-and-climate-the-short-and-the-long-of-it>

Time Requirements

Estimated time to complete the initial unit activities with students is approximately four weeks with opportunities for students to continue to collect and analyze weather data throughout the school year.

Materials and Resources

- Big thermometer
- Art materials (paper, glue, crayons, scissors, etc.)
- 8 two liter pop bottles, (with scissors to cut them).
- 8 thermometers, (with tape).
- To build a barometer: wide-mouthed glass jar or small coffee can, balloon (recommended) or plastic wrap, rubber band, scissors, drinking straw, cardboard strip, glue (recommended) or tape, ruler and pen or pencil, small piece of modeling clay, shoe-box sized cardboard box
- To build a rain gauge: Clear plastic ruler, Cylinder shaped clear jar (e.g. an olive jar), Rubber band, Funnel, Transparent tape
- To build a thermometer: Rubbing Alcohol, Water, Cylinder shaped clear jar or bottle (bottles with a narrow neck work best), 1 straw, Modeling clay, Food coloring
- To build a weather vane: Tag board or manila file folder, Straight pin, Scissors, Glue, Pencil with a new eraser, Plastic drinking straw, Modeling clay, Paper plate
- To build an anemometer: 4 small paper cups, 4 plastic drinking straws, tape, scissors, straight pin, pencil with a new eraser, stapler
- For weather walks, materials are dependent on the type of walks you take—see lesson plan
- For How's the Weather...In Africa: Copies of a world map, Computer with Internet access, Index cards with weather words and images, Images of activities appropriate for different weather conditions and seasons

Activity 1: What's the Weather Outside Today?

This lesson is on reading a thermometer, collecting temperature data, and analyzing temperature data patterns as they connect to changing seasons. This is a good introductory lesson to explore one aspect of weather and build students' data collection and analysis skills.

<http://lessonplanspage.com/ScienceMathMeasuringTempSeasonsK1.htm/>

Activity 2: Make a Weather Station

This activity engages students in constructing weather measurement tools as students explore how weather data collection technology works. Students then collect weather data, including barometric pressure, wind direction, wind speed, temperature, and precipitation in a weather log. Students analyze the weather data, exploring patterns and changes over time.

<http://www.ciese.org/curriculum/weatherproj2/en/lesson1.shtml>

Activity 3: Weather Walks

Weather walks engage students in relevant and real-time exploration of weather events such as sunny days, rainy days, hot days, etc. Students note the characteristics of weather events with related literature connections.

<http://www.uen.org/Lessonplan/preview?LPid=10665>

Activity 4: How's the Weather...in Africa?

In this lesson, students describe and later compare how weather affects human activity in two places on opposite sides of the world. This initial exploration begins to build understandings of how weather impacts our lives and sets the stage for understanding climate.

http://education.nationalgeographic.com/archive/xpeditions/lessons/04/gk2/pgafrika1.html?ar_a=1

Grade Band: 3-5

Unit Title: Earth's Changing Climate

| Next Generation Science Standards for Grade 3 | |
|--|---|
| Category of Standard | Standard |
| 3. Interdependent Relationships in Ecosystem | |
| LS2.C: Ecosystem Dynamics, Functioning, and Resilience | The environment changes in ways that affect a place's physical characteristics, temperature, or availability of resources. As a result, some organisms survive and reproduce, others move to new locations, yet others move into the transformed environment, and some die. (secondary to 3-LS4-4) |
| 3. Weather and Climate | |
| ESS2.D: Weather and Climate | Scientists record patterns of the weather across different times and areas so that they can make predictions about what kind of weather might happen next. (3-ESS2-1) Climate describes a range of an area's typical weather conditions and the extent to which those conditions vary over years. (3-ESS2-2) |
| | Climate describes a range of an area's typical weather conditions and the extent to which those conditions vary over years. (3-ESS2-2) |

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| ESS3.B: Natural Hazards | A variety of natural hazards result from natural processes. Humans cannot eliminate natural hazards but can take steps to reduce their impacts. (3-ESS3-1) (Note: This Disciplinary Core Idea is also addressed by 4-ESS3-2.) |
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Next Generation Science Standards for Grade 4

| Category of Standard | Standard |
|---|---|
| 4. Energy | |
| ESS3.A: Natural Resources | Energy and fuels that humans use are derived from natural sources, and their use affects the environment in multiple ways. Some resources are renewable over time, and others are not. (4-ESS3-1) |
| ETS1.A: Defining Engineering Problems | Possible solutions to a problem are limited by available materials and resources (constraints). The success of a designed solution is determined by considering the desired features of a solution (criteria). Different proposals for solutions can be compared on the basis of how well each one meets the specified criteria for success or how well each takes the constraints into account. (secondary to 4-PS3-4) |
| 4. Earth's Systems: Processes that Shape the Earth | |
| ESS3.B: Natural Hazards | A variety of hazards result from natural processes (e.g., earthquakes, tsunamis, volcanic eruptions). Humans cannot eliminate the hazards but can take steps to reduce their impacts. (4-ESS3-2) (Note: This Disciplinary Core Idea can also be found in 3.WC.) |
| ETS1.B: Designing Solutions to Engineering Problems | Testing a solution involves investigating how well it performs under a range of likely conditions. (secondary to 4-ESS3-2) |

| Next Generation Science Standards for Grade 5 | |
|---|--|
| Category of Standard | Standard |
| 5. Matter and Energy in Organisms and Ecosystems | |
| LS2.B: Cycles of Matter and Energy Transfer in Ecosystems | Matter cycles between the air and soil and among plants, animals, and microbes as these organisms live and die. Organisms obtain gases, and water, from the environment, and release waste matter (gas, liquid, or solid) back into the environment. (5-LS2-1) |
| 5. Earth's Systems | |
| 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) |
| 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) |



Unit Overview

Students are introduced to global climate change, including weather and climate. They will understand some of the forces behind climate change-carbon cycle and greenhouse effect and how human activities can both negatively and positively impact Earth's climate. Students learn about the difference between weather and climate, collect weather data over time, and compare the data to climate data for their area. Students learn the basic scientific phenomena related to climate change, including the carbon cycle. They will gain an understanding of how the carbon cycle is linked to the greenhouse effect and its relation to climate change.

The students will investigate and identify sources of electricity in their community and learn how much energy typical appliances and electronics use. In a service-learning project, students learn about the impact of climate change and what they can do to reduce their individual and school's carbon footprint. By participating in the National Wildlife Federation's Cool School Challenge, students conduct an energy audit of their school and propose ways of reducing their school's energy use. Additional activities are offered for students to explore how climate change is impacting wildlife.

Goals

- Describe aspects of the environment that change on a daily, weekly, monthly, and yearly basis.
- Record weather observations such as precipitation, temperature, or cloud cover.
- Describe the area's climate and identify factors that contribute to it and have changed it over time.
- Understand what global climate change is and how it affects our lives.
- Learn how carbon is stored, and how it is moved and redistributed around the earth system via the carbon cycle.
- Learn about greenhouse gases and begin to consider what events are causing an increase in the amount of greenhouse gases in the atmosphere.
- Identify sources of electricity used in the community (e.g., hydroelectric, fossil fuels, solar, nuclear).
- Identify ways to reduce their school's carbon footprint and design and conduct a carbon-reduction action project.

Time Requirements

Two weeks or more. See each activity for suggested time frame.

Materials and Resources (identified in activities)

- Graph paper
- Pencils
- Colored pencils
- Projector/overhead for displaying information
- Internet access

Activity 1: Differences between Climate and Weather

http://eo.ucar.edu/educators/ClimateDiscovery/LIA_lesson1_9.28.05.pdf

As the first step in understanding global climate change, students need to understand the relationship between weather and climate. In this activity, students learn to collect and graph local weather data. Over several days or weeks, students graph temperature data and compare the data with average climate data where they live. They learn to distinguish between weather and climate.

Time:

- 30 minutes introduction
- 10 minutes daily (for one or more weeks)
- Part 1 graphing/analysis: 45 minutes
- Part 2 graphing/analysis: 45 minutes

Weather and Climate: What's the Difference?-A similar activity to Differences between Weather and Climate.

<http://www.ciese.org/curriculum/weatherproj2/en/activityC5.shtml>

Climate and Weather

<http://video.nationalgeographic.com/video/player/science/earth-sci/climate-weather-sci.html>

National Geographic

Supporting video on distinguishing the difference between weather and climate. Video length: 3:22 minutes.

Activity 2: Carbon Journey

Students learn the basic scientific phenomena related to climate change, including the carbon cycle. The Carbon Journey is a hands-on activity--a kinesthetic game illustrating the dynamics of the carbon cycle. Acting as carbon atoms, students

travel from one carbon reservoir to another. At each reservoir they determine, by rolling dice, how long they stay in the reservoir or how likely it is that they will move to another carbon reservoir.

http://www.andrill.org/education/elf_activities_1C.html

<http://www.andrill.org/education/Activities%20PDFs/1%20Energy/1C/carbonJourneyWCredits.pdf>

Time:

Two class periods for game and discussion

Materials:

- Beads to collect at each of the reservoirs in the journey (having a separate color for each bucket is recommended)
- Bracelet string to hold beads in order
- Buckets to represent reservoirs: Oceans, Plants, Soils, Atmosphere, Animals, Fossil Fuels, Rock, etc., labeled with photographs or pictures of carbon storage types
- Graphic of the carbon cycle
- Cardboard cubes with processes
- Labels and pictures for carbon reservoirs
- Scissors to cut out labels and string
- Glue sticks or tape -- to affix labels to buckets and cubes
- Carbon journey station labels

Activity 3: Climate Change and the Greenhouse Effect

The students will be introduced to the greenhouse effect and how it is heavily influenced by carbon emissions through a demonstration and/or hands-on lab activity. In this activity, students construct a physical model and discover that air trapped in a container will heat up more than air in an open container. The experiment/demonstration is followed by viewing a short video about the greenhouse effect and how it causes changes in global temperatures.

Time: 1 class period (approximately 45 minutes)

THE GREENHOUSE ACTIVITY IN A JAR

<http://sln.fi.edu/tfi/activity/earth/earth-5.html>

Materials (for every group of four students):

- 2 Small thermometers
- 1 Jar or other see-through container
- 1 Clock or watch
- 1 Copy of the worksheet
- Sunlamp or access to a sunny area to perform the experiment

A HOME RUN ON STEROIDS: BASEBALL AND CLIMATE CHANGE

<http://www.climatecentral.org/blogs/steroids-baseball-and-climate-change>

National Center for Atmospheric Research, Climate Central

This short cartoon video uses a simple baseball analogy (steroid use increases probability of hitting home runs) to explain how small increases in greenhouse gases can cause global temperature changes and increase the probability of extreme weather events.

Video length: 2:04 minutes

GLOBAL WARMING FAQ, NOAA SATELLITE AND INFORMATION SERVICE

<http://www.ncdc.noaa.gov/oa/climate/globalwarming.html>

The National Oceanic and Atmospheric Administration created this page to help kids (and adults!) learn more about the greenhouse effect and how it is impacting our planet.

Global Warming Movie, EPA Kids Site http://epa.gov/climatechange/kids/global_warming_version2.html

This website, from the Environmental Protection Agency, provides an animated step-by-step breakdown of the greenhouse effect. The animation is narrated by two young students and is presented in kid-friendly language.

PHOTOSYNTHESIS, TREES, AND THE GREENHOUSE EFFECT, NATIONAL GEOGRAPHIC XPEDITIONS

<http://www.nationalgeographic.com/xpeditions/lessons/08/q68/brainpopphoto.html>

Designed for grades 6–8, this lesson plan leads students in a lab that will help them understand where greenhouse gases come from and also help them begin to think about how we can regulate greenhouse gases.

CLIMATE SCIENCE IN A NUTSHELL: WHERE CARBON DIOXIDE COME FROM?

<http://www.planetnutshell.com/videos/climate-science-in-a-nutshell-5-where-does-carbon-dioxide-come-from>

Planet Nutshell, Utah Education Network

This short video discusses where carbon dioxide, the gas that is mainly responsible for warming up our planet and changing the climate, comes from. It discusses how the rise in

atmospheric carbon dioxide comes directly from the burning of fossil fuels and indirectly from the human need for energy.

Video length: 2:49 minutes.

NPR short videos about carbon and global warming. <http://www.npr.org/news/specials/climate/video/>

Activity 4: Energy

In these activities and videos, students learn about sources of energy, how much energy typical appliances and electronics use, and how much carbon dioxide is released to produce the energy.

PLUGGED IN TO CO₂

http://www.windows2universe.org/teacher_resources/teach_pluggedCO2.html

Lisa Gardiner, Marie Johnson, Jonathan Hoffman, Windows to the Universe

In this classroom activity, students measure the energy use of various appliances and electronics and calculate how much carbon dioxide (CO₂) is released to produce that energy.

Time: 1-2 class periods

Materials:

- Kill-a-Watt meter
- Power strip and outlet
- A collection of small appliances and lamps (may include toaster, microwave, hairdryer, lamp with CFL, lamp with incandescent bulb, cell phone and charger, laptop and charger, iPod and charger, CD player, TV, DVD, video game player, blender, nightlight, vacuum, coffee maker, fan)
- Pencils

ENERGY SOURCES

This video provides an introduction to benefits and limitations of many sources of energy including fossil fuels, nuclear, hydro, wind, solar, geothermal, and biomass. It also discusses hydrogen and hybrid cars.

Video length: 6:09 min.

<http://www.pbslearningmedia.org/resource/phy03.sci.ess.earthsys.energysource/>

WGBH - PBS, Teachers' Domain

SOLUTIONS AND SERVICE PROJECTS

Students learn about the impact of climate change and what they can do to

reduce their individual and school's carbon footprint. Students view a music video on the causes and effect of climate change and then view a short video on how one individual has worked to reduce his family's carbon footprint. The students conduct an action project by participating in the National Wildlife Federation's Cool School Challenge. Students conduct an energy audit of their school and propose ways of reducing their school's energy use.

TAKE AIM AT CLIMATE CHANGE

<http://passporttoknowledge.com/polar-palooza/whatyoucando/taacc/>

This music video features a rap song about some of the causes and effects of climate change with the goal of increasing awareness of climate change and how it will impact nature and humans. The website also includes links to short fact sheets with lyrics to the song that are annotated with the sources of the information in the lyrics. Video length 4 minutes

A STRICT CARBON DIET

<http://www.pbs.org/wgbh/nova/tech/carbon-diet.html>

Doug Hamilton, Producer, NOVA (WGBH-TV)

This short video follows San Francisco inventor and engineer Saul Griffith as he determines his family's carbon footprint and develops a special cargo bike to further reduce his individual footprint. This video highlights innovation, creativity, and design as solutions to problems. The overall message is inspiring and proactive.

Video length: 2:58 min.

THE COOL SCHOOL CHALLENGE-NATIONAL WILDLIFE FEDERATION ECO-SCHOOLS PROGRAM

Students challenge classrooms to reduce their carbon emissions and use a carbon calculator to evaluate progress. Students conduct classroom energy audits and identify major sources of carbon dioxide emissions and ways to reduce their school's energy use. The Cool School Challenge is an educational program intended to engage students and teachers in practical strategies to reduce carbon dioxide (CO₂) and other greenhouse gas emissions schoolwide. Through improved energy efficiency, reduced consumption, increased recycling, and changes in transportation behaviors, Challenge participants will learn how simple actions, taken together, can create a climate of change.

Action project that includes an energy audit, evaluation and action project. Elementary and secondary materials.

<http://www.nwf.org/Eco-Schools-USA/Become-an-Eco-School/Cool-School-Challenge.aspx>

Additional Activities and Resources

National Wildlife Federation, Climate Change 101

NWF provides information for kids about climate change and lesson plans for the classroom on how climate change is impacting wildlife.

<http://climateclassroomkids.org/>

Climate Change Live

<http://climatechangelive.org/index.php?pid=180#4>

CURRICULUM RESOURCES

Global Warming & the Greenhouse Effect. Great Explorations in Math and Science (GEMS), Lawrence Hall of Science, University of California at Berkeley.

Climate Change: Connections and Solutions. An interdisciplinary Curriculum. Facing the Future. www.facingthefuture.org. Curriculum is under their free downloads section.

National Wildlife Federation: Energy Conservation Did I Remember to...

<http://www.nwf.org/pdf/Schoolyard%20Habitats/EnergyConservation.pdf>

Lessons designed to engage student in learning good conservation techniques and practices to use at home and at school. Grades 4-6

Grade Band: 6-8

Unit Name: Arctic Investigations

| Next Generation Science Standards for Grades 6-8 | |
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| Disciplinary Core Ideas | |
| Category of Standard | Standard |
| 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) |

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| 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) |
| Performance Expectations | |
| Category of Standard | Standard |
| 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. |
| MS-ESS3-5 | Ask questions to clarify evidence of the factors that have caused the rise in global temperatures over the past century. |
| MS-ESS3-2 | Analyze and interpret data on natural hazards to forecast future catastrophic events and inform the development of technologies to mitigate their effects. |

Unit Overview

By participating in inquiry-based activities, students become climate scientists as they investigate rapid changes happening in the Arctic regions. Students will use real data collected by climate scientists to determine the rate and severity of changes such as melting sea ice, population declines, and impacts on local peoples. The unit will conclude with activities geared toward a reduction of energy and natural resources that will help students connect their lifestyle choices to reducing the rate of changes in the Arctic.

Unit Goals

[CLEAN](http://cleanet.org/index.html) is the Climate Literacy and Energy Awareness Network (<http://cleanet.org/index.html>). Using activities from [CLEAN](http://cleanet.org/index.html), the students will investigate the following questions:

- How is climate change impacting the Arctic region?
- What is causing these changes?

- How do scientists track changes? Predict future climate?
- How does arctic climate change affect people, wildlife, global climate?
- What can we do?

Time Requirements

The time requirements for each activity are only an estimate. This unit can be done in its entirety within a whole year, within a semester or over several weeks. Teachers can pick and choose various activities to accommodate for time constraints.

Materials

Materials needed for entire unit (see activity links for specific materials):

- Computer/iPad with internet access
- Pencils
- Notebook/scrap paper
- Posterboard
- Markers
- Graph paper
- Projector or Smart Board

Additional Resources

SEA ICE INDEX ANIMATION TOOL

http://nsidc.org/data/seaice_index/archives/image_select.html

Summary: This visualization presents a collection of sea ice data taken over a period of 34 years. Selected data can be animated to show changes in sea ice extent over time. Data is added by the National Snow and Ice Data Center as it becomes available.

COMBATING GLOBAL WARMING MIND MAP

<http://media.learningfundamentals.com.au/combating-global-warming-map.jpg>

Summary: An attractive concept/mind map that illustrates various human strategies for responding to climate change. It was developed by a psychologist and not by an educator or scientist but can be used to inspire discussion and artistic representations of the human dimension to climate and energy issues.

Activity 1: How is climate change impacting the Arctic region? (photo comparison activity only)

Investigation 4 - Changes in Our Local Environment

<http://seagrant.uaf.edu/marine-ed/curriculum/grade-8/investigation-4.html>

Time: One to two 45-minute periods to complete photo comparison activity

Summary: Based on the information and photos they acquired from the interview, students return to photo locations to observe and record changes. Finally, they develop ideas about potential impacts of a warming climate on the ecosystem that surrounds the students.

Activity 2: What is causing these changes?

GREENHOUSE GASES EXPOSED

http://www.ecohealth101.org/index.php?option=com_content&view=article&id=180%3Ateachers-lp-greenhouse-article&catid=130&Itemid=272



Time: One 45-minute period

Summary: In this activity, students learn about the relationship between greenhouse gases and global warming through a simple teacher demo or hands-on lab activity. Everyday materials are used: beakers, baking soda, vinegar, candle, thermometers, heat source such as a goose-necked lamp, etc. Students shine a light onto three thermometers: a control, an upside down beaker w/ a thermometer and air, and a beaker in which CO₂ had been poured.

USING THE VERY, VERY SIMPLE CLIMATE MODEL IN THE CLASSROOM

http://www.windows2universe.org/teacher_resources/teach_climatemodel.html

Time: Two 45-minute periods

Summary: Through a simple online model, students learn about the relationship between average global temperature and carbon dioxide emissions while predicting temperature change over the 21st Century.

Activity 3: How do scientists track changes? Predict future climate? (Teacher picks one)

1) WHITHER ARCTIC SEA ICE?

<http://serc.carleton.edu/eet/seaice/index.html>

Time: Two or three 45-minute periods

Summary: In this activity, students work with real datasets to investigate a real situation regarding disappearing Arctic sea ice. The case study has students

working side-by-side with a scientist from the National Snow and Ice Data Center and an Inuit community in Manitoba.

2) GETTING TO THE CORE OF CLIMATE CHANGE

How can we use ice core data from the polar regions to investigate changes in Earth's climate past, present, and future?

http://tea.armadaproject.org/activity/leppik/gettingtothecoreofclimatechange_main.html

Time: Four to five 45-minute periods

Summary: Students investigate climate changes going back thousands of years by graphing and analyzing ice core data from Greenland and Antarctica. They use information about natural and human-caused changes in the atmosphere to formulate predictions about the Earth's climate.

Activity 4: How does arctic climate change affect people, wildlife, global climate?

PEOPLE

Eyewitnesses to Change: http://forces.si.edu/arctic/pdf/ACT%201_EYEWITNESS.pdf

Link to video: <http://forces.si.edu/arctic/video/eyewitness.html>.

Time: Two 45-minute periods

Summary: Students explore recent changes in the Arctic's climate that have been observed and documented by indigenous Arctic residents. Students watch a video, take notes, and create a concept map. Students also examine historical weather data for an Arctic community.

WILDLIFE

Students can choose one activity to complete for this section.

1) *Changes Ahoof: Could Climate Change Affect Arctic Caribou?*

http://forces.si.edu/arctic/pdf/ACT%205_CHANGES%20AHOOF.pdf

Time: One 45-minute period

Summary: Students run a simplified computer model and create board games to explore how climate conditions can affect caribou—the most abundant grazing animal in the Arctic.

2) *March of the Polar Bears: Global Change, Sea Ice, and Wildlife Migration*

http://mynasadata.larc.nasa.gov/lesson-plans/1332-2/?page_id=474?&passid=90

Time: Two 45-minute periods

Summary: Students will use NASA satellite data to study temperature and snow-ice coverage in the South Beaufort Sea, Alaska. The data can be used to correlate with USGS ground tracking of polar bears, and to relate this to global change, sea ice changes, and polar bear migration. The data can be used to draw conclusions surrounding any migration patterns in the region.

GLOBAL CLIMATE (FEEDBACK EFFECTS)

Changing Planet: Thawing Permafrost and Methane (Video)

<http://www.nbclearn.com/changingplanet/cuecard/52627>

Time: 20-25 minutes to watch video and discuss with class

Summary: This video examines the thawing of permafrost due to changes in climate and shows examples of the impacts that warming temperatures have on permafrost in the Arctic, including the release of the greenhouse gas methane. Dramatic results are shown, including sink holes forming on the landscape and beneath buildings, roads, and other infrastructure, causing some communities to relocate.

UNDERSTANDING ALBEDO

http://www.arcticclimatemodeling.org/lessons/acmp/acmp_912_ClimateChange_UnderstandingAlbedo.pdf

Time: One 45-minute period

Summary: Students learn about albedo and the ice albedo feedback effect as it relates to snow, ice, and the likely results of reduced snow and ice cover on global temperatures.

Activity 5: What can we do?

PLUGGED IN TO CO₂

http://www.windows2universe.org/teacher_resources/teach_pluggedCO2.html

Time: One to two 45-minute class periods

Summary: Students investigate various appliances and electronics, discovering how much energy each uses and how much carbon dioxide (CO₂) is released to produce that energy.

THE LIFESTYLE PROJECT

<http://serc.carleton.edu/introgeo/enviropjects/lifestyle.html>

Time: Can be completed during entire unit or as an independent unit to complement this one

Summary: This three-week project challenges students to learn about environmental alternatives by modifying their own lifestyles. Throughout the project, students reduce their impacts on the environment by changing the way in which they live from day to day.

Grade Band: 9-12

Unit Title: Large Volcanic Eruptions and How They Affect Climate Change

Next Generation Science Standards:

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|------------|--|
| 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. [Clarification Statement: Examples of the causes of climate change differ by timescale, over 1-10 years: large volcanic eruption, ocean circulation; 10-100s of years: changes in human activity, ocean circulation, solar output; 10-100s of thousands of years: changes to Earth's orbit and the orientation of its axis; and 10-100s of millions of years: long-term changes in atmospheric composition.] [Assessment Boundary: Assessment of the results of changes in climate is limited to changes in surface temperatures, precipitation patterns, glacial ice volumes, sea levels, and biosphere distribution.] |
| 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. [Clarification Statement: Examples of evidence, for both data and climate model outputs are for climate changes (such as precipitation and temperature) and their associated impacts (such as on sea level, glacial ice volumes, or atmosphere and ocean composition).] [Assessment Boundary: Assessment is limited to one example of a climate change and its associated impacts.] |

Unit Overview: Students will begin to analyze data and the results of global climate models to predict how regional climate will be altered after a large volcanic eruption. Students will be able to show an understanding of how using models can help explain how the variations in the flow of energy into the atmosphere and geosphere can result in changes in our climate over a time period of 10 years. In this unit, students will analyze and create models from evidence collected from satellite photos and NOAA data and predict the future impacts on regional climate and possible impacts on the whole world. Students will analyze collected data over

time and create a model comparing data to that of other parts of the world. This analysis of data will demonstrate a growing mastery in understanding climate change.

Unit Goals:

- Students will analyze and create models from evidence collected from satellite photos and NOAA data.
- Students will analyze data collected over time and will look for patterns associated with time of year and compare local weather data to weather data in other parts of the world.
- Students will predict the future impact of the climate on the regional climate and possible impact on the whole world.

Background Information: *Scientific American* article – “How Do Volcanoes Affect Climate?”

<http://www.scientificamerican.com/article.cfm?id=how-do-volcanoes-affect-w>

Time Requirements: Estimated time to complete the activities with students is approximately 5 or 6 (50 minute) periods.

Materials and Resources:

- Computer(s) for researching volcanic eruptions
- Poster size map of the world
- Student pages from Activity A and B
- A blank 8.5 x 11 in. map of the world with latitude and longitude lines found at the following link: <http://www.freeusandworldmaps.com/images/WorldPrintable/WorldMercator6LinesPrint.jpg>
- Data tables from activity A and B at the end of this lesson plan
- Coloring pencils
- Ruler
- Blank map of North America (US and Canada) found at: <http://1.bp.blogspot.com/-ztwMAmt7hck/T12d0V0IYhI/AAAAAAAAABkA/KaYFJC8qgjc/s1600/blank-north-america-map.png>
- A copy of the Jet Stream Map found at: <http://www.intellicast.com/National/Wind/JetStream.aspx>

Day 1 Activity: 10 Biggest Volcanic Eruptions in History

Students will choose one volcanic eruption from this list and research the history of the eruption. As a class, students should brainstorm questions that will guide

their research of the eruption of their choice. Students will need to begin to create a list of critical vocabulary words and their definitions from their research. The students will need to compile this list as a class. This research will be used in Day 4 and 5 activities.

<http://www.livescience.com/30507-volcanoes-biggest-history.html>

VEI - Volcanic Explosion Index

<http://www.unc.edu/~rowlett/units/scales/VEI.html>

Days 2 and 3: Krakatoa - Youtube Video (52 minutes)

*Note to teachers: There are two parts to this video. Depending on time, we recommend Part 2 of this video if you only have one class period to spend studying the effect of volcanic eruptions. However, if time allows, Part 1 of this video shows the earth systems of how an eruption begins and builds. If you can show both parts of this video, you can make connections to HS-ESS-2-2 and HS-ESS-2-3. As always, preview the videos before you show them to your students.

Experience the volcanic eruption of Krakatoa - the loudest sound ever heard. Have the students create a timeline of events that lead up to the main eruptions and discuss the environmental impact of this massive eruption on the South Pacific islands and the World.

Creative Writing Activity: Students can create a journal entry that would be similar to those found from 1883 that help today's scientists understand what was happening around them. Have the students pretend to live in Sumatra and describe to future generations what they experience as a series of quakes, eruptions, and how a tsunami devastates the area.

Part 1: (52 minutes) <http://www.youtube.com/watch?v=ha4LQGe6NxY>

Part 2: (Recommended-52 minutes)<http://www.youtube.com/watch?v=YqGkjDIEaMA>

Days 4/5: Below is a link to NOAA activities that will take 2 days to complete. Students will need to answer all questions within the daily activities and complete all tables, charts and maps.

Activity A: Day 4 - Where and when have major volcanic eruptions occurred?

Activity B: Day 5 - How are aerosols dispersed through the atmosphere after a volcanic eruption?

Links to activities found at: http://www.esrl.noaa.gov/gmd/infodata/lesson_plans/Volcanoes%20and%20Climate%20Change.pdf

Day 6: Students will need to choose one of the following Cascade Mountains: Mt. Rainier, Mt. Baker, Mt. St. Helens, or Mt. Hood. Students will be given a copy of a map of North America, a copy of the Jet Stream map, a copy of a world map, and a ruler. Based on the location of the volcano they select in the Cascades Mountains, students will need to determine where the ash plume will be carried and predict a five-day progression of the ash across North America based on jet stream wind speeds. Have them investigate the following: a) How many days would it take for the ash cloud to reach the Atlantic Ocean? and b) If the jet stream were to continue at the same rate of speed, how many days would it take the ash to circle the Earth one time?

Enrichment Activities:

If time permits on any of the previous days:

Have students explore the VAAC website and answer: What is its purpose? What information can geoscientists and environmental scientists all over the world gain from these pages? <http://www.ospo.noaa.gov/Products/atmosphere/vaac/>

Have students watch webcams that are streaming data video from active volcanoes around the world at <http://www.ospo.noaa.gov/Products/atmosphere/vaac/webcams.html>

Grade Band: 9-12

Unit Name: What Can We Do About Climate Change?

| Next Generation Science Standards | |
|-------------------------------------|---|
| Disciplinary Core Ideas | |
| Standard | Clarification Statement |
| ESS2.A: Earth Materials and Systems | The geological 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) Gradual atmospheric changes were due to plants and other organisms that captured CO ₂ and released oxygen. (HS-ESS2-6),(HS-ESS2-7) |
| 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-ESS2-4) |

| | |
|--|--|
| | <p>Changes in the atmosphere due to human activity have increased CO₂ concentrations and thus affect climate. (HS-ESS2-6),(HS-ESS2-4)</p> <p>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)</p> |
| ESS3.A: Natural Resources | <p>Resource availability has guided the development of human society. (HS-ESS3-1). All forms of energy production and other resource extraction have associated economic, social, environmental, and geopolitical costs and risks as well as benefits. New technologies and social regulations can change the balance of these factors. (HS-ESS3-2)</p> |
| ESS3.C: Human Impacts on Earth Systems | <p>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)</p> |
| ESS3.D: Global Climate Change | <p>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)</p> <p>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)</p> |
| ETS1.A: Defining and Delimiting Engineering Problems | <p>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)</p> |

| Performance Expectations | |
|--------------------------|---|
| Standard | Clarification Statement |
| 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. |
| HS-ESS2-7: | Construct an argument based on evidence about the simultaneous coevolution of Earth's systems and life on Earth. |

| | |
|------------|--|
| 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-ESS3-2: | Evaluate competing design solutions for developing, managing, and utilizing energy and mineral resources based on cost-benefit ratios. |
| 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. |
| HS-ETS1-1: | Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants. |

Unit Overview: During this unit, students engage in a wide variety of experiences to gain an understanding of the natural climate system, how this system is changing due to human activities, and how technology and engineering can help us learn more about problems and solutions associated with climate change.

Unit Goals: Using activities from the CLEAN Collection, students will:

- Identify how the climate system has changed over the history of the earth.
- Examine and explain historic climate data for a region.
- Measure and calculate the radiative budget for a variety of Earth surfaces.
- Identify how changing the composition by burning fossil fuels and adding CO₂ to the atmosphere is affecting the planet's radiative budget.
- Evaluate how different existing energy technologies can help to reduce the amount of CO₂ humans are adding to the atmosphere to make societies more sustainable.
- Model and predict the impacts of climate change.
- Investigate the role of engineering to help humans mitigate and adapt to climate change.

Time Requirements: Two to three weeks, depending on the depths of exploration.

Materials: (see activity links for specific materials)

- Computers with Internet access
- Pencils and pens
- Paper (blank, lined, and graph)
- Projector and/or SmartBoard

Extra Resources: *EarthLabs for Educators* found at: <http://serc.carleton.edu/earthlabs/index.html>. This link provides a rich and varied set of resources that will help the educator identify a variety of strategies that will enable a more rigorous and relevant approach to teaching about climate and climate change.

LASP: Climate Change Compendium

<http://lasp.colorado.edu/home/education/k-12/climate-change-compendium/#Grades9-12>

The Climate Change Compendium contains activities and lessons from a variety of sources that will help facilitate classroom studies about the serious issues involved in climate change. Students will be able to learn about the greenhouse effect, natural and human climate records, albedos, feedback loops, and how all of these factors are affecting the polar regions. The Compendium provides background readings, scope and sequences, image banks, and evaluation tools to help teachers bring climate change science into the classroom. At the end of each grade level are various activities outlining what we can do, as well as strategies to reduce the nation's greenhouse gas emissions.

Activities:

A. Interactive Geologic Timeline Activity (ESS2.A)

<http://www.ei.lehigh.edu/eli/cc/sequence/day15.html>

Environmental Literacy and Inquiry Working Group at Lehigh University

Time: One class period or homework assignment

Summary: Students use a web-based geologic timeline to examine temperatures, CO₂ concentrations, and ice-cover data to investigate how climate has changed in the last 715 million years.

B. Normal Climate Patterns (ESS2.D)

<http://serc.carleton.edu/earthlabs/drought/3.html>

Betsy Youngman, LuAnn Dahlman, Earthlabs from TERC

Time: Two class periods.

Summary: Students make in-depth examinations of historical climate data in both graphical and map formats.

C. Earth's Albedo (ESS2.D)

http://www.andrill.org/education/elf_activities_1D.html

Environmental Literacy Framework, ANDRILL

Time: One Class Period

Summary: Students measure albedo using maps and data tables. They estimate the Earth's energy budget by calculating the absorbed radiation of various Earth surfaces.

D. Climate Science in a Nutshell: Where CO₂ Come From? (ESS2.D)

<http://www.planetnutshell.com/videos/climate-science-in-a-nutshell-5-where-does-carbon-dioxide-come-from>

Planet Nutshell, Utah Education Network

Time: the first five minutes of class

Summary: Students view a short video that explains that burning fossil fuels is causing an increase in atmospheric CO₂ which is changing the composition of the atmosphere and causing the climate to warm. (Use as an introduction to the Mass Balancing Model by SERC)

E. Using a Mass Balance Model to Understand CO₂ and Its Connection to Global Warming (ESS2.D)

http://serc.carleton.edu/quantskills/activities/co2_global.html

Robert MacKay, SERC - Teaching Quantitative Skills in Geoscience Collection

Time: Two-three class periods

Summary: Students use an interactive online mode to examine the changes in atmospheric CO₂ for the past several decades. Students make predictions about current and future levels of CO₂ emissions. (Two-three class periods)

F. Stabilization Wedges Game (ESS3.A)

<http://cmi.princeton.edu/wedges/game.php>

Carbon Mitigation Initiative, Princeton University

Time: Two class periods.

Summary: Students work in teams to learn how existing technologies can be implemented and used to dramatically reduce carbon emissions. Students select carbon-cutting strategies to create a carbon mitigation profile, filling in the wedges of a climate stabilization triangle.

G. Earth-the Operator's Manual (ESS3.C)

<http://earththeoperatorsmanual.com/feature-video/earth-the-operators-manual>

Earth-The Operator's Manual, Richard Alley

Time: 1-3 class periods depending on how much of the video series is shown

Summary: This video series provides students with a detailed accounting of the resources that we have available to us and how we can change our usage to become a more sustainable civilization.

H. Changing Planet: Rising Sea Level (ESS3.D)

<http://www.nbclearn.com/changingplanet/cuecard/53460>

NBC Learn, Windows to the Universe

Time: 6:21 minutes

Summary: This video introduces students to some of the social and economic impacts of sea level rise due to global warming. Students hear from scientists who are using different types of technology to measure and observe changes that allow them to model and predict the changes they are witnessing.

I. Carbon Temperature Model (ESS3.D)

<http://earth4u.challenger.org/>

Time: One to two class periods.

Summary: Students select different scenarios (deforestation, volcanoes, hurricanes) and change the inputs and outputs in this interactive model on carbon-temperature relationships. As users change variables, the results are

graphically represented, demonstrating how selections affect the whole system.

J. Connecting Global Climate Change with Engineering (ETS1.A)

<http://www.pbs.org/teachers/stem/professionaldevelopment/050/>

NASA and PBS Teachers

Time: Three to five class periods.

Summary: As students explore engineering careers, they investigate the role of engineering solutions in mitigating and adapting to climate change. Options include removing and storing CO₂