Lesson Plan: Is It Getting Hot in Here?

Climate Change / Grades 9-12 / Earth Science

Focus Question

What are some causes and consequences of global climate change?

Learning Objectives

1. Students will define "forcing factor" and describe at least five forcing factors for climate change.
2. Students will describe at least five ways in which climate change could affect human communities.
3. Students will cite at least three lines of evidence that suggest the Earth's climate may change in the 21st century.

Links to Overview Essays and Resources Needed for Student Research

http://oceanservice.noaa.gov/topics/coasts/ecoscience/

http://coastalscience.noaa.gov/stressors/climatechange

Materials

- Copies of "Climate Change Student Worksheet" found at the end of this lesson plan, one copy for each student or student group. Click here for a seperate printable worksheet.
- (optional) Computers with Internet access; if students do not have access to the Internet, download copies of materials cited under "Learning Procedure" and provide copies of these materials to each student or student group.

Audio/Visual Materials

None

Teaching Time

One or two 45-minute class periods, plus time for student research

Seating Arrangement

Groups of 2-3 students

Maximum Number of Students

21, if each group is to have a unique report topic

Key Words

Climate change
Forcing factor
Greenhouse gas
Paleo proxy

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Background Information

More than half of the U.S. population lives near a coast, and about one of every six jobs in the U.S. is related to coastal or marine resources. Ocean and coastal waters provide food, recreational opportunities, habitats for diverse plant and animal life, minerals, and transportation resources that support trade and commerce. These benefits cannot be taken for granted, because coastal environments are constantly subjected to forces that cause dramatic change. In addition to natural processes such as winds, storms, and rainfall, coastal environments are affected by forces resulting from human activities including pollution, invasive species, and climate change. Climate change associated with human activities increases natural climate variability and adds to natural stresses already present in coastal ecosystems. Processes that cause climate change are called "forcing factors," and can be grouped into five categories:

1. **Ocean Temperature and Sea Ice** – In some part of the ocean, seawater temperatures rose during the last half of the 20th century, causing significant reductions in the extent of sea ice. By the end of the 21st century, seawater temperatures are expected to be much higher, and Arctic sea ice may be absent for most of the year. These changes will dramatically alter many marine ecosystems, and may result in deadly stress to organisms such as corals that live in habitats where temperatures are already near lethal levels. The disappearance of Arctic sea ice may result in extinction of polar bears and other species that depend upon this habitat.

2. **Sea Level Rise** – Globally, sea levels rose by 4-8 inches during the 20th century, continuing a trend that has been underway since the last ice age. But the rate of change is increasing, and the rise of global sea levels is expected to be several times larger during the 21st century. In areas where land is sinking (such as Louisiana and Texas), the relative change in sea level may be as much as 20-40 inches. Impacts of higher sea levels include increased coastal erosion,disappearance of many coastal habitats and their associated natural resources, and intrusion of saltwater into drinking water supplies and freshwater ecosystems.

3. **Ocean Currents** – Changes in global temperature could lead to changes in ocean circulation (such as El Niño in the Pacific Ocean). Such changes in the Atlantic Ocean could alter the flow of the Gulf Stream and cause major air temperature alterations in the North Atlantic, resulting in colder climates in western European countries that are presently warmed by the Gulf Stream.

4. **Coastal Storms** ñ Warmer temperatures can be expected to increase wind speed and rainfall in hurricanes, and the impacts of storm surges will be greater because of higher sea levels. Consequently, the damage to human communities normally associated with hurricanes will be more

severe, coastal ecosystems will experience greater disturbance and stress, and supplies of fresh water may be jeopardized by saltwater intrusion.

5. **Freshwater Inflow** ñ Changing climates are likely to produce significant changes in runoff and river flows, which will affect the influx of chemicals and sediments to estuaries and coastal waters. Because these ecosystems are important nursery habitats for many species and help protect inland areas from erosion by coastal storms, alterations in freshwater flow are likely to be accompanied by stress to living organisms and human communities that depend upon these systems.

Earth's climate has changed many times in its 4,500 million-year history. Regardless of their cause, the climate changes expected during the 21st century will profoundly alter coastal ecosystems as we know them today. Because we depend on these ecosystems in many ways, it is vital to understand the causes of climate change, the resulting impacts to coastal environments, and how human communities should respond. The National Ocean Service's National Centers for Coastal Ocean Science are conducting research to understand the relationship of human-associated and natural climate change forces so that potential impacts on critical coastal ecosystems can be predicted and, where possible, mitigated. In this lesson students will investigate the history and causes of climate change, how these changes have affected natural systems and human communities, and what changes are forecast for the future.

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Learning Procedure

1. To prepare for this lesson, review questions on the ìClimate Change Student Worksheet.î Make copies of the worksheet, one copy for each student or student group

   If you do not plan to have students use the internet for research, download the following:

   - ìOverview of Climate Processesî (http://www.ngdc.noaa.gov/paleo/ctl/about4.html; the Overview includes four Web pages: The Big Picture, The Greenhouse Planet, Climate and the Water Balance, and Time Scales of Climate Change); and
   - ìClimate TimeLine Tutorialî (http://www.ngdc.noaa.gov/paleo/ctl/drought.html; the Tutorial includes three Web pages: Introduction, The Hydrograph Story, and Drought Data Inquiry)

   Make a copy of these pages for each student group. Most of these pages have links to other relevant topics, some of which you may also want to copy.

2. Lead a brief discussion of students' ideas about climate change, including whether they think Earth's climate really is changing, possible causes for such change, and the potential consequences of these changes to natural systems and human communities.

3. Have each student or student group complete the ìClimate Change Student Worksheet.î Lead a discussion of studentsí answers to the worksheet questions.

   Correct answers are:

   1. The primary force outside the Earth's internal system that drives the planet's weather and climate systems is the sun.
   2. Two factors outside Earth's environment and climate system that can cause the amount of energy reaching the surface of the Earth to vary are internal processes within the sun and changes in the Earth's orbit.
   3. About 30% of the radiation entering the Earth's atmosphere is reflected back to space, and about 70% is absorbed by the atmosphere and surface of the planet.
   4. About 25% of the radiation entering the Earth's atmosphere is absorbed by greenhouse gases.
   5. In recent years, concern has grown that human activities, especially the combustion of fossil

fuels, are increasing carbon dioxide levels in the atmosphere to levels that haven't been seen in over 400,000 years.

6. Venus receives about twice the radiation received by Earth and has an atmosphere rich in carbon dioxide.
7. Residence time is the time it takes for a volume of water to cycle through the hydrologic system.
8. Tectonic scales are used to describe variation in Earth's climate over the past 300 million years.
9. Orbital scales are used to describe variation in Earth's climate over the past 3 million years.
10. Centennial scales are used to describe variation in Earth's climate over the past 1,000 years.
11. Temperature is the primary measure of climate and can be measured or reconstructed for the Earth's surface and sea surface.
12. Biomass and vegetation patterns may be discerned in a variety of ways and provide evidence of how ecosystems adapt to climate change.
13. Sea level is usually related to the degree of ice coverage in high latitudes and elevations.
14. Volcanic eruptions can alter climate due to aerosols emitted into the atmosphere.
15. Climate forcing refers to specific phenomena that directly influence changes in climate.
16. The hydrologic cycle has been described as Earth's thermostat.
17. Water vapor is the primary greenhouse gas in the atmosphere.
18. Milankovitch cycles are changes in Earth's orbit that occur in 100,000, 41,000, and 21,000 year periods.
19. Pacific Decadal Oscillation (PDO) is a cycle in the sea surface temperature pattern across the North Pacific Ocean that recurs approximately every ten years.
20. El Niño Southern Oscillation (ENSO) is an oscillation in sea surface temperature and surface pressure across the tropical Pacific Ocean, causing both local and global changes in weather and climate.

4. Tell students that their assignments are to use NOAA's Climate TimeLine Information Tool (http://www.ngdc.noaa.gov/paleo/ctl) to prepare reports on climate variation over various time scales. The Climate TimeLine provides information for time scales of 1 day, 1 year, 10 years, 100 years, 1,000 years, 10,000 years, and 100,000 years. Assign one of these time scales to each student group. Tell students that their reports should summarize information under the "Climate Science " heading for their assigned time scale, including forcing factors, relevant measurements, and how these measurements are made. To access this heading, students should move their cursor over the appropriate time scale on the left side of the page. A menu will pop up with "Summary, " "Climate Science," "Climate History," and "Resources" headings. They should select "Climate Science," and they're off. Students should also review information on adjacent time scales for additional data that may be relevant to their own.
5. Have each student group present their reports. Key points for each time scale are:

1 day – Forcing Factors: Earth's rotation on its axis; rotation of moon around the Earth; volcanic aerosols may induce short-term variations; biological activity can produce short-term fluctuations in atmospheric carbon dioxide concentrations. Relevant Measurements: temperature, rainfall, surface water flows; measured with thermometers, satellites, rain gauges, and stream gauges.

1 year – Forcing Factors: Earth's 23.5° tilt on its axis and revolution around the sun; biological carbon metabolism may affect annual atmospheric carbon dioxide concentrations; volcanic aerosols may induce short-term variations. Relevant Measurements: temperature, rainfall, surface water flows; measured with thermometers, satellites, rain gauges, and stream gauges; paleo proxies such

as tree rings and cores from corals, ice caps, and glaciers can provide historic information.

10 year – Forcing Factors: the El Niño Southern Oscillation (ENSO) is the largest single source of climate variability at this time scale; sunspots may have an influence as well, but this is not certain. Relevant Measurements: temperature, rainfall, surface water flows; measured with thermometers, satellites, rain gauges, and stream gauges; paleo proxies such as tree rings and cores from corals, ice caps, and glaciers can provide historic information.

100 year – Forcing Factors: oscillations in ocean temperatures such as the North Atlantic Oscillation (NAO) and possibly the Pacific Decadal Oscillation (PDO). Relevant Measurements: temperature; paleo proxies such as tree rings and cores from corals, ice caps, and glaciers provide the most useful information.

1,000 year – Forcing Factors: variations in solar irradiance, volcanism, carbon cycles (uptake of carbon dioxide, particularly by living organisms in the oceans, can alter carbon dioxide concentrations in the atmosphere which are involved in the greenhouse effect), and thermohaline circulation (variations in the circulation of deep ocean water). Relevant Measurements: temperature, precipitation, chemical composition of air and water, volcanic activity, and vegetation types; all estimated through various paleo proxies including tree rings; cores from corals, ice caps, and glaciers; pollen analysis; packrat middens; and sediments.

10,000 year – Forcing Factors: variations in Earth's orbit; oscillations in the atmosphere-ocean-ice system (Dansgaard-Oeschger cycles); possibly variations in solar output; abrupt climate change may have been caused by sudden release of glacial water from large lakes. Relevant Measurements: temperature, estimated from variations in the ratio of oxygen isotopes in ice cores.

100,000 year – Forcing Factors: variations in Earth's orbit (Milankovitch cycles). Relevant Measurements: timing of ice ages and orbital fluctuations, estimated with paleo proxies and astronomical observations.

6. Lead a discussion on the possibility of climate change in the 21st century. Ask students what factors might result in climate change. Based on information cited above, students should identify ENSO, NAO, PDO, variations in solar irradiance, volcanism, carbon cycles, and thermohaline circulation as possible forcing factors.

While we don't know for certain how and why climate may change in the 21st century or what the impacts of such change will be, we do know that:

- Concentration of carbon dioxide in the atmosphere is at the highest level in 400,000 years, and the rate of increase coincides with the burning of fossil fuels.
- Recent estimates by NASA indicate that Arctic sea ice is melting at a rate of 9% per decade. Data show that the Arctic warmed significantly during the 1990s, and has continued to do so (see http://www.arctic.noaa.gov/detect/ for more information).
- Most of Earth's 160,000 glaciers have been melting during the last century, but the rate of melting has accelerated dramatically since the mid-1990s. Experts predict that by the middle of the 21st century, the Rocky Mountains, Cascades, and Glacier National Park will have lost almost all their ice (see http://news.nationalgeographic.com/news/2002/08/0821_020821_wireglaciers.html for more information).
- Melting glaciers and polar ice are known to coincide with sea level rise.

There are natural forcing factors that cause these changes, but human activities are increasing the impact of these natural factors. Students should be aware that climate changes have happened repeatedly in Earthís history and natural systems have adapted to these changes. But be sure students also understand that there is no guarantee that any species (including our own) will not be adversely affected by climate change. You may want to point out that 99% of all species of living organisms that have ever lived on Earth are extinct, and climate change is believed to have been responsible for several mass extinctions. Students should also understand that climate change does not always happen gradually over a long period of time; major changes in precipitation and temperature have occurred in less than a decade. Tell

students that some scientists have pointed out that increased atmospheric concentration of greenhouse gases such as carbon dioxide and methane could result in temperature changes that would alter the Gulf Stream. If that happens, the result could be an abrupt cooling in parts of Europe and North America. You may want to review the Climate TimeLine section on Future Forecasts (http://www.ngdc.noaa.gov/paleo/ctl/future.html) for additional discussion.

Students should understand that human activity can affect the capacity of some systems to adapt. Coastal marshes, for example, can survive rising sea levels as long as they are able to accumulate and build soil at least as fast as the water level is rising. But human activities such as roads, canals, and dams can reduce the input of sediments to marshes and can also block their onshore migration. Ask students how human activity might mitigate climate change or its impacts. Using energy sources other than fossil fuels is an obvious strategy. But what about the carbon dioxide that has already entered the atmosphere? One interesting (and expensive) idea being studied is to transfer atmospheric carbon dioxide to another part of the carbon cycle by pumping liquefied carbon dioxide into the deep ocean. See http://www.lbl.gov/Science-Articles/Archive/sea-carb-bish.html/ for more information. Another idea is to fertilize portions of the tropical ocean to stimulate the growth of phytoplankton that theoretically could move carbon from the atmosphere to the deep ocean. See http://www.realclimate.org/index.php/archives/category/climate-science/geoengineering/ for discussion of this idea.

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The Bridge Connection

http://www.vims.edu/bridge/ – In the "Site Navigation" menu on the left, click on "Ocean Science Topics," then "Atmosphere," in the menu bar at the top of the page for links to resources about climate change.

The "Me" Connection

Have students write a brief essay describing what climate changes might be anticipated in their own community, using data from the State Climate Change Impacts information sheets at http://yosemite.epa.gov/OAR/globalwarming.nsf/content/ImpactsStateImpacts.html.

Extensions

Have students analyze climate variation for a specific location chosen by the students or assigned by the teacher. Refer to directions at http://www.ngdc.noaa.gov/paleo/ctl/activity.html.

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Resources

http://www.ngdc.noaa.gov/paleo/ctl – NOAA's Climate TimeLine Information Tool

http://oceanservice.noaa.gov/outreach/pdfs/nccos_climate_change.pdf – Coastal Areas and Marine Resources: The Potential Consequences of Climate Variability and Change

http://www.arctic.noaa.gov/ – NOAA Arctic Theme Page

http://www.oar.noaa.gov/k12/html/atmosphere2.html – Three lesson plans at: Science with NOAA Research: Atmosphere

http://www.realclimate.org/ – RealClimate is a commentary site on which working climate scientists comment on developing stories for the interested public and journalists. In addition, the site also provides context for many subjects that may be missing in mainstream news features.

http://news.nationalgeographic.com/news/2002/08/0821_020821_wireglaciers.html – " Glaciers Melting

Worldwide, Study Finds"

http://www.lbl.gov/Science-Articles/Archive/sea-carb-bish.html – "Climate Change Scenarios Compel Studies of Ocean Carbon Storage"

http://www.epa.gov/climatechange/index.html – EPA climate change Web site

http://topex-www.jpl.nasa.gov/education/education.html – "Ocean Surface Topography from Space" Web site education page with links to educational resources and information about the TOPEX/Poseidon and JASON projects

http://www.ucsusa.org/publication.cfm?publicationID=331 – Curriculum guide with 10 classroom activities that explore global warming and climate change and their effects on the Gulf of Mexico region

http://www.ngdc.noaa.gov/paleo/education.html – NOAA Paleoclimatology Program Educational Outreach - Definition of what paleoclimatology is plus slide sets, data sets, and other educational materials

National Science Education Standards

Content Standard A: Science as Inquiry

- Abilities necessary to do scientific inquiry
- Understandings about scientific inquiry

Content Standard B: Physical Science

- Motions and forces
- Interactions of energy and matter

Content Standard D: Earth and Space Science

- Energy in the earth system
- Understandings about scientific inquiry
- Origin and evolution of the Earth system

Content Standard E: Science as Inquiry

- Understandings about science and technology

Content Standard F: Science in Personal and Social Perspectives

- Personal and community health
- Population growth
- Natural resources
- Environmental quality
- Natural and human-induced hazards
- Science and technology in local, national, and global challenges

Content Standard G: History and Nature of Science

- Nature of scientific knowledge

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Ocean Literacy Essential Principles and Fundamental Concepts

Essential Principle 1. The Earth has one big ocean with many features

- Fundamental Concept c. Throughout the ocean there is one interconnected circulation system powered by wind, tides, the force of the Earth's rotation (Coriolis effect), the Sun, and water density differences. The shape of ocean basins and adjacent land masses influence the path of circulation.
- Fundamental Concept f. The ocean is an integral part of the water cycle and is connected to all of the earth's water reservoirs via evaporation and precipitation processes.
- Fundamental Concept h. Although the ocean is large, it is finite and resources are limited.

Essential Principle 2. The ocean and life in the ocean shape the features of the Earth

- Fundamental Concept b. Sea level changes over time have expanded and contracted continental shelves, created and destroyed inland seas, and shaped the surface of land.
- Fundamental Concept e. Tectonic activity, sea level changes, and force of waves influence the physical structure and landforms of the coast.

Essential Principle 3. The ocean is a major influence on weather and climate

- Fundamental Concept a. The ocean controls weather and climate by dominating the Earth' s energy, water and carbon systems.
- Fundamental Concept b. The ocean absorbs much of the solar radiation reaching Earth. The ocean loses heat by evaporation. This heat loss drives atmospheric circulation when, after it is released into the atmosphere as water vapor, it condenses and forms rain. Condensation of water evaporated from warm seas provides the energy for hurricanes and cyclones.
- Fundamental Concept c. The El Niño Southern Oscillation causes important changes in global weather patterns because it changes the way heat is released to the atmosphere in the Pacific.
- Fundamental Concept d. Most rain that falls on land originally evaporated from the tropical ocean.
- Fundamental Concept e. The ocean dominates the Earth's carbon cycle. Half the primary productivity on Earth takes place in the sunlit layers of the ocean and the ocean absorbs roughly half of all carbon dioxide added to the atmosphere.
- Fundamental Concept f. The ocean has had, and will continue to have, a significant influence on climate change by absorbing, storing, and moving heat, carbon and water.
- Fundamental Concept g. Changes in the ocean's circulation have produced large, abrupt changes in climate during the last 50,000 years.

Essential Principle 6. The ocean and humans are inextricably interconnected

- Fundamental Concept a. The ocean affects every human life. It supplies freshwater (most rain comes from the ocean) and nearly all Earth's oxygen. It moderates the Earth's climate, influences our weather, and affects human health.
- Fundamental Concept f. Coastal regions are susceptible to natural hazards (such as tsunamis, hurricanes, cyclones, sea level change, and storm surges).
- Fundamental Concept g. Everyone is responsible for caring for the ocean. The ocean sustains life on Earth and humans must live in ways that sustain the ocean. Individual and collective actions are needed to effectively manage ocean resources for all.

Essential Principle 7. The ocean is largely unexplored

- Fundamental Concept f. Ocean exploration is truly interdisciplinary. It requires close collaboration among biologists, chemists, climatologists, computer programmers, engineers, geologists, meteorologists, and physicists, and new ways of thinking.

Is It Getting Hot in Here?

Student Worksheet

Refer to "Climate TimeLine Tutorial" and "Overview of Climate Processes" that begin at http://www.ngdc.noaa.gov/paleo/ctl/drought.html and http://www.ngdc.noaa.gov/paleo/ctl/about4.html respectively.

1. The primary force outside the Earth's internal system that drives the planet's weather and climate systems is _____.
2. Two factors outside Earth's environment and climate system that can cause the amount of energy reaching the surface of the Earth to vary are _____ and _____.
3. About _____ % of the radiation entering the Earth's atmosphere is reflected back to space, and about _____ % is absorbed by the atmosphere and surface of the planet.
4. About _____% of the radiation entering the Earth's atmosphere is absorbed by greenhouse gases.
5. In recent years, concern has grown that human activities, most particularly _____, are increasing carbon dioxide levels in the atmosphere to levels that haven't been seen in over 400,000 years.
6. Venus receives about _____ the radiation received by Earth, and has an atmosphere rich in _____.
7. _____ is the time it takes for a volume of water to cycle through the hydrologic system.
8. _____ scales are used to describe variation in Earth's climate over the past 300 million years.
9. _____ scales are used to describe variation in Earth's climate over the past 3 million years.
10. _____ scales are used to describe variation in Earth's climate over the past1000 years.
11. _____ is the primary measure of climate and can be measured or reconstructed for the Earth's surface and sea surface.
12. _____ may be discerned in a variety of ways and provide evidence of how ecosystems change to adapt to climate change.
13. Sea Level is usually related to the degree of _____ in high latitudes and elevations.
14. _____ can alter climate due to aerosols emitted into the atmosphere.
15. _____ refers to specific phenomena that directly influence changes in climactic dynamics.
16. The _____ has been described as Earth's thermostat.
17. _____ is the primary greenhouse gas in the atmosphere.
18. _____ are changes in Earth's orbit that occur in 100,000, 41,000, and 21,000 year periods.
19. _____ is an oscillation in the sea surface temperature pattern across the North Pacific Ocean.
20. _____ is an oscillation in sea surface temperature and surface pressure across the tropical Pacific Ocean, causing both local and far away changes in weather and climate.

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