



## COASTAL ECOSYSTEM SCIENCE LESSON PLAN

# Is It Getting Hot in Here?

### Theme

Climate Change

### Links to Overview Essays and Resources Needed for Student Research

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

<http://coastalscience.noaa.gov/stressors/climatechange/science.html>

### Subject Area

Earth Science

### Grade Level

9-12

### Focus Question

What are some causes and consequences of global climate change?

### Learning Objectives

- Students will be able to define “forcing factor” and will be able to describe at least five forcing factors for climate change.
- Students will be able to describe at least five ways in which climate change could affect human communities.
- Students will be able to cite at least three lines of evidence that suggest the Earth’s climate may change in the 21st century.

### Materials Needed

- (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 Needed

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

### 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:

- **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.

- **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.
- **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.
- **Coastal Storms** – 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.
- **Freshwater Inflow** – 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.

### Learning Procedure

#### 1.

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

- "Overview of Climate Processes" (<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
- "Climate TimeLine Tutorial" (<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 “Climate Change Background Worksheet.”

Lead a discussion of students’ 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/paleoctl>) 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 years – 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 years – 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 years – 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 years – 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 years – 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, the hottest decade in a thousand years (see (<http://earthobservatory.nasa.gov/Study/ArcticIce/> 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](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 Earth's 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 liquified carbon dioxide into the deep ocean. See <http://www.lbl.gov/Science-Articles/Archives/sea-carb-bish.html> for more information.

### The Bridge Connection

<http://www.vims.edu/bridge/> – In the “Site Navigation” menu on the left, click on “Ocean Science Topics,” then “Atmosphere,” then “Global Climate Change” 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>.

### Resources

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

[http://oceanservice.noaa.gov/outreach/pdfs/nccos\\_climate\\_change.pdf](http://oceanservice.noaa.gov/outreach/pdfs/nccos_climate_change.pdf)  
– Coastal Areas and Marine Resources: The Potential Consequences of Climate Variability and Change

<http://www3.nos.noaa.gov/forms/nccoslib/cchange.lasso> – Publications about climate change

<http://www.oar.noaa.gov/k12/html/atmosphere2.html> – Science with NOAA Research: Atmosphere

<http://earthobservatory.nasa.gov/Study/ArcticIce> – “Dwindling Arctic Ice”

[http://news.nationalgeographic.com/news/2002/08/0821\\_020821\\_wireglaciers.html](http://news.nationalgeographic.com/news/2002/08/0821_020821_wireglaciers.html) – “Glaciers Melting Worldwide, Study Finds”

<http://www.lbl.gov/Science-Articles/Archives/sea-carb-bish.html> – “Climate Change Scenarios Compel Studies of Ocean Carbon Storage”

<http://www.epa.gov/globalwarming/index.html> – EPA climate change Web site

<http://interactive2.usgs.gov/learningweb/teachers/globalchange.htm> – U.S. Geological Survey Web site, “Teacher’s resources on climate change”

<http://topex-www.jpl.nasa.gov/> – TOPEX/Poseidon: Understanding Our Oceans & Climate from Space

<http://www.ucusa.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
- Geochemical cycles
- Origin and evolution of the Earth system

**Content Standard E: Science and Technology**

- 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

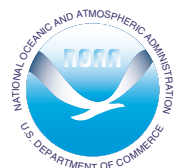
**Content Standard G: History and Nature of Science**

- Nature of scientific knowledge

**Links to AAAS “Oceans Map” (aka benchmarks)**

5D/H2 – Like many complex systems, ecosystems tend to have cyclic fluctuations around a state of rough equilibrium. In the long run, however, ecosystems always change when climate changes or when one or more new species appear as a result of migration or local evolution.

5D/H3 – Human beings are part of the earth’s ecosystems. Human activities can, deliberately or inadvertently, alter the equilibrium in ecosystems.





## COASTAL ECOSYSTEM SCIENCE REVIEW SHEET

**Climate Change Background 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 past 1000 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 climatic 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.