COSEE - Ocean Systems
Centers for Ocean Sciences Education Excellence

Getting to the Core of Climate Change

A two-part hands-on and data centered activity directed at grade levels 6 – 9

Activity Summary:
This activity provides an opportunity for students to 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.
Original Source – Teachers Experiencing Antarctica and the Arctic, Armada Project

Major Concepts Addressed: Climate Change, Fossil Record

Big Idea:
Evidence about past climates comes from a variety of sources such as ocean sediments, fossils, and tree rings. The most detailed continuous record of the Earth's climate comes from cores taken from the enormous ice sheets of Greenland and Antarctica. These cores provide vital clues to understanding climate change past, present, and future.

Key Concepts
- The study of past climates is important to gain an understanding of the range of natural climatic variability prior to human influences.

- Ice cores hold a very detailed record of Earth's climate. Scientists recover and analyze ice cores, examining the different chemical compositions in layers in the ice.

- Each year, snow falling on glacial areas accumulates, piling on top of thousands of years of past snow, compressing the snow into yearly layers of ice, like rings inside a tree trunk. Scientists learn from the following characteristics:
  - Preserved in the ice are tiny bubbles of ancient air that tell us the composition of the atmosphere at that time;
  - The amount of dust in the snow tells us how windy the climate was;
  - The thickness of the layer tells how much precipitation fell that year; and
  - Most importantly, the amount of the "heavy" isotope of oxygen, 18O, lets us infer the average atmospheric temperature, since water vapor with "heavy" 18O molecules condenses out of clouds more readily at cold temperatures.

Essential Questions
- How do we know what pre-industrial greenhouse gas levels were?
- How do we know that most global warming is attributable to human activities rather than natural causes?

- What climate changes will occur as a result of our activities?
- How does a glacier hold records of Earth's climate?
- How might climate change affect your area?

Knowledge and Skills

Students will be able to:

- Create a graph;
- Explain the pattern of data on a graph;
- Make predictions that go beyond the data;
- Analyze and discuss the relationships among data on different graphs;
- Explain how ice cores provide information about Earth's past atmosphere and climate; and
- Describe how natural and human-related (anthropogenic) factors can affect climate.

Prior Knowledge *(according to AAAS Atlas for Science Literacy (ASL) & National Science Education Standards)*

National Science Education Standards – K-12 Unifying Concepts and Processes specifically the concepts of: evidence, models, and explanation; and constancy change, and measurement.

- Grades K-2:
  - The temperature and amount of rain (or snow) tend to be high, low, or medium in the same months every year.
  - Change is something that happens to many things.
- Grades 3-5:
  - The weather is always changing and can be described by measurable quantities such as temperature, wind direction and speed, and precipitation.
  - Often the best way to tell which kinds of changes are happening is to make a table or graph of measurements.
- Grades 6-8*:*
  - The temperature of a place on earth's surface tends to rise and fall in a somewhat predictable pattern every day over the course of a year. The pattern of temperature changes observed in a place tend to vary… *(see ASL Vol. 2 pg. 21)*
  - The earth has a variety of climates…*(see ASL Vol. 2 pg. 21)*
  - Climates have sometimes changed abruptly in the past…*(see ASL Vol. 2 pg. 21)*
  - Human activities…have changed the earth's lands, oceans, and atmosphere.

Common Preconceptions

- *Climate change is the same thing as global warming.* Actually they are not, although this is commonly misrepresented in the media. Global warming is exactly that; the phenomenon where the average temperature of the planet is rising by a fraction of a degree every year. Climate change is different. It is the change of the world's weather trends in response to this warming.
- *Climate change is a steady trend of warming:* This is linked to the misconception that global warming and climate change are the same thing. Since the climate is a balance of very complex factors, it won't be a smooth transition at all. In fact, markers of climate change include large-scale swings in temperature and perhaps even cooling, drought, floods, or more moderate changes in rainfall.

Background

Excerpted from *Remembrance of Things Past: Greenhouse Lessons from the Geologic Record* Thomas Crowley, Consequences Vol. 2, No. 1. 1996.

Global climate--like local weather--is ever changing, on all time scales, in response to natural variations. For this reason, projections of global warming, resulting from increasing levels of atmospheric greenhouse gases, need to be set in the context of what has happened in the past. A knowledge of what has changed, and when and where, provides insights into why past changes have occurred. Such information can also help in evaluating the reliability of global warming forecasts.

Predictions of climate change are based on numerical models of the atmosphere and ocean. The inherent limitations in these models have led those who develop and refine them to seek ways in which projections can be tested and sharpened, including a comparison with times when conditions on the Earth were much different from the present day. We'd like to know, for example, how concentrations of greenhouse gases--or other factors that fix the climate of the Earth--have varied in the past. How has surface temperature responded? Is there evidence for natural controls that limit the range through which climate naturally varies?

To answer these and other questions, geologists and climatologists have literally unearthed a vast amount of information regarding climate and how it has varied. Natural records that tell of past changes are scattered over the globe. They can be recovered only piece by piece, and reassembled like a jigsaw puzzle, through the efforts of many people over many years. What emerges is not only a record of climate change, but a clearer picture of the climate system itself.

Sources of Climate History

- Records of local weather, made with the help of meteorological instruments, cover at most about two hundred years, and an even shorter span if a truly global picture is desired.
- Laboratory analyses of geologic sediments and other layered materials help meet this need, extending what is known of surface temperature, precipitation, and other meteorological parameters many thousands and even millions of years into the past. Many of these tools rely on the fact that plants and other forms of life respond in distinctive ways to changes in the local environment, thus preserving an indirect, or *proxy* record, of climatic conditions.
- Annual growth rings in trees, for example, can be read much like a diary: tree-ring widths tell of seasonal variations of local air and water conditions--as does the chemical composition of the wood within each ring.
- Cores extracted from the floor of the ocean allow us to examine in fossil form the microscopic life that once lived near the ocean surface, and through this analysis, to recover information about the temperature of the ocean many millions of years ago. The extent and composition of coral reefs are indicators of tropical ocean temperatures and, through changes in ocean salinity, of local precipitation.
- A particularly powerful technique of recent years has been the recovery and analysis of ice cores, about ten cm (four inches) in diameter and as much as two miles long, drawn from the permanent glaciers on Greenland and Antarctica. Similar samples have been retrieved from high mountain glaciers in South America and Asia. As in the case of trees, the ice is composed of annual layers, although the temporal resolution degrades systematically from top to bottom in the deepest cores. The analysis of the hydrogen and oxygen in the extracted ice core provides a continuous index of temperature from as far back as 200,000 years ago, sampling conditions in the air above the ice sheet and in the nearby oceans from which the water was evaporated, to later fall as snow. As the snow accumulates, over the years, the underlying layers are compressed into ice. Windblown dust and the residue of ancient volcanic eruptions can also be analyzed. Bubbles entrapped in the ice during the process of compaction preserve samples of fossil air, affording an opportunity for precise measurement of the amount of carbon dioxide (CO2), methane (CH4), and other greenhouse gases in the global atmosphere of long ago.

When combined, these various forms of *paleo-data* allow us to reconstruct an imperfect but ever-clearer picture of the climate of the past. All of them clearly indicate that climate varies, due to natural causes, on all time scales, from decades to millions of years.

Lessons from the Past

The geologic record leaves no doubt that the Earth's climate system is capable of some very large changes. This almost trivial conclusion challenges any presumption that the surface temperature will, through natural checks and balances, remain stable in the face of perturbations that we now impose. The geologic record also provides insight into specific characteristics of the climate system that relate to future greenhouse warming.

Potential for abrupt transitions
The surprising evidence from the paleoclimate record is how quickly the switch between warm and cold states can be accomplished. Evidence from ice-age portions of recent Greenland ice cores suggests that changes of this sort may have taken place in the past in the span of five to ten years. These abrupt transitions are most likely linked to an increase in the release of icebergs from continental glaciers, which on melting contribute large volumes of freshwater into the ocean, systematically reducing the local salinity.

Whatever the cause, we now know that in at least the North Atlantic the climate system can change very rapidly. Might ocean circulation change as rapidly in the future, perhaps as a consequence of other significant changes in the system? The answer is "maybe." There are no permanent ice sheets today on the North American continent, as was the case in the past, but melting of Arctic sea ice or the extensive Greenland ice cap could well influence ocean salinities. Increased precipitation over the North Atlantic, induced by warmer temperatures, could also reduce the saltiness of seawater, short- circuiting the ocean circulation in a manner similar to what occurred during the ice ages. In fact, greenhouse models call for such a change in precipitation, and the present rate of warming in the subpolar North Atlantic--less than what is recorded in the rest of the world--is also in agreement with what should happen as a result of an altered state of ocean circulation. A test of the models is whether the slower warming of the subpolar North Atlantic will persist.

Checking climate model results against paleodata
Even if there were no period in the past that could serve as an analog for future climate, the geologic record can still provide valuable insight into the modeling of specific processes in the climate system. Examples of such processes include the response of climate to changes in freshwater input to the ocean, or to changes in the contour of the land. These changes have occurred in the past and have left their traces in the geologic record. Incorporating more accurate predictions of specific processes will improve the overall reliability of global climate models.

Materials

- world map or globe

Each group of 3-4 students will need:

- graph paper - 2 sheets
- poster paper
- copies and/or transparencies of the graph template
- ice core data set
- graph of recent data
- markers
- colored modeling clay to make core layers – (other materials could also be used in conjunction with the clay suggestions include, small pasta like couscous, sand, just remember that what you use needs to fit into the diameter of a drinking straw)
- clear, plastic, drinking straws

Engagement and Exploration (Student Inquiry Activity)

Activity 1. Drilling an Ice Core Organize the class into groups of 3 to 4 students to form science teams. Distribute a small brick of clay to each group and instruct them to divide it among group members. Have students flatten the clay into a thin layer.

Explain that layers of clay and other materials will represent annual layers of snowfall in cold, polar regions.

Have students come up in turn and place their clay on a flat surface. (You may choose to do the demonstration on a map or globe.) Each layer should be placed on top of the previous layers.

Explain that constructing the mound of clay simulates the formation of an ice sheet from accumulated snowfall over thousands of years.

Explain that the deep layers in the ice sheet contain information about the atmosphere and climate from long ago. Ask how scientists might be able to access that information. Explain that we are going to use straws to simulate the drilling and removal of ice cores.

Give each group a clear, plastic straw. Have each group simulate the recovery of an ice core. By pressing the straw straight down through all layers of the clay and carefully pulling it out they should obtain a core with visible layering.

Discuss which parts of the core represent the youngest and oldest layers of ice. Ask students to describe any differences they see in the layers. Have students speculate on why actual ice layers may have different properties, appearance, or thickness.

Display and describe ice core images.

Activity 2. Polar Applications Each science team is responsible for analyzing some actual ice core data. Their task is to graph, analyze, and report on their particular set of data. The information comes from the GISP2 ice core from Greenland and the Vostok core from Antarctica. You should have students find these locations on a map or globe. Both cores extended down a few thousand meters into the ice sheet providing information dating back over 100,000 years BP (before the present). *Data Sheet 1* illustrates the increase of different chemicals (methane, carbon dioxide, nitrous oxide) that are present in the atmosphere. Data is also provided on past temperatures, determined by measuring the ratio of oxygen isotopes in the ice. The data represents changes in Earth's atmosphere and climate.

Provide each team with one set of data. More than one team may get the same data. You may choose to have each group produce their graph on a large piece of poster paper (lined or grid paper works best). This will allow them to display their graphs for presentation and comparison of the data. You may want them to use the graph template either on a transparency or on paper that can be made into a transparency later. Transparencies will allow you to overlay graphs from different teams for easy comparison.

After finishing the graph, each team should discuss and record the following:

- description of the data including any trends, patterns or cycles they might discern. They should share the unit of measurement (e.g. ppbV - parts per billion of volume) and the magnitude of any changes;
- prediction and rationale for what they expect the data might look like from the last point on their graph up to the present.

Have each team give their presentation to the class. The presentation should include:

- displaying the graph;
- presenting the analysis; and
- sharing the prediction and rationale.

Challenge the class to find any relationships between the data on different graphs. They might look for:

- similar patterns of temperature between the Greenland and Antarctic cores.
- a relationship between temperature and levels of greenhouse gases (carbon dioxide, methane, nitrous oxide).
- a negative relationship between temperature and sulfate levels. Discuss the meaning or potential reasons for these relationships.

Distribute and/or display the graphs that show recent data for gases and temperature. The rapid increases in some gases over the last couple centuries are examples of anthropogenic effects linked to human activities. Have each team record a description of the data and an evaluation of their prediction.

Have the class share their thoughts about the recent data. The following questions can be used to guide the discussion.

- What's the difference between weather and climate?
- How have human activities resulted in the rapid rise in the levels of these gases?
- How has the Earth's temperature changed over the last 1000 years? 140 years?
- Have increased greenhouse gases caused temperature levels to increase?
- How might sulfate in the atmosphere affect climate?
- What natural factors may affect the future climate?
- What effect might climate change have on our lives and those of future generations?
- Should we do anything about the possibility of global warming?

Assessment / Discussion Questions

Students may be evaluated based on:

- Participation in group activities and class discussions
- Quality of the graph produced
- Presentation of the data with a logical analysis and reasonable prediction
- Written or oral explanation of how ice cores are used to learn about climate
- Written or oral description of how natural and human factors affect climate

Vocabulary

Climate - The historical record of average daily and seasonal weather events for a geographic region.

Global warming - The progressive gradual rise of the earth's surface temperature thought to be caused by the greenhouse effect and responsible for changes in global climate patterns. An increase in the near surface temperature of the Earth. Global warming has occurred in the distant past as the result of natural influences, but the term is most often used to refer to the warming predicted to occur as a result of increased emissions of greenhouse gases.

Greenhouse gases - Gases in the Earth's atmosphere that allow sunlight through but absorb and capture infrared radiation. Key gases are carbon dioxide (produced by combustion) and methane (often produced by anaerobic digestion such as occurs in landfill sites, and from the guts of cattle and termites), but also Nitrous Oxide (N2O) in vehicle exhaust fumes, PFCs (perfluorocarbons), SF6 (sulphur hexafluoride) and HFC (hydrofluorocarbons) in refrigerants.

Ice age - Ice age with lowercase letters means a period of time when large segments of the Earth's surface were covered by enormous ice sheets known as glaciers. Ice Age with capital letters means the longest and most widespread ice age. This occurred in the Pleistocene Era (2 million to 11,500 years ago). It was during this ice age that the majority of the Earth's surface was covered by glaciers. Animals, such as the saber-toothed tiger and woolly mammoth, roamed freely.

Ice core - An ice core is a cylinder of ice removed from an ice sheet. It is collected by driving a hollow tube or by core drilling deep into an ice sheet, most commonly in the polar ice caps of Antarctica, Greenland or in high mountain glaciers elsewhere. As the ice sheet forms from the incremental buildup of annual layers of snow, lower layers are older than those on top, and an ice core contains ice formed over a range of years.

Ice sheet - A very large body of land-based ice. Ice sheets are found in Greenland and Antarctica and are also known as continental glaciers.

Oxygen isotope – a particular atom of oxygen (or any element) that has the same atomic number, but a different atomic mass. For example For example O16 and O18 are stable isotopes of oxygen.

Parts per billion - Parts per billion (ppb) is a measure of concentration that is used where low levels of concentration are significant. One part per billion corresponds to one minute in 2,000 years, or a single penny in $10,000,000.
Weather - Weather comprises all the various phenomena that occur in the atmosphere of a planet. "Weather" is normally taken to mean the activity of these phenomena over a period of time of up to a few days. The average weather over a longer period is known as the climate.

Additional resources

News / Press Releases for Background or Student Reading

NOAA - *Mechanisms that Can Cause Abrupt Climate Change*
http://www.ncdc.noaa.gov/paleo/abrupt/story2.html

Will Steger Foundation – *Global Warming 101*
http://www.globalwarming101.com/

Science @ NASA – *A Chilling Possibility*
http://science.nasa.gov/headlines/y2004/05mar_arctic.htm?list7433

Woods Hole Oceanographic Institutions – *Abrupt Climate Change – Should We Be Worried*
http://www.whoi.edu/page.do?pid=12455&tid=282&cid=9986

Weather Underground – *The Science of Abrupt Climate Change*
http://www.wunderground.com/education/abruptclimate.asp

Weather Underground – *The Day After Tomorrow*™ – *Could it really happen?*
http://www.wunderground.com/education/thedayafter.asp

Extension or Supplementary Activities

PBS Nova Teachers – *Mountain of Ice*
http://www.pbs.org/wgbh/nova/teachers/activities/3005_vinson.html

NASA Student Observation Network – *Winter's Story*
http://son.nasa.gov/winterstory/index_e.htm

NASA - *History of Climate Change*
http://vathena.arc.nasa.gov/curric/land/global/climchng.html

NOAA - *Exploring Weather & Climate Change Through the Powers of 10*
http://www.ngdc.noaa.gov/paleo/ctl/index.html

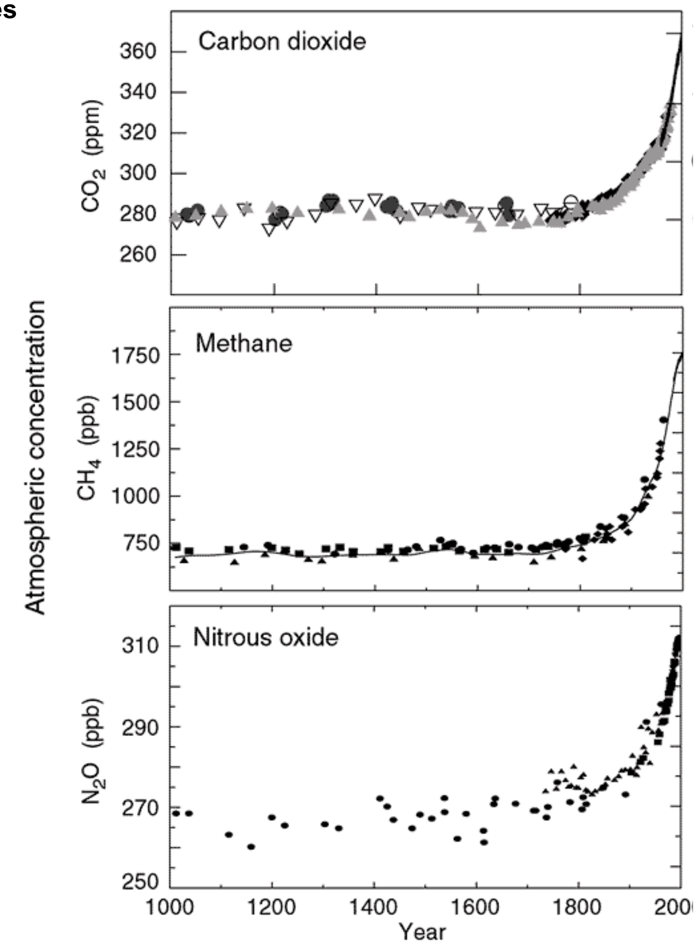
Teachers' Domain - *Greenland Ice Sheet Project 2: A Record of Climate Change*
http://www.teachersdomain.org/resources/ess05/sci/ess/watcyc/greenland/index.html

Notes on Pedagogy:

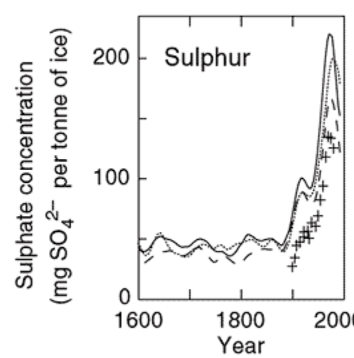
The links provided in the *Additional Resources* offers the opportunity to find supplemental maps and graphs.

Indicators of the human influence on the atmosphere during the Industrial Era

(a) Global atmospheric concentrations of three well mixed greenhouse gases



(b) Sulphate aerosols deposited in Greenland ice



Teacher Background for Figures

Data Sheet 1.

These graphs illustrate long records of past changes in atmospheric composition provide the context for the influence of anthropogenic emissions.

(a) shows changes in the atmospheric concentrations of carbon dioxide (CO2), methane (CH4), and nitrous oxide (N2O) over the past 1000 years. The ice core and firn (old snow) data for several sites in Antarctica and Greenland (shown by different symbols) are supplemented with the data from direct atmospheric samples over the past few decades (shown by the line for CO2 and incorporated in the curve representing the global average of CH4)Since these gases have atmospheric lifetimes of a decade or more, they are well mixed, and their concentrations reflect emissions from sources throughout the globe. All three records show effects of the large and increasing growth in anthropogenic emissions during the Industrial Era.

(b) illustrates the influence of industrial emissions on atmospheric sulphate concentrations. Shown is the time history of the concentrations of sulphate, not in the atmosphere but in ice cores in Greenland. This record, albeit more regional than that of the globally-mixed greenhouse gases, demonstrates the large growth in anthropogenic SO2 emissions during the Industrial Era.

Graphs are from: Climate Change 2001: Working Group I: The Scientific Basis, p. 3: Intergovernmental Panel on Climate Change, Houghton, J.T., Y. Ding, D.J. Griggs, M. Noguer, P.J. van der Linden, X. Dai, K. Maskell, C.A. Johnson, eds.
http://www.grida.no/climate/ipcc_tar/wg1/006.htm

Figure 2: Long records of past changes in atmospheric composition provide the context for the influence of anthropogenic emissions.

(a) shows changes in the atmospheric concentrations of carbon dioxide (CO2), methane (CH4), and nitrous oxide (N2O) over the past 1000 years. The ice core and firn data for several sites in Antarctica and Greenland (shown by different symbols) are supplemented with the data from direct atmospheric samples over the past few decades (shown by the line for CO2 and incorporated in the curve representing the global average of CH4). The estimated positive radiative forcing of the climate system from these gases is indicated on the right-hand scale. Since these gases have atmospheric lifetimes of a decade or more, they are well mixed, and their concentrations reflect emissions from sources throughout the globe. All three records show effects of the large and increasing growth in anthropogenic emissions during the Industrial Era.

(b) illustrates the influence of industrial emissions on atmospheric sulphate concentrations, which produce negative radiative forcing. Shown is the time history of the concentrations of sulphate, not in the atmosphere but in ice cores in Greenland (shown by lines; from which the episodic effects of volcanic eruptions have been removed). Such data indicate the local deposition of sulphate aerosols at the site, reflecting sulphur dioxide (SO2) emissions at mid-latitudes in the Northern Hemisphere. This record, albeit more regional than that of the globally-mixed greenhouse gases, demonstrates the large growth in anthropogenic SO2 emissions during the Industrial Era. The pluses denote the relevant regional estimated SO2 emissions (right-hand scale)