Earth/Environmental Science Grades 9-12

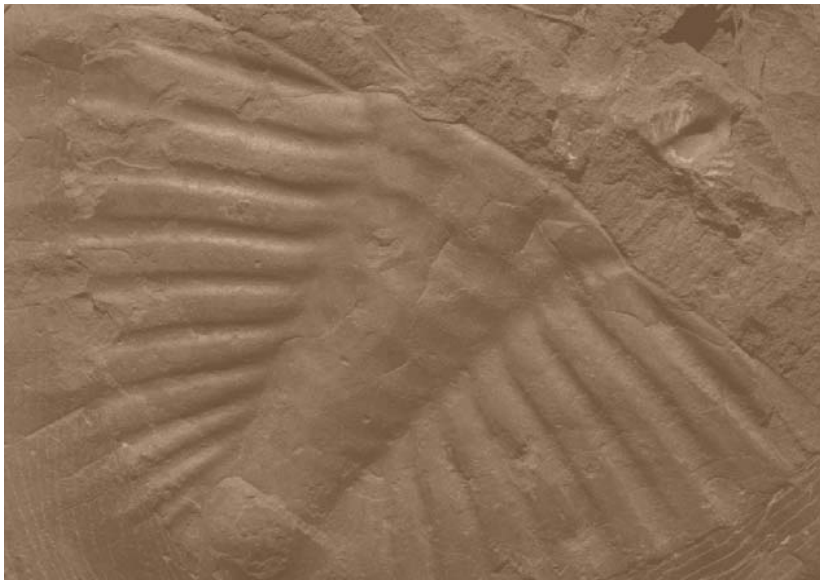
COMPETENCY GOAL 5: The learner will build an understanding of the dynamics and composition of the atmosphere and its local and global processes influencing climate and air quality.

Objectives

5.01 Analyze air masses and the life cycle of weather systems:
- Planetary wind belts.
- Air masses.
- Frontal systems.
- Cyclonic systems.

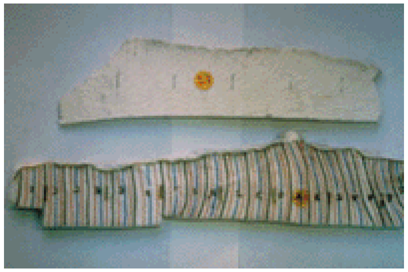
5.02 Evaluate meteorological observing, analysis, and prediction:
- Worldwide observing systems.
- Meteorological data depiction.

5.03 Analyze global atmospheric changes including changes in $\mathbf{CO}_2$, $\mathbf{CH}_4$, and stratosheric $\mathbf{O}_3$ and the consequences of these changes:
- Climate change.
- Changes in weather patterns.
- Increasing ultraviolet radiation.
- Sea level changes.



Paleoclimate Primer

What is Paleoclimatology?

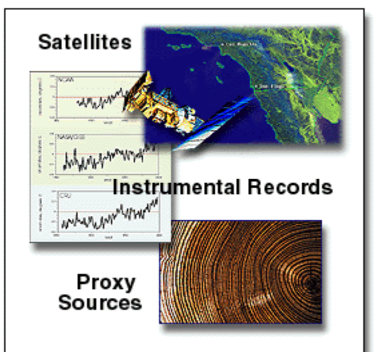


Paleoclimatology is the study of climate prior to the widespread availability of records of temperature, precipitation and other instrumental data. NOAA is particularly interested in the last few thousand years because this is the best dated, best sampled part of the past climatic record and can help us establish the range of natural climatic variability in a period prior to global-scale human influence.

How do we measure past climates?

Environmental recorders are used to estimate past climatic conditions and thus extend our understanding far beyond the 100+ year instrumental record. "Proxy" records of climate have been preserved in tree rings, locked in the skeletons of tropical coral reefs, extracted as ice cores from glaciers and ice caps, and buried in laminated sediments from lakes and the oceans.

How do scientists study past climates?



There are several ways that scientists study how the Earth's climate is changing: satellites, instrumental records, historical records and proxy data.

Some scientists look to satellites to study the Earth's changing climate. However, the satellite record is too short (ca. 20 years) to provide much perspective on changing climate.

The record of instrumental weather measurements, extending back into the 19th century, provides data from thermometers, rain gauges, historical documents and other instruments. However, this record is too short to study many climatic processes. Also, because we have few instrumented observations from before the major industrial releases of carbon dioxide began, it is difficult to separate human and natural influences on climate.

Paleoclimatologists find clues in natural records - proxy data. Proxy data are natural clues to past climate that are buried in sediments at the bottom of the oceans, locked in coral reefs, frozen in glaciers and ice caps, or preserved in the rings of trees. Details on one type of

Cretaceous (120-90 million years ago) indicate globally warm conditions. More recently during the Little Ice Age (AD 1450-1890) historic and instrumental records, predominantly around the North Atlantic, indicate colder than modern temperatures.

If global temperatures over the next decades to centuries continue (as seen for the 1990's), scientists will conclude that climate change has occurred. Understanding the underlying processes will allow us to determining how much of this climate change is the result of greenhouse warming of part of longer cycle of natural climate change and variability.

The Difference Between Weather & Climate

Weather is the state of atmosphere-ocean-land conditions (hot/cold, wet/dry, calm/stormy, sunny/cloudy) that exist over relatively short periods like hours or days. Weather includes the passing of a thunderstorm, hurricane, or blizzard, a persistent heatwave, a cold snap, a drought. Weather variability and extreme events may respond unpredictably in response to climate change.

Climate are weather patterns over a month, a season, a decade, a century from now or in past time periods. More technically climate is defined as the weather conditions resulting from the mean state of the atmosphere-ocean-land system, often described in terms of "climate normals" or average weather conditions.

Tree Rings:

Since tree growth is influenced by climatic conditions, patterns in tree-ring widths, density, and isotopic composition reflect variations in climate. In temperate regions where there is a distinct growing season, tree generally produce one ring a year, and thus record the climatic conditions of each year. Trees can grow to be hundreds to thousands of years old and can contain annually-resolved records of climate for centuries to millennia.

To learn more about tree rings please visit the following:

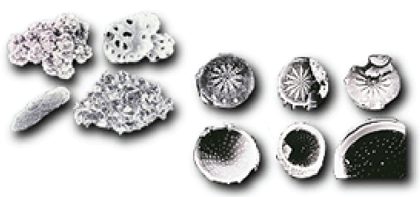
- Laboratory of Tree Ring Research at University of Arizona
- Henri D. Grissino-Mayer's Science of Dendrochronology Web Pages at the University of Tennessee

Ice Cores:

Located high in mountains and in polar ice caps, ice has accumulated from snowfall over many millennia. Scientists drill through the deep ice to collect ice cores. These cores contain dust, air bubbles, or isotopes of oxygen, that can be used to interpret the past climate of that area.

To learn more about ice please visit the following sites:

- The Australian Antarctic Division-Glaciology
- The American Geophysical Union-Deciphering Mysteries of Past Climate From Antarctic Ice Cores
- Greenland Ice Cores Summit (GISP2) Project CD ROM



Ocean & Lake Sediments:

Billions of tons of sediment accumulate in the ocean and lake basins each year. Scientist drill cores of sediment from the basin floors. Ocean and lake sediments include tiny fossils and chemicals that are used to interpret past climates.

To learn more about ocean & lake sediments, please visit the following:

- Ocean Drilling Program-funded by NSF with 22 international partners
- IMAGES– International Marine Global Changes Study international collaboration

The Paleo Perspective

From the paleoclimate perspective, climate change is normal and part of the earth's natural variability related to interactions among the atmosphere, ocean, and land, as well as changes in the amount of solar radiation reaching the earth. The record includes a plethora of evidence for large-scale climate changes. Massive terrestrial ice sheets throughout the Northern Hemisphere indicate cold conditions during the last glacial maximum (21,000 years ago). Warm climate vegetation, dinosaurs, and corals living at high latitudes during the mid

proxy data, corals, can be found on our pages Coral Paleoclimatology: What can corals tell us about climate?

What can Paleoclimatology tell us about climate change and the future?

If there is one thing that the paleoclimatic record shows, it is the that Earth's climate is always changing. Climatic variability, including changes in the frequency of extreme events (like droughts, floods and storms), has always had a large impact on humans. A particularly severe El Niño, or relatively short drought, can cost US citizens billions of dollars. For this reason, scientists study past climatic variability on various time scales to gain clues that will help society plan for future climate change.

Natural Climate Forcings
(i.e., volcanic eruptions and changes in the sun's output)

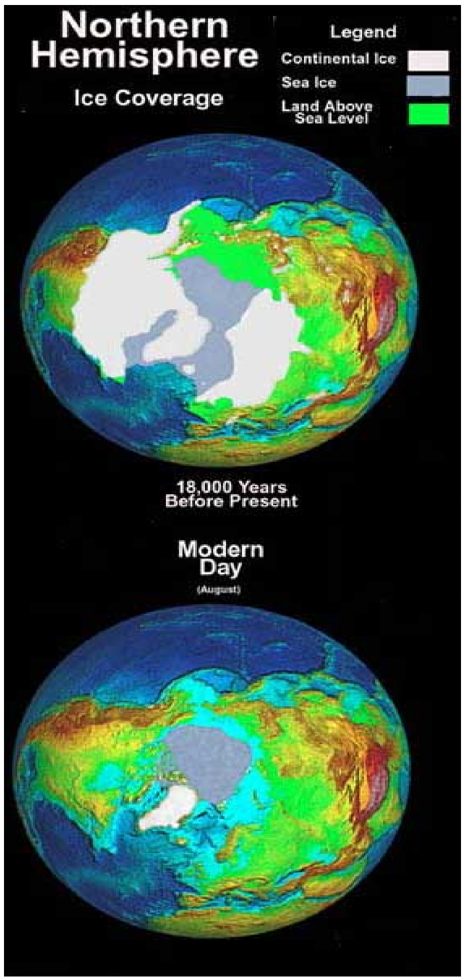
Unfortunately, records of past climate change from satellites and human measurements (thermometers, rain gauges) generally cover less than 150 years. These are too short to examine the full range of climatic variability. For this reason, it is critical to examine climate change going back hundreds and thousands of years using paleoclimatic records from trees, corals sediments, glaciers and other natural or "proxy" sources.

The study of paleoclimates has been particularly helpful in showing that the Earth's climate system can shift between dramatically different climate states in a matter of years and/or decades. Understanding "climate surprises" of the past is critical if we are to avoid being surprised by abrupt climatic change.

The study of past climate change also helps us understand how humans influence the Earth's climate system. The climatic record over the last thousand years clearly shows that global temperatures increased significantly in the 20th Century, and that this warming was likely to have been unprecedented in the last 1,200 years. The paleoclimatic record also allows us to examine the causes of past climate change, and to help unravel how mucdh of the 20th Century warming may be explained by natural causes, such as solar variability, and how much may be explained by human influences.

Lastly, most state of the art climate prediction is accomplished using large sophisticated computer models of the climate system. A great deal of research has been focused on ensuring that these models can simulate most aspects of the modern, present-day, climate. It is also important to know how these same models simulate climate change. This can be accomplished by comparing simulations of past cliamte change with observations from paleoclimatic records. Thus, paleoclimatology helps us improve the ability of computer models to simulate future climate.

What do we know about the history of climate?



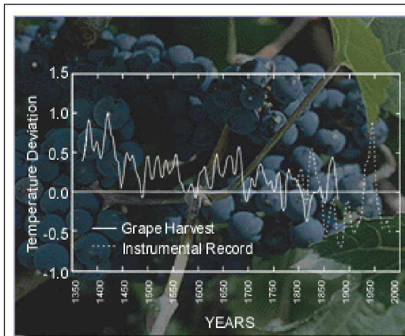
Good weather records extend back less than 150 years in most places. In that time, the Earth's global average temperature has [increased by approximately 0.5 degrees centigrade]or 0.9 degrees Fahrenheit. Scientists are trying to determine how much of this warming is a natural fluctuation and how much is a result of human induced [greenhouse warming].

Since the end of the last ice age occurred over 10,000 years ago, the planet has continued to undergo changes in climate. Warming during medieval times and cooling during the "Little Ice Age" a few centuries ago dominate the last millennia. From paleo records, we know that the climate of the past million years has been dominated by the [glacial cycle], a pattern of [ice ages] and glacial retreats lasting thousands of years.

The image to the left shows the changes in ice cover over the Northern Hemisphere. Eighteen-thousand years ago, at the peak of the last ice age, scientists estimate that nearly 32% of the Earth's land area was covered with ice, including much of Canada, Scandinavia, and the British Isles. These glaciers developed because the earth was in the midst of an ice age. Today ice cover about 10% of the Earth's land surface.

Paleo Proxy Data

Paleoclimatologists gather proxy data from natural recorders of climate variability such as tree rings, ice cores, fossil pollens, ocean sediments, corals and historical data. By analyzing records taken from these and other proxy sources, scientists can estend our understanding of climate far beyond the 100+ year instrumental record. Listed below are some widely used proxy climate data types:



Historical Data:

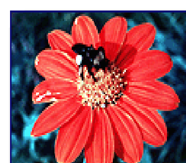
Historical documents contain a wealth of information about past climates. Observations of weather and climatic conditions can be found in ship and farmer's logs, traveler's diaries, newspaper accounts, and other written records. When properly evaluated, historical data can yield both qualitative and quantitative information about past climate.

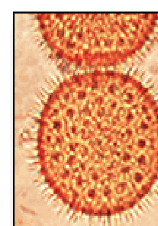
The example above demonstrates how historical grape harvest dates were used to reconstruct summer temperatures.

Corals:

Corals build their hard skeletons from calcium carbonate, a mineral extracted from sea water. The carbonate contains [isotopes] of oxygen, as well as trace metals, that can be used to determine the temperature of the water in which the coral grew These temperature recordings can then be used to reconstruct climate when the coral lived.

To learn more about the study of corals please visit





Fossil Pollen:

All flowering plants produce pollen grains. Their distinctive shapes can be used to identify the type of plant from which they came. Since pollen grains are well preserved in the sediment layers in the bottom of a pond, lake or ocean, an analysis of the pollen grains in each layer tell us what kinds of plants were growing at the time the sediment was deposited. Inferences can then be made about the climate based on the types of plants found in each layer.

To learn more about fossil pollen, please visit the following:

- The [Institute of Paleontology], University of Vienna, Austria.
- [Fossil Groups: Spores and Pollens], U.S. Geological Survey (USGS)