Name:

Earth Sci/Nork

Reading Across the Curriculum: "Understanding Climate Variability"

I. Multiple Choice

______1. The earliest records of Earth's climate go back to the year

a. 1715 b. 1776 c. 1860 d. 1941

______2. The Milankovitch cycle which involves a change in the shape of Earth's orbit occurs every

a. 4,900 years b. 21,000 years c. 41,000 years d. 100,000 years

______3. The date of the Earth's current perihelion (when it is closest to the sun) occurs on

a. January 4 b. March 20 c. July 4 d. December 16

______4. Which of the following CANNOT be determined by studying ice cores from glaciers in Antarctica?

a. previous volcanic and wind activity
b. the climate temperature when the ice was formed
c. the changes in annual growth rates of trees
d. the concentration of atmospheric carbon dioxide

II. Open-Ended Response. Use complete sentences and additional paper of necessary.

1. Scientific records of climate change only go back so far. Describe the methods that scientists use to study climates which existed hundreds, even thousands, of years ago.

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2. The article mentions that climate change appears to be "the rule" rather than "the exception," and that human activities are speeding up this process. Discuss the likely causes of long-term changes in climate which occur naturally (regardless of human activity).

Understanding Climate Variability

by Gail Littlejohn

When we talk about climate change as a current event, we sometimes forget that the planetary systems that govern climate are never static. Forty-five million years ago, the high Arctic was balmy enough to support redwoods and cedars up to 30 meters tall and a meter in diameter. Eighteen thousand years ago, most parts of Canada and the northern United States were under ice. And nearly everywhere in North America there has been a period since the retreat of the glaciers when the climate was warmer than it is today. In fact, climate change appears to be the rule, not the exception. ’he difference now, of course, is that it is *our* climate and it is human activities that appear to be setting these changes in motion.

In attempting to determine how much influence humans are having and to predict what the consequences might be, climatologists frequently pose questions about past conditions. For example, a useful question might be: When the level of carbon dioxide in the atmosphere was this high in the past, how warm was the Earth? or How high were sea levels during those times in the past when the Earth was as warm as we think it will be in the future? Knowing about the past can help us understand what is occurring at present and foresee (and perhaps better prepare for) what might happen the future. For students attempting to grasp the cur-tly unfolding science of climate change, it is additionally helpful to know how scientists acquire and interpret the information we have about the Earth's past.

Gail Littlejohn

Paleobotanists extract a sediment core from Wagner Lake near Uxbridge, Ontario. Fossil pollen preserved in the layers of this lake-bottom mud will give evidence of changes in plant communities and climatic conditions since the retreat of the glaciers.

How do we know about past climate?

If all we had to rely on were thermometer readings, our knowledge of the Earth's climate would reach back only to about 1860 when meteorologists and mariners began taking systematic measurements of temperatures around the world. Fortunately, temperature records are not the only fingerprints of past climate. All living organisms depend to some degree on a certain range of climatic conditions and much has been learned about the past by looking at evidence they have left behind. Three important sources of information are sediment cores, tree rings and glacial ice cores.

Sediment cores

The muddy sediments at the bottoms of oceans and lakes contain particles of soil and ash and the fossil remains of aquatic creatures and plant material that have been deposited layer-upon-layer over eons. By driving hollow tubes into these sediments, scientists extract cores, or long cylinders of mud that can be read like timelines. Each layer provides clues to the local climate at the time the sediments were deposited. For example, fossil pollen in 5,000-year-old lake sediments is evidence of the types and abundance of the plants that lived nearby, and by looking at the modern ranges and communities of these plants we can infer what the climate was like at that time. Other clues are found by analyzing the type, or isotope, of oxygen contained in the calcium carbonate ($CaCO_3$) shells of marine organisms buried in ocean sediments. During periods of glaciation when a higher proportion of annual precipitation stayed frozen on land instead of cycling back to the sea, a lighter isotope of oxygen (oxygen-16) accumulated in ice sheets. Meanwhile, sea water became enriched with a heavier oxygen (oxygen-18), as did the oxygen-containing shells of the sea creatures who lived at that time.

Tree rings

The oldest living trees on Earth are the gnarled bristlecone pines (*Pinus longaeva*) that grow in the White Mountains of eastern California, one of which is estimated to be up to 4,900 years old. By counting and measuring the width of the tree rings, scientists called dendrochronologists track changes in annual growth over thousands of years. They can then correlate these changes with the environmental conditions that likely gave rise to them.

Activity

Have students examine crosscuts ("tree cookies") to determine the age of a tree when it was cut and to look for variations in the width of the rings. Wider rings indicate a year in which climatic conditions were optimal for that species. If you know when and where the tree was cut, try to correlate ring-width patterns with meteorological data on annual temperatures and rainfall during the lifetime of the tree.

Left: Bristlecone pine in southern California: The annual rings of these oldest living trees tell the story of temperature and precipitation patterns over thousands of years. Right: The uplift of mountain ranges can alter climate by affecting patterns of wind and precipitation.

Glacier ice

Ice cores extracted from glaciers in Greenland and Antarctica have provided information about past climate change as well as about past concentrations of atmospheric gases. By analyzing the proportions of different isotopes of oxygen and hydrogen at each level of the ice, scientists can determine what the temperature was when the ice was formed; and by analyzing bubbles of "fossil air" trapped in the ice, they can measure the concentration of atmospheric carbon dioxide at that time. Other useful information is gleaned from impurities in the ice: layers of ash and dust, for example, may reflect volcanic activity and high winds.

What causes climate change?

Much is still to be learned about the complex interplay of biogeophysical forces that lead to major shifts in climate. The following are some of the likely prime movers in these long-term processes.

Earth's position

The position of the Earth in relation to the sun determines the distribution of solar radiation around the globe through the seasons. In 1941, a Serbian scientist named Milankovitch looked beyond these well-known seasonal variations and hypothesized that there are three very long-term cyclic changes in Earth's position which have a major influence on climate. The first Milankovitch cycle is a change in the shape of the Earth's orbit which every 100,000 years takes the Earth further away from the sun at the perihelion (the closest point of the year), resulting in a colder climate. The second cycle, of about 41,000 years' duration, is a shift in the tilt of the Earth's axis from 22° to 25° (currently it is midway at 23.5°). When tilt is greater, polar regions receive more solar radiation in summer and less in winter, a situation that could result in more extreme seasonal temperature variations. Finally, there is a 21,000-year cycle which, every 58 years, advances the perihelion by one day. Presently, the Earth is closest to the sun on January 4, but 10,500 years ago it was closest on about July 4. Northern winters would likely have been colder, but summers would have been hotter. This more intense summer heat is thought to be a likely cause of the melting of the great ice sheets in North America.

Activity

Have students create mini-globes by drawing the hemispheres, continents, meridians and latitudes on foam balls. Insert a pencil into the south pole of each ball as a rotational axis. Rotate the globes around a bright lightbulb in a dark room to see how changes in orbital shape (from elliptical to nearly circular), axial tilt (from 22° to 25°), and date of the perihelion (the day when Earth is closest to the sun) might affect the amount of light that strikes different regions.

Tectonic movement

The Earth's tectonic plates are always on the move, although most of us are aware of it only when an earthquake strikes. Yet if we look at the shape of the world's continents, it is easy to imagine them as pieces of a giant jigsaw puzzle which have broken away from each other and drifted apart. This is exactly what is thought to have occurred about 200 million years ago when a large supercontinent called Pangaea ("all earth") split apart. The subsequent rearrangement of land masses may have altered climate by re-routing ocean currents which distribute heat around the globe. Similarly, the uplifting of mountain ranges on land changes temperature and precipitation patterns by altering wind movement.

Activity

Cut out the shapes of the continents and move them around to see how they once fit together in the supercontinent Pangaea. Discuss why the present-day arrangement of the continents might hinder the distribution of heat from the equatorial zone.

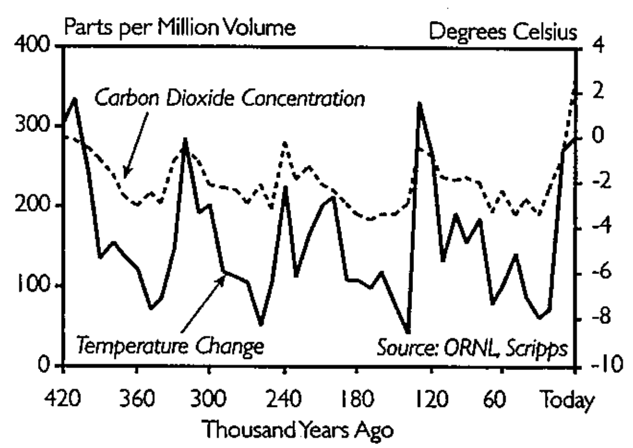
Changes in ice and snow cover

Extensive snow and ice cover has a cooling effect, not just because snow is cold but because it reflects rather than absorbs the sun's energy. Cooling leads, in turn, to the accumulation of more ice and snow, which causes even more of the sun's energy to be reflected, which in turn leads to more cooling. This is called a positive feedback effect, and over time it can accelerate climate change. A similar positive feedback loop occurs during warming trends: as ice and snow melt, more radiation is absorbed and released as heat by newly exposed soil surfaces. This heat in turn leads to more melting.

Demonstration

Chill several small paving stones of equal size, color and composition in a refrigerator. Take them out, wrap one in aluminum foil and the others in paper or cloth of various colors, including white and black. Leave one stone uncovered. Place the stones in a sunny window for about 30 minutes; then unwrap them and pass them around. (The stones should hold their temperature long enough for everyone to touch them.) Relate the results to experiences such as feeling the warmth absorbed by a dark jacket on a cold sunny day, or noticing places where snow melts quickly, such as around a tree trunk or a leaf in a snowbank. If, as scientists believe, average temperatures in the far north are rising more rapidly than elsewhere on Earth, what consequences might this have?

Atmospheric Carbon Dioxide and Temperature Change, 420,000 years ago to Present



(World Resources Institute, *State of the World 2001*)

Volcanic activity

Erupting volcanoes spew tremendous amounts of particulate matter and sulfur gases (which form sulfur aerosols) into the atmosphere. These particulates and aerosols shield the Earth from solar radiation by reflecting incoming light back into space. Most volcanic eruptions therefore have a short-term cooling effect at the Earth's surface. However, very large eruptions may initiate a positive feedback effect that could amplify a cooling trend that was already underway.

Changes in concentrations of greenhouse gases

Analysis of air bubbles in ice cores has revealed a strong correlation between temperature and atmospheric CO_2 over the past 420,000 years (see graph), but it cannot describe for us the mechanisms of past fluctuations. A temperature-driven model might suggest that during warmer periods the level of CO_2 went up because the respiration rate of plants and soil bacteria increased. An atmosphere-driven model might suggest that high concentrations of CO_2 led to warming by enhancing the natural greenhouse effect. While we may never answer such chicken-and-egg questions about the past, it is increasingly clear that human activities that increase greenhouse gases — especially the burning of fossil fuels and deforestation — are responsible for the climate changes observed and predicted at present.

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