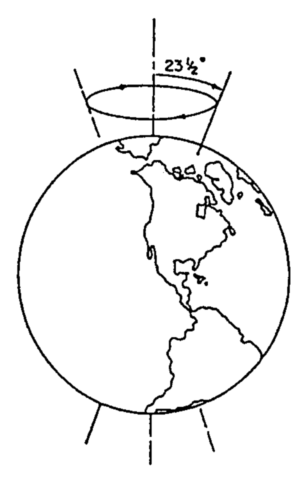
Teacher Information Sheet: Natural Climate Change

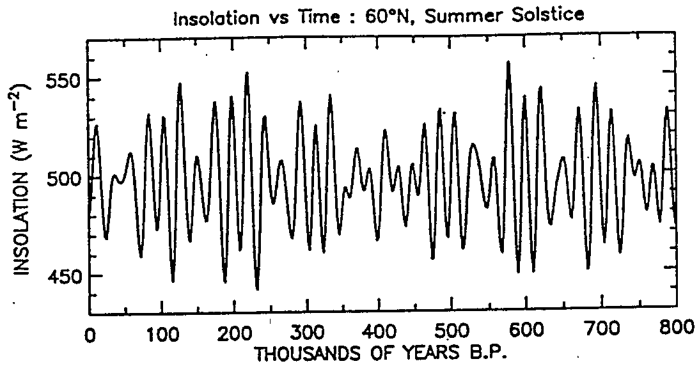
Scientists know that Earth's climate has varied naturally over the past billions of years, with extremes represented by warm environments in the Cretaceous and Eocene and comparatively frigid conditions over the past few million years. The climates of the past billion years, when most of the biological evolution took place, have been some 10 -15 degrees C warmer than our present climate and probably not much more than 5 degrees C colder. Gradual temperature changes of these magnitudes have been associated with radical changes in the ecology of the Earth. For example, 100 million years ago, dinosaurs roamed a planet some 15 degrees warmer than today, and tropical plants and animal fossils have been found in high latitude locations such as Alaska. The great cooling that began 100 million years ago and initiated the cycle of glacial and interglacial periods, has seen sea level drop approximately 300 m (1000 ft) or more, permanent ice accumulate at the poles, life zones of warm and cold loving species evolve, and many species go extinct as they lost their ecological niche.

There are two types of causal factors to consider when attempting to identify the reasons behind variations in Earth's climate over time: ***external forcings*** and ***internal oscillations.*** External forcings are factors outside the climate system which would presumably occur regardless of the state of the weather (i.e.,volcanic activity, astronomical theories). Internal oscillations are causal factors based on the idea that the major subcomponents of the climate system can exchange energy, momentum and materials, as well as respond to disturbances resulting from external forcing on a variety of time scales. These subsystems include the atmosphere, the ocean (both upper and deep) the sea ice, the ice sheets, the land surface and the biota. This theory involves the idea of ***feedback.*** Feedback is evident in many smaller scale living systems in which any process basically creates conditions that cause change in one system to influence other systems and in turn, feed back change into the first system. Feedbacks can be either positive (contributing to the process) or negative (detracting from the process). From detailed surveys made of natural variations in climate over the past several million years, scientists have identified several possible causal factors:

- **changes in the tilt of the rotation axis of the Earth with respect to the position of the Earth on its orbit around the Sun;**

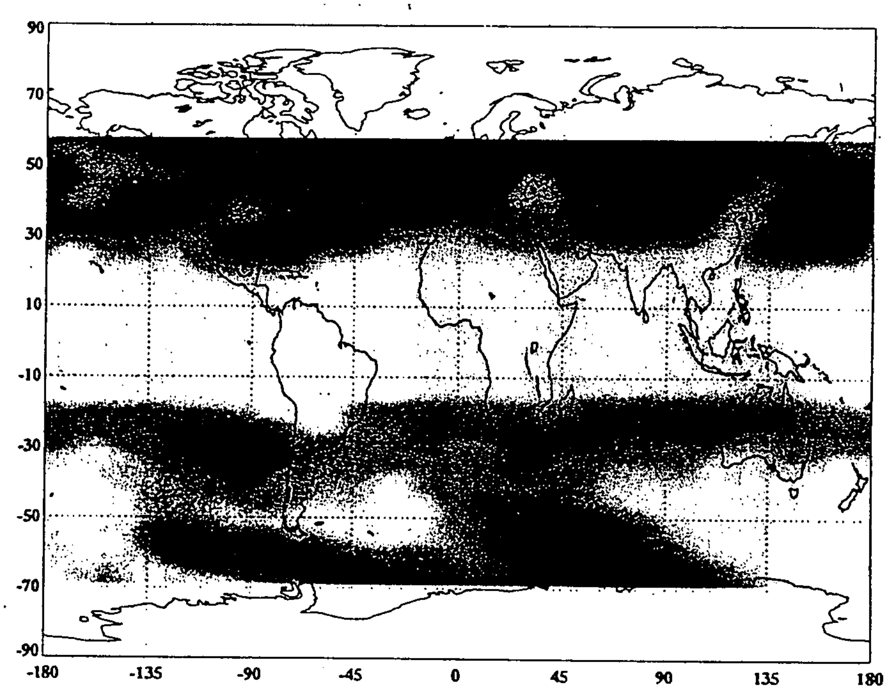


- changes in insolation (the amount of solar energy) reaching a specific location on the Earth's surface;



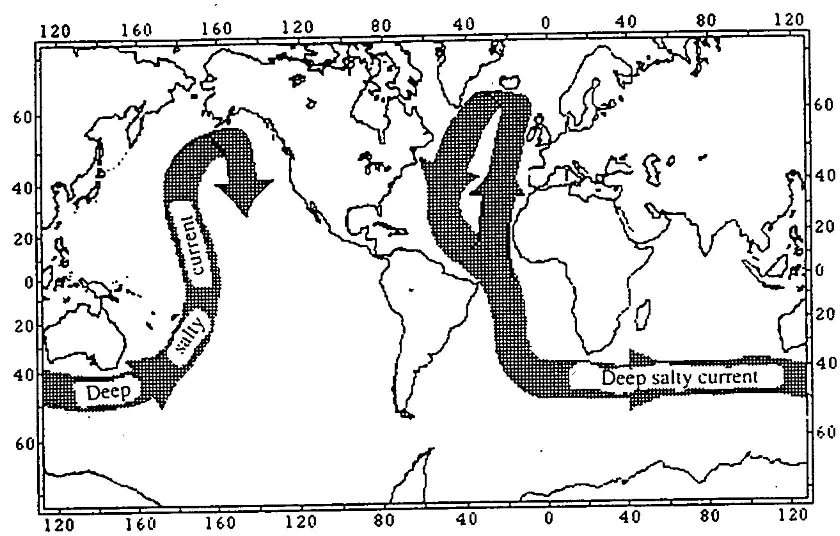
Variation of daily insolation at 60°N for summer solstice over the past 800,000 years. Source: After Berger (1978).

- changes in volcanic and tectonic activity;



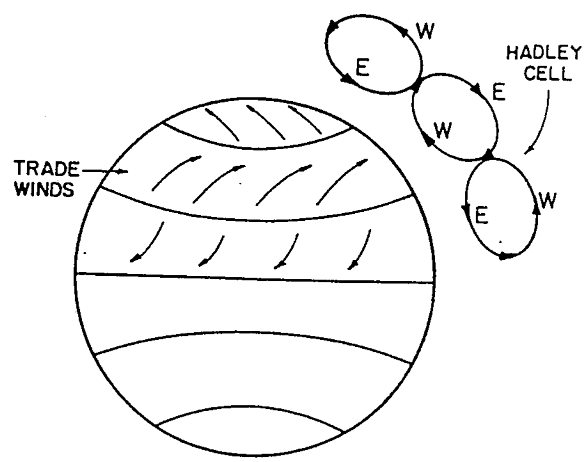
Cloud of sulfuric acid aerosols produced by the Pinatubo eruption, measured by the Stratospheric Aerosol and Gas Experiment (SAGE) II satellite. Higher concentrations of aerosols are shown by lighter shading. By October-November, the Pinatubo cloud had spread around the globe, dispersing more extensively into the Southern than into the Northern Hemisphere. Pinatubo's cloud was so dense that readings of the SAGE instrument — which gauges the blockage or extinction of sunlight — were saturated, and maximum densities went undocumented. (Courtesy M. Patrick McCormick, NASA Langley Research Center)

- **changes in ocean surface temperature, salinity and circulation patterns;**



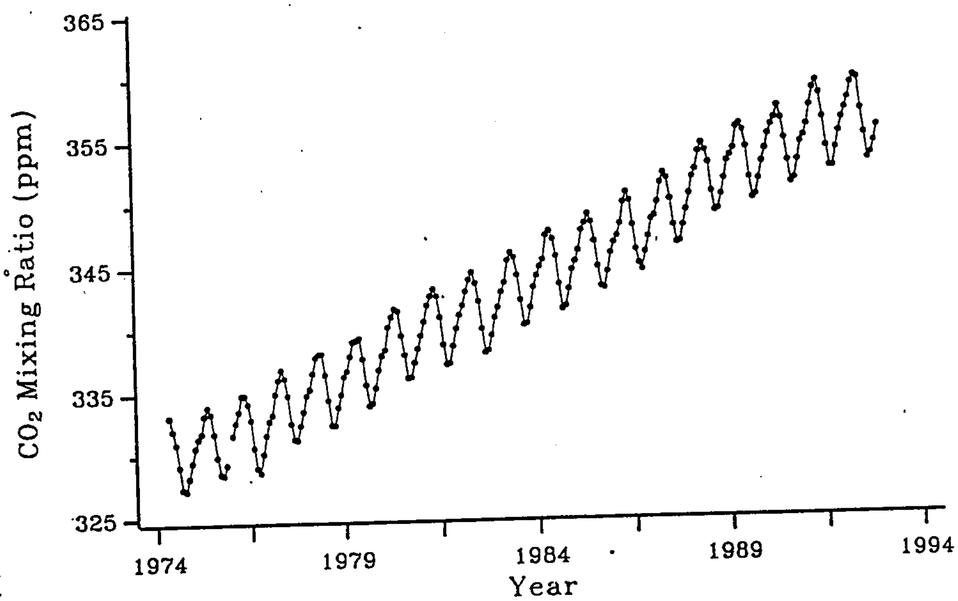
A mechanism operating in today's ocean, which may create rapid climate shifts. Salt-laden North Atlantic Deep Water (NADW) flows down the length of the Atlantic, around Africa through the Southern Indian Ocean, and finally northward in the deep Pacific. This acts as a large-scale salt transport system, compensating for the transport of water vapour through the atmosphere from the Atlantic to the Pacific. This system may be self-stabilizing. Records from ice and sediment cores suggest that it was disrupted in glacial times and replaced by an alternate mode of operation.

- **changes in atmospheric circulation patterns ;**



The position of Hadley cell indicated for the present climate. Note the presence of westerly winds aloft with easterlies (trade winds) near the surface. It is suggested that during unusually warm conditions the Hadley cell may be more extensive, under extreme conditions reaching close to the poles.

- changes in the concentration of heat absorbing atmospheric gases;



Monthly atmospheric CO_2 mixing ratios at Mauna Loa.

- changes in biological activity;

- changes in Earth's biogeochemical cycles;

How is it that scientists know how long an ice age or interglacial period lasts, what the relative temperature differences were, or what the composition of the atmosphere may have been during the ice ages or previous interglacials?

One way is to analyze the air trapped in ice thousands of years ago from ice cores. Because the massive domes of ice on Antarctica and Greenland are made up of compressed snow that has accumulated over several hundred thousand years, these two locations are ideal for studying the history of the atmosphere. As snow is squeezed by the weight of additional precipitation on top, it slowly turns to ice. As the ice forms, the air that surrounds the snowflakes is trapped in bubbles and held in the ice until it is discharged into the ocean - usually hundreds of thousands of years after deposition. By drilling down thousands of meters into the ice and extracting core samples, scientists can bring up samples of the air that was breathed by early humans. The ice is transported for analysis to special facilities where it is kept frozen. It is then sliced into fine sections and the gases are extracted. As the ice is heated, the air bubbles trapped in it are released and assessed carefully to determine the changing concentration of gases in the atmosphere over time. Analyses from core samples taken at places like Vostok in Antarctica show that concentrations of CO_2 were from 25 - 30% lower during glacial times than at interglacial times over the past 160,000 years.

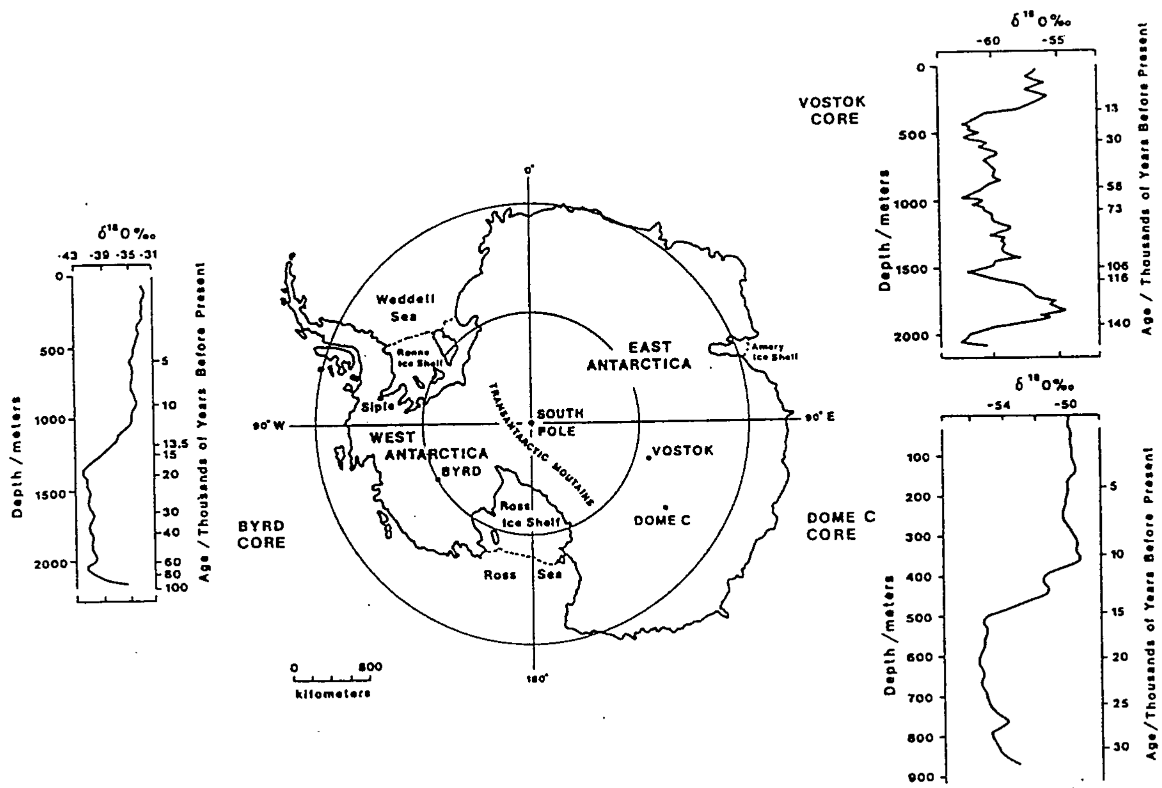
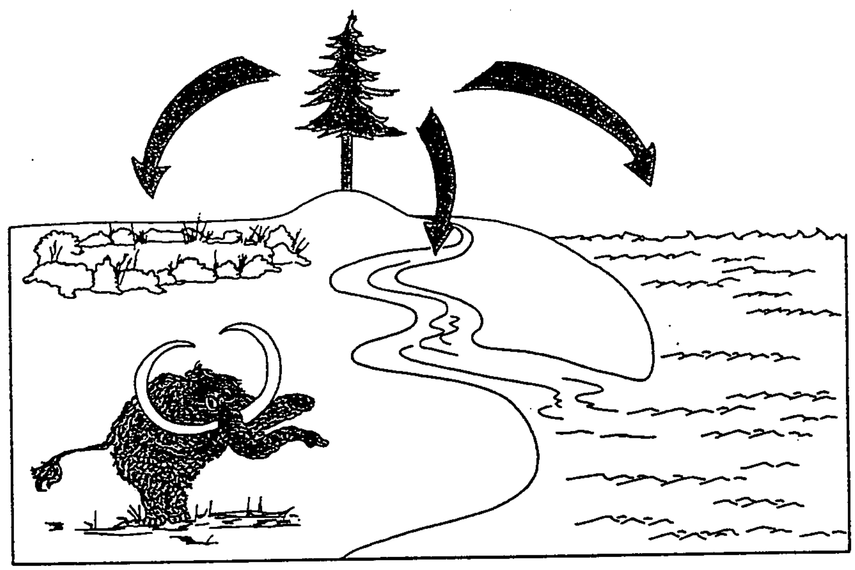


Figure 1. Antarctica, showing the location of sites where ice cores have been drilled. Examples of the oxygen-isotope records from the three deep cores—the Vostok core, the Dome C core and the Byrd core—are shown for comparison. Depth and estimated age are shown on the left and right hand side, respectively, of each profile.

Several other investigative methods are available for acquiring information about the climates of the past in addition to the data acquired from ice cores:

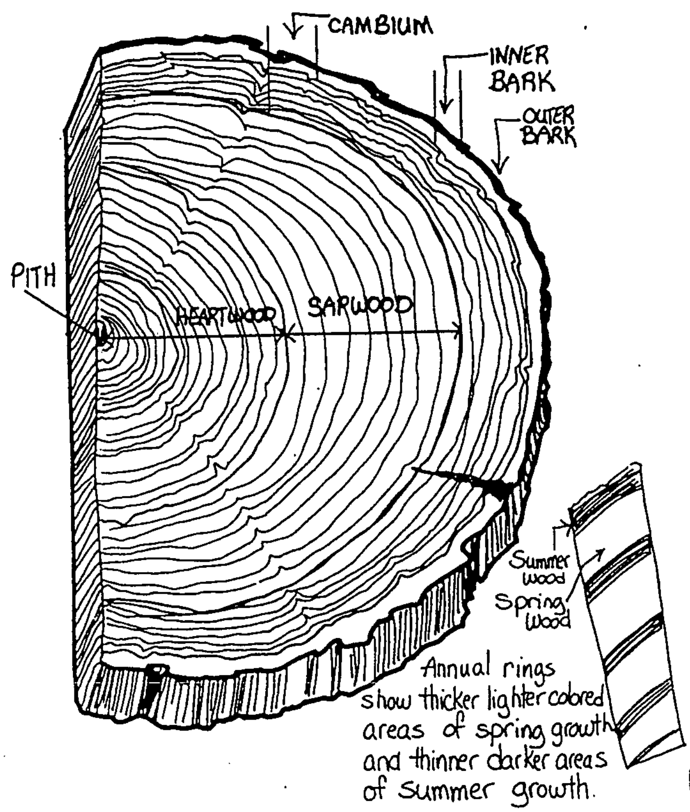
- **fossil pollen studies from freshwater and marine sediments;**

Most of the millions of pollen grains dispersed into the atmosphere are deposited within a short distance (less than a thousand meters) from their source, as symbolized by the left-hand arrow showing pollen from a lone pine tree dropping into a nearby lake. Pollen from vegetation growing immediately along the seacoast is carried by wind to the ocean, as shown by the right-hand arrow. Empirical studies show that fluvial transport (via streams and rivers), the middle arrow, carries most pollen to the ocean, where it is deposited along with the carbonate skeletons of marine microorganisms. Deep sea cores from the continental margins subsequently retrieve sediment containing both marine microorganisms and pollen—an unequaled source of terrestrial and marine paleoclimatic data.

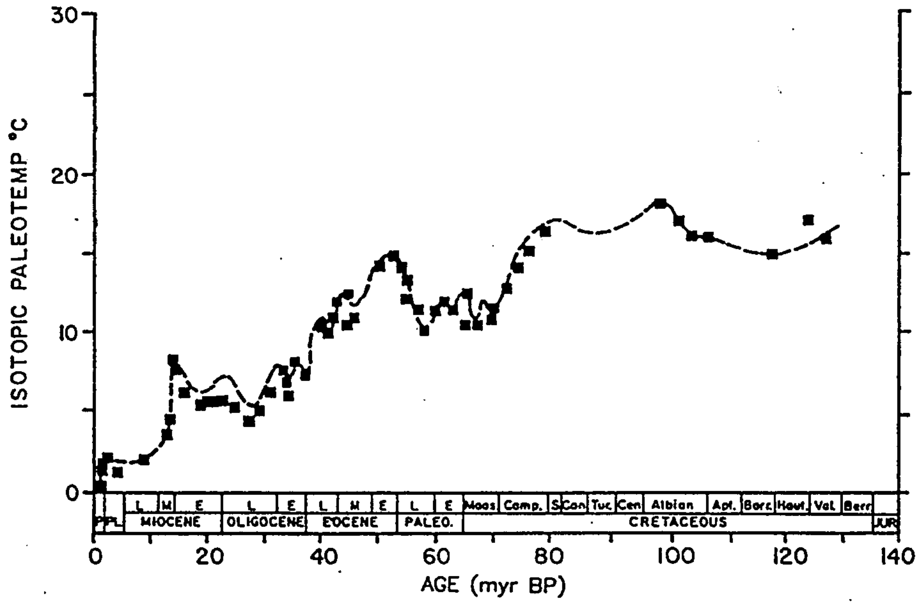


- **tree ring and core analysis;**

Counting tree rings gives a fairly accurate account of a trees age and the weather conditions in the area where the tree grew. The wider the rings, the more growth, indicating ideal growth conditions. The narrower rings indicate less growth due to drought or cold cycles.



- stable isotope studies;

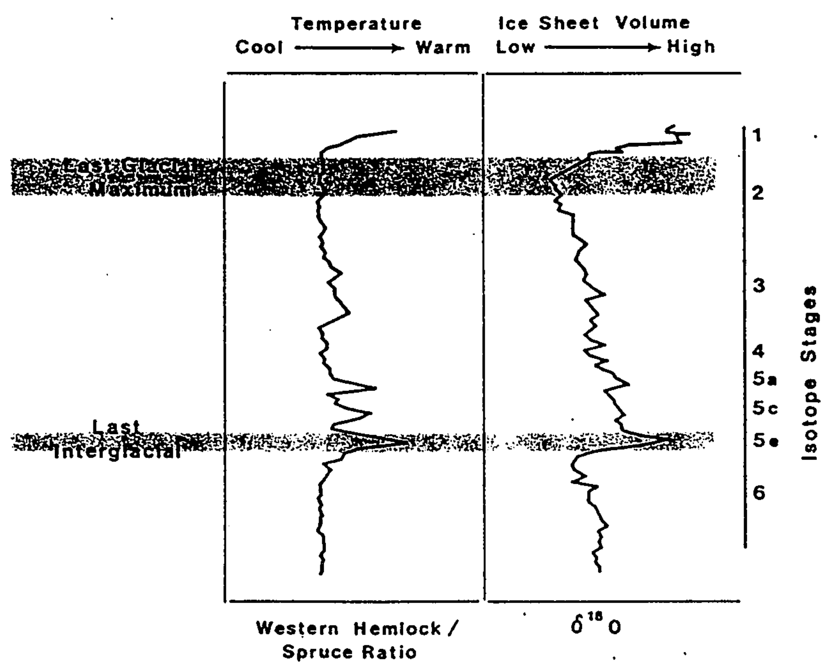


A graph of reconstructed temperature of the tropical Pacific ocean over the past 140 million years based on the oxygen isotopic composition of benthic foraminifera (plankton).

- deep sea sediment core sampling;

A 16- meter deep sea core from the northeast Pacific Ocean gave climate signals from the last 150,000 years. The core contains fossil pollen from western hemlock and spruce from western Washington and Oregon. The ratio of the hemlock to spruce pollen allow scientists to infer paleotemperature trends for the area.

(Note: The temperatures in western hemlock dominated coastal forests are 1-2 degrees higher than in spruce dominated forests.)



Natural climate variations make it difficult to distinguish long term trends. If there happened to be a natural temperature cycle which was at a minimum in 1861 and near a maximum at present, then plotting out temperatures over this time period and drawing a straight line could give a misleading impression of the trend. Take an analogy: if you made a series of measurements of the brightness of the Sun, starting at noon and ending at midnight two and a half days later, you might well conclude that the world was getting darker --- and you would be wrong. Of course, modern statistical techniques assume nothing so naive as a straight line. Instead, they attempt to explain observed variations in terms of a long-term trend (which may or may not be a straight line) as well as a set of fairly regular fluctuations about the trend. Thus they reduce a complicated signal to a small number of fairly simple patterns.