Paleoclimatology: Can We Infer Past Climates?

What is Paleoclimatology?
taken from http://serc.carleton.edu/microbelife/topics/proxies/paleoclimate.html

Paleoclimatology is the study of past climates. Since it is not possible to go back in time to see what climates were like, scientists use imprints created during past climate, known as proxies, to interpret paleoclimate. Organisms, such as diatoms, foraminifera, and coral serve as useful climate proxies. Other proxies include ice cores, tree rings, and sediment cores (which include diatoms, foraminifera, microbiota, pollen, and charcoal within the sediment and the sediment itself). These records can then be integrated with observations of Earth's modern climate and placed into a computer model to infer past as well as predict future climate.

How Are Organisms Used As Proxies?

Foraminifera, also known as forams, and diatoms are commonly used climate proxies. Forams and diatoms are shelled organisms found in aquatic and marine environments. There are both planktonic, or floating in the water column, and benthic, or bottom dwelling, forms. Foram shells are made up of calcium carbonate (CaCO$_3$) while diatom shells are composed of silicon dioxide (SiO$_2$). These organisms record evidence for past environmental conditions in their shells. Remains of foram and diatom shells can be found by taking sediment cores from lakes and oceans, since their shells get buried and preserved in sediment as they die. The chemical make up of these shells reflect water chemistry at the time of shell formation. Stable oxygen isotope ratios contained in the shell can be used to infer past water temperatures. These oxygen isotopes are found naturally in both the atmosphere and dissolved in water. Warmer water tends to evaporate off more of the lighter isotopes, so shells grown in warmer waters will be enriched in the heavier isotope. Measurements of stable isotopes of planktonic and benthic foram and diatom shells have been taken from hundreds of deep-sea cores around the world to map past surface and bottom water temperatures.

How Are Ice Cores Used?
taken from http://earthobservatory.nasa.gov/Features/Paleoclimatology_IceCores/

Ice core records- deep ice cores, such as those from Lake Vostok, Antarctica, the Greenland Ice Sheet Project, and North Greenland Ice Sheet Project can be analyzed for trapped gas, stable isotope ratios, and pollen trapped within the layers to infer past climate.

Throughout each year, layers of snow fall over the ice sheets in Greenland and Antarctica. Each layer of snow is different in chemistry and texture, summer snow differing from winter snow. Summer brings 24 hours of sunlight to the polar regions, and the top layer of the snow changes in texture—not melting exactly, but changing enough to be different from the snow it covers.
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The season turns cold and dark again, and more snow falls, forming the next layers of snow. Each layer gives scientists a treasure trove of information about the climate each year.

To pry climate clues out of the ice, scientists began to drill long cores out of ice sheets in Greenland and Antarctica. The longest cores are nearly 2-miles-long (3 km) from the Greenland ice sheet, providing a record of at least the past 110,000 years. Even older records going back about 750,000 years have come out of Antarctica. Scientists have also taken cores from thick mountain glaciers in places such as the Andes Mountains in Peru and Bolivia, Mount Kilimanjaro in Tanzania, and the Himalayas in Asia.

The ice cores provide annual records of temperature, precipitation, atmospheric composition, volcanic activity, and wind patterns. In a general sense, the thickness of each annual layer tells how much snow accumulated at that location during the year. Differences in cores taken from the same area reveal local wind patterns by showing where the snow drifted. More importantly, the make-up of the snow itself can tell scientists about past temperatures. Just like forams, ratios of oxygen isotopes in snow reveals temperature, though in this case, the ratio tells how cold the air was at the time the snow fell. In snow, colder temperatures result in higher concentrations of light oxygen.

When scientists lower an ultra-precise thermometer into a hole in the ice, they can detect the temperature variations that have occurred since the Ice Age. The near-surface ice temperature, like the atmosphere today, is warm, and then the temperature drops in the layers formed roughly between AD 1450 and 1850, a period known as the Little Ice Age, one of several cold snaps that briefly interrupted the overall warming trend ongoing since the end of the Ice Age. As the thermometer goes deeper into the ice sheet, the temperature warms again, and then plummets to the temperatures indicative of the Ice Age. Finally, the bottom layers of the ice sheet are warmed by heat coming from the Earth. These directly measured temperatures represent a rough average—a record of trends, but climatologists can compare the thermometer temperatures with the oxygen isotope record.

As valuable as the temperature record may be, the real treasure buried in the ice is a record of the atmosphere’s characteristics. When snow forms, it crystallizes around tiny particles in the atmosphere, which fall to the ground with the snow. The type and amount of trapped particles, such as dust, volcanic ash, smoke, or pollen, tell scientists about the climate and environmental conditions when the snow formed. As the snow settles on the ice, air fills the space between the ice crystals. When the snow gets packed down by subsequent layers, the space between the crystals is eventually sealed off, trapping a small sample of the atmosphere in newly formed ice. These bubbles tell scientists what gases were in the atmosphere, and based on the bubble’s location in the ice core, what the climate was at the time it was sealed. Records of methane levels, for example, indicate how much of the Earth wetlands covered because the abundance of life in wetlands gives rise to anaerobic bacteria that release methane as they decompose organic material. Scientists can also use the ice cores to correlate the concentration of carbon dioxide in the atmosphere with climate change—a measurement that has emphasized the role of carbon dioxide in global warming.