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ATS 320

Paleoclimatology: An Introduction into Ice Core Research

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Abstract

Paleoclimatology is the study of climate change throughout the entire history of the Earth. Currently, the climate is consistently being scrutinized for causation of the increased rate of change influencing our climate. Proxy data is gathered from many different means, including corals, tree rings, sediment analysis, and ice core research.

Ice cores are collected via drills- most are from the Greenland or Antarctic ice sheets. Dependent on the depth and temperature of the ice core to be extracted, different drills are used. Ice core analysis of bubbles and dust particles, for example, give quantitative information about past climate forcing and patterns.

As with most scientific processes, limitations are reached with ice core research. Further exploration of ice cores can allow us to understand and isolate the differences between anthropogenic and natural influences of climate change.

Paleoclimatology: An Introduction into Ice Core Research

Paleoclimatology is the study of climate change throughout the entire history of the Earth. Since the Industrial Revolution, much emphasis has been placed on the impact that humans have had on our planet's climate. A large understanding of today's climate begins with the trends obtained via proxy data gathered from multiple sources.

Proxy data is data collected indirectly and is used in place of direct measurements which tend to be lacking before the 1880's, when reliable climate measurements and projections first became viable for analysis. Proxy data used for climate analysis comes from collection and study of matter such as tree rings, ice cores, pollen distribution, corals, and ocean sediments. Ice cores have provided information regarding atmospheric concentration back hundreds of thousands of years (NOAA, 2003).

Ice cores contain information about past climate change. By studying ice cores, we obtain data regarding snowfall, dust particles, salts, ash, gas bubbles, and pollutants. The chemical and physical properties of ice can provide information ranging from seasonal climate changes to climate change happening over thousands of years. The information gathered from these ice cores can help us reconstruct past climate variables such as temperature, precipitation, frequency/strength of natural processes, etc. Evidence of these natural processes are laid down in ice sheets and preserved well enough to infer about climate change (NOAA, 2003).

Ice drilling became known in the early 1950's, when a Danish scientist named Willi Dansgaard discovered the correlation between precipitation of heavy oxygen isotopes (^{18}O) and temperature of the location (Univ. of Copenhagen). It was suggested by Dansgaard that the best way to collect historical mediums of precipitation would be to drill into ice structures. The first sample from an iceberg was taken from the Greenland ice caps in the late 1950's. By the mid 1960's, ice core drilling had blossomed into a highly sought after practice to gain data about past climates. Many of the first ice cores were as long as 1400 meters. It was found that low concentrations of ^{18}O correlated with low temperatures, and vice versa. By the 1980's, ice drilling was considered a foundation for further extrapolation of climate trends and projections (Univ. of Copenhagen, 2010).

The two primary locations for ice core extraction are Greenland and Antarctica due to the fact that these generally undisturbed ice sheets are immense in size and thickness (Readinger, 2006). However, lower-latitude samples of ice cores include those of the Himalayan plateau, the Andes mountains, and Mt. Kilimanjaro. These low-latitude ice cores supply scientists with different information of climate forces than those from polar caps (Readinger, 2006). Unfortunately, at the rate of atmospheric warming and land ice melting as a result, the samples currently possessed of these ice sheets could be the only ones ever collected from these areas. Once ice cores are obtained from drill sites, they can be sent back to ice laboratories. Some of the most well-known ice core labs include the Oregon State University ice core lab, the National Ice Core Laboratory in Lakewood, Colorado, and even on-site in Antarctica (Readinger, 2006).

Ice cores are extracted using a vertical drill that cuts the ice into cylindrical samples 4-5 inches in diameter and in 1-meter bursts (Readinger, 2006). The type of drill is dependent on the temperature (and therefore, depth) of the ice. Ice well below freezing temperatures is mostly extracted using electro-mechanical drilling. Warmer ice cores are extracted using thermal electric drills (Readinger, 2006). The most common source of power for these drills is fuel, however solar-powered drills are also widely used for extraction. Some analysis can be done at the drill site, however most samples are sent to cold storage rooms for analysis. Some instruments used for ice core analysis include mass spectrometer, electron microscopes, microparticle counters, and gas chromatographers (Readinger, 2006).

Information about temperature trends can be gathered by studying atomic isotope concentrations in ice cores. Heavier isotopes such as deuterium (^{2}H) have a direct correlation to temperature due to the fact that these isotopes are in higher concentrations in ice cores when temperatures are warm (Univ. of Copenhagen, 2010). In contrast, ^{16}O (light oxygen isotope) concentrations are higher in ice than ^{18}O (heavy oxygen isotope) concentrations in warmer weather as a result of these isotopes being "favored" in evaporation processes, which eventually get laid down as snow in ice sheets and preserved for thousands of years (Univ. of Copenhagen, 2010).

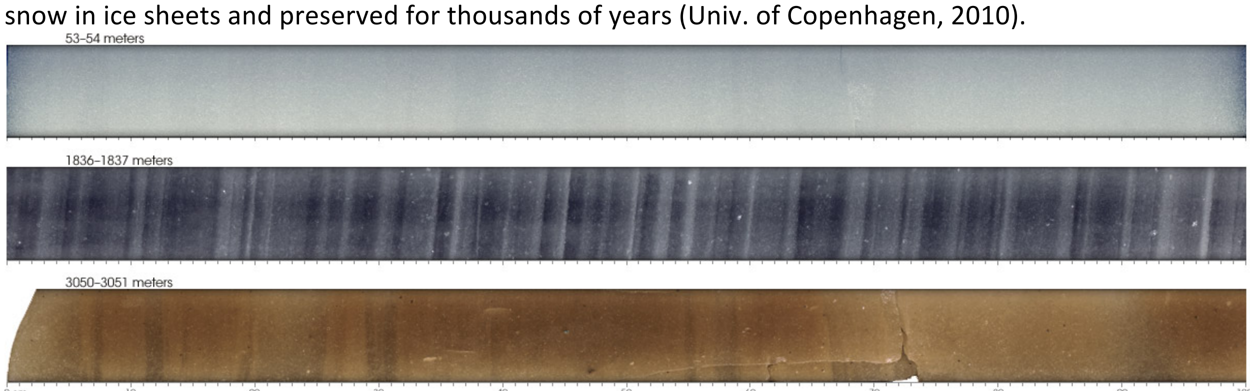

Photo courtesy of NASA, 2005

The photo above depicts the attributes of ice cores as we recover ice from thousands of meters below the Earth's surface. Ice toward the bottom of the core sample is much more compact due to the weight of additional ice layers, thus compressing the annual layering present in ice. The annual layers are easily depicted in the middle ice core sample, taken from 1836 meters. This particular ice core was extracted from the Greenland ice sheet, and provides a record of approximately the past 110,000 years (Readinger, 2006).

Dust particle composition and concentration gives information regarding atmospheric circulation, volcanic eruption, and wind speeds (Readinger, 2006). Dust particles can be used to date ice cores in annual layers, as well as helping accurately estimate the frequency and severity of many natural occurrences including volcanoes, El Nino oscillations, monsoons and wind storms (NASA, 2005). Studying the composition of these dust particles tells whether current wind patterns are as energy-rich as in the past. The compositions of these dust particles are compared against dust particles from other areas to determine the identity and original location of the particles (Univ. of Copenhagen, 2010).

Other impurities within ice cores include acids, ash particles, and molecular compounds such as sulfate, nitrate, and ammonium. Ammonium is a byproduct from biomass burning (such as during forest fires), but is also indicative of emissions from soil and vegetation (Univ. of Copenhagen, 2010). Concentrations of salt ions (Na^+ and Cl^-) tell us the amount of sea ice that was present during that year.

Bubbles in these ice cores also contain information about past atmospheric composition, such as greenhouse gas concentrations. Bubbles are trapped between layers of snow and are preserved in air as the snow compresses and becomes ice after a long process (Readinger, 2006). The faster this process happens, the less interaction there is between these bubbles and outside contaminants. Therefore, bubbles formed in under 100 years contain the purest sample of atmospheric composition at the time the snow had fallen (Readinger, 2006). Carbon dioxide (CO_2) concentrations are of great concern currently, as they seem to have a high correlation with temperature variation as seen with ice core data and other means of proxy data. As most of us have ascertained, high levels of CO_2 have been linked to high temperatures in the past. In fact, CO_2 levels in interglacial periods are much higher than in periods of glaciation. What most people don't know, however, is that ice core research (as well as other paleoclimate data) has shown that temperature spikes actually precede increases in CO_2- not the other way around as is often perceived (SEED). This is evident in ice cores when information about annual cycles is extrapolated from the air bubbles present within the sample.

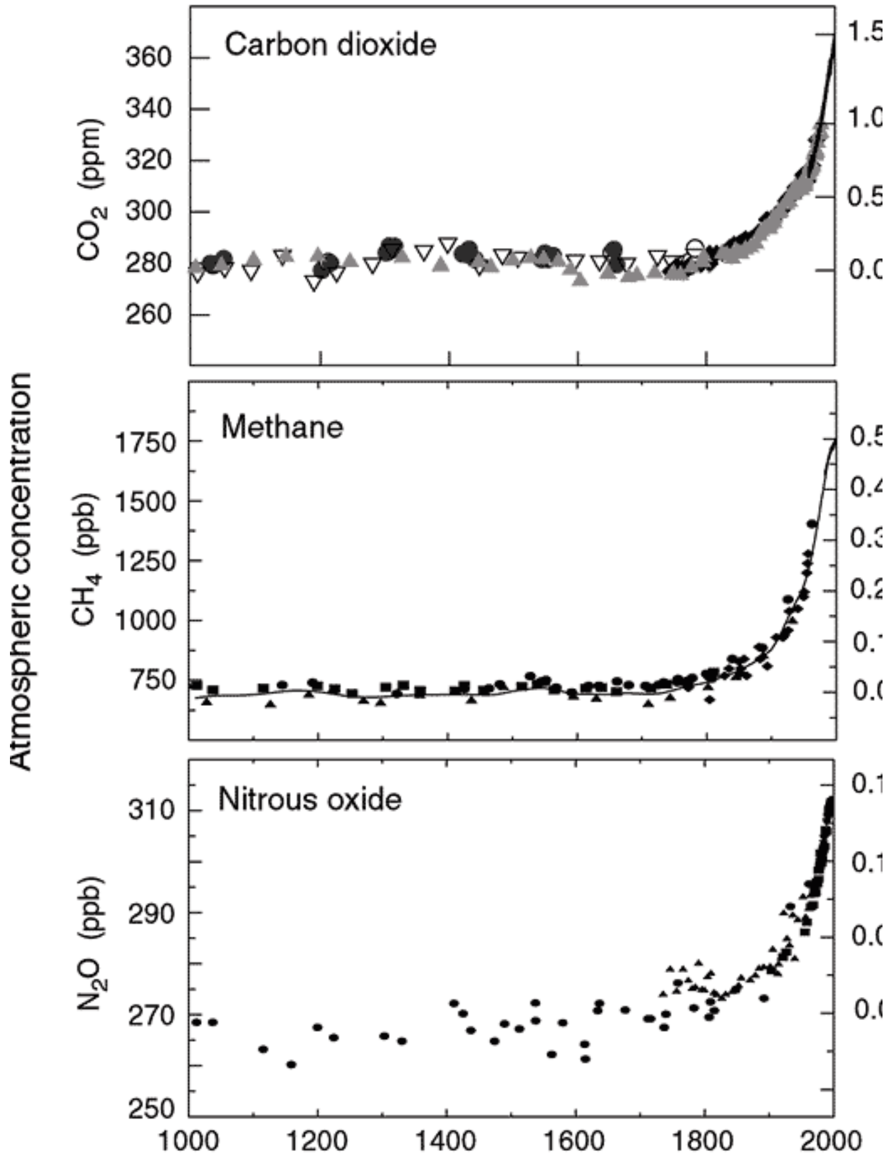

Photo courtesy of Christopher Readinger, 2006

The figure above portrays the quantitative values and rate of increase in three important greenhouse gases (carbon dioxide, methane, and nitrous oxide) over the past 1,000 years. Ice core data has helped measure and approximate greenhouse gas concentrations throughout history via bubble Analysis (Readinger, 2006). From this information, we can begin to anticipate the effects of natural processes due to the apparent rate of change for current greenhouse gas concentrations as compared to past samples.

As with most scientific processes, ice core research does have its limitations. The most obvious limitation to ice core research is the simple ability for evidence captured within the ice core to be destroyed. For example, ice cap melting is continuing to be a problem with potential drilling sites. Water percolating from the melt through the dating layers in ice can contaminate or destroy them, as well as any history they may house (Readinger, 2006). Greenland is currently an area where much ice core data is collected. A current climate projection suggests that the Greenland ice sheet may be almost completely melted in 20 years (Univ. of Copenhagen, 2010). This could mean a devastating reduction in ice core collection, as well as a limit to further knowledge gained from the Greenland area in regards to climate change.

Another example of ice core limitation is that conditions are only measurable if they occur during snowfall (Readinger, 2006). Therefore, ice core research is not an entirely cumulative collection of year-round weather patterns. Extreme lack of snowfall can produce an issue with accurately dating ice core samples. Comprehensive analyses of short-term patterns is much more difficult in areas such as Antarctica, where annual snowfall is low (Readinger, 2006). Therefore, long-term patterns are best analyzed from ice cores collected from Antarctica. Antarctica also has higher wind speeds on average than other drilling sites, and often several cores from corresponding areas must be collected to account for winds carrying particulate matter and other impurities to other locations on the continent. The unpredictability of ice beds and the sediments underneath often make it difficult for scientists to choose an adequate drill site that will provide deep enough samples suitable for analysis (Readinger, 2006).

By obtaining a thorough data record of ice cores, we can only begin to divulge the rate at which our atmosphere and climate will change in the future. Currently, it is very difficult to create a climate model that will accurately project the fate of our atmosphere (NOAA, 2003). Further exploration of ice core data will help differentiate and isolate the causes of natural climate change from the causes of anthropogenic climate change causes. Continuing to collect data from all modes of paleoclimatology-related research and coalescing it with current climate data ensures a more cohesive understanding about future climate events.

Sources Cited

National Aeronautics and Space Administration (NASA), 2005. “Paleoclimatology: The Ice Record” http://earthobservatory.nasa.gov/Features/Paleoclimatology_IceCores/

National Oceanic and Atmospheric Administration (NOAA), 2003. “Paleo Proxy Data” http://www.ncdc.noaa.gov/paleo proxies.html

Readinger, C., 2006. “ Ice Core Proxy Methods for Tracking Climate Change.” CSA Discovery Guides. http://www.csa.com/discoveryguides/icecore/review.pdf

University of Copenhagen, 2010. “The History of Danish Ice Core Research” http://www.iceandclimate.nbi.ku.dk/about_centre/history/

Schlumberger Excellence in Educational Development (SEED). “CO_2 and Temperature Change“ http://www.planetseed.com/relatedarticle/co2-and-temperature-change