Ice Core Perspectives on Paleothermometry

Lonnie G. Thompson
School of Earth Sciences and Byrd Polar Research Center
The Ohio State University
thompson.3@osu.edu

Stable isotopic ratios, particularly of oxygen ($\delta^{18}O$), preserved in glacier ice provide records of climate changes at high resolution over long time periods from pole to pole. The isotopic signal is driven primarily by temperature, in polar ice sheets while on the low-latitude, high-altitude glaciers isotopic ratios yield a climate signal that likely depends on a variety of hydrologic and temperature influences. Unfortunately our current level of understanding does not allow a straightforward and rigorous separation of the temperature and hydrologic components in this signal. However, on time-scales of decades or longer, the $\delta^{18}O$ histories preserved in tropical ice cores appear to record primarily large-scale atmospheric temperature changes. A conundrum arises as the seasonal relationship between temperature and $\delta^{18}O$ in the tropics is opposite that found in the Polar Regions, where the more negative $\delta^{18}O$ values characterize winter snowfall. Furthermore, while the seasonal temperature range in the tropics is only a few degrees, the seasonal range of $\delta^{18}O$ in the snowfall is much larger, often over to 20‰. These observations raise the question: If the most isotopically depleted (negative) $\delta^{18}O$ values characterize summer precipitation in the tropics, how does $\delta^{18}O$ in tropical precipitation record temperature over longer time scales? The nature of the seasonal $\delta^{18}O$-temperature relationship in the tropics will be discussed.

Like polar ice cores, the $\delta^{18}O$ records from the Andes, the Himalaya and Tibetan Plateau preserve evidence of century to millennial-scale temperature fluctuations. The cooler Late Glacial Stage and warmer Holocene are evident in ice-core records from pole to pole. Recent well-documented climate events of shorter duration are also preserved in tropical cores, particularly those from Peru. The Quelccaya and Huascarán ice cap $\delta^{18}O$ records reflect from 1520 through 1880, the so-called “Little Ice Age” and the 20th century warming more prominently than those from polar ice cores. Greenland experienced a pronounced period of warmth around A.D. 1000 (during the medieval anomaly), a cool period from 1600 through 1900 “Little Ice Age” , and a modest 20th century warming and although some coastal sites in Antarctica show 20th century warming, the interior sites do not. None of the Antarctic cores contain evidence of warming during the medieval anomaly.

Ice-core records from the Andes, the Himalaya and the Tibetan Plateau show that the climate of the 20th century was unusual with respect to the preceding 2,000 years. All available evidence indicates that the Himalaya and Tibetan Plateau region warmed over the last century, but Andean climate changes are inconsistent over space and time in ways that are not yet fully understood but may be related to ENSO influence in this region. Quelccaya is the best tropical ice cap for preserving records of both stable isotopes and net balance as the intense solar radiation, even in the wet season, fuses the surface snow before significant drifting and reworking occur. Quelccaya provides the only truly tropical glacier records of isotopic ratios and net balance that are annually-resolved back 1688 years. Running correlations (21-year moving) between $\delta^{18}O$ and net balance over this period show that statistically significant positive and negative correlations occur sporadically, but overall the two time series are uncorrelated. However, the 5-year running means (1854 to 2007) of $\delta^{18}O$ and ENSO-associated tropical Pacific SSTs are strongly correlated (R^2 =0.55), and contain linkages with tropospheric temperatures over the tropical Andes. The strong correlations between many other ice core $\delta^{18}O$ records throughout the tropics and tropical SST's likely reflect the influence of tropical evaporation on the water vapor flux to the atmosphere. This provides insight to global-scale teleconnections of processes that affect stable isotopic values in tropical precipitation and perhaps in global precipitation as well.