Research resolves discrepancy in Greenland temperatures during end of last ice age

September 4 2014

Bo Vinther prepares an ice core for visual inspection. Credit: Christian Morel

A new study of three ice cores from Greenland documents the warming of the large ice sheet at the end of the last ice age – resolving a long-standing paradox over when that warming occurred.

Large ice sheets covered North America and northern Europe some 20,000 years ago during the coldest part of the ice age, when global

average temperatures were about four degrees Celsius (or seven degrees Fahrenheit) colder than during pre-industrial times. And then changes in the Earth's orbit around the sun increased the solar energy reaching Greenland. Beginning some 18,000 years ago, release of carbon from the deep ocean led to a graduate rise in atmospheric carbon dioxide (CO2).

Yet past analysis of ice cores from Greenland did not show any warming response as would be expected from an increase in CO2 and solar energy flux, the researchers note.

In this new study, funded by the National Science Foundation and published this week in the journal *Science*, scientists reconstructed air temperatures by examining ratios of nitrogen isotopes in air trapped within the ice instead of isotopes in the ice itself, which had been used in past studies.

Not only did the new analysis detect significant warming in response to increasing atmospheric CO2, it documents a warming trend at a rate closely matching what climate change models predict should have happened as the Earth shifted out of its ice age, according to lead author Christo Buizert, a postdoctoral researcher at Oregon State University and lead author on the *Science* article.

"The Greenland isotope records from the ice itself suggest that temperatures 12,000 years ago during the so-called Younger Dryas period near the end of the ice age were virtually the same in Greenland as they were 18,000 years ago when much of the northern hemisphere was still covered in ice," Buizert said. "That never made much sense because between 18,000 and 12,000 years ago atmospheric CO2 levels rose quite a bit."

Scientists use a sled to move equipment at the NEEM camp in northern Greenland. Credit: Christian Morel

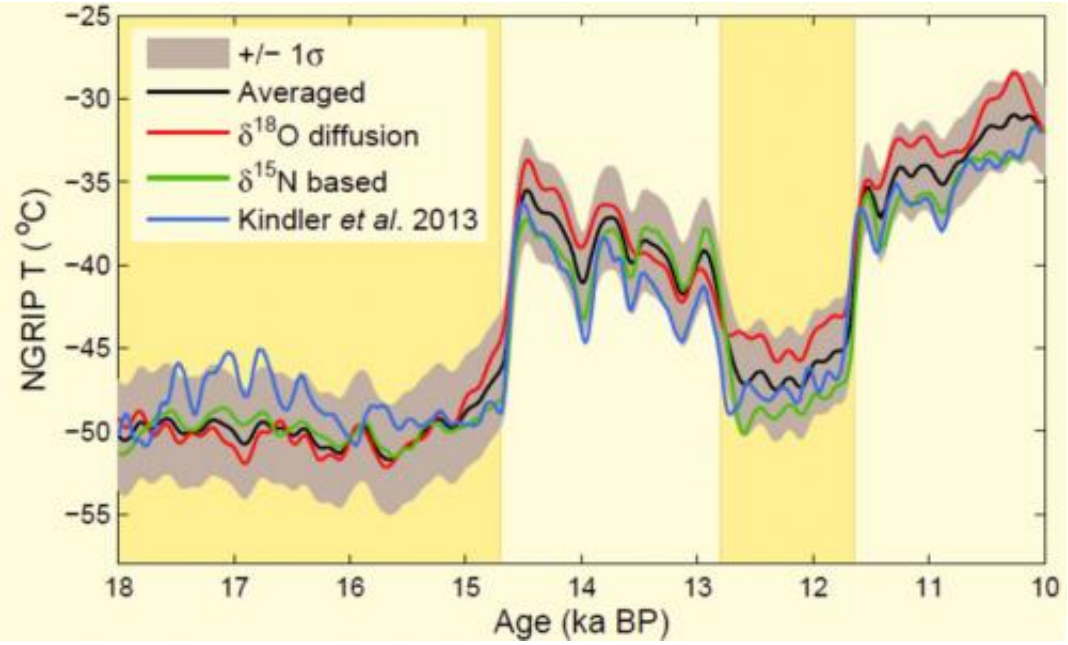
"But when you reconstruct the temperature history using nitrogen isotope ratios as a proxy for temperature, you get a much different picture," Buizert pointed out. "The nitrogen-based temperature record shows that by 12,000 years ago, Greenland temperatures had already warmed by about five degrees (Celsius), very close to what climate models predict should have happened, given the conditions."

Reconstructing temperatures by using water isotopes provides useful information about when temperatures shift but can be difficult to calibrate because of changes in the water cycle, according to Edward Brook, an Oregon State paleoclimatologist and co-author on the *Science* study.

"The water isotopes are delivered in Greenland through snowfall and

during an ice age, snowfall patterns change," Brook noted. "It may be that the presence of the giant ice sheet made snow more likely to fall in the summer instead of winter, which can account for the warmer-than-expected temperatures because the snow records the temperature at the time it fell."

In addition to the gradual warming of five degrees (C) over a 6,000-year period beginning 18,000 years ago the study investigated two periods of abrupt warming and one period of abrupt cooling documented in the new ice cores. The researchers say their leading hypothesis is that all three episodes are tied to changes in the Atlantic meridional overturning circulation (AMOC), which brings warm water from the tropics into the high northern latitudes.



The revised Greenland temperature history (black curve, grey uncertainties) for the period 18,000 to 10,000 before present. This temperature history is based on temperature interpretation from nitrogen measurements (green curve) and O18 diffusion measurements (red curve). The blue curve is from a previous study, based on nitrogen measurements. Credit: Niels Bohr Institute

The first episode caused a jump in Greenland's air temperatures of 10-15 degrees (C) in just a few decades beginning about 14,700 years ago. An apparent shutdown of the AMOC about 12,800 years ago caused an abrupt cooling of some 5-9 degrees (C), also over a matter of decades.

When the AMOC was reinvigorated again about 11,600 years ago, it caused a jump in temperatures of 8-, 11 degrees (C), which heralded the end of the ice age and the beginning of the climatically warm and stable Holocene period, which allowed human civilization to develop.

"For these extremely abrupt transitions, our data show a clear fingerprint of AMOC variations, which had not yet been established in the ice core studies," noted Buizert, who is in OSU's College of Earth, Ocean, and Atmospheric Sciences. "Other evidence for AMOC changes exists in the marine sediment record and our work confirms those findings."

In their study, the scientists examined three ice cores from Greenland and looked at the gases trapped inside the ice for changes in the isotopic ration of nitrogen, which is very sensitive to temperature change. They found that temperatures in northwest Greenland did not change nearly as much as those in southeastern Greenland – closest to the North Atlantic – clearly suggesting the influence of the AMOC.

"The last deglaciation is a natural example of global warming and climate change," Buizert said. "It is very important to study this period because it can help us better understand the climate system and how sensitive the surface temperature is to atmospheric CO2."

"The warming that we observed in Greenland at the end of the ice age had already been predicted correctly by climate models several years

ago," Buizert added. "This gives us more confidence that these models also predict future temperatures correctly."

More information: "Greenland temperature response to climate forcing during the last deglaciation," by C. Buizert et al. *Science*, www.sciencemag.org/lookup/doi/ … 1126/science.1254961

Provided by Oregon State University