

Greenland ice may exaggerate magnitude of 13,000-year-old deep freeze

June 25 2012

Ice samples pulled from nearly a mile below the surface of Greenland glaciers have long served as a historical thermometer, adding temperature data to studies of the local conditions up to the Northern Hemisphere's climate.

But the method -- comparing the ratio of oxygen isotopes buried as snow fell over millennia -- may not be such a straightforward indicator of air temperature.

"We don't believe the ice cores can be interpreted purely as a signal of temperature," says Anders Carlson, a University of Wisconsin–Madison geosciences professor. "You have to consider where the precipitation that formed the ice came from."

According to a study published today by the *Proceedings of the National Academy of Sciences*, the Greenland [ice core](#) drifts notably from other records of Northern Hemisphere temperatures during the Younger Dryas, a period beginning nearly 13,000 years ago of cooling so abrupt it's believed to be unmatched since.

Such periods of speedy cooling and warming are of special interest to climate scientists, who are teasing out the mechanisms of high-speed change to better understand and predict the changes occurring in our own time.

In the case of the Younger Dryas, average temperatures -- based on the

Greenland ice -- plummeted as much as 15 degrees Celsius in a few centuries, and then shot back up nearly as much (over just decades) about 1,000 years later.

"In terms of temperature during the Younger Dryas, the only thing that looks like Greenland ice cores are Greenland ice cores," Carlson says. "They are supposed to be iconic for the Northern Hemisphere, but we have four other records that do not agree with the Greenland ice cores for that time. That abrupt cooling is there, just not to the same degree."

Working with UW–Madison climatologist Zhengyu Liu, collaborators at the National Center for Atmospheric Research and others, Carlson found their computer climate model breaking down on the Younger Dryas.

While it could reliably recreate temperatures in the Oldest Dryas -- a similar cooling period about 18,000 years ago -- they just couldn't find a lever in the model that would simulate a Younger Dryas that matched the Greenland ice cores.

"You can totally turn off ocean circulation, have Arctic sea ice advance all the way across the North Atlantic, and you still will have a warmer climate during the Younger Dryas than the Oldest Dryas because of the carbon dioxide," Carlson says.

By the time the Younger Dryas rolled around, there was more carbon dioxide in the air -- about 50 parts per million more. The warming effects of that much CO₂ overwhelmed the rest of the conditions that make the Oldest and Younger Dryas so alike, and demonstrates a heightened sensitivity for Arctic temperatures to rising greenhouse gases in the atmosphere.

The researchers zeroed in on the Northern Hemisphere's temperature

outlier, Greenland ice cores, and found that the conversion of oxygen isotope ratio to temperature typically used on the ice cores did not account for the sort of crash climate change occurring during the Younger Dryas. It assumes prevailing winds and jet streams and storm tracks are providing the moisture for Greenland precipitation from the Atlantic Ocean.

"The Laurentide ice sheet, which covered much of North America down into the northern United States, is getting smaller as the Younger Dryas approaches," Carlson says. "That's like taking out a mountain of ice three kilometers high. As that melts, it allows more Pacific Ocean moisture to cross the continent and hit the Greenland ice sheet."

The two oceans have distinctly different ratios of oxygen isotopes, allowing for a different isotope ratio where the water falls as snow.

"We ran an oxygen isotope-enabled atmosphere model, so we could simulate what these ice cores are actually recording, and it can match the actual oxygen isotopes in the ice core even though the temperature doesn't cool as much," Carlson says. "That, to us, means the source of precipitation has changed in Greenland across the last deglaciation. And therefore that the strict interpretation of this iconic record as purely temperature of snowfall above this ice sheet is wrong."

By the study's findings, Greenland temperatures may not have cooled as significantly as climate headed into the Younger Dryas relative to the Oldest Dryas, because of the rise in atmospheric carbon dioxide that had occurred since the Oldest Dryas.

"You can say at the end of the Younger Dryas it warmed 10, plus or minus five, degrees Celsius. But what happened on this pathway into the event, you can't see," Carlson says.

It's a fresh reminder from an ancient ice core that climate science is full of nuance, according to Carlson.

"Abrupt climate changes have happened, but they come with complex shifts in the way climate inputs like moisture moved around," he says. "You can't take one difference and interpret it solely as changes in temperature, and that's what we're seeing here in the Greenland ice cores."

Provided by University of Wisconsin-Madison

Citation: Greenland ice may exaggerate magnitude of 13,000-year-old deep freeze (2012, June 25) retrieved 23 April 2024 from <https://phys.org/news/2012-06-greenland-ice-exaggerate-magnitude-year-old.html>

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