Ice core chemistry study expands insight into sea ice variability in Southern Hemisphere

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Sea ice pressure ridge off the Antarctic coast. Credit: Dominic Winski

Sea ice cover in the Southern Hemisphere is extremely variable, from summer to winter and from millennium to millennium, according to a University of Maine-led study. Overall, sea ice has been on the rise for about 10,000 years, but with some exceptions to this trend.

Dominic Winski, a research assistant professor at the UMaine Climate

Change Institute, spearheaded a project that uncovered new information about millennia of sea ice variability, particularly across seasons, in the Southern Hemisphere by examining the chemistry of a 54,000-year-old South Pole ice core.

The Southern Ocean experiences the largest seasonal difference in sea ice cover in the world, with Antarctica surrounded by 18.5 million-square-kilometers of sea ice in the winter and only 3.1 million-square-kilometers of it in the summer. According to researchers, this seasonal disparity in sea ice has a significant influence on regional and global climate, yet scientists for years knew relatively little about the extent of sea ice variation in the Southern Hemisphere before 1979.

When a team of scientists recently retrieved the deepest and oldest ice core from the South Pole and analyzed it, Winski saw an opportunity to learn more about seasonal and overall changes in sea ice in the Southern Hemisphere throughout the Holocene—the last 11,400 years. The CCI research assistant professor and his colleagues decided to examine the chemistry of the ice core, particularly its sea salt concentrations, to learn more about sea ice variability in the region.

Karl Kreutz, a UMaine professor of Earth and climate sciences, and researchers from Dartmouth College, South Dakota State University, the University of Washington and the University of Colorado Boulder participated in the project. *Geophysical Research Letters* published the paper detailing their findings.

The team capitalized on the massive seasonal variations in Southern Ocean climate in order to create a sea ice record showing distinct summer and winter variability. They combined this information with a state-of-the-art atmospheric chemistry model to link the ice core measurements with sea ice variability. The result is a detailed record of Southern Ocean sea ice revealing major fluctuations, especially in

wintertime sea ice.

Salt levels in the core, which are sensitive to sea ice changes, increased in the past 11,400 years, particularly in the past 8,000-10,000 years, correlating with a growth in ice cover. Winter sea salt concentrations, which originated primarily from salty snow atop sea ice, specifically increased over millennia, demonstrating an overall boost in wintertime sea ice. This pattern is seen elsewhere in Antarctica, which led the research team to hypothesize an Antarctic-wide increase in sea ice during this period.

"One of the most important and challenging goals in our field is to produce detailed reconstructions of sea ice variability. " Winski says. "The exceptional detail of the South Pole Ice Core combined with results from our modeling team gives us a powerful dataset for understanding Antarctic sea ice."

Winski and Kreutz helped retrieve the 54,000-year-old ice core they used for their recent study during two expeditions between 2014 and 2016.

The project, called SPICEcore (South Pole Ice Core), involved scientists from 18 institutions all aiming to create an archive of climate conditions in East Antarctica during the past 54,000 years, including changes in atmospheric chemistry, climate and biogeochemistry.

"The South Pole Ice Core (SPICEcore) is the most precisely dated climate record in this region of Antarctica. We put in a tremendous amount of effort to collect individual chemistry samples for every centimeter of ice," Winski says. "In total, we had to analyze the chemistry of over 100,000 vials of melted ice, but the effort paid off since now we have the rare opportunity to investigate seasonal changes in the Antarctic environment for over 10,000 years."

While the Southern Hemisphere experienced an overall increase in ice cover throughout the Holocene, researchers identified an abrupt drop in sea salt concentrations in the ice core that date back to between 5,000 and 6,000 years ago. According to the team, the drop in salt levels indicates a decrease in ice cover specific to the South Atlantic at that time, a finding corroborated by earlier research.

Ice cover in the North Atlantic, conversely, was more extensive during that period, which researchers claim indicates "a linked and opposing sea ice signal in the North and South Atlantic most likely due to changing ocean circulation." This pattern of opposing North and South Atlantic climate is well-known during abrupt climate change events of colder times deep in the past. The findings of this study may be a hint that the same processes could still be relevant under modern conditions.

Accounting for seasonal variation when studying changes in sea ice across tens of thousands of years helps scientists not only to thoroughly describe past Antarctic climate, but also to understand the mechanisms and processes driving climate change.

"Huge changes in sea ice can occur very rapidly," Winski says, "leading to ramifications for climate worldwide. We still don't entirely understand the forces influencing sea ice variability, which is why detailed climate information from the past is absolutely critical."

More information: Dominic A. Winski et al, Seasonally Resolved Holocene Sea Ice Variability Inferred From South Pole Ice Core Chemistry, *Geophysical Research Letters* (2021). DOI: 10.1029/2020GL091602

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