Antarctic sea ice is key to triggering ice ages, study finds

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A new study by UChicago scientists show how an increase in Antarctic sea ice could trigger a chain of events leading to an ice age. Credit: Yvonne Firing

We've known for years that Earth's climate is like a giant Rube Goldberg machine: Pull one lever, and a massive chain of events starts into motion. Yet many of the steps that drive these changes have remained shrouded in uncertainty.

"One key question in the field is still what caused the Earth to periodically cycle in and out of ice ages," said Asst. Prof. Malte Jansen, whose research at the University of Chicago seeks to discover and understand the processes that make up global climate. "We are pretty confident that the carbon balance between the atmosphere and ocean must have changed, but we don't quite know how or why."

In a new study, Jansen and former UChicago postdoctoral researcher Alice Marzocchi lay out how an initial change in climate could start a chain of events that leads to an ice age. Their model shows how the increase in Antarctic sea ice in a colder climate could trigger a waterfall of changes that could contribute to tipping the global climate into glacial periods.

Responsibility (or blame) for Earth's climate is shared among land, life, atmosphere and ocean. Elements move back and forth among all four in a slow dance that has kept Earth habitable for billions of years—but can change the climate as elements build up in one or more of the locations.

For example, we're currently in a break between ice ages; for the past two-and-a-half million years, glaciers have periodically covered the Earth and then retreated. Scientists, therefore, have been piecing together clues about how this process of glaciation works and how it's triggered. It's likely that slight changes to Earth's orbit led to some cooling. But that alone wouldn't do it, Jansen said. There would have had to have been massive accompanying changes in the climate system to account for the amount of cooling that followed.

"The most plausible explanation is that there was some change in how carbon was divided between the atmosphere and the ocean," Jansen said. "There's no shortage of ideas about how this happens, but it's not quite clear how they all fit together." Simulations disagree, and none line up completely with the geological evidence available to scientists.

Building on a study Jansen published a couple of years ago, Jansen and Marzocchi fleshed out a model of how the glacial transition could have played out.

In their picture, the atmosphere cools enough to cause Antarctic sea ice to start building. "The Southern Ocean around Antarctica plays a key role in ocean circulation, as it is a region where deep waters rise to the surface before disappearing again into the abyss," Jansen said. "As a result, increased Antarctic sea ice has outsize consequences."

The lid of ice changes ocean circulation, but it also physically blocks the ocean from exchanging carbon dioxide with the atmosphere. This means more and more carbon is drawn into the deep ocean and stays there. Less carbon dioxide in the atmosphere would lead to a reverse greenhouse effect, causing the planet to cool.

"What this suggests is that it's a feedback loop," said Marzocchi, now a research scientist at the UK's National Oceanography Center. "As the temperature drops, less carbon is released into the atmosphere, which triggers more cooling."

The explanation fits with evidence about the past climate from sources like sediments, coral reefs, and core samples from glaciers.

"What surprised me is how much of this increased storage can be attributed to physical changes alone, with Antarctic sea-ice cover being the key player," Marzocchi said. Just the physical effects, before accounting for changes from biological growth, account for about half the drawdown in carbon dioxide that is thought to have happened.

The results are another step toward understanding how the Earth's climate works over long time scales, the scientists said.

"The ocean is the largest carbon reservoir over geological timescales," Marzocchi said. "So studying the role that the ocean plays in the carbon cycle helps us more accurately simulate future environmental change."

More information: Alice Marzocchi et al. Global cooling linked to increased glacial carbon storage via changes in Antarctic sea ice, *Nature Geoscience* (2019). DOI: 10.1038/s41561-019-0466-8

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