Study shows it's not too late to save the West Antarctic Ice Sheet

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Credit: Hugh Chittock / Antarctica New Zealand

New research has found a "missing piece of the puzzle" of West Antarctic Ice Sheet melt, revealing that the collapse of the ice sheet in the Ross Sea region can be prevented—if we keep to a low-emissions pathway.

More than 5 meters of potential global sea-level rise is locked within the

West Antarctic Ice Sheet, so understanding whether the regions of the ice sheet that appear "stable" today might melt in the future is critical for forecasting how much and how fast our seas will rise around the world.

One such region that is currently stable is West Antarctica's Siple Coast, where rivers of ice flow over the continent and drain into the Ross Sea. This ice flow is slowed down by the Ross Ice Shelf, a floating mass of ice nearly the size of Spain, which serves as a buttress to the ice sheet glaciers. Compared to other ice shelves in West Antarctica, the Ross Ice Shelf has very little melting at its base due to the very cold ocean waters that travel through the ocean gateway below.

But this region of the ice sheet has not always been stable. Radiocarbon dating of sediments from beneath the ice sheet show that it retreated (melted) by hundreds of kilometers about 7,000 years ago, and then readvanced (grew) to its present position within the last 2,000 years.

A new study from GNS Science Te Pū Ao, Te Herenga Waka—Victoria University of Wellington, and an international team including NASA's Jet Propulsion Laboratory, published in *Nature Communications*, used computer model simulations to explain this ice sheet retreat and advance. These simulations looked at how changes in the ocean and Earth's crust influenced the ice sheet.

"When we project future ice sheet response, we have to grapple with many uncertainties about which processes drive ice sheet behavior. Our study sought to unravel what happened to the West Antarctic Ice Sheet in this region in the past, in order to better predict what will happen in the future," says the lead author, Dan Lowry, GNS Science ice sheet and climate modeler.

Deep ocean mixing the primary driver of West

Antarctic Ice Sheet behavior

When surface ocean water freezes as sea ice, salt is released. This creates very dense cold salty water that can mix deep into the ocean, including into ocean cavities such as the space under the Ross Ice Shelf. This dense water acts as a barrier between warmer ocean water and the ice shelf, preventing melting. But Antarctic ice cores and geological records show that in the past, this ocean mixing was weaker, which means melting rates may have been higher.

As an ice sheet shrinks in size, the change in ice load causes the Earth's crust to slowly lift up in response. The rate of this crustal uplift depends on the viscosity—or "stickiness"—of the mantle, the layer of the Earth beneath the crust. Crustal uplift as the ice sheet retreated thousands of years ago may have re-grounded the floating ice, allowing the ice sheet to stabilize and then advance again.

By comparing geological records with the simulations of ice sheet flow under different scenarios of mantle "stickiness" and rates of ocean mixing, the study found that the retreat and advance of the ice sheet was best explained by changes in the ocean temperature, but that the rate of crustal response also impacts how sensitive the ice sheet is to the ocean. The ice sheet, ocean and solid earth all interact and influence each other.

Mitigation still matters

Recent research found that in another part of West Antarctica—the Amundsen Sea Embayment—the ocean cavities beneath the ice shelves are already warm, melting is underway, with further melting "unavoidable" even if emissions are mitigated globally.

However, Lowry says this new study shows that it is still possible to

prevent the retreat of the West Antarctic Ice Sheet in the Siple Coast region.

"Our modeling has helped us understand what caused changes in the past; we know that by mitigating greenhouse gas emissions to meet the Paris Agreement target, it is possible to limit that ocean warming to levels that won't cause collapse of the ice sheet. This region is vulnerable, but we're not there yet."

Global climate models run under high-emissions scenarios show less sea ice formation and less deep ocean mixing. This could lead to the same cold-to-warm ocean switch and extensive ice sheet retreat observed thousands of years ago.

Lowry says that the modeling incorporated a wider range of processes than previous models, for example changes in sea level that occur near the ice sheet as it melts, due to the ice sheet's gravitational pull.

"We went more complex, we've tested these hypotheses in a more robust way than has been ever done before. This is a topic that the scientific community has been trying to figure out for several years; obtaining these results is like finding that missing piece in the puzzle of what makes ice sheets tick."

More information: Daniel P. Lowry et al, Ocean cavity regime shift reversed West Antarctic grounding line retreat in the late Holocene, *Nature Communications* (2024). DOI: 10.1038/s41467-024-47369-3

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