Global warming may lead to practically irreversible Antarctic melting

A study outlines a series of temperature-related tipping points for the continent's ice

Rising temperatures will lead to a series of tipping points for Antarctica's ice sheets, leading to practically irreversible melting, simulations suggest. Here, the Getz Ice Shelf in West Antarctica is shown.
JEREMY HARBECK/NASA

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How is melting a continent-sized ice sheet like stirring milk into coffee? Both are, for all practical purposes, irreversible.

In a new study published in the Sept. 24 *Nature*, researchers outline a series of temperature-related tipping points for the Antarctic ice sheet. Once each tipping point is reached, changes to the ice sheet and subsequent melting can't be truly reversed, even if temperatures drop back down to current levels, the scientists say.

The full mass of ice sitting on top of Antarctica holds enough water to create about 58 meters of sea level rise. Although the ice sheet won't fully collapse tomorrow or even in the next century, Antarctic ice loss is accelerating (*SN: 6/13/18*). So scientists are keen to understand the processes by which such a collapse might occur.

"What we're really interested in is the long-term stability" of the ice, says Ricarda Winkelmann, a climate scientist at Potsdam Institute for Climate Impact Research in Germany. In the new study, Winkelmann and her colleagues simulated how future temperature increases can lead to changes across Antarctica in the interplay between ice, oceans, atmosphere and land.

In addition to direct melting due to warming, numerous processes linked to climate change can speed up overall melting, called positive feedbacks, or slow it down, known as negative feedbacks.

For example, as the tops of the ice sheets slowly melt down to lower elevations, the air around them becomes progressively warmer, speeding up melting. Warming temperatures also soften the ice itself, so that it slides more quickly toward the sea. And ocean waters that have absorbed heat from the atmosphere can transfer that heat to the vulnerable underbellies of Antarctic glaciers jutting into the sea, eating away at the buttresses of ice that keep the glaciers from sliding into the sea (*SN: 9/11/20*). The West Antarctic Ice Sheet is particularly vulnerable to such ocean interactions — but warm waters are also threatening sections of the East Antarctic Ice Sheet, such as Totten Glacier (*SN: 11/1/17*).

In addition to these positive feedbacks, climate change can produce some negative feedbacks that delay the loss of ice. For example, warmer atmospheric temperatures also evaporate more ocean water, adding moisture to the air and producing increased snowfall (*SN: 4/30/20*).

The new study suggests that below 1 degree Celsius of warming relative to preindustrial times, increased snowfall slightly increases the mass of ice on the continent, briefly outpacing overall losses. But that's where the good news ends. Simulations suggest that after about 2 degrees Celsius of warming, the West Antarctic Ice Sheet will become unstable and collapse, primarily due to its interactions with warm ocean waters, increasing sea levels by more than 2 meters. That's a warming target that the signatories to the 2015 Paris Agreement pledged not to exceed, but which the world is on track to surpass by 2100 (*SN: 11/26/2019*).

As the planet continues to warm, some East Antarctic glaciers will follow suit. At 6 degrees Celsius of warming, "we reach a point where surface processes become dominant," Winkelmann says. In other words, the ice surface is now at low enough elevation to accelerate melting. Between 6 and 9 degrees of warming, more than 70 percent of the total ice mass in Antarctica is loss, corresponding to an eventual sea level rise of more than 40 meters, the team found.

Those losses in ice can't be regained, even if temperatures return to preindustrial levels, the study suggests. The simulations indicate that for the West Antarctic Ice Sheet to regrow to its modern extent, temperatures would need to drop to at least 1 degree Celsius below preindustrial times.

"What we lose might be lost forever," Winkelmann says.

There are other possible feedback mechanisms, both positive and negative, that weren't included in these simulations, Winklemann adds — either because the mechanisms are negligible or because their impacts aren't yet well understood. These include interactions with ocean-climate patterns such as the El Niño Southern Oscillation and with ocean circulation patterns, including the Atlantic Meridional Overturning Circulation.

Previous research suggested that meltwater from the Greenland and Antarctic ice sheets might also play complicated feedback roles. Nicholas Golledge, a climate scientist with Victoria University of Wellington in New Zealand, reported in *Nature* in 2019 that flows of Greenland meltwater can slow ocean circulation in the Atlantic, while cold, fresh Antarctic meltwater can act like a seal on the surface ocean around the continent, trapping warmer, saltier waters below, where they can continue to eat away at the underbelly of glaciers.

In a separate study published Sept. 23 in *Science Advances*, Shaina Sadai, a climate scientist at the University of Massachusetts Amherst, and her colleagues also examined the impact of Antarctic meltwater. In simulations that look out to the year 2250, the researchers found that in addition to a cool meltwater layer trapping warm water below it, that surface layer of freshwater would exert a strong cooling effect that could boost the volume of sea ice around Antarctica, which would in turn also keep the air there colder.

A large plug of such meltwater, such as due to the West Antarctic Ice Sheet's sudden collapse, could even briefly slow global warming, the researchers found. But that boon would come at a terrible price: rapid sea level rise, Sadai says. "This is not good news," she adds. "We do not want a delayed surface temperature rise at the cost of coastal communities."

Because the volume and impact of meltwater is still uncertain, Winkelmann's team didn't include this factor. Robert DeConto, an atmospheric scientist also at the University of Massachusetts Amherst and a coauthor on the *Science Advances* study, notes that the effect depends on how scientists choose to simulate how the ice breaks apart. The study's large meltwater volumes are the result of a controversial idea known as the marine ice-cliff hypothesis, which suggests that in a few centuries, tall ice cliffs in Antarctica might become brittle enough to suddenly crumble into the ocean like dominoes, raising sea levels catastrophically (*SN: 2/6/19*).

Despite lingering uncertainties over the magnitude of feedbacks, one emerging theme — highlighted by the *Nature* paper — is consistent, DeConto says: Once the ice is lost, we can't go back.

"Even if we get our act together and reduce emissions dramatically, we will have already put a lot of heat into the ocean," he adds. For ice to begin to grow back, "we'll have to go back to a climate that's colder than at the beginning of the Industrial Revolution, sort of like the next ice age. And that's sobering."

CITATIONS

J. Garbe *et al*. The hysteresis of the Antarctic Ice Sheet. *Nature*. Vol. 585, September 24, 2020, p. 538. doi: 10.1038/s41586-020-2727-5.

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