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A Major Alarm Is Flashing Under Greenland's Ice

Greenland's northern ice shelves have lost more than a third of their volume since 1978, new research finds.

PHOTOGRAPH: ANDERS BJØRK

SAVE

CLIMATE CHANGE WOULD be much worse if it weren't for the oceans, which have absorbed 90 percent of the excess heat humanity has pumped into the atmosphere. That warming of the oceans has already been devastating for the organisms that live there, but it's also come back to bite us in a more unexpected way: It's contributing to the destruction of ice sitting *on top* of Greenland.

That ailing ice sheet (the bit resting on land) contributed more than 17 percent of observed sea level rise between 2006 and 2018, and new research delivers yet more ominous news. (Greenland has much less ice than Antarctica but is losing 270 billion tons of it a year, compared to Antarctica's 150 billion tons.) Greenland's northern ice shelves—the ice that floats on the ocean instead of resting on land—have actually lost more than a third of their volume since 1978, thanks to warm sea water eating away at their bellies. Three of these northern ice shelves have completely collapsed since the year 2000, and the five that remain are rapidly deteriorating, in turn destabilizing nearby glaciers.

While ice shelves *themselves* don't really contribute to sea-level rise, since they're already floating in the ocean, they act like dams to regulate the amount of ice discharged into the ocean from the interior of the ice sheet on land. "We see that the ice shelves are getting weaker and weaker and weaker," says Grenoble Alpes University glaciologist Romain Millan, lead author of a new paper in *Nature Communications*. "We have observed that in response to this increased melting, the glaciers are retreating, and they are already discharging more ice into the ocean."

Millan and his colleagues used satellites and modeling to check several aspects of the health of northern Greenland's ice shelves. For one, satellite imagery allowed them to determine how the total volume and area of ice has declined over the decades. More deeply, they were able to track the "grounding line," where the ice sheet lifts off land to become a floating ice shelf. As tides go in and out, the ice heaves up and down, movement that is tracked by satellites to pin down the exact location of the grounding lines.

Since ice shelves are shrinking and getting thinner, those lines are quickly retreating inland, where the topography adds still more troubles. Moving from the coast inland, the bedslope is retrograde, meaning the surface of the ground under the ice gets deeper as you move toward the center of the island. "If the grounding line starts to retreat, it may enter an unstoppable retreat because it's on a retrograde bedslope," says Millan.

If, by contrast, the slope went *up* as you traveled inland, it would be harder for the grounding line to retreat. Imagine how far inland floodwaters can travel if the terrain is flat compared to mountainous. "When the grounding moves toward a deeper bed, the amount of ice from the bed to the surface is thicker, which means that the quantity of ice discharged into the ocean is larger," says Millan. "When moving downward, you are also exposing more ice to a warmer ocean, and consequently more melting, more speedup, more discharge."

As those northern Greenland grounding lines retreat—by up to 8 kilometers, or 5 miles, in the most extreme cases that the researchers measured—more of an ice shelf's belly is exposed to saltwater, which is getting warmer and warmer. "The atmospheric circulation which pushes the ocean currents around has been changing, and that has been trending toward putting more water of subtropical origin along the coast of Greenland," says Eric Rignot, a glaciologist and remote sensing scientist at the University of California, Irvine, who wasn't involved in the new paper. That means the water can heat up super fast. "You change the winds and it starts pushing more warm water, that's faster than the time it would take to warm up all these ocean waters along Greenland."

Indeed, the new study found that melt rates along the bottom of northern Greenland's ice shelves have been rising dramatically since the year 2000, peaking in 2015. That corresponds with a peak in ocean temperatures in the area. "It's the case for all the remaining ice shelves across northern Greenland," Millan says. "This increase in basal melting rate is really well correlated with the increase in ocean temperature in this area of the Greenland ice sheet. What we see is that ice shelves are getting thinner and losing mass."

Going forward, this insight will help scientists better model the decline of northern Greenland's ice, and the consequent sea-level rise. "Being able to show how the timing of these large calving, or disintegration, of ice shelves corresponds to increased ocean temperatures, we can get a sense of how sensitive the remaining ice shelves will be," says Michalea King, a glaciologist at the University of Washington's Polar Science Center who studies Greenland's ice sheet but wasn't involved in the new paper.

Imagine if you started chipping off the concrete from the face of a dam, bit by bit. As it gets thinner, it weakens, until it can no longer hold water and collapses. Same goes for these ice shelves that act like floating dams, only they're thinning from the ocean below. And they're holding back *way* more water than is held in a reservoir, in the form of Greenland's ice sheet. "We have already seen examples of some glaciers in northern Greenland, and their floating extensions collapsed," says Millan. That doubled the discharge of ice into the sea. "If the other glaciers lose their floating ice, we can expect the same kind of behavior."

Greenland's ice sheet and shelves aren't just contending with higher ocean temperatures. Air temperatures are also skyrocketing as the Arctic warms up to four times faster than the rest of the planet. That melts the ice from above as it's also melting from warmer waters below. "It is definitely getting warmer," says Earth system scientist Shfaqat Abbas Khan of the Technical University of Denmark, who studies Greenland's ice but wasn't involved in the new paper. "But also this region is where you have, I would say, more or less a year-round sea ice. The ice shelves are protected by sea ice, and this is also slowly disappearing."

This is also happening in Antarctica, which has seen record low levels of sea ice this year. Sea ice is distinct from ice shelves, coming and going seasonally. (It's that floating, broken-up ice, as opposed to the more cohesive ice shelf.) Though ephemeral, it's extremely important, acting as a sort of buffer to keep wind and waves from battering and weakening ice shelves. If it disappears as air and sea temperatures rise, that's yet another threat to the ice shelves of Greenland and Antarctica.

Relatively warm seawater is also eating away at the undersides of Antarctica's ice shelves, causing grounding lines to retreat and generally accelerating the decline of ice sheets there. Just one of the glaciers down there could add several feet to sea levels if it totally collapsed. Last week, researchers reported how they used a robot to study crevasses on the underside of those ice shelves. Whereas a perfectly flat icy belly would form a protective layer of cold water, preventing warmer seawater from eating away at the ice shelf, these undulations lead to more movement of water. That could help explain why Antarctica's glaciers are melting faster than predicted by models.

For Greenland, many factors are conspiring to degrade the ice sheet: hotter air and ocean temperatures, less sea ice, and weaker ice shelves to hold back the glaciers on land. But the speeding up of glaciers flowing into the sea is a uniquely daunting threat. "Down the line, that will be the dominant factor," says Rignot. Melting is crucial, of course, but if "you can make the glaciers flow 10 times faster in the north," Rignot adds, "that's something else."

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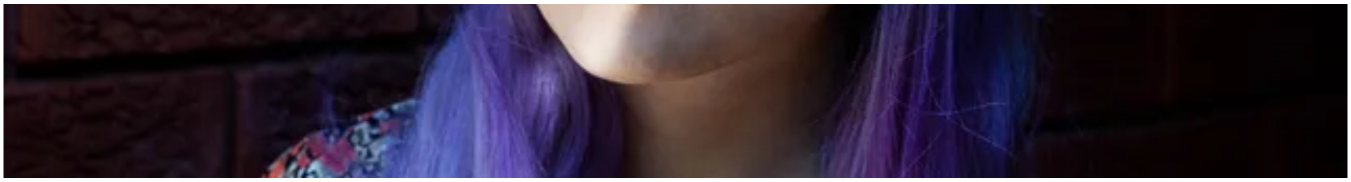

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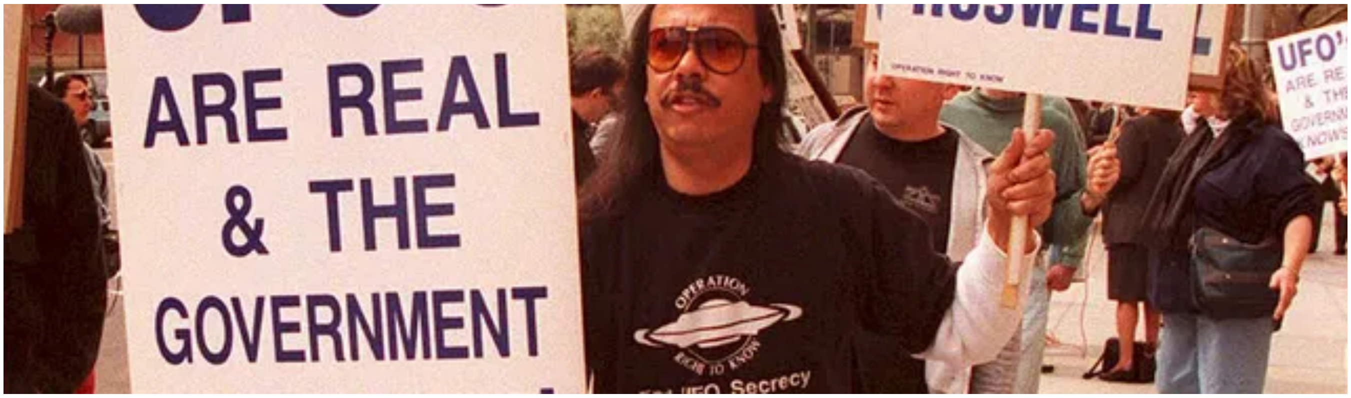

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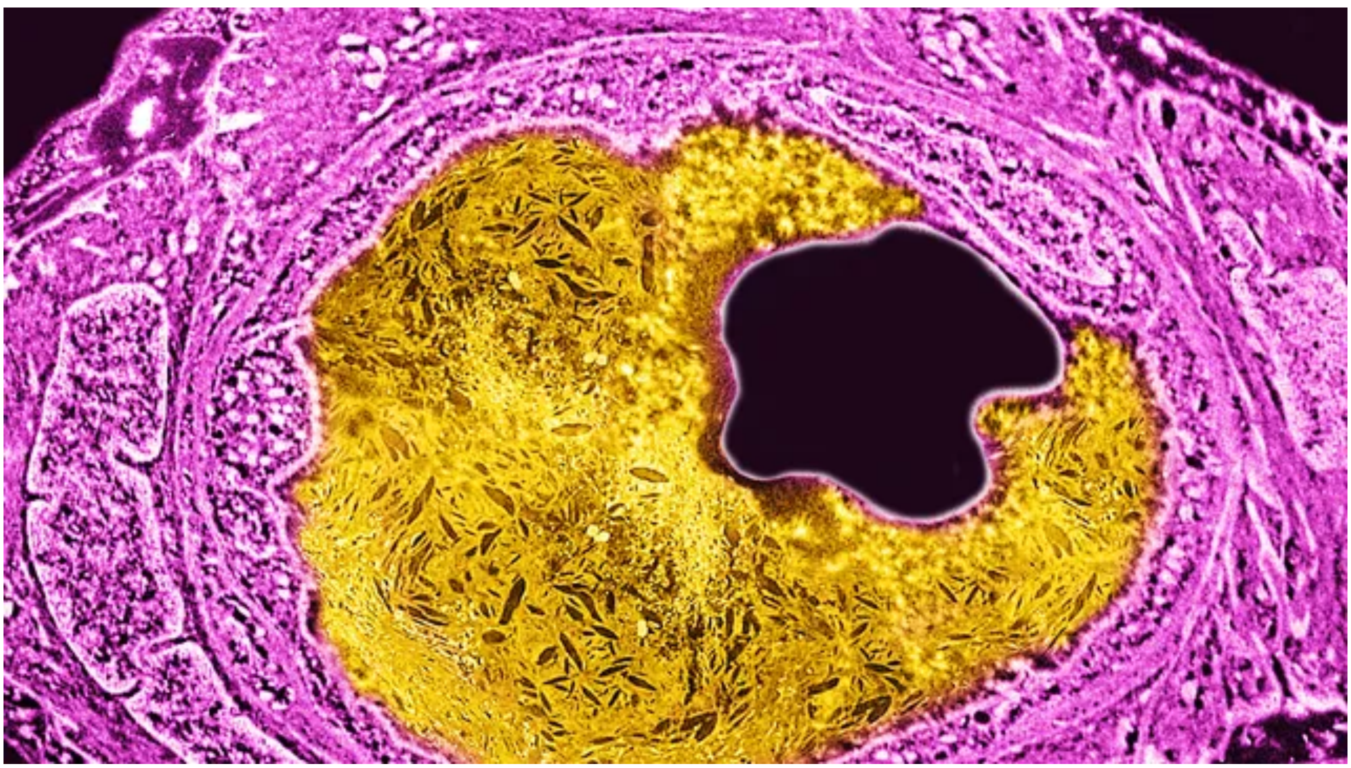

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