POLAR SCIENCE

How warming oceans unleashed an ice stream

Accelerating retreat of a Greenland glacier could raise sea level for decades to come

By **Carolyn Gramling**

Beneath the calm, white surface of Greenland, rivers of ice are flowing into the ocean—and some are moving very fast indeed. The speedy glaciers on the island's warmer west coast, shedding kilometers of ice into the sea each year as warm ocean waters undermine them, have raised the most alarm about potential sea level rise. But a much bigger glacier is now on the move in Greenland's remote northeast—and a new study suggests it's likely to continue its rush to the sea for decades to come.

The vulnerable glacier, part of a broader flow of ice called the Northeast Greenland Ice Stream, shows that yet another region of Greenland is feeling the effects of warming oceans. "Until fairly recently, we've seen the Northeast Greenland Ice Stream as a cold, remote feature that wasn't likely to do anything interesting," says Ben Smith, a glaciologist at the University of Washington, Seattle, who was not involved in the study. But as Jeremie Mouginot of the University of California (UC), Irvine, lead author of the new paper published online in *Science* today, explains, "It's one more side of Greenland that's starting to lose mass … It's like a boat that is taking on water from all sides."

Hundreds of fjords indent Greenland's coastline, filled with glaciers ending in tongues of floating ice that periodically break off into chunks, or calve. The 600-kilometer-long Northeast Greenland Ice Stream is one of the island's largest, draining 12% of the interior ice sheet. "It's part of the central nervous system of Greenland," says Eric Rignot, also of UC Irvine and a co-author on the paper. "You can see the trace of this ice stream all the way to the summit."

In 2002, a large chunk of one of the ice stream's three terminating glaciers, Zachariæ Isstrøm, broke off. But even then, Smith says, "it wasn't certain that the glacier would respond in any dramatic way." However, in 2012, something appeared to kickstart the giant glacier. "In the last 3 years, it's been going way faster than before," moving at a rate of 2 kilometers per year, Mouginot says. Scientists wanted to know why.

Compiling airborne and satellite data from six different space agencies—NASA, the Japan Aerospace Exploration Agency, the Canadian Space Agency, and three European agencies—the team pieced together ice motions in the region over 40 years. "For the first 25 years, the glacier was stable," Mouginot says. But from 2000 to 2012, it began to move more rapidly; and each year since 2012 it has sped up by about 125 meters per year. Meanwhile, increased melting is whittling away at the leading edge, where the ice meets the ocean, at a rate of about 2 kilometers per year. That's several times slower than the speedy Jakobshavn glacier on the island's west coast—but as Zachariæ Isstrøm continues to flow into the warmer ocean, Mouginot notes, "it has a huge potential" to spur sea level rise.

What is going on under the ice, however, raises the most concern. Using satellite interferometry, the team mapped how the ice bobbed with the tides to infer the point at which the ice floats free of the bedrock. Before 2012, they found, that "grounding line" remained stable, because the glacier was firmly anchored to the sea floor by an underwater rise, or sill. In that year, however, warm ocean waters undermined the glacier far enough to detach it from the sill, they say. "It took a while to push it free of this anchor," Rignot says, which allowed it to flow—and retreat—faster.

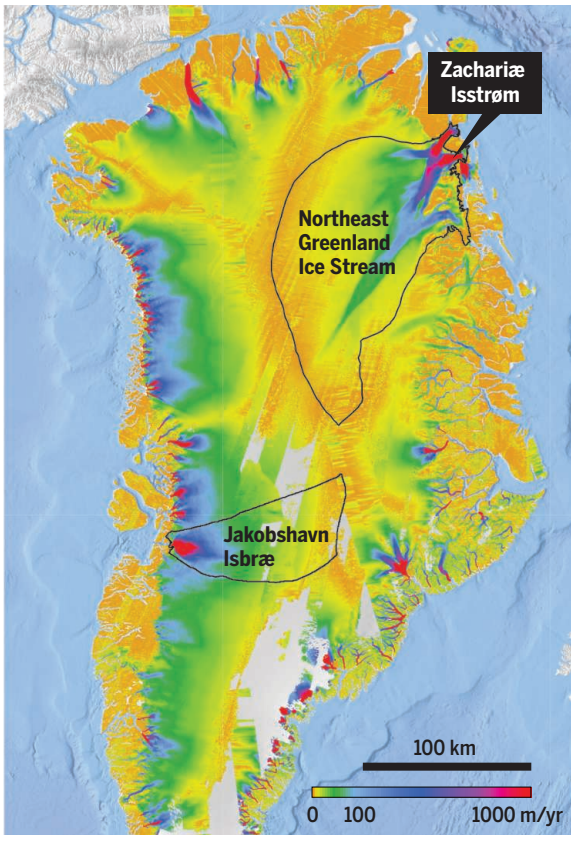
The glacier is likely to continue to retreat at its current pace for another 20 to 30 years, he adds, based on the shape of the sea floor. On the inland side of the sill, the sea floor drops and forms a deep basin, into which relatively warm water can easily intrude. Even after the glacier retreats for about another 30 kilometers, reaching the inland end of that basin, a deep channel in the fjord will still let seawater gnaw at the glacier from below.

This work "compellingly" shows the glacier's vulnerability, Smith says—but "figuring out what's going to happen next is the challenge on the table now." The estimate of 20 to 30 years of further grounding line retreat "may be a bit more specific than we can really be at this point," he adds, noting that scientists still have a lot to learn about the warm Atlantic water melting the glacier from below.

Rignot agrees that researchers need a lot more data about both the nearby sea floor and the ocean temperatures next to the glaciers. This summer, NASA began a 6-year project—called the Oceans Melting Greenland (OMG) study—to help close the gap. OMG aims to deploy robot probes to measure seawater temperatures around the coastline while airplanes measure the contours of the glaciers and ships trace the complex bathymetry of its fjords. A sharper picture should emerge of just how warming ocean waters are eating away at the island's fringe of ice—and what the future holds. ■

Draining Greenland

Large regions of the Greenland Ice Sheet drain through speedy Jakobshavn Isbræ and the Northeast Greenland Ice Stream, including the now-accelerating Zachariæ Isstrøm. Fastest flow shown in red.



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