New study explains surprising acceleration of Greenland's inland ice

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Meltwater from the surface of the Sermeq Avannarleq Glacier drains down toward interior ice. This photograph depicts a region about 10 miles from the ice sheet margin in Southwest Greenland. A new CIRES-led study helps explain the surprising acceleration of inland ice. Meltwater draining through the ice likely warms the ice sheet from the inside and like a stick of warm butter, the sheet softens, deforms and can flow faster. Credit: William Colgan/CIRES

Surface meltwater draining through cracks in an ice sheet can warm the sheet from the inside, softening the ice and letting it flow faster, according to a new study by scientists at the Cooperative Institute for Research in Environmental Sciences (CIRES) at the University of

Colorado Boulder.

During the last decade, researchers have captured compelling evidence of accelerating ice flow at terminal regions, or "snouts," of Greenland glaciers as they flow into the ocean along the western coast. The new CIRES research now shows that the interior regions also are flowing much faster than they were in the winter of 2000-01, and the paper proposes a reason for the speedup.

"Through satellite observations, we determined that an inland region of the Sermeq Avannarleq Glacier, 40 to 60 miles from the coast, is flowing about one and a half times faster than it was about a decade ago," said Thomas Phillips, lead author of the new paper and a CIRES research associate at the time of the study. In 2000-01, the inland segment was flowing at about 130 feet (40 meters) per year; in 2007-08, that speed was closer to 200 feet per year (60 meters).

"At first, we couldn't explain this rapid interior acceleration," Phillips said. "We knew it wasn't related to what was going on at the glacier's terminus. The speedup had to be due to changes within the ice itself."

To shed light on the observed acceleration, Phillips and his team developed a new model to investigate the effects of meltwater on the ice sheet's physical properties. The team found that meltwater warms the ice sheet, which then—like a warm stick of butter—softens, deforms and flows faster.

Previous studies estimated that it would take centuries to millennia for new climates to increase the temperature deep within ice sheets. But when the influence of meltwater is considered, warming can occur within decades and produce rapid accelerations. The paper has been accepted for publication in the *Journal of Geophysical Research*: Earth Surface, a journal of the American Geophysical Union.

The CIRES researchers were tipped off to this mechanism by the massive amount of meltwater they observed on the ice sheet's surface during their summer field campaigns, and they wondered if it was affecting the ice sheet. During the last several decades, atmospheric warming above the Greenland Ice Sheet has caused an expanding area of the surface to melt during the summer, creating pools of water that gush down cracks in the ice. The meltwater eventually funnels to the interior and bed of the ice sheet.

As the meltwater drains through the ice, it carries with it heat from the sun.

"The sun melts ice into water at the surface, and that water then flows into the ice sheet carrying a tremendous amount of latent energy," said William Colgan, a co-author and CIRES adjunct research associate. "The latent energy then heats the ice."

The new model shows that this speeds up ice flow in two major ways: One, the retained meltwater warms the bed of the ice sheet and preconditions it to accommodate a base layer of water, making it easier for the ice sheet to slide by lubrication. Two, warmer ice is also softer (less viscous), which makes it flow more readily.

"Basically, the gravitational force driving the ice sheet flow hasn't changed over time, but with the ice sheet becoming warmer and softer, that same gravitational force now makes the ice flow faster," Colgan said.

This transformation from stiff to soft requires only a little bit of extra heat from meltwater. "The model shows that a slight warming of the ice near the ice sheet bed—only a couple of degrees Celsius—is sufficient to explain the widespread acceleration," Colgan said.

The findings have important ramifications for ice sheets and glaciers everywhere. "It could imply that ice sheets can discharge ice into the ocean far more rapidly than currently estimated," Phillips said. "It also means that the glaciers are not finished accelerating and may continue to accelerate for a while. As the area experiencing melt expands inland, the acceleration may be observed farther inland."

The new model will help scientists more accurately forecast these impacts, and it is being incorporated into Earth-system models for predicting future ice discharge from the Greenland Ice Sheet.

The findings suggest that to understand future sea-level rise, scientists need to account for a previously overlooked factor—meltwater's latent energy—and its potential role in making glaciers and ice sheets flow faster into the world's oceans. In 2007, the Intergovernmental Panel on Climate Change (IPCC) wrote that one of the most significant challenges in predicting sea-level rise was "limited" understanding of the processes controlling ice flow. This paper, and others that have advanced scientific understanding of ice sheet and glacier behavior, are likely to inform the IPCC's next assessment, due out in 2014.

"Traditionally, latent energy has been considered a relatively unimportant factor, but most glaciers are now receiving far more meltwater than they used to and are increasing in temperature faster than previously imagined," Colgan said. "The chunk of butter known as the Greenland Ice Sheet may be softening a lot faster than we previously thought possible."

Provided by University of Colorado at Boulder