Researchers find Greenland's groundwater changes with thinning ice sheet

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For more than a decade, a team of University of Montana researchers and students have studied the dynamics of the Greenland Ice Sheet as it responds to a warming climate. University of Montana (UM)

Department of Geosciences researchers Toby Meierbachtol and Joel Harper said water has always been central to their research.

"The water from melting of the ice can run off the surface to the ocean and contribute to sea level rise, it can refreeze in place and actually warm the ice, and it can even reach the bottom of the ice sheet and act as a sort of lubricant to make the ice slide quickly over its bed," Meierbachtol said. "The importance of water in controlling the response of Greenland to warming is hard to overstate."

But while much of their focus has been on the importance of water in controlling processes occurring on the ice sheet, their most recent research findings have flipped the order of their thinking.

As outlined in their recent article in *Nature Geoscience*, Meierbachtol, Harper and an international team of researchers discovered that changes to the ice sheet have an immediate impact on the groundwater underlying the Greenland island, an area larger than the state of Alaska.

"We have been focused on water's impacts on ice sheet change," said Harper. "But our most recent findings show that changes in the ice sheet have a real impact on Arctic hydrology—specifically the massive groundwater system extending under the ice sheet."

This latest revelation occurred thanks to a marriage of drilling techniques, with international collaborators boring an angled hole 650 meters through bedrock underneath a Greenland glacier to measure groundwater conditions deep under the ice sheet. Meanwhile, UM and University of Wyoming researchers drilled 32 holes from atop the glacier, through nearly a kilometer of ice, to measure water conditions at the interface between ice and bedrock, which forms an important boundary controlling groundwater flow below.

The system that UM has perfected over the years involves drilling with a combination of very hot water under high pressure typically for 12 or more hours at a time.

"We practice and rehearse to make the operation flow smoothly," Harper said, noting they always include one to two undergraduate students on an expedition. "Everyone on the team has an important and specific role to fill."

After drilling the team installs sensors in the ice column and at the ice sheet bed to measure ice dynamics and water conditions as water flows under the ice to margin. Time is always of the essence because the cold ice freezes the hole shut in as little as two hours.

The dual drilling approach facilitated the first-ever measurements of groundwater response to a changing ice sheet, and the eight-year data record yielded some unexpected results.

"By studying areas that were covered by ice 10,000 years ago during the last ice age, the field has known that the huge mass and vast amounts of water from melting ice can impact the underlying groundwater," Meierbachtol said, "but the paradigm has been that the groundwater response to ice sheet change is long: Thousands of years. What we've shown here is that the groundwater response to Greenland's change is immediate."

This new understanding could have important downstream implications for how Greenland's thinning impacts the Arctic, Harper said. The thinning ice could reduce the rate of groundwater flow to the ocean, changing the water temperature and salinity balance that is important for ocean circulation patterns.

"In thinking about the complex feedbacks that occur from Greenland's

ongoing change, we as a field have really neglected the groundwater component because we thought it was more or less dormant over the decade to century timescales that are important for us as a society," Harper said. "But now we recognize that the groundwater system actually changes quite rapidly, and there are some compelling reasons for why this could really matter for the broader Arctic."

Future research will need to work toward quantifying the impacts of groundwater change on the ocean, both Meierbachtol and Harper noted. But the first step was the discovery.

More information: Lillemor Claesson Liljedahl et al, Rapid and sensitive response of Greenland's groundwater system to ice sheet change, *Nature Geoscience* (2021). DOI: 10.1038/s41561-021-00813-1

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