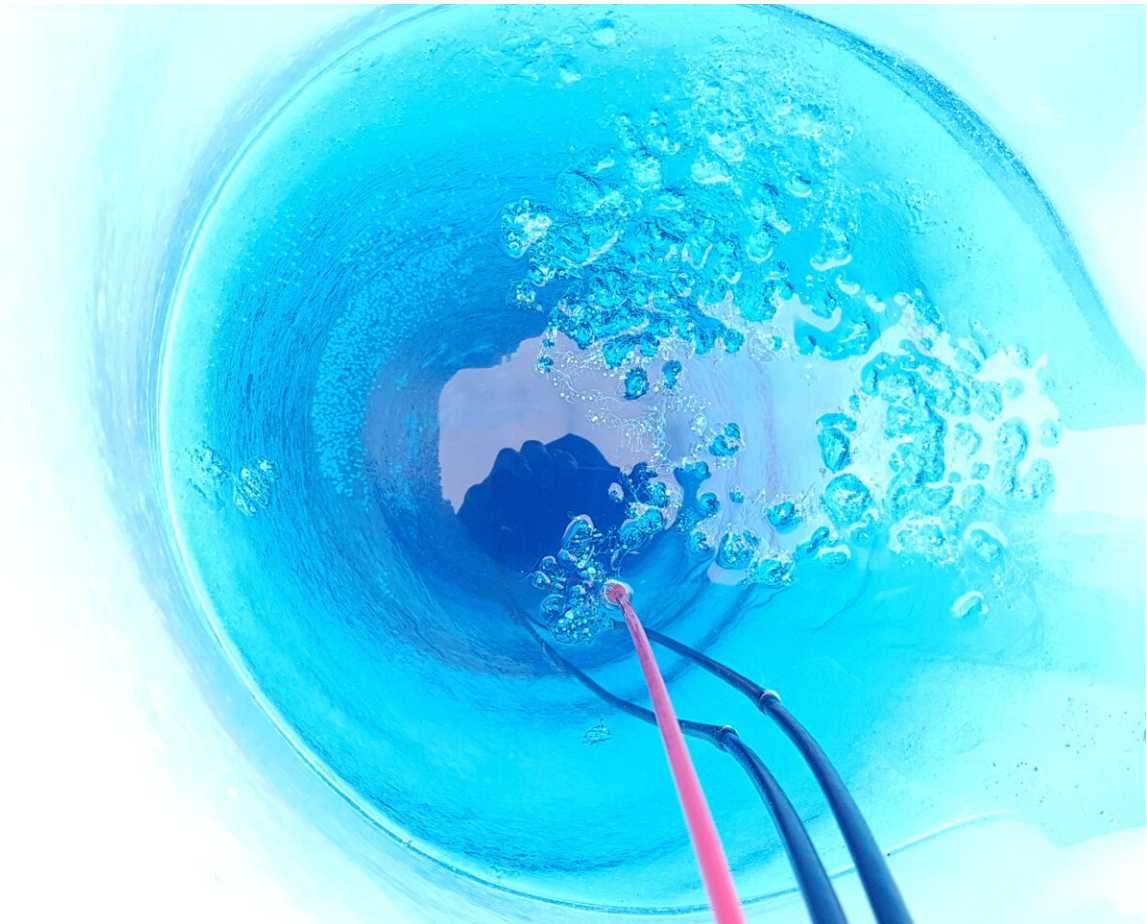


Fibre-optics used to take the temperature of Greenland Ice Sheet

May 14 2021



Fibre-optic cable (red) installed in 1 km deep borehole drilled on Store Glacier in Greenland. Credit: Poul Christoffersen and RESPONDER team

Scientists have used fibre-optic sensing to obtain the most detailed measurements of ice properties ever taken on the Greenland Ice Sheet. Their findings will be used to make more accurate models of the future movement of the world's second-largest ice sheet, as the effects of climate change continue to accelerate.

The research team, led by the University of Cambridge, used a new technique in which [laser pulses](#) are transmitted in a fibre-optic cable to obtain highly detailed temperature measurements from the surface of the ice sheet all the way to the base, more than 1000 metres below.

In contrast to previous studies, which measured temperature from separate sensors located tens or even hundreds of metres apart, the new approach allows temperature to be measured along the entire length of a fibre-optic cable installed in a deep borehole. The result is a highly detailed profile of temperature, which controls how fast ice deforms and ultimately how fast the ice sheet flows.

The temperature of ice sheets was thought to vary as a smooth gradient, with the warmest sections on the surface where the sun hits, and at the base where it's warmed by geothermal energy and friction as the ice sheet grinds across the subglacial landscape toward the ocean.

The new study found instead that the temperature distribution is far more heterogenous, with areas of highly localised deformation warming the ice further. This deformation is concentrated at the boundaries between ice of different ages and types. Although the exact cause of this deformation remains unknown, it may be due to dust in the ice from past volcanic eruptions or large fractures which penetrate several hundred metres below the surface of the ice. The results are reported in the journal *Science Advances*.

Mass loss from the Greenland Ice Sheet has increased sixfold since the

1980s and is now the single largest contributor to global sea-level rise. Around half of this mass loss is from surface meltwater runoff, while the other half is driven by discharge of ice directly into the ocean by fast flowing glaciers that reach the sea.



Night shift: installing fibre-optic cable in a borehole at 3 am after a long day of drilling. Credit: Adam Booth and RESPONDER team

In order to determine how the ice is moving and the thermodynamic processes at work within a glacier, accurate ice temperature measurements are essential. Conditions on the surface can be detected

by satellites or field observations in a relatively straightforward way. However, determining what is happening at the base of the kilometre thick ice sheet is far more challenging to observe, and a lack of observations is a major cause of uncertainty in projections of global sea-level rise.

The RESPONDER project, funded by the European Research Council, is addressing this problem using hot-water drilling technology to bore through Sermeq Kujalleq (Store Glacier) and directly study the environment at the base of one of Greenland's largest glaciers.

"We normally take measurements within the ice sheet by attaching sensors to a cable that we lower into a drilled borehole, but the observations we've made so far weren't giving us a complete picture of what's happening," said co-author Dr. Poul Christoffersen from the Scott Polar Research Institute who leads the RESPONDER project. "The more precise data we are able to gather, the clearer we can make that picture, which in turn will help us make more accurate predictions for the future of the ice sheet."

"With typical sensing methods, we can only attach about a dozen sensors onto the cable, so the measurements are very spaced out," said first author Robert Law, a Ph.D. candidate at the Scott Polar Research Institute. "But by using a fibre-optic cable instead, essentially the whole cable becomes a sensor, so we can get precise measurements from the surface all the way to the base."

To install the cable, the scientists had to first drill through the glacier, a process led by Professor Bryn Hubbard and Dr. Samuel Doyle from Aberystwyth University. After lowering the cable into the borehole, the team transmitted laser pulses in the cable, and then recorded the distortions in the scattering of light in the cable, which vary depending on the temperature of the surrounding ice. Engineers at Delft University

of Technology in the Netherlands and geophysicists at the University of Leeds assisted with data collection and analysis.

"This technology is a big advance in our ability to record spatial variations in ice temperature over long distances and at really high resolution. With some further adaptations, the technique can also record other properties, such as deformation, at similarly high resolution," said Hubbard.

"Overall, our readings paint a picture that's far more varied than what current theory and models predict," said Christoffersen. "We found temperature to be strongly influenced by the deformation of ice in bands and at the boundaries between different types of ice. And this shows there are limitations in many models, including our own."

The researchers found three layers of ice in the glacier. The thickest layer consists of cold and stiff ice which formed over the last 10,000 years. Below, they found older ice from the last ice age, which is softer and more deformable due to dust trapped in the ice. What surprised the researchers the most, however, was a layer of warm ice more than 70 metres thick at the bottom of the glacier. "We know this type of warm ice from far warmer Alpine environments, but here the glacier is producing the heat by deforming itself," said Law.

"With these observations, we are starting to better understand why the Greenland Ice Sheet is losing mass so quickly and why discharge of ice is such a prominent mechanism of ice loss," said Christoffersen.

One of the major limitations in our understanding of climate change is tied to the behaviour of glaciers and ice sheets. The new data will allow the researchers to improve their models of how the Greenland Ice Sheet is currently moving, how it may move in the future, and what that this will mean for global sea-level rise.

The research was funded in part by the European Union.

More information: Thermodynamics of a fast-moving Greenlandic outlet glacier revealed by fiber-optic distributed temperature sensing, *Science Advances* (2021). [DOI: 10.1126/sciadv.abe7136](https://doi.org/10.1126/sciadv.abe7136)

Provided by University of Cambridge

Citation: Fibre-optics used to take the temperature of Greenland Ice Sheet (2021, May 14)
retrieved 29 April 2024 from
<https://phys.org/news/2021-05-fibre-optics-temperature-greenland-ice-sheet.html>

This document is subject to copyright. Apart from any fair dealing for the purpose of private study or research, no part may be reproduced without the written permission. The content is provided for information purposes only.