Programme for Monitoring of the Greenland Ice Sheet

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How meltwater can create an ice lid in the snow blanket over the Greenland ice sheet

Cores extracted from multi-year snow on the Greenland ice sheet give new insights into its capability to store meltwater through refreezing. This refreezing process was previously believed to be an efficient buffer absorbing meltwater, thus delaying sea-level rise – however, now we find this is not always the case.

What started as a mission to learn more about physical processes in multi-year snow (firn) blanketing the large interior of the Greenland ice sheet, turned into a large, in-depth study on how meltwater refreezes in firn. It took three expeditions to Greenland to gather all the evidence we needed. In spring 2012, the GEUS glaciology group coordinated a week-long expedition to the accumulation area of the ice sheet, at 1840 m above sea level, east of Kangerlussuaq (Fig. 1). Central to the campaign was to install thermistor strings in the firn and to extract as many firn cores as time would allow (Fig. 2) to be able to determine energy and mass fluxes into the firn. The site had already been monitored using mass-balance stakes (Utrecht University) and a weather station (GEUS) in the previous years.

We anticipated finding firn with some ice layers, the site being located high enough in the ice sheet interior for annual snowfall to be larger than melt, but low enough for substantial melting to occur in summer. Yet we found evidence of large melting in previous years judging from a layer of six metres of mostly solid ice (refrozen meltwater), concealed by roughly one metre of snow on top. It soon became evident that we had to return the year after to find out how far

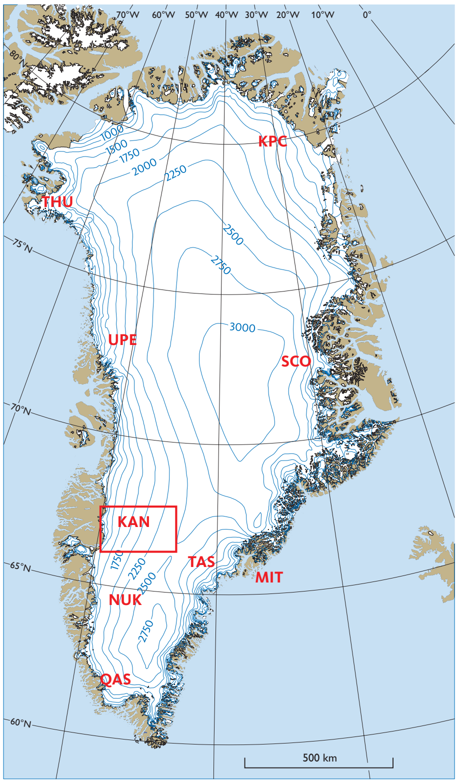

Figure 1. The region of core extractions (red box) and the regions with PROMICE weather stations (red lables).

these ice layers stretched horizontally, and what they meant for the capability of the ice sheet to store meltwater in the cold firn underneath this ice lid. It proved the start of a fruitful collaboration with the Cooperative Institute for Research in Environmental Sciences (CIRES) in Boulder, USA.

We did not have to wait long to learn about some of the consequences of the ice layer. In July 2012 the Greenland ice sheet was hit by the most widespread melting event in recorded history, with melt occurring even in the highest and generally coldest regions. The surface at our drill site was marked with a well-developed network of channels transporting meltwater to lower elevations (Fig. 3), in a region where meltwater had not lingered at the surface in summers before, but had always percolated into the firn. We suspected that the thick ice layers were preventing meltwater from refreezing locally, and urging it to flow towards the ocean.

The 2013 spring expedition set out to drill more firn cores, to a greater depth (up to 20 m), and for a larger region of the ice sheet (Fig. 1). Ground-penetrating radar was used in between the drill sites to confirm that our cores were representative of a larger region. Our scientific goals thus required us to move around with our tent camp making use of snow mobiles. In spite of harsh conditions including several storms and temperatures dropping to –40°C, the expedition was a great success.

The newly obtained data did not only confirm that the ice layers were vast and thick, but also that relatively great quantities of meltwater in 2012 could not find efficient passage through this ice lid into the porous space between the ice grains below. Thus the underlying firn is largely sealed, and it can no longer efficiently absorb meltwater, which instead runs into the sea, contributing to sea level rise. Yet previous findings on the ice sheet, predating the 2010 and 2012 high melt years, had suggested the likelihood of meltwater percolating and refreezing locally until all pore space in the firn had been filled. We added temporal perspective by also extracting firn cores at locations where other cores were drilled in the 1990s. From these we concluded that great changes occurred in the firn over this period, attributal only to an increase in local temperatures, increasing melting and the formation of ice layers in firn.

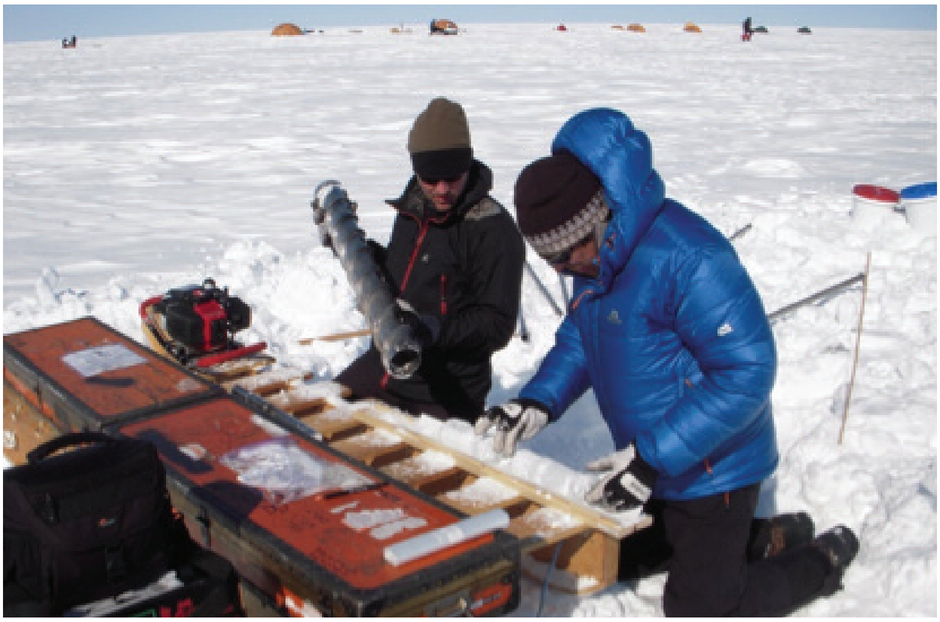

Figure 2. M. MacFerrin (CIRES) and H. Machguth (then GEUS) processing a segment of a firn core in May 2012. The camp is visible in the background.

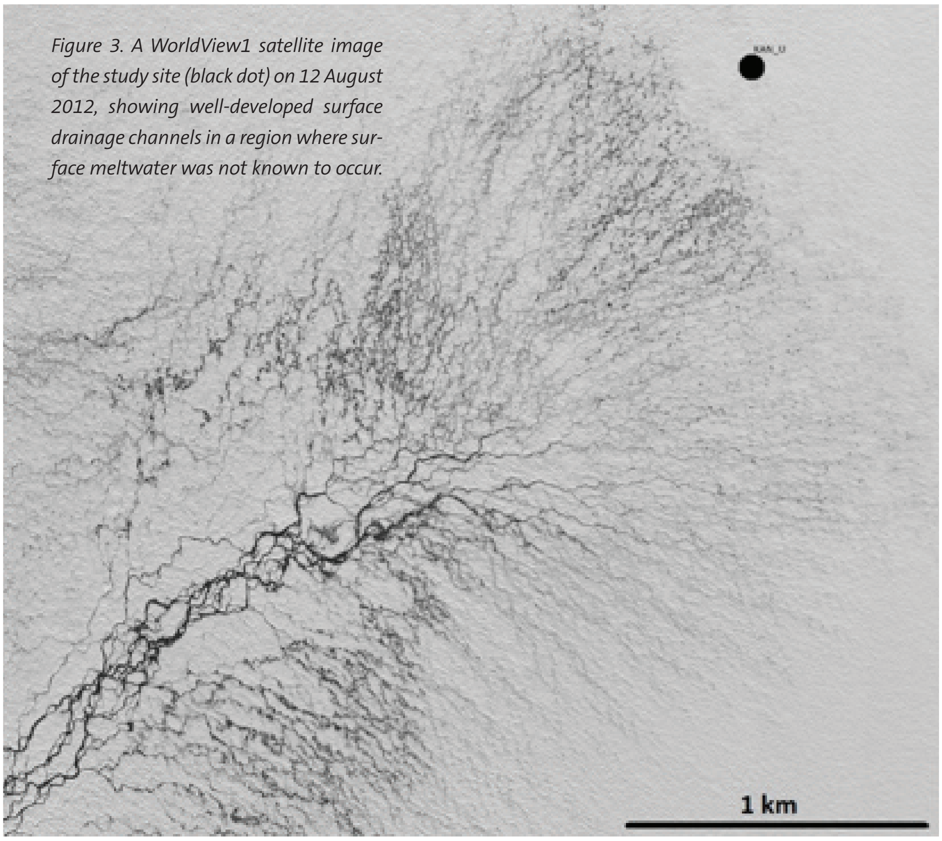

Figure 3. A WorldView1 satellite image of the study site (black dot) on 12 August 2012, showing well-developed surface drainage channels in a region where surface meltwater was not known to occur.

These findings formed the basis of a study published in Nature Climate Change (Machguth et al. 2015), and supported several other studies of Greenland firn (e.g. Charalampidis et al. 2015). In 2015 another expedition took place, adding even more perspective, and with the potential to investigate firn processes over the entire Greenland ice sheet in a CIRES-run project named FirnCover. All three expeditions were done in tight collaboration between CIRES (funded by NASA) and GEUS. GEUS involvement relied on contributions from the projects GAP, REFREEZE, RETAIN, Svali and PROMICE.

Work Cited

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Machguth H, MacFerrin M, Van As D, Box JE, Charalampidis C, Colgan W, Fausto RS, Meijer HAJ, Mosley-Thompson E and Van de Wal RSW (2016) Greenland meltwater storage in firn limited by near-surface ice formation. Nature Clim. Change (doi:10.1038/nclimate2899)

Further information

http://www.promice.dk
http://www.undergroundchannel.dk/an-icelid-more-greenland-meltwater

PROMICE

PROMICE is financed by the Ministry of Energy, Utilities and Climate through the climate support programme DANCEA (Danish Cooperation for Environment in the Arctic), which is managed by the Danish Energy Agency.

- The purpose of PROMICE is to monitor the mass loss of the Greenland ice sheet, both the melting on the surface and the volume of icebergs discharged into the sea
- PROMICE is headed in Denmark by GEUS in cooperation with DTU Space and Asiaq in Greenland. Furthermore the programme collaborates with the Danish Meteorological Institute and foreign universities and authorities.
- Read more about PROMICE on promice.org, where you can find photos and videos, get direct access to measuring data from the ice sheet and the PROMICE outreach material. On the website you can also subscribe to our newsletter.
- Information can also be found on porlarportal.org a new website where Danish research institutions display the results of their monitoring of the Greenland ice sheet and the sea ice in the Arctic.

Authors
Dirk van As (GEUS), Horst Machguth (UZH, Switzerland) and Mike MacFerrin (CIRES, USA)

Editors
Signe Bech Andersen, senior researcher, GEUS.
Jane Holst, GEUS.

Layout
Henrik Klinge Pedersen, GEUS.

Geological Survey of Denmark and Greenland
Øster voldgade 10
DK-1350 Copenhagen K
Denmark

Technical University of Denmark
Anker Engelunds Vej 1, 101A
DK-2800 Kgs. Lyngby
Denmark

Asiaq
Qatserisut 8, P.O. Box 1003
3900 Nuuk
Greenland

Ministry of Energy, Utilities and Climate
Stormgade 10–12
DK-1470 Copenhagen K
Denmark

Danish Energy Agency
Amaliegade 44
DK-1256 Copenhagen K
Denmark