

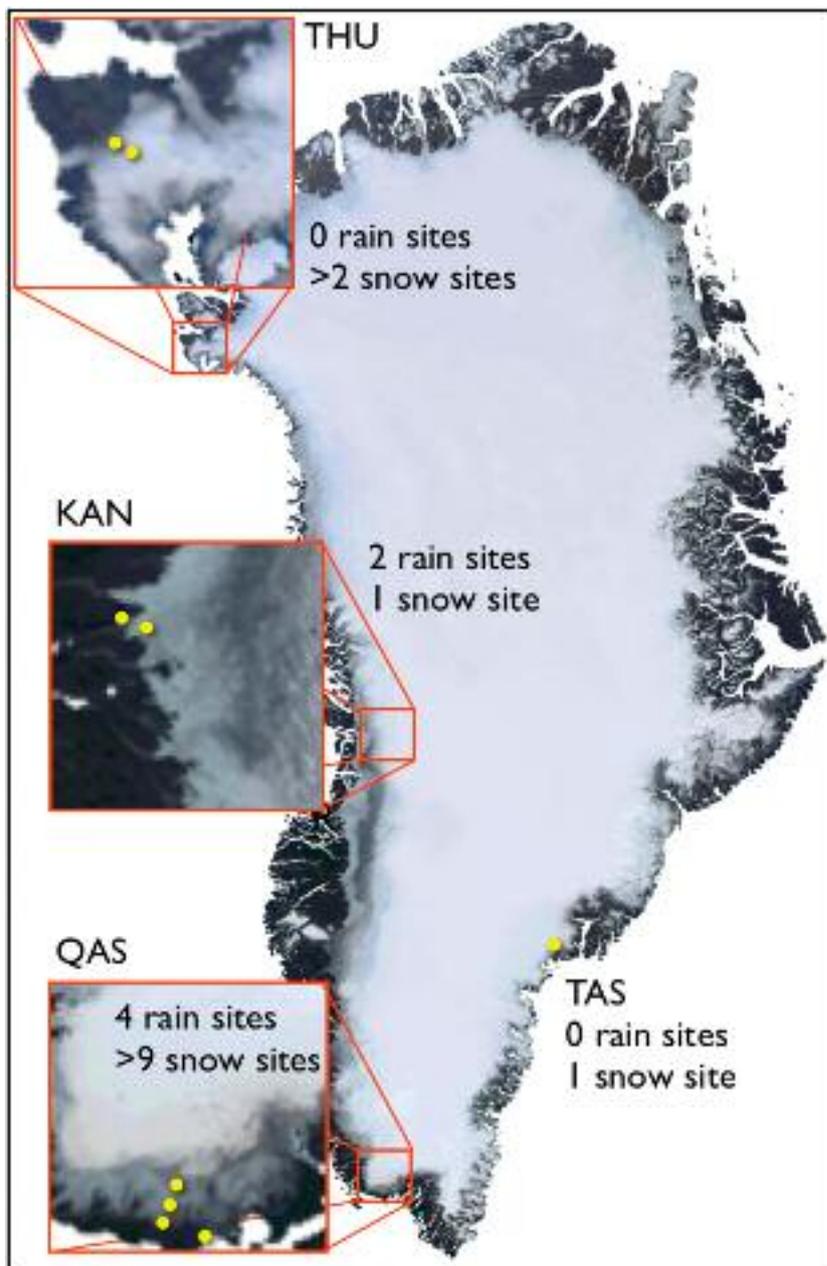
How much snow and rain falls on Greenland ice?

In a number of ways, PROMICE has been expanding its ability to measure how much snow and rain falls on Greenland ice. To understand Greenland's melt, it turns out to be important to gauge the mass input from snow or rain.

Regional climate models have their largest disagreements over the lowest third of the ice sheet elevation profile, where both melting and snowfall reach maximum values. While PROMICE accurately monitors ice ablation, the highly variable snowfall influences ice ablation rates. Further, there is evidence for increasing snowfall with climate warming. On the other hand, the rainfall fraction of total precipitation has been increasing with climate warming. Therefore, knowledge of the magnitude and spatial pattern of snow accumulation is fundamental to understanding the present and future mass balance of the ice sheet. By servicing PROMICE automatic weather stations in spring, it is possible to measure not only melt amounts but mass inputs from snowfall.

Springtime snow survey

Near the southern tip of the Greenland ice sheet on the Qagssimiut lobe, high accumulation and melt rates indicate a high mass turnover (Hermann et al. 2018). In late spring, it is possible to measure the main snow mass accumulating during the cold season. Visits are made by helicopter, ski or snow mobile traverses. Field teams have been shoveling out snow 'pits' and coring, to weigh the precipitation accumulating on top of glacier ice. Surveys have been made near the southern tip of the ice sheet since 2014. In 2017 and 2018, sites in northwest Greenland were measured when the Camp Century Climate Monitoring team was working on the ice sheet near Thule Air



Locations of snow and rain data gathering

Base. Springtime snow surveys, at QAS on the Qagssimiut ice lobe each lasting one week, expanded the coverage with ski traverse by 25

km in 2017, sampling 9 locations between 288 m and 1134 m elevation. In 2018, the distance tripled to 75 km, obtaining 19 snow profiles at



Snow coring right before melt season, to measure how much snow accumulates each winter on top of bare ice.

seven locations between 1102 m and 1845 and 1102 m elevation. The larger 2018 distance was covered by snow kiting.

Rain gauges

Rainfall is recognized to be increasing on the Greenland ice sheet. Yet, very few in-situ measurements have been made. Starting August, 2016, a number of tipping bucket rain gauges were deployed at the PROMICE sites thought to have the most rainfall. The result is already a powerful record of surprisingly large rainfall cases. At the QAS_M station, for year 2017 the (not undercatch-corrected) rainfall totaled 696 mm.

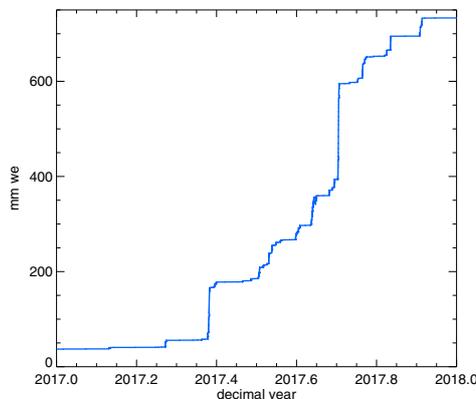
Airborne radar

Using the University of Kansas Center for



Skiing between measurement sites.

Remote Sensing of the Ice sheets (CRISIS) ultra-wide band high frequency (2 to 6.5 GHz) Snow Radar on board NASA Operation IceBridge (OIB) airborne surveys, a new PROMICE study is developing snow accumulation measurements. The study measures the effect of the rolling surface of the ice sheet, having undulations of ~100 m vertical over 2000 m horizontal distance. Along the Snow Radar survey tracks, we find the remotely-sensed snow depth variations to be responsive to convexity or concavity, explaining up to 55% of the accumulation signal on 10 km length scales. The range in snow depth due to undulations along the southern Greenland ice sheet Q-transect ranged by 59% in 2015. We plan to



Rain accumulation at the QAS_M site measured by a simple 'tipping bucket' rain gauge during a 1.5 year period of operation (11 Aug 2016 - 5 May, 2018) that is ongoing.

IceBridge to expand the airborne radar survey in synergy with PROMICE.

Neutron probes

A new technology enables continuous monitoring of the mass of snow accumulating on the lower Greenland ice sheet. The technique exploits the fact that snow absorbs neutrons raining down on Earth from cosmic rays. The EU INTAROS and GEM projects, have respectively financed four and one of these new SnowFox instruments that by now have been installed at 4 locations around Greenland (two on the south Greenland QAS region; one at the southeastern TAS region; one at the western KAN region; one at the northwestern THU region; and one to be installed on Disko Island. We eagerly await gathering the data during year 2019 fieldwork.

Work Cited:

Hermann, M., Box, J.E., Fausto, R.S., Colgan, W.T., Langen, P.L., Mottram, R., J. Wuite, B. Noel, M.R. van den Broeke, and D. van As (2018). Application of PROMICE Q-transect in situ accumulation and ablation measurements (2000–2017) to constrain mass balance at the southern tip of the Greenland ice sheet. *Journal of Geophysical Research: Earth Surface*, 123, 1235–1256.

<http://dx.doi.org/10.1029/2017JF004408>

Further information

<http://www.promice.dk>

<http://www.undergroundchannel.dk/how-much-snow-falls-on-greenland>

Author:

Jason Box (GEUS)

Editor:

Robert Fausto, GEUS.

Layout

Henrik Klinge Pedersen, GEUS.

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.



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