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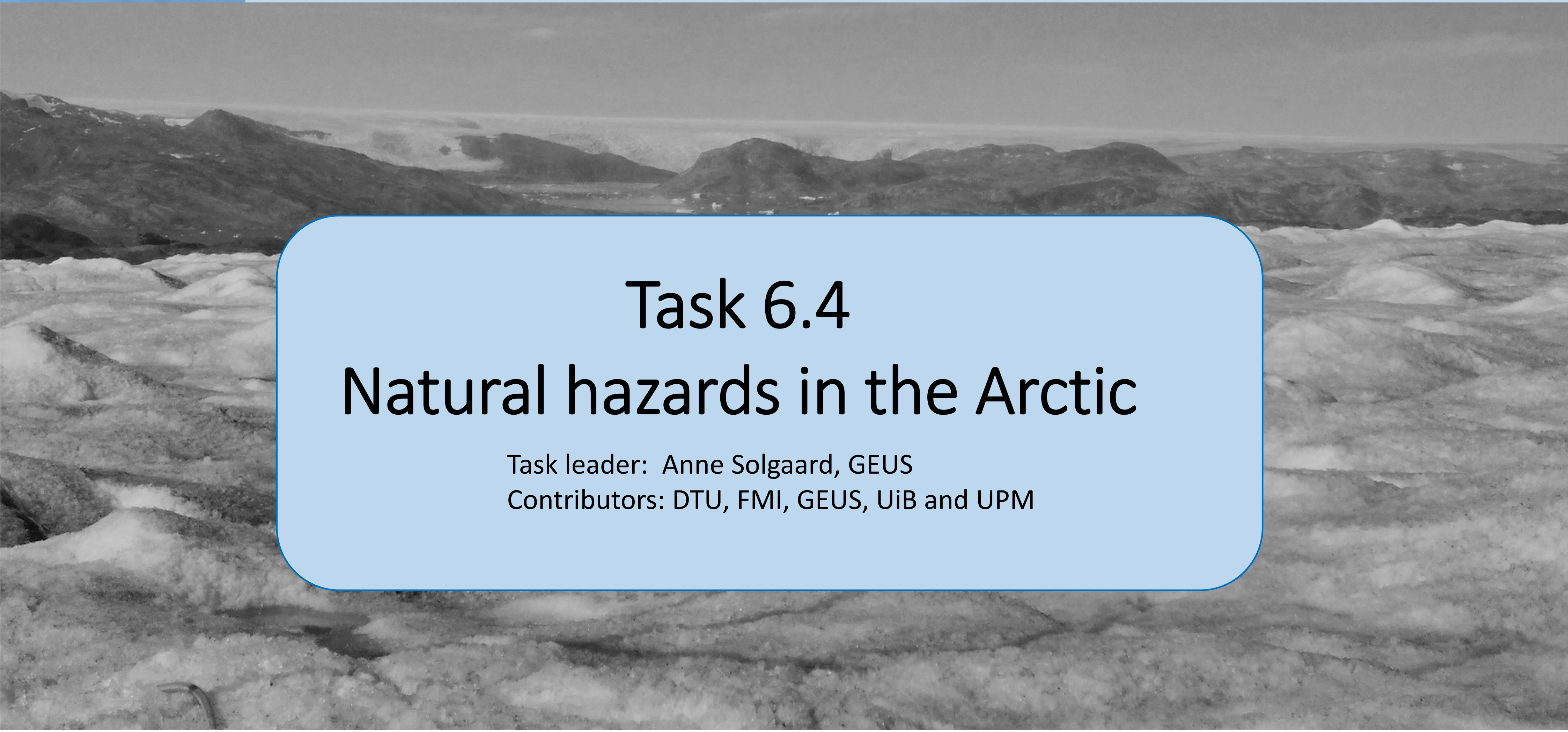


# Task 6.4
# Natural hazards in the Arctic

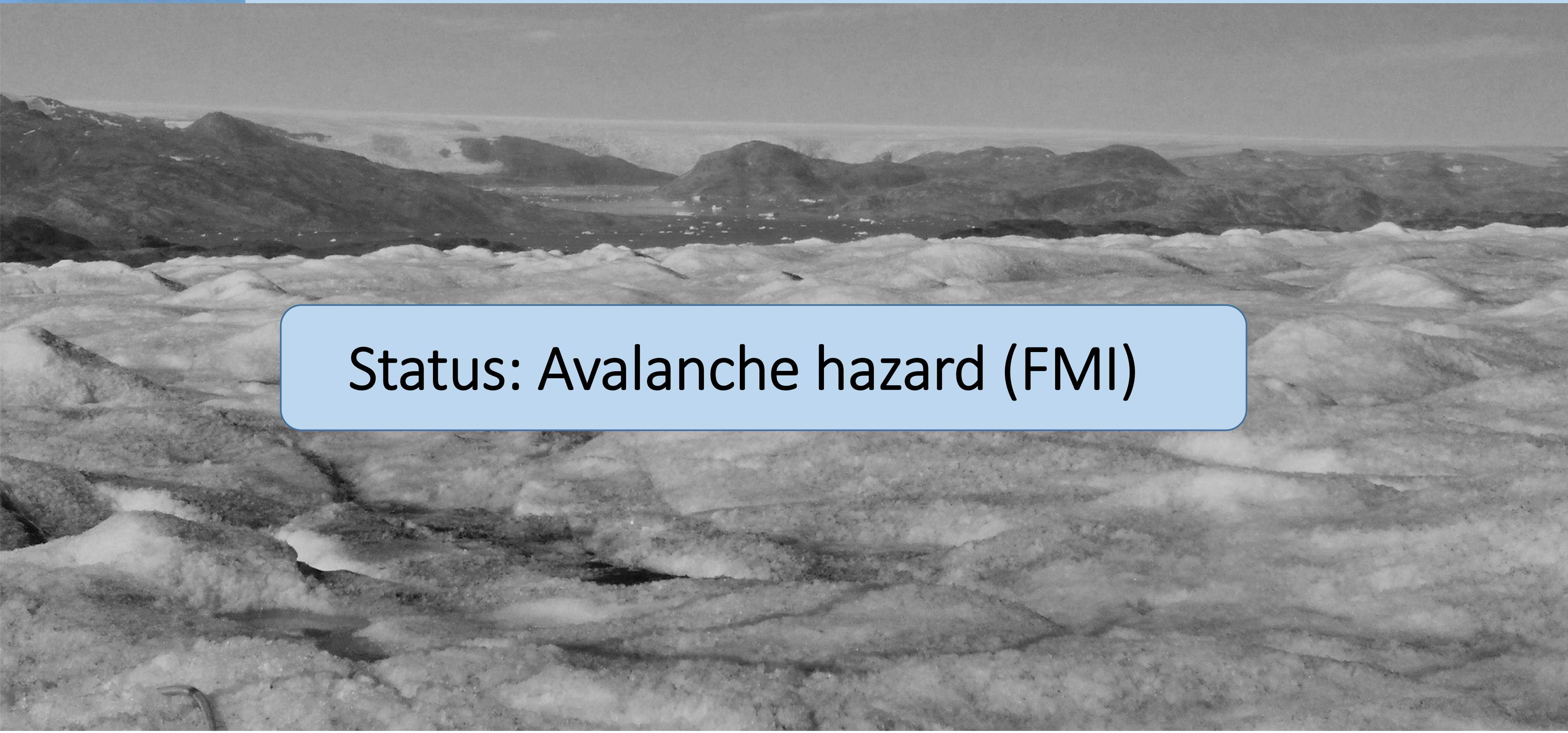
Task leader: Anne Solgaard, GEUS
Contributors: DTU, FMI, GEUS, UiB and UPM

Task 6.4 aims to demonstrate how the iAOS can be exploited to better understand natural hazards in the Arctic. Specifically, three different hazards will be addressed:

- Avalanche hazard
- Earthquakes
- Mass loss from the Greenland Ice Sheet and selected Svalbard glaciers

**D6.16** Natural hazard assessment in the Arctic. (Resp. GEUS; M58)

**D6.17** Ice discharge from glaciers to the ocean: Model-based demonstration of calculations of ice discharge from selected glaciers to the ocean, aimed to predict the contribution of glaciers to sea level rise. (Resp. UPM; M58)



# Status: Avalanche hazard (FMI)

# FMI: Improving input to avalanche forecast models in Longyearbyen valley, Svalbard

General Assembly, 2021

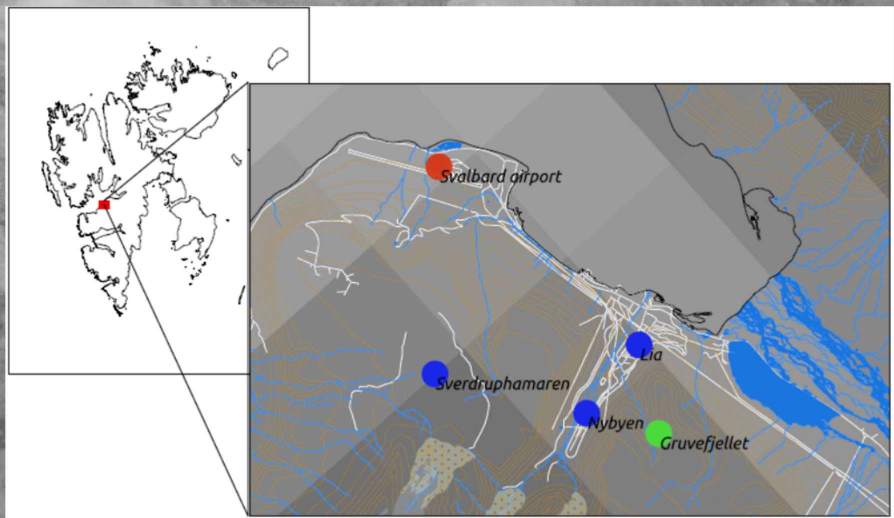
Roberta Pirazzini, Tiina Nygård, Ilona Valisuo, Laura Rontu

**Rationale:** Avalanche forecast models require input from numerical weather prediction models, which, however, cannot resolve the complex Svalbard topography and therefore cannot provide accurate snow precipitation and snow accumulation in the mountain slopes where avalanches can take place.

→ We develop a statistical method to improve the snow accumulation forecast in the mountain slopes facing the town of Longyearbyen. → It will Improve input to avalanche models!

<u>DATA (Nov 2017 – May 2018):</u>

- AROME-Arctic model data (precipitation, temperature, wind) -> replaced by CARRA reanalysis (almost same data, but easier to work with)
- In situ snow depth observation from 3 automatic stations (blue dots in the map) from UNIS
- In situ air temperature and wind (all dots in the map) from METNO

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# Ongoing data analysis
(according to planned schedule)

General Assembly, 2021

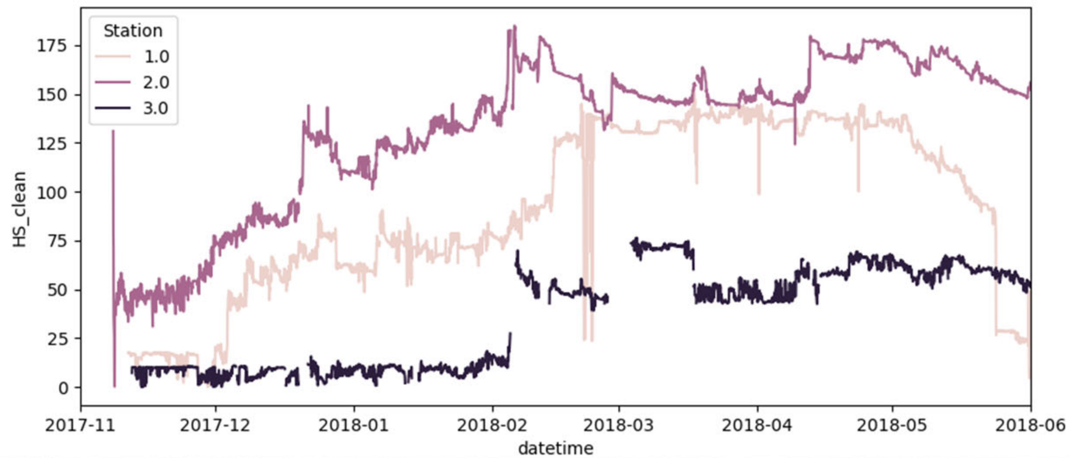
**HYPOTHESIS**: Correlations between in situ snow depth and temperature, wind, and precipitation will be different at different stations depending on how the slopes are positioned with respect to the surrounding mountains and the dominant circulation.

**METHOD:**

- For each snow station, correlations between snow depth and atmospheric parameters are searched for selected wind sectors, and when changes in snow depth occur.
- These correlations will be used to modify the input met variables (wind and temperature) to the snow avalanche model, so that the snow accumulation modelled in the avalanche forecast model will be more realistic

The complex orography strongly affect the distribution of snow accumulation: close by snow stations have very distinct snow accumulation time series

*Snow accumulation at the 3 snow station in Longyearbyen valley*

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# Collaboration with Mines ParisTech (WP5) to showcase the usefulness of the statistical tools available in the iAOS



Statistical tools are applied to generate high resolution snow depth maps on the mountain slopes facing Longyearbyen. The method is developed using old data (winter 2017-2018) but it can later be applied to further improve the input to snow avalanche models or to validate the model output.

**DATA APPLIED (in addition to the model outputs and in situ data used by FMI):**

- Digital elevation model (20m resolution)
- Snow depth maps on the slopes generated with a Terrestrial Laser Scanner (from UNIS)
- In situ meteorological data (temperature and wind) from weather stations on nearby valleys (from METNO)

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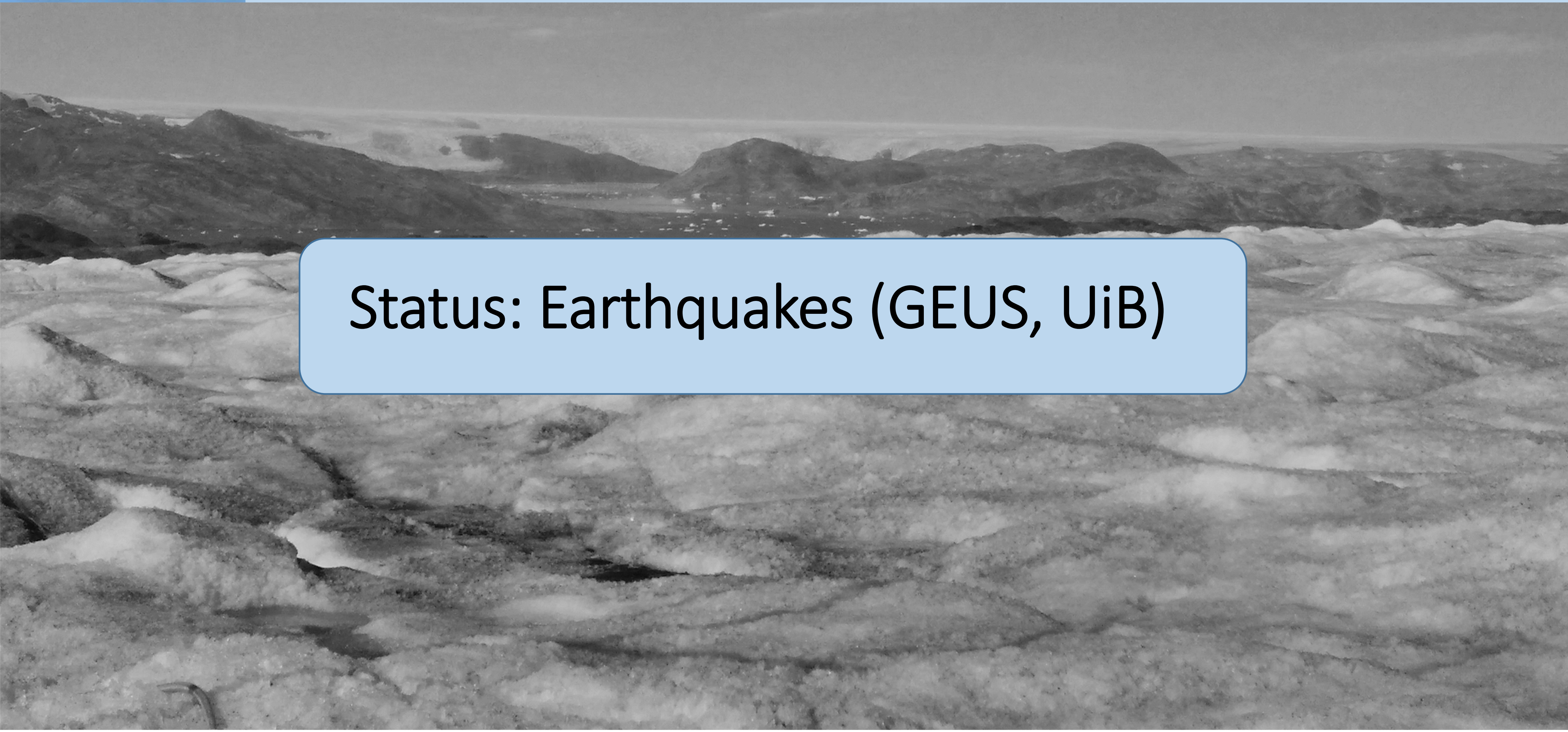


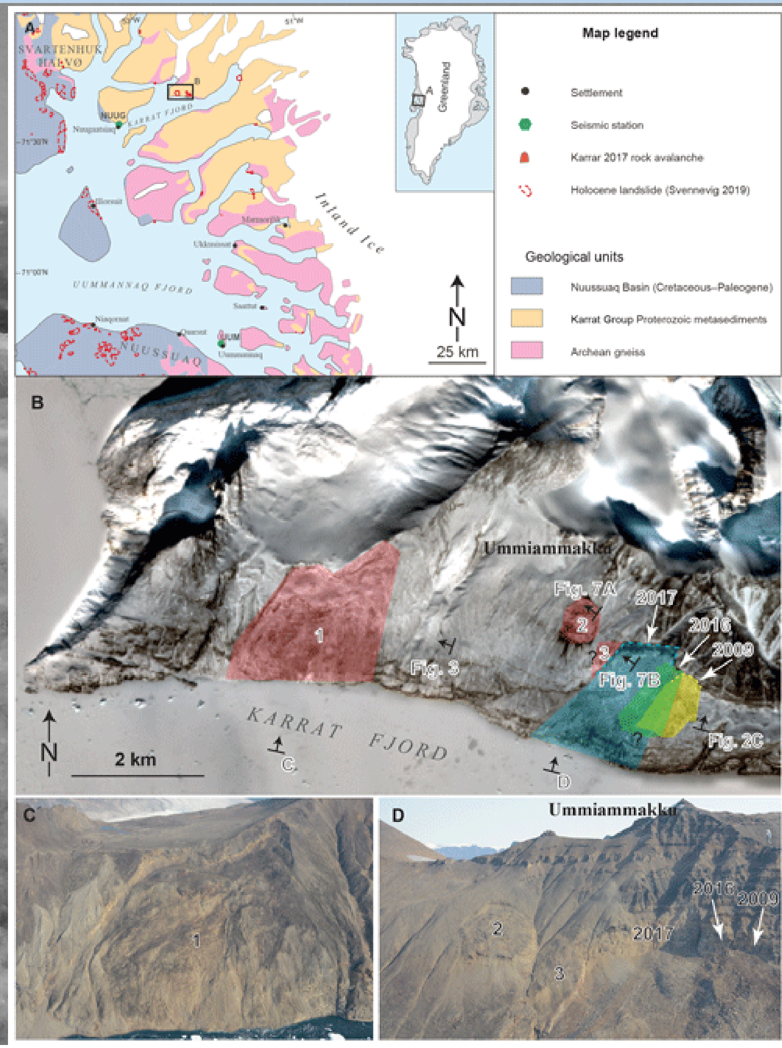
# Status: Earthquakes (GEUS, UiB)

# Earthquakes

General Assembly, 2021

Data from INTAROS seismic stations in Greenland have been used in a study of landslides in West Greenland. The seismic data was used in combination with satellite data to detect possible landslides and determine the time of landslides wich high accuracy, which is not possible  with satellite data.

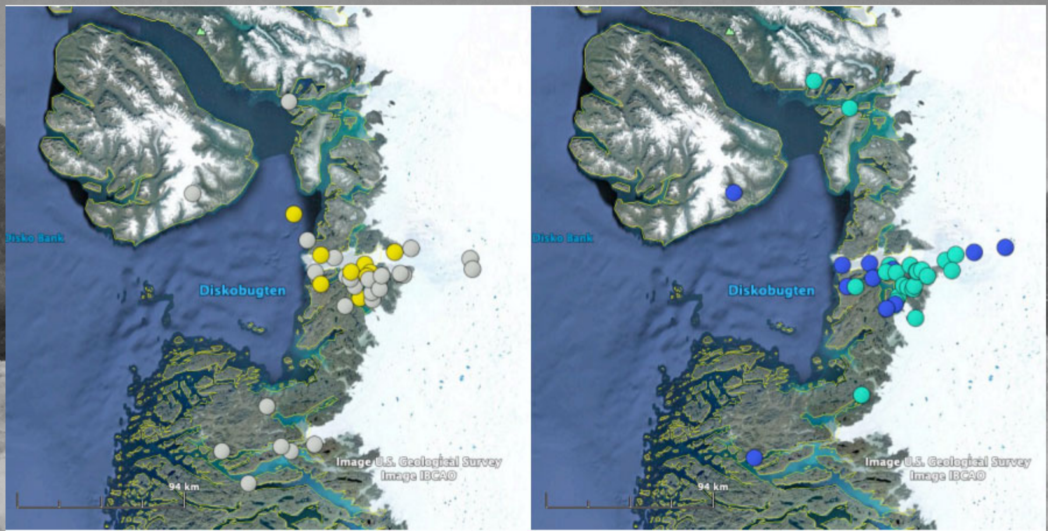
The outcome was presented at The European Polar Science Week and by Svennevig et al. (2020), see figure.




Svennevig et al. (2020)  https://doi.org/10.5194/esurf-8-1021-2020, 2020

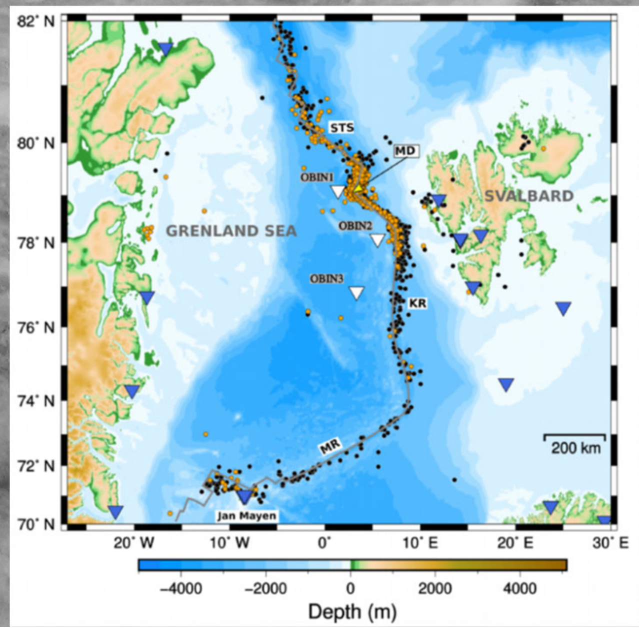
# Earthquakes

General Assembly, 2021



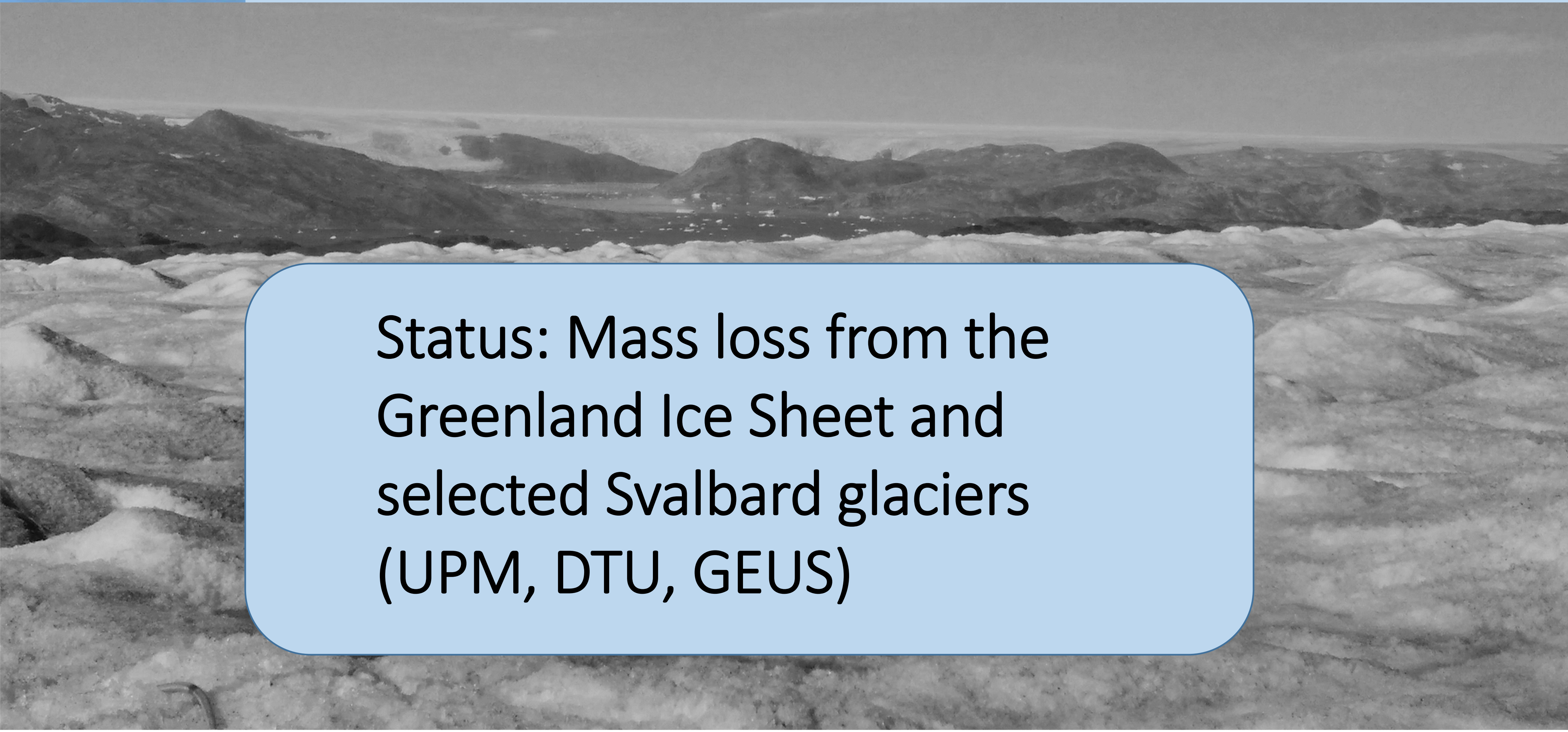

Data for earthquake monitoring collected by INTAROS is used in studies on the discrimination between tectonic and cryo-generated seismic events.
Figure from **Sølund (2020)** showing Disko Bay area, East Greenland, yellow and gray are confirmed and presumed tectonic earthquakes, light and dark blue are confirmed and presumed glacial events.

A study of the seismicity in the Fram Strait shows how the Ocean Bottom Seismometers (OBS) deployed by INTAROS have improved the detection threshold and location accurracy, and thus provided new knowledge on seismicity previously not detected by land instruments, **Jeddi et al. (submitted 2021).**
Black: earthquakes detected by land stations (blue triangles); orange: new detections with OBS instruments (white triangles).



INTAROS

General Assembly, 2021



# Status: Mass loss from the Greenland Ice Sheet and selected Svalbard glaciers (UPM, DTU, GEUS)

INTAROS

General Assembly, 2021

**Goal of the work:**

- Provide time series of Greenland Ice Sheet mass loss from satellite gravimetry (GRACE).
- Provide time series of uplift from GPS due to ice loss from the Greenland Ice Sheet.
- **Merge GRACE and GPS data to provide improved spatial resolution of Greenland Ice Sheet mass loss.**

**Status of the work:**

- Completed!

Method about merging GPS and GRACE data is published in:

Wang, L., Khan, S. A., Bevis, M., van den Broeke, M. R., Kaban, M. K., Thomas, M., & Chen, C. (2019). Downscaling GRACE predictions of the crustal response to the present-day mass changes in Greenland. Journal of Geophysical Research: Solid Earth, 124. https://doi.org/10.1029/2018JB016883

JGR Solid Earth

RESEARCH ARTICLE
10.1029/2018JB016883

**Key Points:**
- GRACE results can be improved by using scaling factors estimated from two models of surface mass fields in Greenland
- Scaled GRACE-derived and GPS-observed vertical displacements were compared at 53 Greenland GPS Network (GNET) stations
- GRACE-based estimates of accurate uplift rates in Greenland needs to

## Downscaling GRACE Predictions of the Crustal Response to the Present-Day Mass Changes in Greenland

Linsong Wang[1,2], Shfaqat A. Khan[3], Michael Bevis[4], Michiel R. van den Broeke[5], Mikhail K. Kaban[2], Maik Thomas[2,6], and Chao Chen[1]

[1]Hubei Subsurface Multi-scale Imaging Key Laboratory, Institute of Geophysics and Geomatics, China University of Geosciences, Wuhan, China, [2]Helmholtz Centre Potsdam, GFZ German Research Centre for Geosciences, Potsdam, Germany, [3]DTU Space-National Space Institute, Technical University of Denmark, Kongens Lyngby, Denmark, [4]School of Earth Sciences, Ohio State University, Columbus, OH, USA, [5]Institute for Marine and Atmospheric Research Utrecht, Utrecht University, Utrecht, Netherlands, [6]Institute of Meteorology, Freie Universität Berlin, Berlin, Germany

DTU

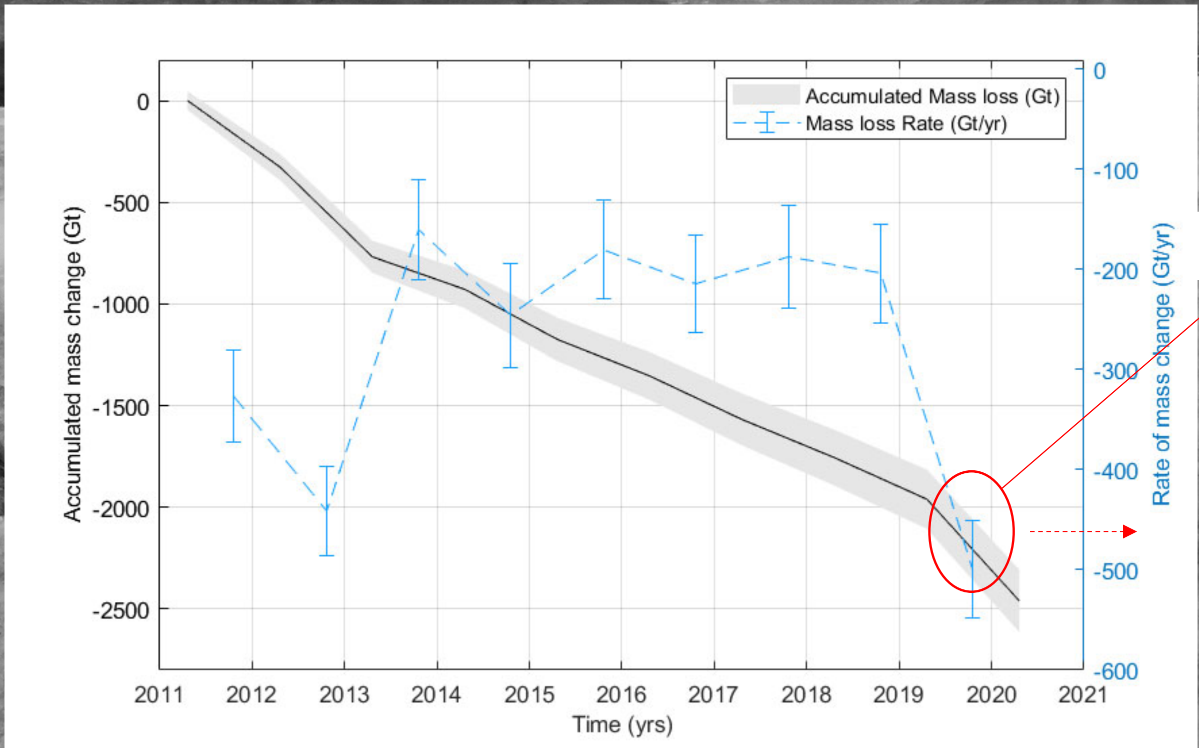
# Analysis of GPS data and satellite altimetry data show exceptional high ice mass loss in 2019.

INTAROS

General Assembly, 2021

Example using cryosat-2 data:

The black line show (left axis) show accumulated loss Gt
The blue line (right axis) show mass loss rate in Gt/yr




Record high melt rate

- In 2019, the Greenland ice sheet lost 499 $\pm$ 49 Gigaton ice,
- Equivalent to 1.4 mm global sea level rise.
- This corresponds to 33% of a total sea level rise of 4.2 mm in 2019.
- The Greenland ice sheet has become the largest contributor to global sea level rise.

DTU

INTAROS

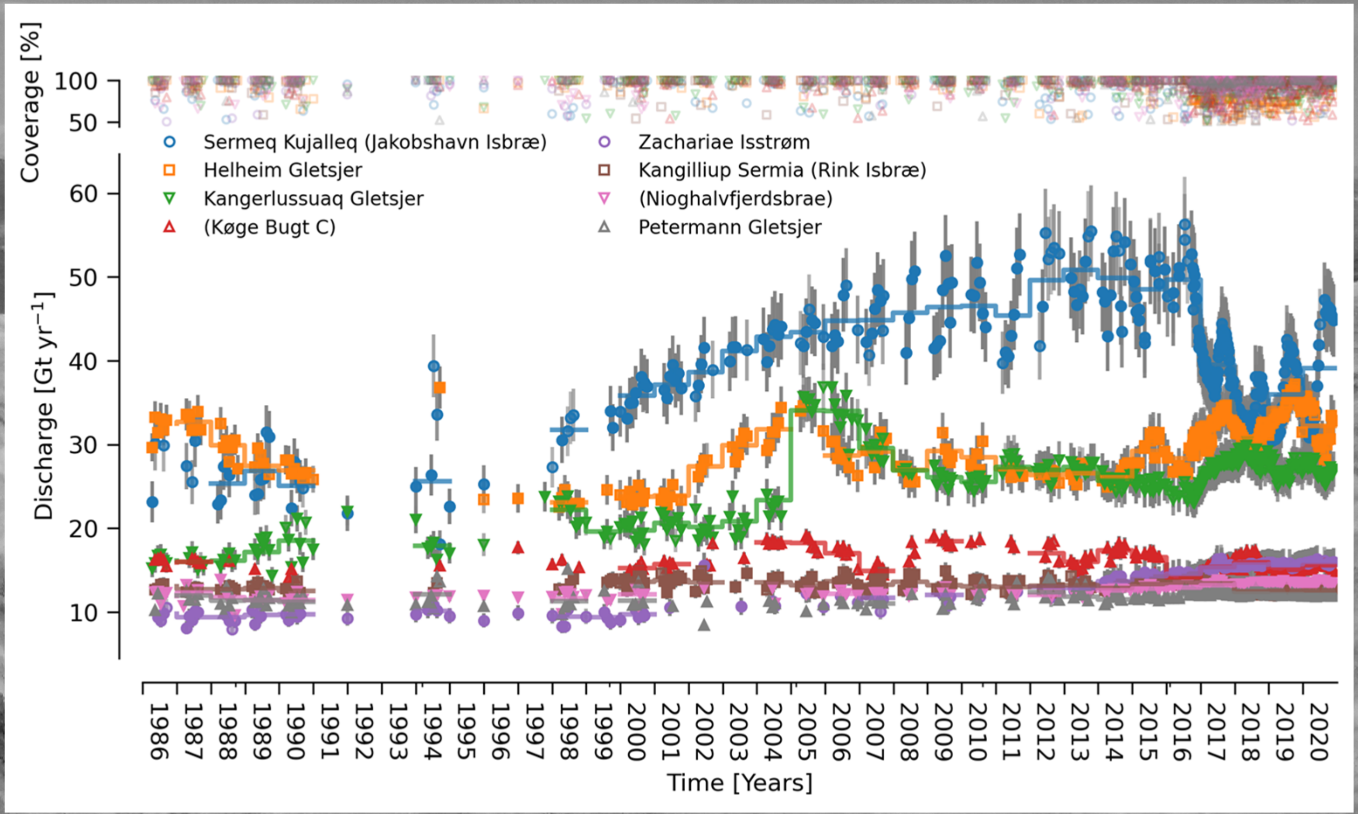
# Ice Discharge from the Greenland Ice Sheet

General Assembly, 2021

**Goal of the work:**

Mass loss from the Greenland Ice Sheet:

- **Finalize and publish paper on solid ice discharge from GIS**
- Finalize and publish paper on liquid water discharge from GIS
- Combine solid & liquid to estimate total mass loss (2021-02-01 )




- Covers all marine terminating glaciers with fast-flowing ice
- Updates every ~12 days

INTAROS

# Ice Discharge from the Greenland Ice Sheet

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Earth Syst. Sci. Data, 11, 769–786, 2019
https://doi.org/10.5194/essd-11-769-2019


Open Access Earth System Science Data

## Greenland Ice Sheet solid ice discharge from 1986 through 2017

Kenneth D. Mankoff[1], William Colgan[1], Anne Solgaard[1], Nanna B. Karlsson[1], Andreas P. Ahlstrøm[1], Dirk van As[1], Jason E. Box[1], Shfaqat Abbas Khan[2], Kristian K. Kjeldsen[1], Jeremie Mouginot[3], and Robert S. Fausto[1]

[1]Department of Glaciology and Climate, Geological Survey of Denmark and Greenland (GEUS), Copenhagen, Denmark
[2]DTU Space, National Space Institute, Department of Geodesy, Technical University of Denmark, Kgs. Lyngby, Denmark
[3]Department of Earth System Science, University of California, Irvine, CA, USA

**Correspondence:** Kenneth D. Mankoff (kdm@geus.dk)

Received: 12 February 2019 – Discussion started: 21 February 2019
Revised: 21 April 2019 – Accepted: 2 May 2019 – Published: 6 June 2019

- Covers all marine terminating glaciers with fast-flowing ice
- Updates every ~12 days

# Ice Discharge



**Goal of the work:**

Mass loss from the Greenland Ice Sheet:

- Finalize and publish paper on solid ice discharge from GIS
- **Finalize and publish paper on liquid water discharge from GIS**
- Combine solid & liquid to estimate total mass loss (2021-02-01 )

Earth Syst. Sci. Data, 12, 1367–1383, 2020
https://doi.org/10.5194/essd-12-1367-2020


Open Access Earth System Science Data

## Greenland Ice Sheet solid ice discharge from 1986 through March 2020

**Kenneth D. Mankoff[1], Anne Solgaard[1], William Colgan[1], Andreas P. Ahlstrøm[1], Shfaqat Abbas Khan[2], and Robert S. Fausto[1]**

[1]Department of Glaciology and Climate, Geological Survey of Denmark and Greenland (GEUS), Copenhagen, Denmark
[2]DTU Space, National Space Institute, Department of Geodesy, Technical University of Denmark, Kgs. Lyngby, Denmark

**Correspondence:** Kenneth D. Mankoff (kdm@geus.dk)

Received: 11 December 2019 – Discussion started: 20 January 2020
Revised: 10 April 2020 – Accepted: 30 April 2020 – Published: 19 June 2020

- Covers all marine terminating glaciers with fast-flowing ice
- Updates every ~12 days

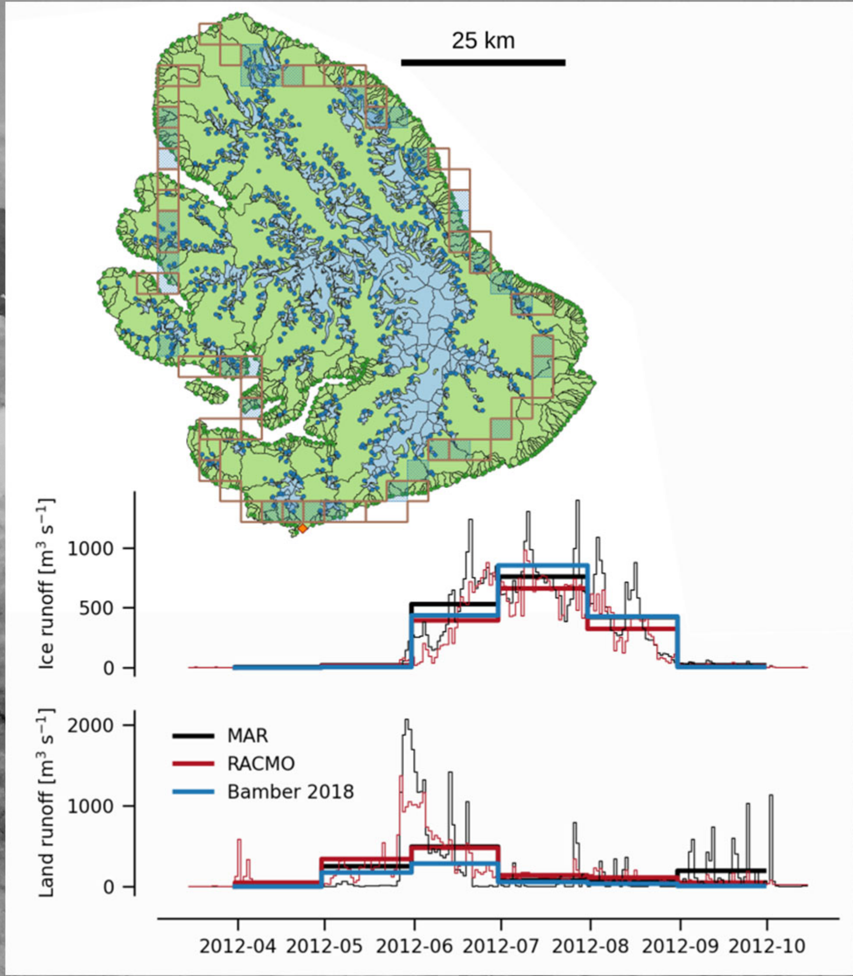
# Freshwater Runoff

General Assembly, 2021

**Goal of the work:**

Mass loss from the Greenland Ice Sheet:

- Finalize and publish paper on solid ice discharge from GIS
- **Finalize and publish paper on liquid water discharge from GIS**
- Combine solid & liquid to estimate total mass loss (2021-02-01 )




- Example graphic here is only for Disko Island, but product covers all of Greenland
- Daily runoff from 2 RCMs (RACMO & MAR)
- Runoff partitioned to ~25,000 ice margin outlets, or ~30,000 land coast outlets
- Product validated against 10 stream gauge observation data sets

# Freshwater Runoff

INTAROS

General Assembly, 2021

**Goal of the work:**

Mass loss from the Greenland Ice Sheet:

- Finalize and publish paper on solid ice discharge from GIS
- **Finalize and publish paper on liquid water discharge from GIS**
- Combine solid & liquid to estimate total mass loss (2021-02-01 )

Earth Syst. Sci. Data, 12, 2811–2841, 2020
https://doi.org/10.5194/essd-12-2811-2020


Open Access Earth System Science Data

## Greenland liquid water discharge from 1958 through 2019

**Kenneth D. Mankoff[1], Brice Noël[2], Xavier Fettweis[3], Andreas P. Ahlstrøm[1], William Colgan[1], Ken Kondo[4], Kirsty Langley[5], Shin Sugiyama[4], Dirk van As[1], and Robert S. Fausto[1]**

[1]Department of Glaciology and Climate, Geological Survey of Denmark and Greenland (GEUS), Copenhagen, Denmark
[2]Institute for Marine and Atmospheric Research, Utrecht University, Utrecht, the Netherlands
[3]SPHERES research unit, Department of Geography, University of Liège, Liège, Belgium
[4]Institute of Low Temperature Science, Hokkaido University, Sapporo, Japan
[5]Asiaq – Greenland Survey, Nuuk, Greenland

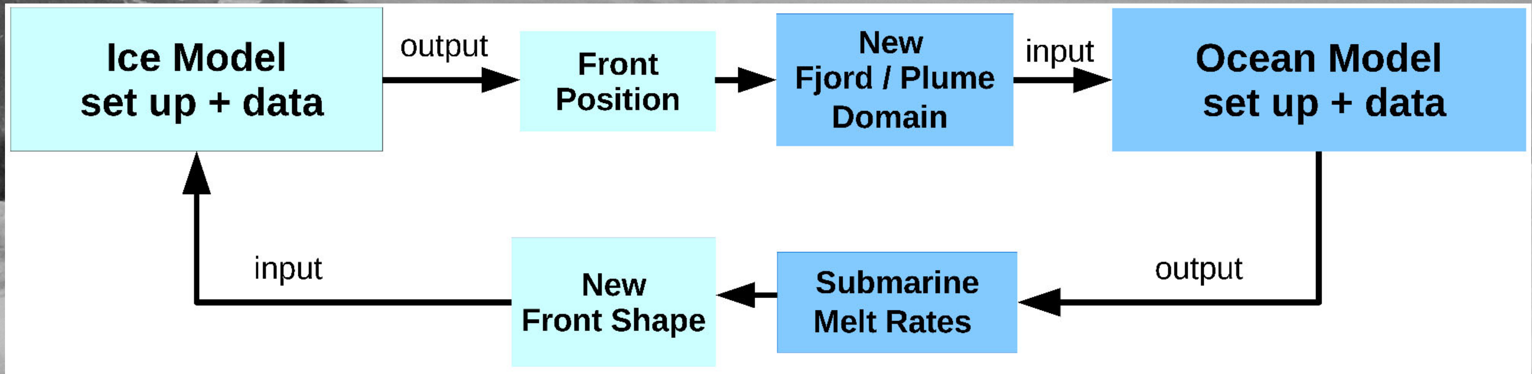
**Correspondence:** Kenneth D. Mankoff (kdm@geus.dk)

Received: 26 February 2020 – Discussion started: 7 April 2020
Revised: 22 October 2020 – Accepted: 28 October 2020 – Published: 14 November 2020

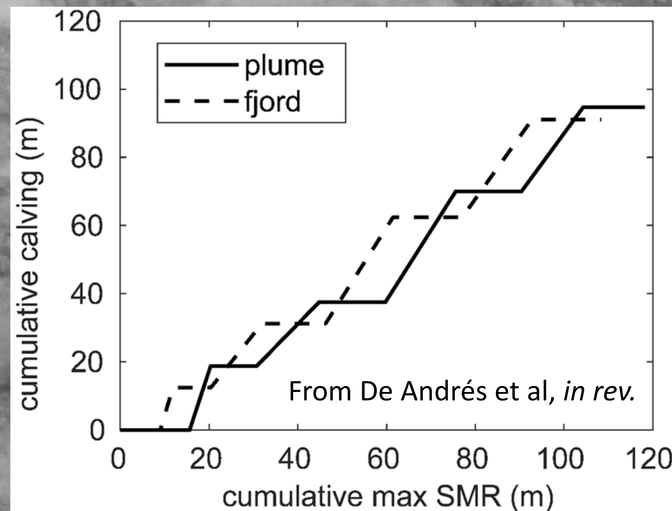
# To separate ice discharge into solid iceberg production and submarine melting…

General Assembly, 2021

- We developed a new more computationally-efficient version of our 2D glacier-fjord coupled model by parameterizing plume dynamics at the glacier front.



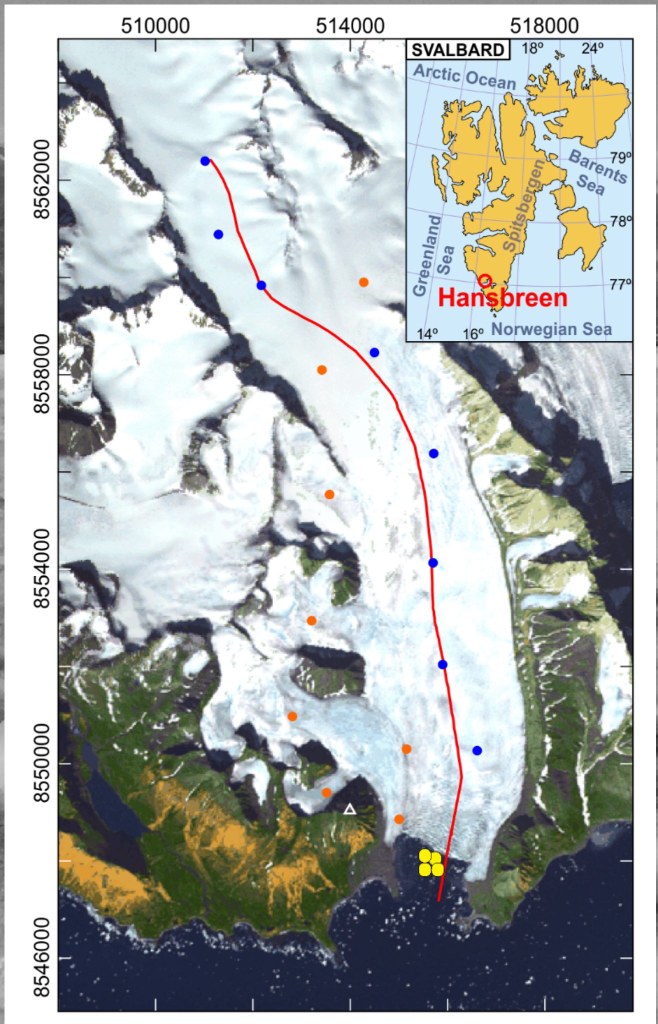

- Applied to Hansbreen-Hansbukta system (SW Svalbard). Results show good agreement with those of the more computationally-demanding fjord circulation-glacier dynamics coupled model.
- Over a melt season, both calving and submarine melting are comparable in terms of contribution to frontal mass loss (£100 m by each mechanism).



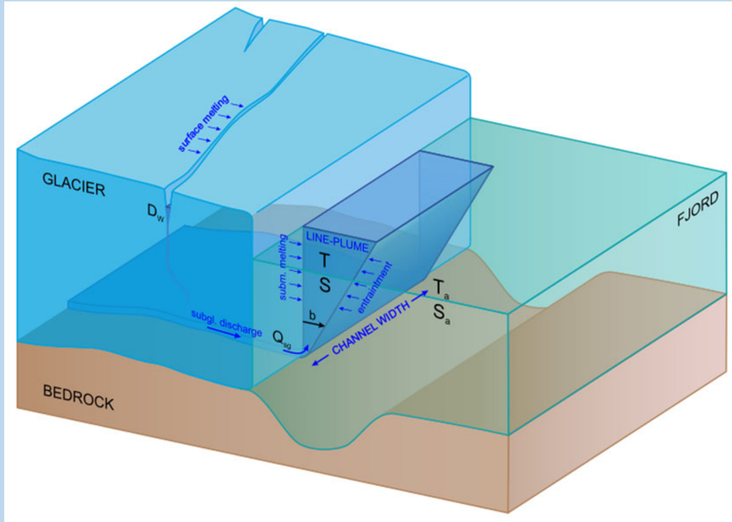

POLITÉCNICA

# Ongoing work






- Development of a 3D glacier-fjord coupled model with embedded plume parameterization (ElmerIce/MITgcm).




- Application to Hansbreen-Hansbukta system, using various data sets: glacier velocities from stakes, time lapse camera for front position and plume/s location, CTDs for fjord conditions. Comparison with the 2D-model results.