POLAR+ project:
4DGreenland

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DTU Space
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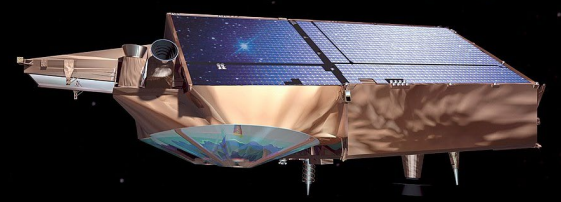


About 4DGreenland

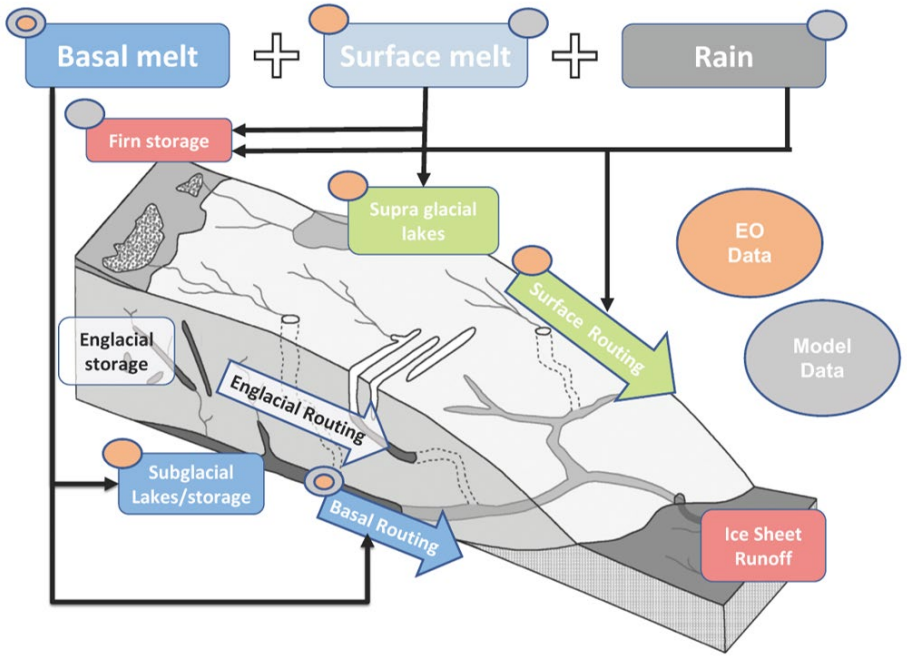
- POLAR+ Theme 2.
- Sept 2020- Sept 2022. Nine partners

Objectives:

- Generate novel datasets characterizing the different components of the hydrological system.
- Perform thorough validation of all derived products
- To perform an integrated pan-Greenland scientific analysis and study of the hydrological system.
- Advance our understanding of the Greenland hydrology and its impacts on the Greenland and Arctic environment.
- To develop a scientific roadmap providing recommendations to ESA to further advance the use of EO technology to address the main knowledge gaps and scientific challenges

4DGreenland structure

- **Activity 1** : Surface melt processes
- **Activity 2** : Supraglacial storage and drainage
- **Activity 3** : Subglacial melt, drainage and lakes
- **Activity 4** : Integrated Greenland hydrology assessment



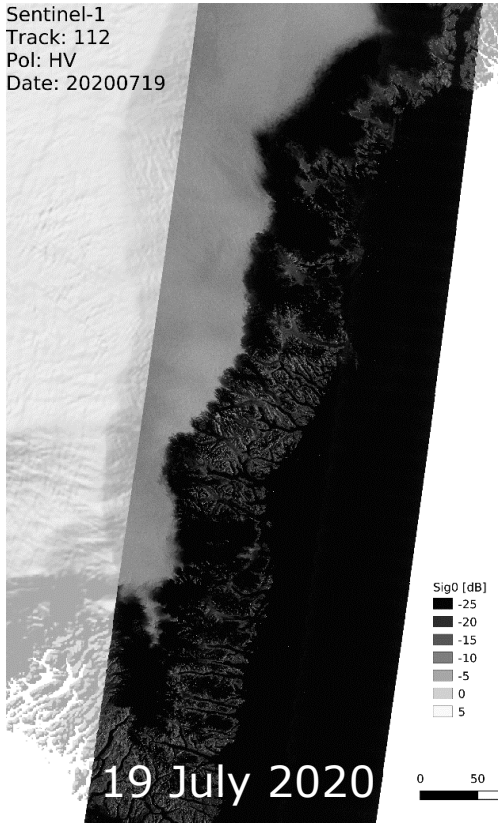
Background image adapted from Cuffey and Paterson (2010)

Surface Melt Extent from SAR & PMW

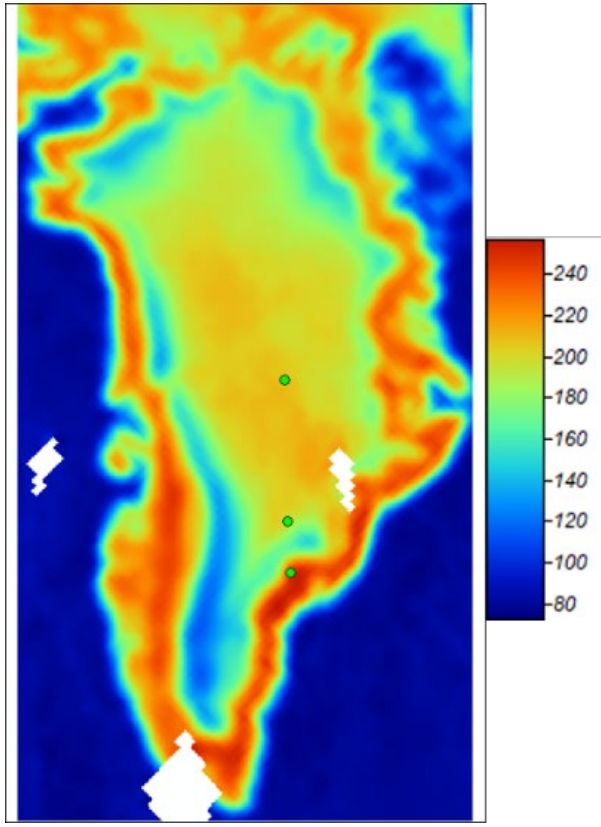
Primary goal

- Develop, test & implement algorithm for generating maps of surface melt extent from:
  - High-medium resolution C-band backscatter measurements (S1, ASCAT)
  - Low resolution PMW data (SMOS, SMAP, SSMIS, AMSR2)
  - Investigate possibility to use the developed methods in a synergistic way
- Value added products: onset & end date per year, melt duration, intensity (LWC)
- Validation of algorithm with in-situ meteorologic data

4DG partners : ENVEO, FMI, GEUS

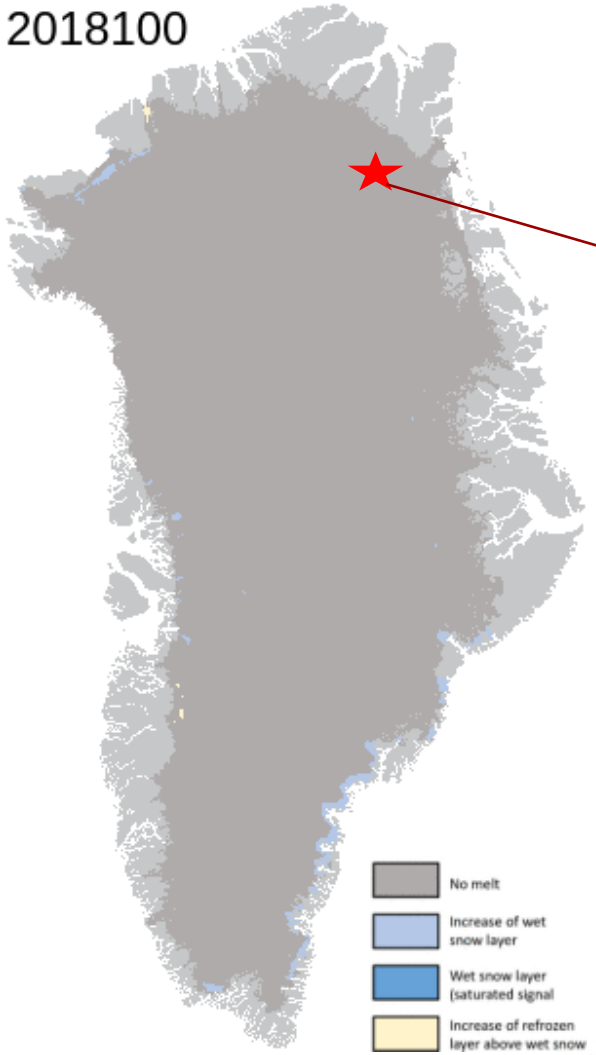


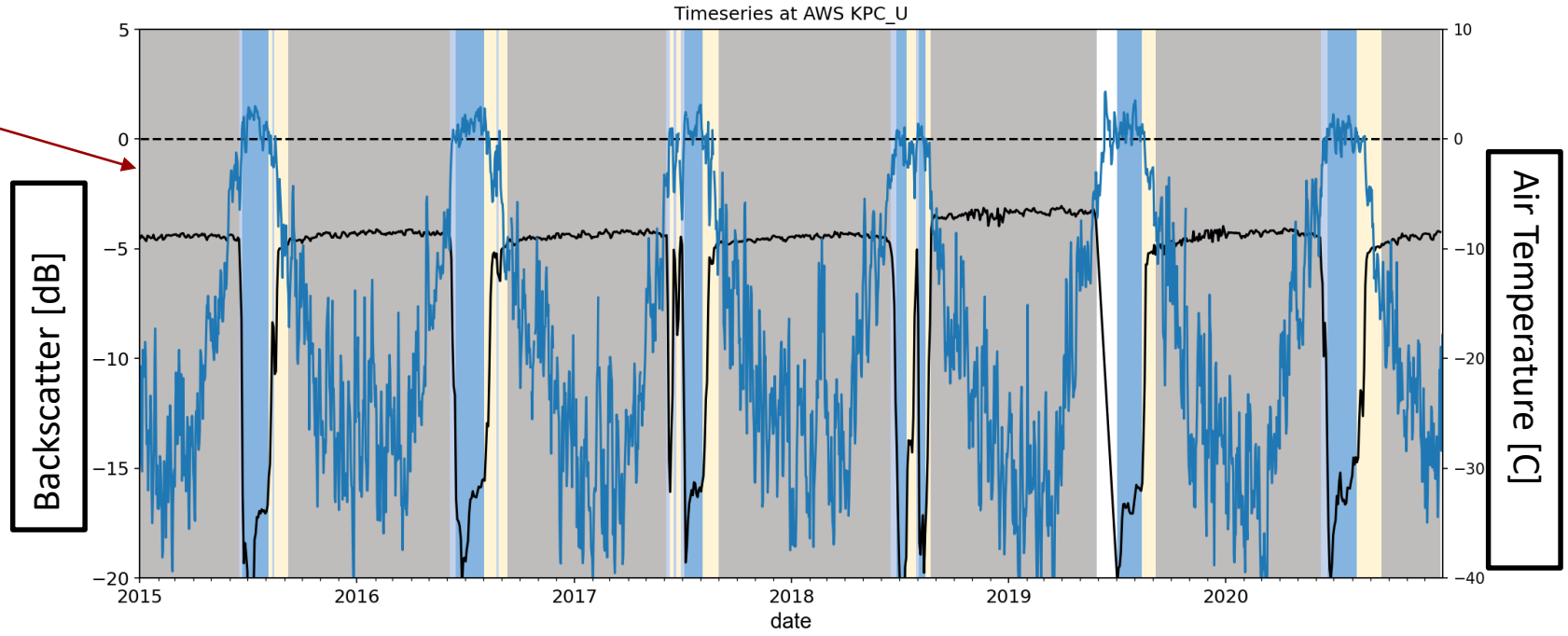
Sentinel-1



SMOS

Surface Melt Extent from SAR & PMW



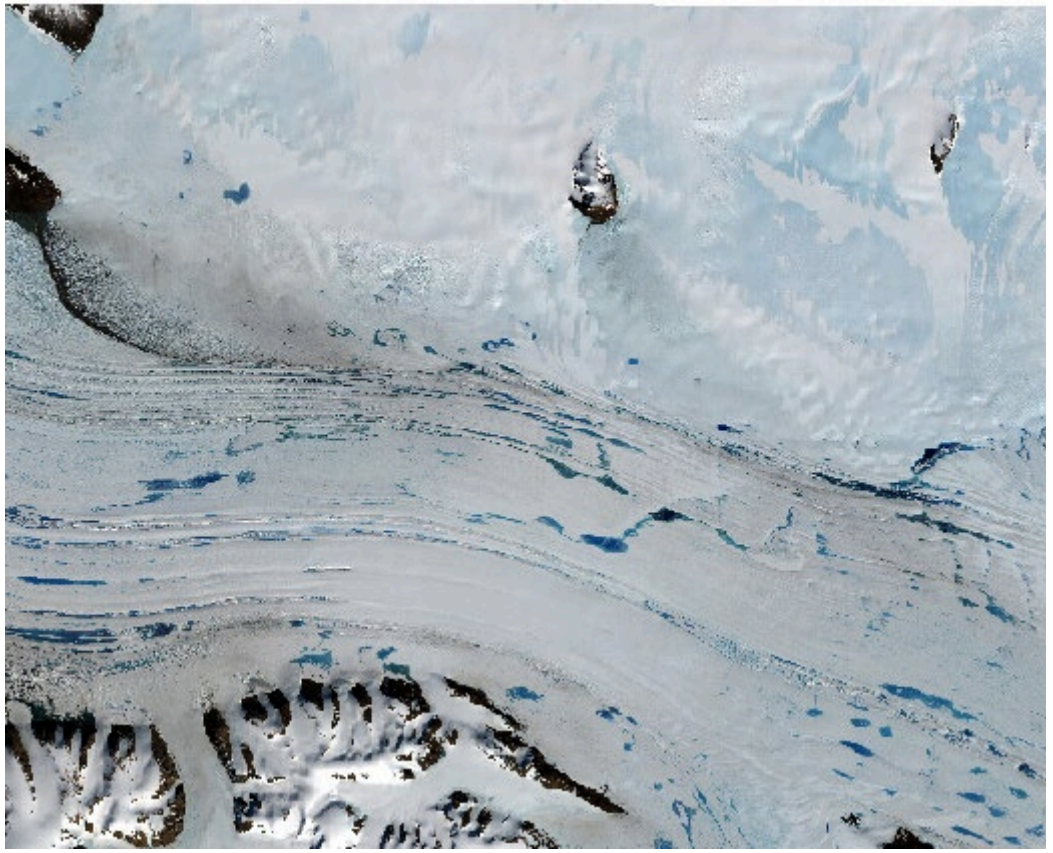


Method supported by backscatter modelling, identification of surface melt and surface refreezing (co&cross pol); combined with ASCAT backscatter maps; coordinated with 4D Antarctica

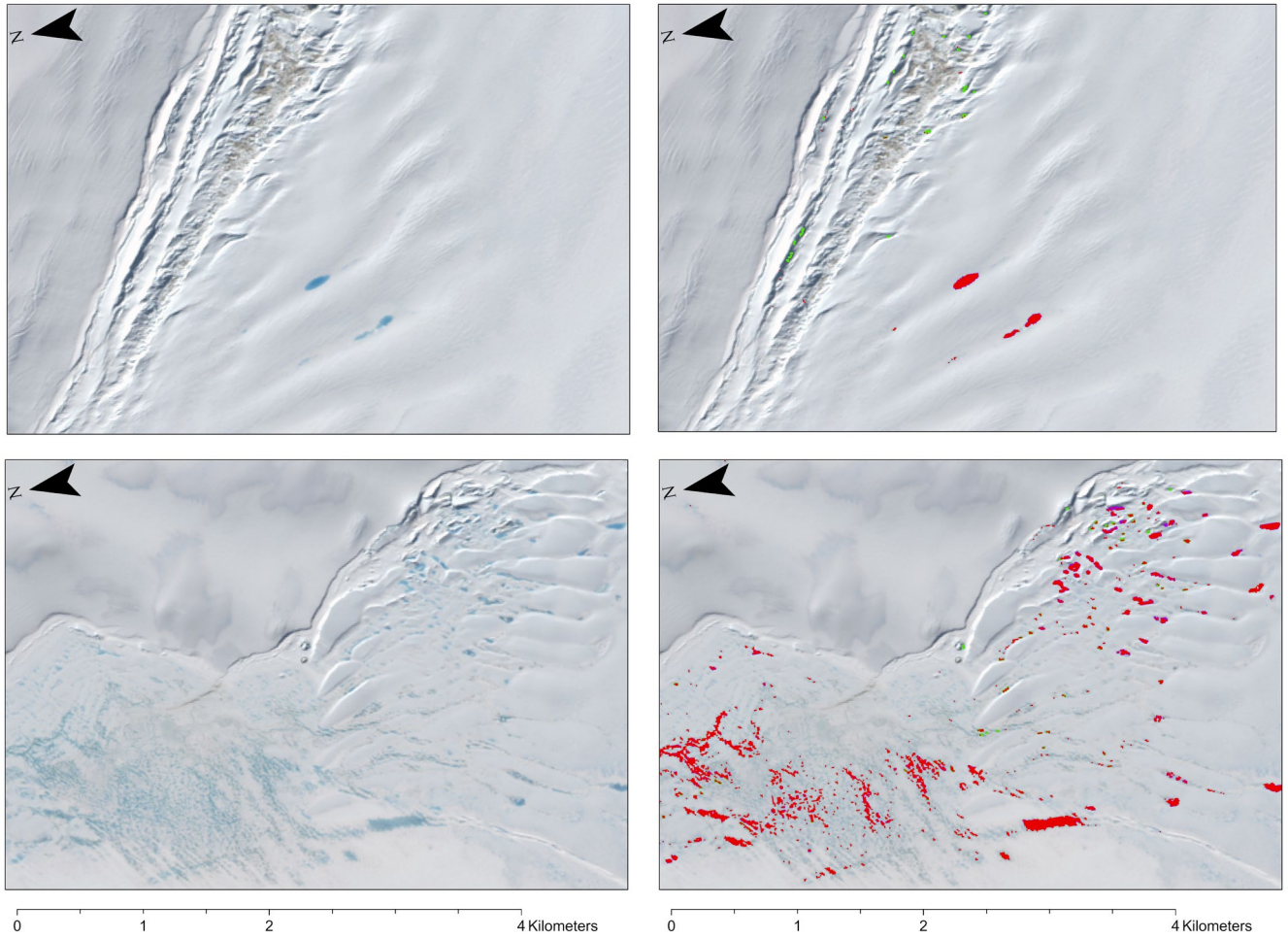
4DG partners : ENVEO, FMI, GEUS

Supraglacial activities

- Main activity: Use a Random Forest approach (Supervised Learning algorithm) to map supraglacial hydrological features ice sheet wide.
- Traditional methods (NDWI thresholding) require manual post-processing (MPP) to remove false positives from e.g. shadows and rocks
- Machine Learning Random Forest techniques reduces need for manual intervention.
- Goal: Produce results using Random Forest as accurately as NDWI+MPP without need for time consuming manual interventions.



Supraglacial activities



- Random forest Results Compared to NDWI.
- Highly accurate + run efficiently on large datasets, can be applied ice sheet wide.
- Multiple features contain spectral similarities to surface water can be classified separately: Rock, shaded pixels, sediment, blue ice, slush
- No need for manual post processing.

Amundsen Coast

RF Classification

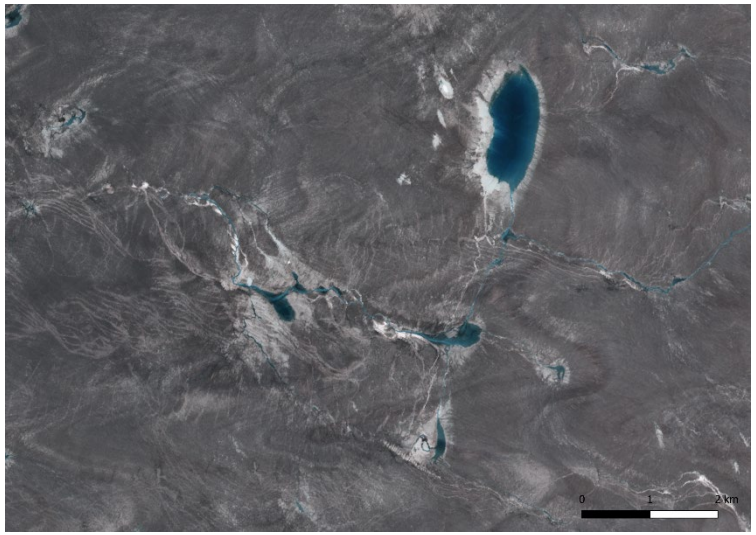
NDWI+ Classification

MPP NDWI+ Classification

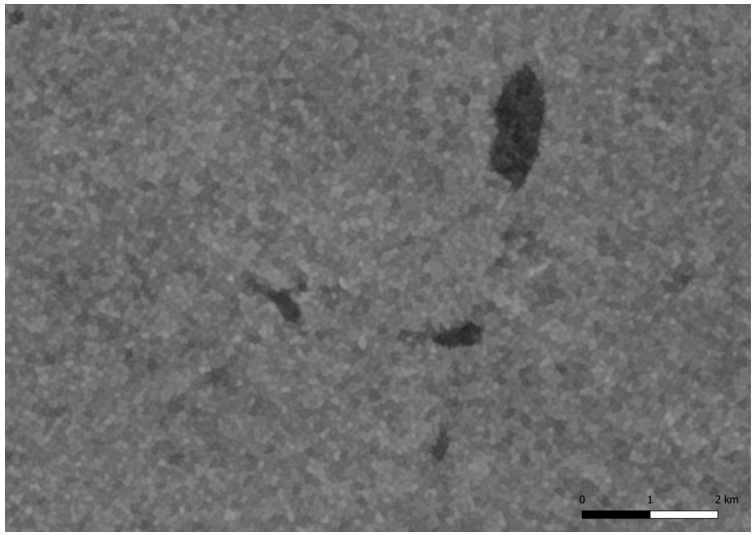
Supraglacial activities

Map supraglacial lakes from SAR imagery using a thresholding method.

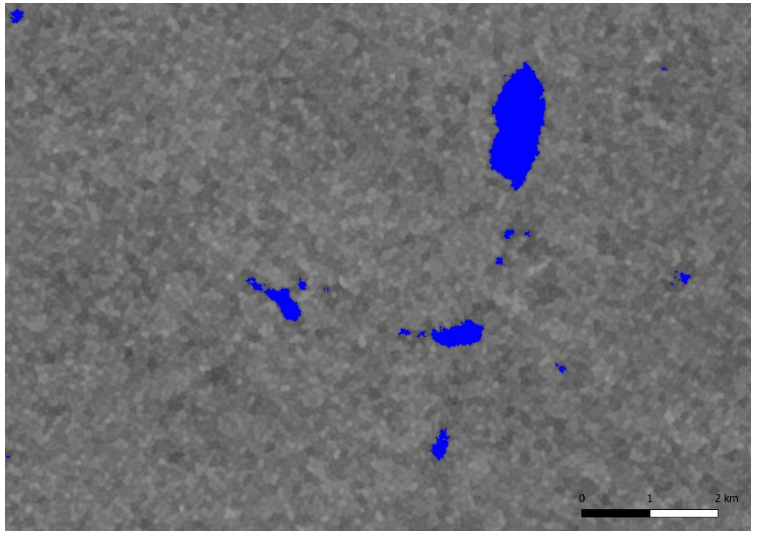
Proof-of-concept studying for mapping supraglacial lakes from Deep Learning methods using optical and SAR imagery.



Sentinel-2 optical image (Watson region Greenland)



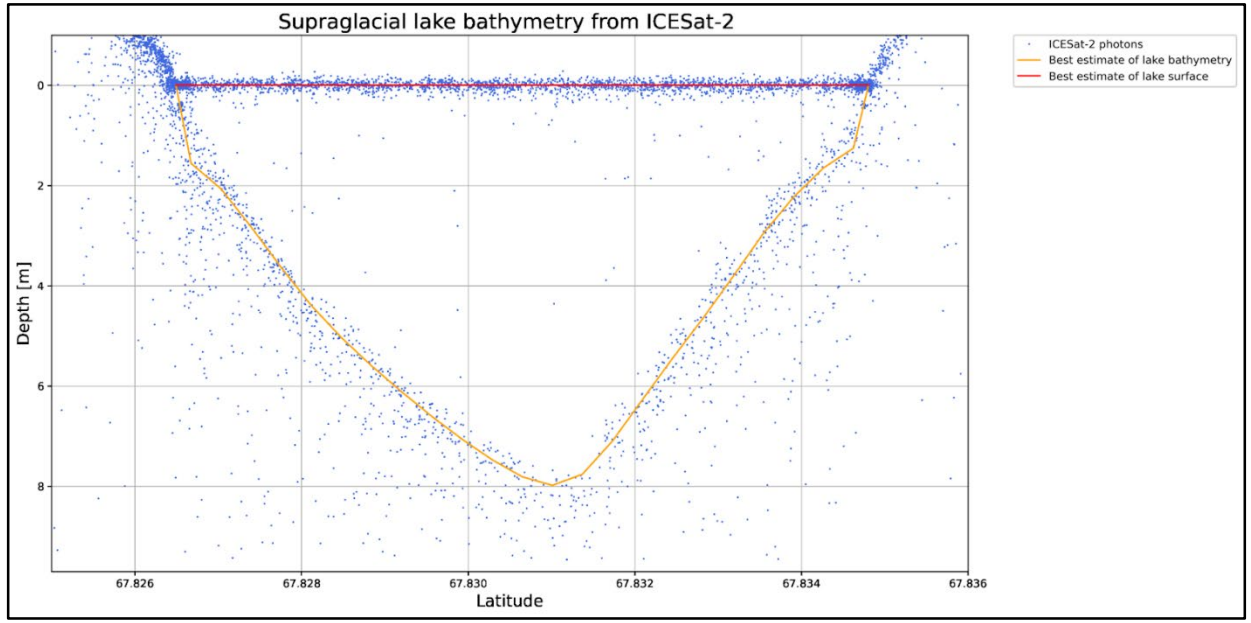
Sentinel-1 SAR image HV polarisation

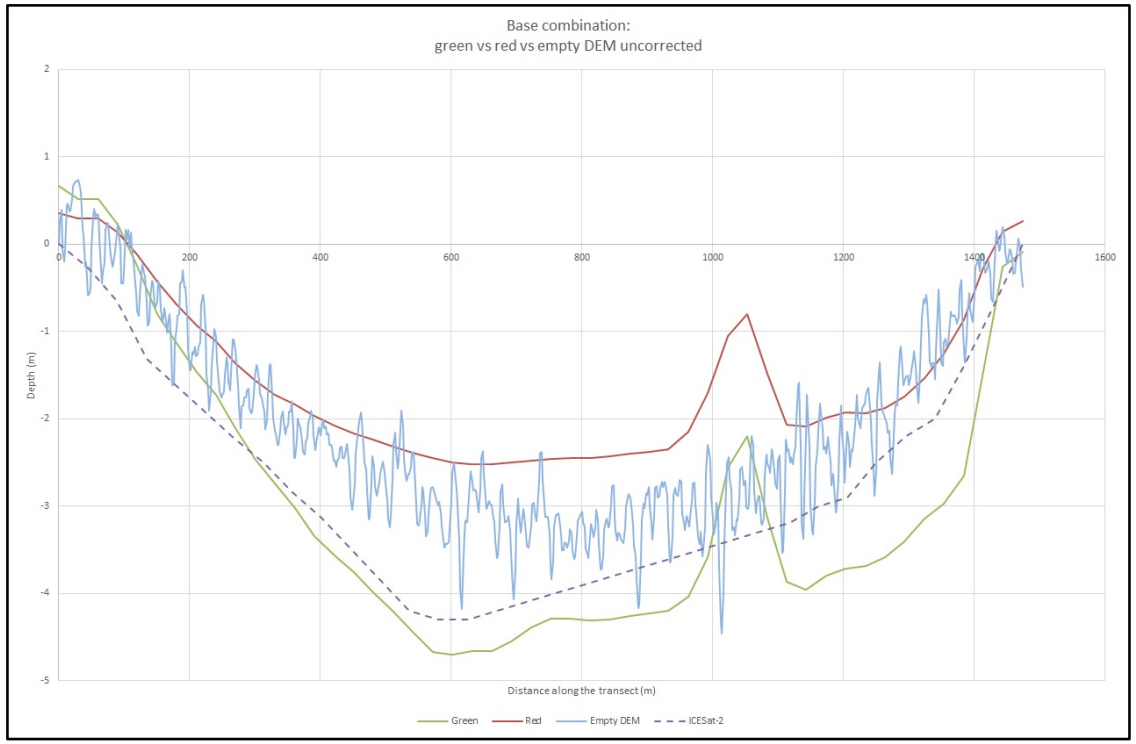


Sentinel-1 SAR lake/no lake threshold

Supraglacial activities

Using different approaches to map supraglacial lake bathymetry





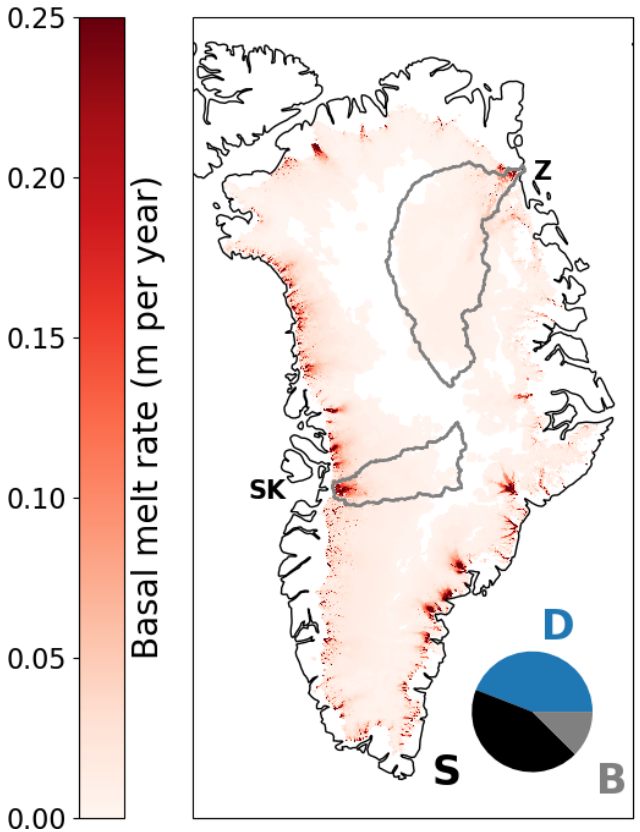
Basal Melt of the Greenland Ice Sheet

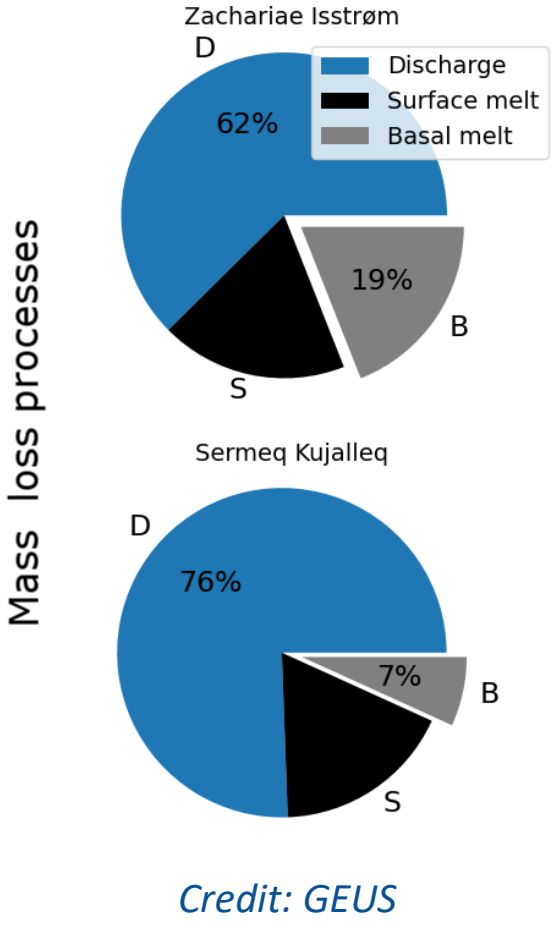
The basal melt of the ice sheet caused by geothermal, friction and viscous heat (see Karlsson et al., 2021, Nature Comm.).

We aim to compare the basal mass loss to other processes and assess its relative importance for different regions and outlet glaciers.

Right: Ice-sheet wide basal melt. Mass loss processes D (iceberg discharge), S (surface melt) and B (basal melt).

Pie plots show Zachariæ Isstrøm and Sermeq Kujalleq (Jakobshavn Ice Stream).

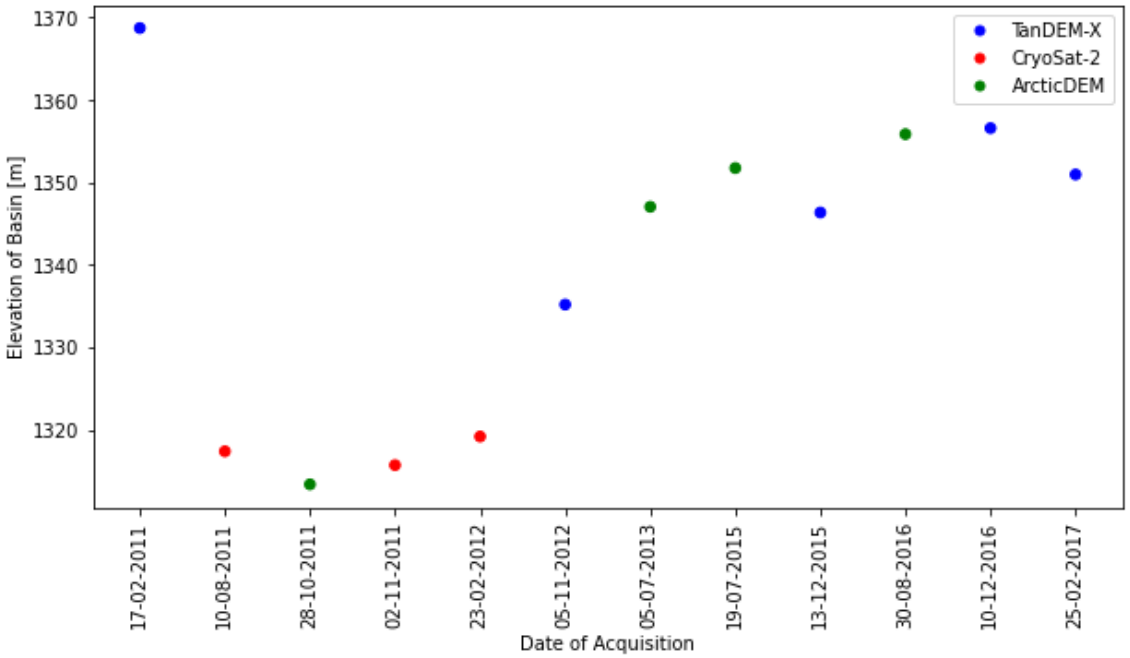




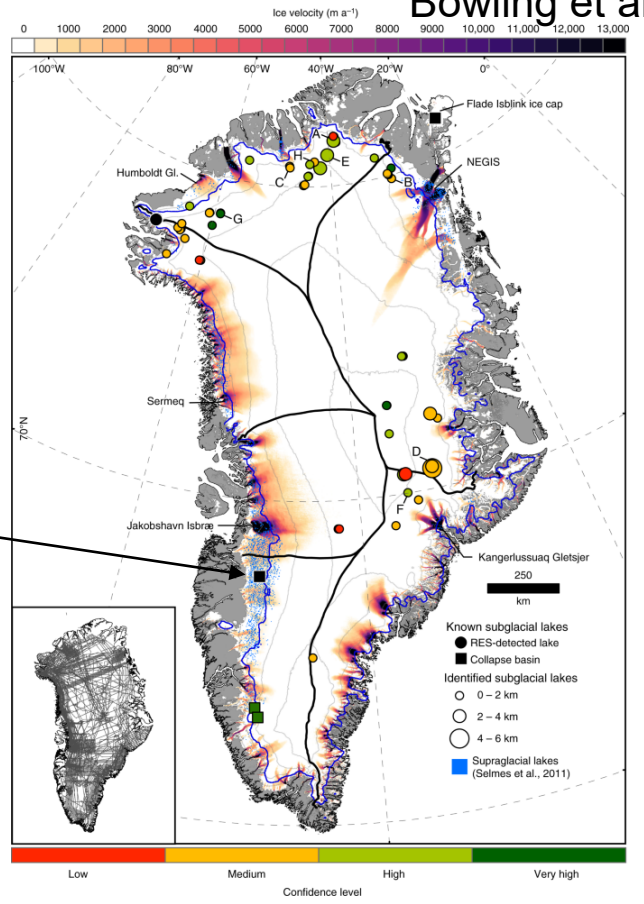
Credit: GEUS

Subglacial lakes

- Exploratory study to see if we can map subglacial lake activity in Greenland.
- CryoSat-2 swath processed data
- Tandem-X DEMs



Bowling et al., 2019



Subglacial lakes

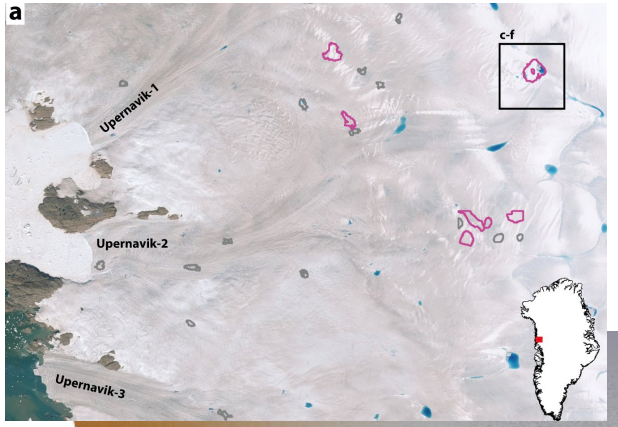
4DGreenland analysis limited to the three known active lake sites.

We know now of several other candidate sites – potential for exciting future work.

CS2 swath data together with Tandem-X DEMs provide additional information on the temporal behavior of the lakes.

CS2 swath processing limited dur to small size of lakes.


North Ice Cap
Wolstenholme Fjord


a
c-f
Upernavik-1
Upernavik-2
Upernavik-3

Recommendations for future work

- 4DGreenland will add to our understanding and quantification of the freshwater flux from Greenland to the Arctic Ocean.

Would be obvious in future work to join forces with other scientific communities (river discharge, sea ice, modellers) to investigate the freshwater budget of the Arctic Ocean. Such a goal requires a large and diverse partner consortium. Potential for really ground breaking results.

- It is important to ensure future funding for exploratory studies and not just product-oriented projects. In 4DGreenland we have a small exploratory study on the possibilities of mapping subglacial lake activity in Greenland, which shows exciting results.

- Therefore, we also find it interesting and achievable to build an observing system for subglacial lakes in Greenland.

- Several data products from 4DGreenland could be made operational in other projects such as e.g. CCI+ or C3S.

Thank you for the attention.

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