The 4DGreenland project

Quantifying Greenland ice sheet hydrology components from remote sensing

Louise Sandberg Sørensen & the 4DGreenland team

4DGreenland

About the 4DGreenland project

- Funded by ESA through the POLAR+ programme, Theme 2.
- The project runs Sept 2020- Sept 2022. Nine partners.

Objectives:

- Generate novel Earth Observation-derived 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.

The 4DGreenland team

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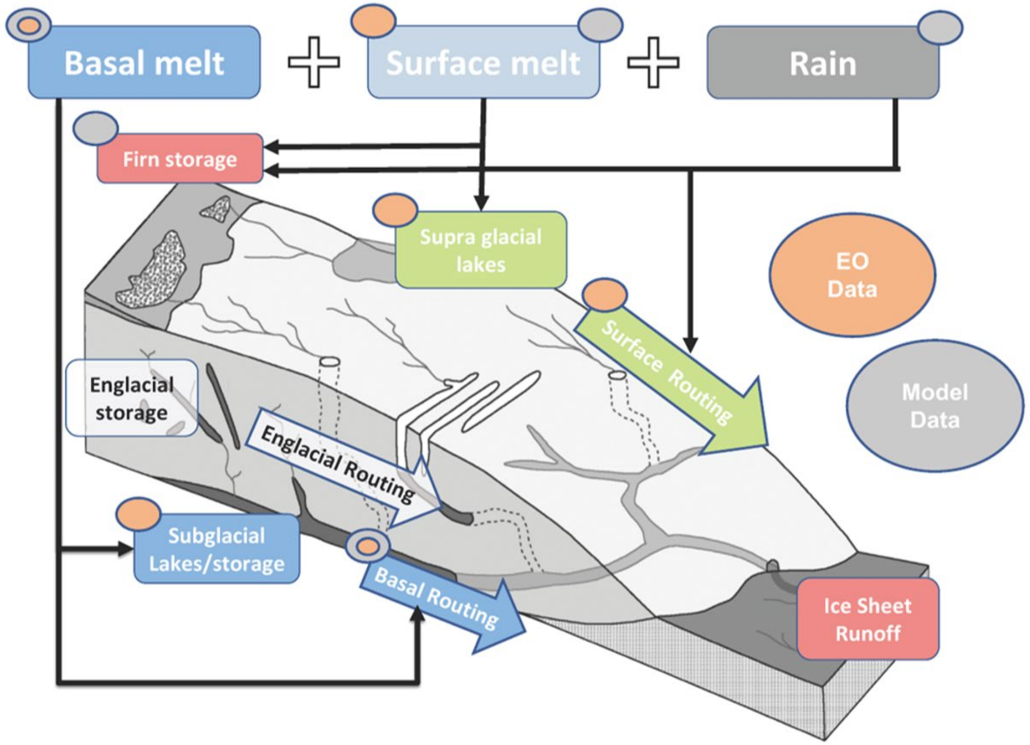
Shepherd SPACE ltd	Andrew Shepherd

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)

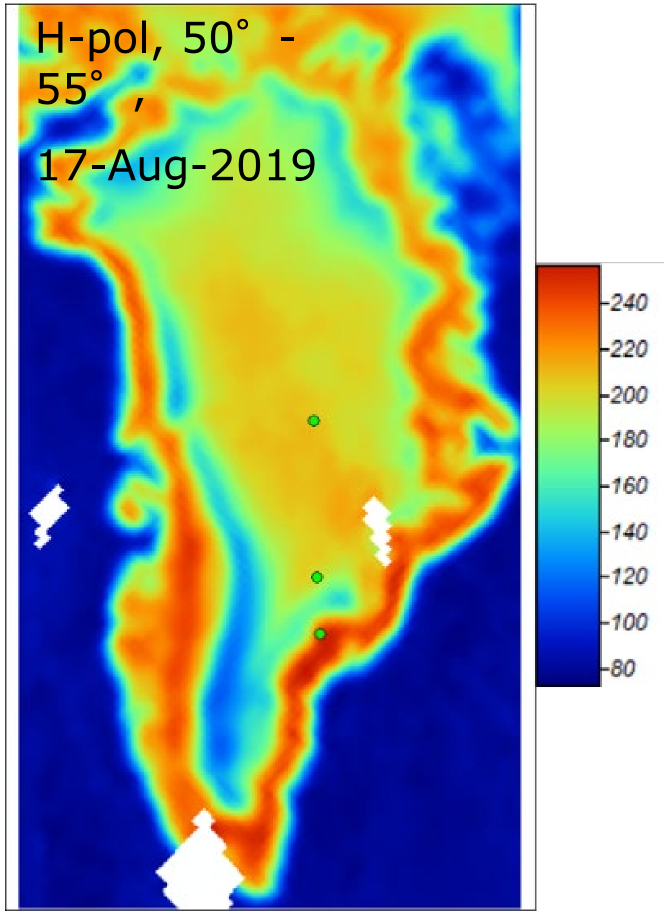
Surface Melt Retrieval from Active & Passive MW

Primary goal

- Develop, test & implement algorithm for generating maps of surface melt extent and melt phase from:
  - High to medium resolution C-band backscatter measurements (S1, ASCAT)
  - Lower 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, melt stage
- Assessment of algorithms with in-situ meteorologic data (AWS) and Regional Climate Models (RCMs)

Sentinel-1 TOPS IW

SMOS



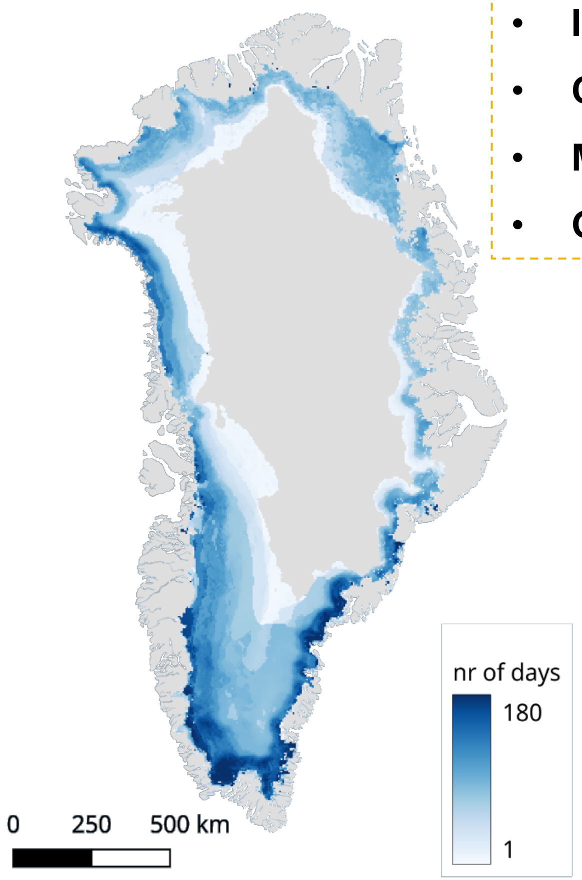
Surface Melt Retrieval from Active & Passive MW

- **Identification of surface melt and refreezing by ASCAT**
- **Combined with Sentinel-1 backscatter maps (co&cross pol)**
- **Method supported by backscatter modelling**
- **Good agreement with RCMs and AWS data**

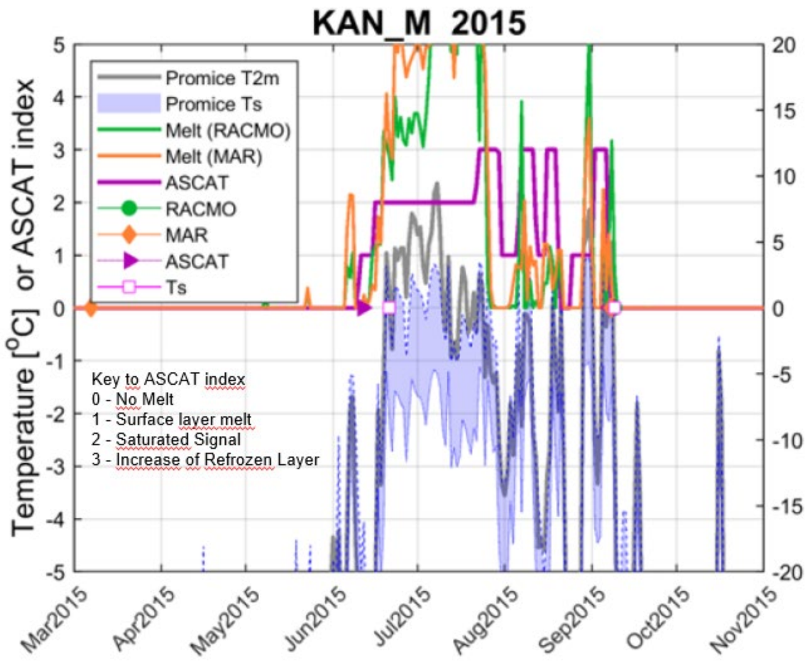
ASCAT data:

SIR product BYU - MERS

Daily 5-km ASCAT* melt maps 2012



Melt Duration 2020



AWS/RCM Intercomparison

#LPS22 POSTER Wuite et al.: 63768 - Monitoring of Surface Melt Processes in Greenland and Antarctica using Sentinel-1 SAR and Metop ASCAT backscatter time series – ON DISPLAY: Thursday 26th May

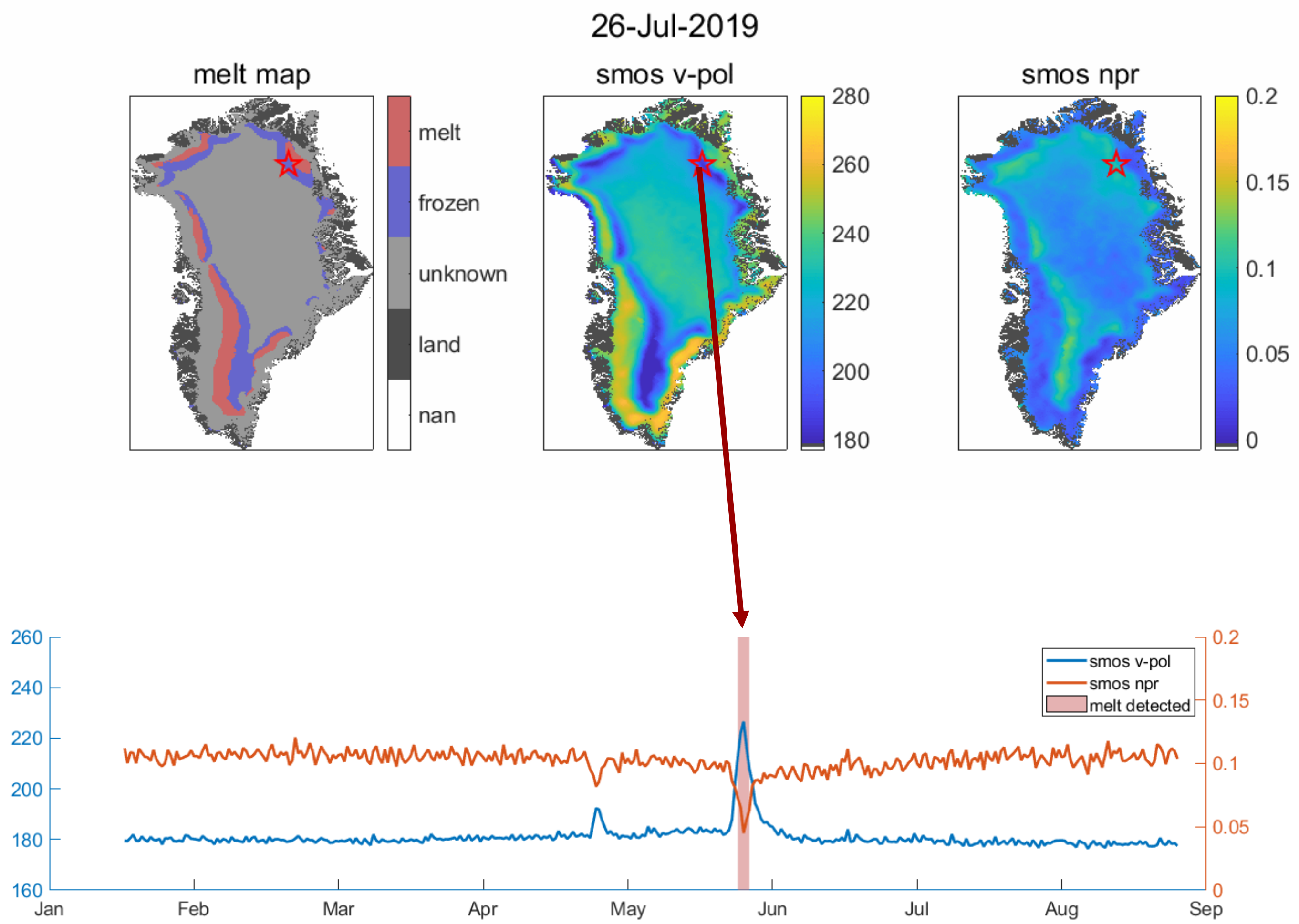
Surface Melt Retrieval from Active & Passive MW

<u>L-band PWM melt detection to support high resolution SAR method</u>

- L-band – different response to the melt event, potential information from deeper layers. Less sensitive to structural changes after re-freeze.
- Brightness temperature and NPR signals for melt detection

$$NPR = \frac{T_{b,V} - T_{b,H}}{T_{b,V} + T_{b,H}}$$

- Method developed originally for SMAP (Mousavi et al., 2021) - sigma above winter mean.



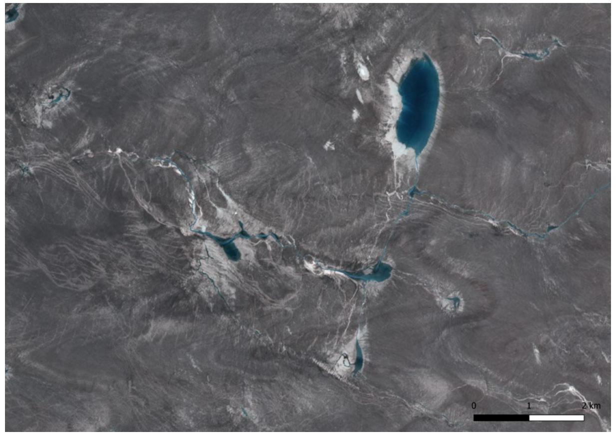
Melt detection using SMOS Level 3TB, 2019

Supraglacial storage and drainage

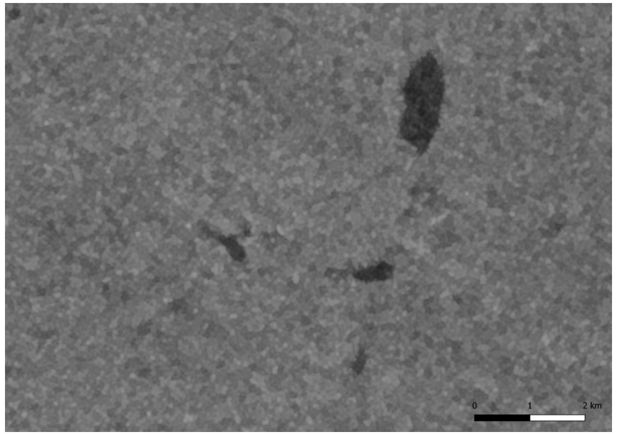
Proof-of-concept studies within this work package include:

Exploring SAR imagery to map supraglacial lakes using dynamic thresholding and deep learning methods.

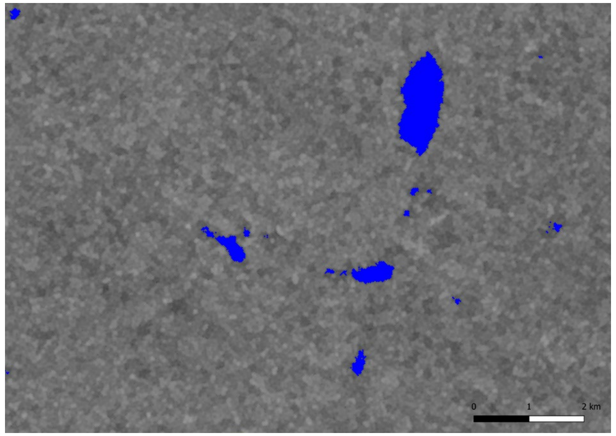
- SAR imagery is advantageous compared to optical datasets for two main reasons: 1) SAR is not limited by cloud cover unlike optical datasets; and 2) it is possible to monitor supraglacial lakes through winter with SAR.
- The proof-of-concept study has shown large lakes are detected and delineated with accuracy from SAR but small channels (<50 m wide) were not identified. There is an opportunity for further method development to ensure methods are mature enough to roll out over large (ice sheet basin) spatial scales.



Sentinel-2 optical image 25th July 2019



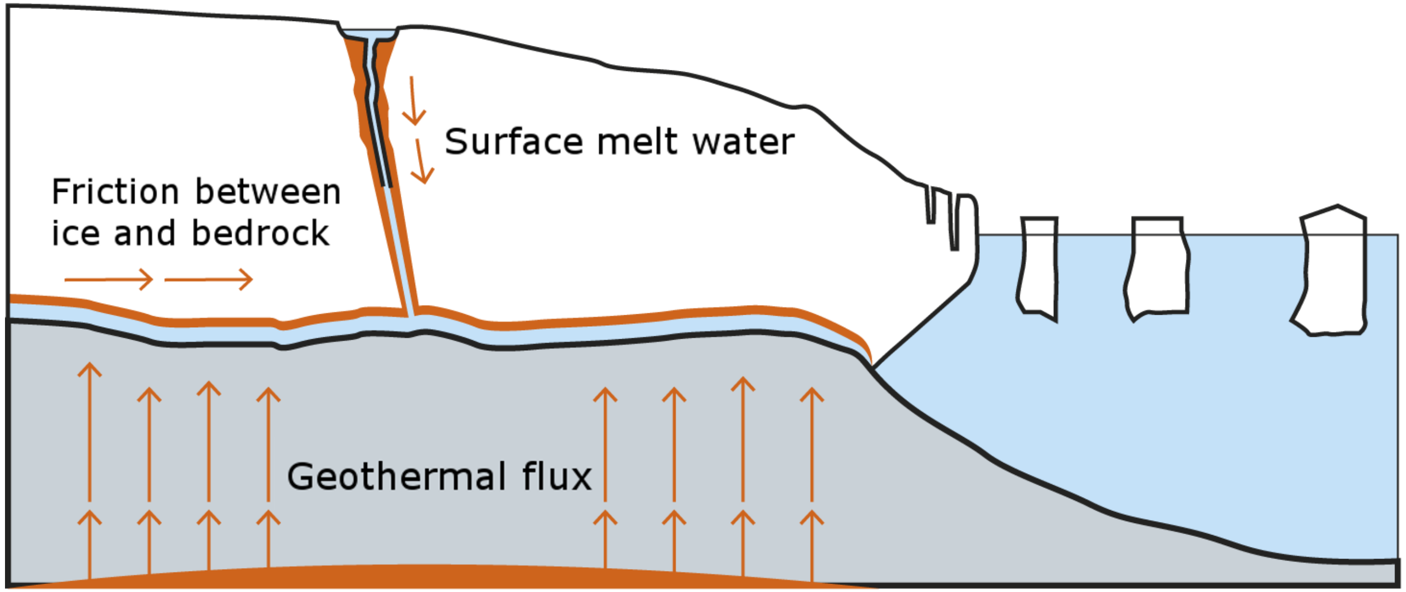
Sentinel-1 SAR image HV polarisation



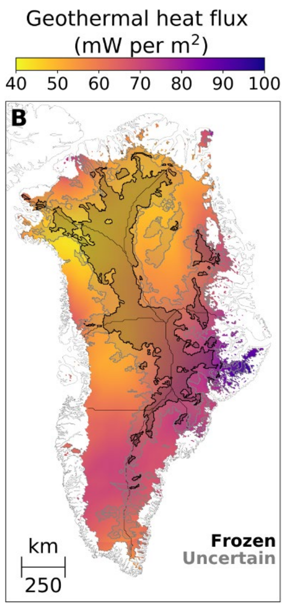
Lake/no lake classification derived from dynamic threshold overlay on SAR image.

Subglacial melt

- Melt at the bed is very difficult to measure directly.
- Melt is generated by three heat sources:
  - Geothermal flux
  - Friction between ice and bedrock
  - Heat from surface melt water



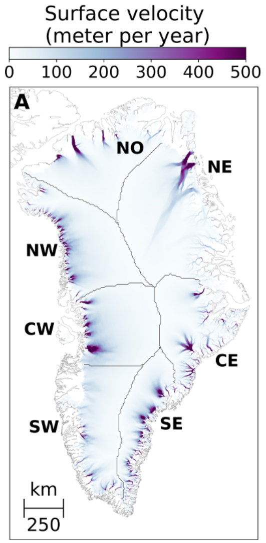
Subglacial melt



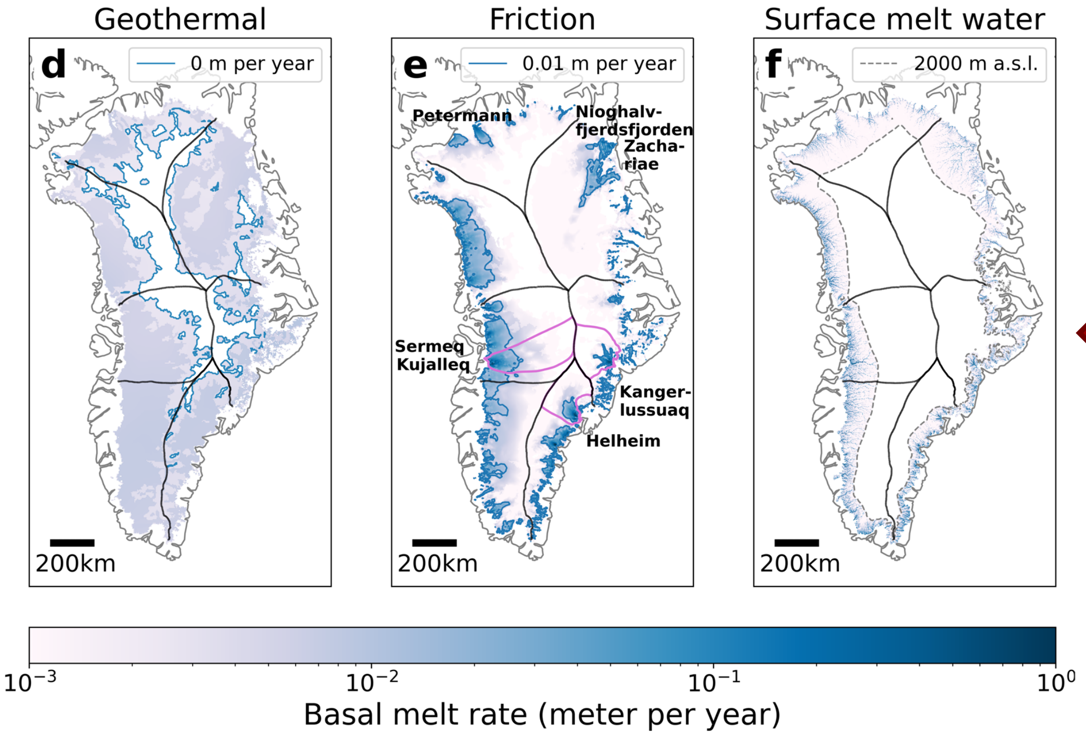
Geothermal flux:

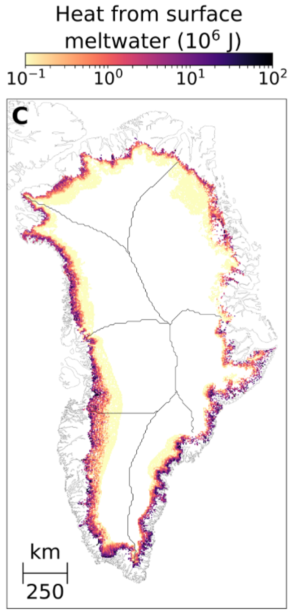
The average of three heat maps:

Shapiro & Ritzwoller (2014), Fox Maule et al. (2009) and Martos et al. (2018)



Elmer/Ice model (Gillet-Chaulet et al., 2012) tuned to assimilate observed surface velocities produces an estimate of friction heat.

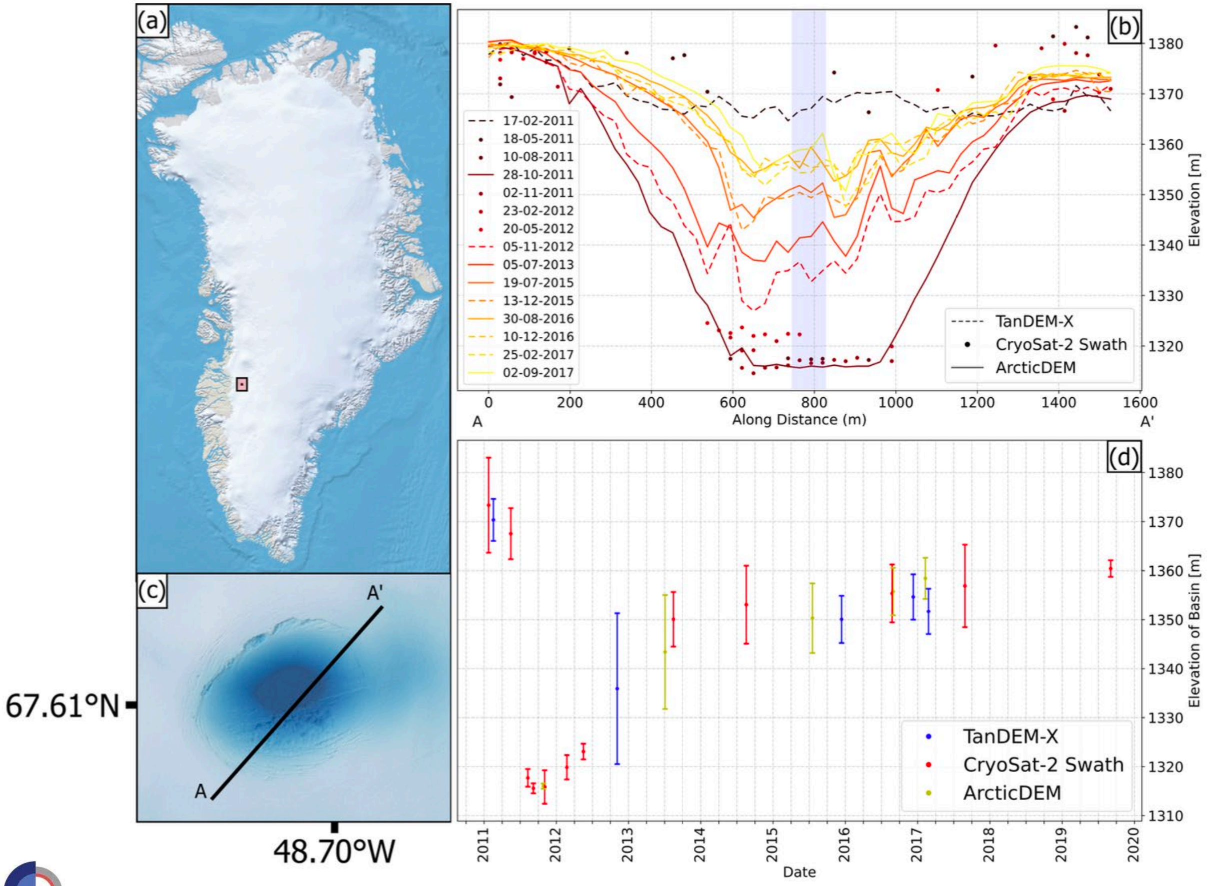




Viscous heat from surface meltwater (Mankoff et al., 2017; 2020) is routed through the subglacial system.

Active Subglaciale lakes

- Goal: Better constrain subglacial lake activity by CryoSat-2 swath processed data and TanDEM-X DEMs.



Four collapse basins found in Greenland are associated with drainage of subglacial lakes (Bowling et al., 2019).

The addition of CryoSat-2 and TanDEM-X data helps to constrain the discharge event and the re-filling rate

Melt retention in the firn

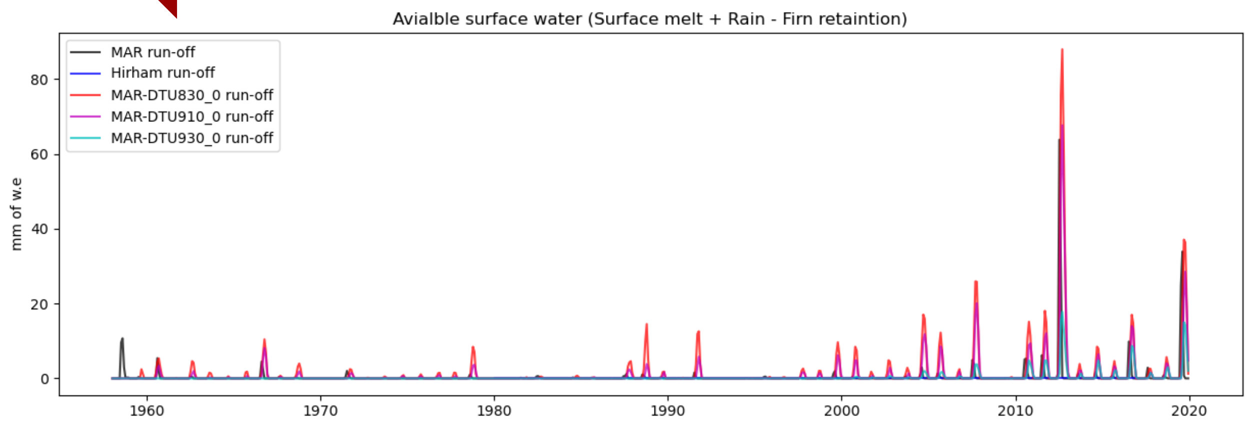
The improved DTU-firn model now provides updated estimates of meltwater retention and delayed.

Results depend on RCM used and percolation limit assumptions.

Run-off for the Watson area in time:

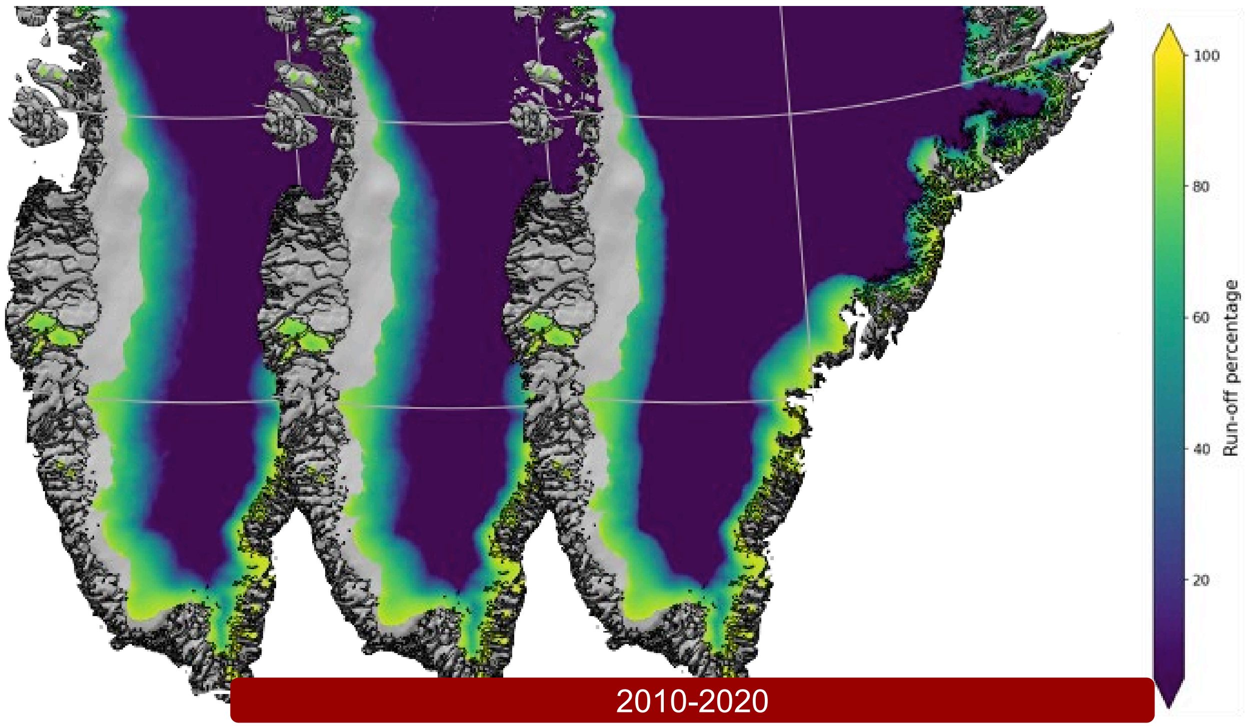
HIRHAM : 0.0% MAR: 2.5%

DTU_{830} : 9.0% DTU_{910} : 6.0% DTU_{930} : 1.8%

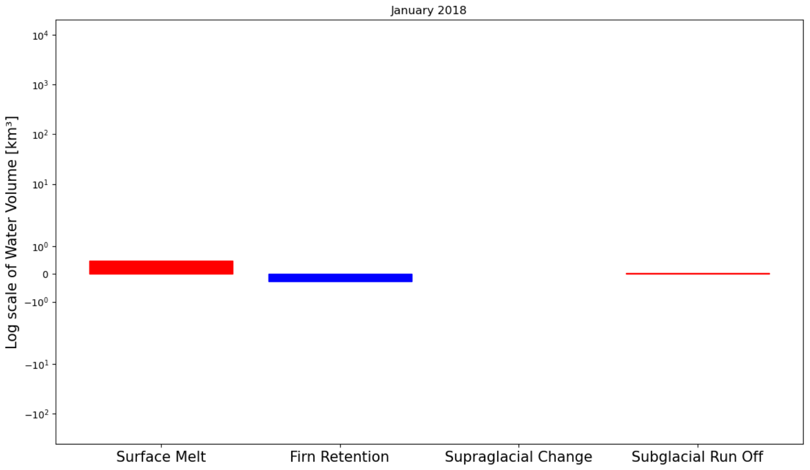


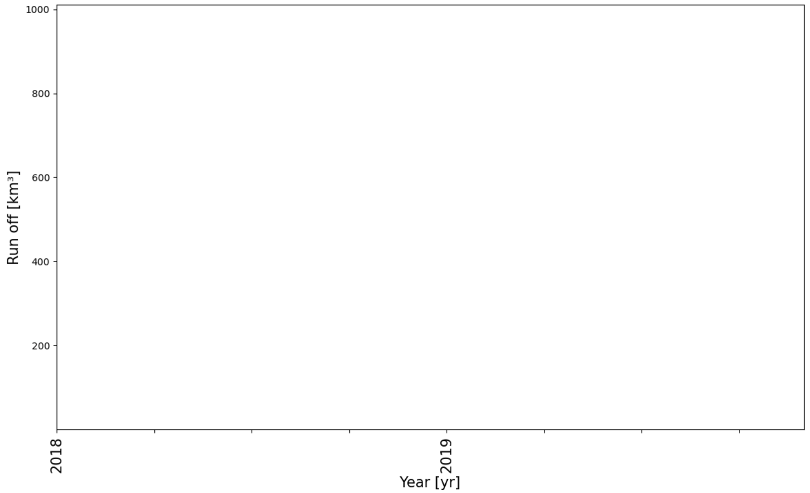
Percolation limit

830 kg/m³ 910 kg/m³ > 917 kg/m³

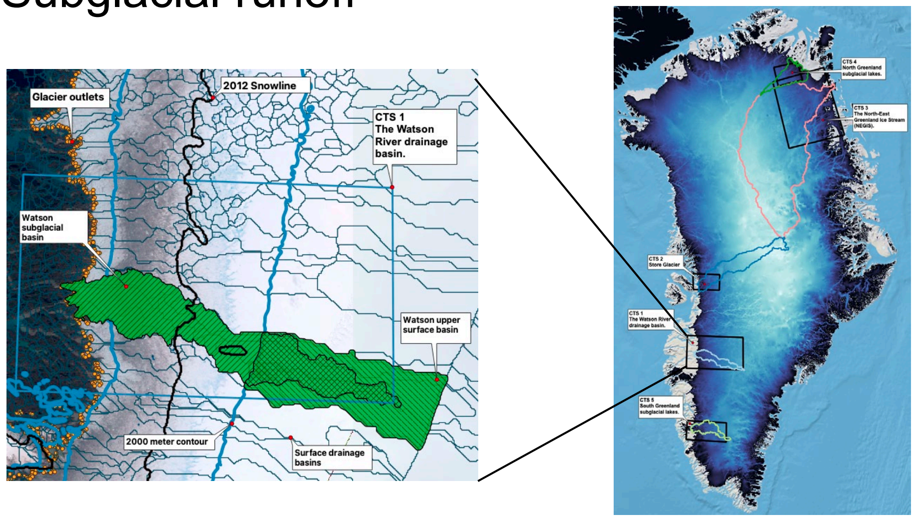


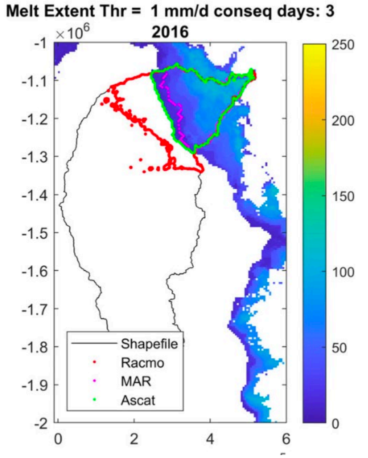
Integrated assessment



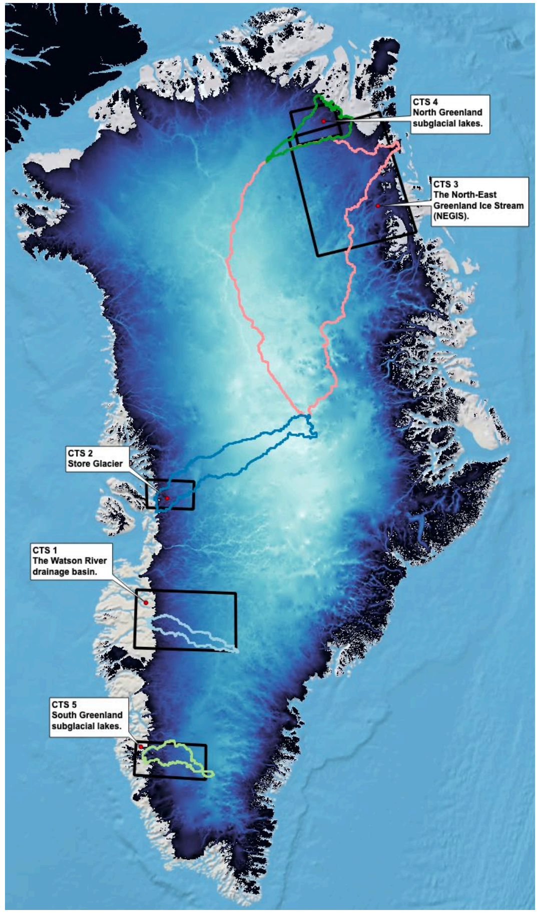


- As a first attempt to make an integrated assessment we have focused on the Watson drainage basin in West Greenland 2018-2019.
- Combining all products to estimate monthly runoff:
  - ➢Surface melt volume
  - ➢Melt retained in the snow
  - ➢Change in the meltwater volume in supraglacial lakes
  - ➢Subglacial runoff





Experimental datasets



In June our experimental datasets will be made available.
They are provided for our four test regions.
Final data products ready by end of project (September 2022)

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Thank you for the attention.

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