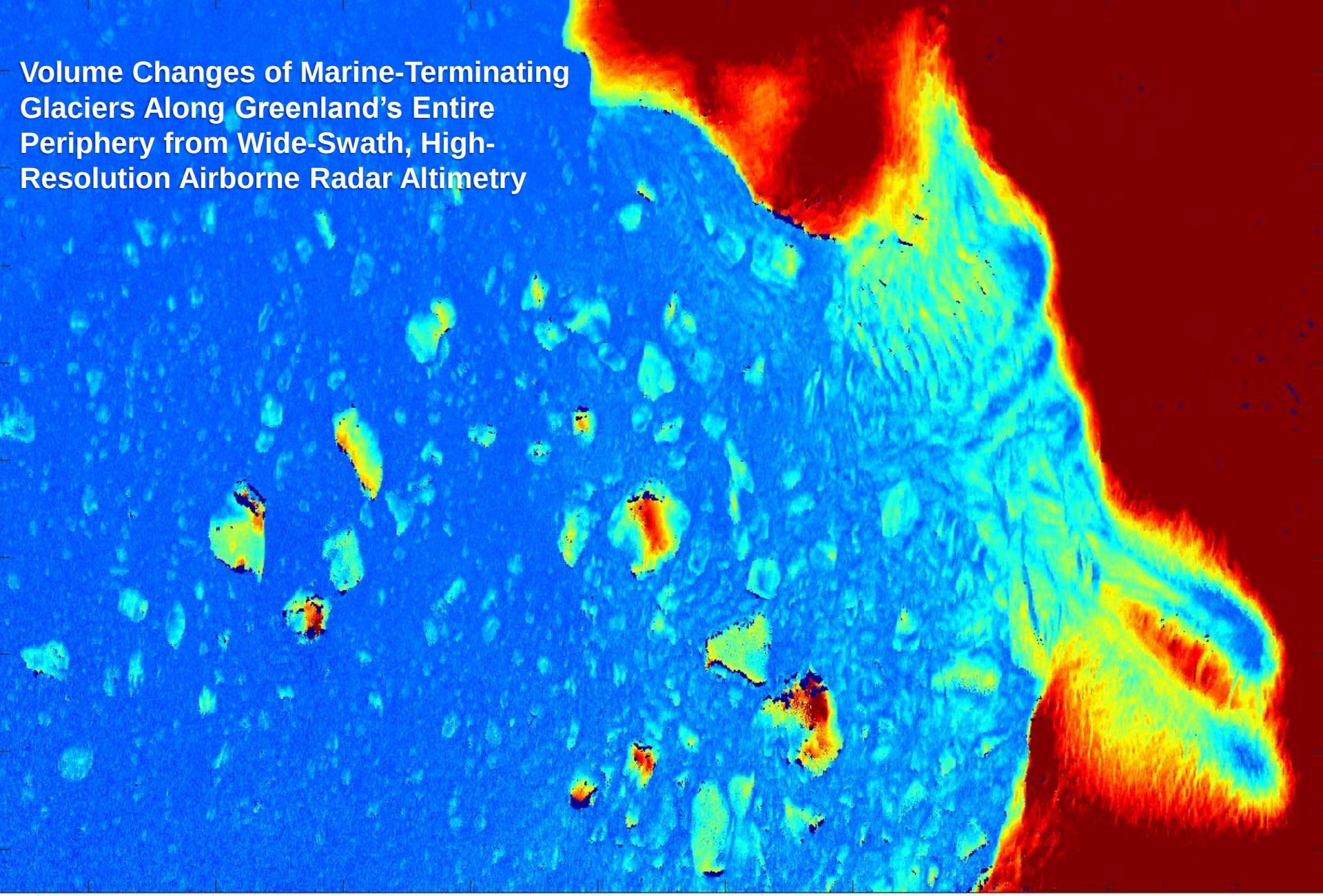
Volume Changes of Marine-Terminating Glaciers Along Greenland's Entire Periphery from Wide-Swath, High-Resolution Airborne Radar Altimetry



Ala Khazendar[1] Ian Fenty[1] Josh Willis[1] Delwyn Moller[2] Eric Rignot[1,3] Alex Gardner[1]

[1]Jet Propulsion Laboratory, California Institute of Technology [2]Remote Sensing Solutions [3]UC Irvine

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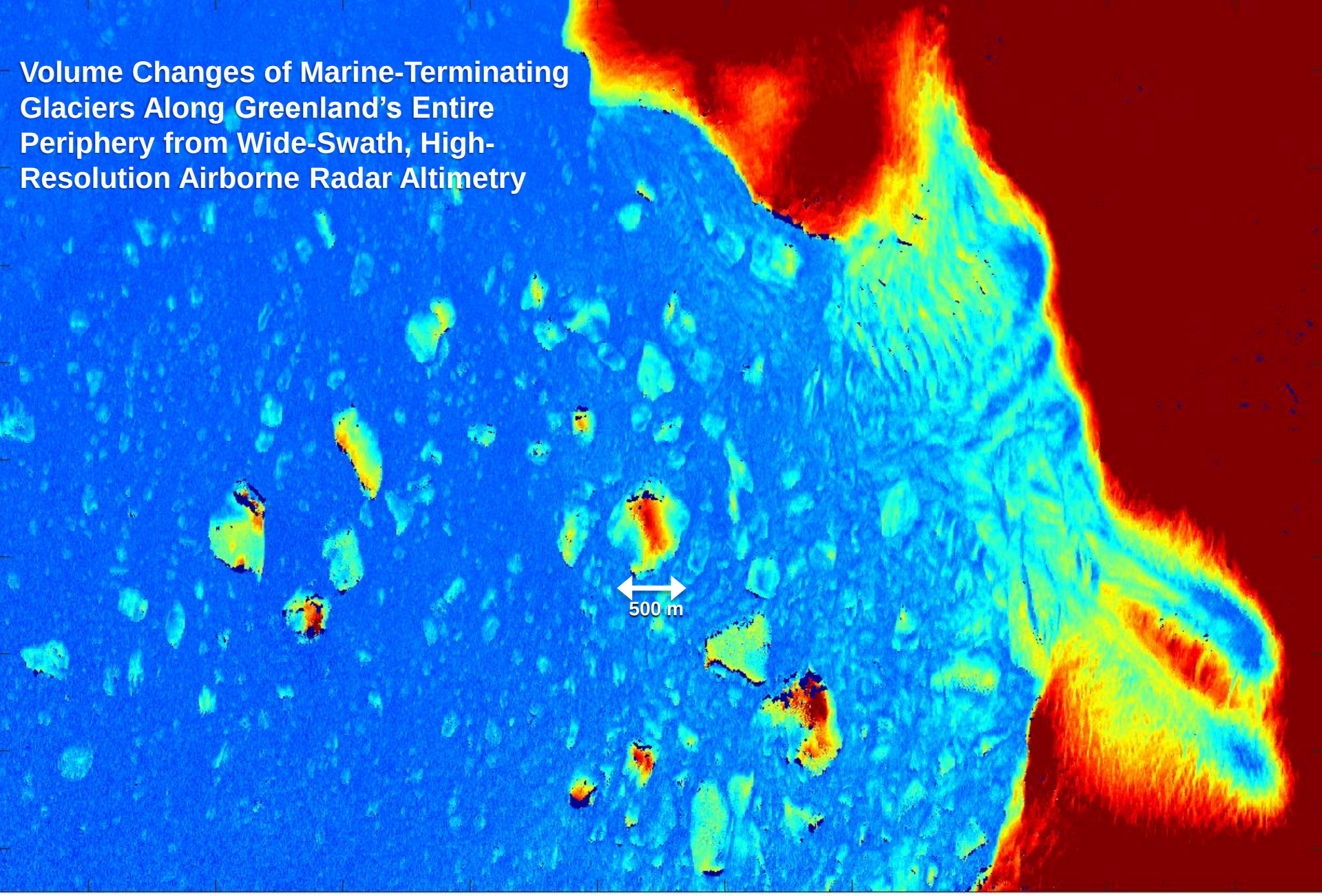
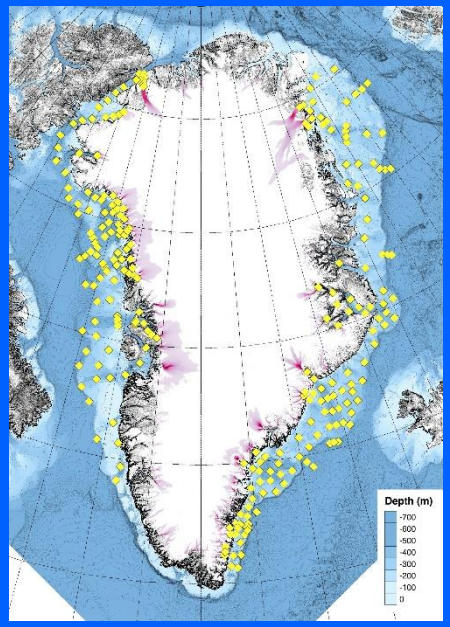


OMG: Mission Components

Ocean campaigns

CTD

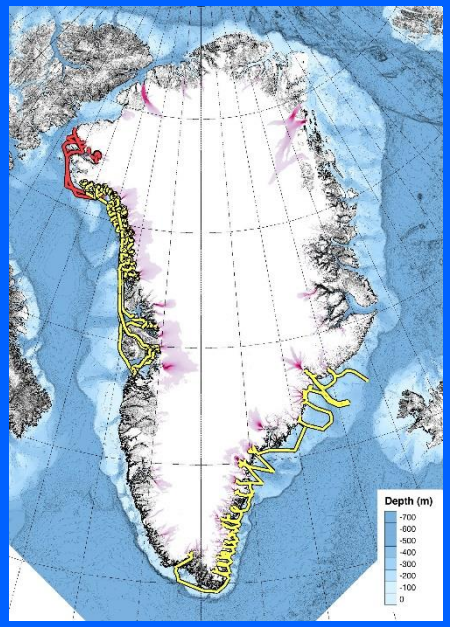
Airborne eXpendable Conductivity, Temperature and Depth (AXCTD)



in situ temperature and salinity from ~250 CTD probes deployed mainly on the Greenland shelf.

Bathymetry

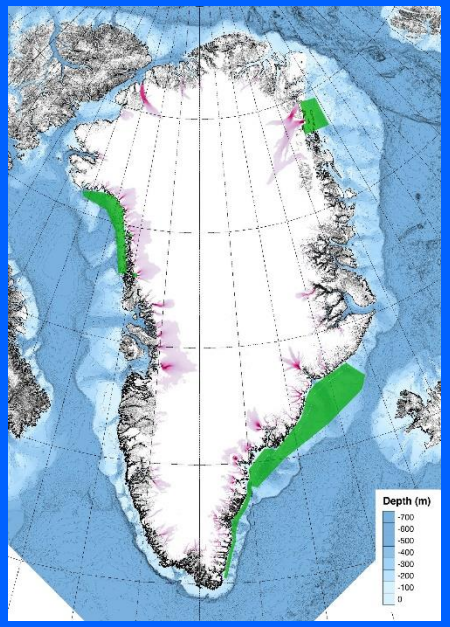
Multibeam + singlebeam echo sounders



Bathymetry from sonar.

Horizontal res: 25 m, vertical precision < 1 m.

Airborne gravimetery

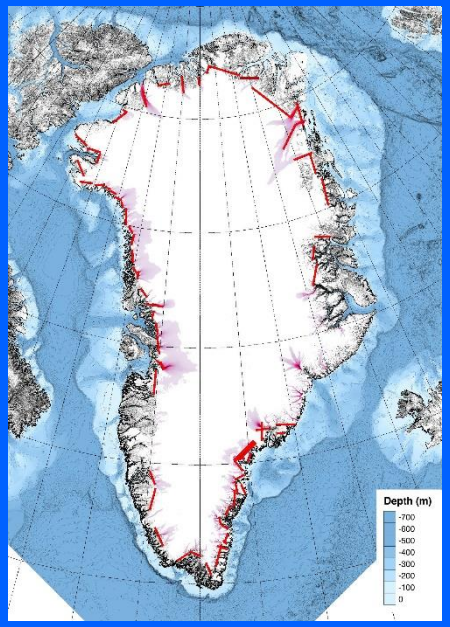


Bathymetry from gravity anomalies.

Horizontal res: 1.5 km, vertical precision of ~ 100 m.

Glacier campaign

GLacier and Ice Surface Topography INterferometer (GLISTIN-A)



Glacier elevation in a 10 km swath from radar.

Horizontal res: 3 m, vertical precision < 0.5 m.

OMG: Mission Components

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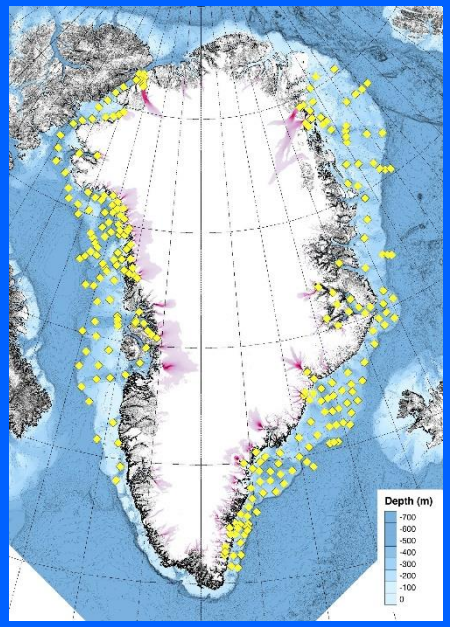

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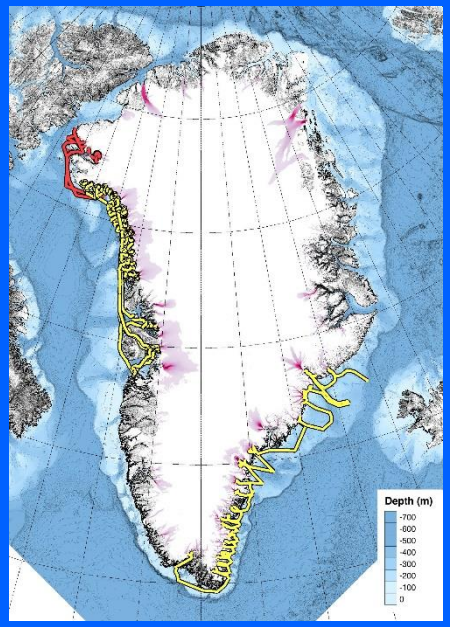
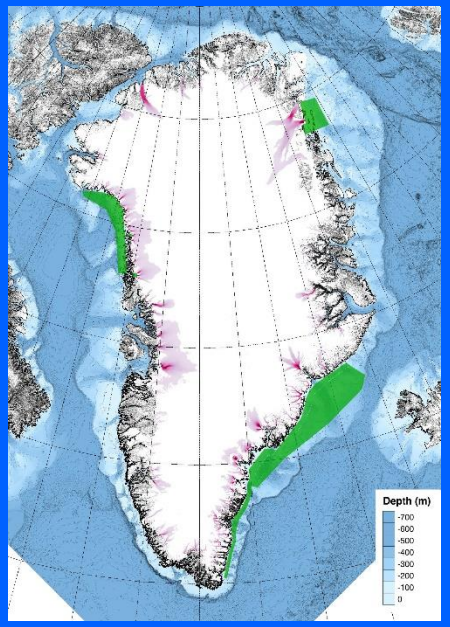


Bathymetry from sonar.

Horizontal res: 25 m, vertical precision < 1 m.

Airborne gravimetery



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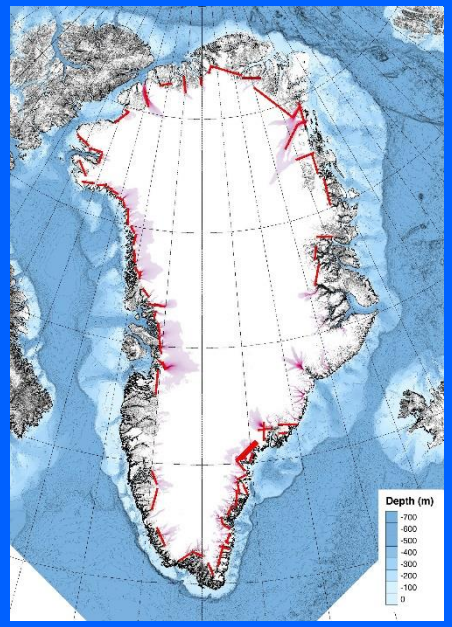


Glacier elevation in a 10 km swath from radar.

Horizontal res: 3 m, vertical precision < 0.5 m.

GLISTIN-A

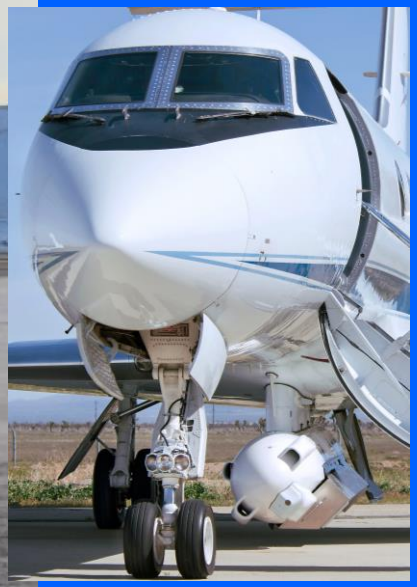
Radar is Ka-band (35 GHz; 8.5-mm wavelength) single pass interferometer (25-cm baseline length), flown on NASA's Gulfstream III aircraft, designed to measure ice topography.

Swath width: 10 – 12 km

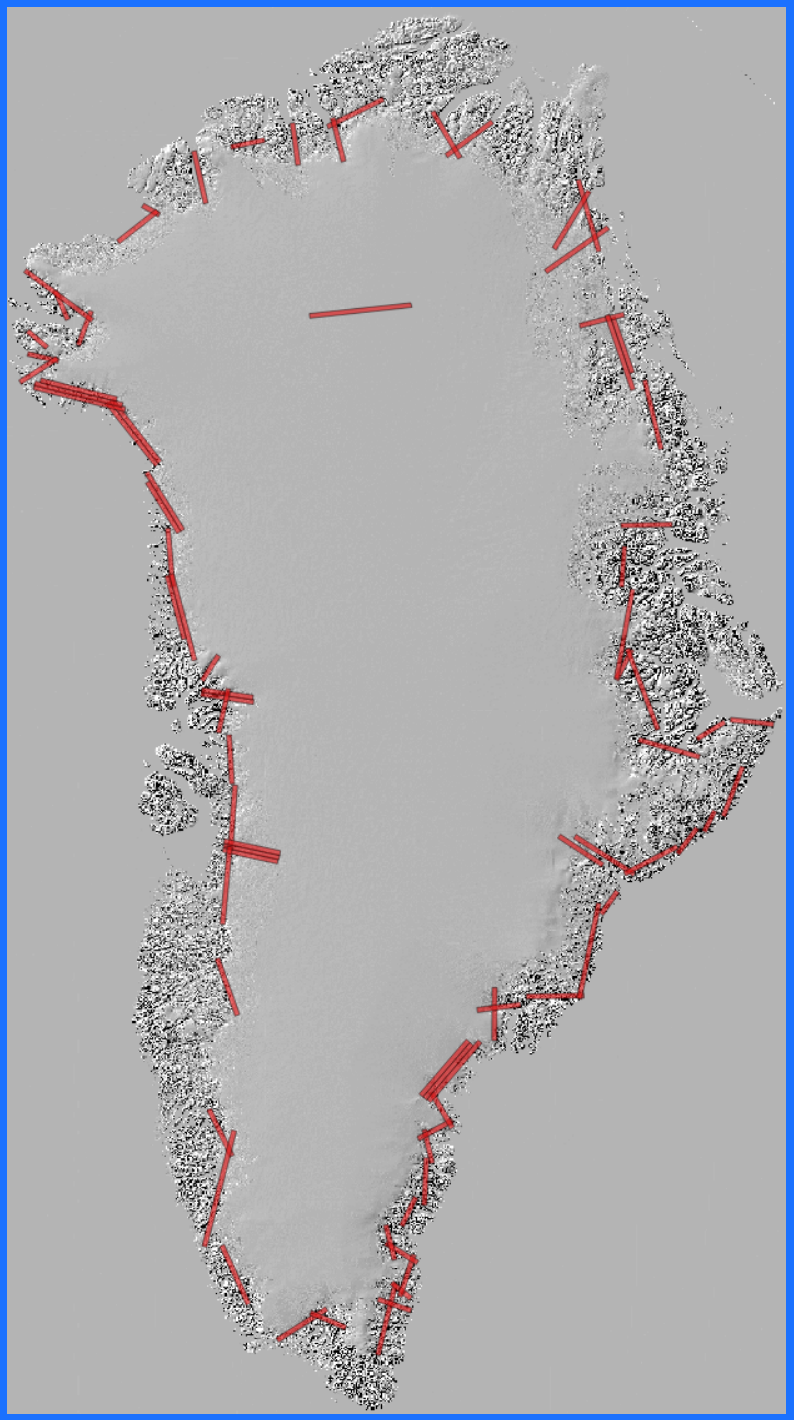
(*Moller et al.*, 2011; *Hensley et al.*, 2016)

NASA engineers installing the GLISTIN-A instrument on the Gulfstream-III aircraft at Armstrong Flight Research Center in March, 2016.

NASA's Gulfstreram-III aircraft, with the GLISTIN-A radar instrument visible below, on the runway at Thule Air Base, Greenland.



Coverage



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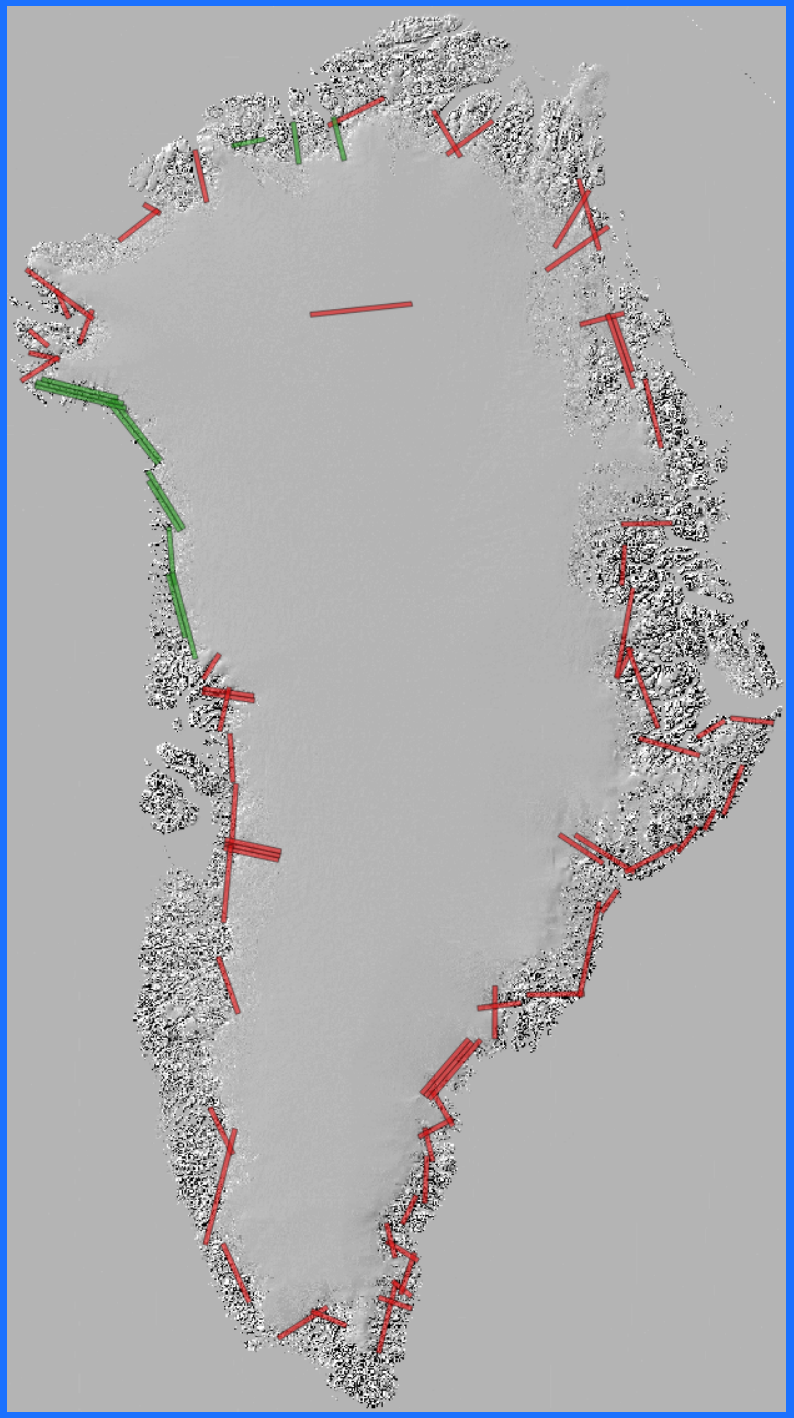


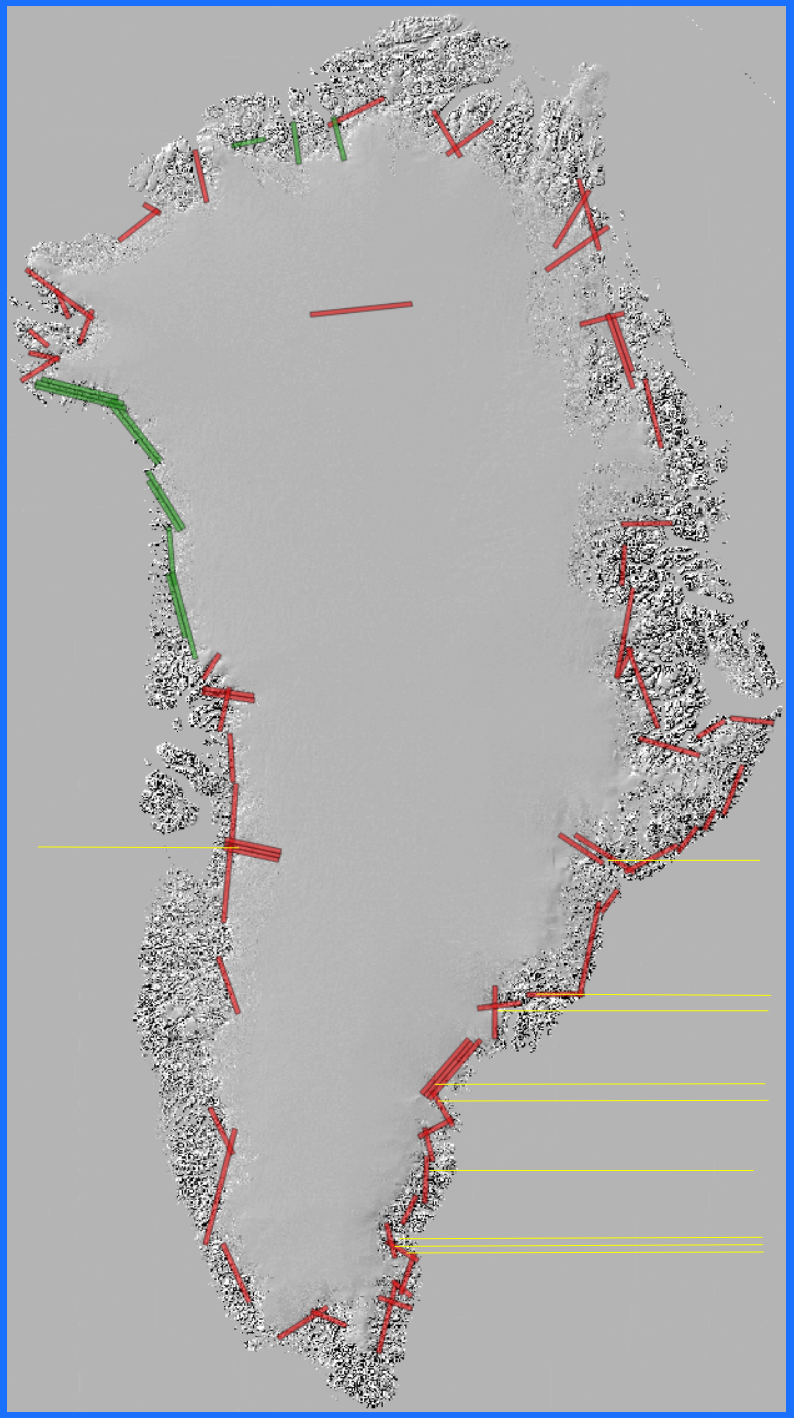
Talk Plan

Data Validation (Jakobshavn)

Changes in the Southeast

Jakobshavn

Summary and Conclusions



Background DEM:
Howat et al. (2015)

Glacier fronts:
Joughin and Moon (2015)

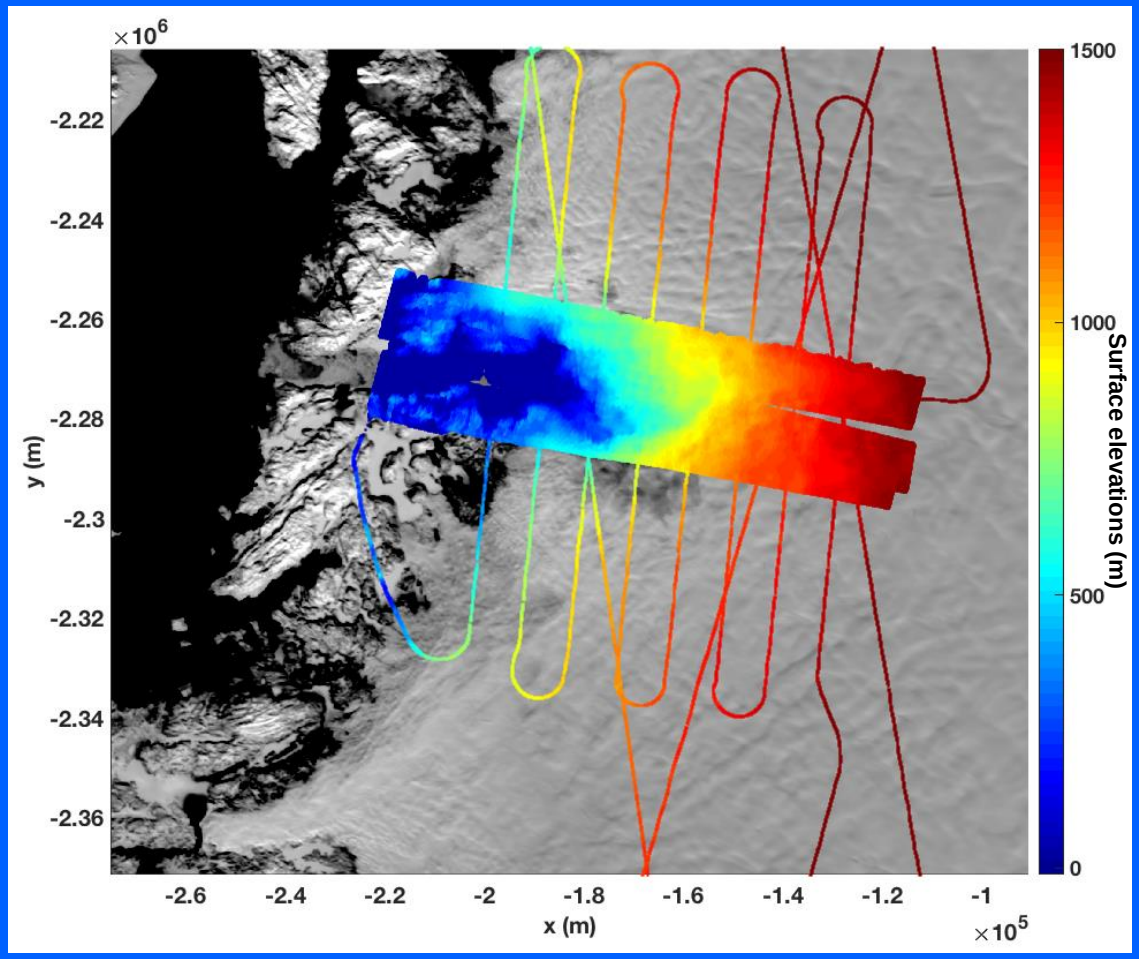
Glacier mass-loss ranking:
Enderlin et al. (2014)

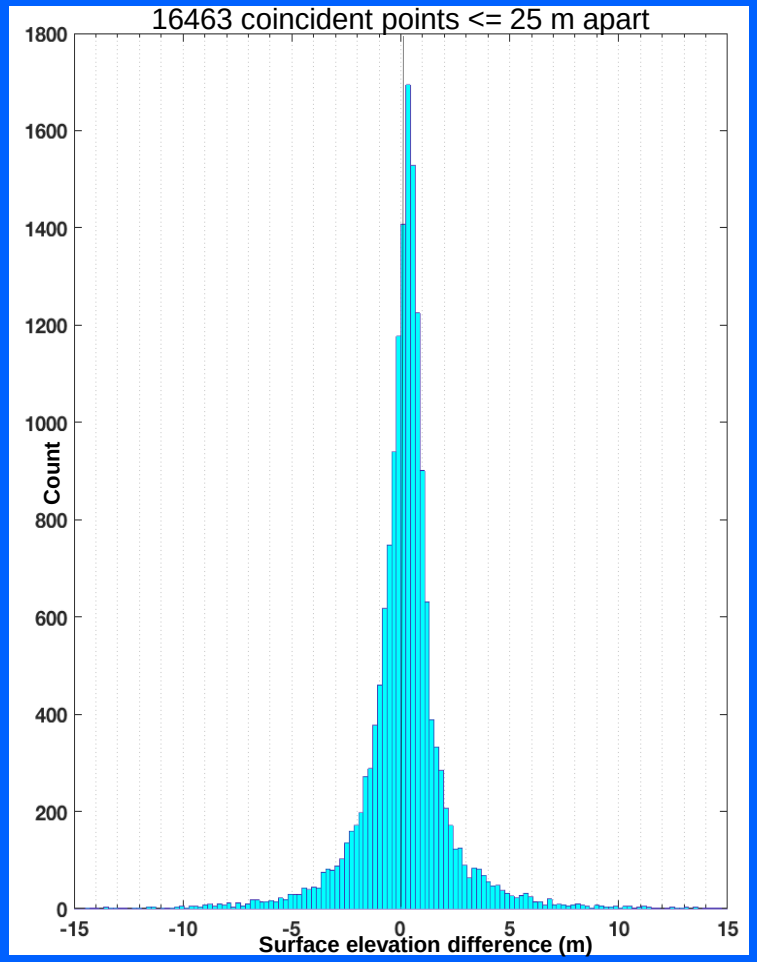
Data Validation

GLISTIN – ATM
(Jakobshavn northern swath)

GLISTIN : 20 March 2016
ATM : 16 May 2016

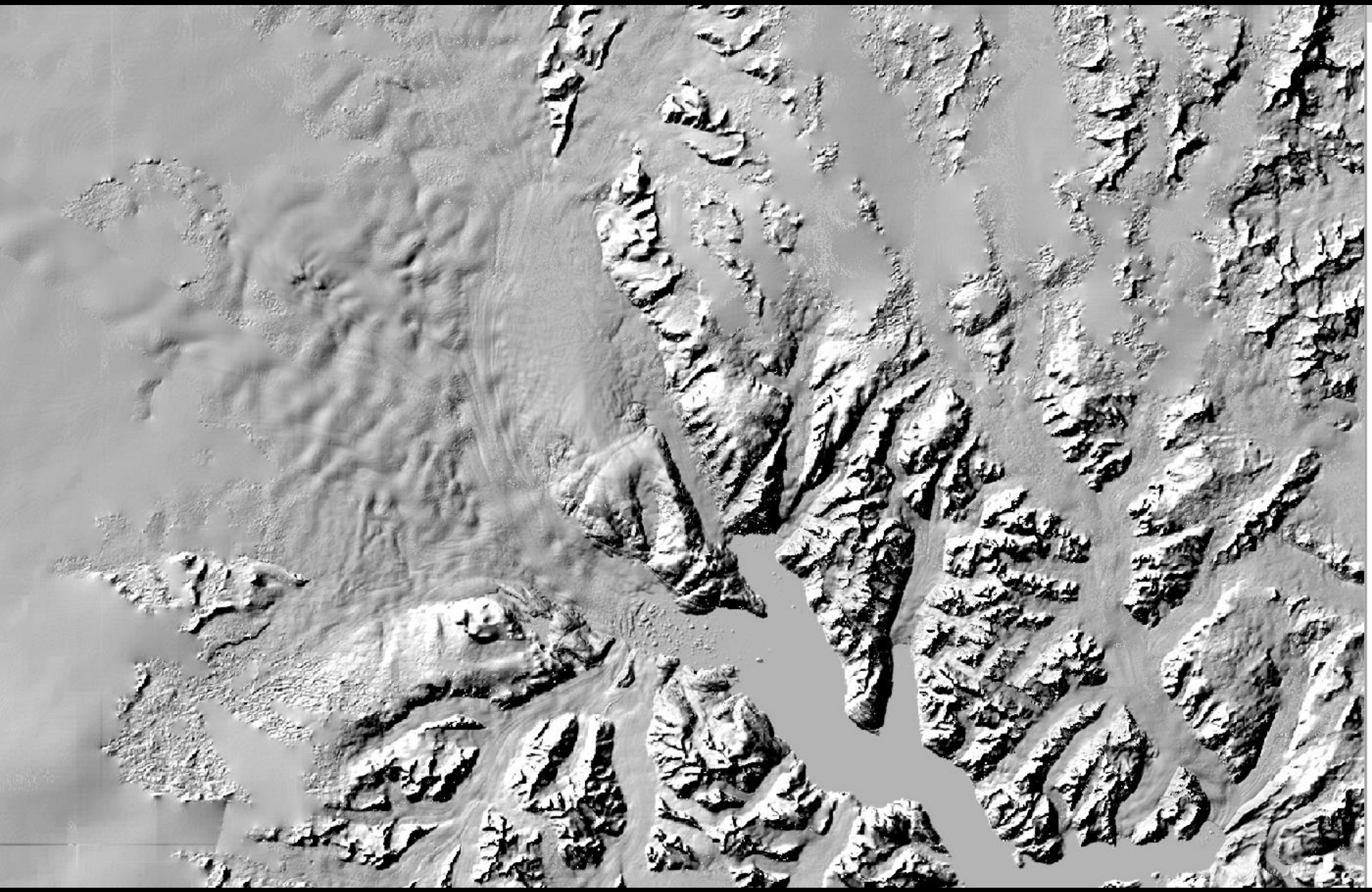
Mean = 0.18 m
Std = 2.15 m



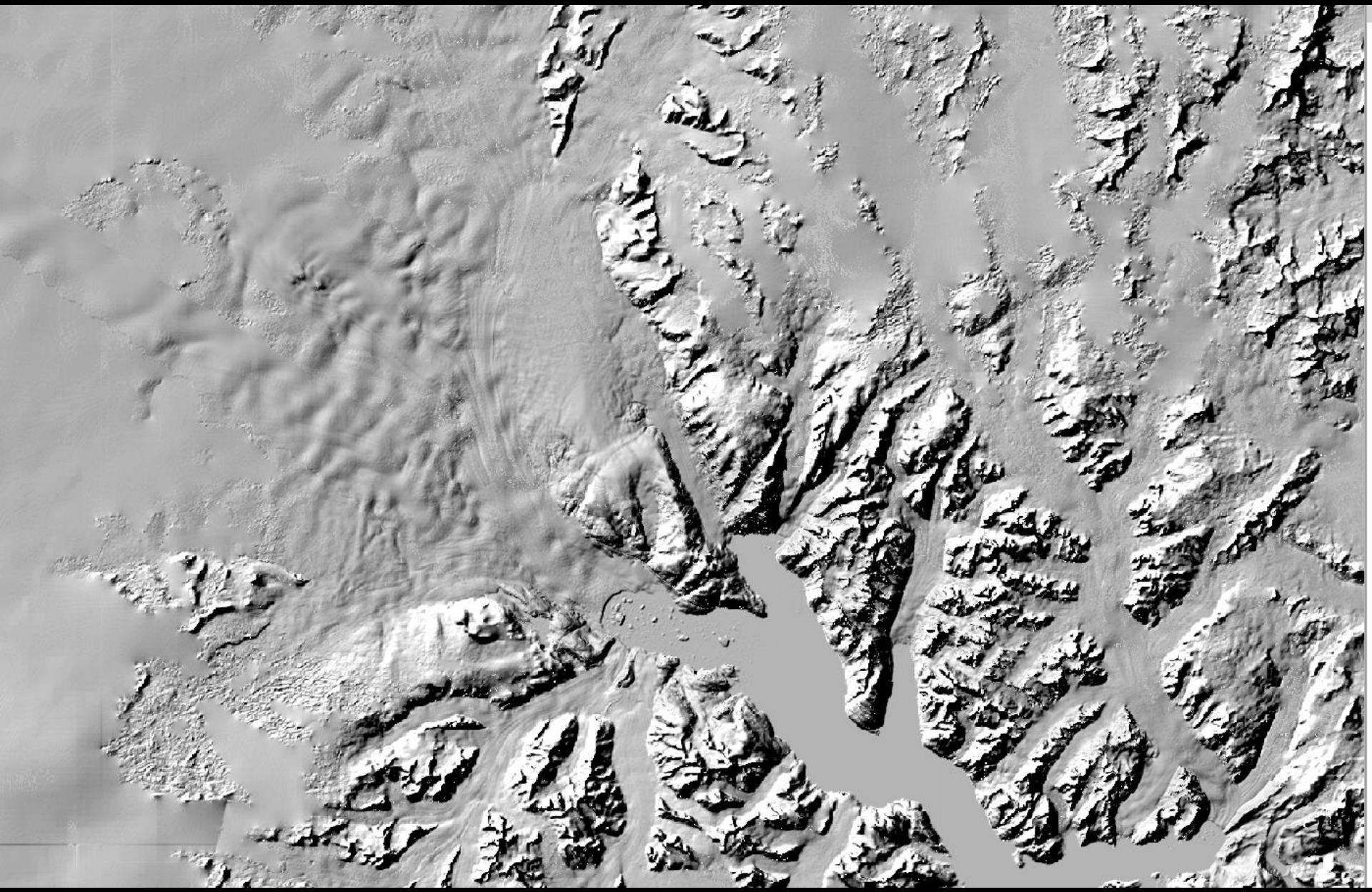


Related presentation: Delwyn Moller et al., Tuesday 13:40 - 18:00, Poster B23B-2065 (invited)
"Calibration and Validation of the GLISTIN-A Instrument: Results From the First Two Years of NASA's Oceans Melting Greenland Mission"

Kangerlussuaq 2016

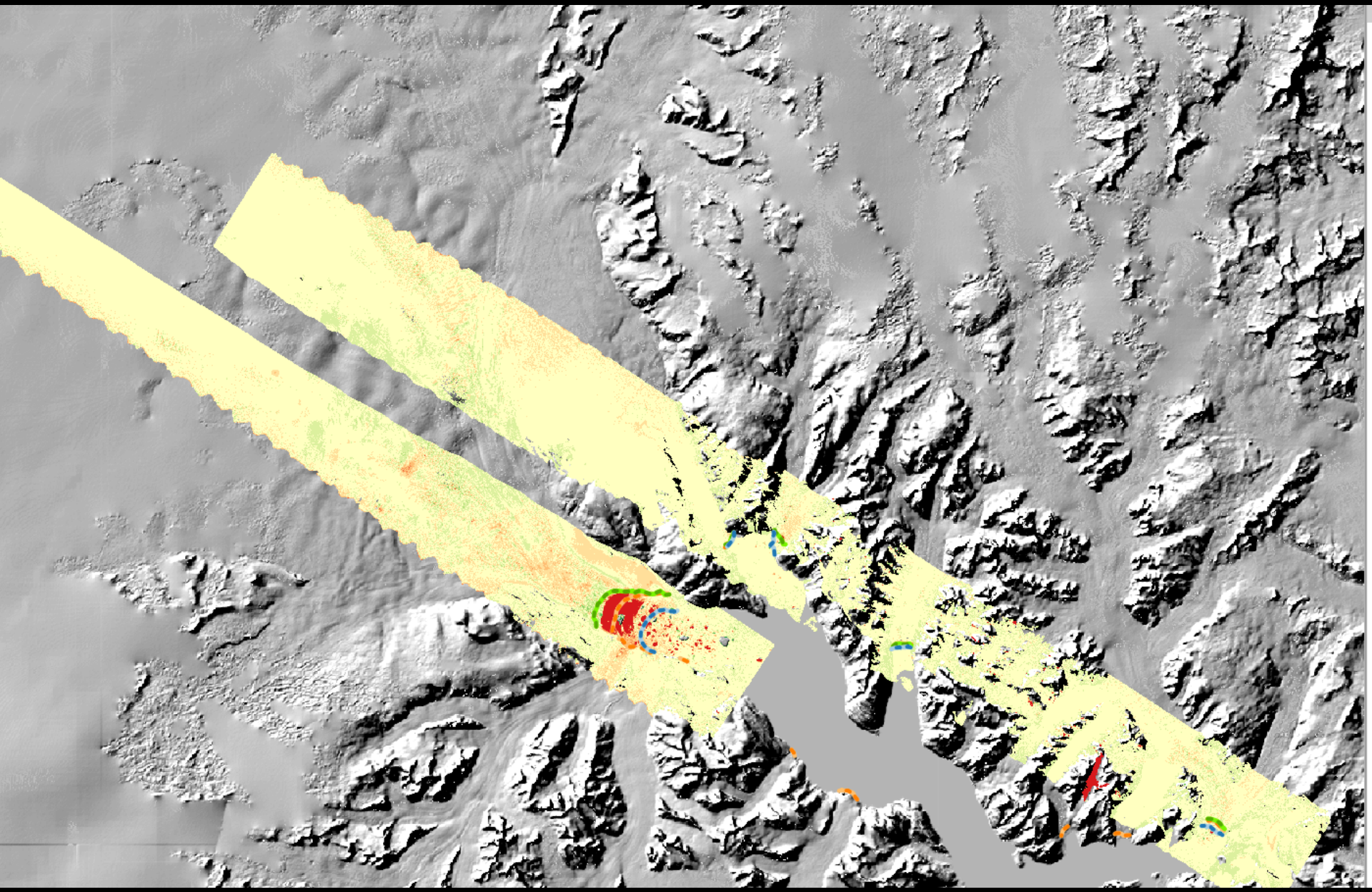


Kangerlussuaq 2017



Kangerlussuaq

2017 - 2016



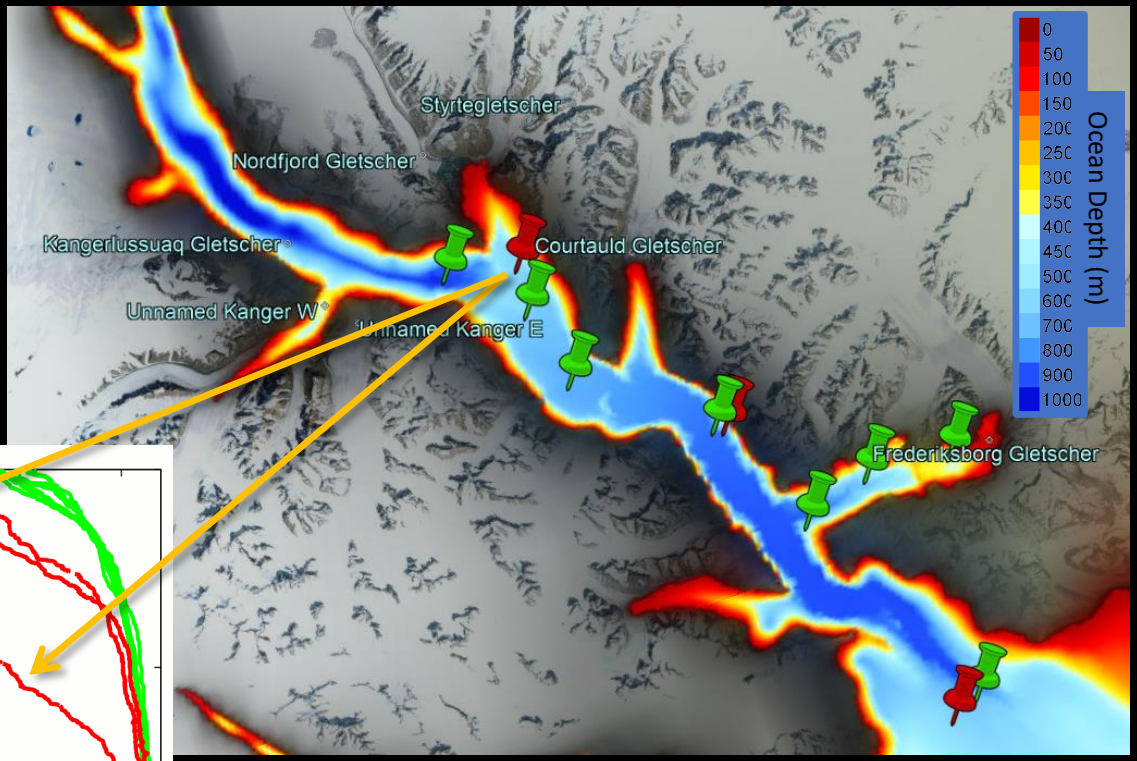
Fronts: 2001 2012/2013 2015

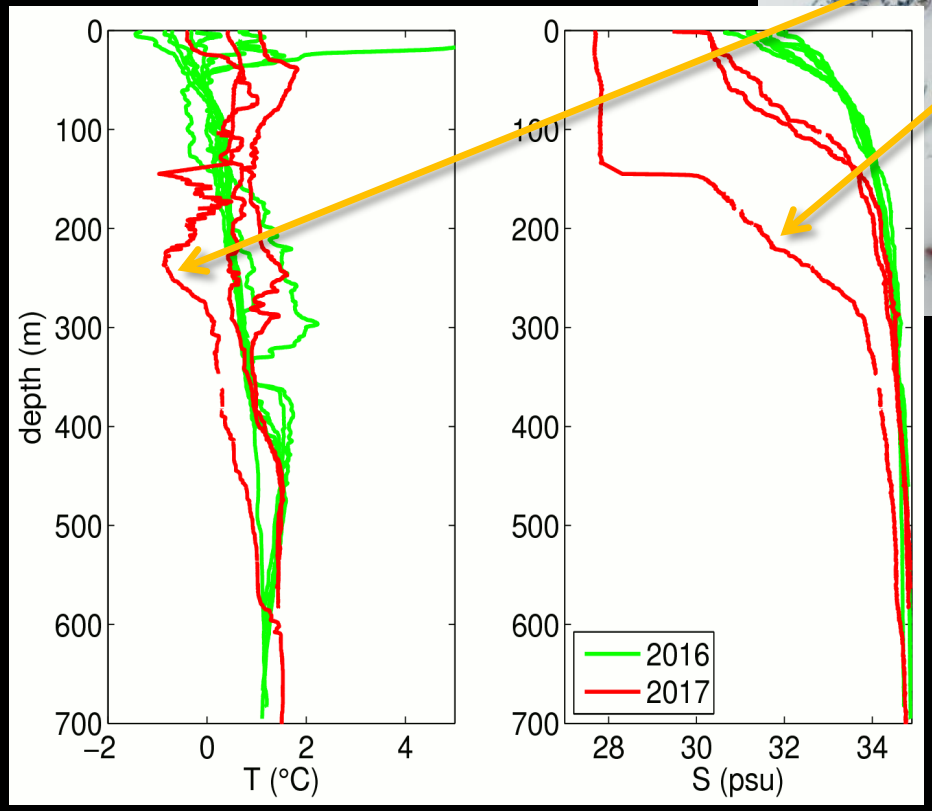
Surface △h (m): -30 -24 -18 -12 -6 0 6 12 18 24 30

Kangerlussuaq

CTD data: 2016 and 2017

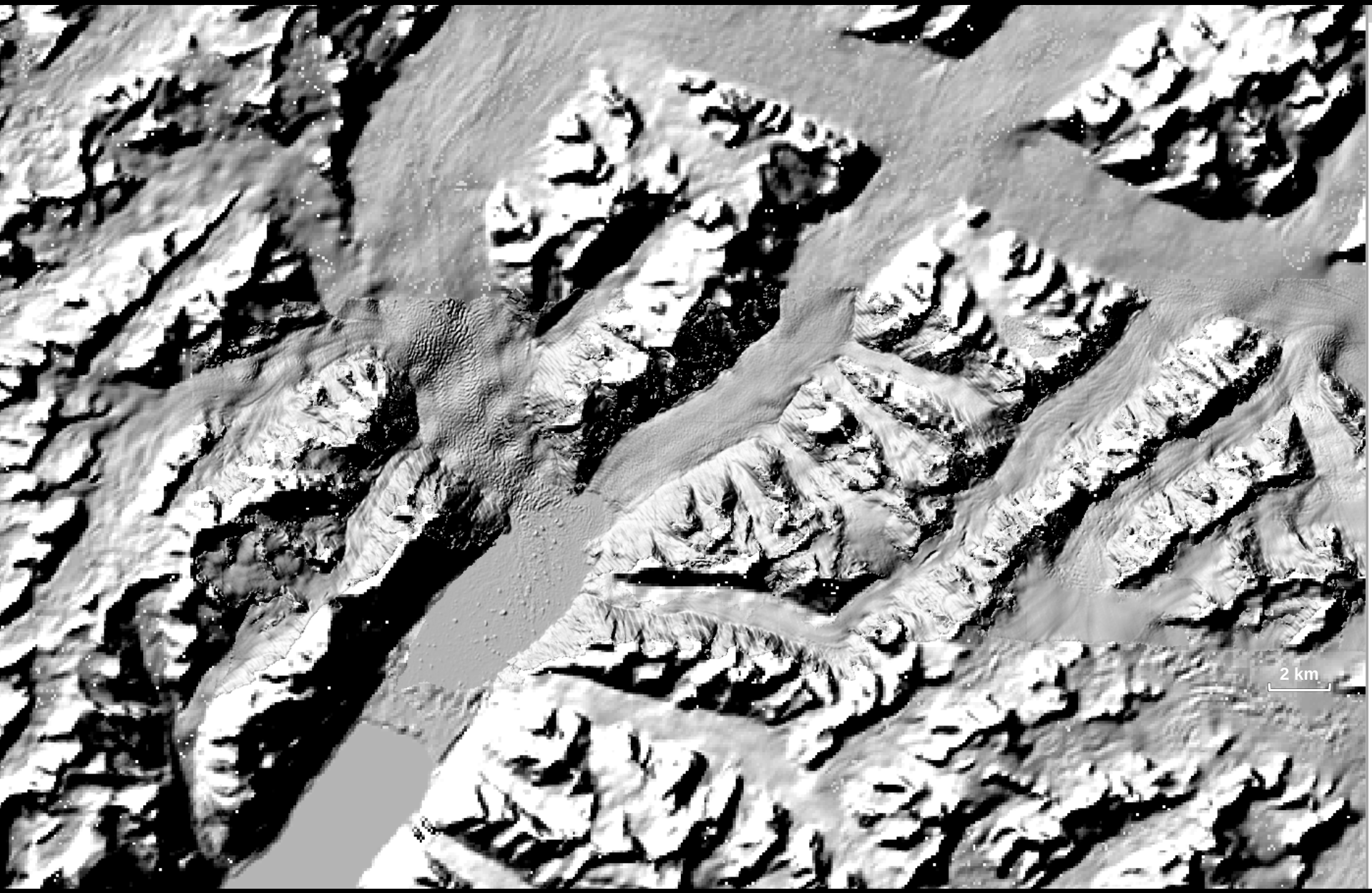
11 profiles during the summers of 2016 and 2017



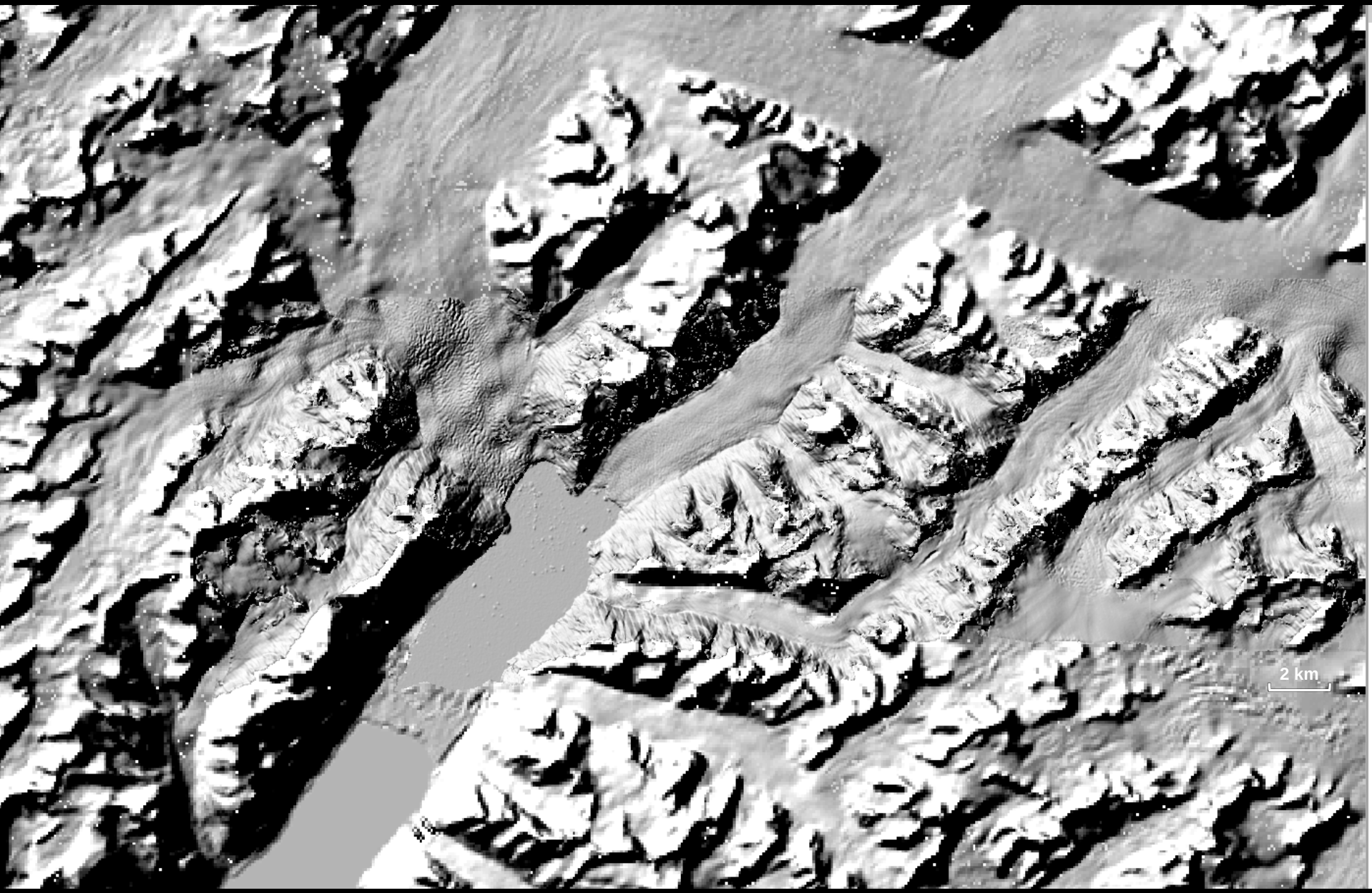


Much freshening at depth in 2017, suggesting possible subglacial discharge and/or subsurface melt.

Midgard 2016

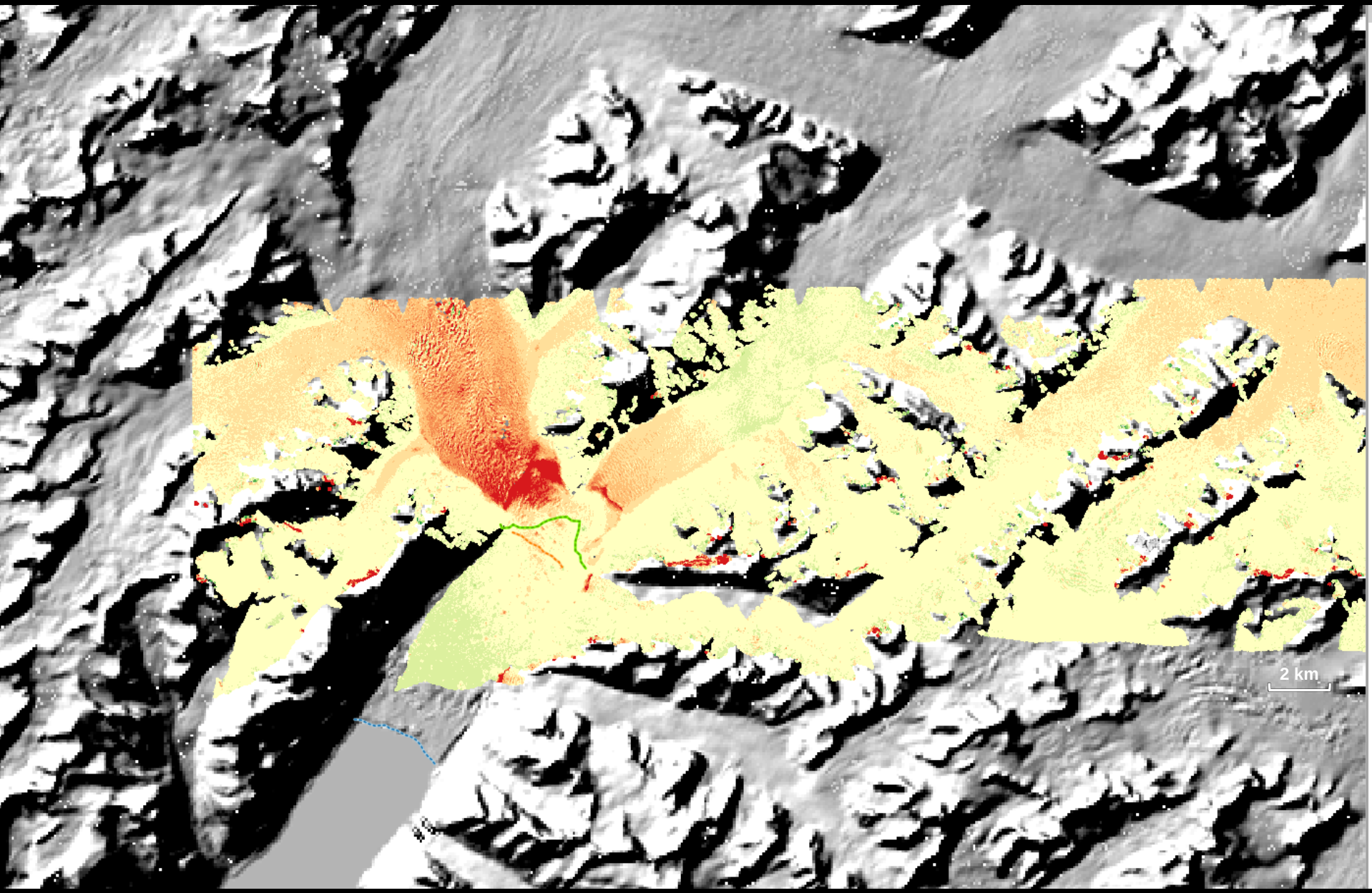


Midgard 2017



Midgard

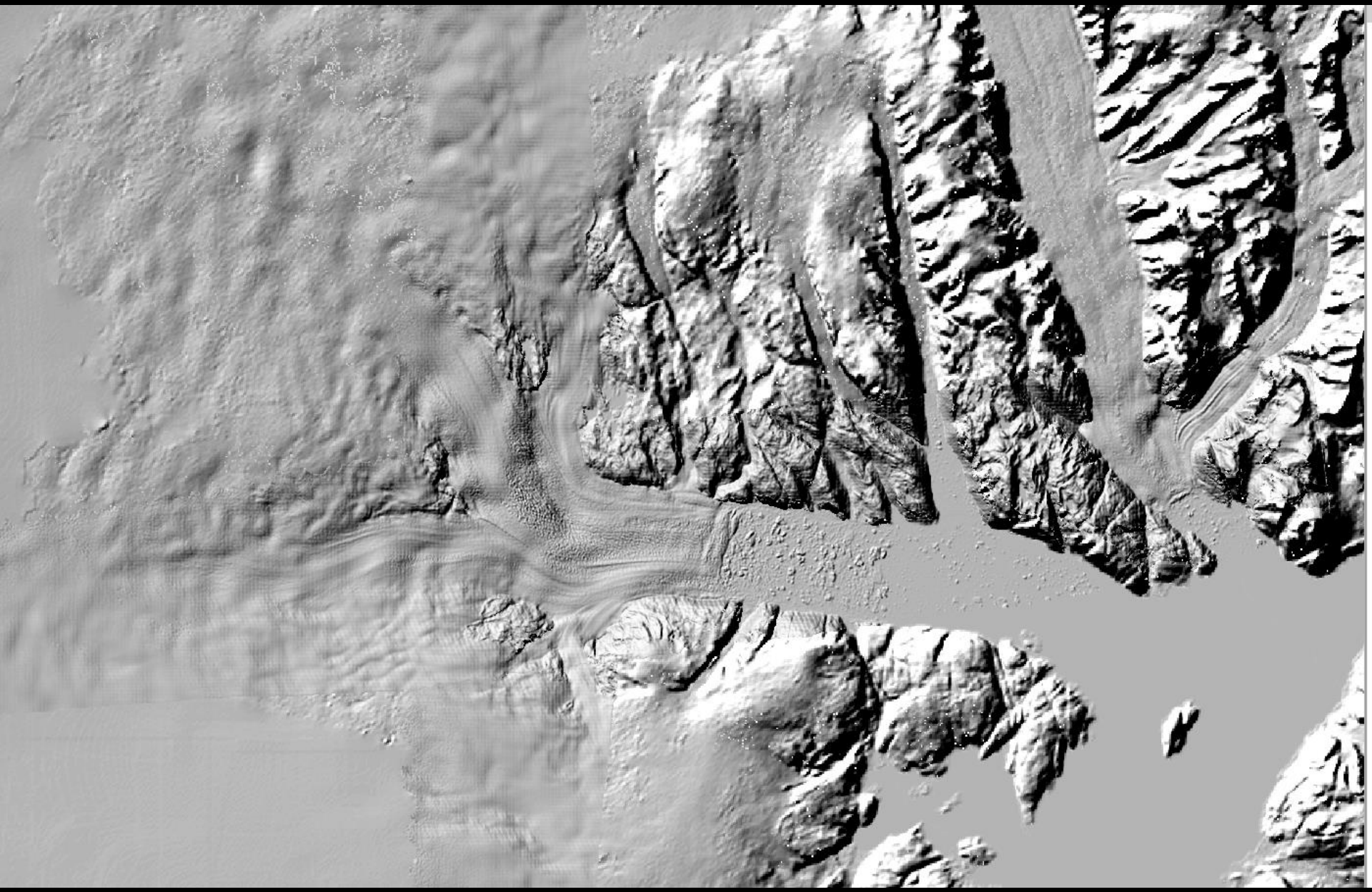
2017 - 2016



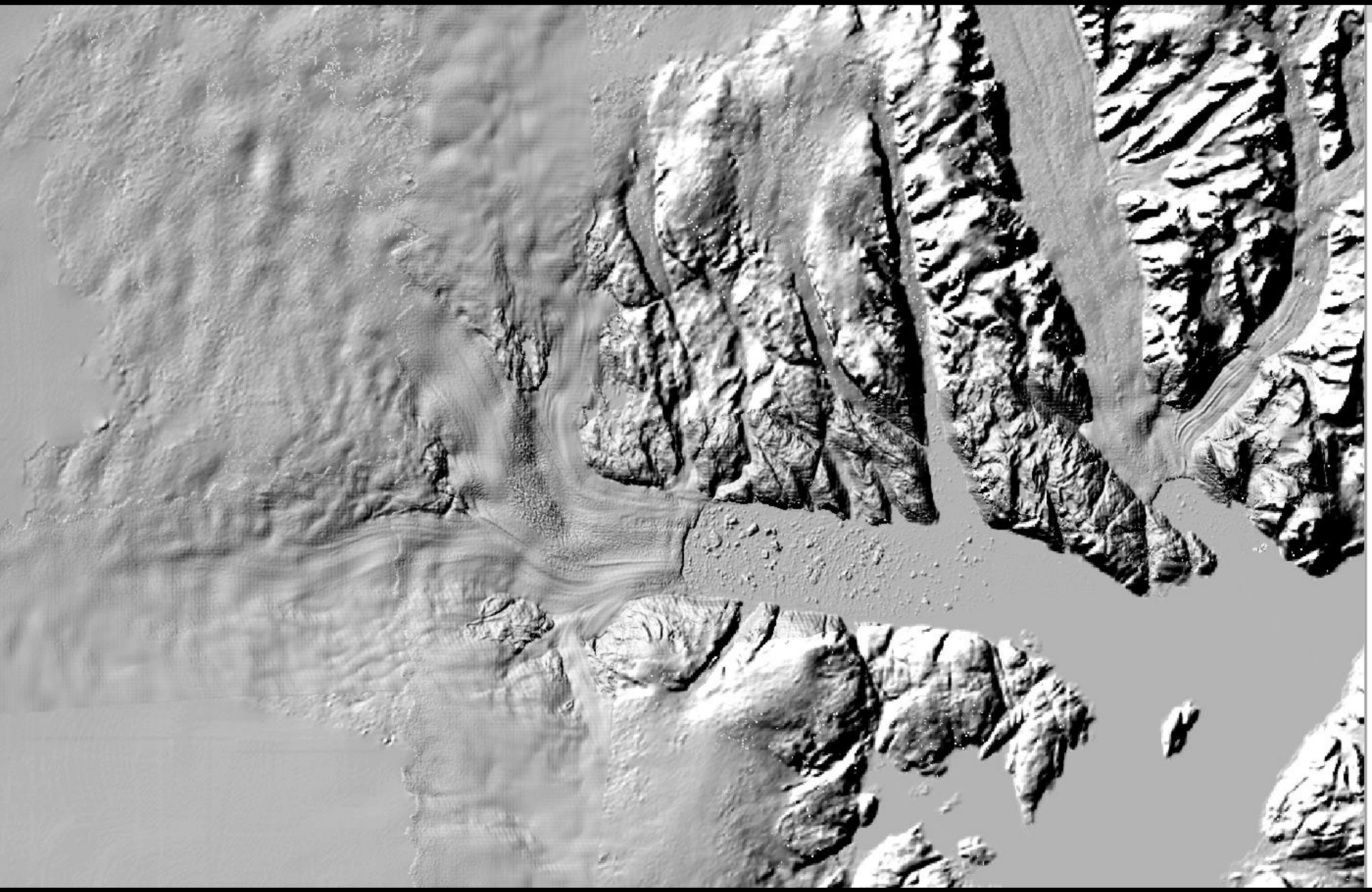
Fronts: 2001 2012/2013 2015

Surface △h (m): -30 -24 -18 -12 -6 0 6 12 18 24 30

Helheim 2016

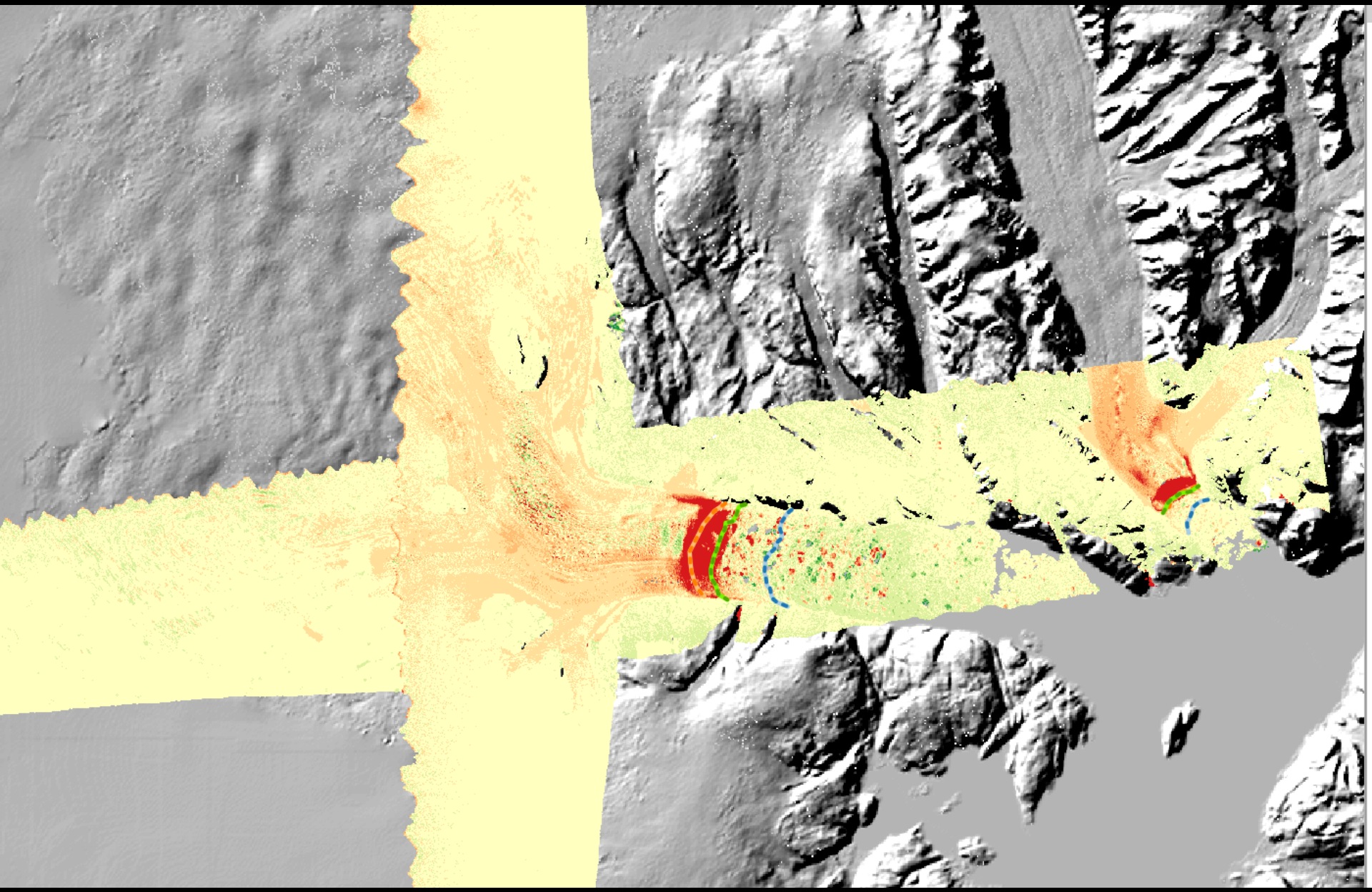


Helheim 2017



Helheim

2017 - 2016

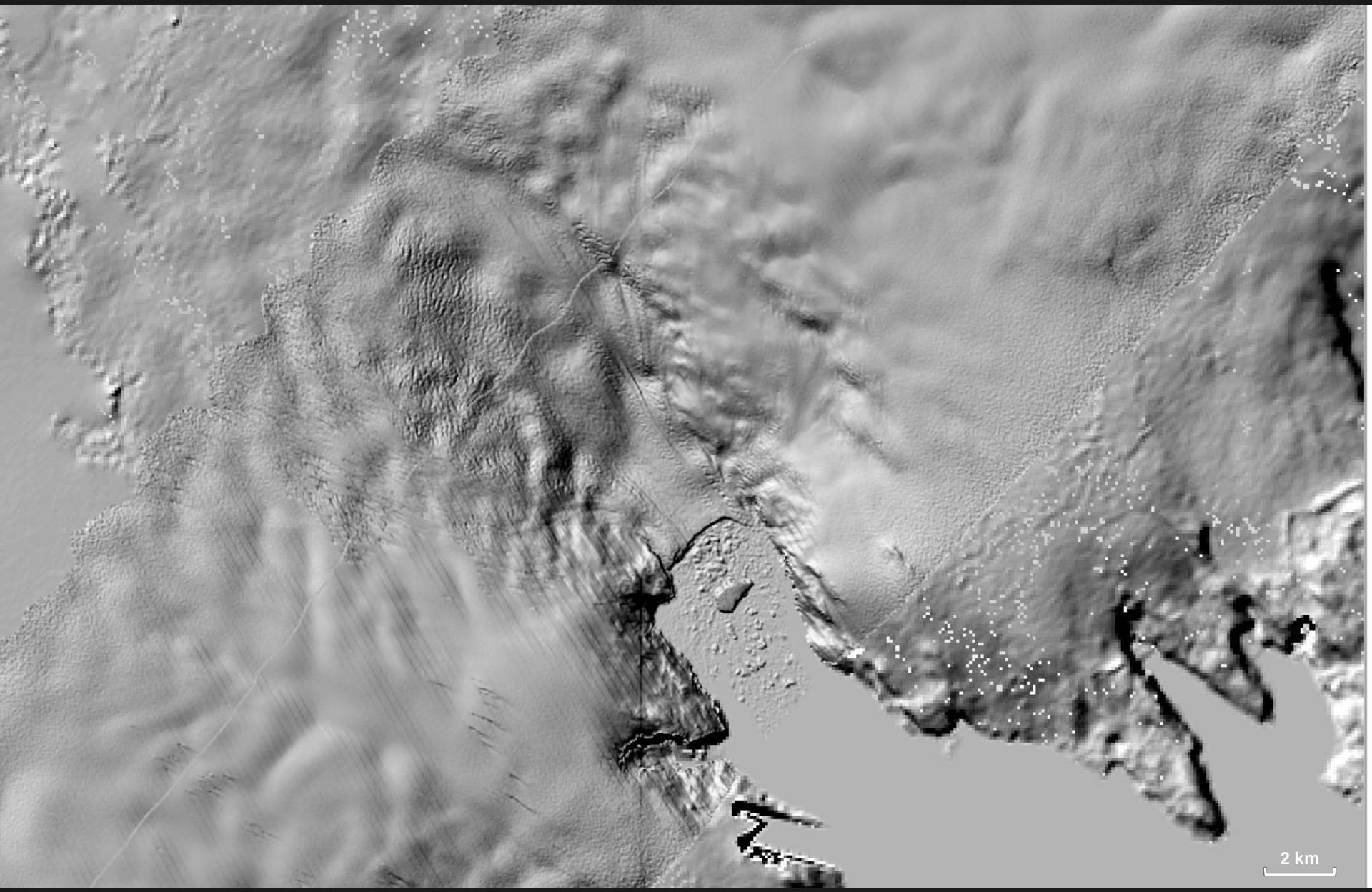


Fronts: 2001 2012/2013 2015

Surface △h (m): -30 -24 -18 -12 -6 0 6 12 18 24 30

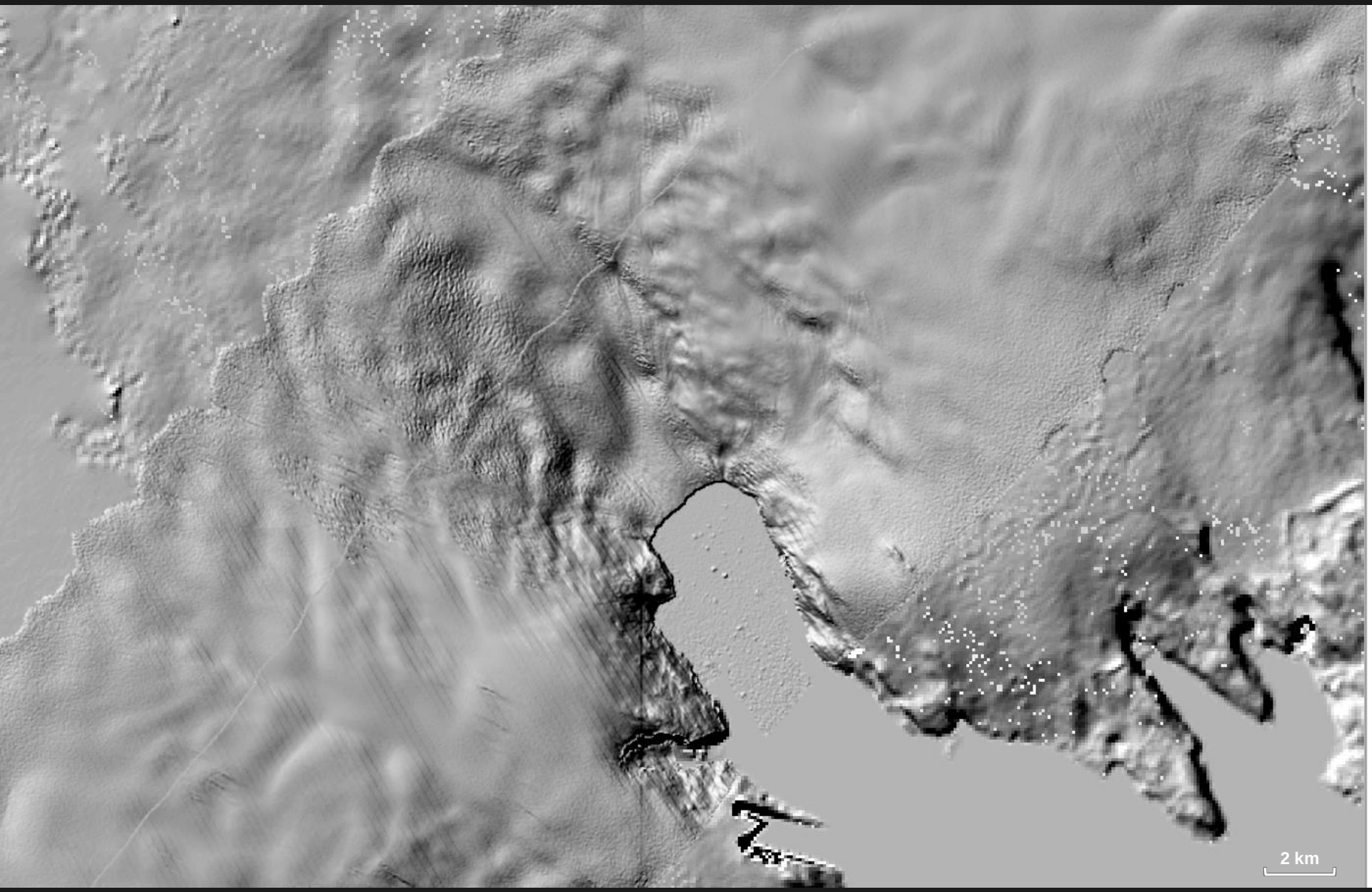
Koge Bugt

2016



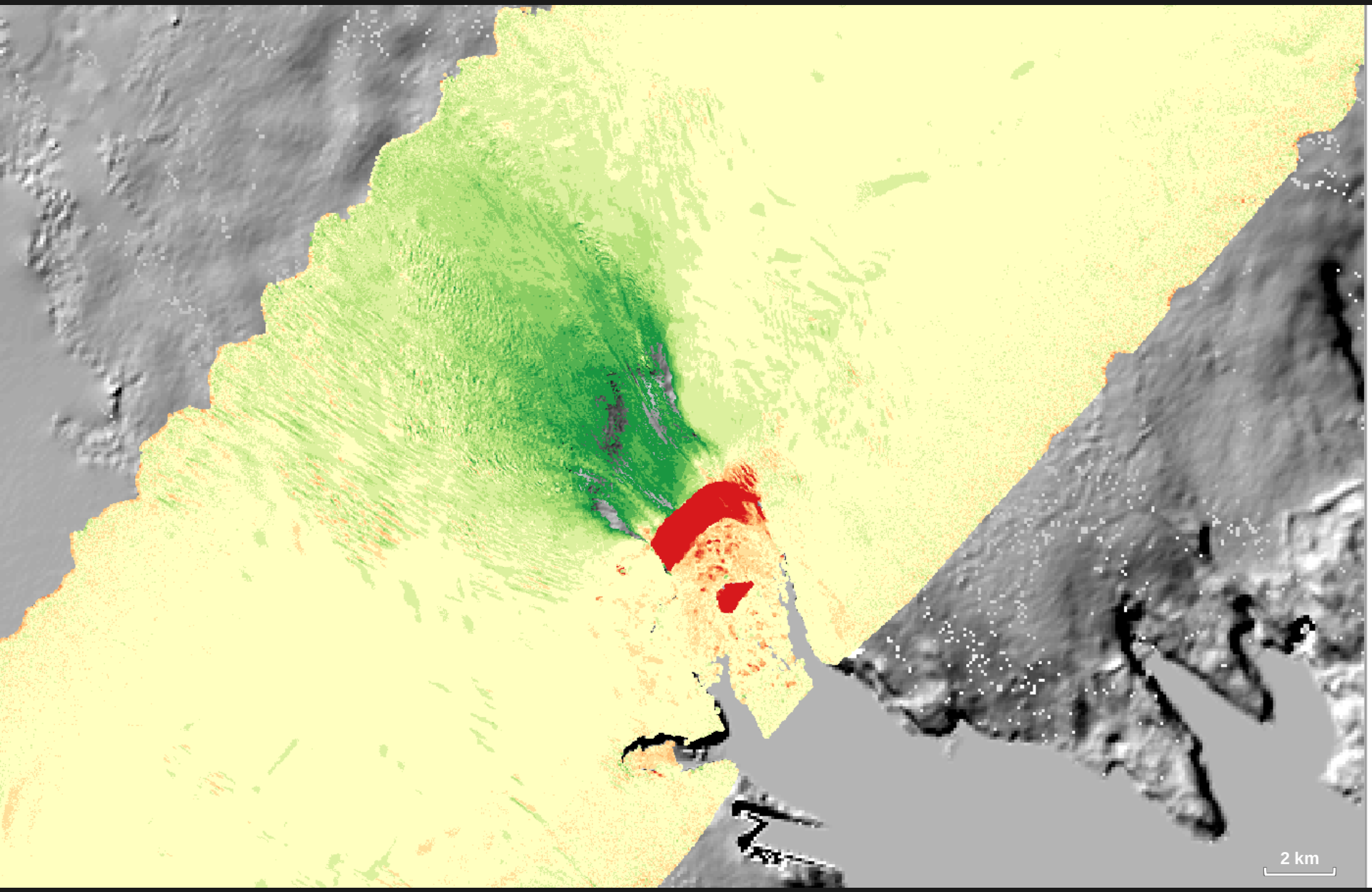
Koge Bugt

2017



Koge Bugt

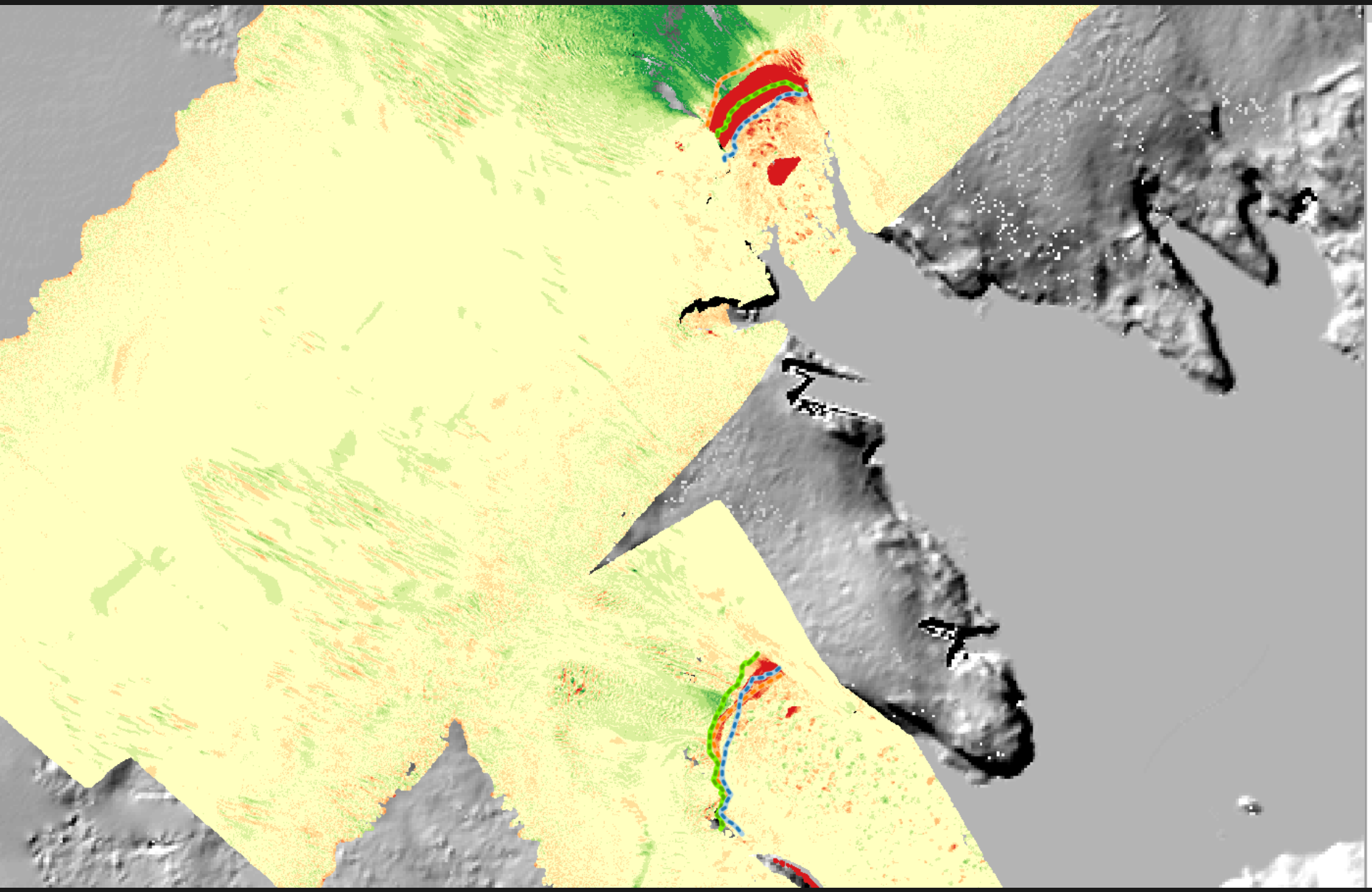
2017 - 2016



Surface △h (m):

Koge Bugt (Central and South)

2017 - 2016

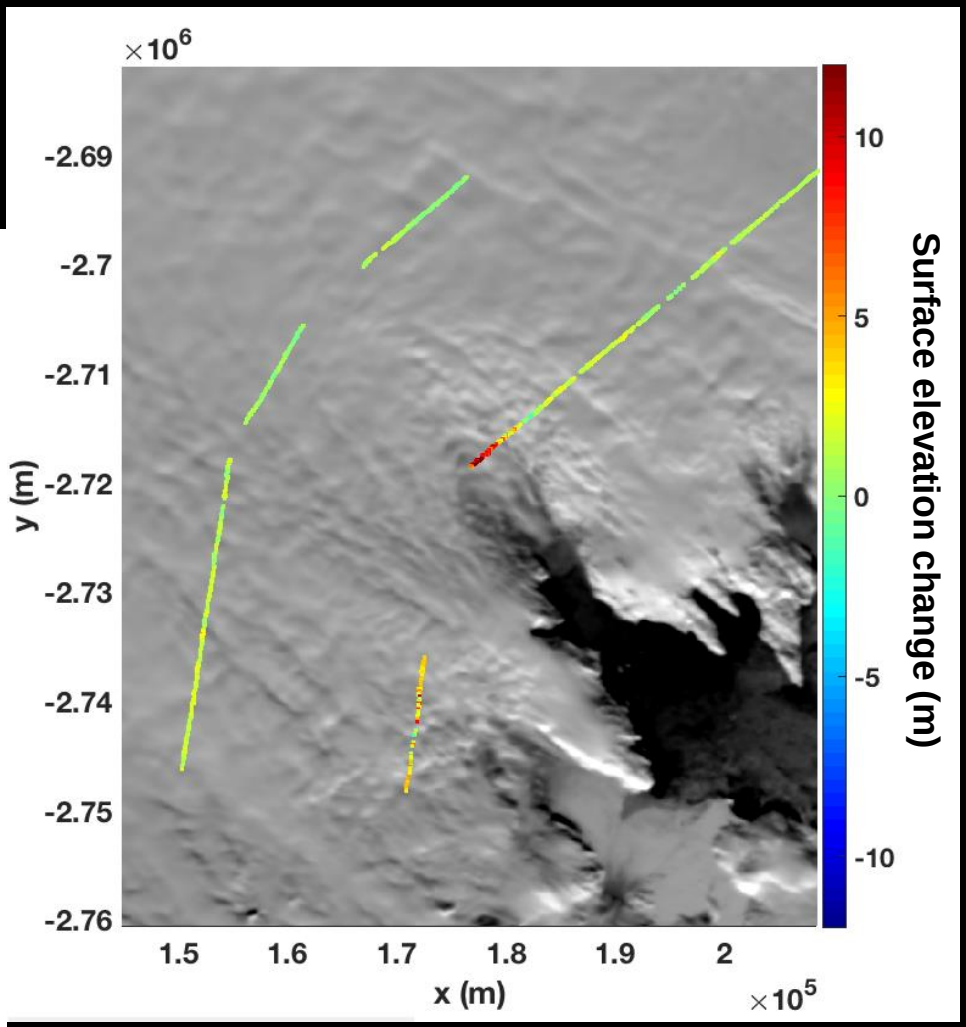


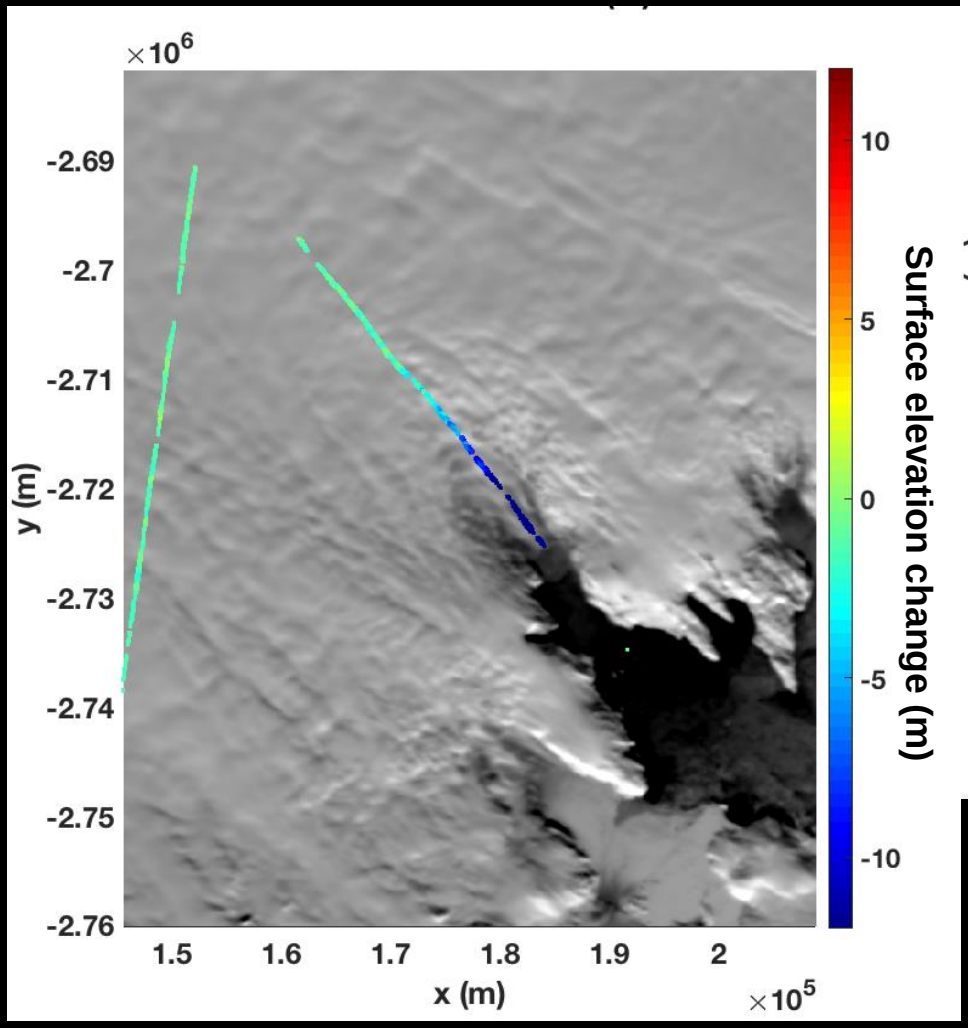
Fronts: 2001 2012/2013 2015

Surface △h (m): -30 -24 -18 -12 -6 0 6 12 18 24 30

Koge Bugt

ATM △h : 2016 - 2015



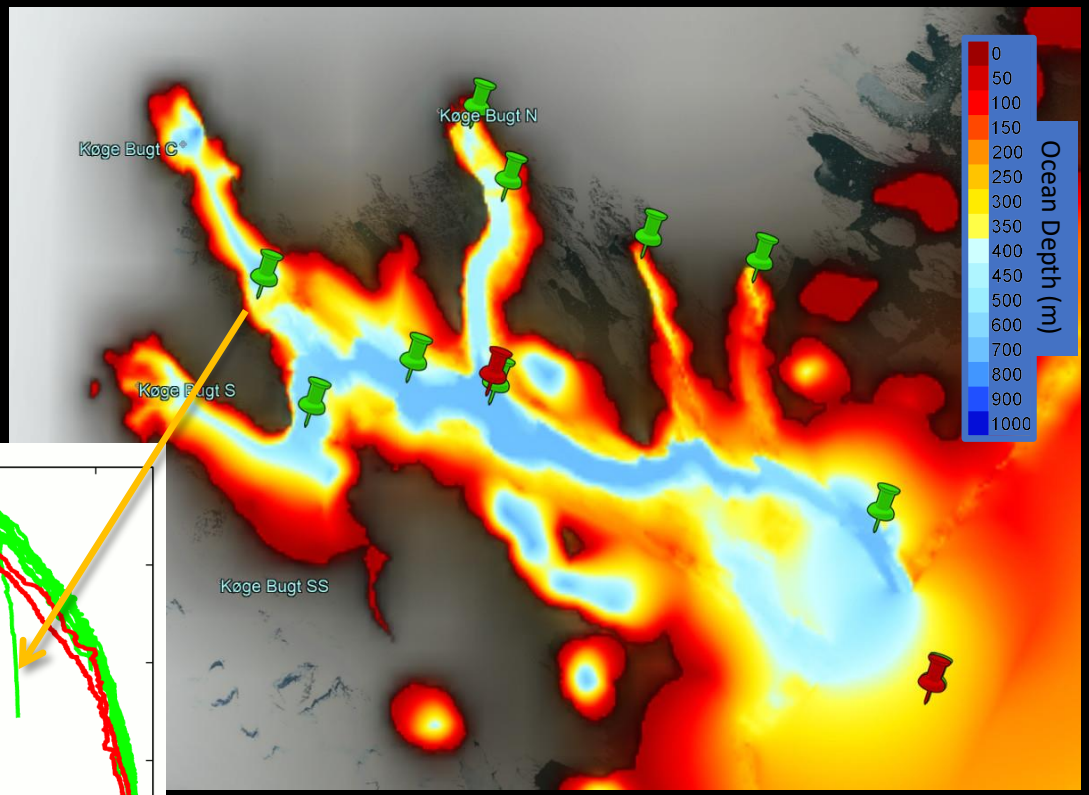


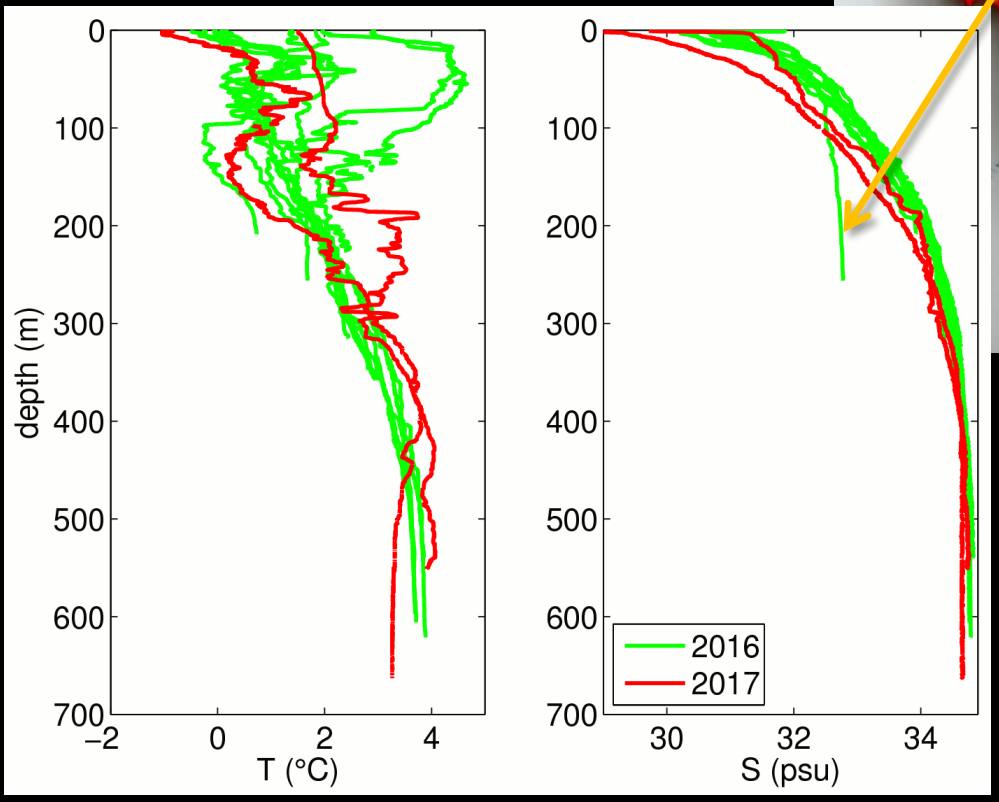
ATM △h : 2015 - 2014

Koge Bugt

CTD data: 2016 and 2017

12 profiles during the summers of 2016 and 2017

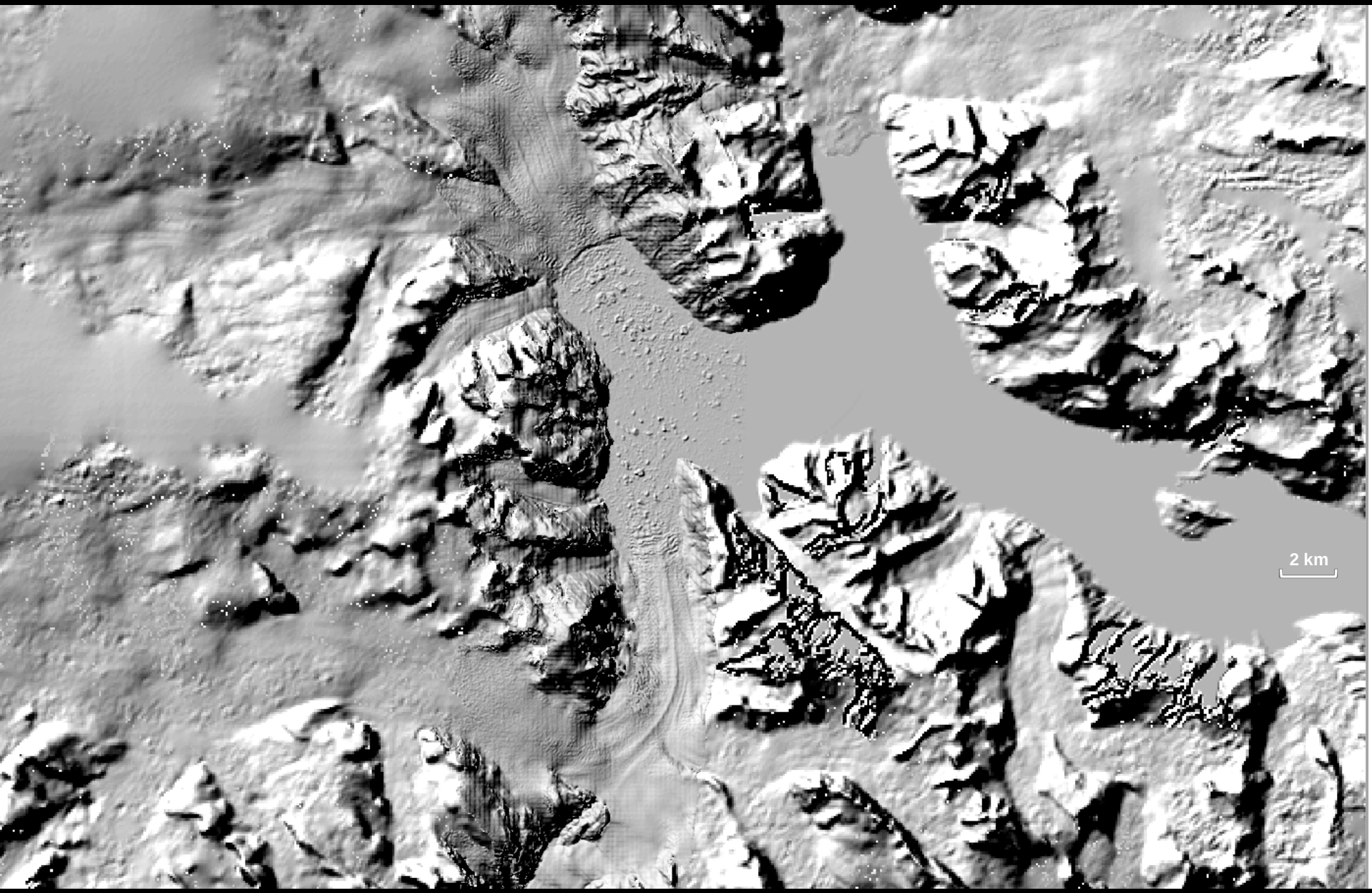




Plenty of very warm water in the trough. Low salinity occurs in the western most profile. Possible a sign of subglacial discharge and/or subsurface melt.

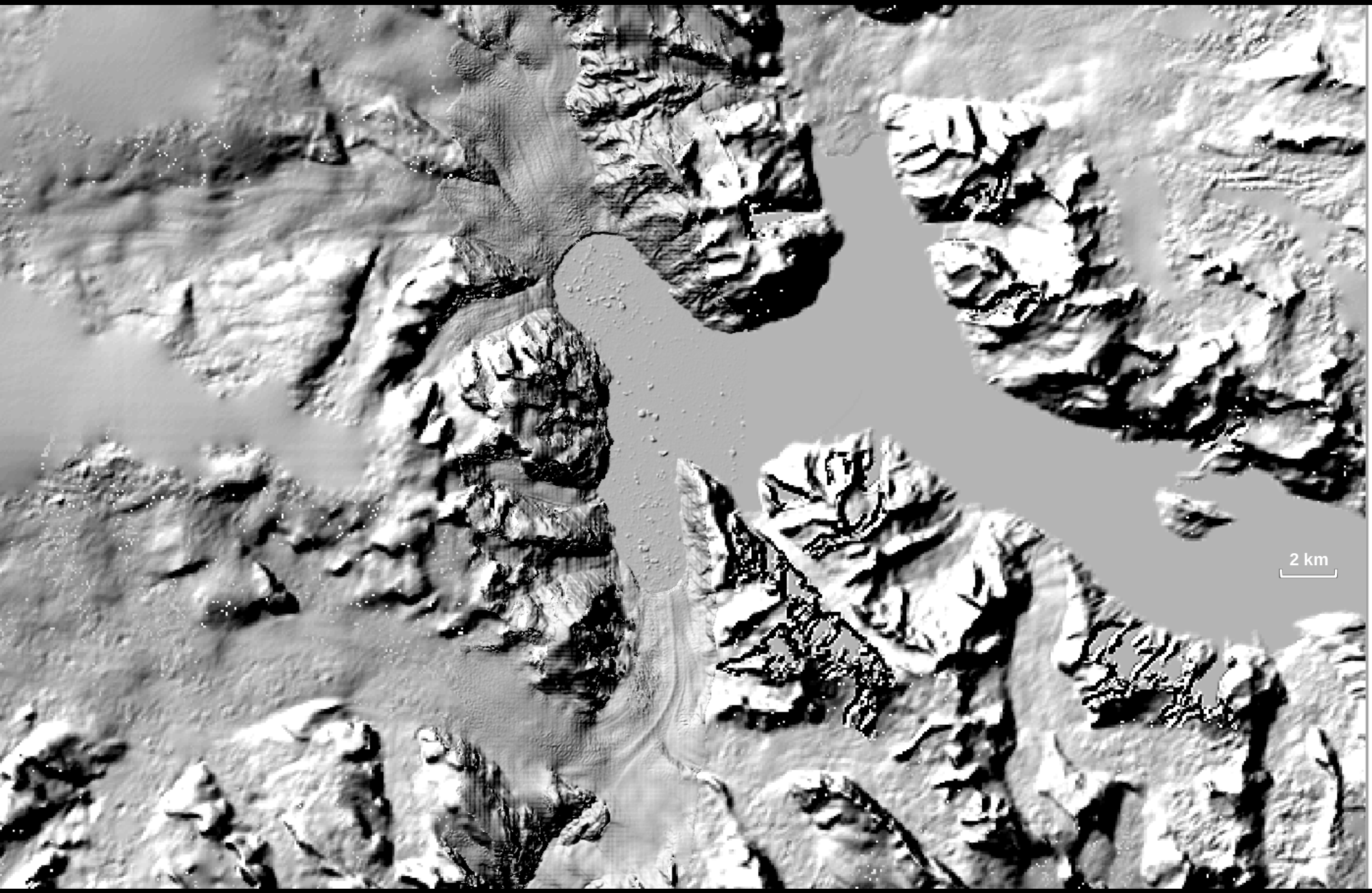
Maelkevejen

2016



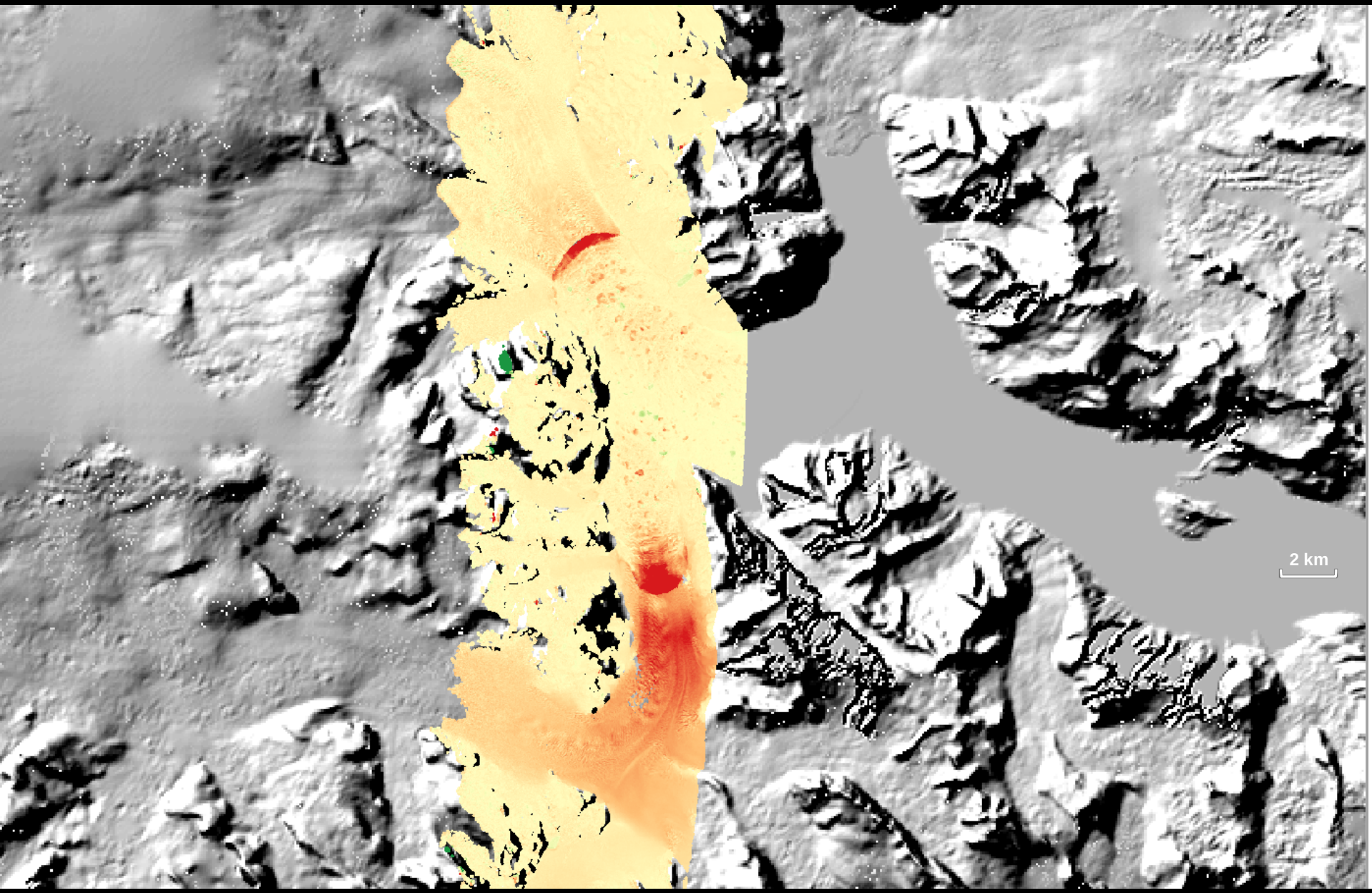
Maelkevejen

2017



Maelkevejen

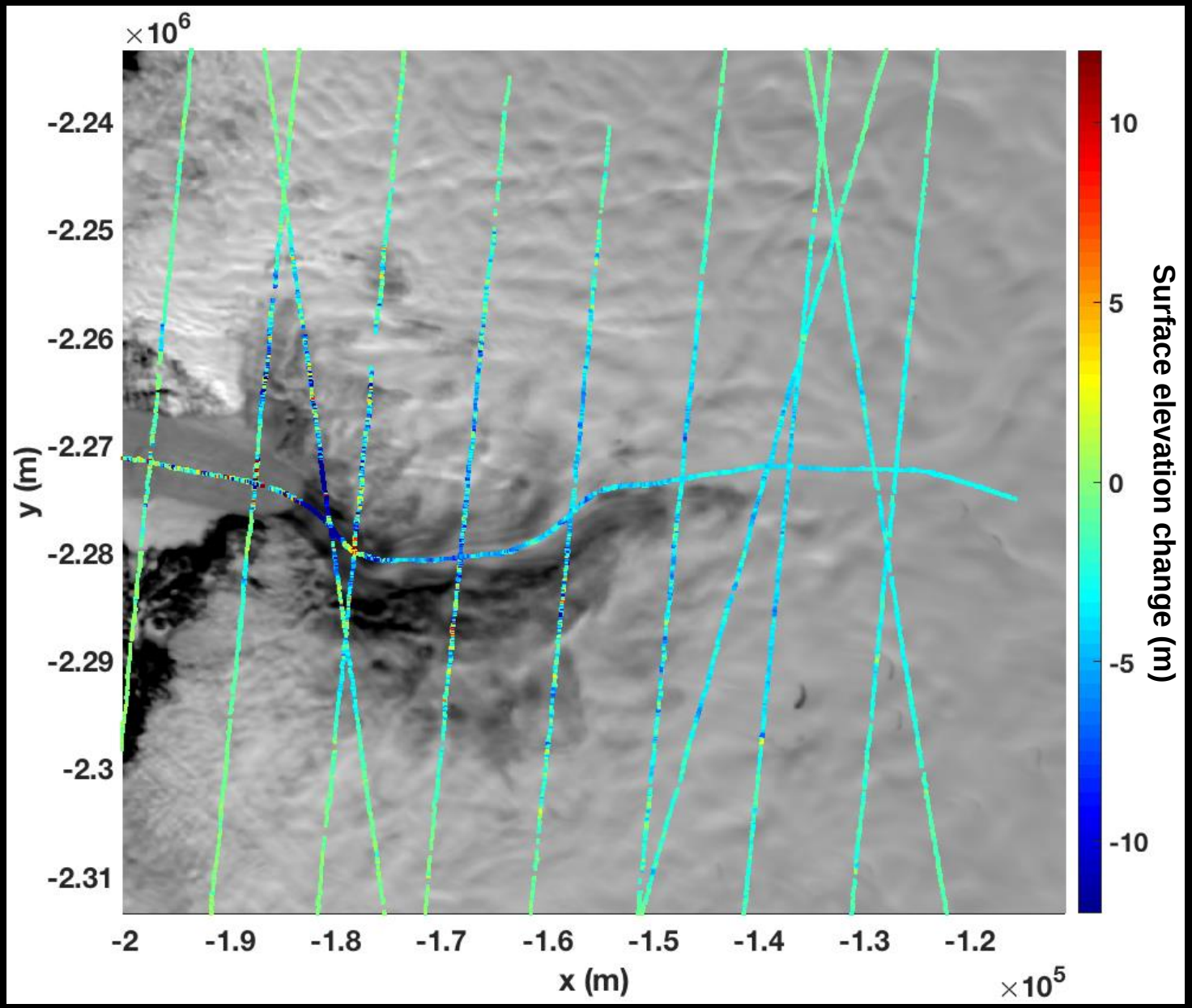
2017 - 2016



Surface △h (m):

Jakobshavn

ATM △h : 2016 - 2015

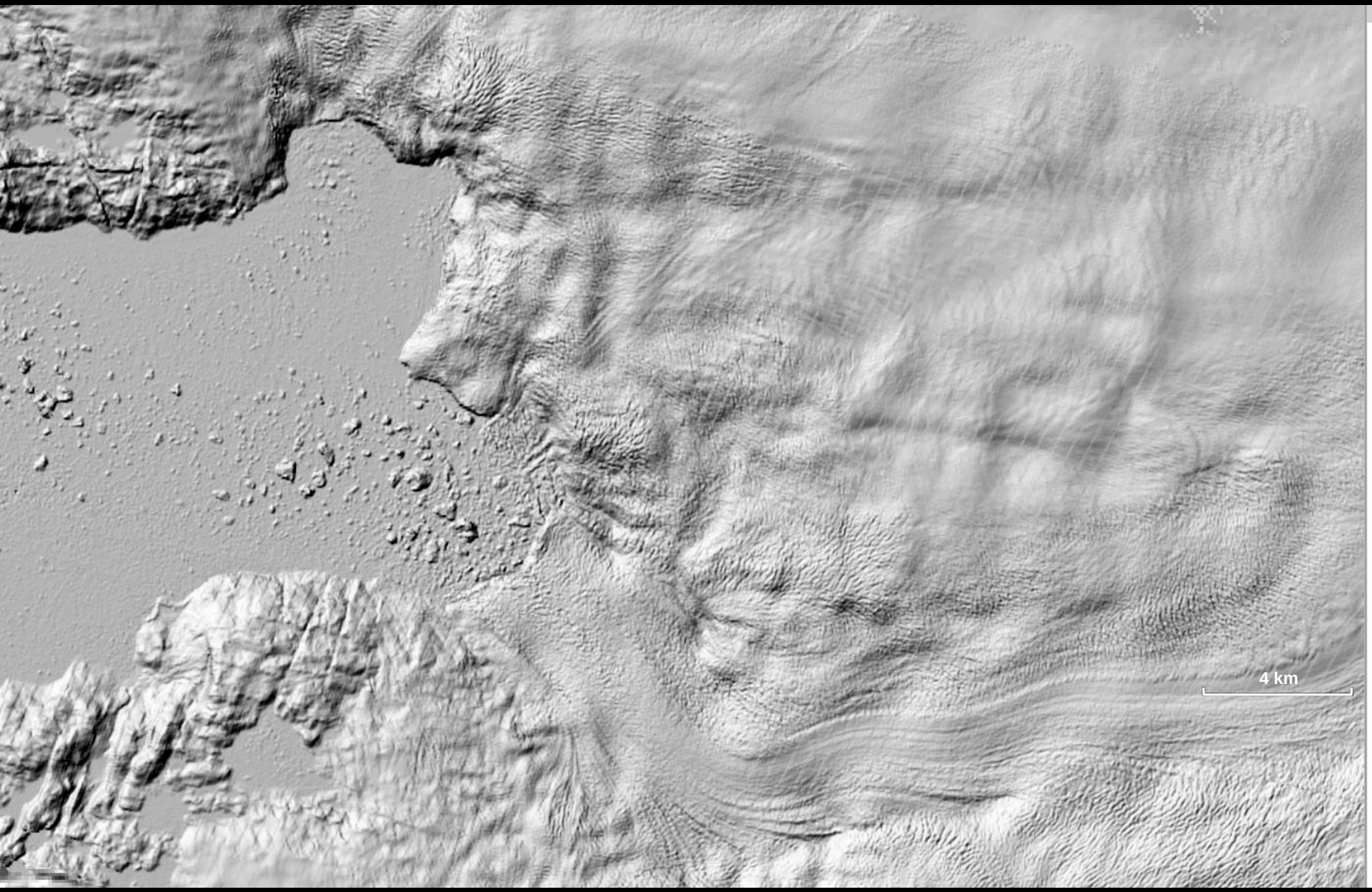


Largest source of cumulative mass loss.

(e.g., Enderlin et al., 2014; Holland et al., 2008)

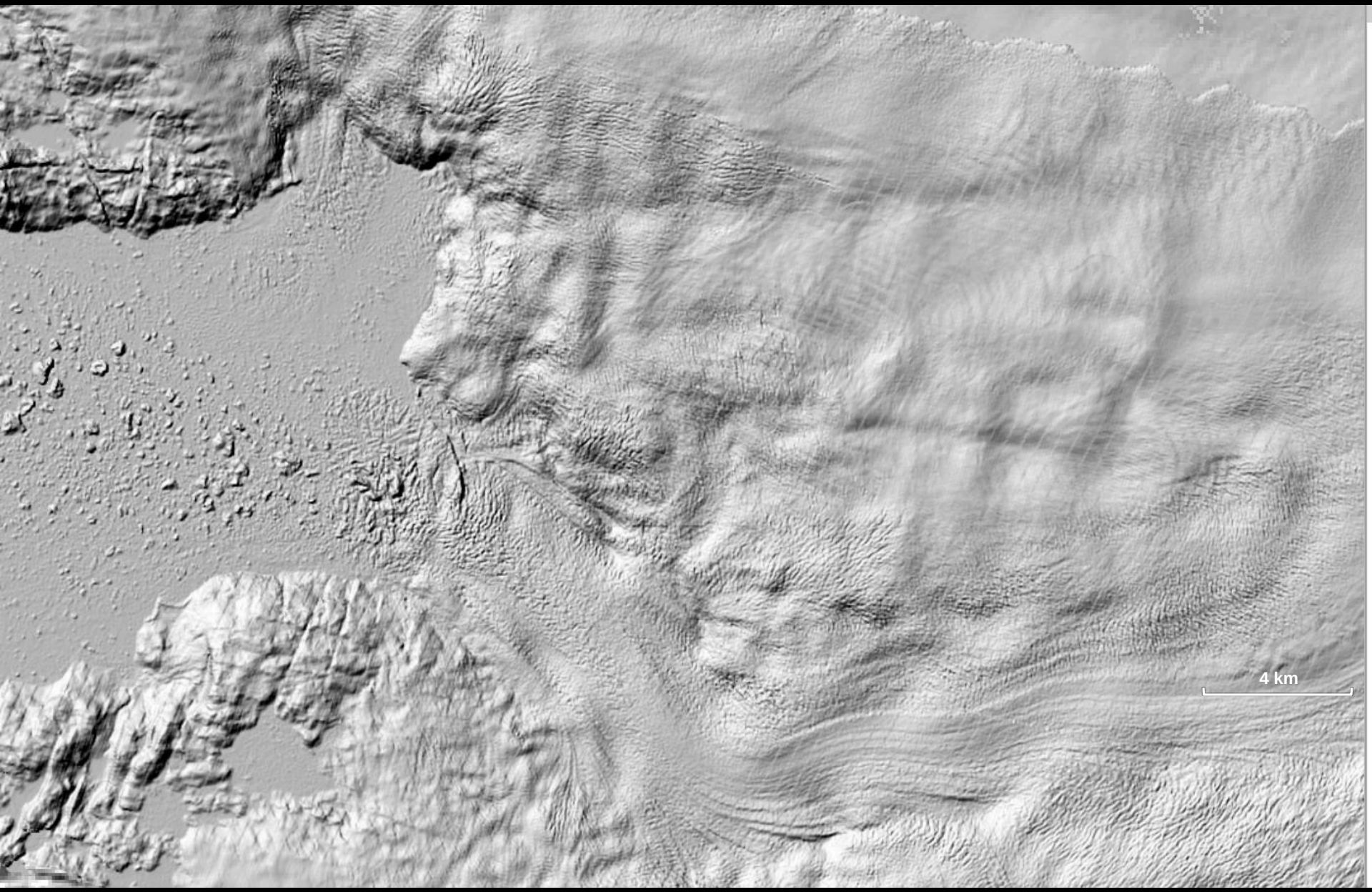
Jakobshavn

2016



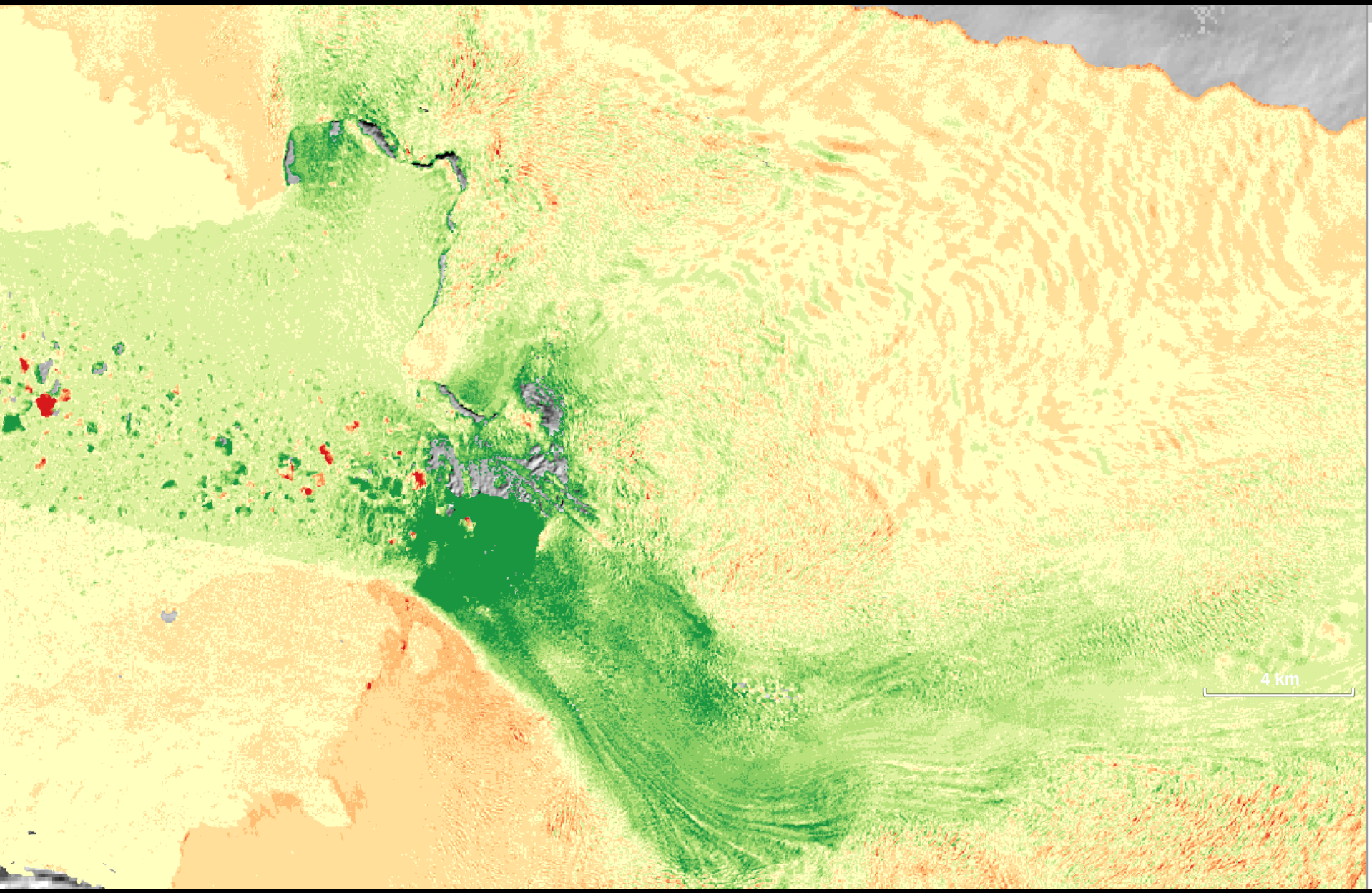
Jakobshavn

2017



Jakobshavn

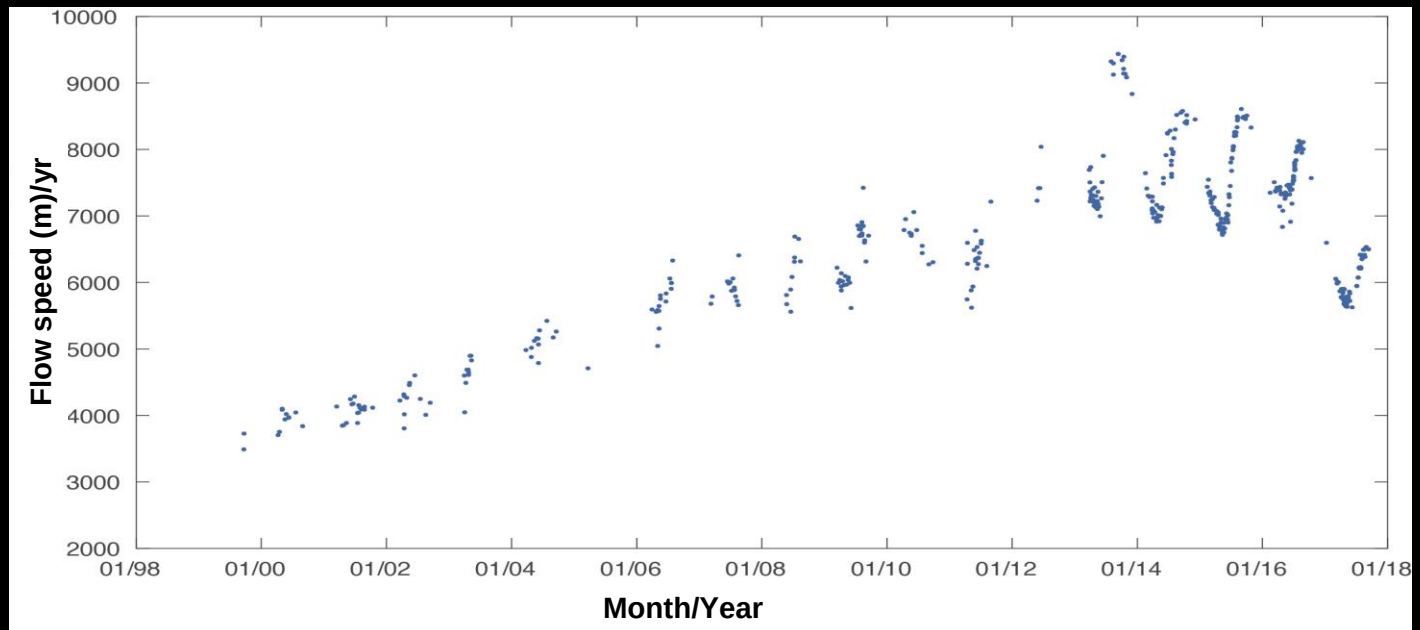
2017 - 2016



Surface △h (m):

Jakobshavn

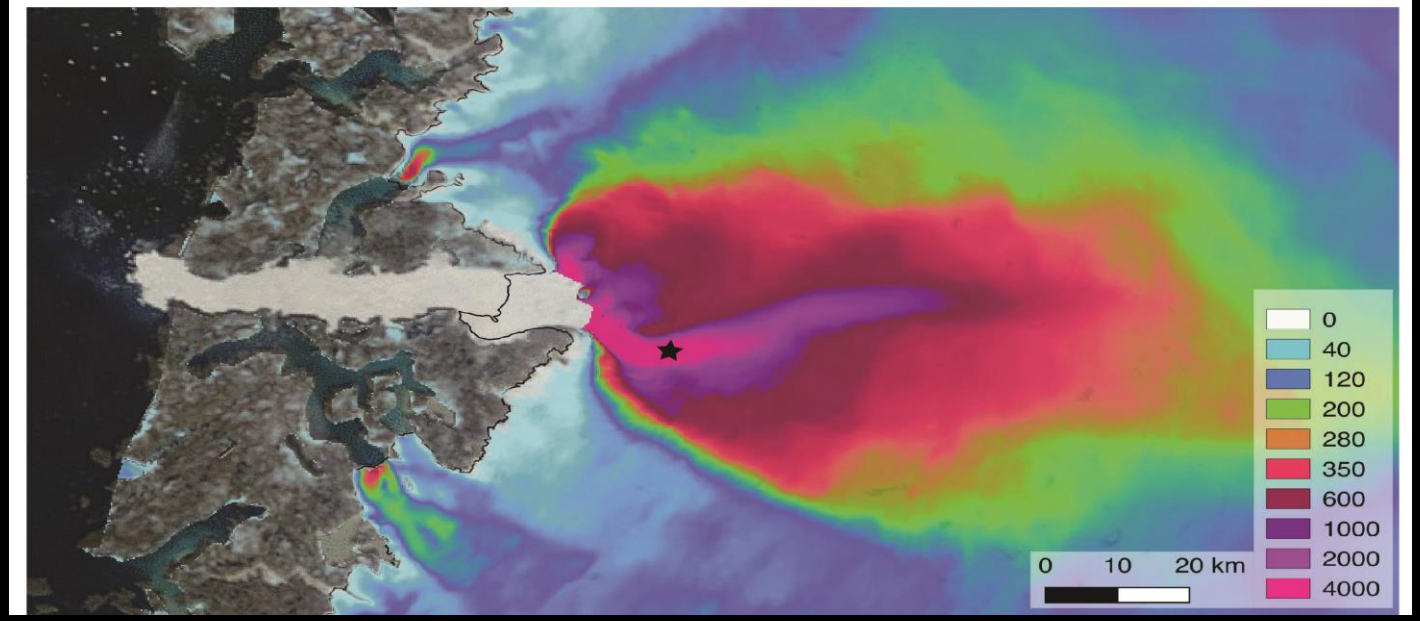
Flow Speeds: 2000 - 2016



Glacier flow has been slowing.

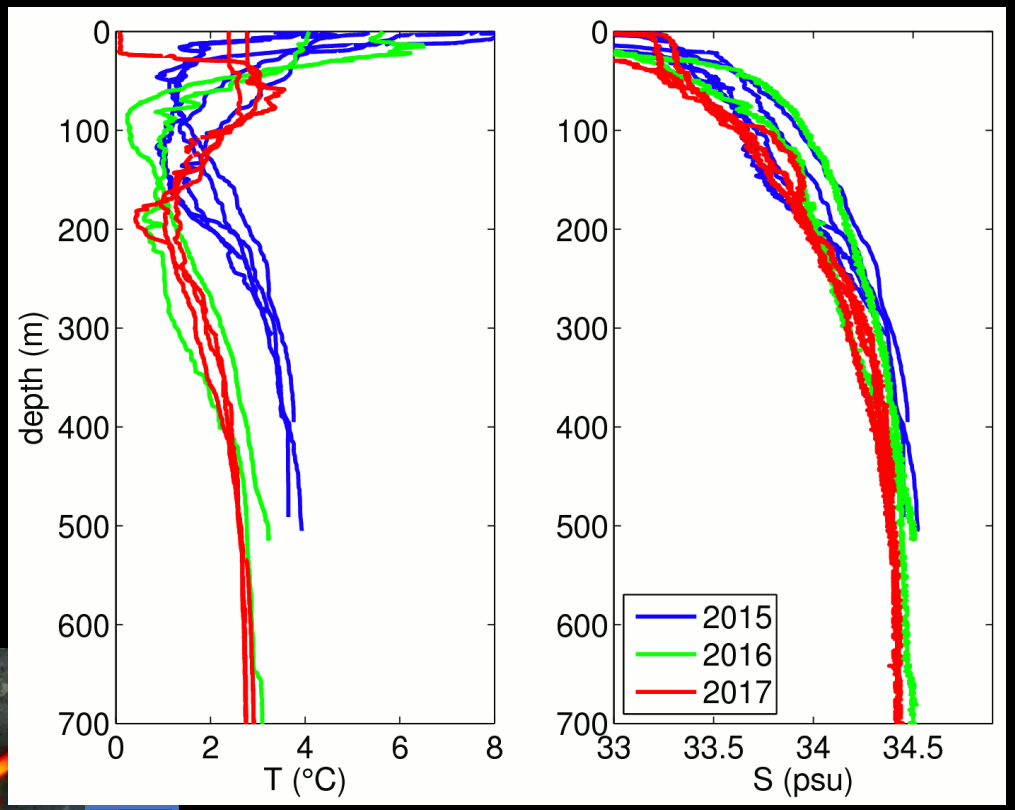
Measurements uncertainty: ±100 m/yr.

Velocities were generated from Landsat 4, 5, 7 and 8 imagery using JPL 's auto-RIFT (autonomous Repeat Image Feature Tracking).

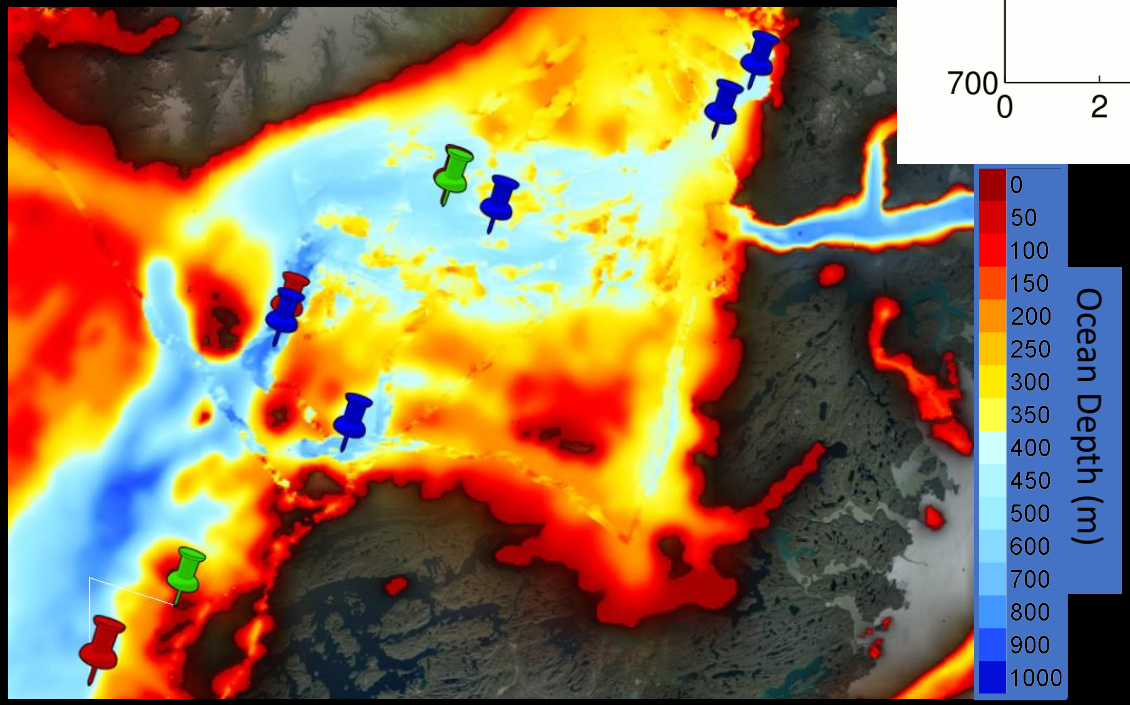


Jakobshavn

CTD data: 2015, 2016 and 2017



10 profiles with data from below 300 m in Disko bay during summers of 2015, 2016 and 2017.



Cooling of 1.5 to 2°C in Atlantic water between 2015 and 2017.

Summary and Conclusions

1. Jakobshavn : 15 to 20 m

2. Kangerlussuaq : -5 to -10 m

3. Koge Bugt : 20 to 30 m

5. Helheim : -10 m

6. Midgard : -20 to -25 m
(Eastern branch : -10 m)

7. Koge Bugt South: No clear change

9. Mogens South : -10 m

15. Mogens North : -20 to -30 m

>> Mogens Central : -15 to -20 m

>> Maelkevejen : -35 to -40 m

Summary and Conclusions

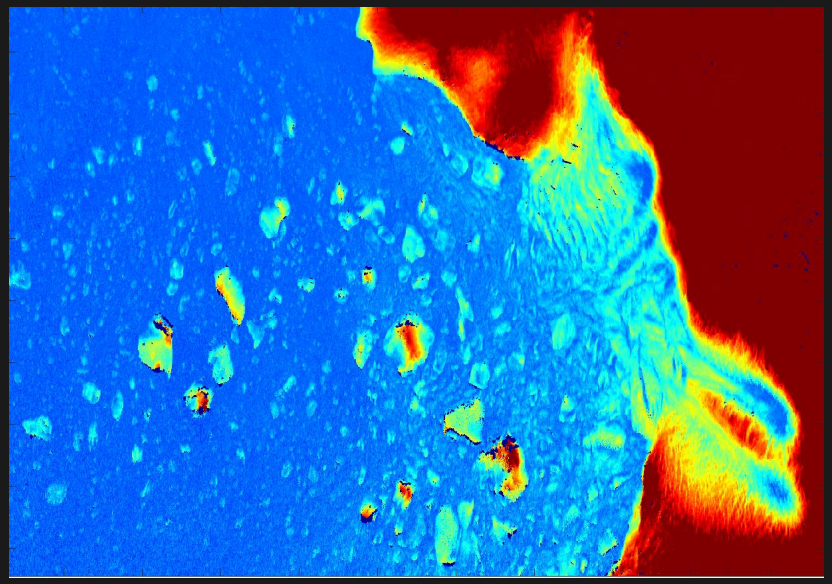
Jakobshavn might be entering a new regime of slower flow, increased volume, advancing front and cooler ocean conditions.

In the southeast, changes in glacier and ocean conditions are diverse.

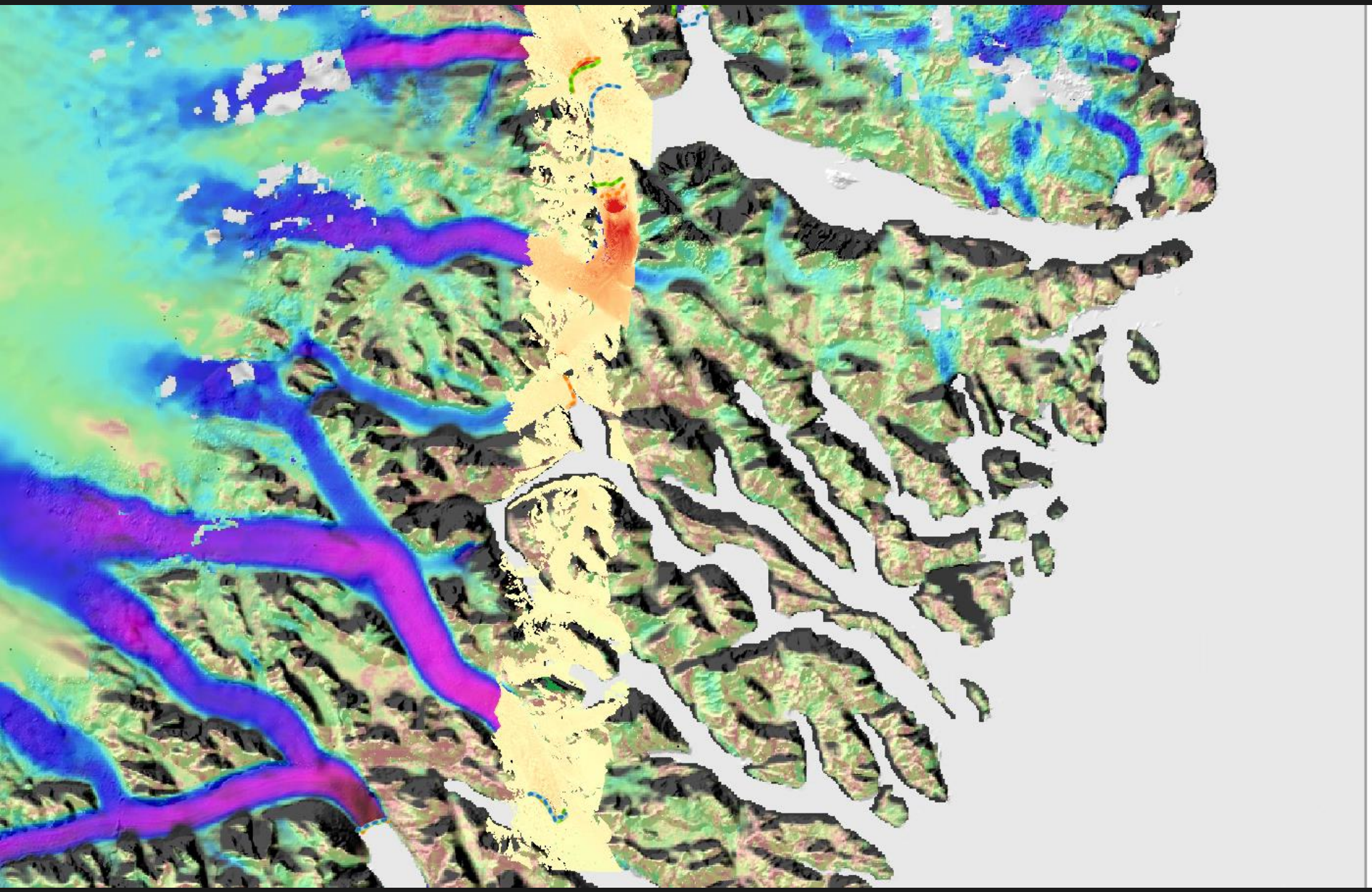
Wide-swath, high-resolution observations help interpretation and can constrain numerical models.

Simultaneous observations of ice and ocean conditions are providing valuable insights into observed changes.

Data are publically available at:
https://omg.jpl.nasa.gov/portal/browse/

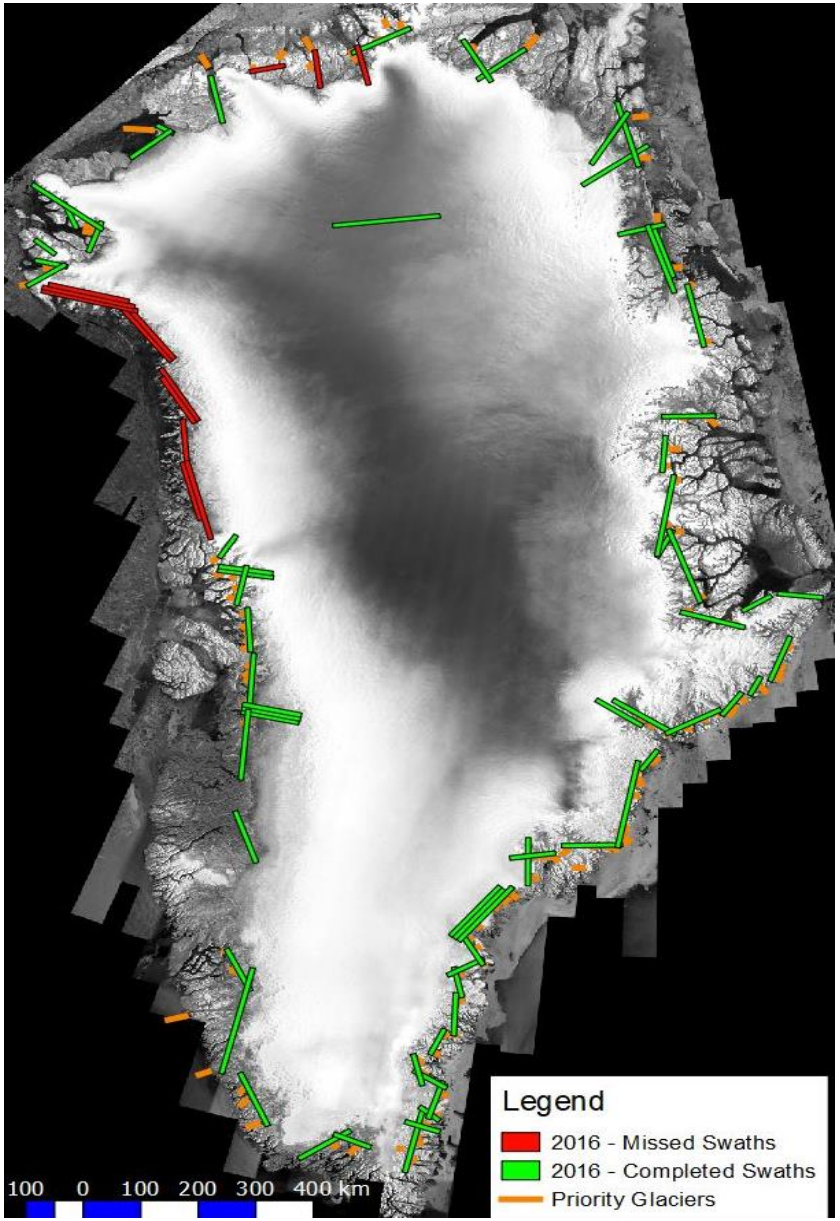


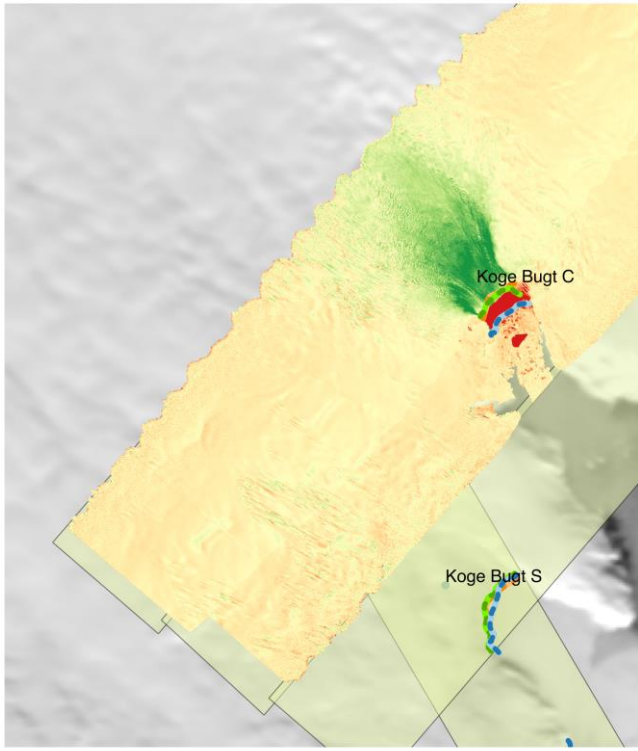
Maelkevejen



Fronts: 2001 2012/2013 2015

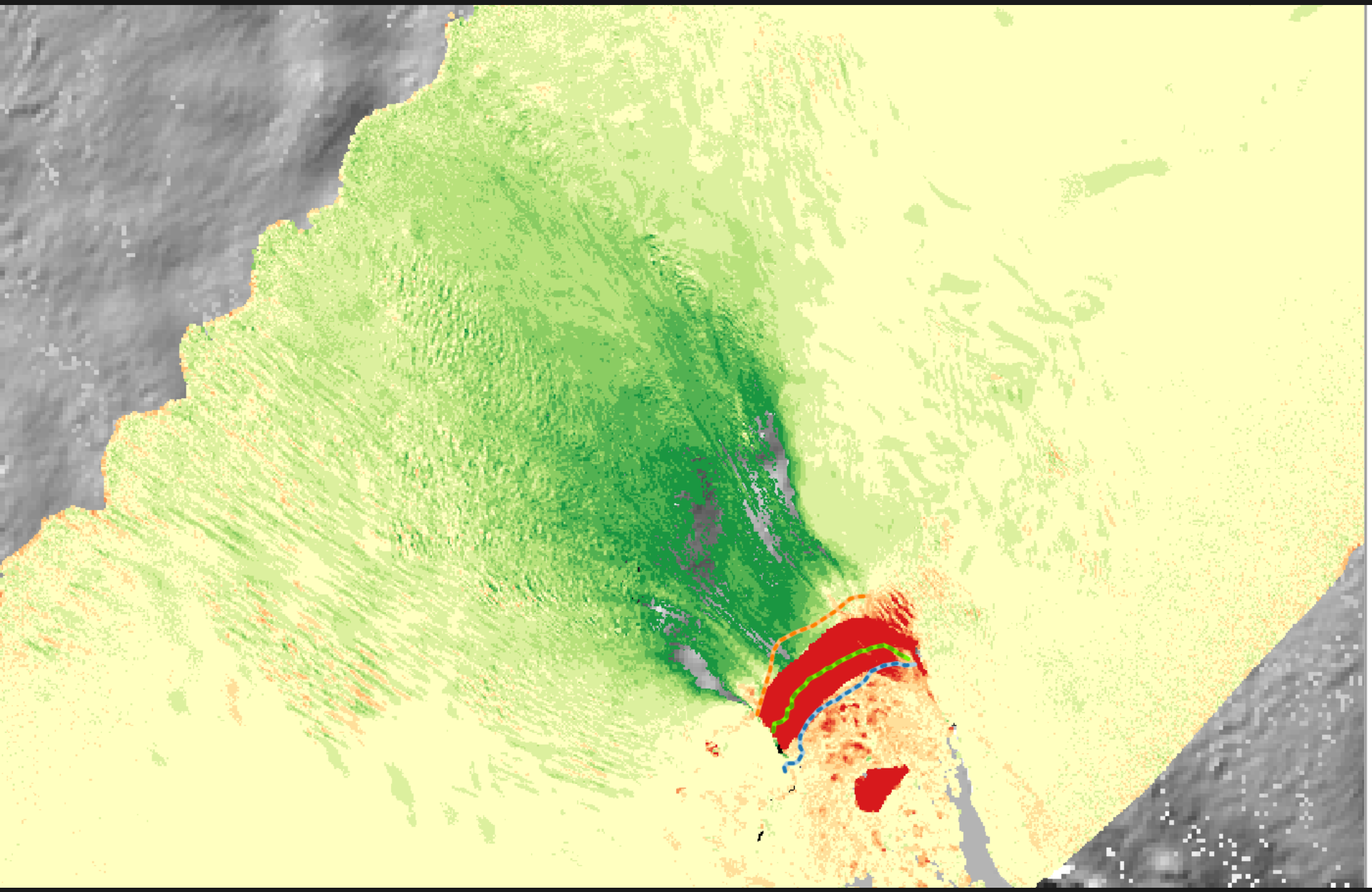
Surface △h (m): -50 -40 -30 -20 -10 0 10 20 30 40 50


Legend
2016 - Missed Swaths
2016 - Completed Swaths
Priority Glaciers
100 0 100 200 300 400 km


Koge Bugt C
Koge Bugt S

Koge Bugt

2017 - 2016



Fronts: 2001 2012/2013 2015

Surface △h (m): -30 -24 -18 -12 -6 0 6 12 18 24 30

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