CASSANDRA - Accelerating mass loss of Greenland: firn and the shifting runoff limit

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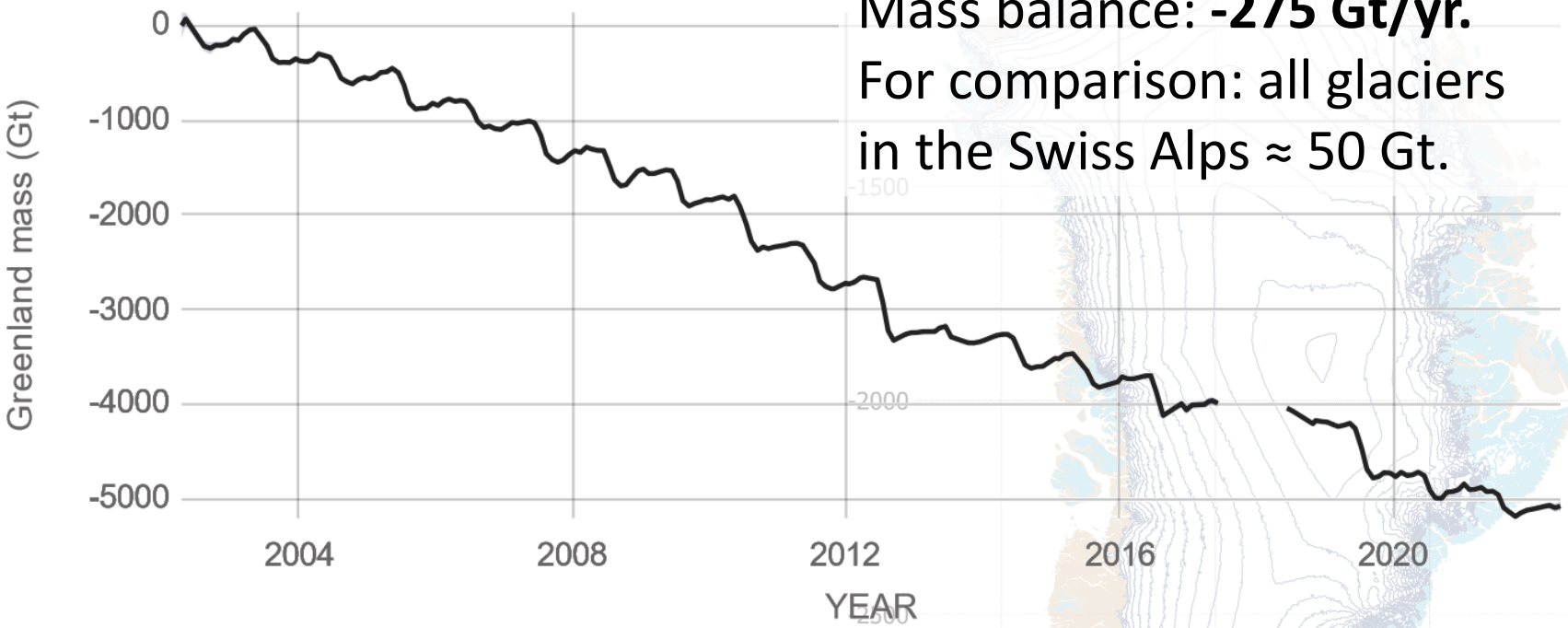
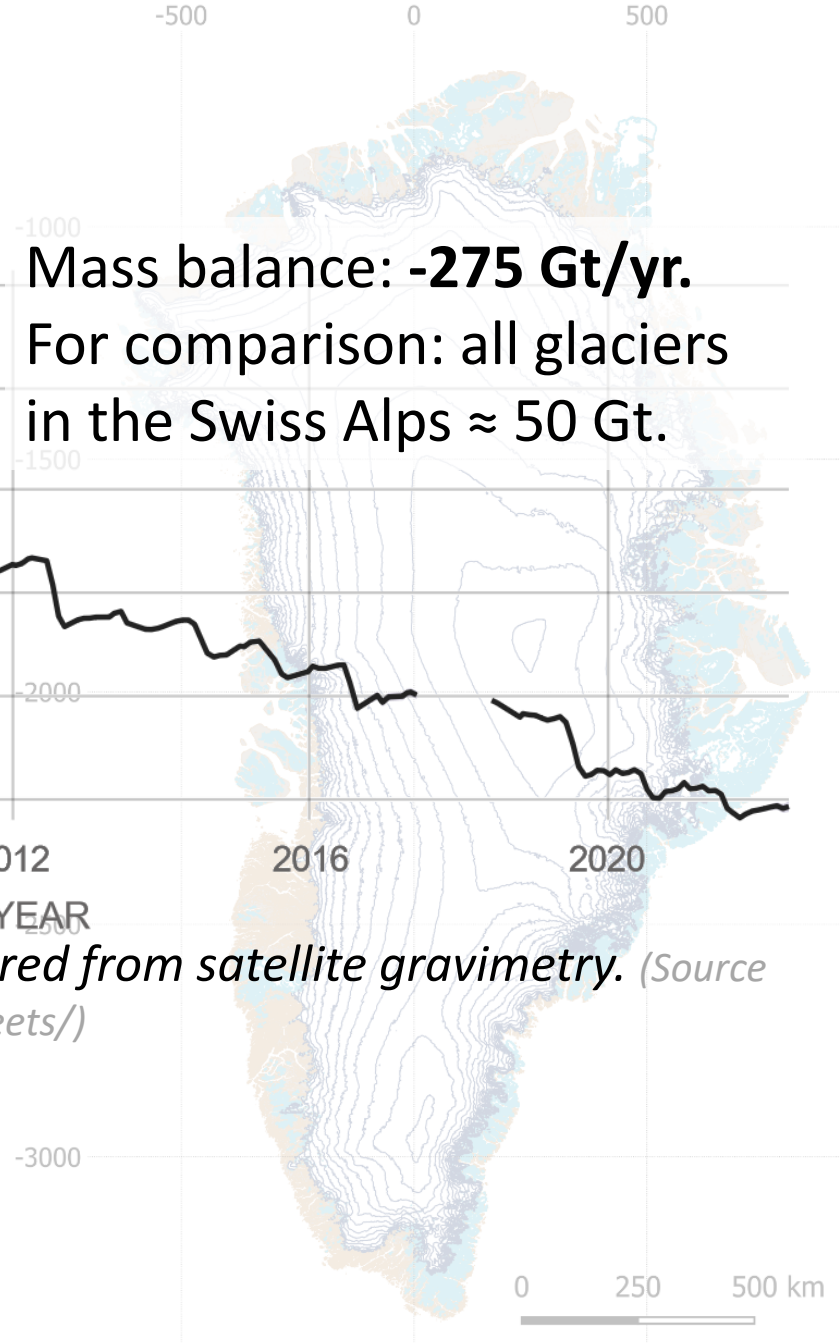
Background | Greenland mass balance



Mass balance: **-275 Gt/yr.**
For comparison: all glaciers in the Swiss Alps ≈ 50 Gt.

Total mass balance Greenland as measured from satellite gravimetry. *(Source NASA: https://climate.nasa.gov/vital-signs/ice-sheets/)*



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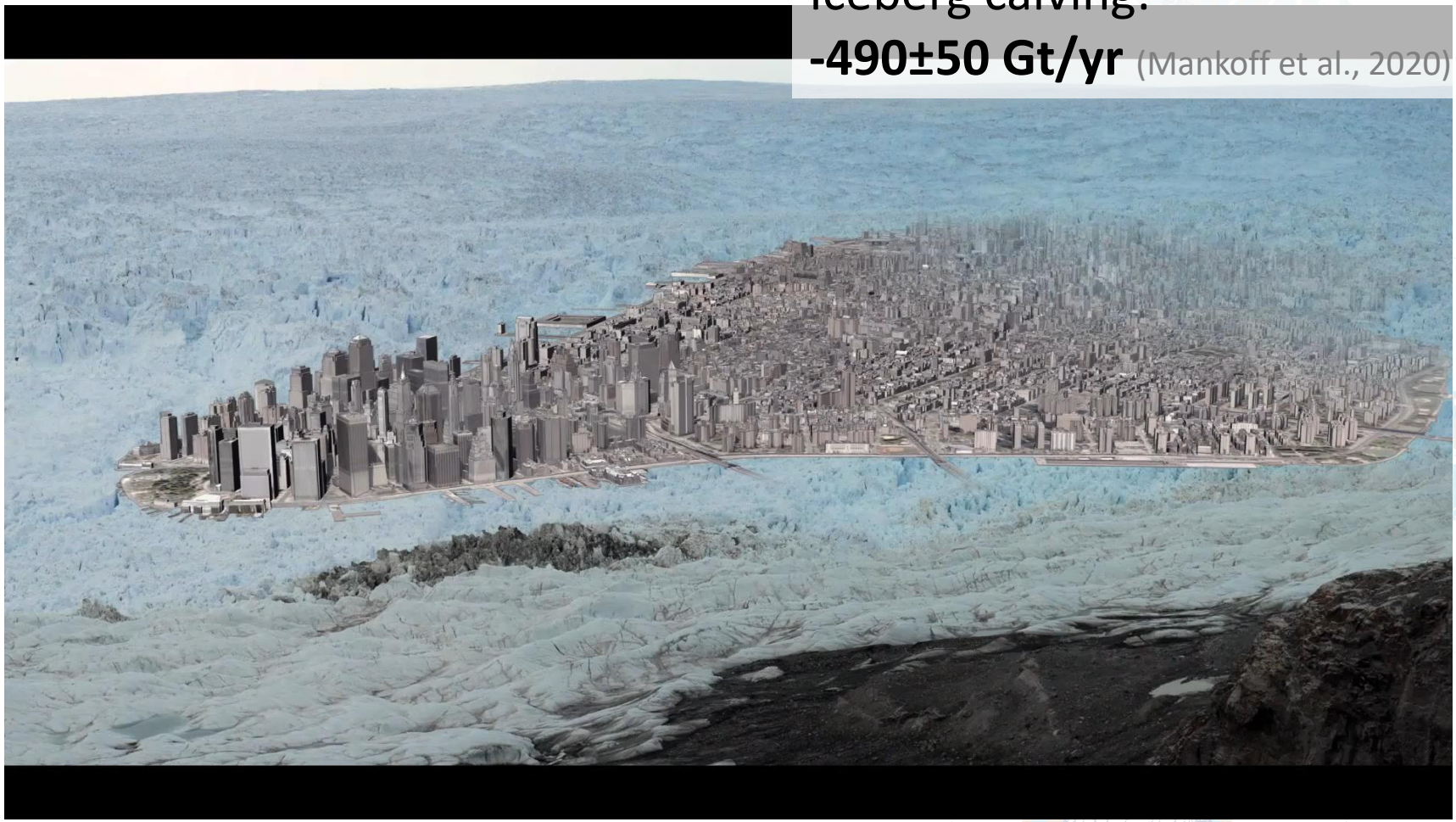
Background | Mass fluxes

Snowfall:
+690±85 Gt/yr (Imbie Team, 2020)

Blizzard on the Greenland ice sheet.

Background | Mass fluxes

Iceberg calving:
-490±50 Gt/yr (Mankoff et al., 2020)

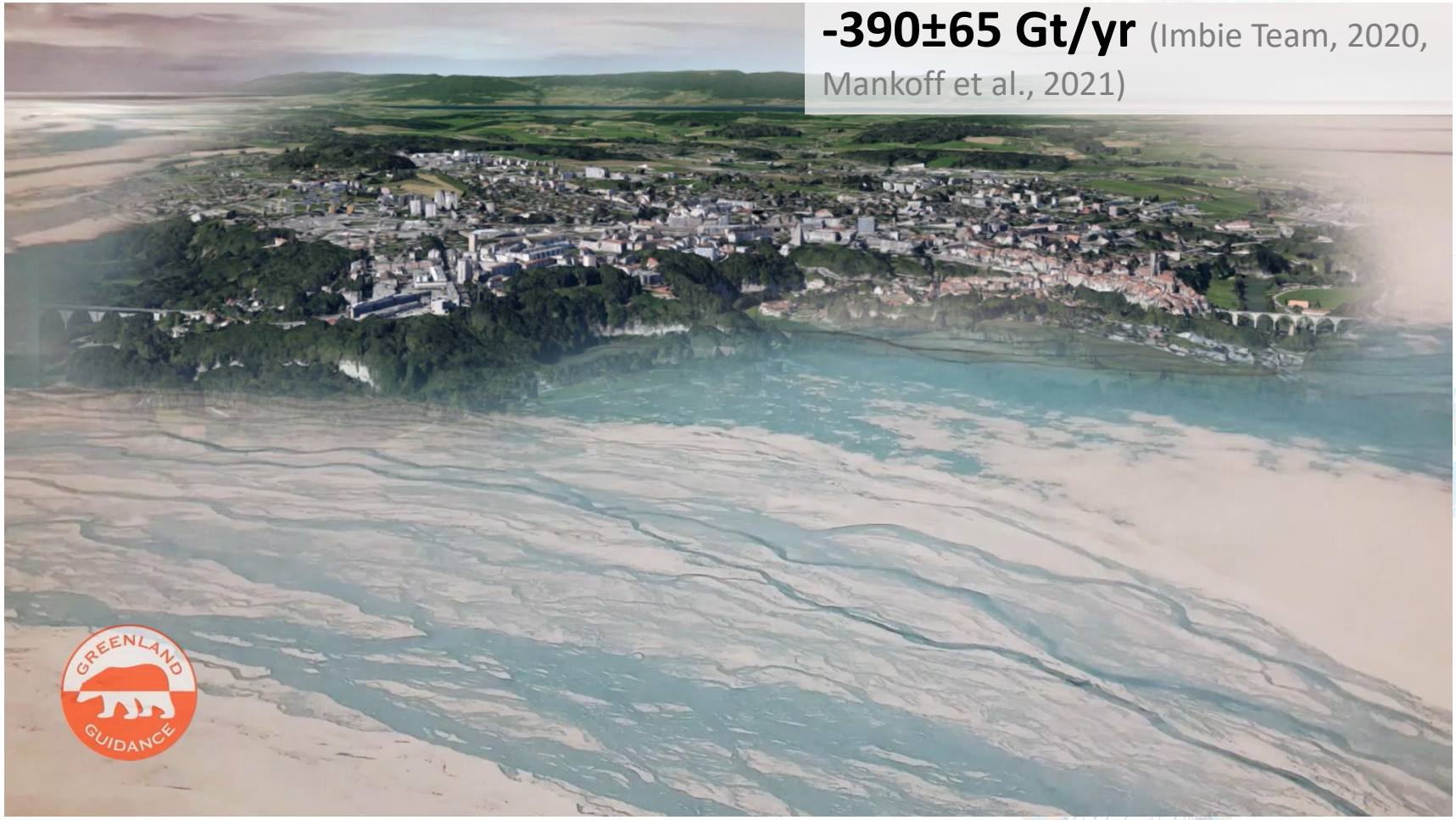


Calving event at Sermeq Kujalleq (Jakobshavn Isbræ) *(Source: Extreme Ice Survey, Chasing Ice)*

Background | Mass fluxes

Meltwater runoff:

-390±65 Gt/yr (Imbie Team, 2020, Mankoff et al., 2021)



Meltwater on the ice sheet surface, 19 August 2021 at ~1740 m a.s.l. 67.0091 / -47.3019 *(Source: Dirk van As, Greenland Guidance)*

Background | Annual mass balance (2010-2021)

Satellite gravimetry: **-274 Gt/yr**

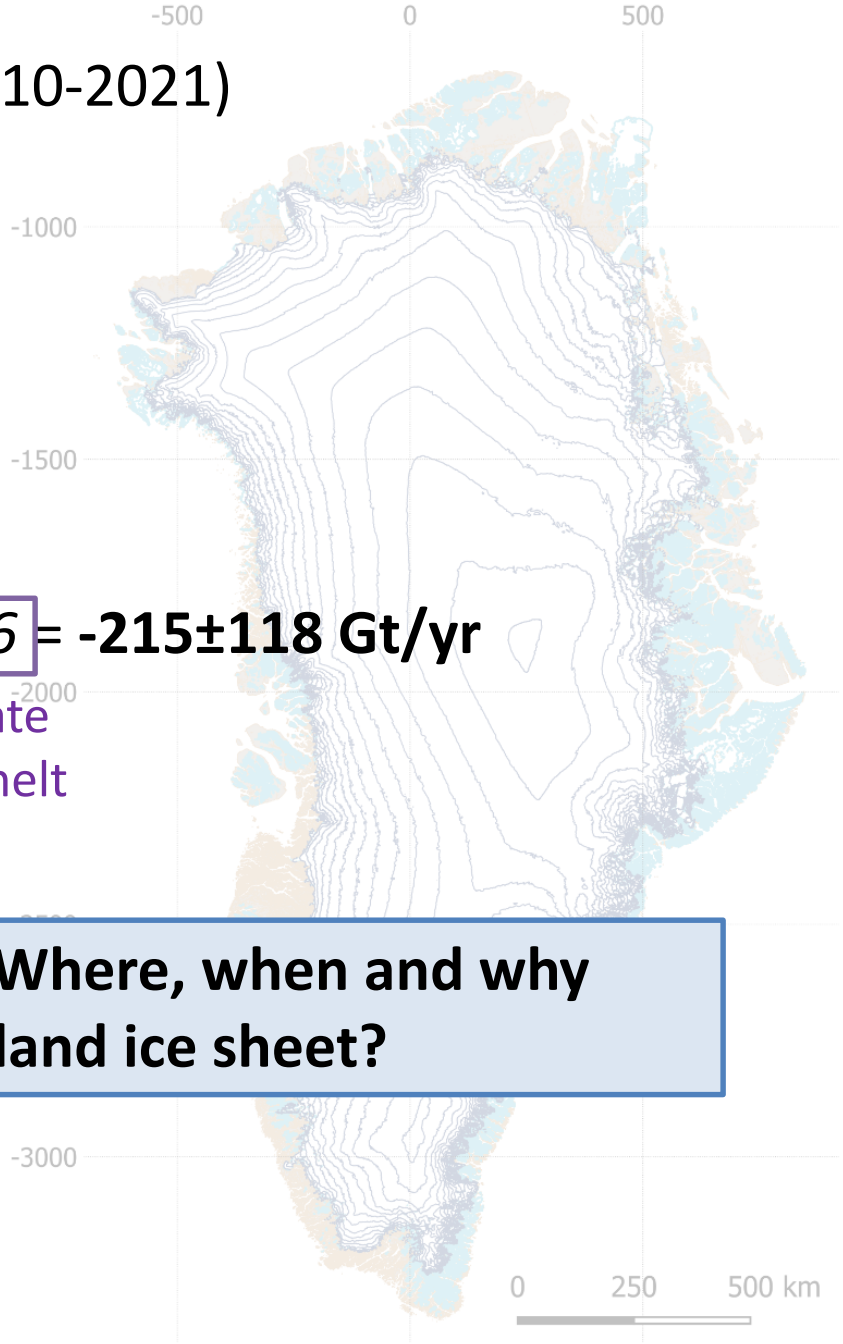
≈measured mass balance

Based on mass fluxes:

690±85 - 490±50 - 390±65 - *25±6* = **-215±118 Gt/yr**

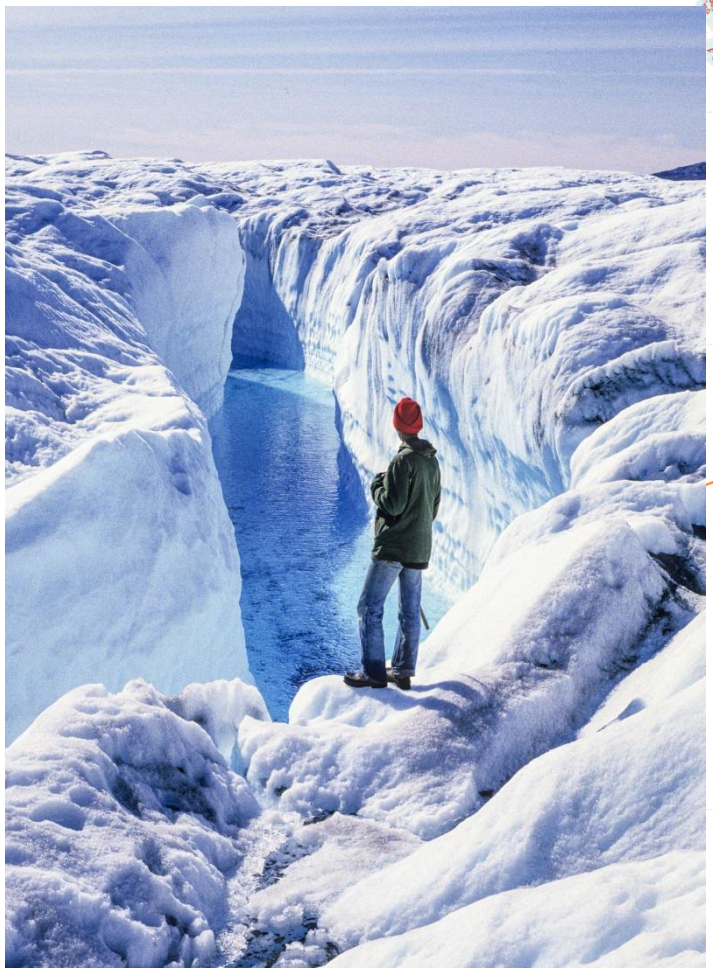
modelled snowfall | ≈measured calving | modelled runoff | estimate basal melt

CASSANDRA focuses on runoff: Where, when and why takes runoff place on the Greenland ice sheet?

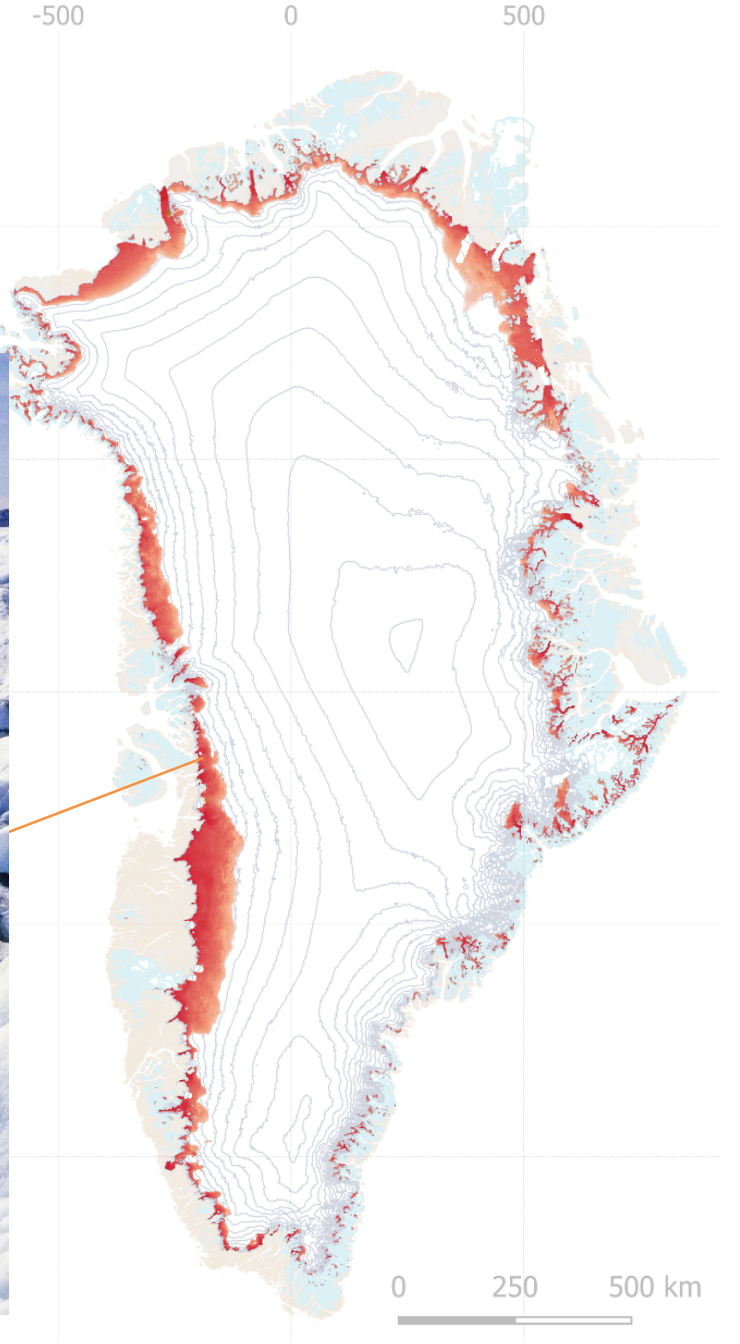


Background | Meltwater

Runoff is meltwater. An estimated 60 % of melt runs off.

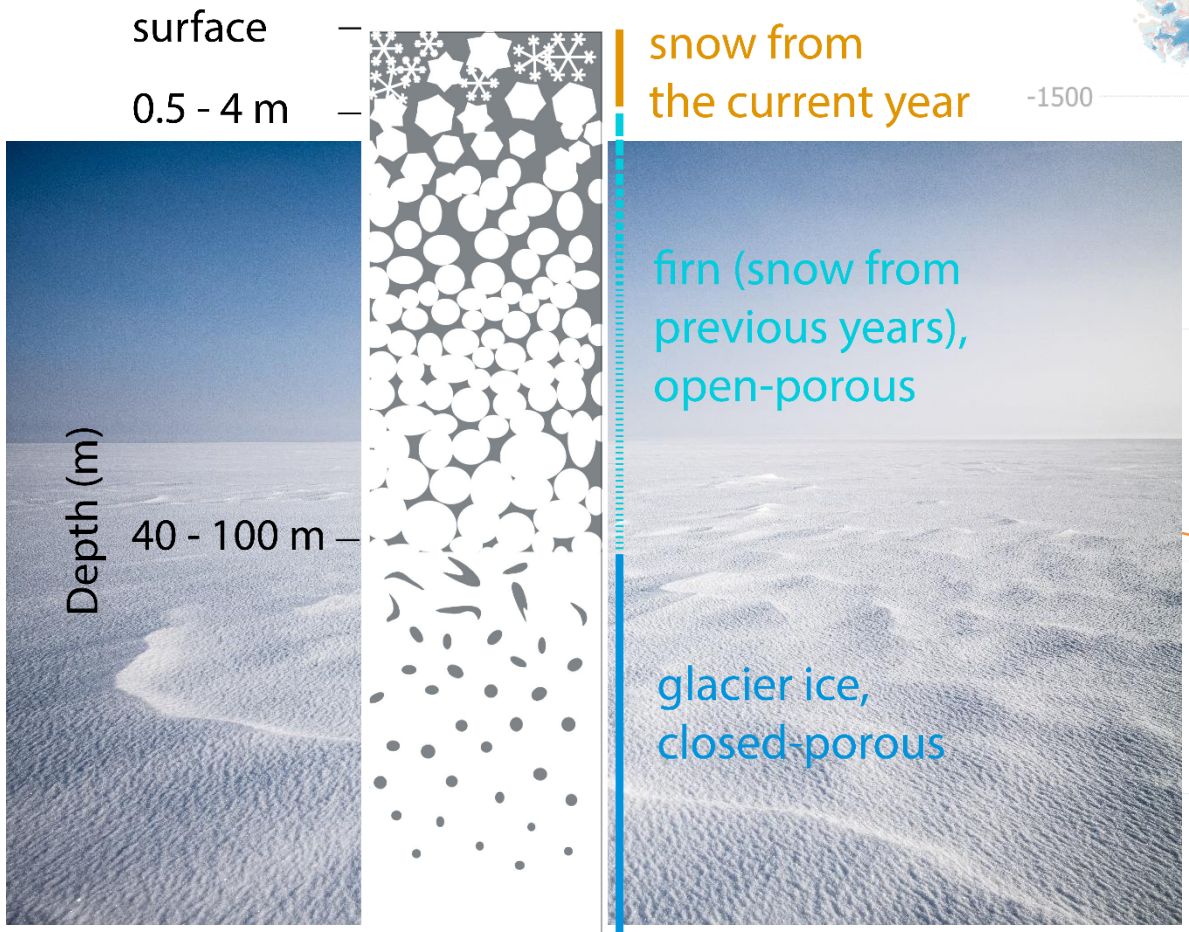


Ablation area of the ice sheet (Niels Reeh at Paakitsoq, 1985) *Photo: Henrik H. Thomsen*



Background | Meltwater

The Greenland firn area is a porous sponge where meltwater percolates and refreezes



Firn area (or accumulation area) of the Greenland ice sheet

Project aim

How can the area of surface runoff expand; by which physical processes?

Will the percentage of meltwater retention change in a warming climate?

Remote sensing: ***Track surface runoff*** *over the entire ice sheet and satellite-era*

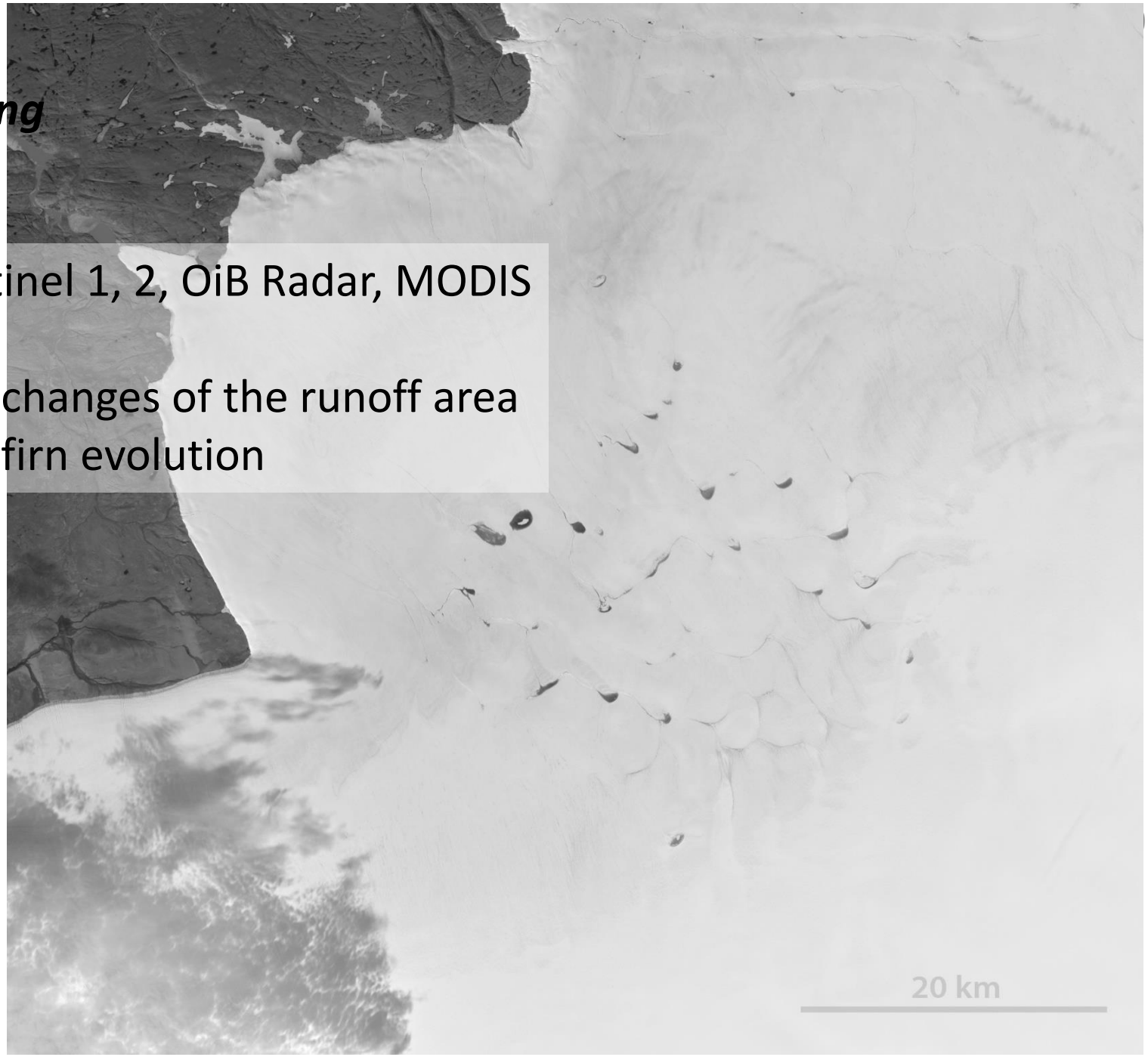
Fieldwork: ***Measure the hydrology of meltwater in firn***

Model meltwater runoff *in context of firn changes + ice dynamics*

Remote sensing

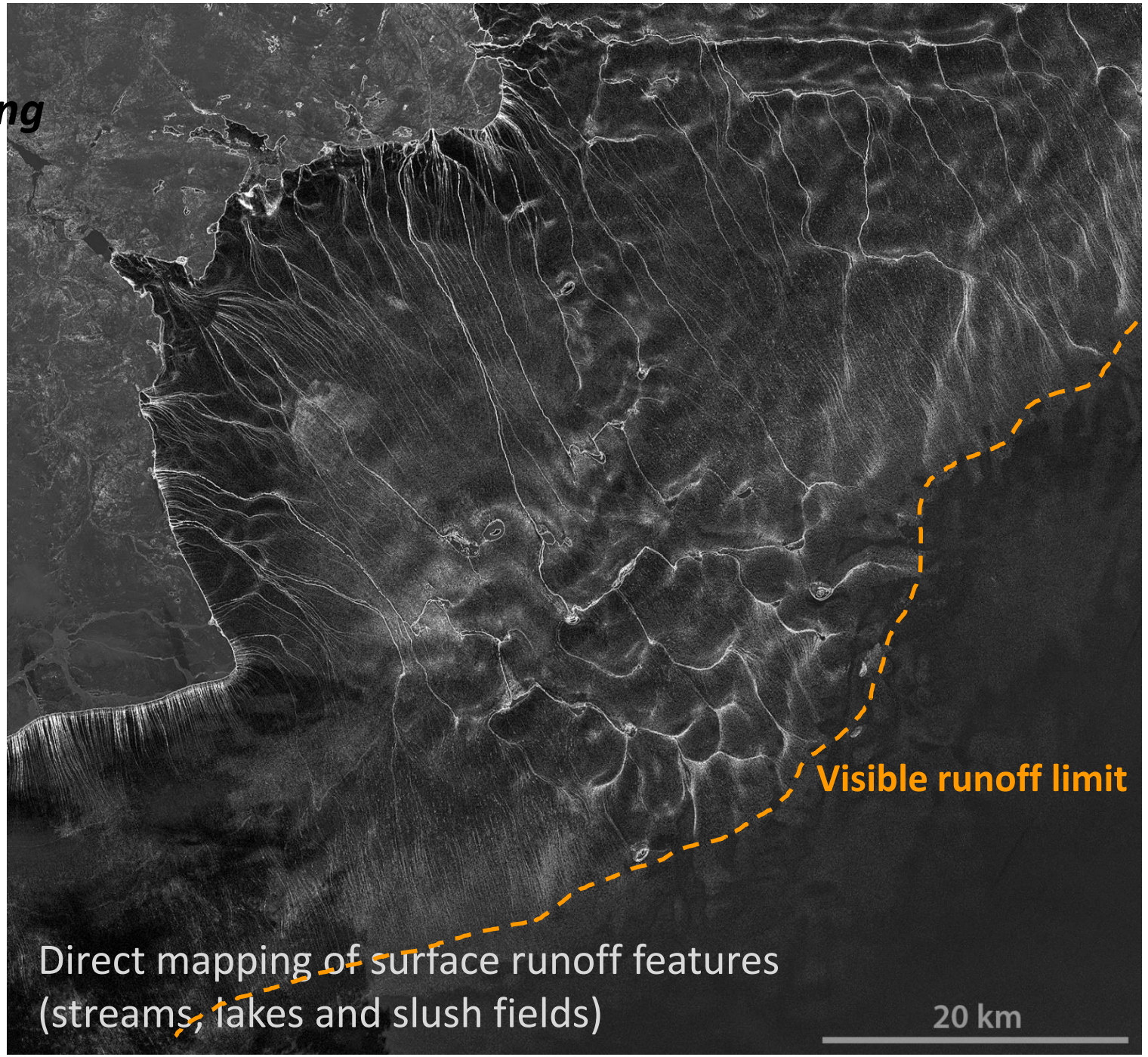
Landsat, Sentinel 1, 2, OiB Radar, MODIS

- Long-term changes of the runoff area
- Long-term firn evolution



Unprocessed Sentinel-2 image (band 4) Greenland ice sheet margin, Northwest Greenland.

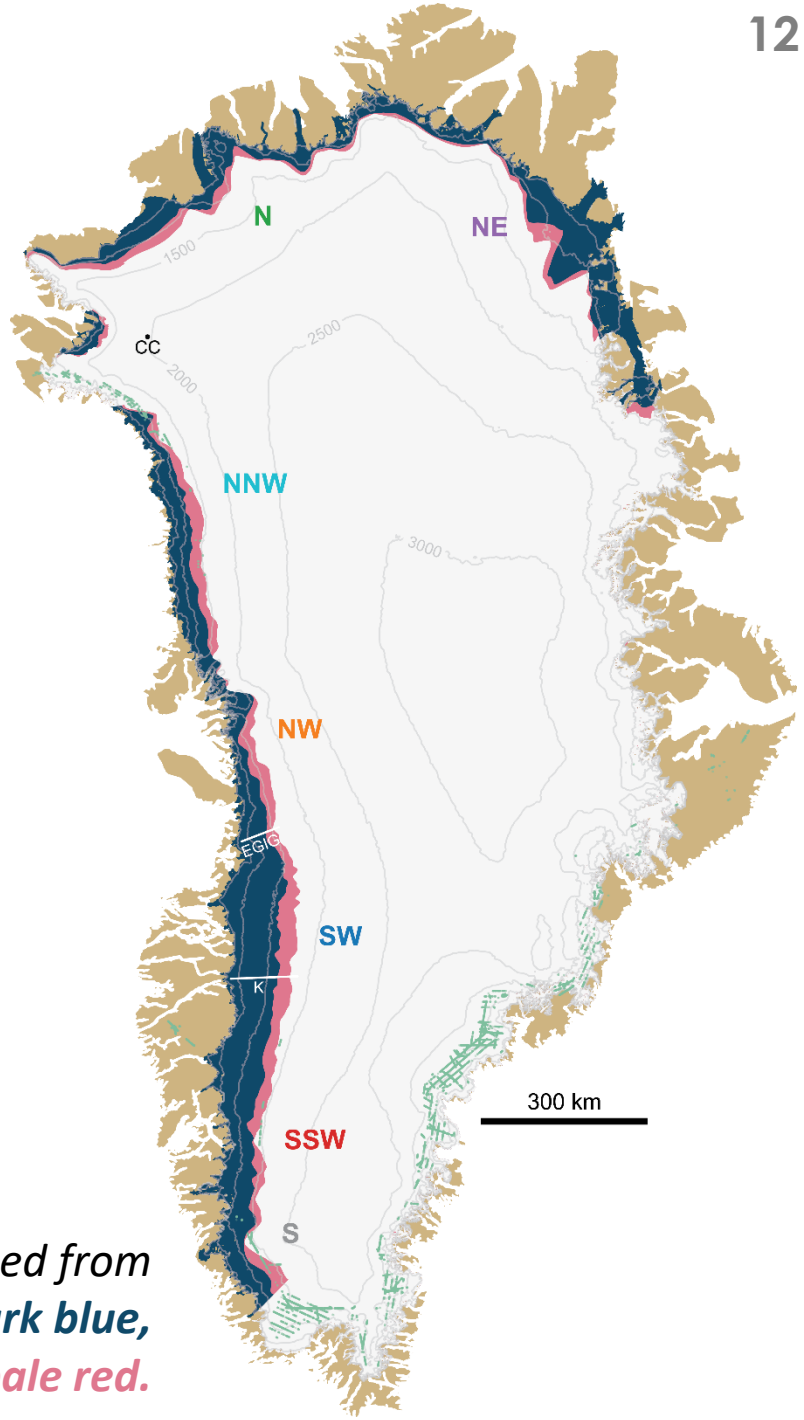
Remote sensing



Gabor filtered (Yang et al., 2015) Sentinel-2 image highlighting melt rivers on the Greenland ice sheet, Northwest Greenland.

Remote sensing

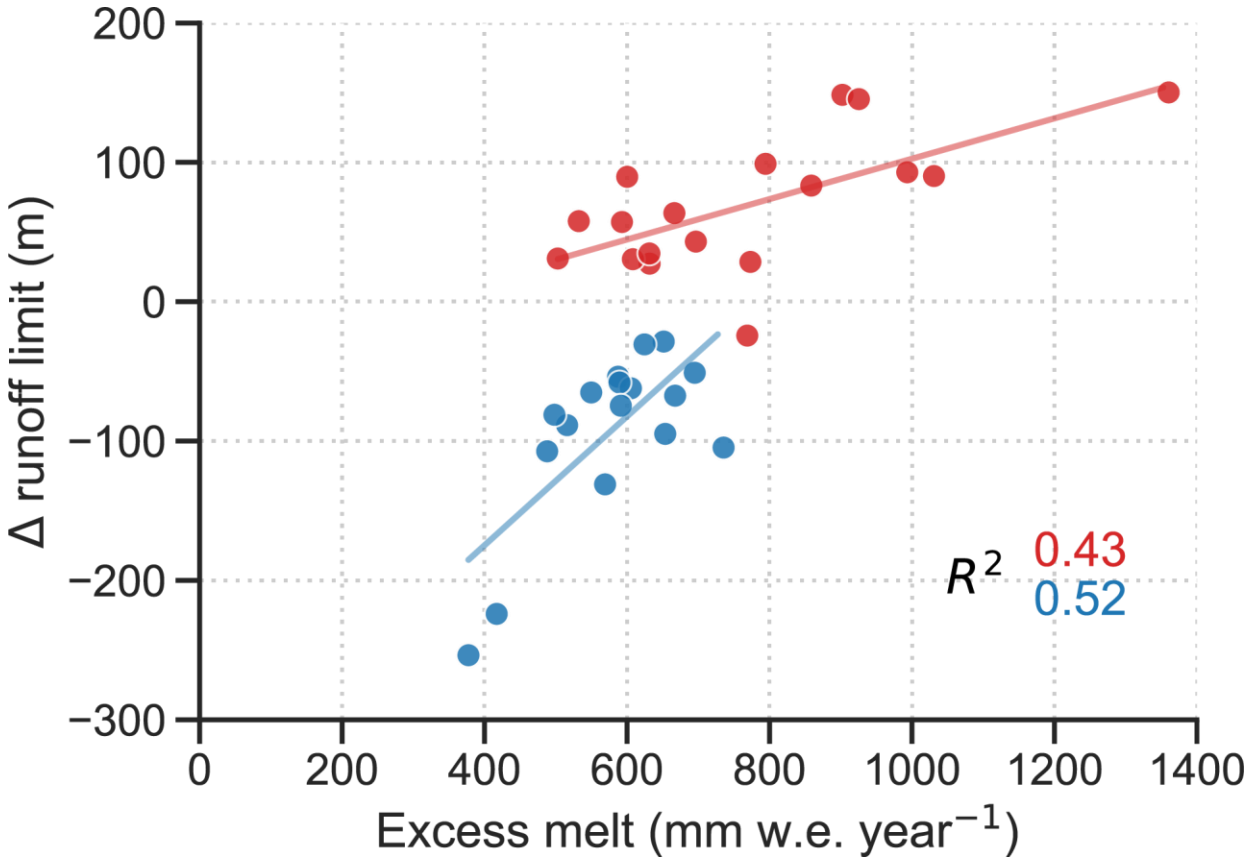
- Analysed **>25’000 Landsat scenes** (1985 to present) for surface hydrological features
- **Visible runoff area** of the ice sheet **expanded by ~29%** (1985-1992 vs. 2013-2020)



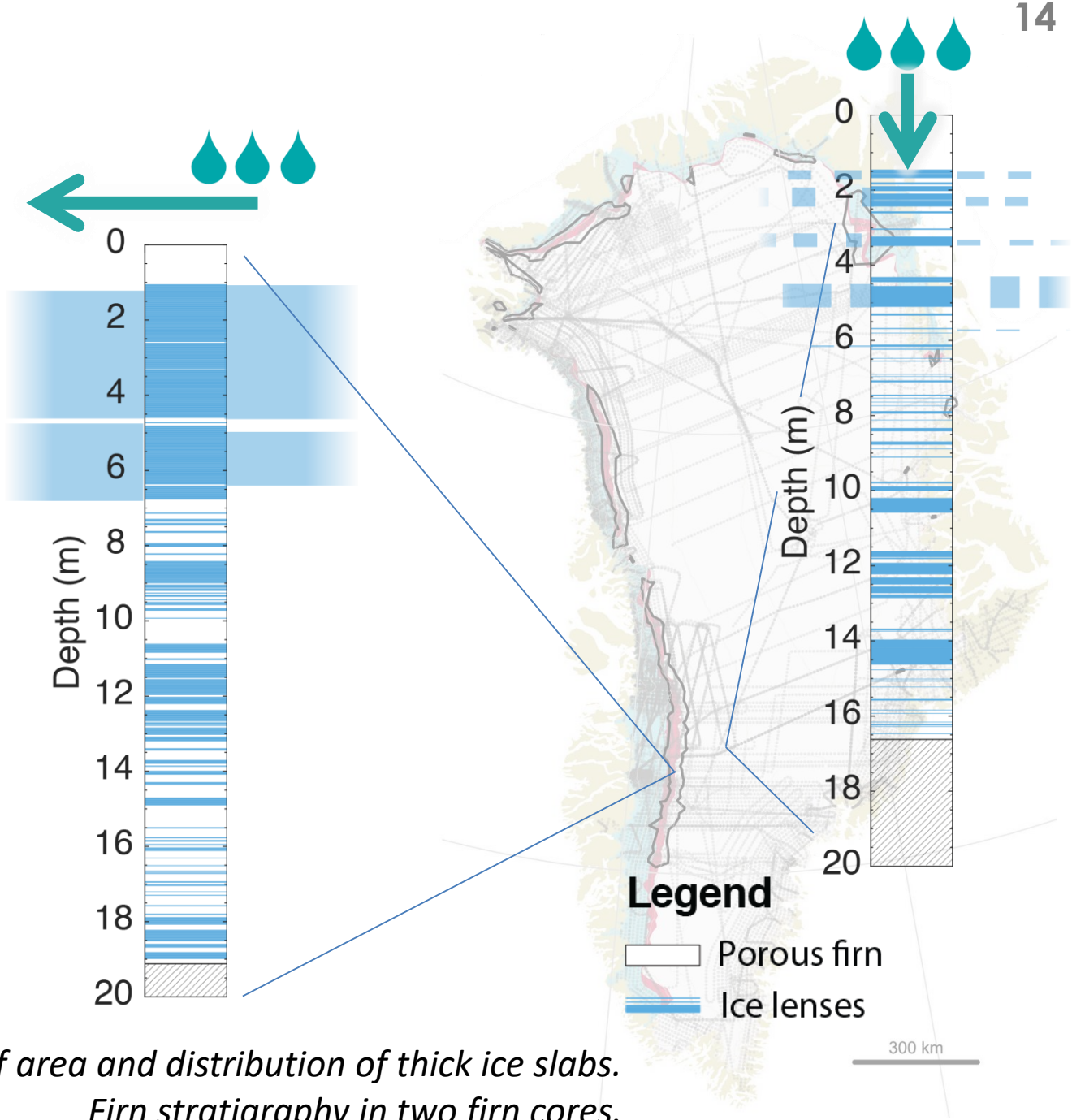
*Extent of visible surface runoff, as mapped from Landsat: Runoff area **1985-1992 in dark blue,** additional runoff area **2013-2020 in pale red.***

Remote sensing

*Relationship between annual excess melt (≈melt intensity) and annual Δ runoff limit. The latter denotes the deviation from the 1985 to 2020 average Greenland runoff limit. Linear regressions calculated for **1985-2003** and **2004-2020.***



Remote Sensing



Newly formed runoff area and distribution of thick ice slabs.
Firn stratigraphy in two firn cores.

Fieldwork

Cover of Greenland's "Motoori" magazine, June 2021 issue, showing our snowmobiles being slung off the ice sheet. *The title reads "equipment for researchers".*

Fieldwork

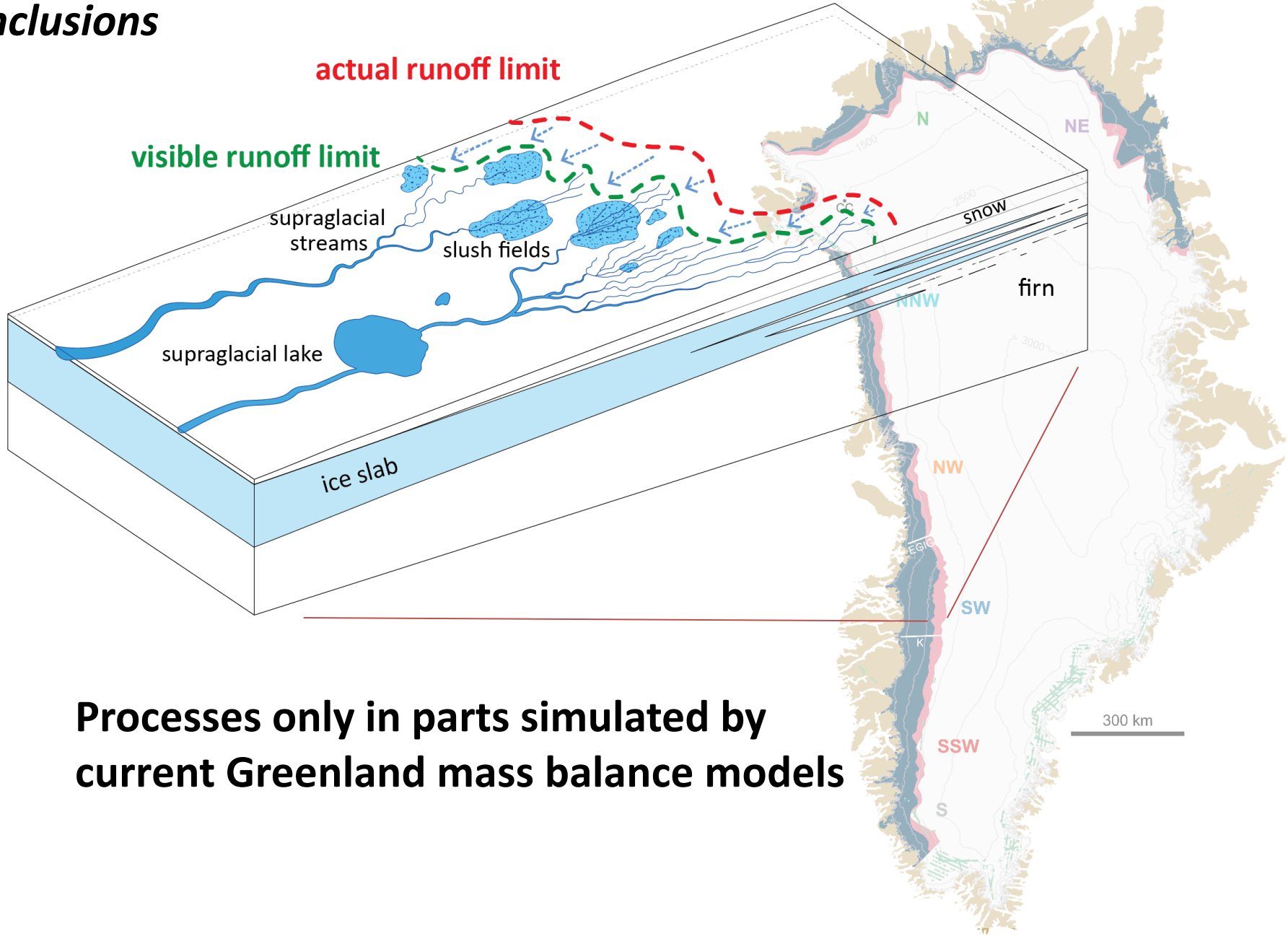
Snowpit on July 29 2020, 1760 m a.s.l.
Depth of pit 62 cm, thereof 42 cm water filled.

Fieldwork

- Meltwater percolates laterally inside the snow, directly on top of the ice slab, **at 7±3 m/hr.**

July 21 2020, 1760 m a.s.l.: *salt-dilution experiment to measure velocity at which water flows laterally through saturated snow matrix.*

Conclusions



Processes only in parts simulated by current Greenland mass balance models

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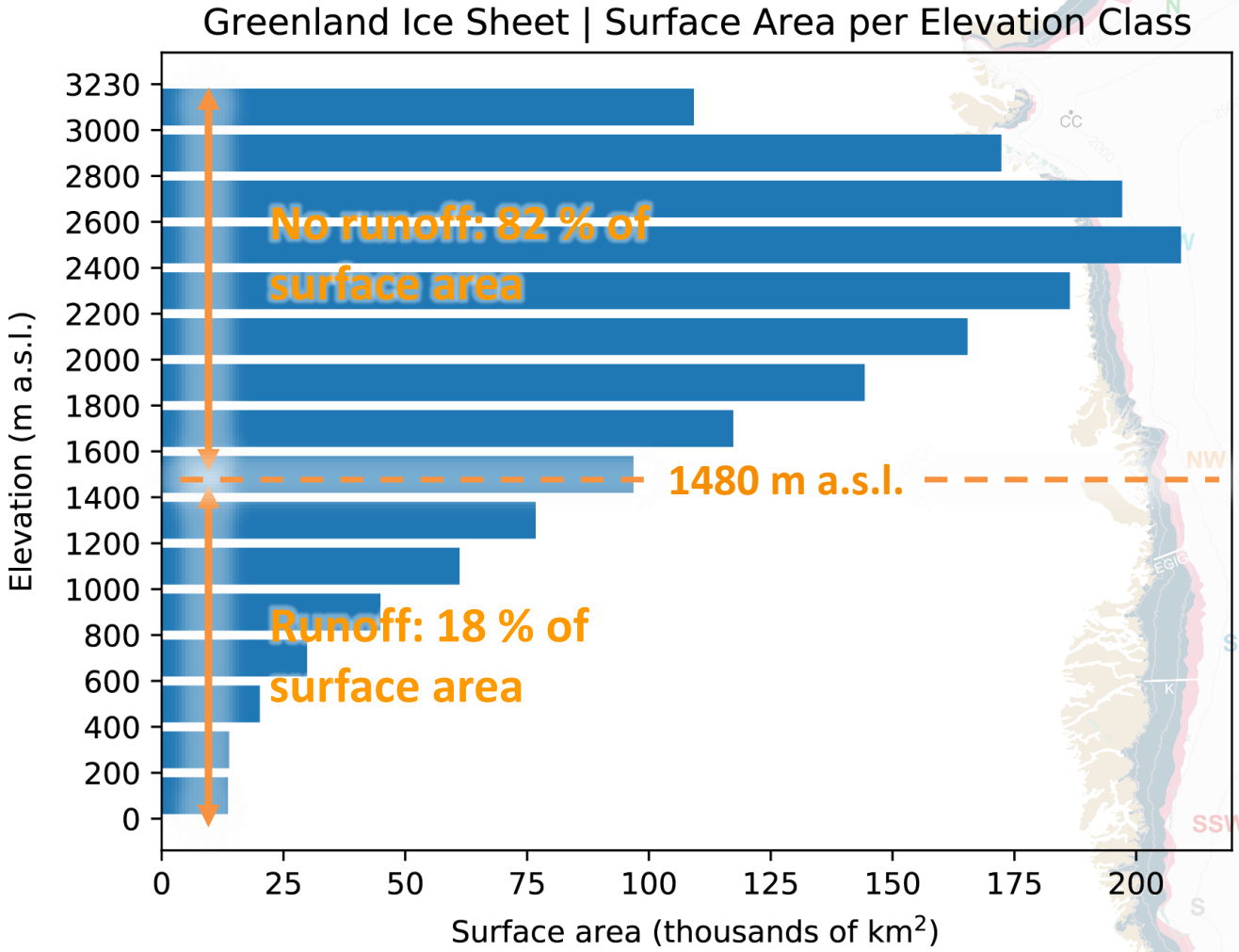
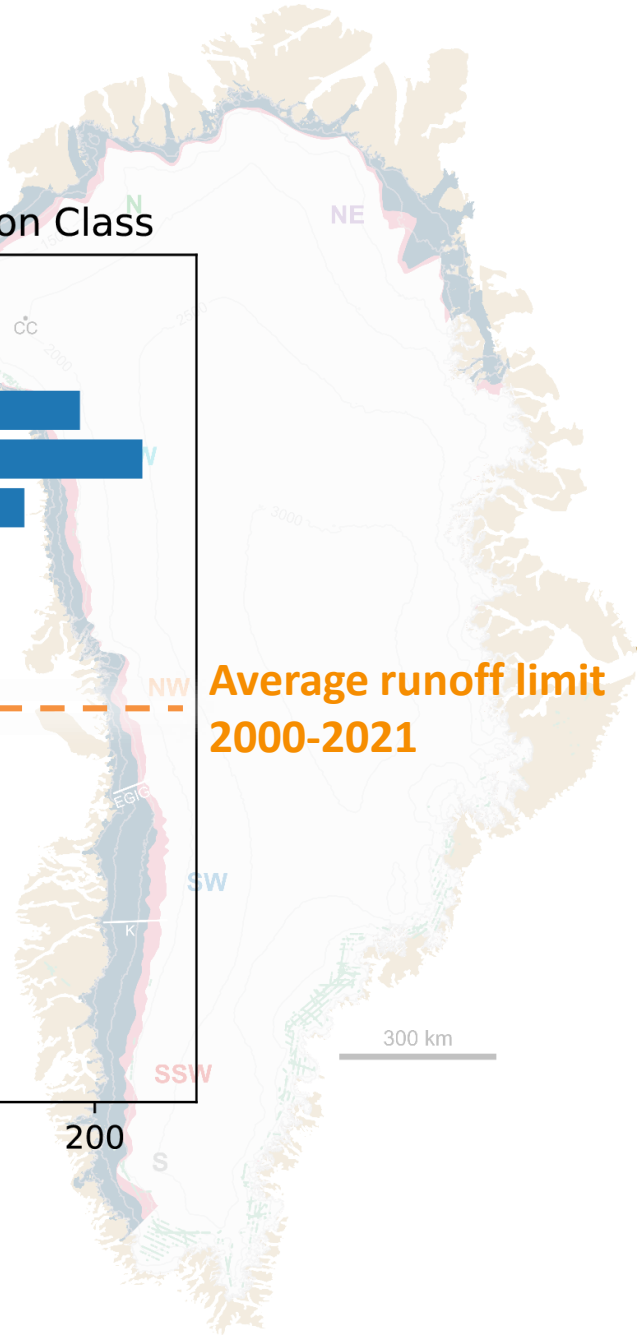
Conclusions



















Dan Trailers



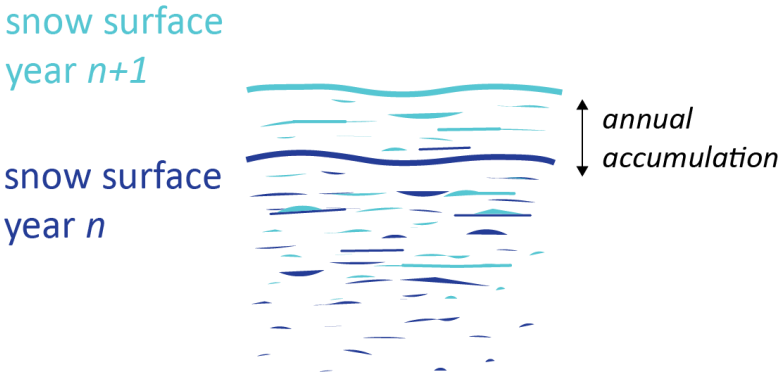





Thank You!

Appendix

Western slope of the ice sheet: *low* annual accumulation



Eastern slope of the ice sheet: *high* annual accumulation