Svalbard glacier change

Jack Kohler
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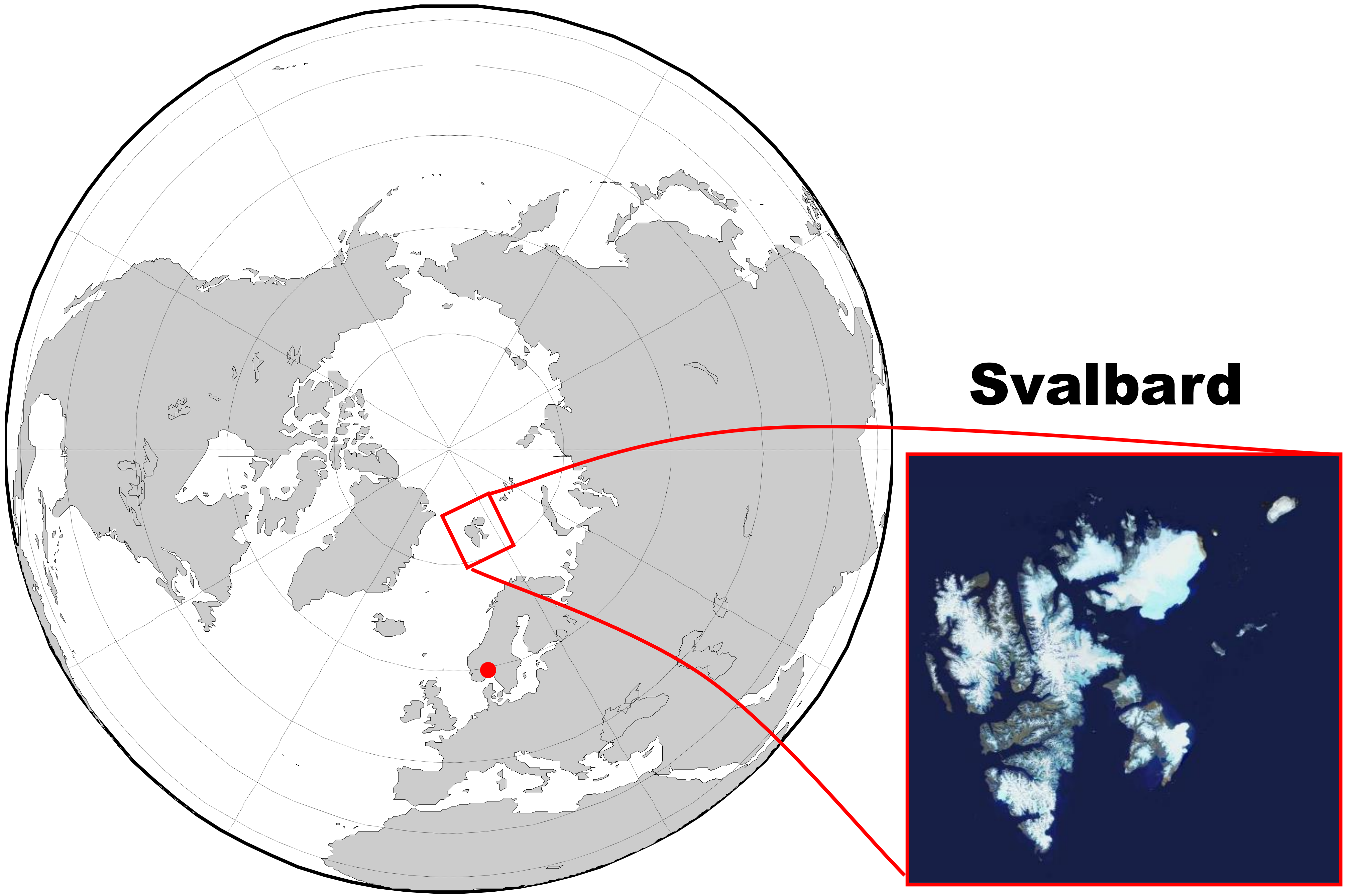
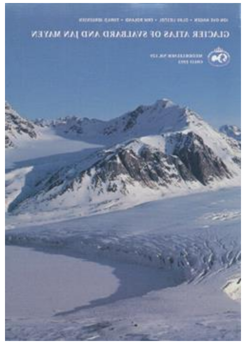

Svalbard

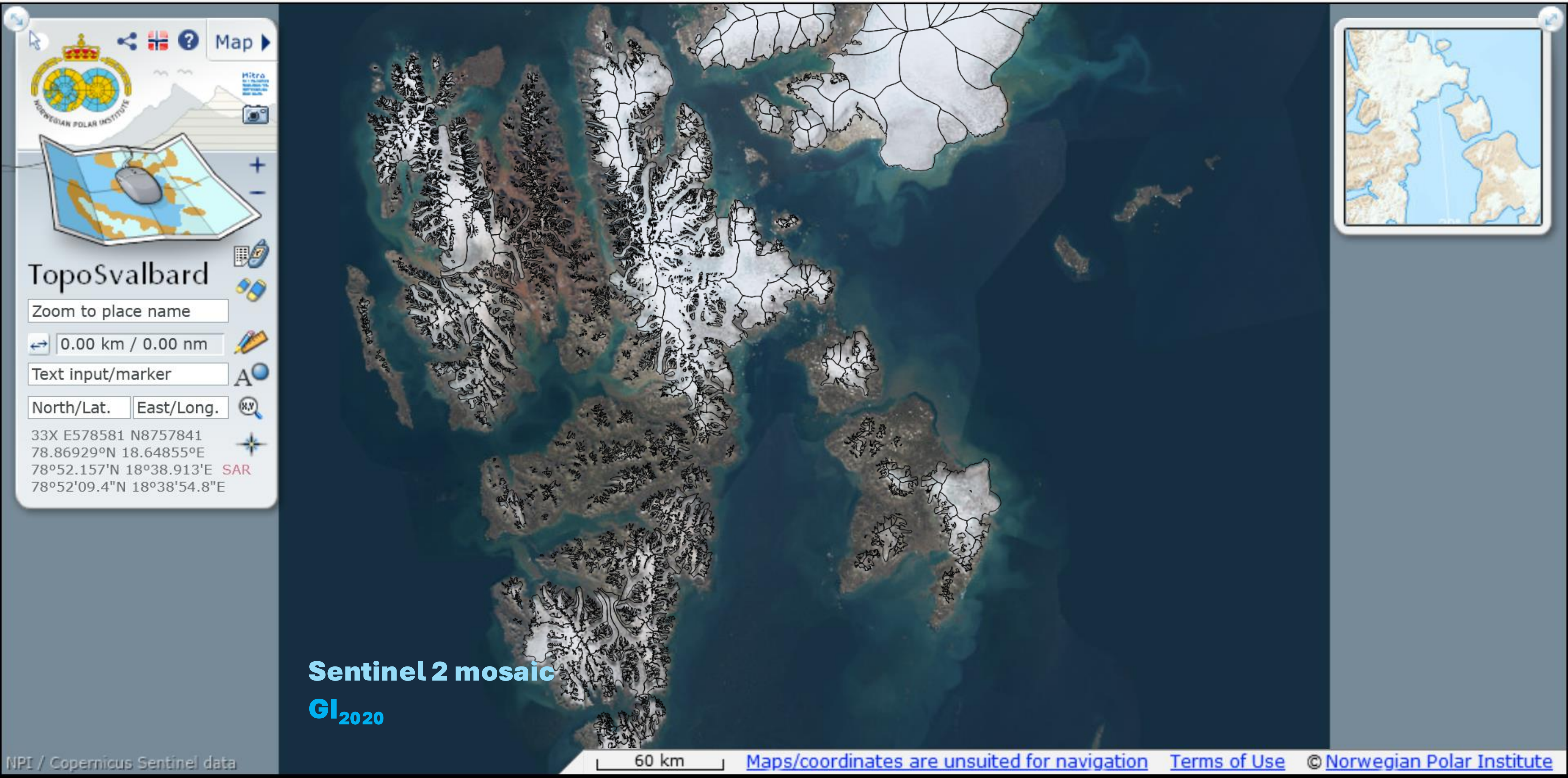
Svalbard

- Total area ~60,000 km^2
- "60%" glacier-covered
- Valley glaciers, tidewater glaciers, ice caps
- No ice shelves
- Thickest ice ~650 m

Glacier area change

Glacier Inventories (GIs)

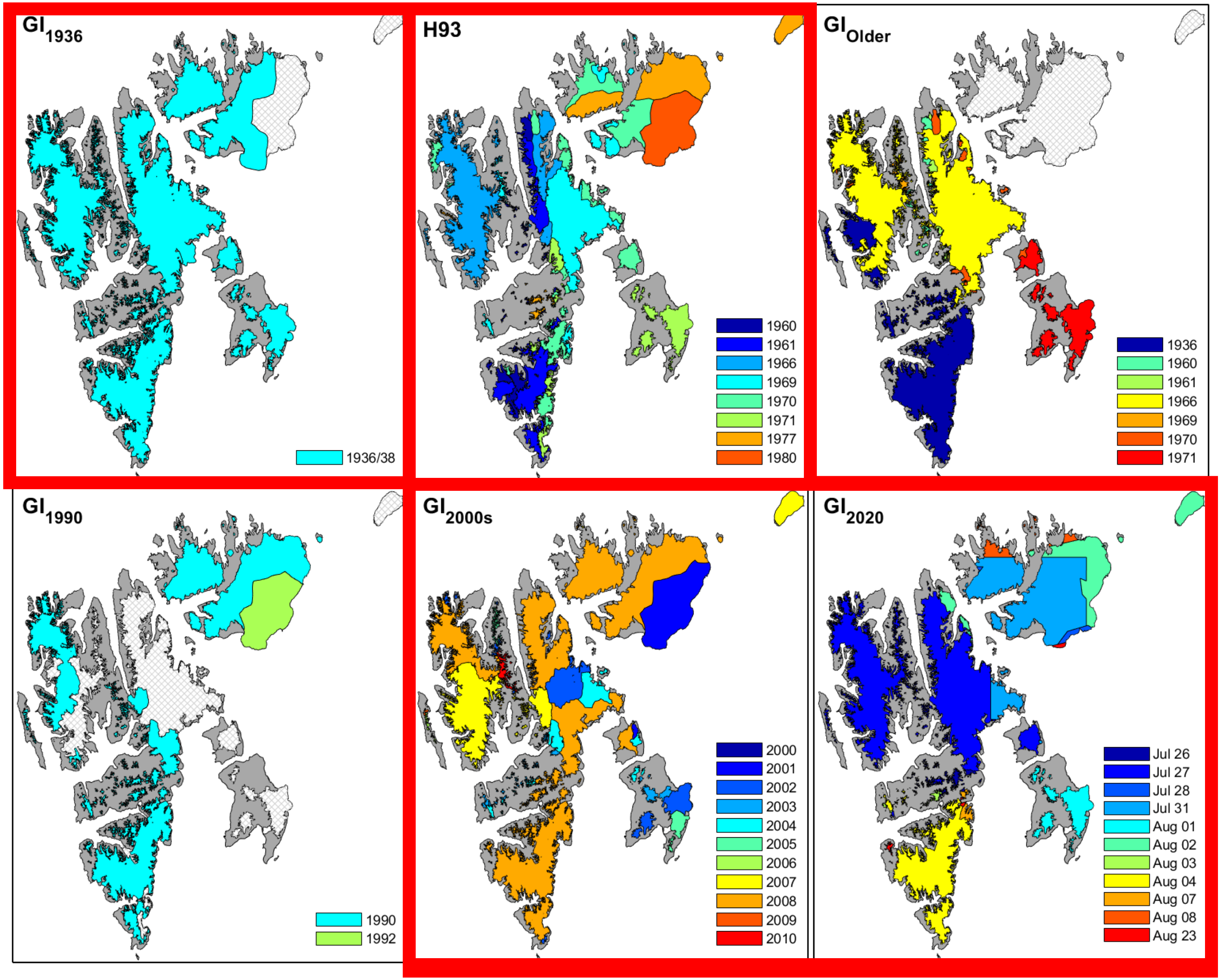
				
Name	**H93**			
Reference	Hagen et al., 1993			
Years	**1960-1980**			
Percent coverage	100%			
Digital outlines	**N**			
Source	NPI maps			

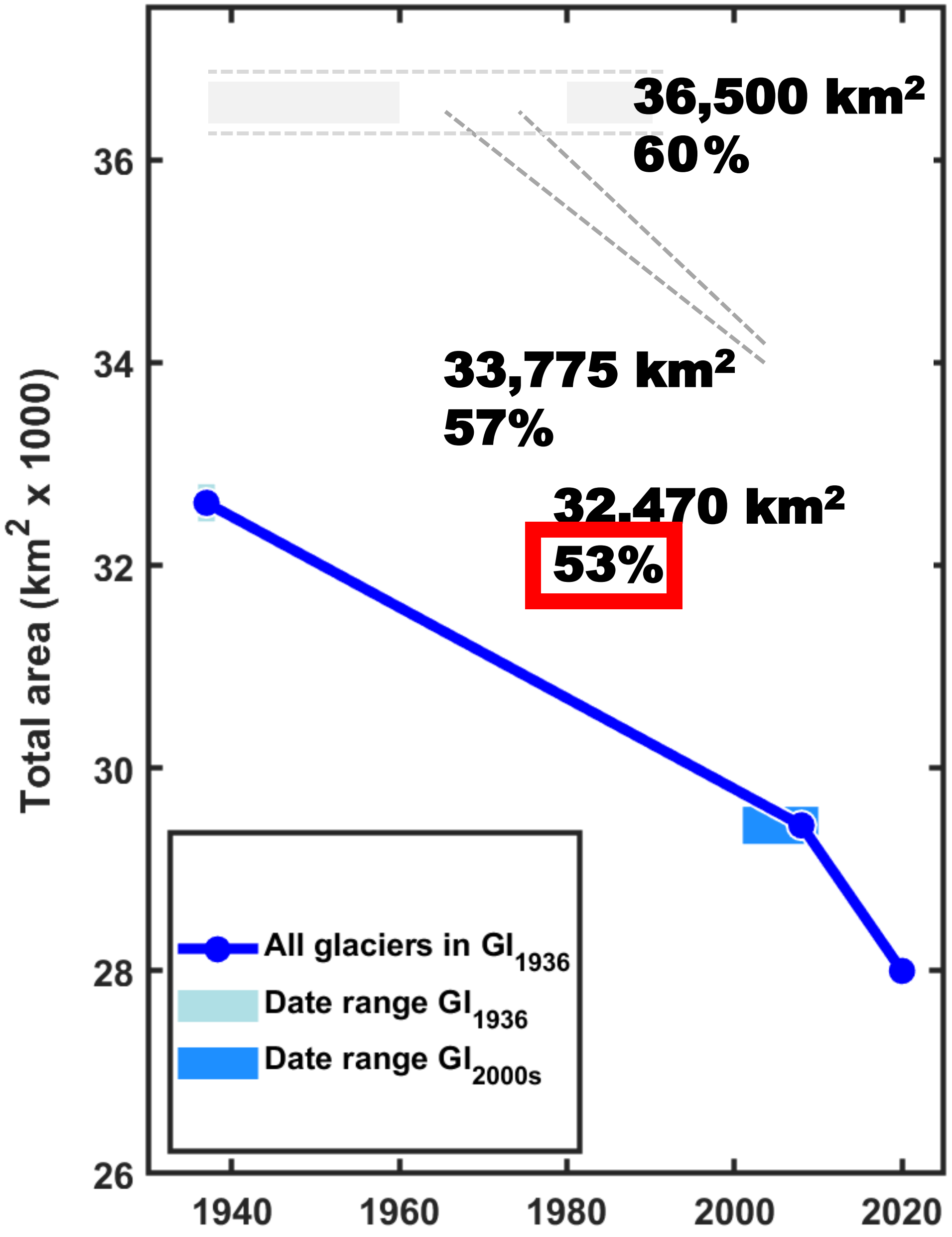


Sentinel 2 mosaic

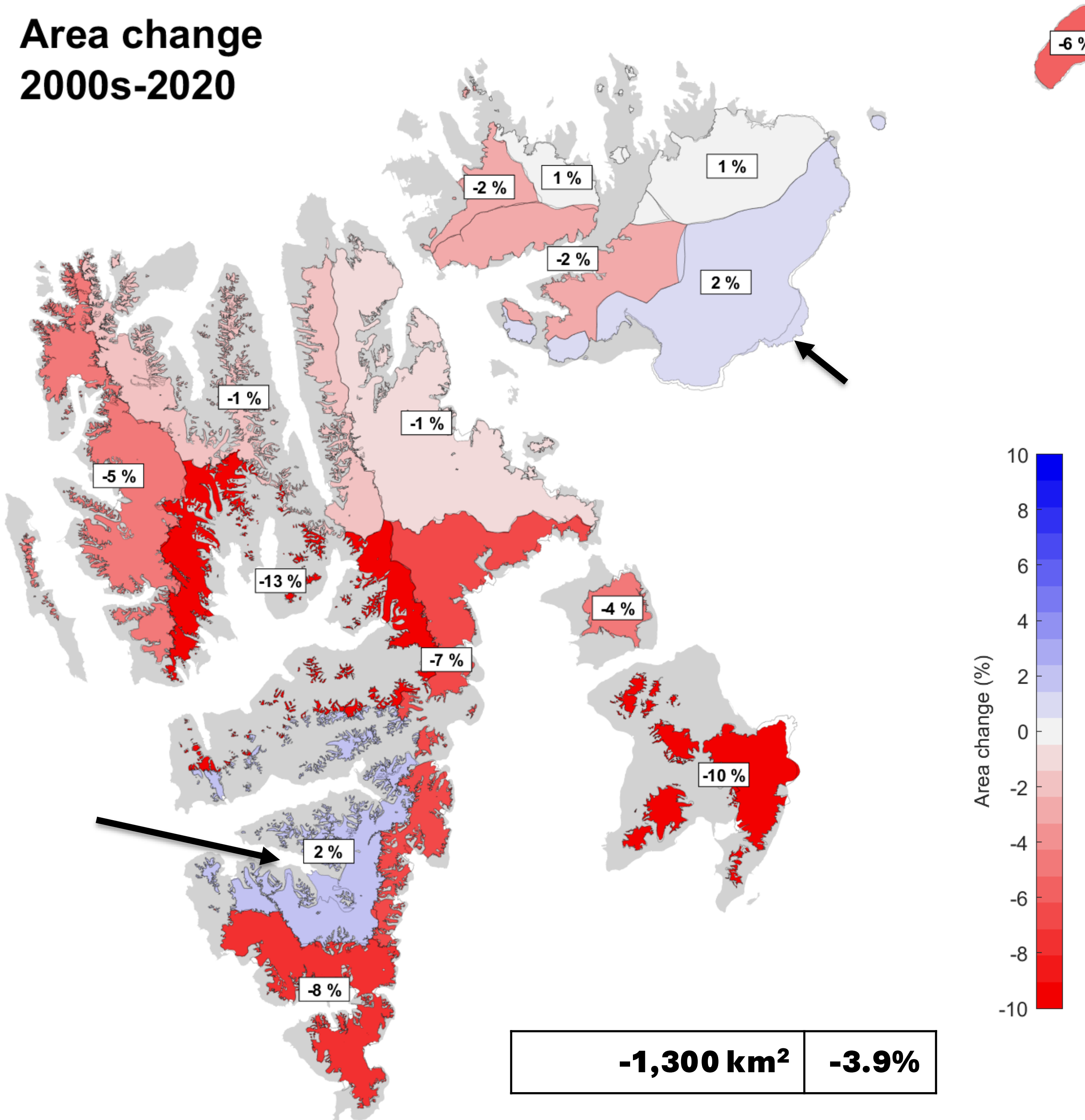
GI$_{2020}$

Glacier inventories coverage





Area change 2000s-2020



-1,300 km²	**-3.9%**

Glacier surges

Surges in Basin-3 area, Austfonna 2011-2016

Animation derived from
RADARSAT-2 (2011-2014) and Sentinel-1 (2015-2016) imagery

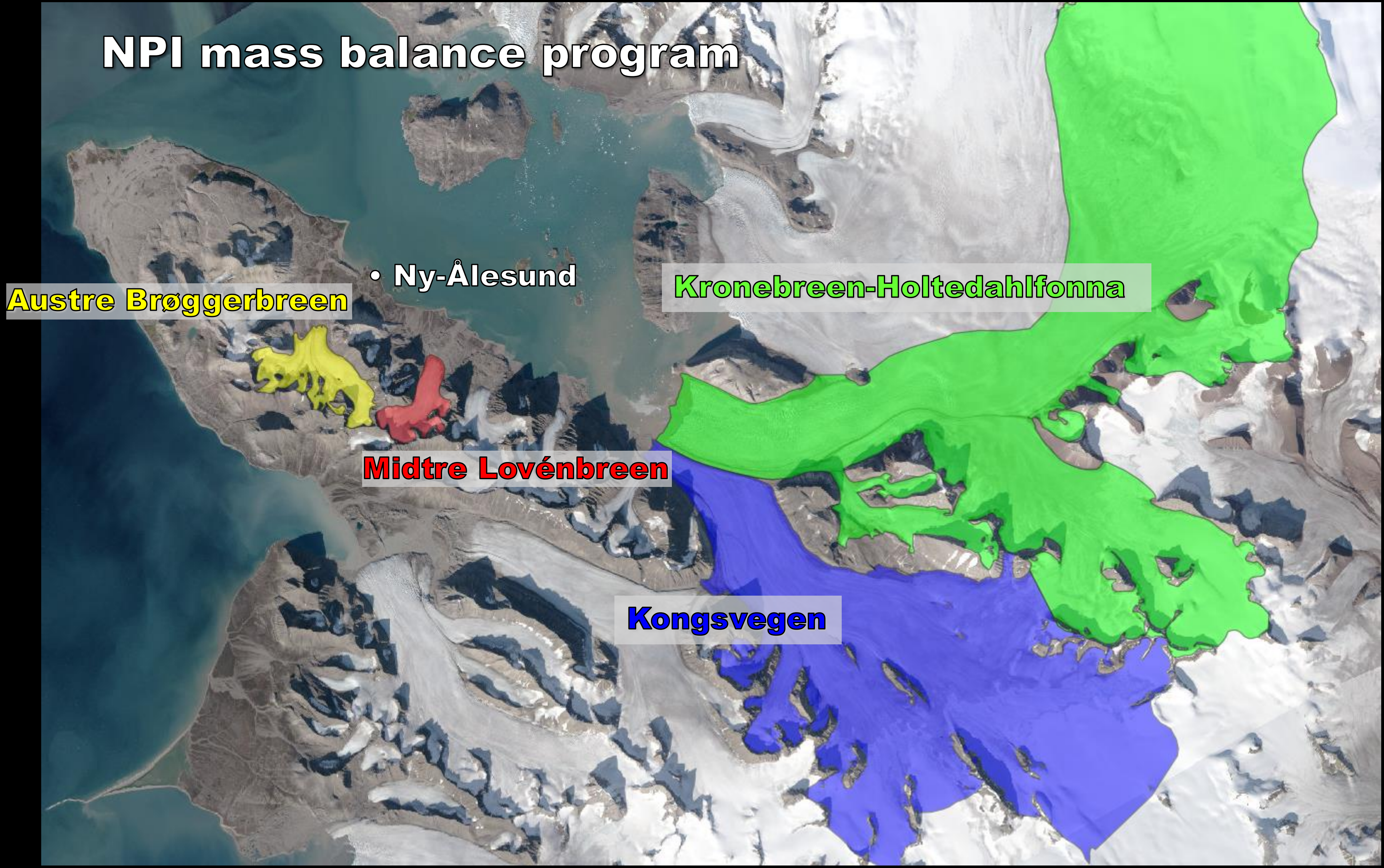
Jack Kohler[1], Max König[1], Geir Moholdt[1], Thorben Dunse[2]
[1]Norwegian Polar Institute [2]University of Oslo

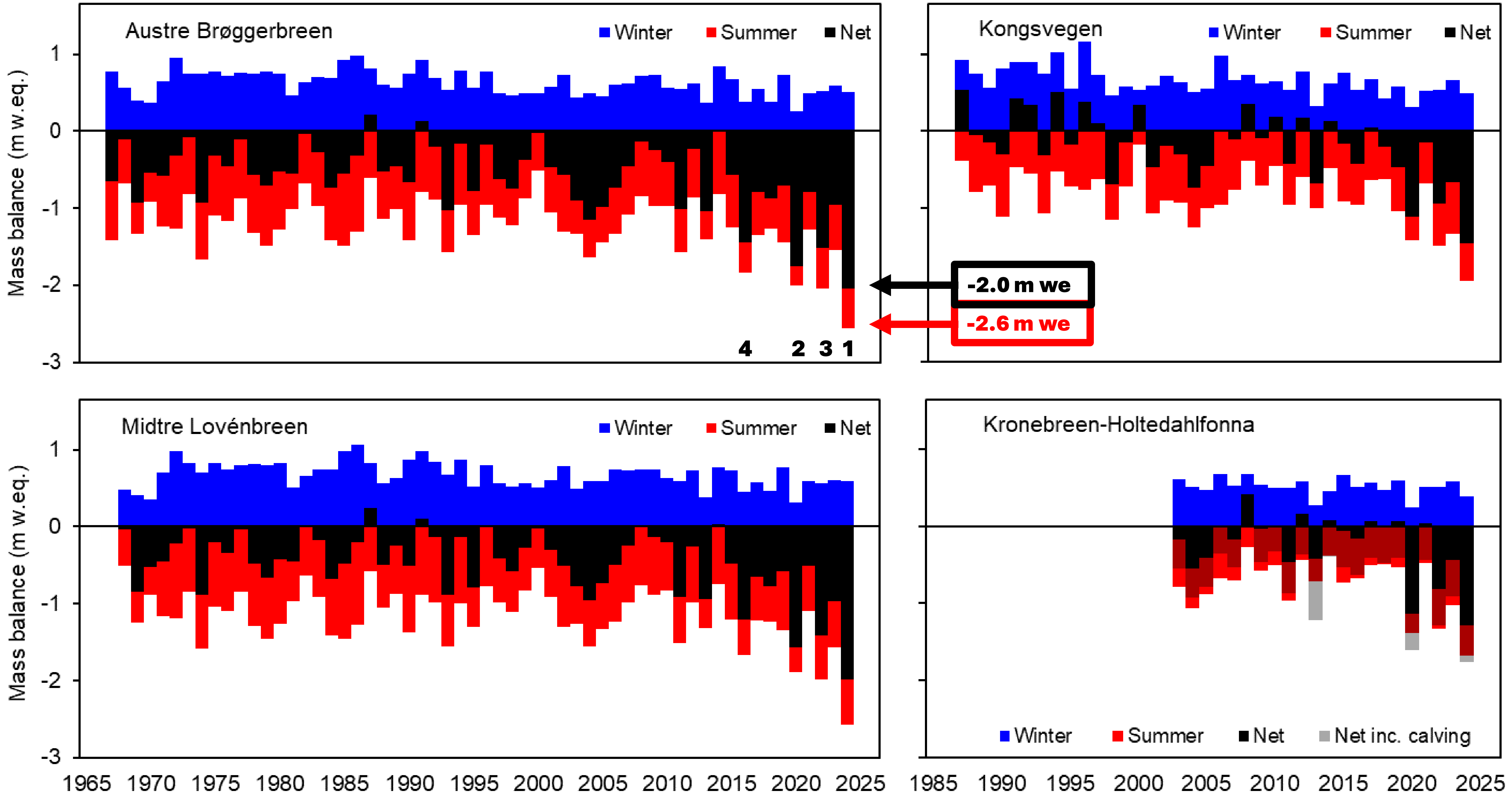
See also: Dunse, T., T. Schellenberger, J.O. Hagen, A. Kääb, T.V. Schuler, C.H. and Reijmer. 2015. Glacier-surge mechanisms promoted by a hydro-thermodynamic feedback to summer melt, The Cryosphere, 9, 197-215, doi:10.5194/tc-9-197-2015, 2015.

Glacier mass change

Field

NPI mass balance program

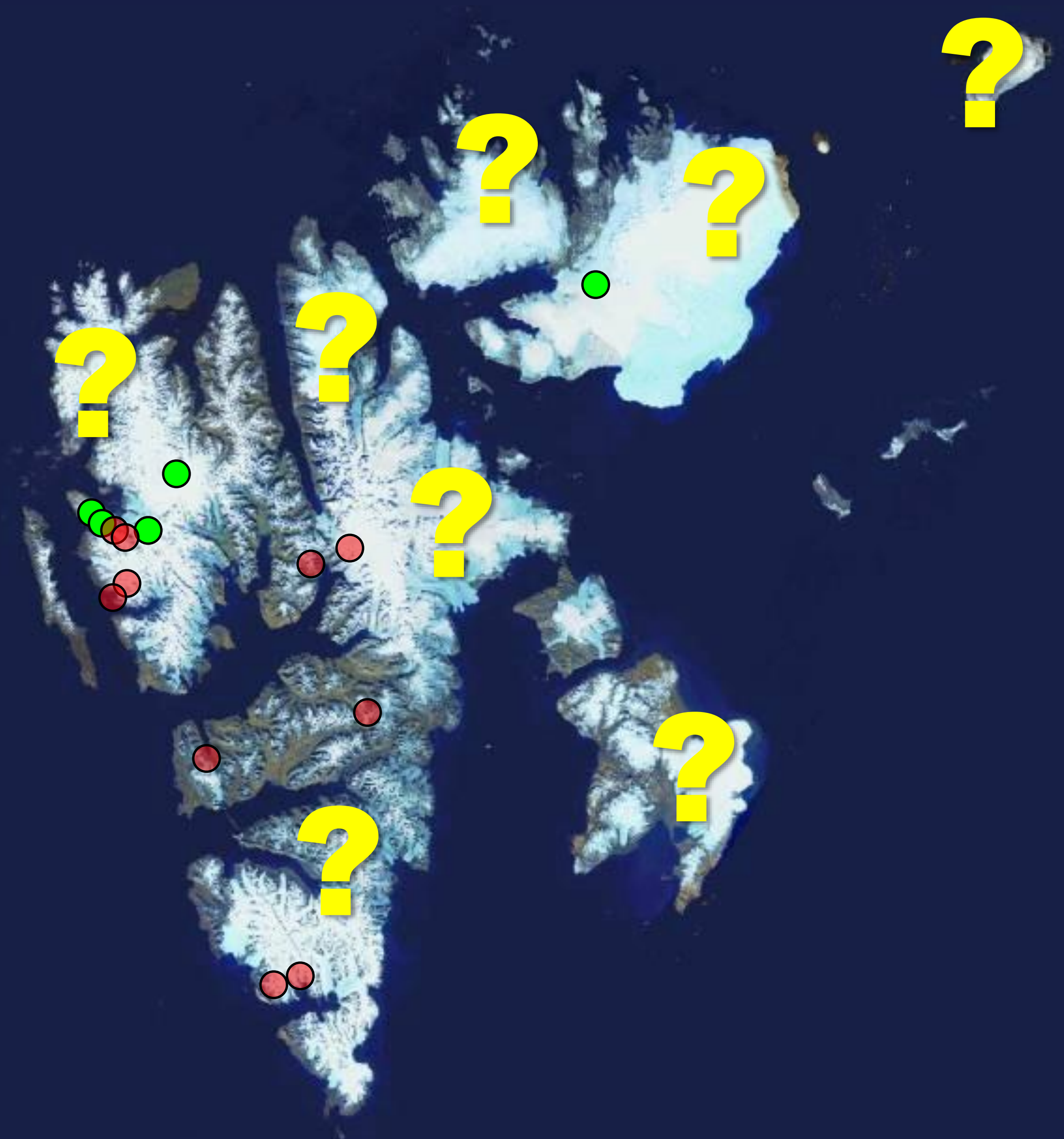


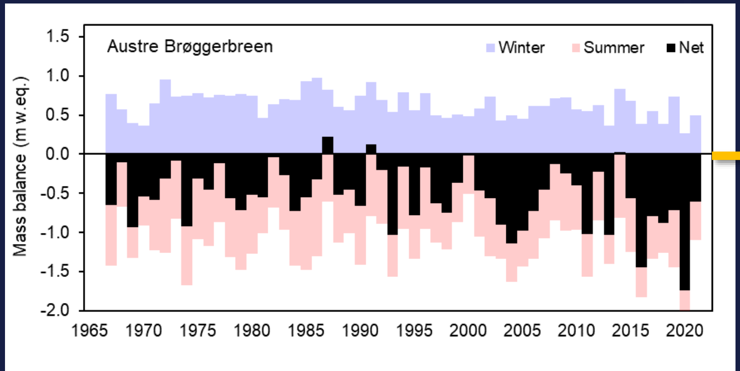


Austre Brøggerbreen
Winter
Summer
Net
Kongsvegen
Winter
Summer
Net
-2.0 m we
-2.6 m we
4
2
3
1
Midtre Lovénbreen
Winter
Summer
Net
Kronebreen-Holtedahlfonna
Winter
Summer
Net
Net inc. calving
Mass balance (m w.eq.)
Mass balance (m w.eq.)
1
0
-1
-2
-3
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
2015
2020
2025
1985
1990
1995
2000
2005
2010
2015
2020
2025

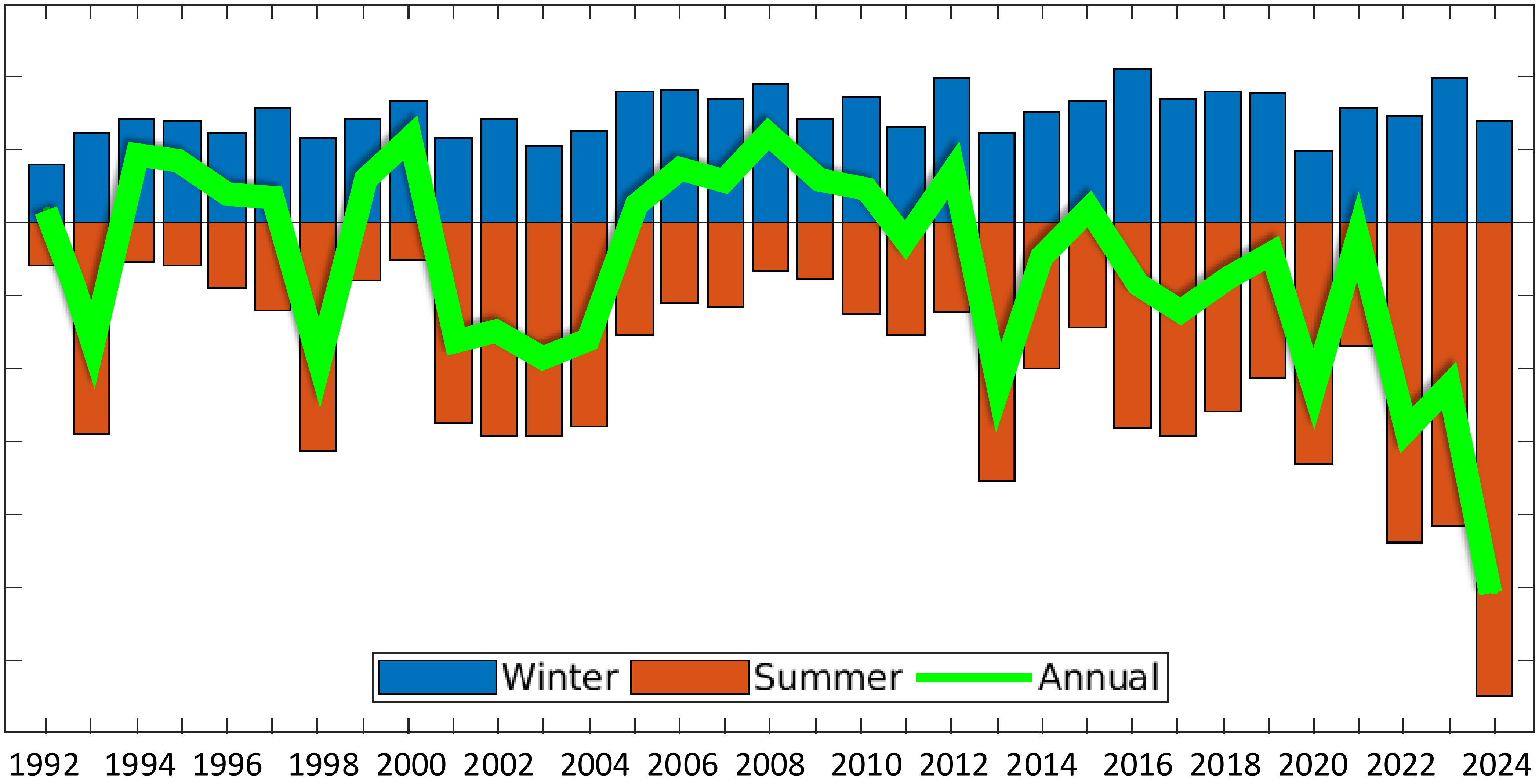
Svalbard mass balance field programs

- NPI
- Other institutions





Glacier mass change: models



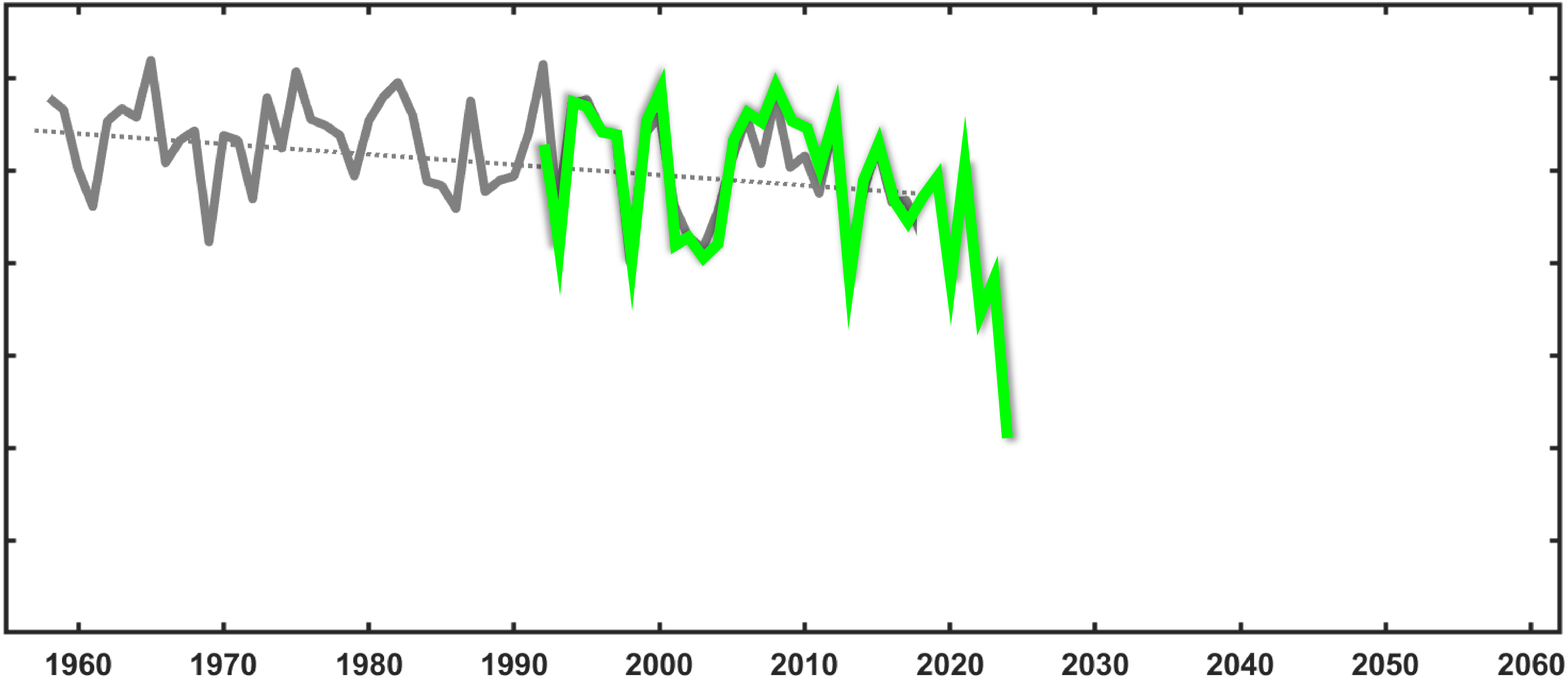
Svalbard Portal

Here you can view the latest status of the Svalbard Cryosphere, based on model results

The Cryosphere, 17, 2941–2963, 2023
https://doi.org/10.5194/tc-17-2941-2023

Meltwater runoff and glacier mass balance in the high Arctic: 1991–2022 simulations for Svalbard

Louise Steffensen Schmidt[1], Thomas Vikhamar Schuler[1], Erin Emily Thomas[2,a], and Sebastian Westermann[1]



Journal of Glaciology

IGS

Article

Accelerating future mass loss of Svalbard

The Cryosphere, 13, 2259–2280, 2019
https://doi.org/10.5194/tc-13-2259-2019

A long-term dataset of climatic mass balance, snow conditions, and runoff in Svalbard (1957–2018)

Ward van Pelt[1], Veijo Pohjola[1], Rickard Pettersson[1], Sergey Marchenko[1], Jack Kohler[2], Bartłomiej Luks[3], Jon Ove Hagen[4], Thomas V. Schuler[4,5], Thorben Dunse[4,6], Brice Noël[7], and Carleen Reijmer[7]

Glacier mass change: elevation data

Article

Historical glacier change on Svalbard predicts doubling of mass loss by 2100

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Check for updates

Emily C. Geyman[1,4]✉, Ward J. J. van Pelt[2], Adam C. Maloof[3], Harald Faste Aas[1] & Jack Kohler[1]

The melting of glaciers and ice caps accounts for about one-third of current sea-level rise[1–3], exceeding the mass loss from the more voluminous Greenland or Antarctic Ice Sheets[3,4]. The Arctic archipelago of Svalbard, which hosts spatial climate gradients that are larger than the expected temporal climate shifts over the next century[5,6], is a natural laboratory to constrain the climate sensitivity of glaciers and predict their response to future warming. Here we link historical and modern glacier observations to predict that twenty-first century glacier thinning rates will more than double those from 1936 to 2010. Making use of an archive of historical aerial imagery[7] from 1936 and 1938, we use structure-from-motion photogrammetry to reconstruct the three-dimensional geometry of 1,594 glaciers across Svalbard. We compare these reconstructions to modern ice elevation data to derive the spatial pattern of mass balance over a more than 70-year timespan, enabling us to see through the noise of annual and decadal variability to quantify how variables such as temperature and precipitation control ice loss. We find a robust temperature dependence of melt rates, whereby a 1 °C rise in mean summer temperature corresponds to a decrease in area-normalized mass balance of −0.28 m yr^{-1} of water equivalent. Finally, we design a space-for-time substitution[8] to combine our historical glacier observations with climate projections and make first-order predictions of twenty-first century glacier change across Svalbard.

The Arctic archipelago of Svalbard is one of the most climatically sensitive regions in the world[9–11]. Since 1991, mean annual air temperatures have risen at a rate of 1.7 °C per decade, which is more than twice the Arctic average and seven times the global average for the same period[11]. The recent warming is associated with accelerating ice loss[4,12]. However, quantitative links between climate and glacier mass balance on Svalbard are limited by the scarcity of pre-2000 observations. For example, empirical estimates of late twentieth century mass balance—based on extrapolating sparse field observations or using a patchwork of historical topographic maps—disagree by more than a factor of four (−0.12 to −0.55 m yr^{-1})[12–15] (Extended Data Fig. 1). Likewise, mass balance models—based on a range of approaches from simple degree-day formulations[16] to coupled energy balance and snow pack models[5,17]—produce twentieth century glacier change estimates on Svalbard that vary not only in magnitude, but also in direction (that is, positive versus negative)[5,16–19]. If we cannot understand the past, how can we predict the future? Historical photographs provide rare windows into pre-satellite-era glacier configurations and enable the reconstruction of long-term (decadal to centennial) quantitative records of glacier change[20–22].

1936/1938 mapping campaign on Svalbard

In the summers of 1936 and 1938, Norwegian expeditions led by Adolf Hoel used a scout plane equipped with a Zeiss camera (18 × 18 cm film, focal length 210.71 mm) to acquire 5,507 high- oblique aerial images covering most of Svalbard[7]. The images were collected with the intention of creating topographic maps[7]. However, the mapping project was put on hold when Germany invaded Norway in 1940. By the 1960s, newer imagery of Svalbard had been acquired and the 1936/1938 photographs were put aside and archived by the Norwegian Polar Institute (NPI).

Data-driven predictions of mass balance

The 1936/1938 images (Fig. 1a) enable the quantification of glacier change over the last century. However, we also seek to understand how glaciers will respond to climate change and contribute to sea-level rise in the upcoming century. One way to constrain glacier response to climate is to study temporal trends[4,23]. For example, dividing the acceleration in melt rates (m yr^{-2}) by the warming trend (°C yr^{-1}) yields a temperature sensitivity of glacier mass balance (m yr^{-1} $°C^{-1}$)[4,23]. However, long observational time series are sparse; of the more than 200,000 glaciers around the world, only 38 have in situ observations spanning more than 50 years[24]. Rich observing platforms in the satellite era enable the quantification of mass balance from nearly every glacier on the planet[2–4], but the relatively short observational interval (≤20 years) limits the signal of observed increases in both melt rates and temperature. Dividing one small number (melt rate acceleration) by another (warming trend) produces an uncertain estimate, especially when mass balance time series are obscured by substantial interannual variability[25,26]. For example, faced

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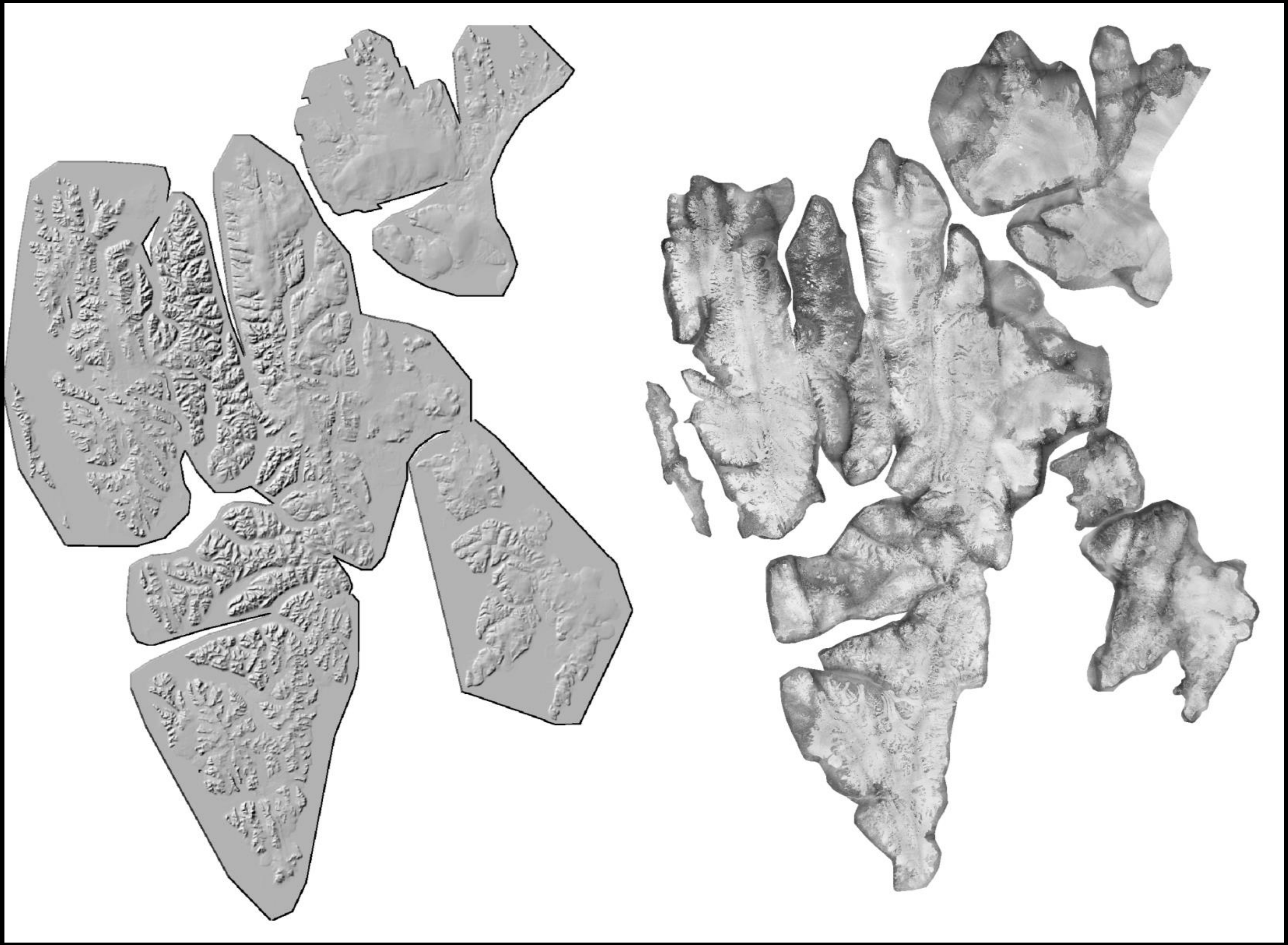
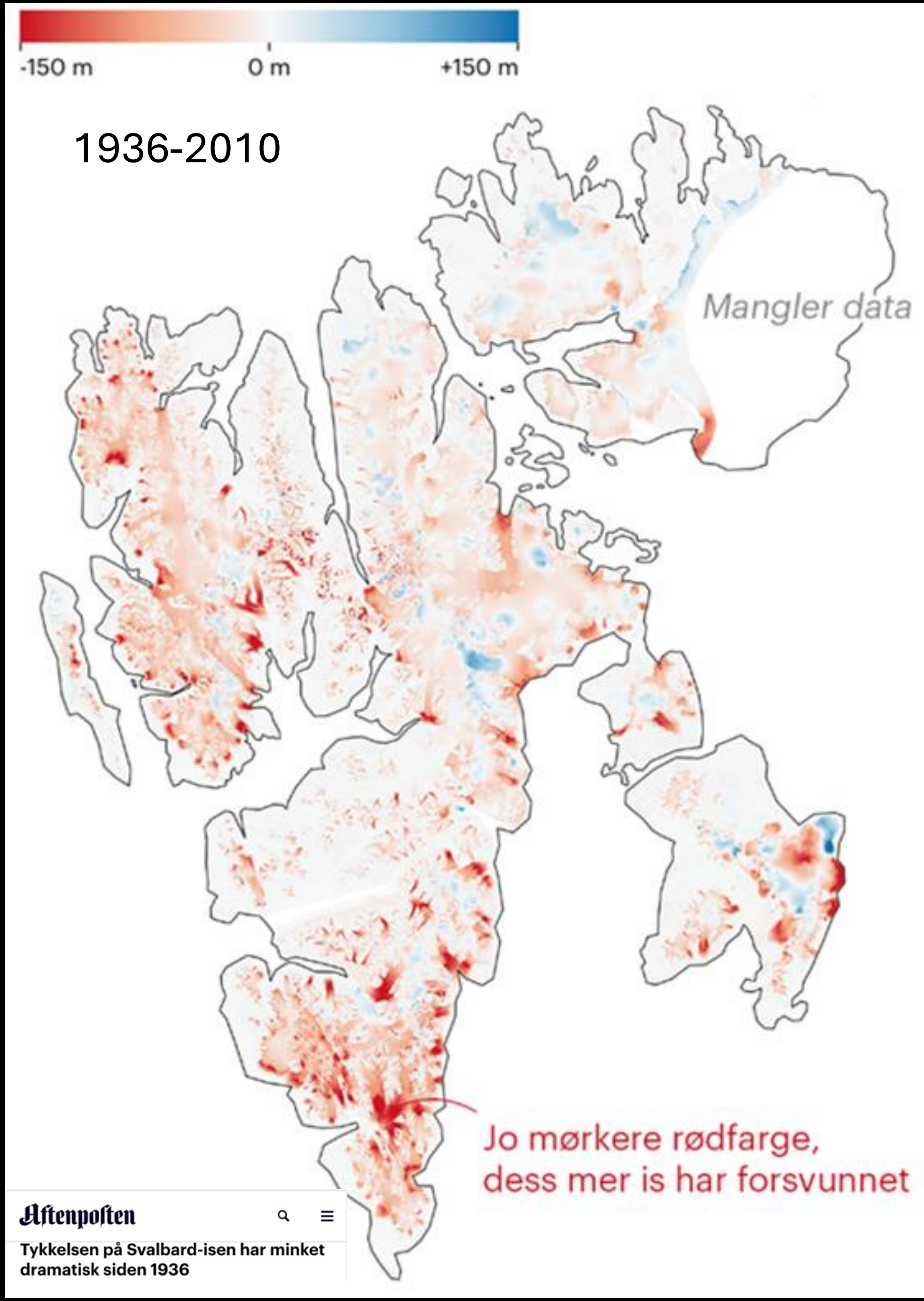
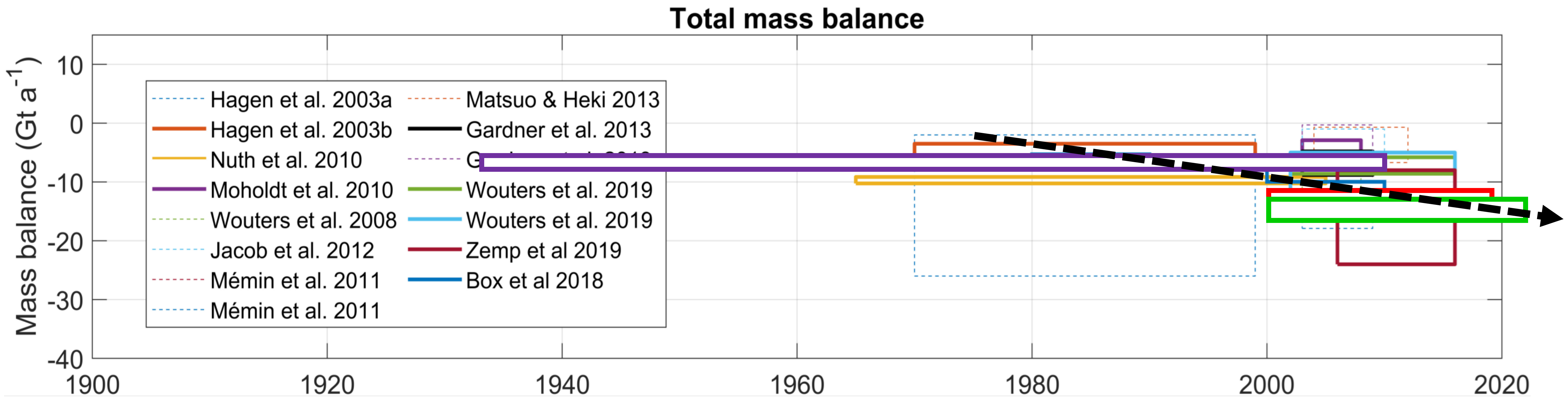




- **Between 1936 to 2010, mean ice thickness reduced by ~26 m, or 0.35 m/a.**
- **Equivalent to -593 Gt, or -7.8 Gt/yr**
- **Spatial correlation between summer temperature and elevation change used with future climate change scenarios to estimate future ice loss**
- **By 2100, glacier thickness change predicted to range from -0.67 to -0.92 m/year**
- **Ca. 2-4 times the 1936-2010 rate**



2024

frontiers in Earth Science

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Reconciling Svalbard Glacier Mass Balance

Thomas V. Schuler[1,2], Jack Kohler[3], Nelly Elagina[4], Jon Ove M. Hagen[1], Andrew J. Hodson[5,6], Jacek A. Jania[7], Andreas M. Kääb[1], Bartłomiej Luks[8], Jakub Małecki[9], Geir Moholdt[3], Veijo A. Pohjola[10], Ireneusz Sobota[11] and Ward J. J. Van Pelt[10]*

Geyman et al., 2022

Hugonett et al., 2021

Glambie Team, 2025

Conclusions

- 2020 Svalbard glacier area = 32,470 km^2
- 53% of total area
- Area decreased by 4% or 1 300 km^2, in just over a decade
- Rate of area loss increasing over time
- Mass balance is negative…
- …and becoming increasingly more negative over time
- 2024 saw a record loss, equivalent to that from Greenland