ESA Fringe 2026, Kraków, June 2026

InSAR Svalbard

Ground Motion Service for Svalbard

Observing surface displacement in the High Arctic

Gökhan Aslan[1], Line Rouyet[2], Marie Bredal[1], Tom Rune Lauknes[2], Lotte Wendt[2], Daniel Stødle[2], Heidi Hindberg[2], Jelte von Oostveen[2], Yngvar Larsen[2], Emma Hauglin[1], John Dehls[1], Anja Sundal[3], Anna Odh[3], Dag Anders Moldestad[3]

1 NORGES GEOLOGISKE UNDERSØKELSE - NGU -

2 NORCE

3 Norwegian Space Agency

https://svalbard.insar.no

Why Monitor Ground Motion in Svalbard?

Rapid Arctic Warming

↓

Permafrost Thawing

↓

Ground Instability

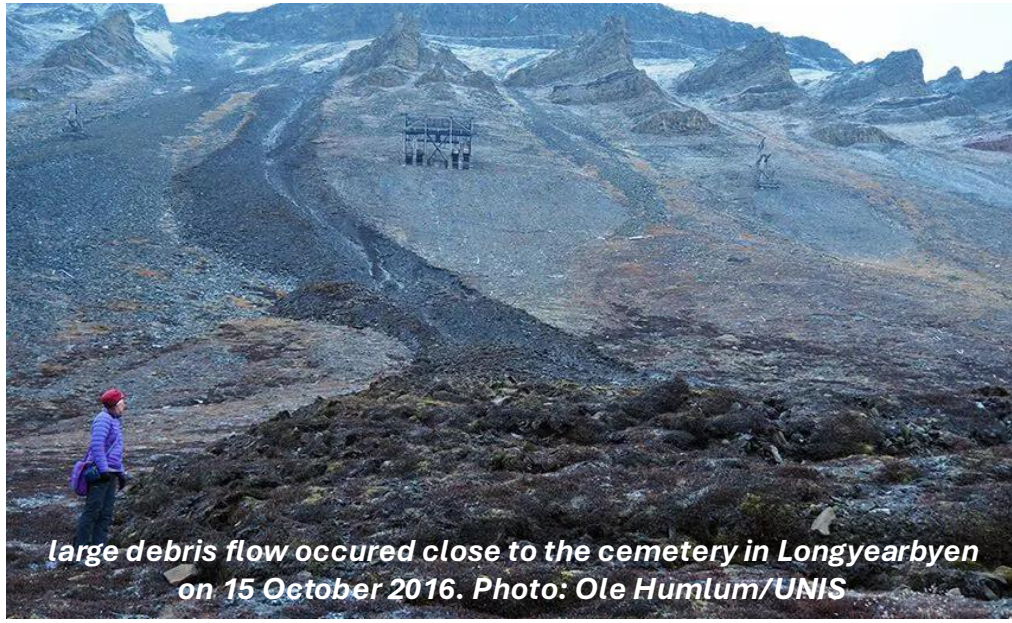
↓

Infrastructure & Slope Hazard

3× faster than global average (*AMAP 2021*)

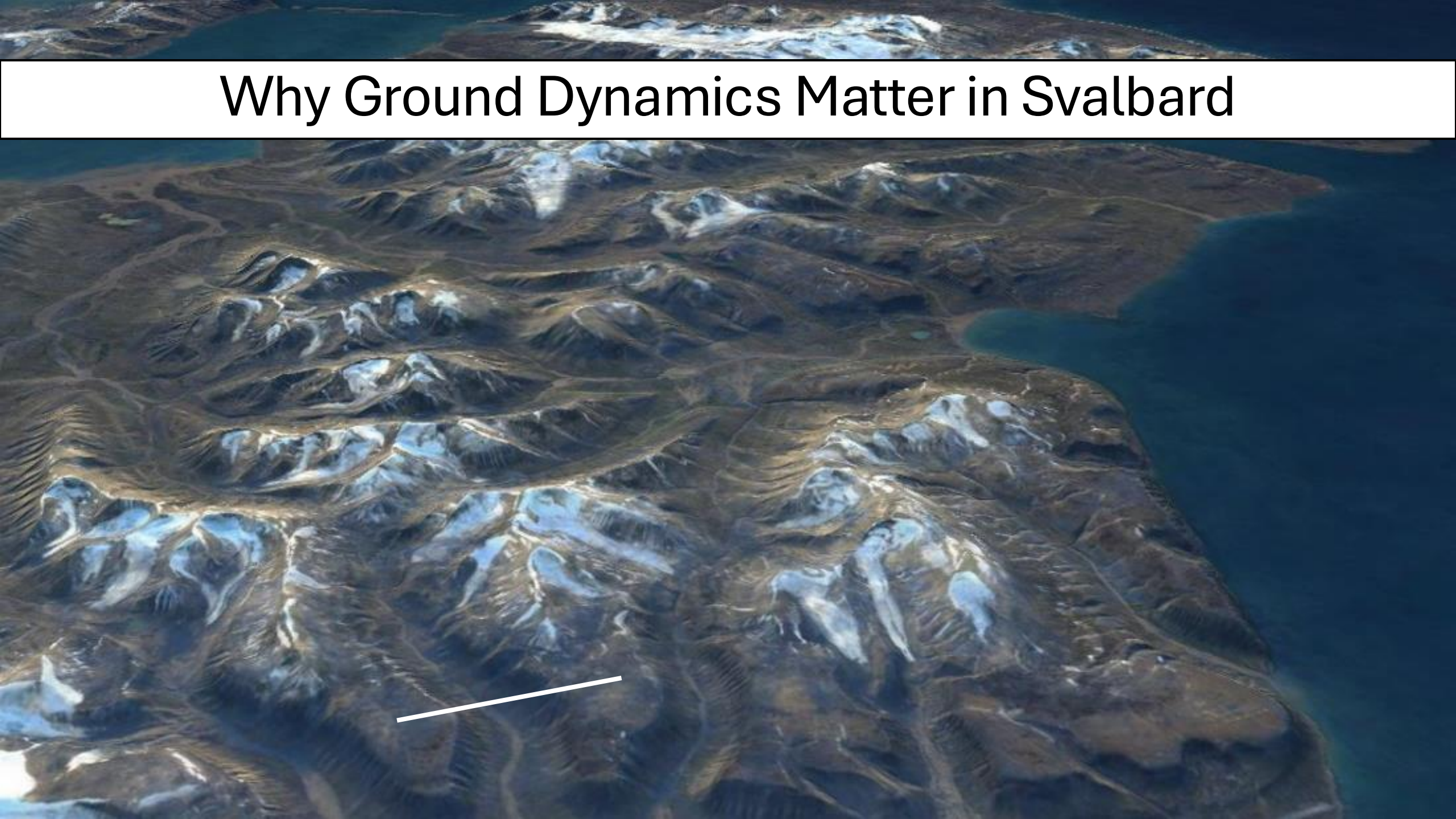
Svalbard up to **7× faster**! (*Førland et al., 2020*)

Norwegian Polar Institute and Geyman et al. (2022), Nature

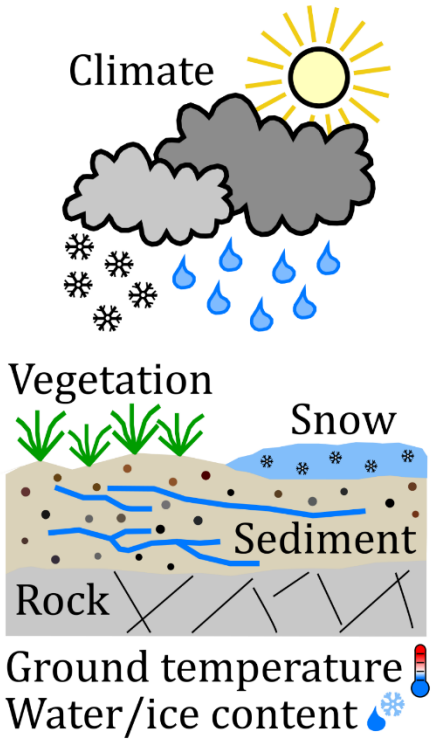


large debris flow occured close to the cemetery in Longyearbyen on 15 October 2016. Photo: Ole Humlum/UNIS

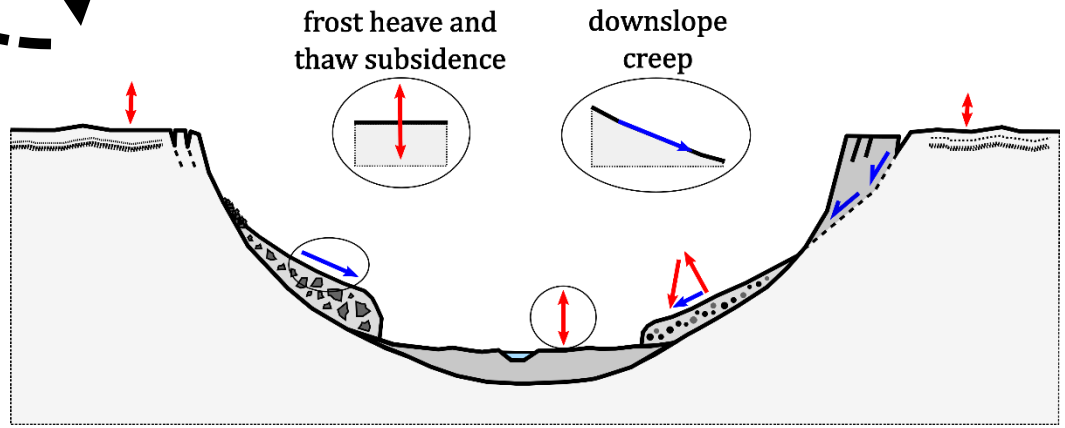
Why Ground Dynamics Matter in Svalbard



Why Ground Dynamics Matter in Svalbard



CONTROLS



GROUND DYNAMICS

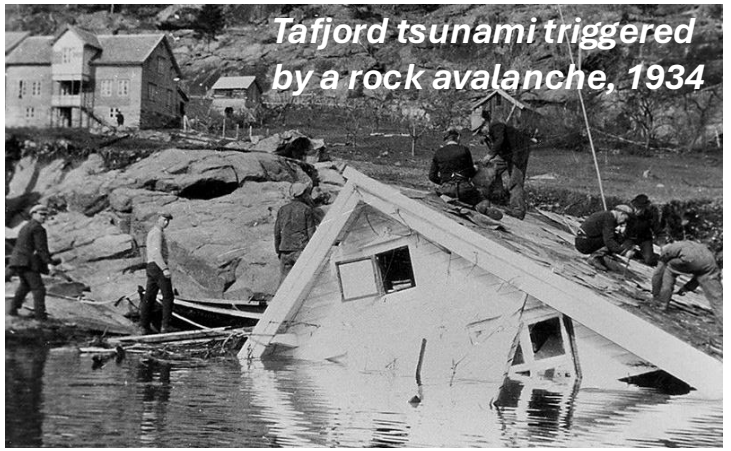
IMPACTS

RESEARCH:

Changing ground dynamics as indicator of changing environment

MANAGEMENT:

Stability management and geohazard assessment



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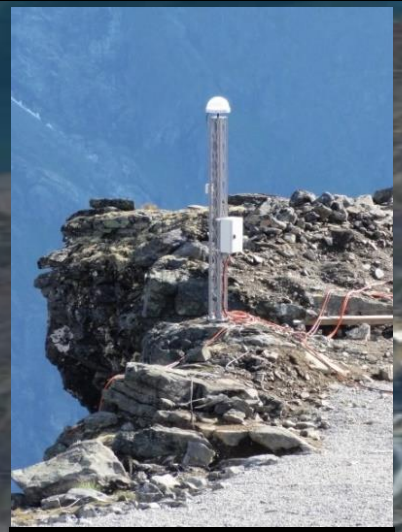
In situ measurements & field mapping



GPS

Field mapping

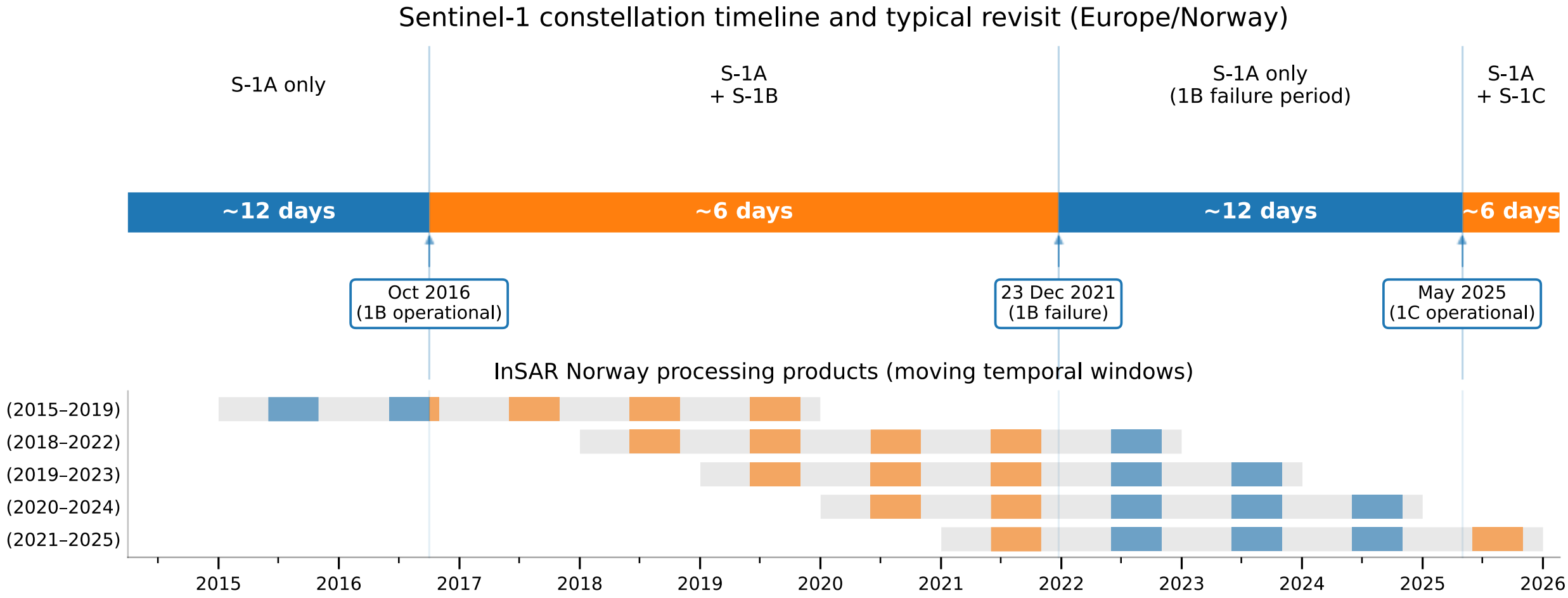
Underground investigation

Geophone

DMS

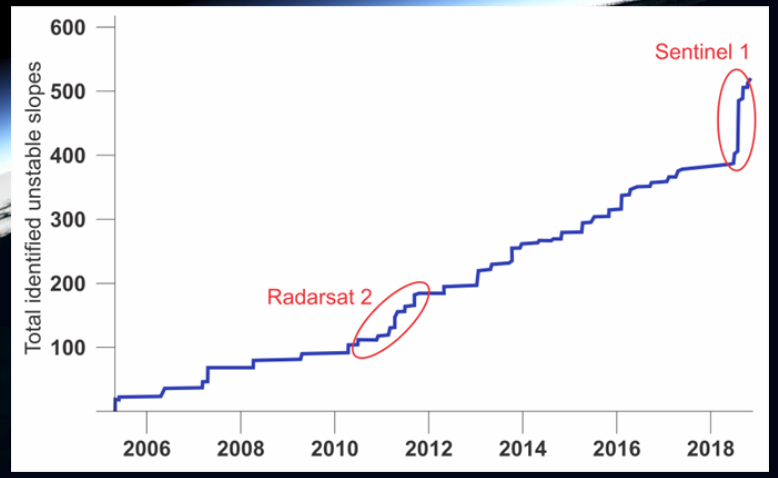
How do we monitor ground motion across all of Svalbard?

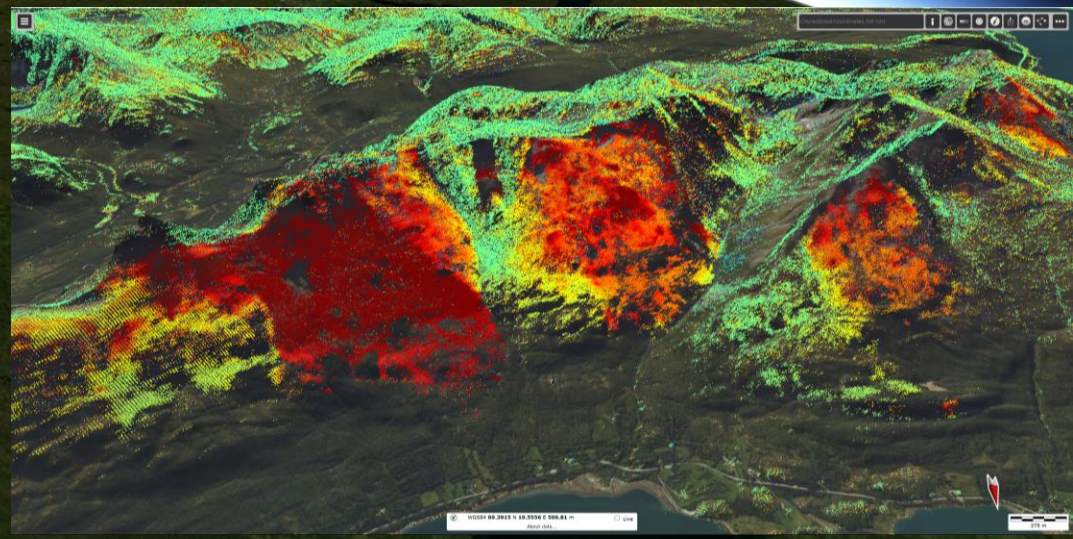
Sentinel-1 Revisit Timeline

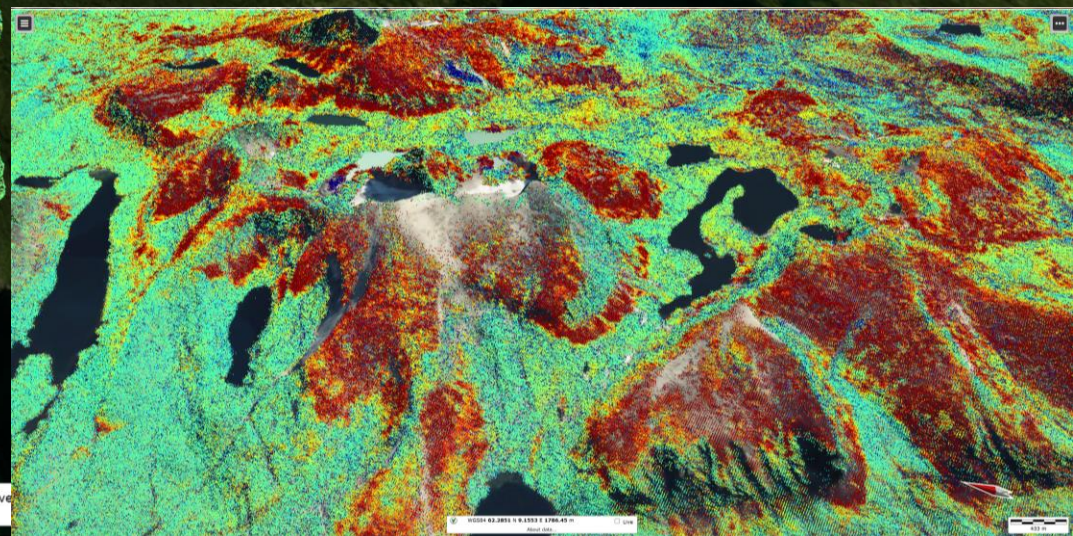


Nominal repeat: ~12 days per satellite; ~6 days with two satellites.

InSAR Norway: *An operational Ground Motion Service*







NORGES GEOLOGISKE UNDERSØKELSE
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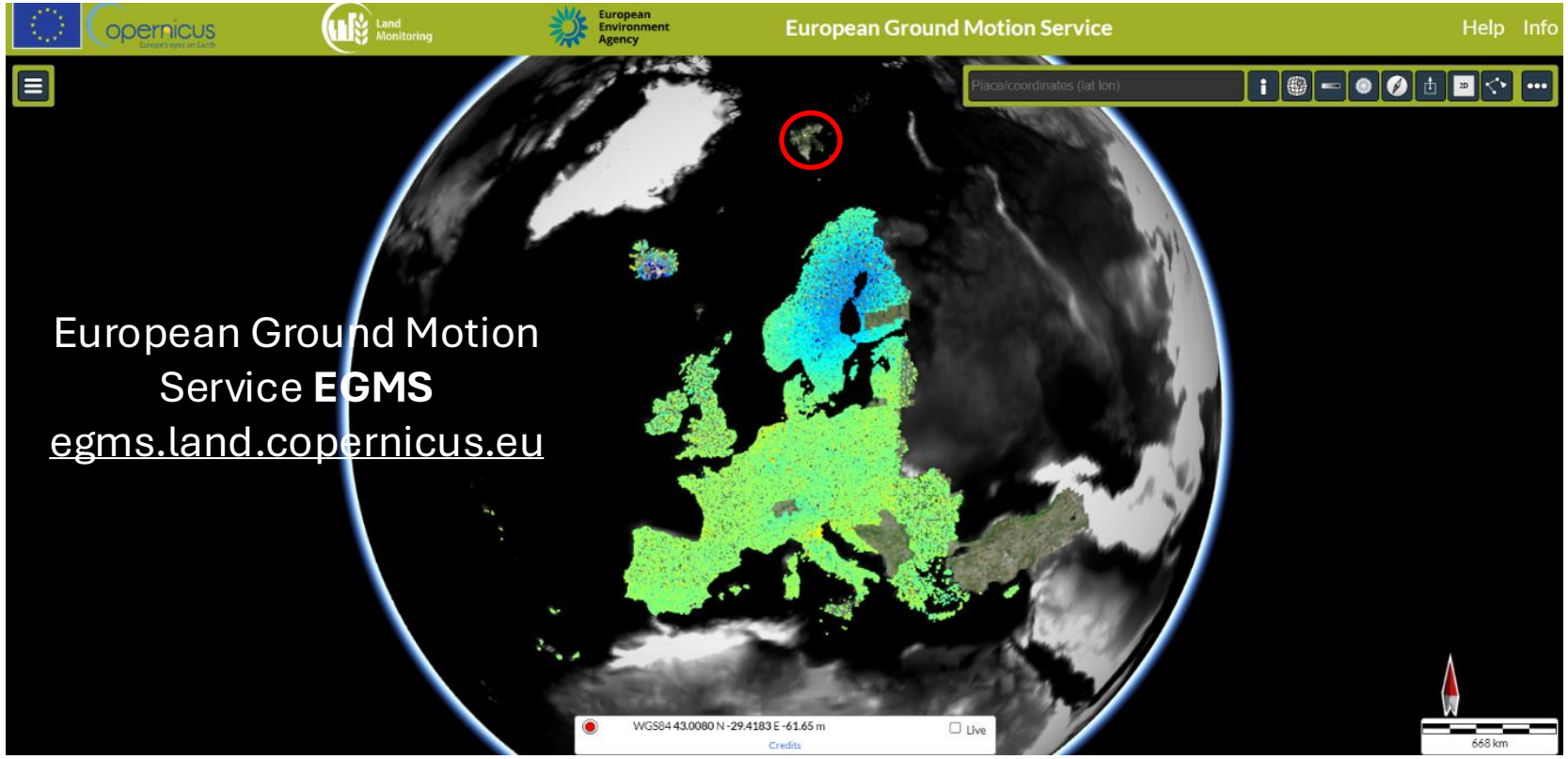
NORCE

Norwegian Space Agency

WGS84 58.6319 N 4.6918 E -0.51 m
About data...
Live

Mainland Norway and Europe Are Covered, **But Not Svalbard!**



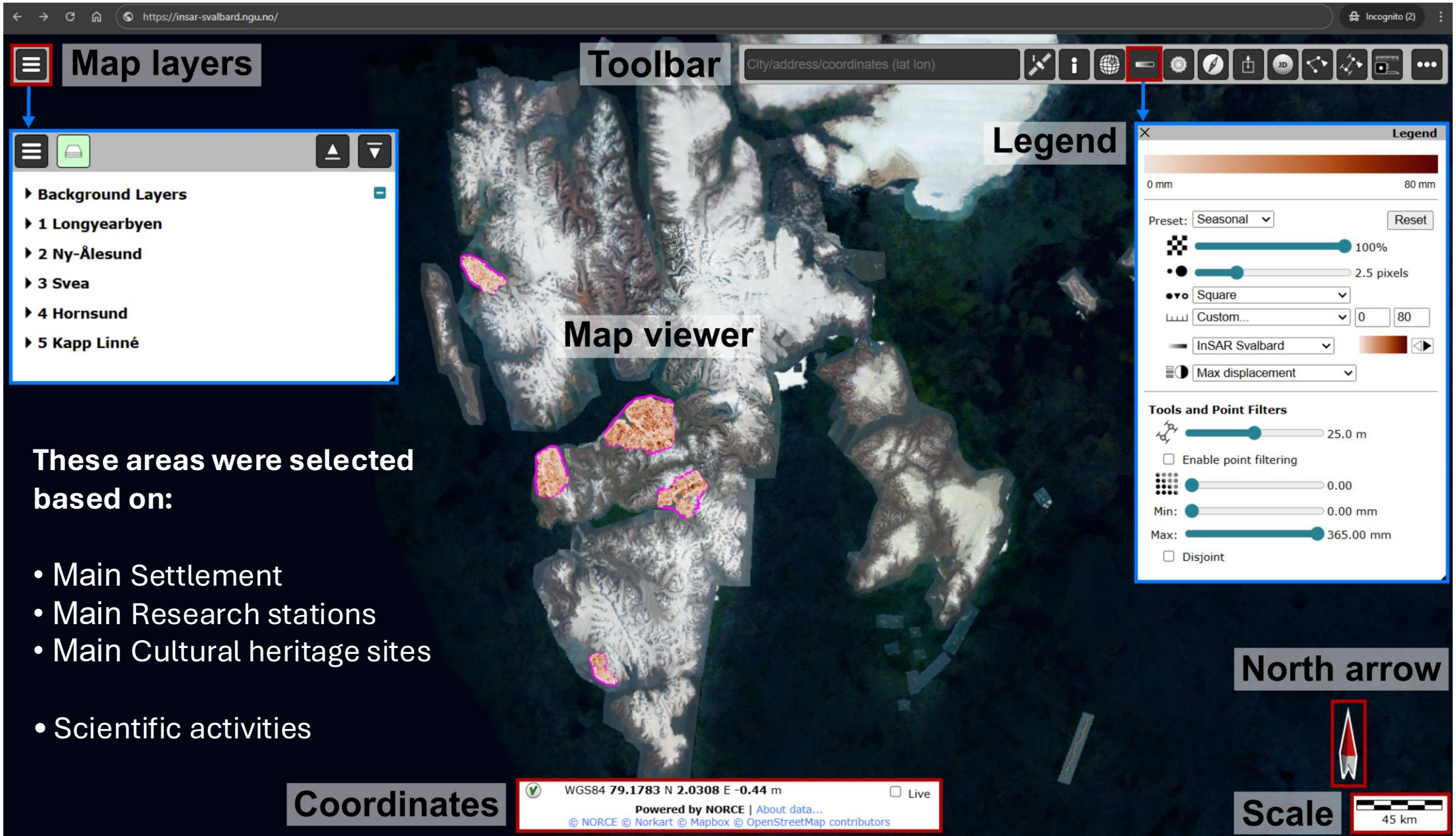
WHAT ABOUT SVALBARD?

Two main reasons Svalbard is not part of the existing GMS:

- **Unique technical challenges** that require different processing strategies.
- **Different user needs and communities** that require tailored product types.

3 year long dialog with potential users and iterative process during the development

https:// svalbard.insar.no



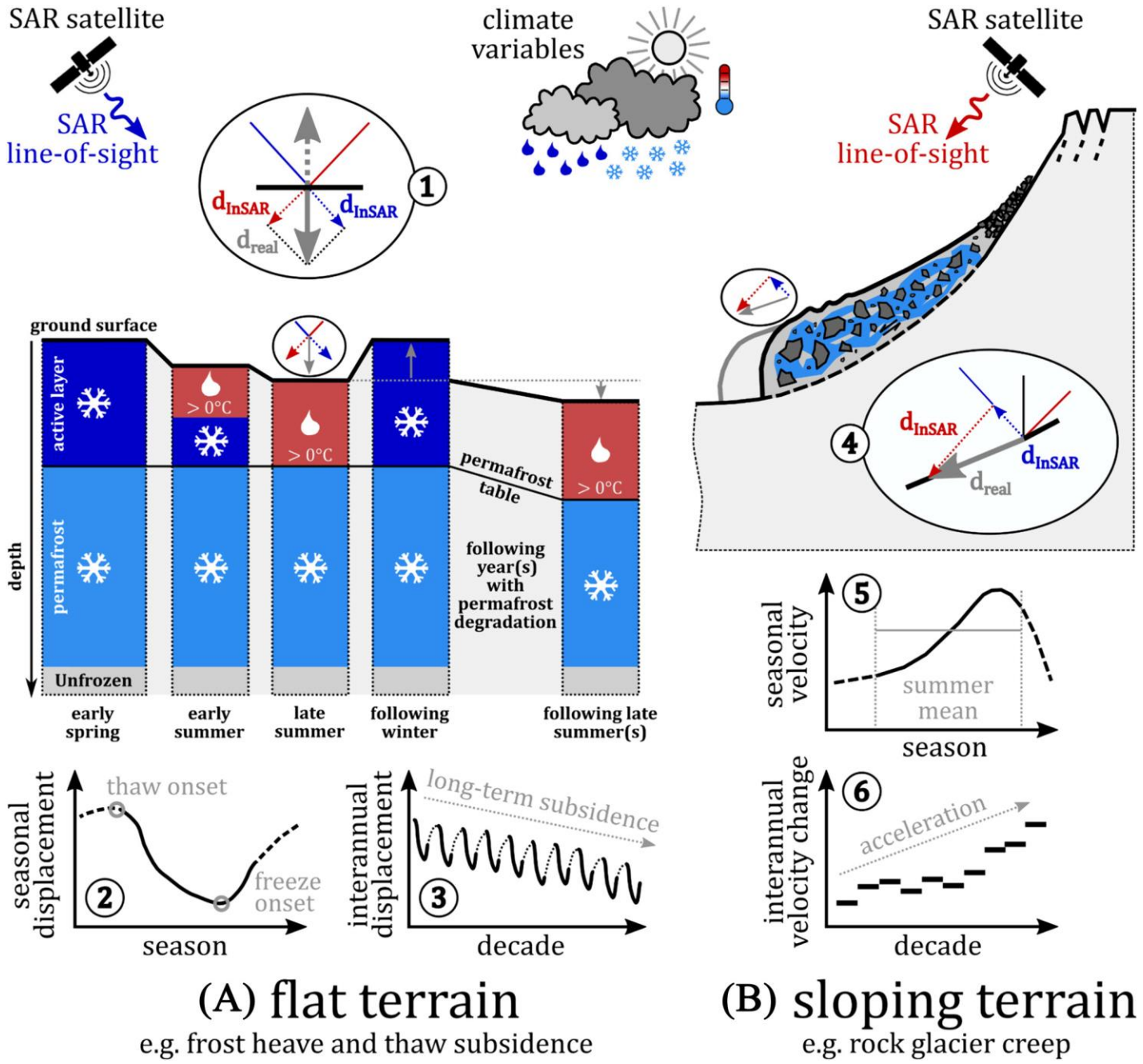
Product types

1 Seasonal

2 Interannual

Two complementary processing strategies to generate two different types of products

- Documenting both **short-term** (seasonal) and **long-term** (interannual) displacement patterns.
- Enabling InSAR Svalbard products to capture ground dynamics from **diverse processes** across **multiple timescales**.



Zwieback et al., 2024

Same area, different time scales of motion

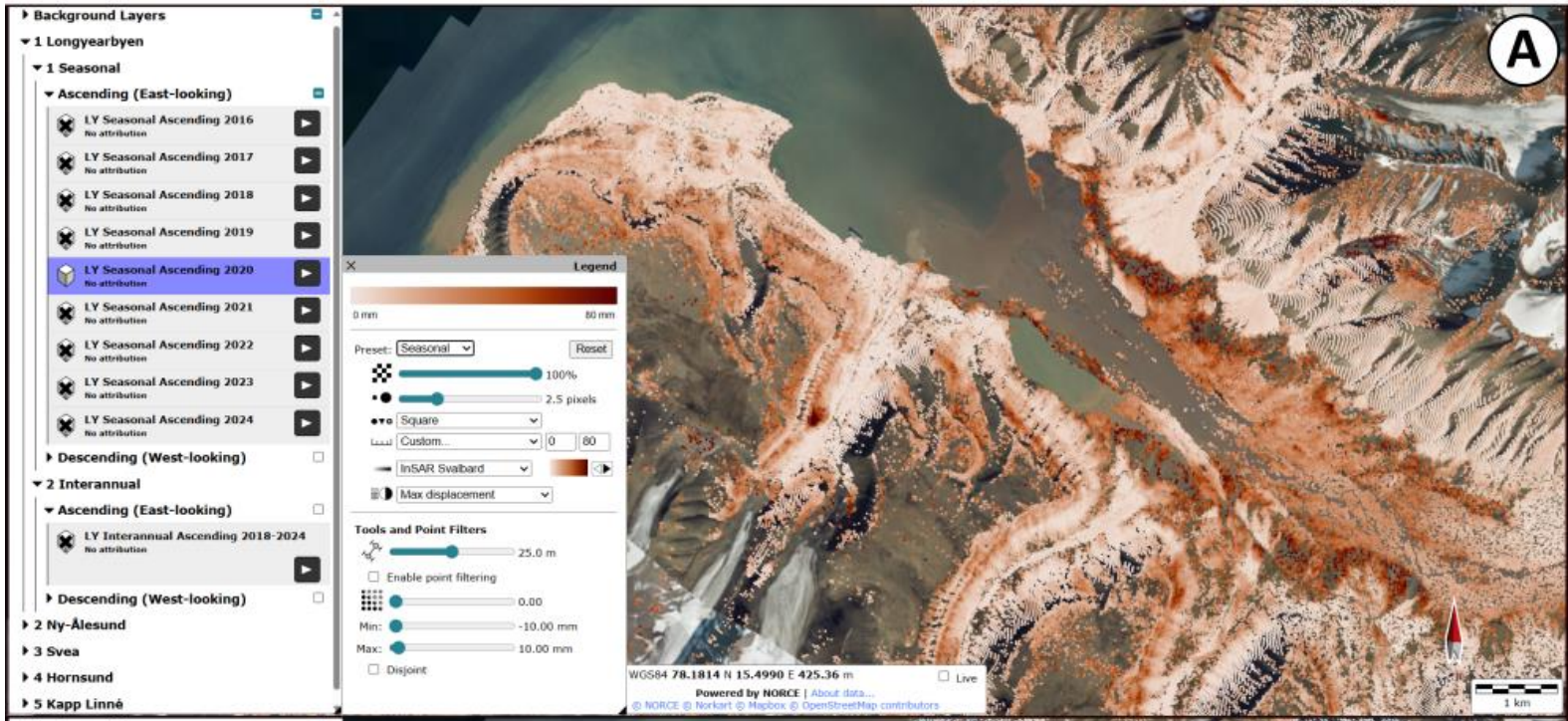
- **Seasonal product**

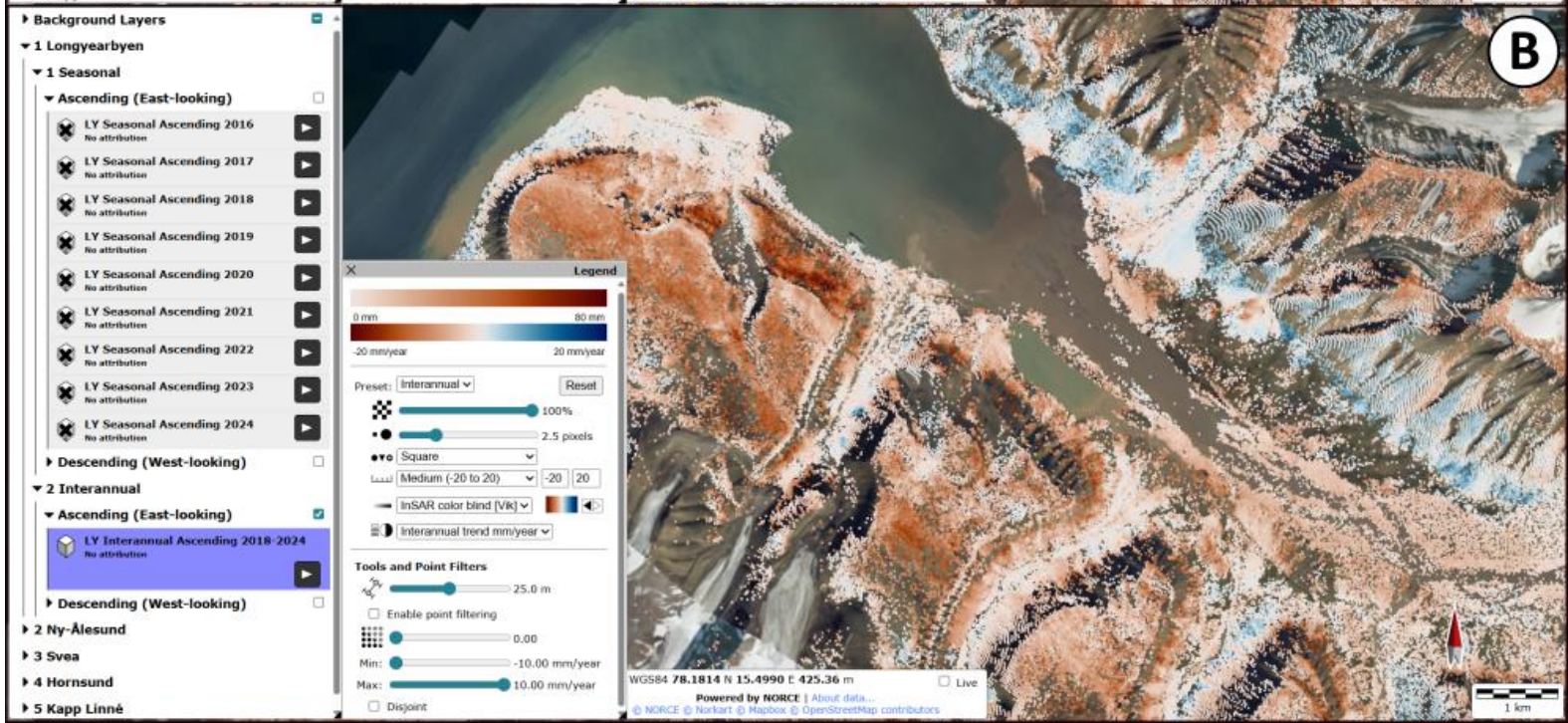
→ We map the **maximum displacement** during each season (color scale: 0-80 mm, 2016 – 2024)

- **Interannual product**

→ We map the average yearly velocity (color scale: -20 to 20 mm/yr along the LOS, 2018-2024)

https://svalbard.insar.no

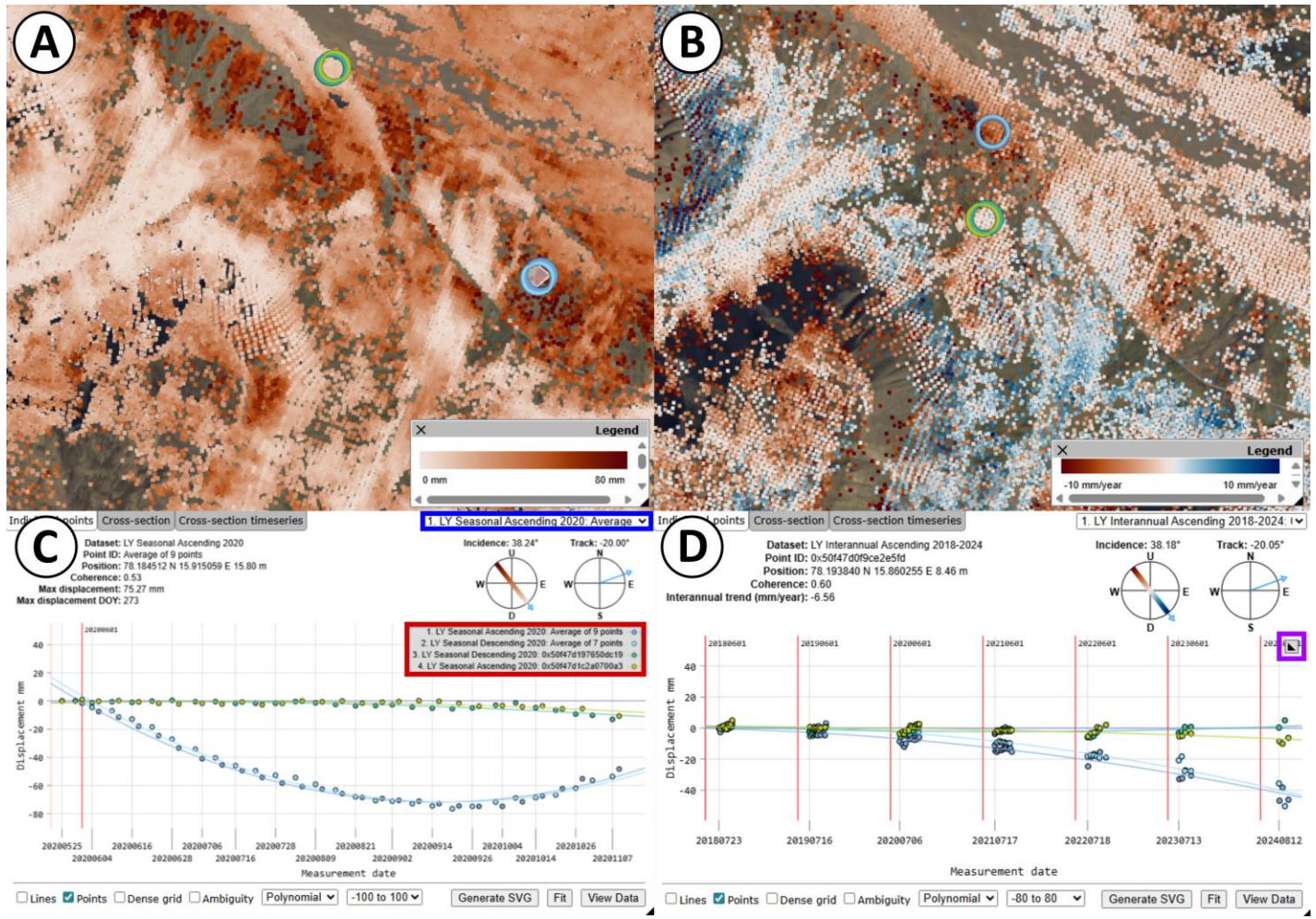




InSAR Svalbard: pilot product types

Seasonal products

- Ground motion **within one snow-free season**
- Captures **thaw subsidence & frost heave effects**
- Each year processed **separately**
- We map the **absolute maximum displacement** during that season.

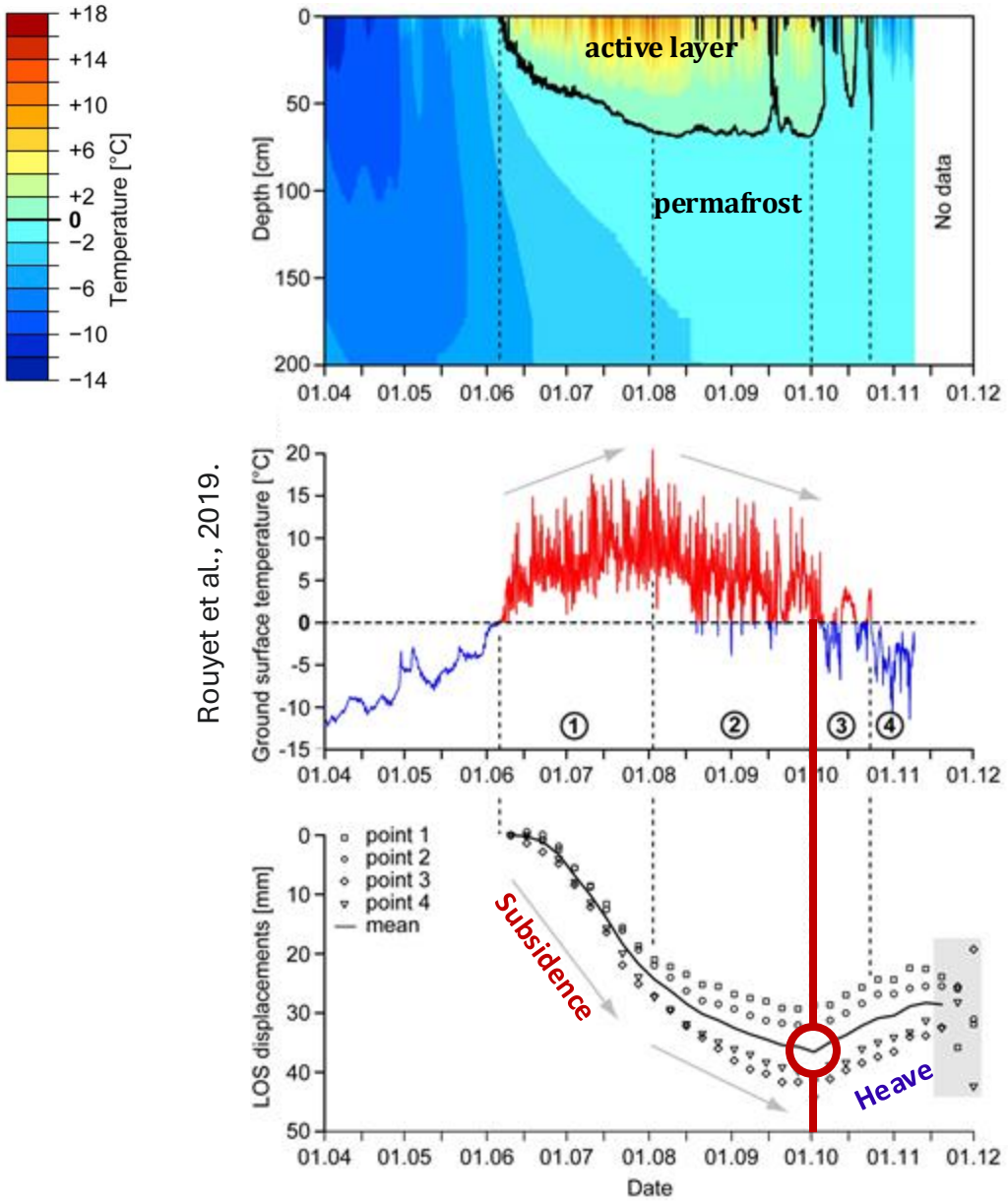


Interannual products

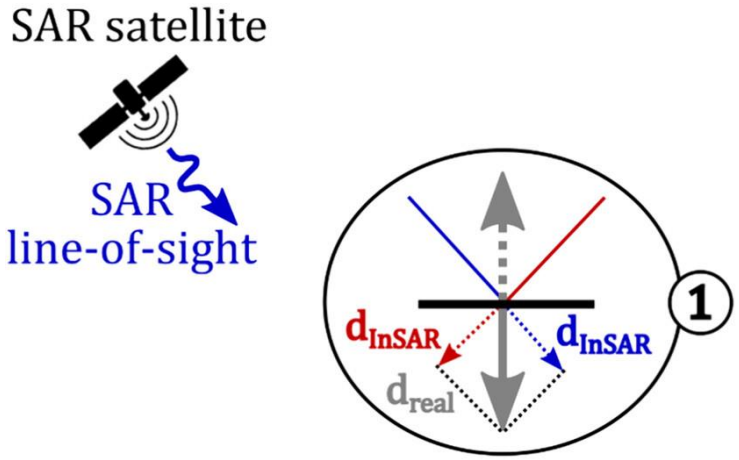
- Ground motion **between different snow-free seasons**
- Highlights **long-term trends** in surface displacement
- All available years processed **together**
- We map the **average yearly velocity** between 2018-2024.

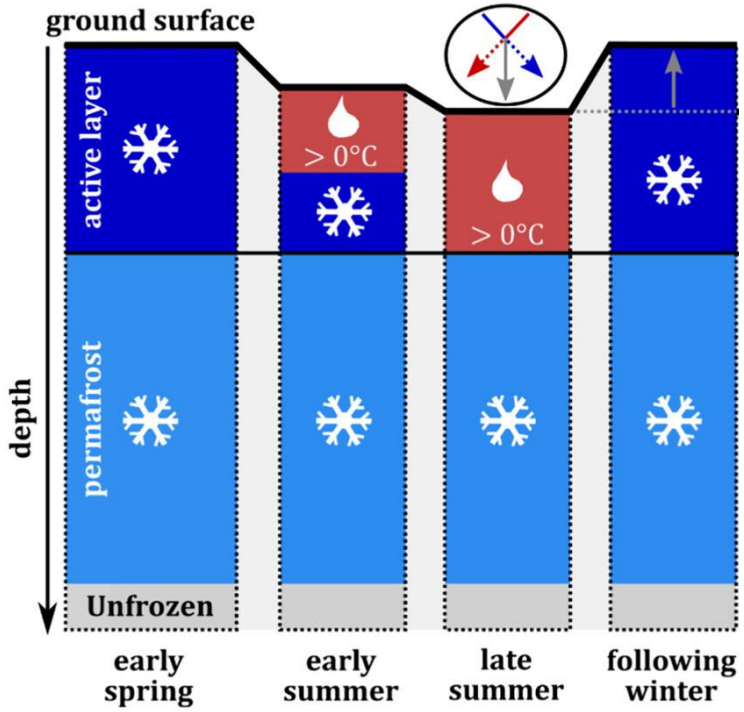
https://svalbard.insar.no

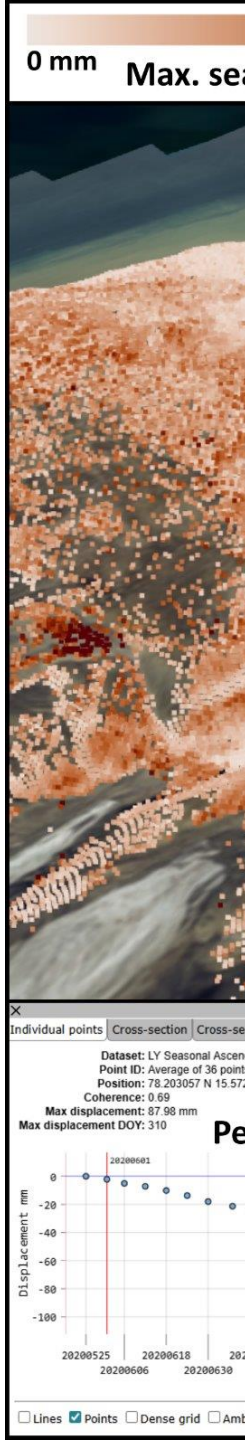
Seasonal InSAR Svalbard products

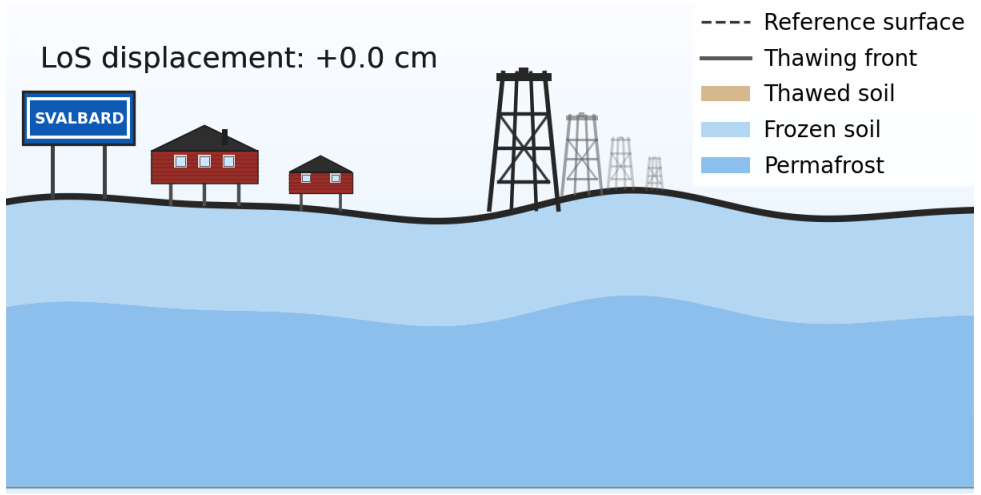


Rouyet et al., 2019.









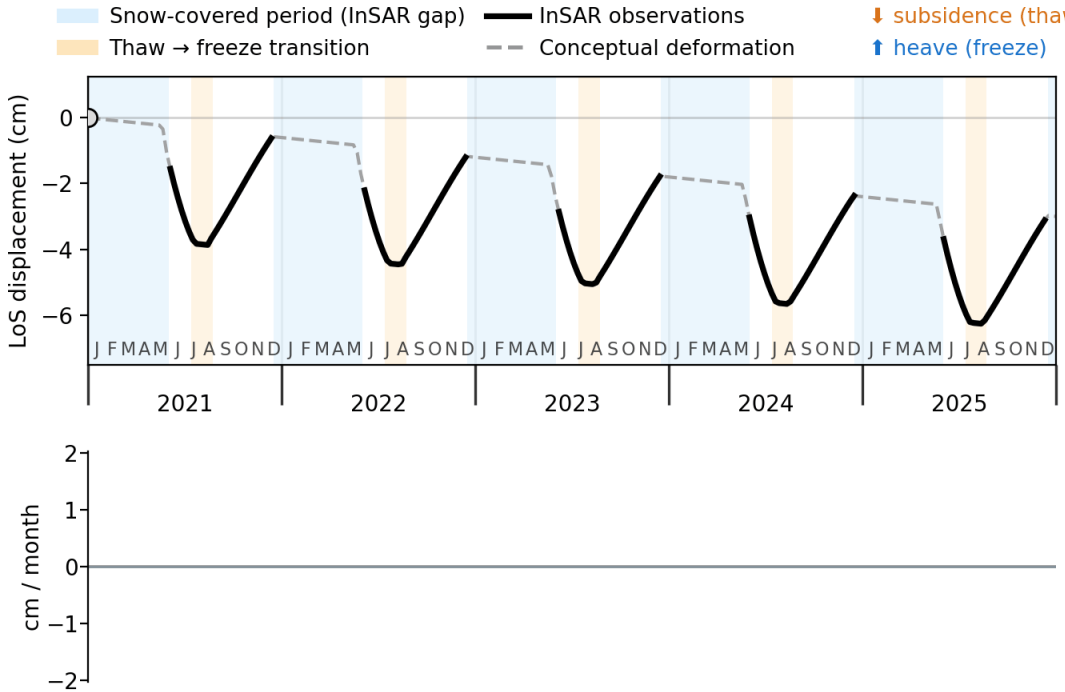
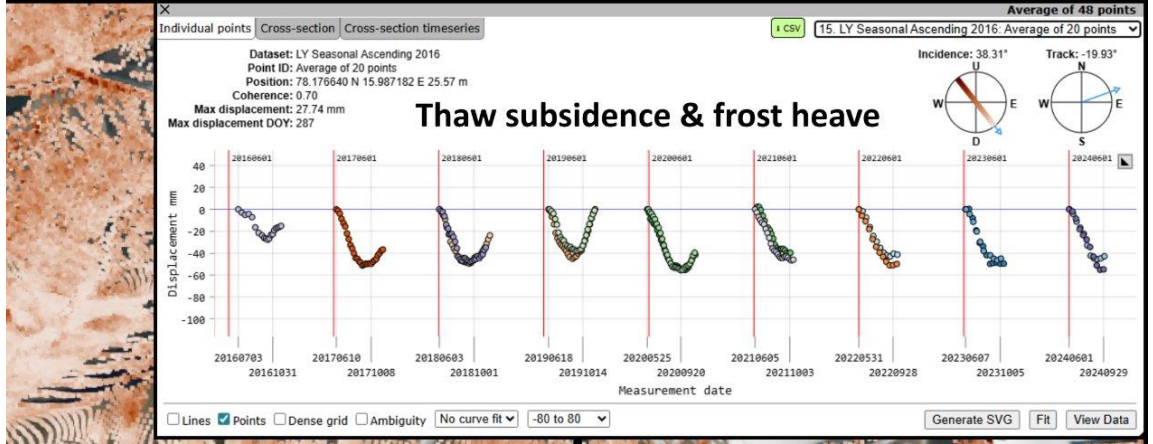
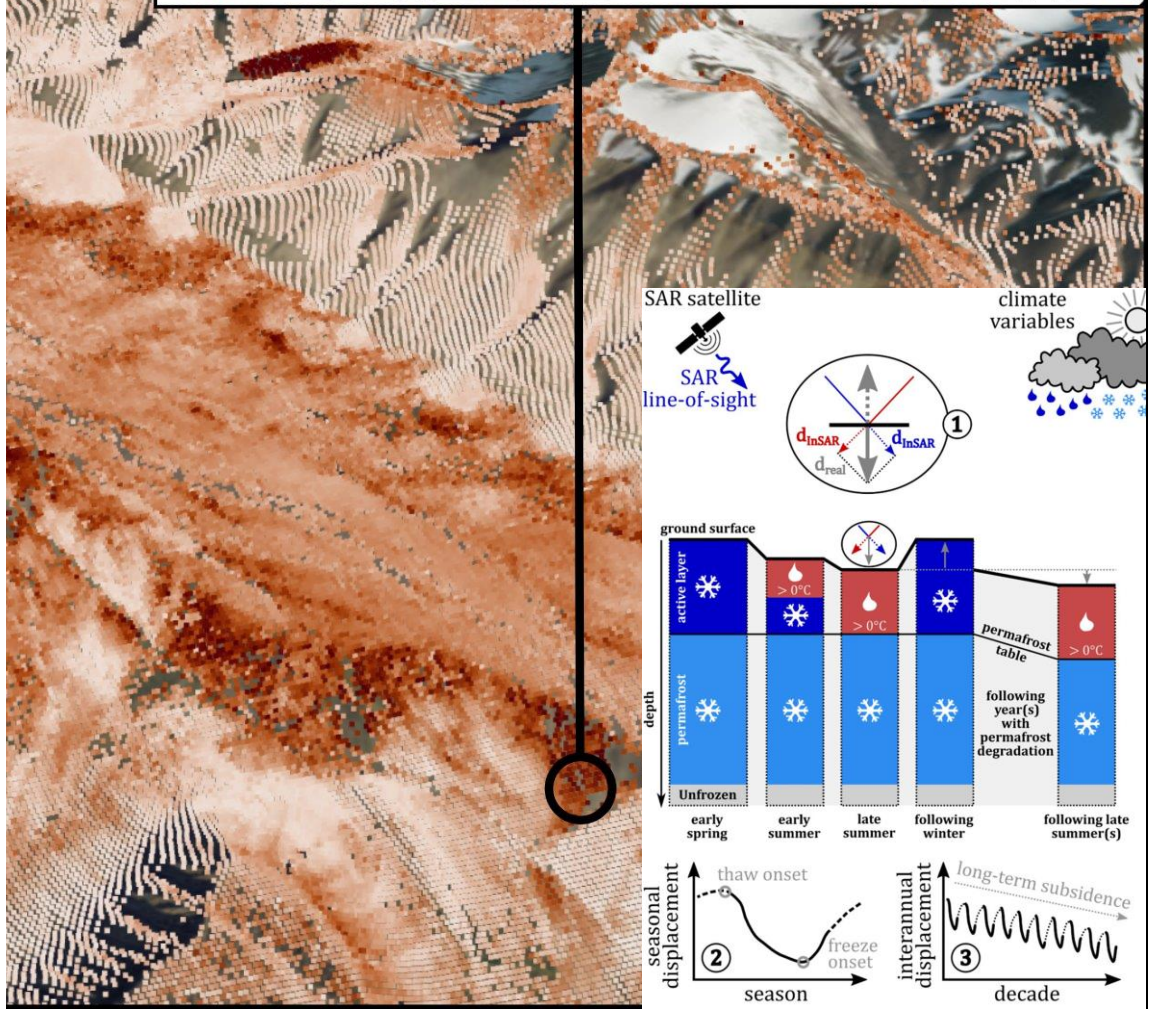


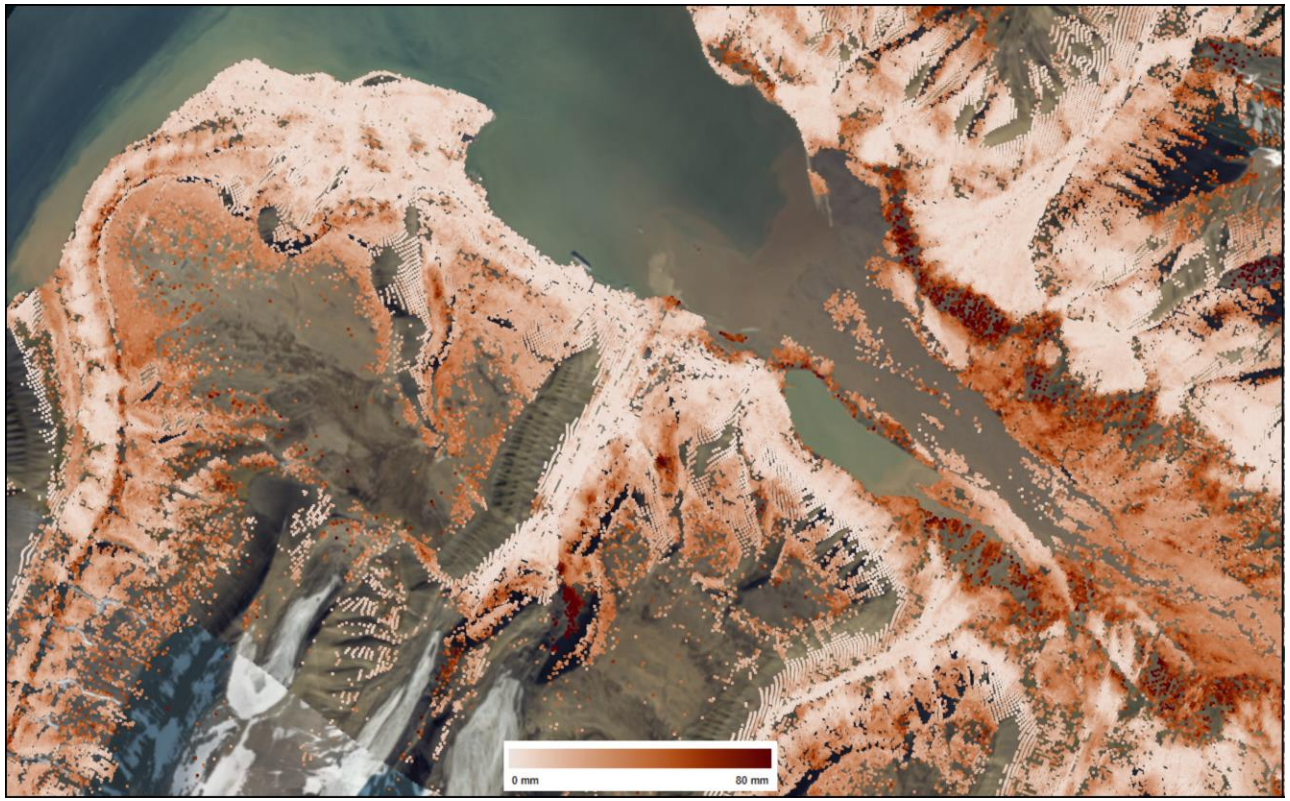
Figure by Gökhan Aslan





What is InSAR not measuring?

The results are spatially **discontinuous**.
In some areas, **there is no data**.
No data does not mean no movement!



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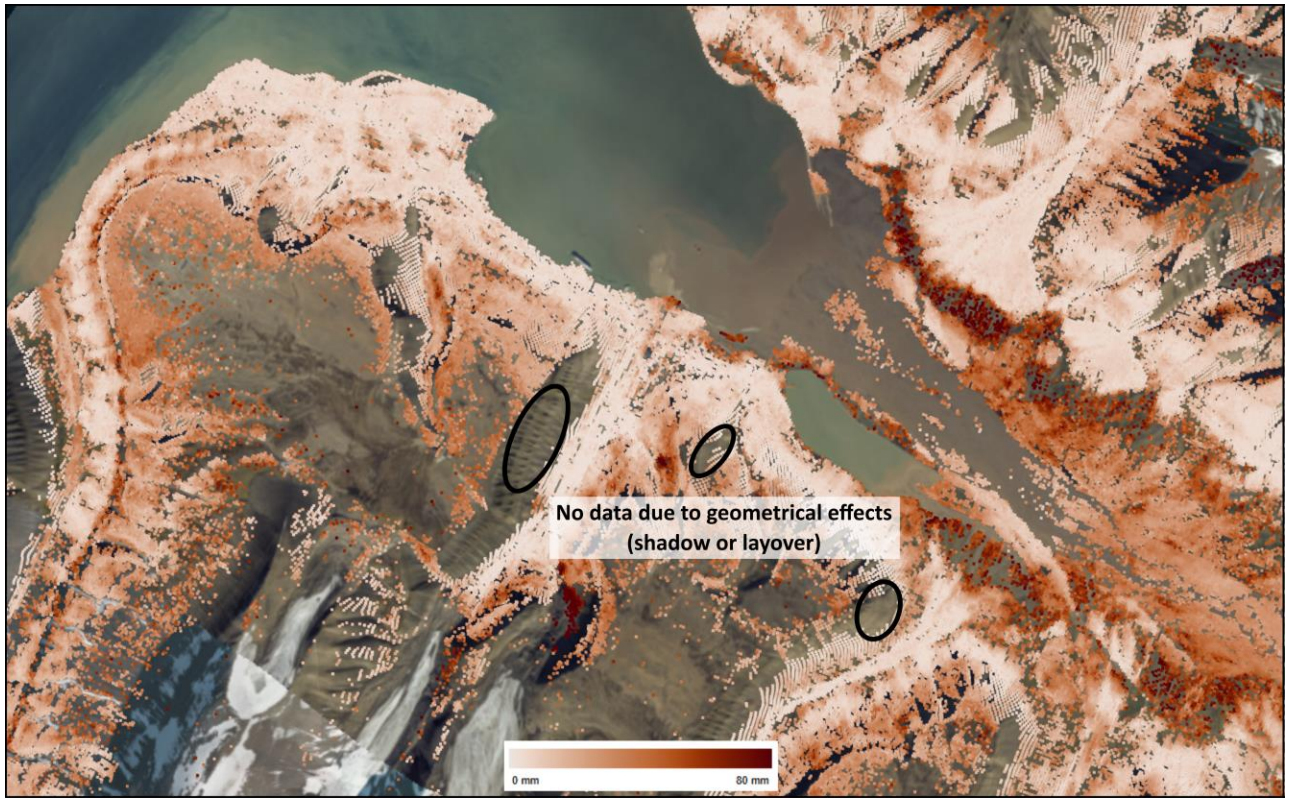
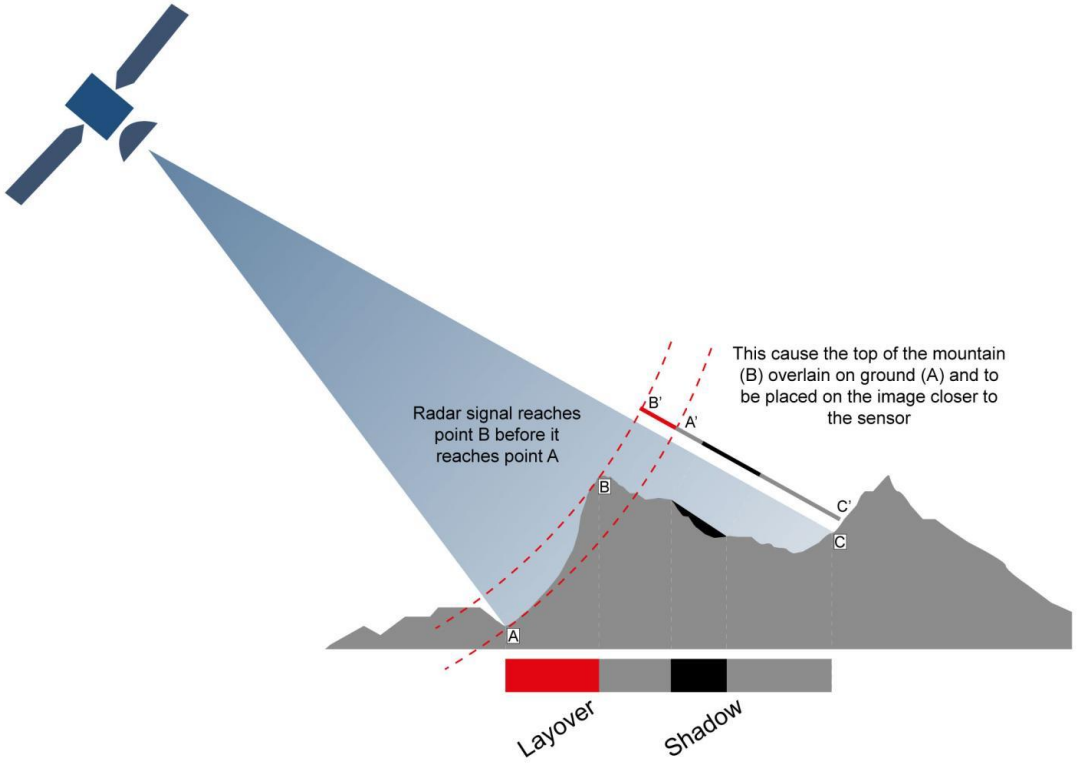


Due to side-looking geometry:

- **Black:** Shadow and layover in mountains



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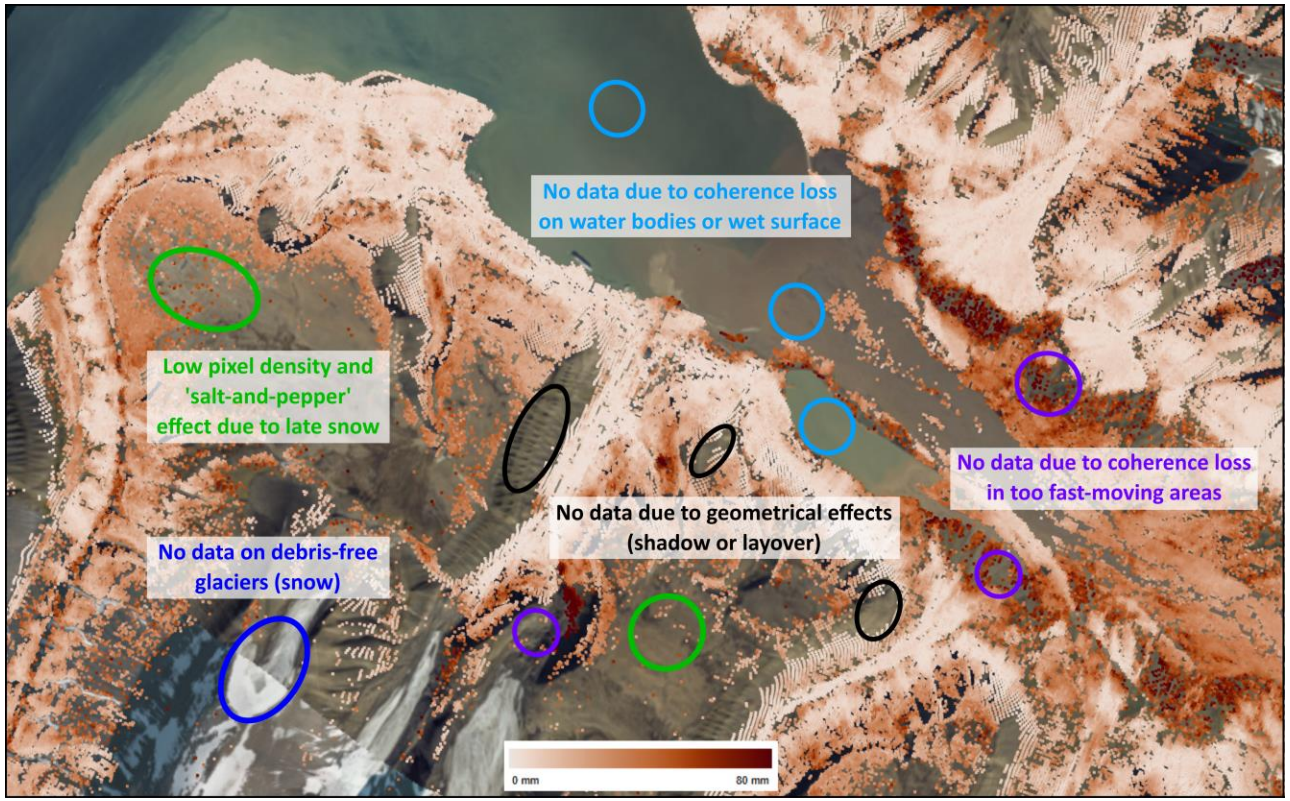


Due to side-looking geometry:

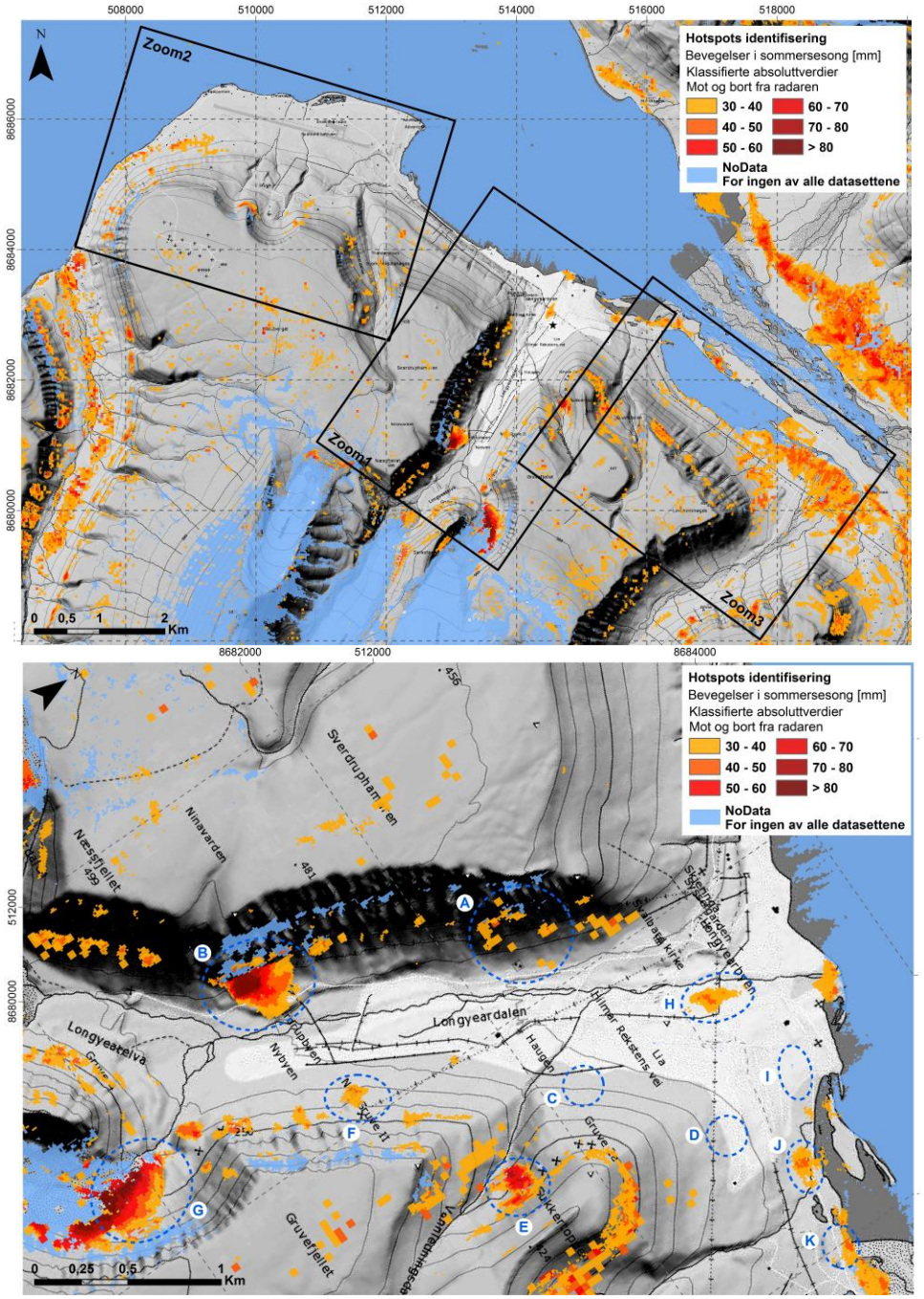
- **Black:** Shadow and layover in mountains

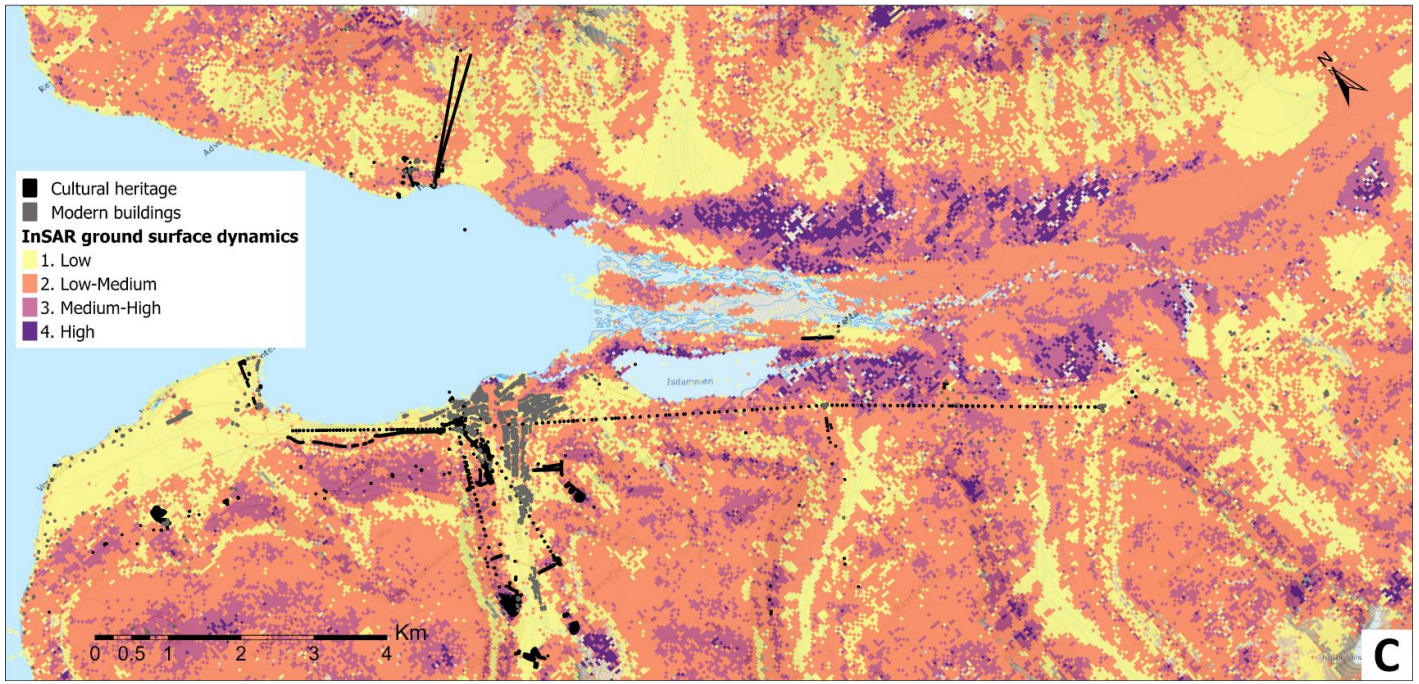
Other causes for reduced data coverage and data reliability:

- **Light Blue:** loss of signal stability on wet surfaces
- **Purple:** loss of signal stability on areas moving faster than the detection limit
- **Green:** loss of signal stability or bias due to snow cover (permanent or late-lying)
- **Dark blue:** glaciers are often not documented (combination of the three previous limitations)

In general: **avoid overtrusting single pixels** without looking at the surrounding pixels.

Hotspot analysis: other studies



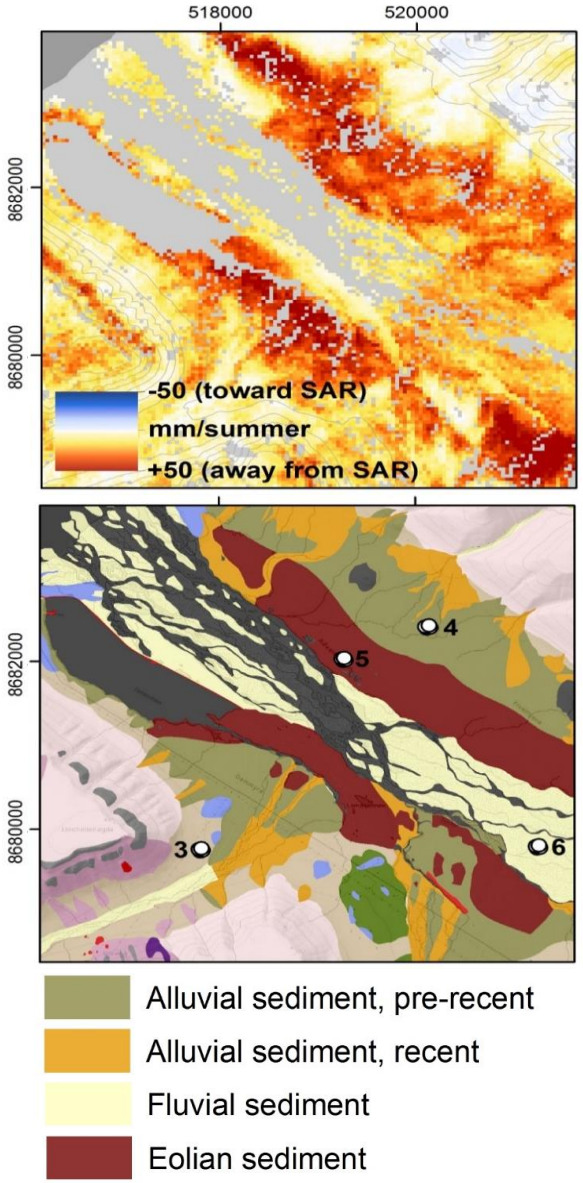


Nicu, et al. in prep. PermaRICH data paper.

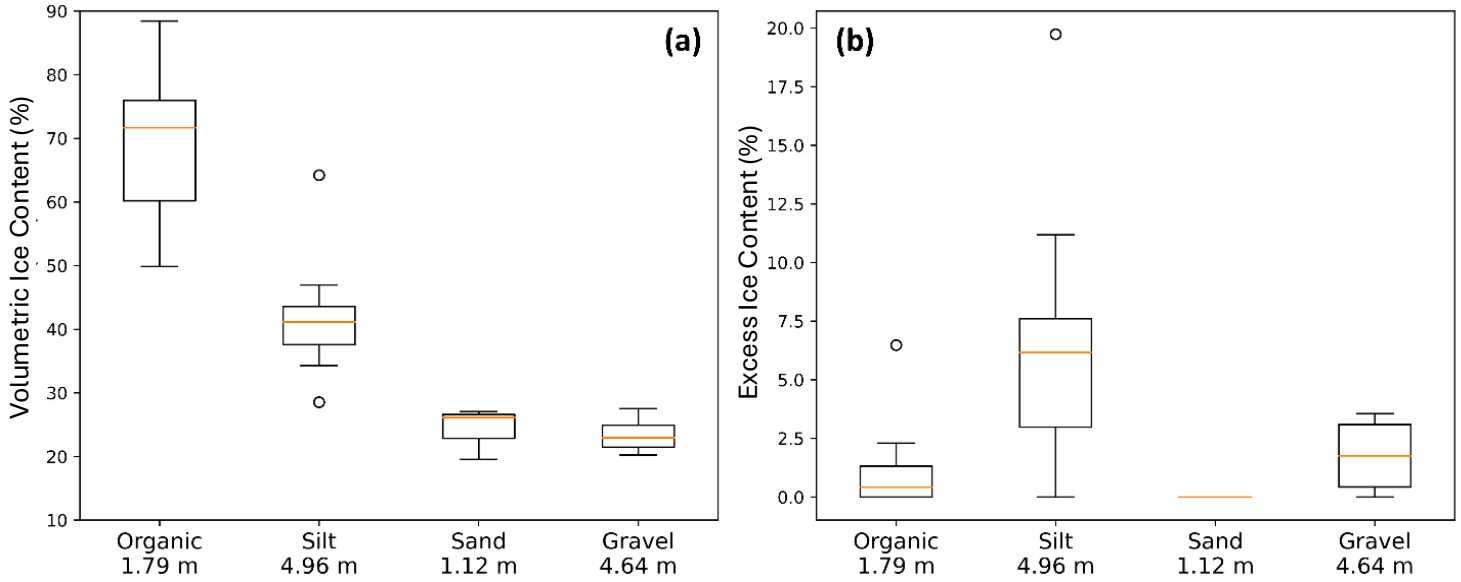
Rouyet, et al. 2017. https://hdl.handle.net/11250/2647824.

InSAR interpretation: comparison with ground type

Rouyet et al., 2019.



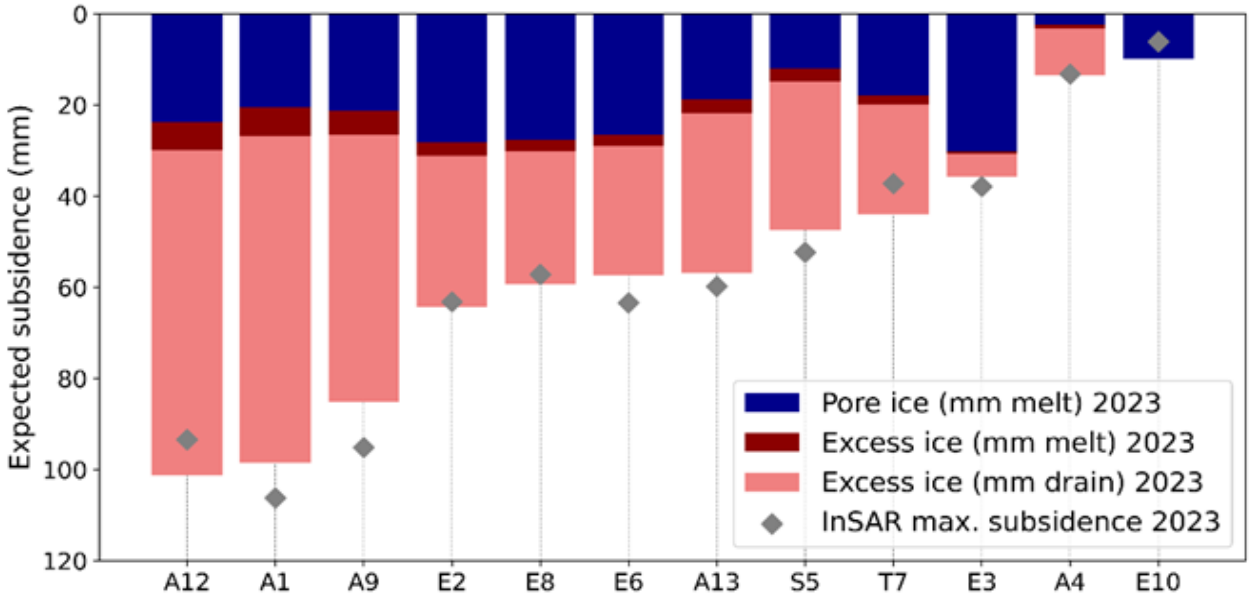
In lowlands, the amplitude and spatial distribution of the seasonal signal aligns with the **sediment type**, due to different **ice content** and **frost susceptibility**.



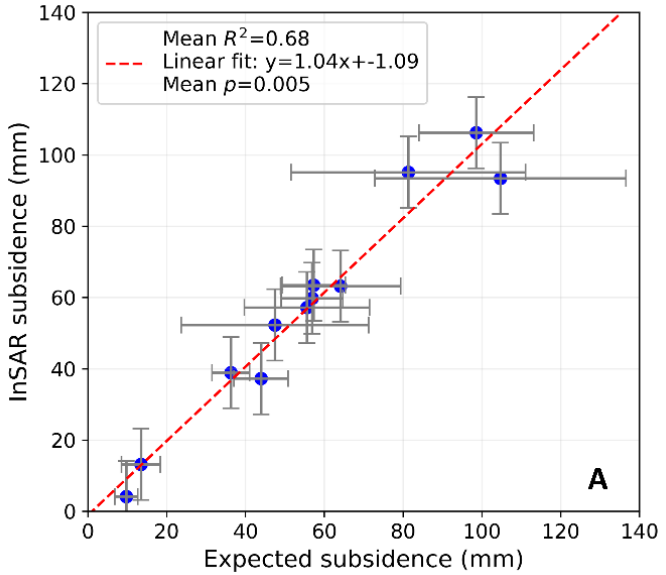
Wendt et al. 2024.

InSAR interpretation: comparison with ground ice content

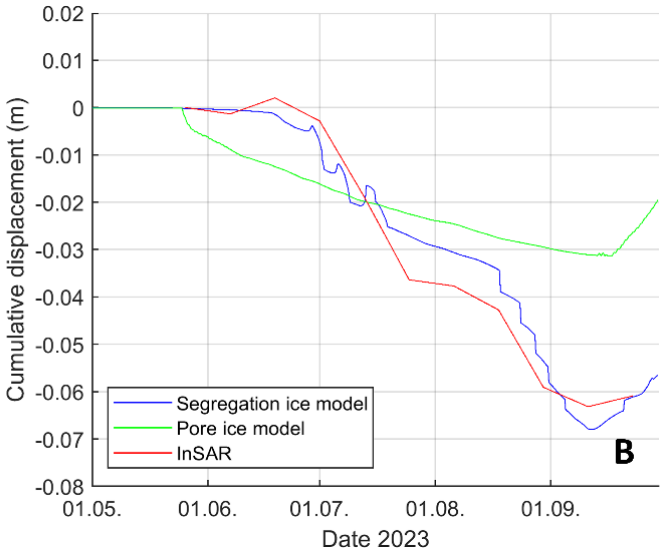
InSAR compared with expected subsidence calculated based on ice content from cores collected in Adventdalen.



Wendt et al., 2024



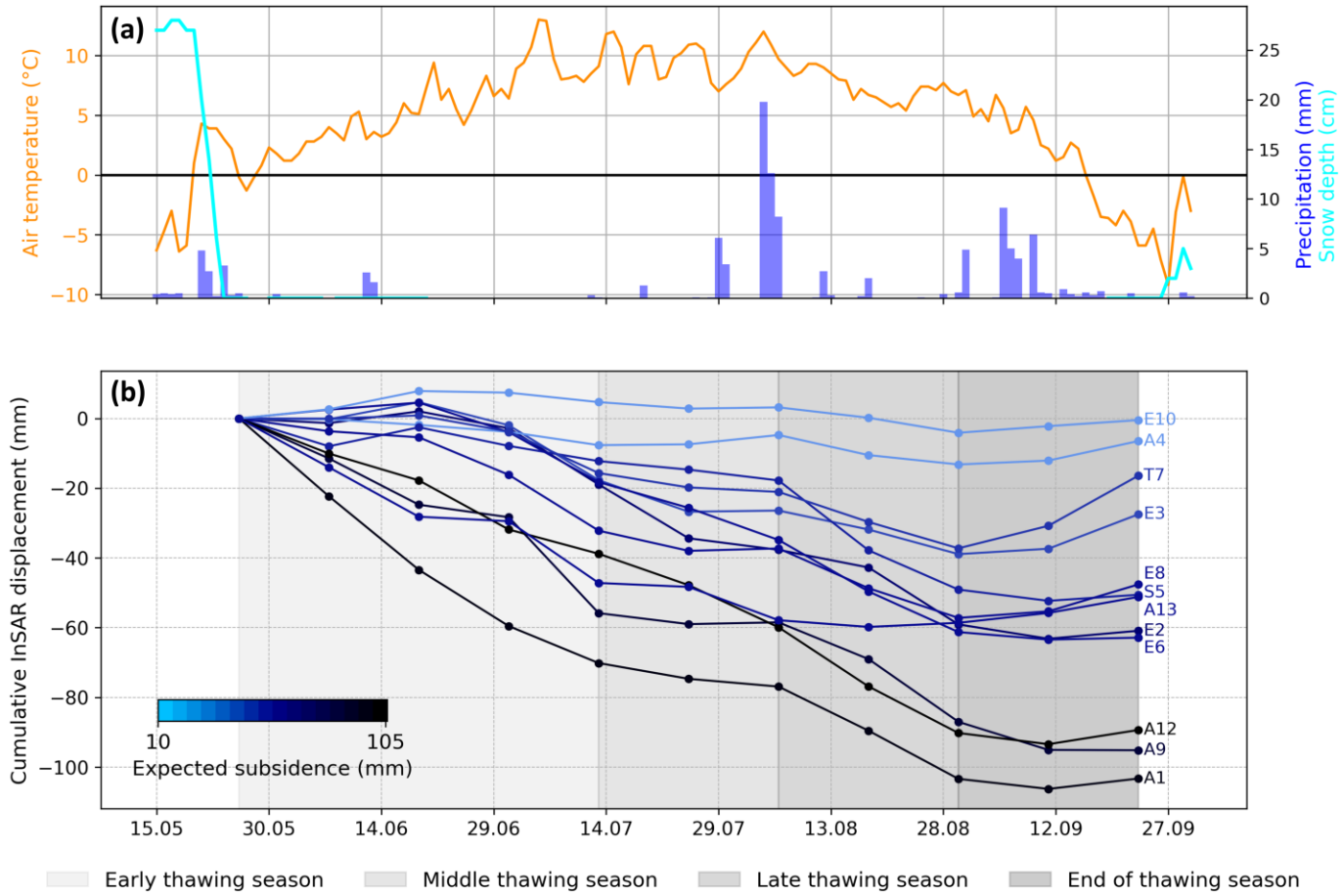
Good correlation btw InSAR-measured & expected subsidence from in-situ ice content.

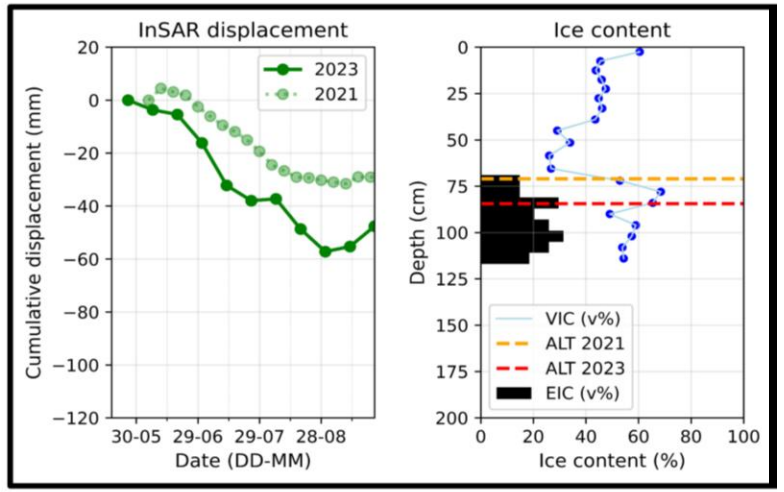


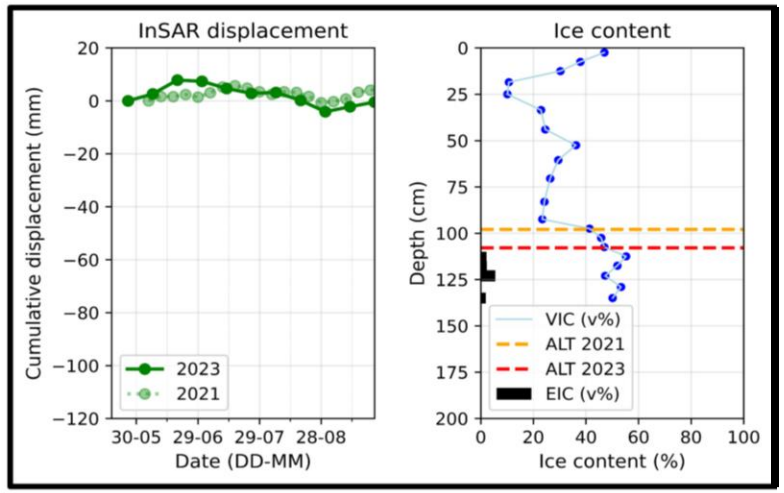
Good alignment between InSAR observation & model when accounting for segregation ice.

InSAR interpretation: comparison with ground ice content

Amplitude and timing of seasonal subsidence related to **amount, type and location of ground ice content along the vertical profile**.



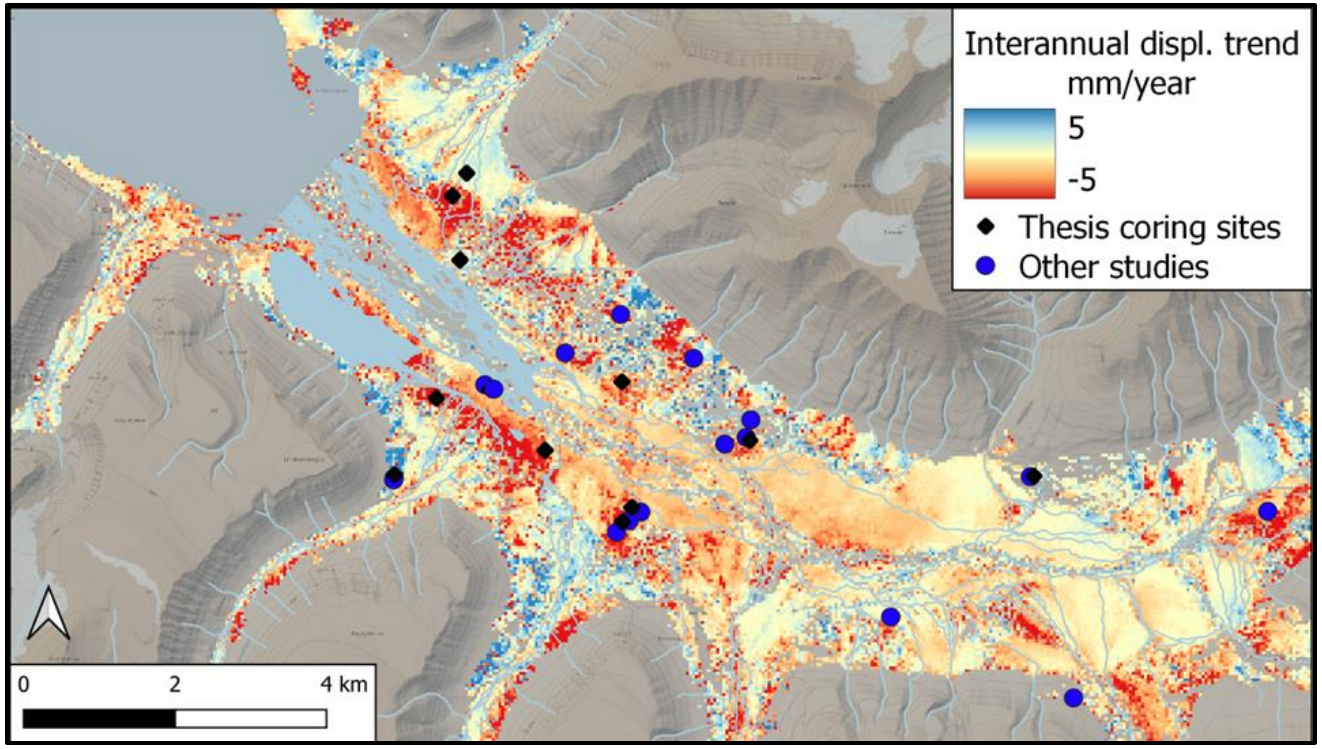




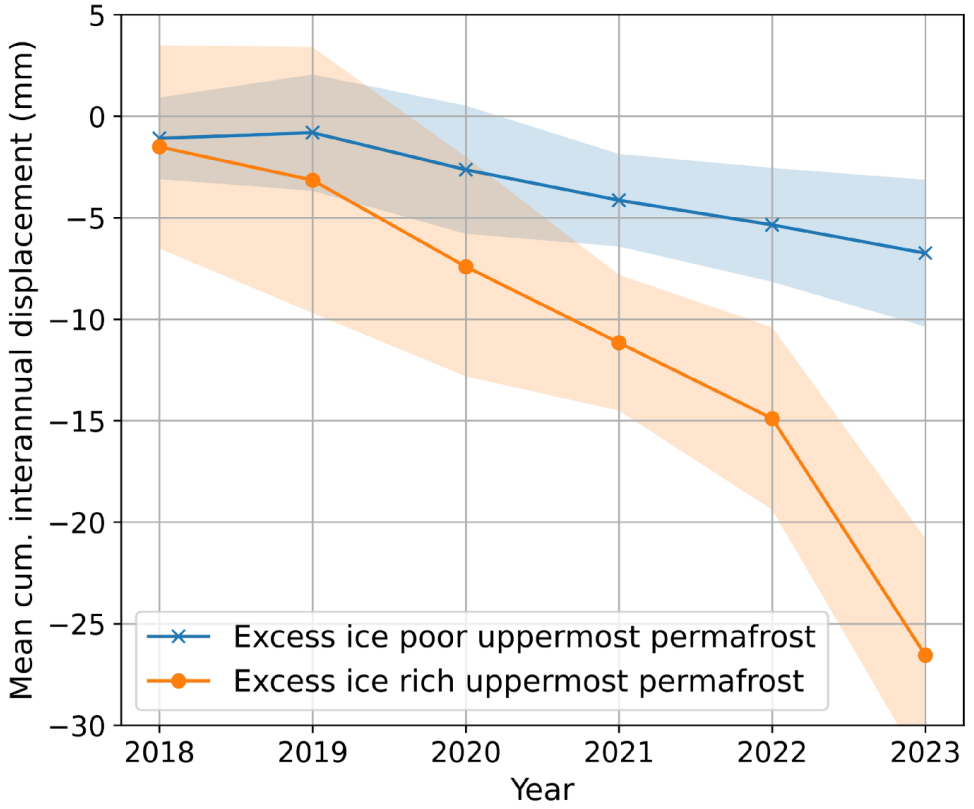
Wendt et al., 2024

InSAR interpretation: comparison with ground ice content

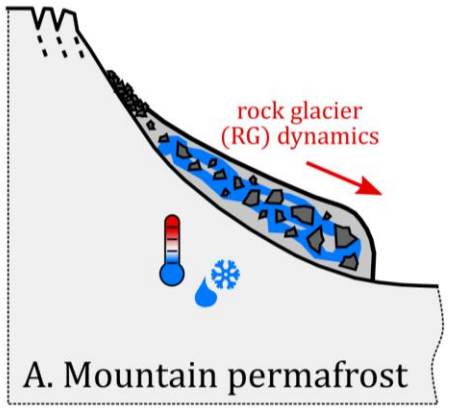
- Comparison between ice content from coring and InSAR interannual trend to **evaluate the representativity of the InSAR long-term subsidence**.
- **Interannual subsidence** visible at sites with an **ice-rich uppermost permafrost**.

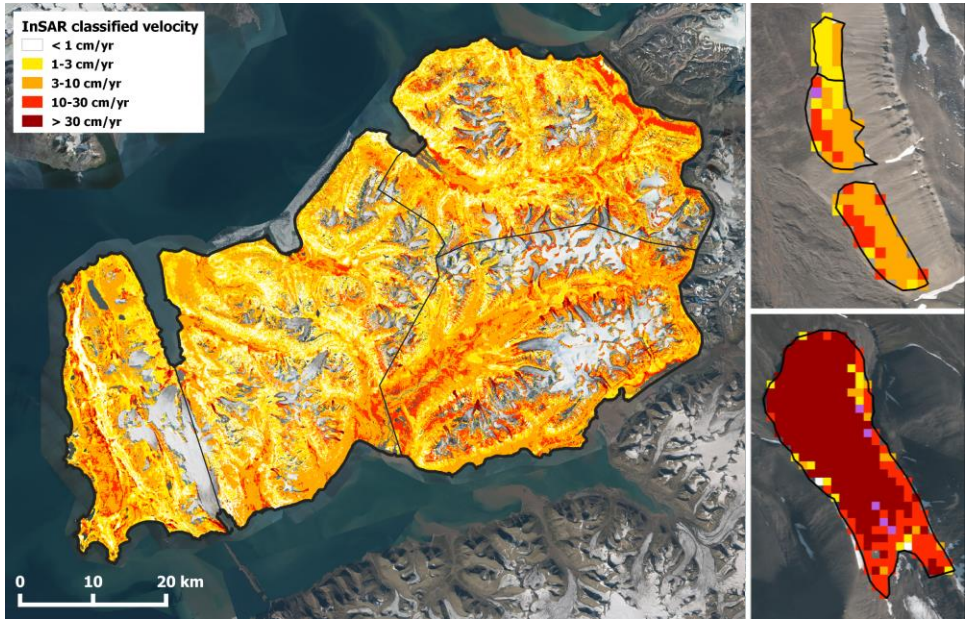


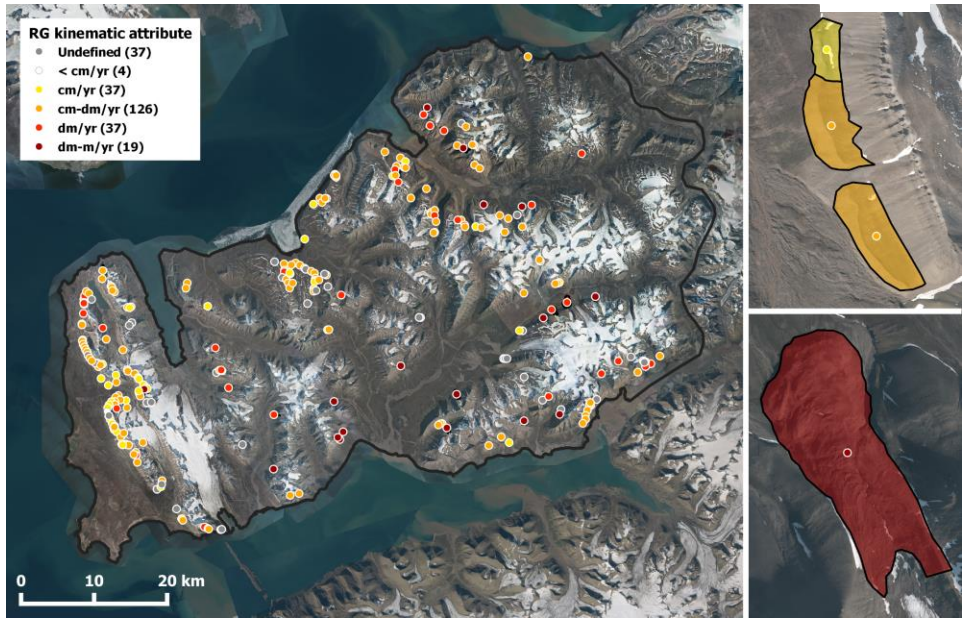
Wendt, 2024



InSAR interpretation: slope movements



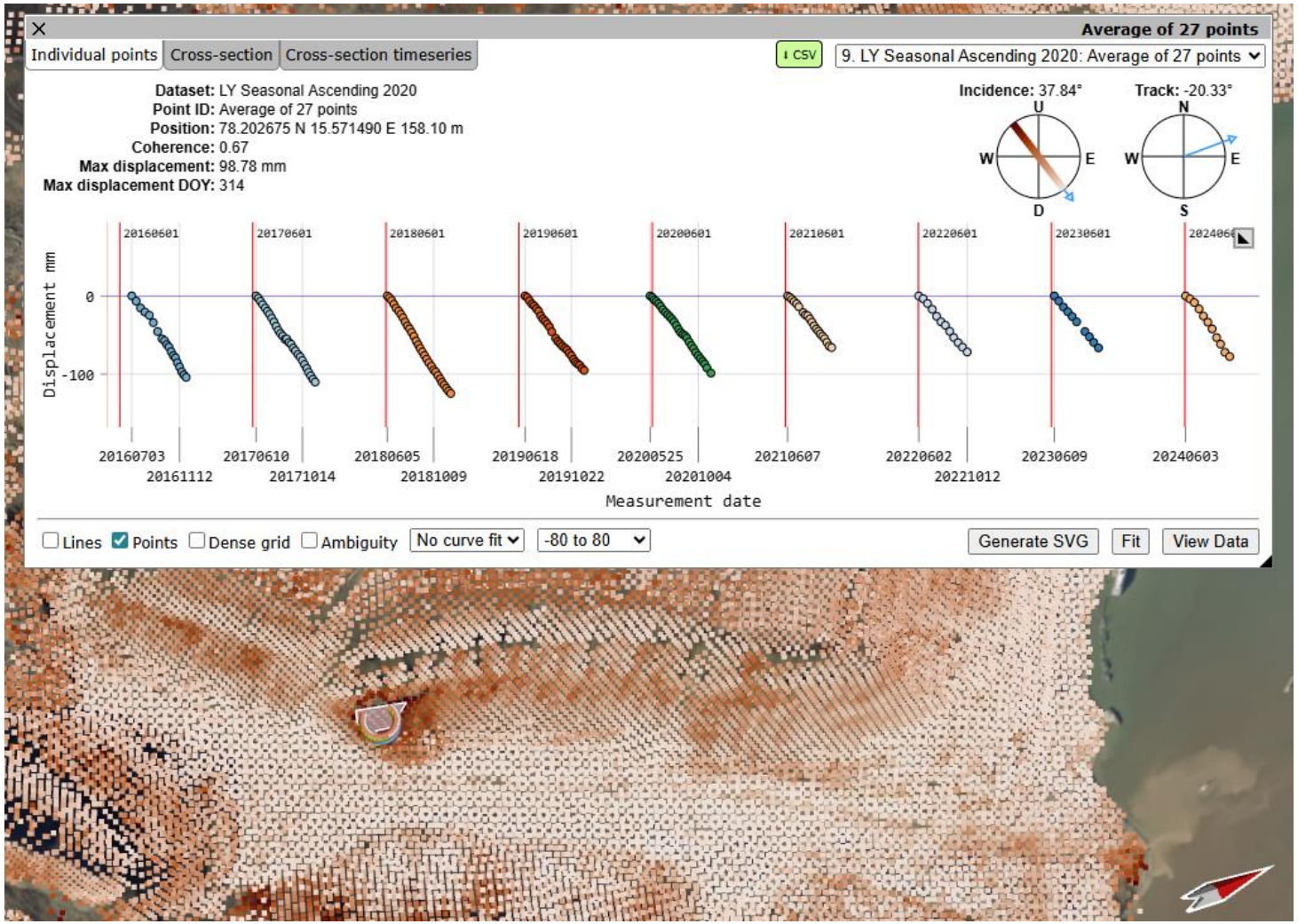




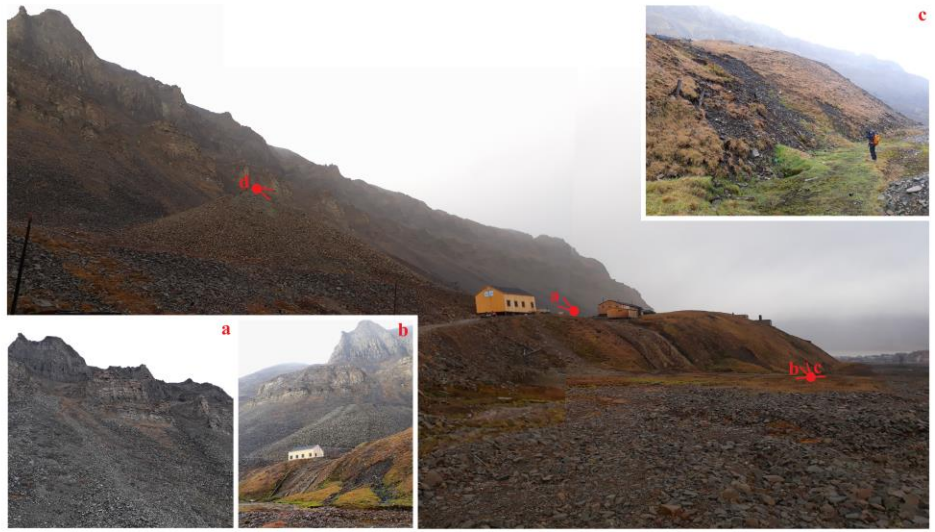
InSAR to map rock glaciers and characterise their movement rates

permafrost cci

InSAR interpretation: slope movements



Seasonal time series in Sverdrupbyen (rock glacier / mining pile)

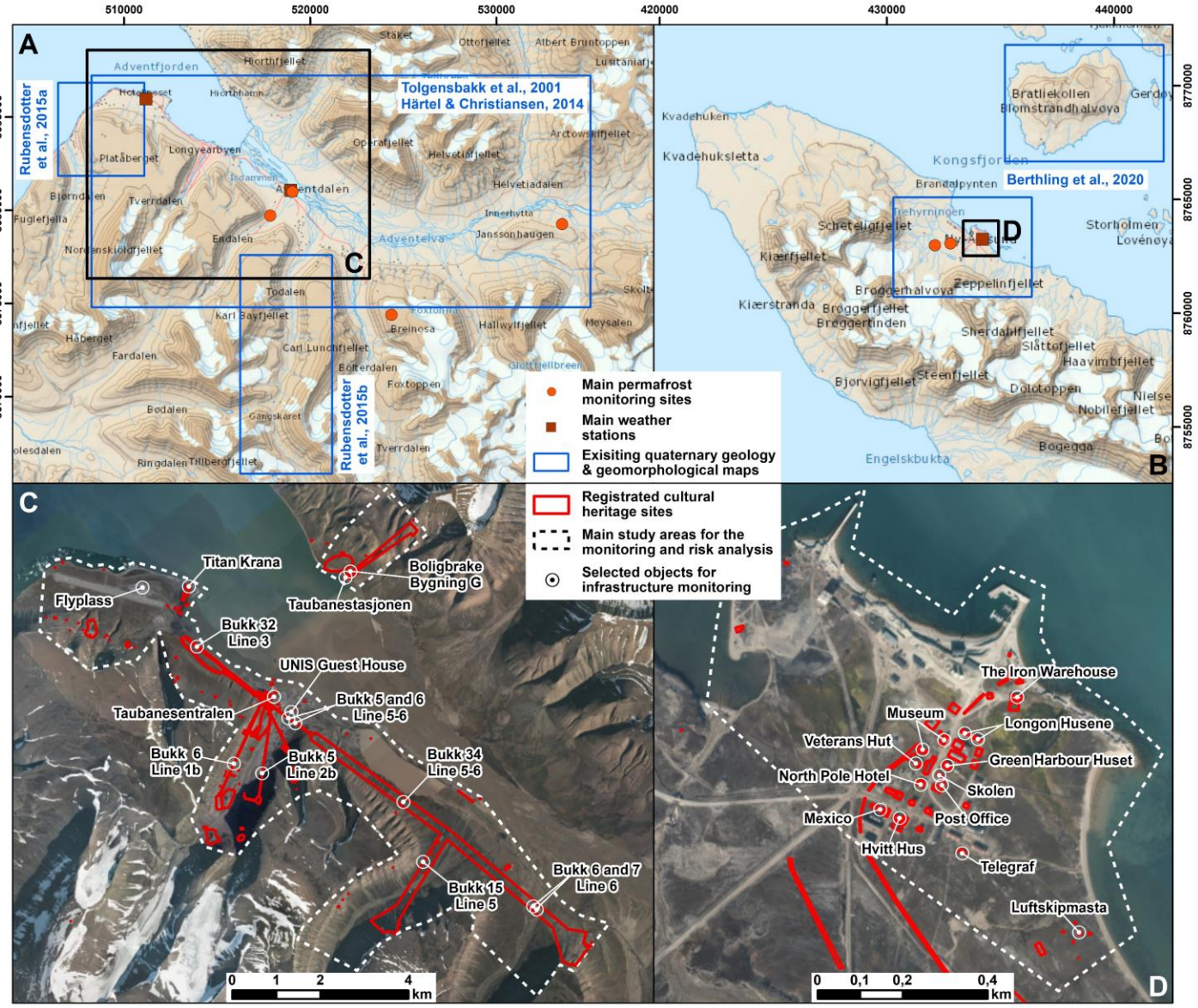


Permafrost-related Hazard and Risk Assessment for Cultural Heritage (CH) and Modern Buildings (MB) in Svalbard

Line Rouyet[1], Ionut Cristi Nicu[2], Lena Rubensdotter[3], Anatoly Sinitsyn[4], Hanne H. Christiansen[5,6], Elisabeth Angell[1], Lotte Wendt[1], Tom Rune Lauknes[1], Matthieu Leydier[5], Maaike F. Weerdersteijn[5], Yared Bekele[4], Alma E. Tuestad[3], Lise Loktu[3]

[1]NORCE Norwegian Research Centre AS, Tromsø. [2]Norwegian Institute for Cultural Heritage Research (NIKU), Tromsø. [3]The Geological Survey of Norway (NGU), Trondheim. [4]SINTEF AS, Trondheim. [5]The University Centre in Svalbard (UNIS), Longyearbyen. [6]Aarhus University, Roskilde, Danmark

The Fram Centre PermaRICH project (2023-2025)

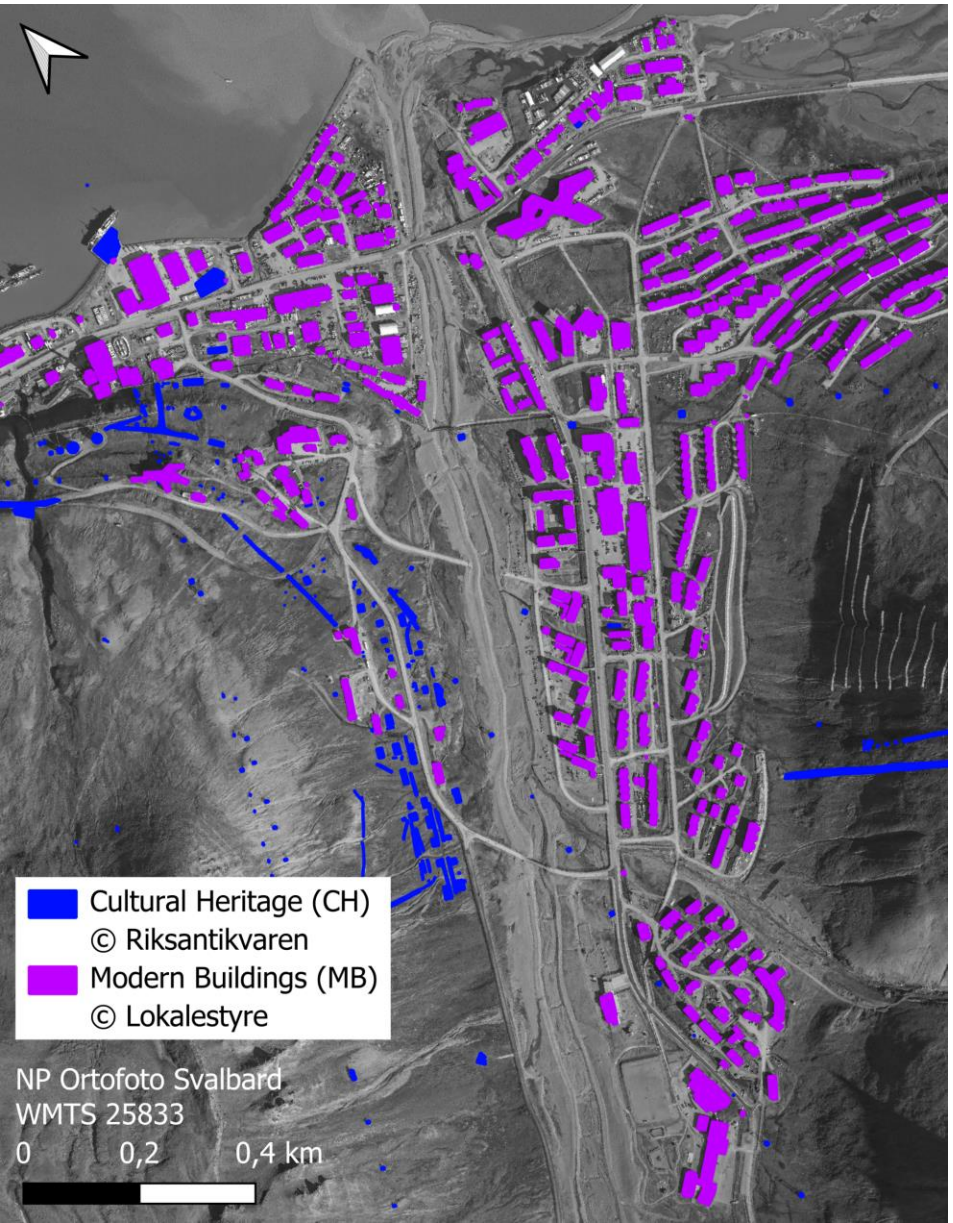


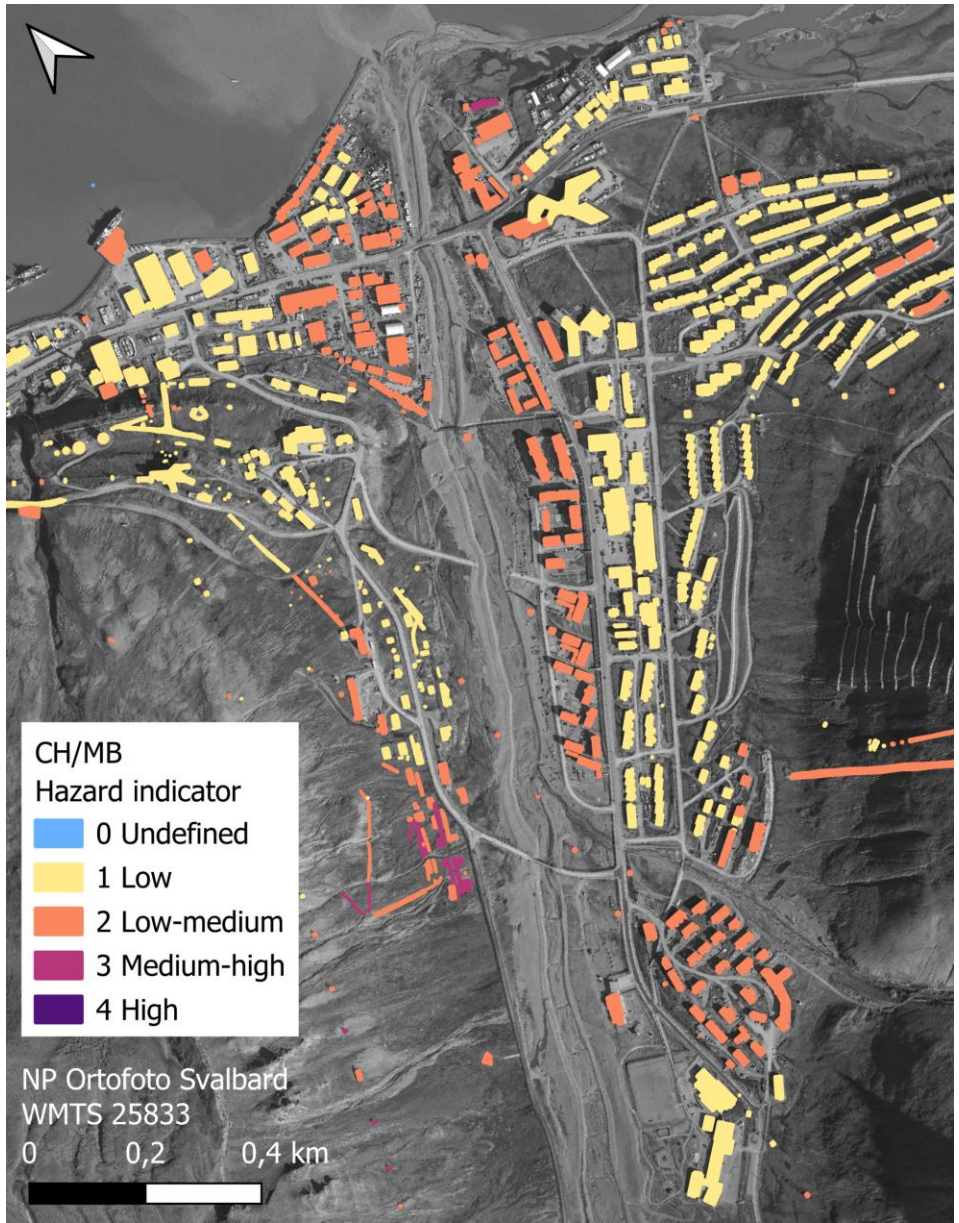
- PermaRICH is a research project funded by the **Fram Centre**, an umbrella organisation for High North Research For Climate and Environment, located in Tromsø.
- PermaRICH is a 3-years project (2023-**2025**).
- We are now **finishing** the project and **working on disseminating the results.**

Objective: Assess the risks related to terrain movement in inhabited permafrost landscapes and evaluate the potential impact on cultural heritage sites and modern buildings preservation and stability.

Focus areas: Longyearbyen and Ny-Ålesund.

CH & MB: Hazard indicator





- 639 CH (LYR)
  90 CH (NYÅ)
- 1028 MB (LYR)
  128 MB (NYÅ)

Hazard indicator:

Normalized sum of extracted indicators for each polygon:

- Geomorpho-based hazard susceptibility
- InSAR surface movement indicator
- Coastal erosion indicator

Application Areas and Future Directions

Potential application areas include:

- Monitoring **permafrost thaw and subsidence**
- Estimating **ground ice distribution**
- Assessing **terrain stability for infrastructure**
- Detecting **slow-moving slopes and shallow landslides**
- Mapping **glacier forefield evolution and sediment dynamics**

Next Development Steps

- Update with new Sentinel- 1 snow free seasons.
- Including more areas with the goal to extent whole Svalbard!
- Refining processing strategies
- Expanding product types (other satellites, modes)
- Maximizing the societal and scientific value of the product by enhancing the dialogue with end users.

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Thanks for your attention! Questions?