

Brief Communication – InSAR Svalbard Ground Motion Service: Observing Surface Displacements in the High Arctic

Marie Bredal, Line Rouyet, Lotte Wendt, Heidi Hindberg, Daniel Stødle, Tom Rune Lauknes, Jelte van Oostveen, Yngvar Larsen, Gökhan Aslan, Emma Hauglin, John Dehls, Anja Sundal, Anna Odh, and Dag Anders Moldestad

We answer the reviewers' comments hereafter in red. The line numbering corresponds to the track change version of the revised manuscript.

RC1: '[Comment on egusphere-2026-2189](#)', Anonymous Referee #1, 26 May 2026

The InSAR Svalbard initiative represents a significant milestone for Arctic research. The manuscript presents its background and relevance in a clear and functional manner. Overall, I believe the paper is suitable for publication, pending minor revisions.

I would suggest that the handling editor consider elevating the manuscript to a Research Article, given the uniqueness and potential impact of the service proposed to users. In its current form, the paper gives the impression that additional technical detail could have been included, and that the reliance on external documentation is driven more by space constraints than by a deliberate stylistic choice.

For instance, a more detailed discussion of InSAR limitations in Chapter 3 would be valuable for technical readers, particularly in relation to the motion characteristics of the Svalbard archipelago. Similarly, the solutions adopted for the data viewer, currently only briefly described in Chapter 4, would likely be of interest to InSAR service providers and practitioners, and could be expanded.

We thank the reviewer for the positive feedback. We understand the comment regarding the format. We initially submitted the manuscript as a longer and more comprehensive Research Article. However, the editor asked us to convert the manuscript to a Brief Communication due to the lack of extensive discussion of the results at this stage of the project. This request required a significant change of structure, during which we decided to take out all technical details and compile them in an online user manual (see reference at l.273-275). We believe that it is an elegant way to promote the service, while allowing interested users to read the details of the service and data in a dedicated manual. Considering the recent release of the datasets, no comprehensive data exploitation has been performed at this stage. So far, the focus has been placed on the service design, data processing and product dissemination. The article mostly aims to increase the visibility of the service and make the open data known to a larger audience. In the future, we hope several users will take advantage of the data to perform novel research that might lead to the publication of advanced scientific papers.

Specific comments:

- Please clarify why the short-term observation periods differ between the two orbits.

Added at l.101-102: “Over Svalbard, Sentinel-1 IW images were unavailable before 2018 in the descending geometry.”

- Please define what is meant by a “season.” In particular, specify how the “average” snow-free season is determined and characterized (e.g. using external models or RS data).

Added at l.79-82: “Only images from the snow-free periods were processed, because snow causes decorrelation of the phase signal. There are gaps in winter, and the observation time window varies each year due to variable climatic conditions. The documented season typically spans from June to October (at best, from late May to early December). The images are selected with a data-driven approach based on signal stability metrics (interferometric coherence).”

- If, due to article-type constraints, a more extensive description of limitations (ref. line 78) and WebGIS functionalities (ref. line 126) cannot be included, I recommend providing at least a concise list of key elements that users should focus on when consulting the external documentation.

While trying to remain as concise as possible, we added extra information, examples about the content of the user manual and references to the relevant chapters.

See at l.90-94: The processing workflow includes removal of orbital and topographic phase components, filtering to reduce speckle noise and atmospheric effects, phase calibration, interferogram unwrapping, SBAS inversion and geocoding. Overall, it followed the same steps applied to past Svalbard InSAR case studies (Rouyet et al., 2019; Wendt et al., 2026). Details about the processing settings, product properties and related limitations are available in the InSAR Svalbard user manual (Bredal et al., 2026b; see Chapters 2, 3 and 5).

See at l.113-114: For both products, various filtering techniques have been applied to discard low-quality pixels, irrelevant signals and areas likely to be affected by unwrapping errors and phase ambiguities (Bredal et al., 2026b; Section 2.2).

See at l.120-123: All WebGIS functions, e.g. tools to average and plot time series, are described in the InSAR Svalbard user manual (Bredal et al., 2026b; Chapter 4). Advice for interpretation, e.g. explanations on the spatio-temporal variability

in the data coverage and quality, are also provided (Bredal et al., 2026b; Chapter 5).

See at l.148-151: All WebGIS functions, e.g. tools to select and compare time series at several locations, are described in the InSAR Svalbard user manual (Bredal et al., 2026b; Chapter 4). Advice for interpretation, e.g. explanations on the key differences with the seasonal products, are also provided (Bredal et al., 2026b; Chapter 5).

- Does Svalbard have a pre-existing database of slow-moving processes?
Clarifying this would help highlight the added value of the project (e.g., whether it provides an update or constitutes a first systematic mapping).

The background of InSAR research and the relevance of the GMS were already provided at l.34-42. We complemented it with the following: “Svalbard has a long history of geoscientific and geoengineering research (Humlum et al., 2003). However, surface movement and periglacial processes have not been consistently mapped across the archipelago. Satellite remote sensing has the potential to fill this gap thanks to operational missions with large spatial coverage and regular image acquisition.” (l.32-34).

- With reference to line 179: the project clearly illustrates the operational burden and challenges associated with extending a continental-scale Ground Motion Service (GMS) to the Arctic environment. This can be commented.

This point was partly covered in the introduction (l.27-29). We complemented it with the following sentence: “The cold climate and the perennally frozen ground (permafrost) lead to challenging surficial conditions to process InSAR (snow, wetness), and heterogenous and nonlinear deformation patterns, which require alternative processing strategies compared to the temperate mainland.” (l.29-31).

The last paragraph is modified as follows (l.203-209): “InSAR Svalbard provides a robust foundation for long-term ground motion observations in the archipelago. As new Sentinel-1 images get available and other satellite missions become operational, the platform might evolve into a flexible, service-oriented system supporting research, hazard assessment, and sustainable land-use planning in Svalbard. On the way further, we hope InSAR Svalbard may contribute to setting a baseline for the development of similar InSAR services tailored for polar conditions and permafrost terrain (Duchossois et al., 2024). Developing a pan-Arctic GMS especially designed for cold-climate conditions could complement the existing continental services less suited for such challenging environments.”

RC2: '[Comment on egusphere-2026-2189](#)', Anonymous Referee #2, 08 Jun 2026

The manuscript titled “InSAR Svalbard Ground Motion Service: Observing Surface Displacements in the High Arctic” presents an operational InSAR-based platform for monitoring ground displacement in Svalbard using Sentinel-1 data. The topic is highly relevant for Arctic geohazard and permafrost research, and the development of an open-access InSAR service for Svalbard represents an important contribution to the community. The paper is concise and generally well structured. However, the manuscript currently lacks sufficient methodological detail to fully support several of the scientific interpretations presented. I therefore recommend publication after minor revision.

We thank the reviewer for positive feedback. Considering the Brief Communication format requiring a concise structure, we could not detail all processing steps and parameters. The contribution must be seen as an introduction/pitching paper, rather than a complete technical report. We ask the readers to refer to the linked user manual for processing details and advice for data interpretation (see reference at l.273-275). See also the first answer to reviewer 1 (page 1 of this document). That said, we tried to address the comments below and complement the manuscript with a few more explanations targeting the specific requests.

Comments:

1. Lines 79 – 94 (Method): the present description of the methodology is insufficiently detailed. The two complementary SBAS processing strategies that were applied to generate two types of InSAR Svalbard products must be described in greater depth, with a full account of the strategies and the type of results obtained.

The processing details are provided in the user manual (see l.93-94). However, we tried adding some complements directly in the manuscript, while referring to the relevant Chapters of the user manual for more details.

At l.78-85: “We used Sentinel-1 SAR images acquired in the Interferometric Wide (IW) swath mode from track 14A (ascending geometry) and track 154D (descending geometry). Only images from the snow-free periods were processed, because snow causes decorrelation of the phase signal. There are gaps in winter, and the observation time window varies each year due to variable climatic conditions. The documented season typically spans from June to October (at best, from late May to early December). The images are selected with a data-driven approach based on signal stability metrics (interferometric coherence). To reduce the noise, a spatial multi-looking factor of 8×2 (range $\times$ azimuth) was applied to the IW images, resulting in a final ground resolution of ~ 30 m. The temporal resolution corresponds to the satellite’s revisit interval: 6 days

during dual-satellite operation (2017–2021); 12 days before fall 2016 and after the Sentinel-1B failure in December 2021.”

At l.90-93: “The processing workflow includes removal of orbital and topographic phase components, filtering to reduce speckle noise and atmospheric effects, phase calibration, interferogram unwrapping, SBAS inversion and geocoding. Overall, it followed the same steps applied to past Svalbard InSAR case studies (Rouyet et al., 2019; Wendt et al., 2026).”

At l.96-98: “The SBAS workflow is similar, but the time intervals used to build the interferometric pairs vary to capture ground dynamics across multiple timescales.”

At l.113-114: “For both products, various filtering techniques have been applied to discard low-quality pixels, irrelevant signals and areas likely to be affected by unwrapping errors and phase ambiguities (Bredal et al., 2026b; Section 2.2).”

2. Lines 102 – 112 & 128 – 136 (Results): the authors discuss the interpretation of displacement signals. These signals include thaw subsidence, rock glaciers, solifluction, and permafrost creep. However, the absence of quantitative validation against independent datasets or report is evident.

Due to the Brief Communication format, the section “Results” is only an overview of the products available in the service, with some examples of interpretation. Indeed, at this stage, we do not have performed comprehensive validation, mostly due to the difficulty of finding data directly comparable in Svalbard (generally few in-situ measurements documenting surface movement, and difficulty comparing with InSAR due to different spatiality, temporality and dimensionality). So far, our mandate has focused on the service design, the data processing and the product dissemination. At this stage, the priority is to promote the availability of this new set of data. In the future, we hope this will trigger related research and comparison with other datasets to contribute to validation. We mention it as prospect: l.199-200.

3. Lines 149 – 158 (Potential applications): the authors discuss the potential of the data to support several operational and research activities. The following list details the relevant applications of the current InSAR Svalbard products: It is recommended that the author provide illustrative examples of research papers on each of these pertinent applications

I can suggest these papers:

- Chen, J., Wu, Y., O'Connor, M., Cardenas, M. B., Schaefer, K., Michaelides, R., & Kling, G. (2020). Active layer freeze-thaw and water storage dynamics in permafrost environments inferred from InSAR. *Remote Sensing of Environment*, 248, 112007.

- Poggi, F., Nardini, O., Fiaschi, S., Montalti, R., Intrieri, E., & Raspini, F. (2025). Multi-Sensor Satellite Analysis for Landslide Characterization: A Case of Study from Baipaza, Tajikistan. *Remote Sensing*, 17(12), 2003.
- Cigna, F., Banks, V. J., Donald, A. W., Donohue, S., Graham, C., Hughes, D., ... & Parker, K. (2017). Mapping ground instability in areas of geotechnical infrastructure using satellite InSAR and Small UAV surveying: A case study in Northern Ireland. *Geosciences*, 7(3), 51.
- Becattini, F., Poggi, F., Tanteri, L., Confuorto, P., Del Soldato, M., Moretti, S., & Raspini, F. (2025). Opensource InSAR data for the characterization of geomorphic processes at different scales. *Geografia Fisica e Dinamica Quaternaria*, 48(1-2), 103-119.

We understand the comment and agree that all the references above are relevant to the potential applications of the InSAR Svalbard data. However, one requirement of the Brief Communication format is a maximum of 20 references. The current version of the manuscript reaches this limit. In addition to mandatory references (data reference, figure references), we focused on references targeting the Arctic and Svalbard for key background info and examples of interpretation. If you have a concrete suggestion about which reference could be removed and replaced, we can consider it in the next version of the manuscript.

4. Line 146: The designation of chapter “6 Potential applications and future perspectives” should be changed to “5 Potential applications and future perspectives”.

Thanks for spotting this error. It is now corrected (l.170).