Seasonal Thaw Displacement in Low-Land Permafrost Areas at L-, C- and X-Band

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Funding: This research has been supported by the European Space Agency CCI+ Permafrost project

Key Message

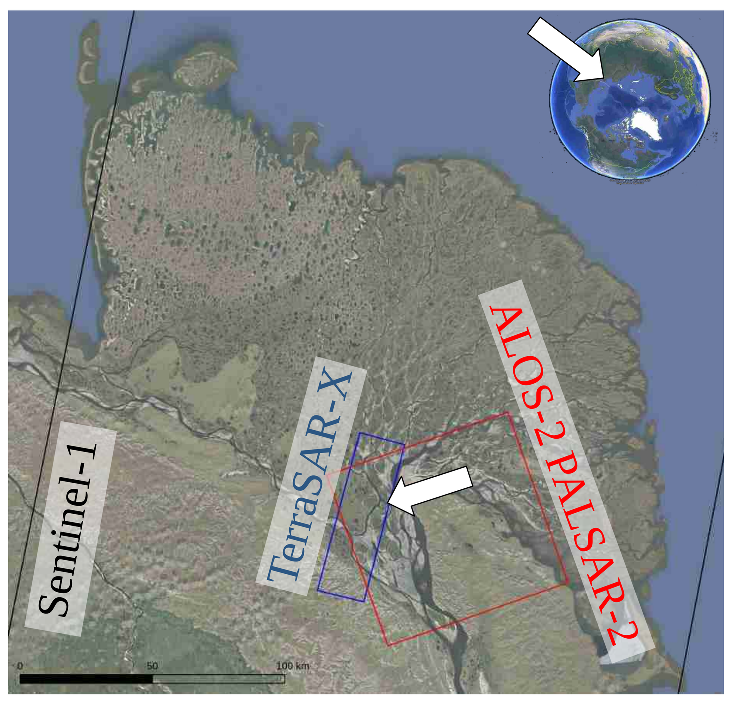
Can we effectively monitor seasonal thaw displacement in low-land Arctic permafrost areas with differential SAR interferometry despite the influence of changing atmospheric, soil moisture, vegetation and snow-cover conditions?

The high level of agreement of the subsidence maps measured during the thaw season 2018 over Samoylov Island with Sentinel-1, TerraSAR-X and ALOS-2 PALSAR-2 at different frequencies and acquisition dates suggests surface motion as the prevailing effect.

Introduction

- Low-land permafrost areas, with active layers rich in ice and water, are subject to annual cycles of vertical surface deformation processes due to phase changes from ice to liquid water and viceversa.
- Satellite differential SAR interferometry (DInSAR) has been used in the past to measure seasonal thaw subsidence and frost heave.
- However, the DInSAR phase not only contains information about land displacement, but is also influenced by changes in the atmospheric, soil moisture, vegetation and snow-cover conditions.
- We measured the surface thaw displacement in 2018 on Samoylov Island (Lena Delta, Northeastern Siberia) using Sentinel-1 (C-band), TerraSAR-X (X-band) and ALOS-2 PALSAR-2 (L-band) and compared the results.

Lena Delta

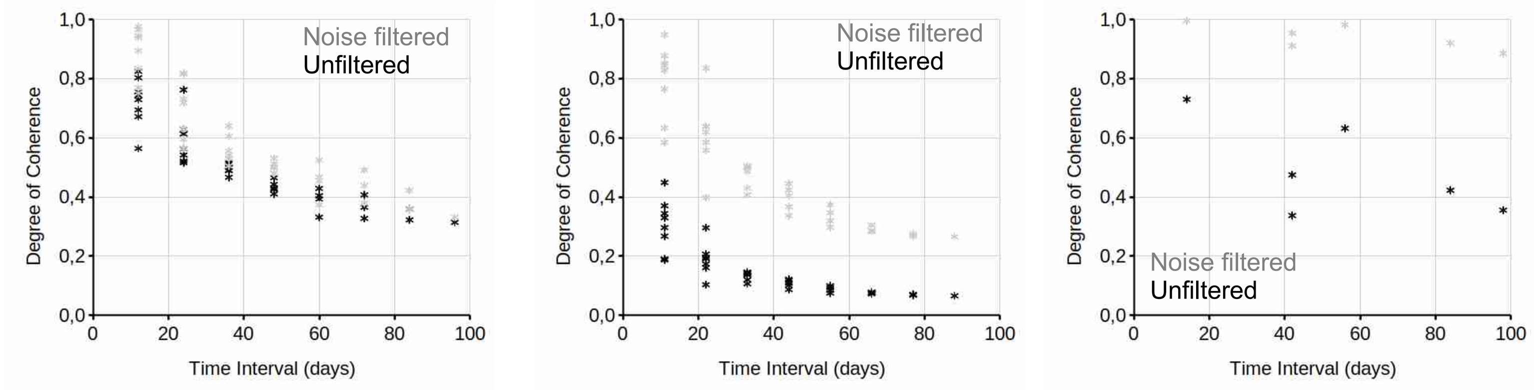


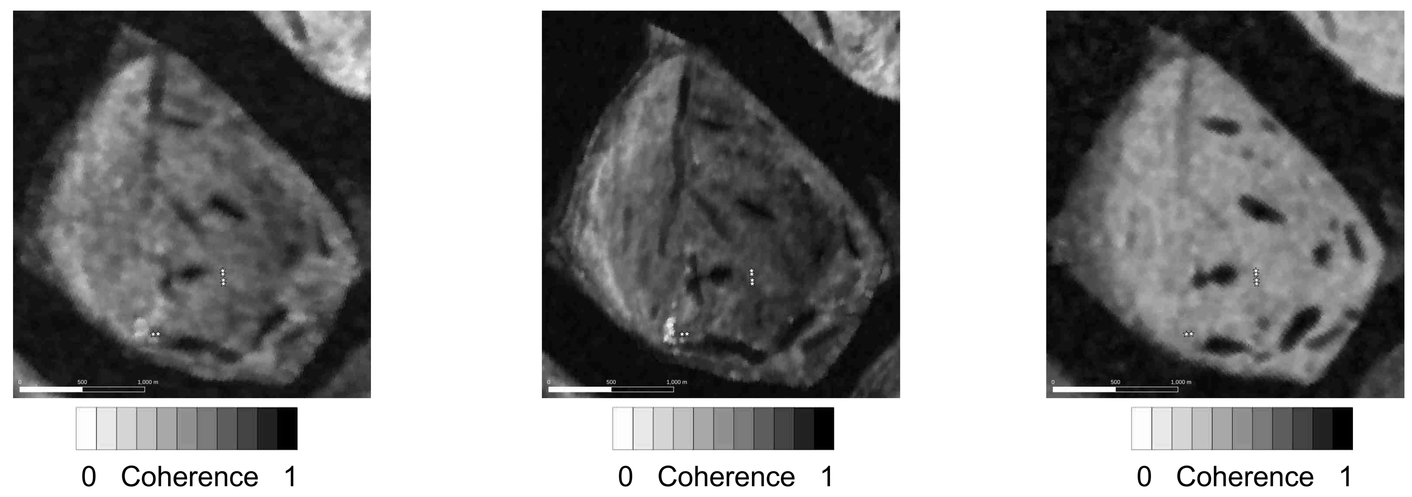
Samoylov Island

Methods

- We derived the seasonal thaw displacement for Sentinel-1 between 12 June and 16 September 2018 (9 images), TerraSAR-X between 18 June and 14 September 2018 (9 image) and ALOS-2 PALSAR-2 between 12 June and 18 September 2018 (4 images).
- We processed interferograms in series with time intervals of 12 days for Sentinel-1, 11 days for TerraSAR-X and 42/14 days for ALOS-2 PALSAR-2 to provide consistent, coherent and correctly unwrapped input data necessary for the inversion to seasonal thaw displacement.
- Extending the temporal baselines to longer time intervals was not feasible because of the rapid decrease in coherence caused by the pronounced subsidence and prominent vegetation and soil moisture conditions.

Sentinel-1 TerraSAR-X ALOS-2 PALSAR-2

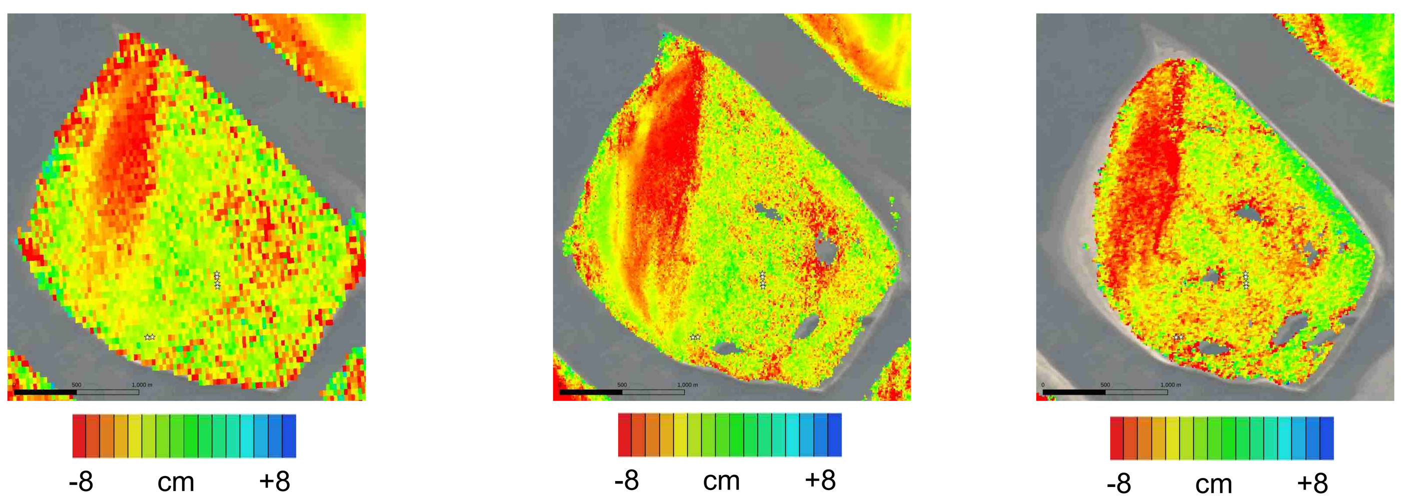


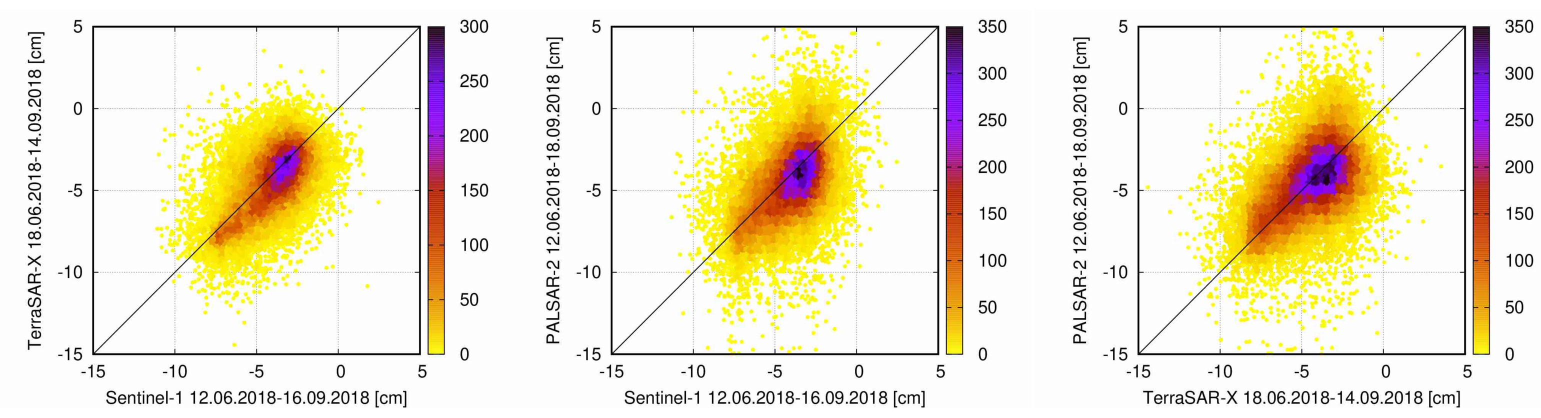


Results

- We observe a high agreement of the seasonal thaw displacement maps measured at different frequencies and dates over a terrain characterized by heterogeneous soil moisture and vegetation conditions.
- This suggests that surface motion is the predominant effect on the DInSAR phase, rather than variations in soil moisture, which should increase with wavelength as penetration depth is greater at lower frequencies, and vegetation, which should cause stronger systematic distortions at higher frequencies.

Sentinel-1 TerraSAR-X ALOS-2 PALSAR-2

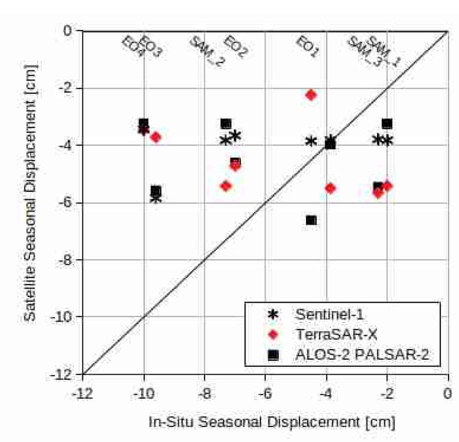




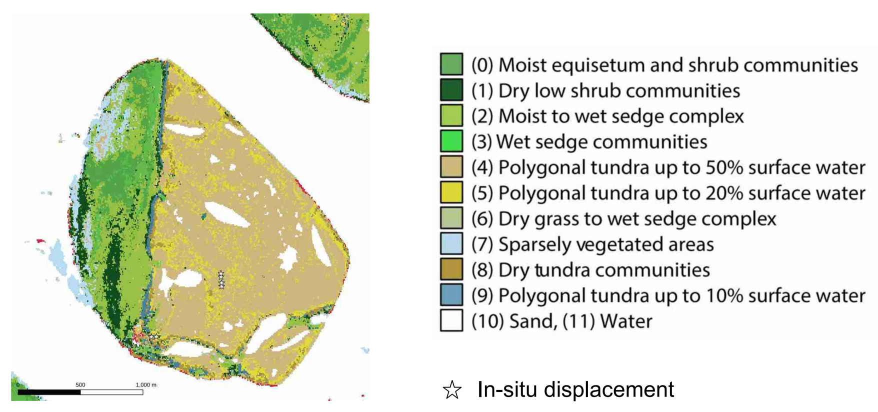
Discussion

- Validation with in-situ measurements shows subsidence of several centimeters in both cases; however, the in-situ values are larger than the remote values, which means that strong variations in displacement on a sub-metric scale are biased at the spatial resolution of the satellite.
- Comparison with a detailed habitat type map illustrates that the magnitude of the seasonal deformation is predominantly related to the soil type and moisture conditions.

Validation



Habitat classes (Lisovski et al., 2023)



Sentinel-1 TerraSAR-X ALOS-2 PALSAR-2