Surface Deformation Monitoring in High-Latitude Permafrost Areas with Sentinel-1 SAR Interferometry

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Abstract

Permafrost areas are subject to intense freezing cycles and characterized by remarkable surface displacement. Within the ESA GlobPermafrost project we are using Sentinel-1 InSAR data to analyze the surface displacement over several cold spots in the Arctic and Antarctica. In this contribution we will discuss the processing approach, show selected Sentinel-1 summer subsidence maps and time-series of motion with sampling intervals of 6 to 12 days, and introduce the ongoing validation activities.

Keywords: Surface deformation; Sentinel-1 SAR interferometry; Arctic; Antarctica.

Introduction

Low-land permafrost areas are subject to intense seasonal freezing and thawing cycles and, due to phase changes from ground ice to liquid water, are exposed to surface deformation processes. Thaw subsidence of the active layer at the surface in summer is followed by frost heave during refreezing in winter. Domination of one of the processes in a long term may result in significant changes of the Earth surface and can be a direct measure of permafrost change.

SAR interferometry (InSAR) has been applied in the past to measure surface deformation over permafrost during thawing seasons (Liu *et al.*, 2010; Short *et al.*; 2011; Strozzi *et al.*, 2012) and to derive remotely sensed active layer thickness (Shaffer *et al.*, 2015) using in particular satellite SAR data of the ERS-1/2 SAR, ALOS-1 PALSAR-1, TerraSAR-X and Radarsat-2 sensors. Nowadays, the Sentinel-1 mission represents the newest approach to SAR mission design with acquisitions regularly available over all polar areas every 6 to 12 days. We use Sentinel-1 SAR data to monitor subsidence in several cold spots regions in the Arctic and Antarctica (Fig. 1).

Figure 1. Study areas.

Sentinel-1 SAR Interferometry

Our investigations are based on multiple interferograms acquired during the summer season. Stacks of Sentinel-1 images are built in the two summer seasons of 2016 and 2017 in order to provide consistent series of interferograms with 6 to 12 days time intervals, which show good coherence under snow-free conditions. Yearly Sentinel-1 interferograms from the end of the summer do also show a sufficient level of coherence to link data from the two years.

Our InSAR processing sequence includes the co-registration of the single-look complex Sentinel-1 images, the computation of interferograms in series and over one year at the end of the season, the removal of the topographic-related phase with use of an external Digital Elevation Model (usually TanDEM-X), adaptive filtering, phase unwraping, computation of summer cumulative displacement maps and time series of movement via short-baseline InSAR (Werner et al., 2012), and terrain-corrected geocoding.

Results

Sentinel-1 interferograms acquired every 12 days from 14 June to 12 October 2017 were used to compute a map of the averaged displacement rates in the satellite line-of-sight direction for Teshekpuk Lake (Alaska) (Fig. 2). As suggested in Liu *et al.* (2010) floodplain areas were picked-up as reference. A temporal series of displacements on a selected location (Fig. 2) indicates that subsidence during the thawing season is occurring rather quickly, in early summer, with maximum displacements of more than 5 cm. Cross-validation with in-situ information is ongoing.

Acknowledgments

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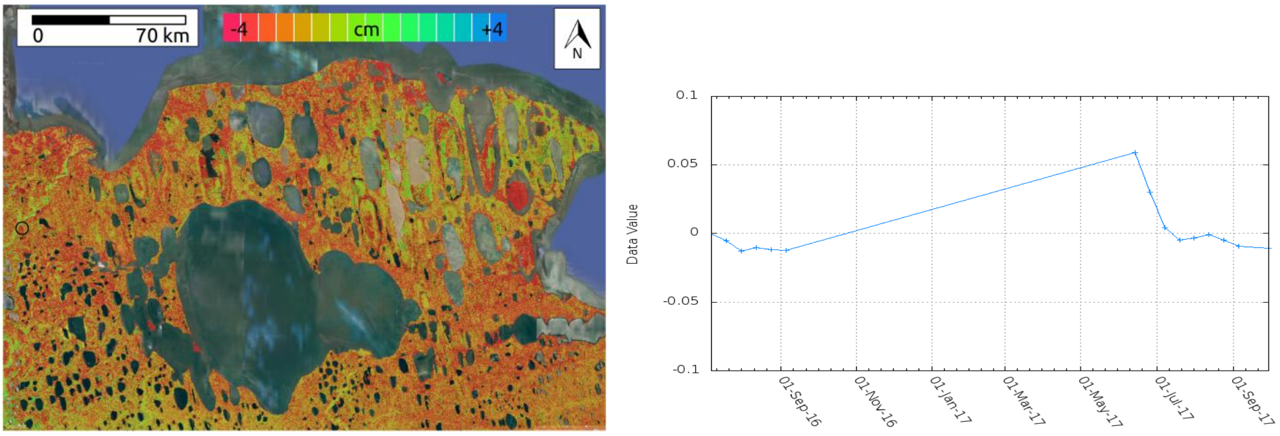

Figure 2. Subsidence map over Teshekpuk Lake (Alaska) from Sentinel-1 InSAR from 14 June to 12 October 2017 and time series of displacement in the line-of-sight direction over location "o".