Surface displacement after a wildfire in a permafrost region of Central Yaktuia detected by L-band SAR Interferometry

*Takahiro Abe[1], Go Iwahana[2,3], Takeo Tadono[1]

1. Earth Observation Research Center, Japan Aerospace Exploration Agency, 2. International Arctic Research Center, University of Alaska Fairbanks, 3. Arctic Research Center, Hokkaido University

Wildfire is known to have great impact on arctic permafrost regions in terms of not only causing permafrost degradation but also atmospheric and biospheric environments. Given the fact that permafrost thaw release soil organic carbon as greenhouse gases and it can be positive feedback on global warming (Shuur et al., 2015), it is essential to know how much permafrost thaws to clarify the carbon budget after wildfires more precisely. Ground survey has been conducted to understand permafrost thaw dynamics by only point measurements so far, and knowledge about surface displacement and its spatial variation a regional scale is essential. Therefore, remote sensing techniques that can cover wider areas are indispensable for better understanding what is going on in post-wildfire area more detail.

InSAR is an SAR processing technique for detecting surface displacement with order of 2-3 cm and has been widely applied to various applications such as crustal deformation and glacier dynamics. InSAR has been recently used to monitor permafrost in Alaska (Liu et al., 2010; Iwahana et al., 2016), Canada (Short et al., 2011), Lena Delta (Antonova et al., 2018; Strozzi et al., 2018), and Tibet (Chen et al., 2018). but there was only a few application of L-band InSAR so far. In the last JpGU, Yanagiya and Furuya (2019) and Abe et al. (2019) reported L-band InSAR application of a post-wildfire surface displacement and thermokarst monitoring in Eastern Siberia. Both studies reveal surface subsidence of post-wildfire and of thermokarst, which demonstrated usefulness of L-band SAR for permafrost study.

To quantify how much permafrost degrades after a wildfire, we applied ALOS (2007-2010) and ALOS-2 (2014-2019) L-band InSAR to examine surface displacement over a wildfire area occurred in 2013 in Mayya, 40 km southeast of Yakutsk. The InSAR images from ALOS data did not show obvious signals indicating surface displacement over the wildfire area, whereas the results from ALOS-2 ascending SM3 InSAR clearly show long-term surface subsidence up to 6 cm for 5 years. The rate of the subsidence decreased exponentially and there seems to be little displacement in 2018 and 2019. The area of the subsidence corresponds to that of low NDVI (Normalized Difference Vegetation Index) derived from Landsat-8. The NDVI in 2018 and 2019 is relatively high and visibly same, which means the vegetation almost recovered 5 years after the wildfire.

In order to examine seasonal displacement, ALOS-2 ascending SM3 and descending SM1 frequently acquired in 2018 and 2019 were analyzed. Both datasets indicate significant uplift up to 6 cm in 2018 and 2019 winter seasons, and 6 cm subsidence in 2019 summer. The uplift and subsidence correspond to seasonal thaw and frost heave. The annual subsidence between 2018 and 2019 is almost zero. This result is consistent with the recovery of vegetation in 2018 and 2019.

The post-wildfire surface subsidence was caused by excess of permafrost thaw due to loss of vegetation, which has a role of prevention from solar radiation. The loss of vegetation by wildfire accelerates permafrost thaw, and the degradation continues for several years to decade after a fire (Yoshikawa et al., 2002), which may induce thermokarst (Jorgenson and Osterkamp, 2005). We did not identify any evidence for initiation of thermokarst so far, but it is necessary to continue to monitor the fire area for better understanding surface change in permafrost regions after a wildfire.

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