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Thaw subsidence and frost heave caused by 2018-20 forest fires around Batagay: validation with multiple InSAR data and field observation

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The Arctic has experienced numerous fires in last year, and from June to August 2020, satellite data showed record carbon dioxide emissions from forest fires. Peatland in the Arctic contains large amounts of organic carbon, and their release into the atmosphere can create positive feedbacks for further increase of air temperature. In addition, forest fires burn the surface vegetation layer that has been acting as a heat insulator, which will accelerate the thawing of permafrost on scales of years to decades. Although the thaw depth can recover together with the recovery of surface vegetation, the massive segregated ice is not recoverable once it melted. Our study area is around the Batagay, Sakha Republic, Eastern Siberia. In June 2020, Verkhoyansk, located about 55 km west of Batagay, recorded the highest daily maximum temperature of 38.0 degrees Celcius. The Sentinel-2 optical satellite images showed a number of forest fires in 2019-20. We detected the surface deformation signals at each fire site with the remote-sensing method called InSAR (Interferometric Synthetic Aperture Radar). Also, we conducted a field observation in September 2019 for validations: 1) installed a soil thermometer and soil moisture meter; 2) established a reference point for leveling and first survey; 3) measured the thawing depth with a frost probe.

For seasonal ground deformations immediately after the fire, we mainly analyzed Sentinel-1 images. Sentinel-1 is the ESA's C-band SAR satellite, which has a short imaging interval of 12 days. As the short wavelength, vegetation changes lost coherence, and some pairs failed to detect ground deformation signals immediately after the fire. However, after the end of September, we detected displacements toward the satellite line-of-sight direction at all the fire sites. It indicates uplift signals due presumably to frost heave at the fire scar. For long-term deformations over one year, we used ALOS2 imaged derived by JAXA's L band SAR satellite. In the previous studies in Alaska, the ground deformation signal immediately after a fire could not be detected due to the coherence loss in the pairs derived from pre-fire and post-fire SAR images. Indeed, we could not detect deformation signals at the fire scars from the June pairs derived before and after the fire. However, the January pairs and March pairs, both of which were acquired before and after the fire,

showed relatively high coherence even in the fire scar and indicated clear subsidence signals by as much as 15 cm. We interpret that, because the studied Verkhoyansk Basin is very dry and has little snow cover, the microwaves could penetrate the snow layer, which allowed us to detect deformation signals even in winter. Yanagiya and Furuya (2020) validated the consistency of the winter uplift signal for the 2014 fire site. We also analyzed the SM1 high spatial resolution mode (3 m) ALOS2 InSAR to investigate the specific ground deformation at each fire site.