Changes in surface conditions and permafrost environment of a summit area of the Daisetsu Mountains, Hokkaido, Japan

*Go Iwahana[1], Toshio Sone[2], Masao Uchida[3], Tokuta Yokohata[3]

1. International Arctic Research Center, University of Alaska Fairbanks, 2. Institute of Low Temperature Science, Hokkaido University, 3. National Institute for Environmental Studies

This paper reports about results of permafrost and the micrometeorological monitoring by microwave and optical remote sensing and detected changes in surface conditions at a summit area of the Daisetsu Mountains, Japan. Mountain permafrost is distributed in a complex manner over a large area of the upper approximately 1700m of the Daisetsu Mountains (43˚N, 142˚E). Numerous periglacial landforms were identified from the 1960s to 1980s suggesting the occurrence of perennially cryotic ground in this area. Our recent long-term monitoring confirmed the occurrence of permafrost in multiple windswept areas. Given the increasing number of reports about rapid permafrost thaw and landform changes in the Arctic under the global warming, it is of broad concern to understand a situation in mountain permafrost environment which influences changes in entire mountain ecosystem in the future. A 4m tower with micrometeorological instruments was installed at a representative point (Goshiki station) of the mountain permafrost zone (2038m a.s.l.) in July 2005. Micrometeorological measurements including monitoring of thermal and hydrological conditions in the ground were conducted from 2005 to 2018 at the Goshiki Station. In addition, we investigated a set of remote sensing data (high-resolution optical and microwave imagery) in order to discuss environmental controls of the occurrence and temporal variation of the mountain permafrost. The mean annual air temperature fluctuated between -3.4 and -4.7 ˚C with no obvious inter-annual trends. Consecutive northwesterly driving wind prevents snow accumulation in the mountain permafrost site and enhances the energy exchange between ground and atmosphere in winter. The active layer thickness was in a range between 1.0 and 1.7m around the Goshiki Station. Permafrost base was at a depth deeper than 10 m at least. Permafrost temperature at the depth of 8-10m showed a monotonous increase at rates between 0.03 and 0.07 ˚C/year from 2010 to 2017, while upper layers displayed no marked increasing trend in ground temperature. The annual mean air temperature was comparable to those of Siberian or Alaskan Tundra; however, the relative humidity had been quite high with large summer precipitation (about 700-1000mm). The summer precipitation easily penetrates through a highly permeable active layer and significantly affects the near-surface thermal regime. The surface radiation conditions were controlled largely by the precipitation and ground surface phenology. We found no significant trends in surface changes in optical remote sensing and in-situ micrometeorological monitoring, although there are large fluctuations in measured parameters depending on weather conditions. L-band SAR interferometry measured seasonal surface displacement up to 20 cm/year and stacking analysis showed inter-annual subsidence ranging a few cm/year some areas with little vegetation covers. Slow slope movements were also detected in some block slopes and vegetated slopes, presumably associated with permafrost. The surface displacement behavior measured by our InSAR analysis largely depended on geomorphological and topological conditions, which was also closely related to ground freeze and thaw regimes. Our results demonstrated applications of the InSAR technique for monitoring of high mountains in Japan and identify areas of rapid changes in ground-surface conditions, which provides important information for land management and adaptation strategies in the future warming mountain environment.

Keywords: InSAR, Permafrost, Frozen ground, mountain, slope, land slide