Volcano-snow interaction and assessment of multi-hazards at snow-clad volcanoes: Examples from the 2014 eruption of Ontake volcano and 2018 eruption of Kusatsu-Shirane volcano

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Two thirds of active volcanoes in Japan are covered with snow during winter for several months. Risk assessments and hazard maps of lahars at such snow-clad volcanoes focus on traveling time and distance of lahars caused by snow melting at a magmatic eruption. However, flows and triggers due to volcano-snow interaction are variable as volcanic mixed avalanches by pyroclastic currents sweeping across snow (Pierson, 1994) and ice-slurry lahars (Kilgour et al., 2010) at a phreatic eruption were observed. Triggers, size, and types of mixed flows (including lahars) of snow, water, and volcanic material can vary with the timing of event, whether it happens during the rainy season, snow season, or snow-melting season. Therefore, several scenarios for lahar hazards and assessment should be considered at snow-clad volcanoes in Japan.

After the 2014 phreatic eruption at seasonally snow-clad Ontake volcano, a rain-triggered lahar occurred on October 5, 2014 and traveled along the Akagawa and Nigorigawa Rivers. The lahar deposits are muddy with very high clay content (10-20wt%) indicative of cohesive debris flow condition. The clay-rich characteristic is derived from source material of ashfall deposits which also contain large amount of clay (> 30 wt%) in sediments. Another lahar flow occurred on April 20, 2015, under a rain-on-snow (ROS) condition. The ROS resulted in a total 332 mm precipitation (with snowmelt) over 13hrs until the generation of the lahar. The ROS-triggered lahar was erosive in upstream and left hyperconcentrated flow deposits in downstream.

A sudden eruption onset at Kusatsu-Shirane (Motoshirane) volcano on January 23, 2018 occurred in a ski field. Further eruptions, rainstorms and snowmelt can cause lahars, snow avalanches, volcanic mixed avalanches, and slushflows, and therefore, sedimentological analysis of eruptive material, snow survey, and meteorological observation have been carried out. Eruption deposits are composed of armored lapilli-like aggregates. It mainly consists of white hydrothermally altered rock fragments and feldspar mineral grains with very fine pyrite grains. Glassy rock fragments are rare. Bulk chemistry shows high sulfur content (~9 wt%) of the deposits. Finer fractions (< 2mm) consists of 45 -50 wt% of mud population (< 0.063 mm). Further analyses for clay mineral assemblages and clay content are necessary to assess the property of cohesiveness of the possible future lahar flows. Snow survey revealed a snow water equivalent of ~450 mm at ~ 2000 m above sea level at the volcano in the end of January. A sudden melting of the snow cover can provide such amount of water at elevated upstream areas. Further observation of meteorological and snow condition, as well as hydrological monitoring at downstream rivers is necessary with consideration of a possible ROS-triggered lahar during the snowmelt season.

Keywords: Kusatsu-Shirane (-Motoshirane) volcano, Ontake volcano, lahar, snow-clad volcano, rain-on-snow, multiple hazards

