Predictions of snowmelt type volcanic mudflow including the occurrence and run-on processes

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Snowmelt type volcanic mudflows occur when snow or glaciers on volcanoes are melted by high-temperature sediments such as volcanic ash and pyroclastic flows. The snowmelt water mixes with the hot sediment, erodes the slope, and eventually becomes a mudflow. Snowmelt type volcanic mudflows are highly fluid and can cause significant damage to unexpected downstream areas. The total amount of mudflows have been estimated from the comparison of the heat content of volcanic sediment and the amount of snow cover. The purpose of this study is to propose a prediction method consisting of mudflow generation, development, flow, and inundation models.

A one-dimensional snowmelt experiment using high-temperature volcanic sediment, which is the first stage of mudflow generation, was conducted to investigate the snowmelt and infiltration processes. 2200-year-old pyroclastic flow deposit and snowpack collected from the Ashiarai-dani basin, northwest of the active volcano Mt. Yake. A heat-resistant glass column was filled with the snow and then the heated sediment was supplied from the top. The bottom of the column was sealed with a wooden board, and the snowmelt water reaching the bottom formed a saturated zone. The experiment was conducted under various temperatures of the sediment from about 250 to 630°C and snow densities from 77 to 409 kg/m^3. The snowmelt water penetrated the unsaturated snow layer and formed a saturated zone at the bottom of the column. Based on these experimental results, a model for snowmelt and water infiltration by high temperature sediment was validated. The model consists of a heat exchange model between the hot sediment and snow layers and a snowmelt water infiltration model.

The slope section was divided into 10m grids, consisting of impermeable bedrock layer, soil layer, and snow layer. The above snowmelt and infiltration model was applied to calculate the saturated water levels in the snow soil layers, respectively. The safety factors of the snow and soil layers were calculated. When the obtained safety factor was less than 1, i.e., the collapse occurred at each slip surface, the mudflow mixed with the material above the slip surface was generated. The erosion and deposition by the mudflow on the slope were computed. The downstream end of the slope region was determined at a point with a bed slope of 10 degree.

The mudflow calculated at the downstream end of the slope domain was used as the boundary condition for the river section. In the river section, a two-dimensional shallow water flow model containing sediment was used, which was previously validated by a snowmelt volcanic mudflow case. The transport rate of sediment was calculated for each grain size and the erosion of side banks was also involved in the model.

The prediction method was applied to the Ashiarai-dani basin and its downstream areas. The snow depth conditions were spatially distributed depths measured by aerial laser surveys and uniform depths of 1 and 2 m. The snow densities were varied from 150 to 270 kg/m^3. The eruption volume was assumed to be 2.1×10^6 m^3, and the temperature was assumed to be 1000 degrees Celsius. The simulated mudflow discharges in the slope section demonstrated that the peak flow rate at the downstream end appeared at very early timings of 210-310 seconds from the supply of the volcanic sediment. The peak flow rate was 2 to 9 times higher than that of the conventional method. In the river section, the time when the mudflows reached a village located about 7 km from Mt. Yake was simulated 40-50 minutes, which was not significantly different from the conventional method. However, the maximum simulated flow depths were 12 - 17 m, which was larger than that of the conventional method of about 7 m. These results suggested that damages in the downstream areas may be larger by involving the mudflow generation and development processes on the slope.

Keywords: Spatially distributed model, Infiltration, Innundation

