Fluid ascent dynamics of the Onikobe geyser, NE Japan: Insight from the thermal infrared imagery

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Geysers provide a natural laboratory of multiphase eruptive processes like volcanoes due to their advantages for observation, frequent eruptions, and simple material properties. Thus, by understanding the dynamics of geyser eruptions, we may provide potential insights not only into geysers themselves but also into volcanic eruptions. For understanding the eruption dynamics of volcanoes and geysers, thermal observations have been used. Harris et al. [2012], analyzing high frame rate (33 Hz) thermal video data, estimated the velocities of ejecta and described the plume ascent dynamics at Stromboli volcano, Italy. Karlstrom et al. [2013], using the visual and infrared video data, estimated the velocities of water effusions and defined four phases during an eruption cycle at Lone Star Geyser, Yellowstone National Park, USA. However, the details of fluid ascent process are still not fully understood in both volcanoes and geysers. In this study, using the thermal infrared imagery and acoustic signals, we examine the fluid ascent dynamics of geysers.

We conducted a field observation at Onikobe geyser, NE Japan, on 24 October, 2019. We observed the erupted fluid thermally using an infrared camera (InfReC G100, Nippon Avionics Co. Ltd.) and measured the acoustic emission using an acoustic sensor (SI102, Hakusan Corp.) deployed about 2 m distant from the vent. The thermal infrared data was collected at a sampling rate of 10 frame/s. The acoustic data was collected using a data logger (HKS-9700, Keisokugiken Corp.) with a sampling frequency of 100 Hz.

We analyze the obtained thermal infrared data using a software (InfReC Analyzer NS9500 Standard, Nippon Avionics Co. Ltd.). For investigating the evolution of fluid ascent from the vent, we make two kinds of time series of the thermal infrared data: (1) the raw temperature of the thermal plume along the vertical axis set at above the vent, and (2) the total temperature at each height integrated in the horizontal direction. In addition, to discriminate the behaviors of water and vapor with hotter and lower temperatures, we set a threshold of temperature at 30 degree and make the two kinds of time series for the hotter and lower temperature.

The time series (1) and (2) show many individual bursts from the vent for each effusion with a duration of about 40 s. Oscillatory signals with period of about 1 s are recognized especially in the latter period of effusion (about 15-40 s from the onset of effusion). The spectrogram of the infrared data is well matched with that of the acoustic signals. In the time-height evolution of hotter and lower temperature data, we can trace the trajectories of water and vapors. We find two characteristic ascent velocities: (1) relatively high velocity (about 10-20 m/s) and (2) low velocity (about 1-2 m/s). The higher velocity is explained by the theory of ballistic motion under the gravity and air resistance with viscous drag. We estimate the ejection velocity to be 5-25 m/s and a radius of each water droplet that forms water jets with about 0.1–0.3 mm. On the other hand, the water and vapors in the lower temperature image seem to vertically ascend with a slightly accelerated low velocity of 1-2 m/s. From this result and visual observations at the geyser, we infer that the other mechanisms such as buoyant thermal plume may explain this ascending water and vapors.

Keywords: Geyser, Thermal infrared imagery, Acoustic emission, Ascent velocity

