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Sampling volcanic plume using aircraft for remote determinations on the temperature of fumaroles: Sakurajima volcano

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Molecular hydrogen (H_2) in fumarolic gases shows the hydrogen isotope exchange equilibrium with coexisting H_2O at a temperature more than 400 ℃. Recently, we developed a new remote temperature sensing using the characteristics of D/^{1}H ratio of H_2 (HIReTS). In this method, the D/^{1}H ratio of fumarolic H_2 is obtained remotely from the observation of volcanic plume, and the outlet temperature of the fumaroles is estimated from the D/^{1}H ratio, assuming that the hydrogen isotope exchange equilibrium is quenched within volcanic plume during the process of admixture between fumarolic gases and air. In the previous studies applying HIReTS in active volcanoes, such as Aso and Satsuma-Iwo volcano in Japan, the volcanic plumes were taken at the rim of each volcanic crater, at the distance of a few hundred meters from fumaroles. Direct access to such volcanic crater rims, however, is neither practical nor safe in many highly active volcanoes. In general, volcanic plumes spread laterally at the height close to the summit of each volcano where the plumes are ejected. As a result, we must utilize some flying devices, such as aerial vehicles, balloons, or kites, to take the samples of volcanic plume in safety area distant from fumaroles, for the aim of applying HIReTS to highly active volcanoes.

In this study, we used an aerial vehicle to take samples of volcanic plume ejected from highly active Sakurajima volcano in Japan, to determine the outlet temperature of fumaroles remotely by using HIReTS, at the distant of more than 3 km from the fumaroles. Sakurajima volcano has continued its explosive activity at the summit crater since 1955 so that nobody dared to determine the outlet temperature of fumaroles directly.

The average H_2 concentration of the plume samples taken during two flights on Sep. 2014 was 0.76 ppm (from 0.60 to 1.29 ppm), while that taken apparently outside the volcanic plume was 0.60 ppm. Besides, the reciprocal of the H_2 concentration in the plume samples showed a good linear relationship with the D/^{1}H ratio ratio. By extrapolating the linear relationship to exclude the contribution of the tropospheric H_2, we estimated that the δD value of the fumarolic H_2 to be -134.6±6.5 ‰ (vs. VSMOW) and the outlet temperature to be 1050±80 ℃, assuming global average δD value of magmatic H_2O to the fumarolic H_2O. The estimated temperature was close to the melting point of lava in the volcano, implying that magma have been close to the surface in the volcano, at least during the observation.

Keywords: fumarolic gases, volcanic plume, molecular hydrogen, stable isotopes, remote temperature sensing, Sakurajima volcano