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Volcanic plume measurement with UAV

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Volatiles in magmas are the driving force of volcanic eruptions and quantification of volcanic gas flux and composition is important for the volcano monitoring. Recently we developed a portable gas sensor system (Multi-GAS) to quantify the volcanic gas composition by measuring volcanic plumes and quantified volcanic gas compositions of actively degassing volcanoes such as Miyakejima, Asama and Aso. As the Multi-GAS measures variation of volcanic gas component concentrations in the pumped air (volcanic plume), we need to bring the apparatus into the volcanic plume. Commonly the observer brings the apparatus to the summit crater by himself but such measurements are not possible under conditions of high risk of volcanic eruption or difficulty to approach the summit due to topography etc. In order to overcome these difficulties, volcanic plume measurements were performed by using manned and unmanned aerial vehicles. The volcanic plume measurements by manned aerial vehicles, however, are also not possible under high risk of eruption. The strict regulation against the modification of the aircraft, such as installing the sampling pipes, also causes the difficulty due to the high cost. In order to avoid these difficulties, we are trying to apply the UAVs for the volcanic plume measurements.

The Multi-GAS consists of IR-CO2 and H2O gas analyzer, SO2-H2O chemical sensor and H2 semiconductor sensor and the total weight ranges 3?6 kg including batteries. The necessary conditions of the UAV for the volcanic plumes measurements with the Multi-GAS are the payloads larger than 3 kg, maximum altitude larger than the plume height and installation of the sampling pile without contamination of the exhaust gases. Since the exhaust gases contain high concentrations of H2, SO2 and CO2, its contamination should be avoided. Up to now, three different types of UAVs were applied for the measurements; Kite-plane (Sky Remote) at Miyakejima operated by JMA, Unmanned airplane (Air Photo Service) at Shinomoedake, Kirishima volcano, and Unmanned helicopter (Yamaha) at Sakurajima volcano operated by ERI, Tokyo University. In all cases, we could estimated volcanic gas compositions, such as CO2/SO2 ratios, but also found out that it is necessary to improve the techniques to avoid the contamination of the exhaust gases and to approach more concentrated part of the plume. It was also revealed that the aerial measurements have an important advantage of the stable background. The error of the volcanic gas composition estimates are largely due to the large fluctuation of the atmospheric H2O and CO2 concentrations near the ground. The stable atmospheric background obtained by the UAV measurements enables accurate estimate of the volcanic gas compositions. One of the most successful measurements was performed on May 18, 2011 at Shinomoedake, Kirishima volcano during repeating Vulcanian eruption stage. The major component composition was obtained as H2O=97, CO2=1.5, SO2=0.2, H2S=0.24, H2=0.006 mol%; the high CO2 contents suggests relatively deep source of the magma degassing and the apparent equilibrium temperature obtained as 400C indicates that the gas was cooled during ascent to the surface. The volcanic plume measurement with UAV will become an important tool for the volcano monitoring that provides important information to understand eruption processes. The measurement of the plume produced by large explosive eruptions, however, is not possible yet even with the UAVs because of the high concentration of volcanic ashes. As accumulation of bubbles is considered as the cause large explosive eruptions, the volcanic gas compositions are the key to understand these processes and further development is required to enable such measurements.

Keywords: Volcanic plume, Volcanic gas, UAV, Multi-GAS, Volcano monitoring