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Volcano Observations Using an Unmanned Autonomous Helicopter : seismic and GPS observations near the active summit area of Sakurajima and Kirishima volcano, Japan

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Observations in the vicinity of summit area of active volcanoes are very important from various viewpoints such as understanding physical processes in the volcanic conduit. It is, however, highly difficult to install observation sensors near active vents because of the risk of sudden eruptions. We have been developing a safe volcano observation system based on an unmanned aerial vehicle (UAV). As an UAV, we adopted an unmanned autonomous helicopter manufactured by Yamaha-Motor Co., Ltd. We have also developed earthquake observation modules and GPS receiver modules that are exclusively designed for UAV installation at summit areas of active volcanoes. These modules are light weight, compact size, and solar powered. For data transmission, a commercial cellular-phone network is used.

Our first application of the sensor installation by the UAV is Sakurajima, one of the most active volcanos in Japan. In November 2009, 2010, and 2011, we installed up to four seismic sensors within 2km from the active summit crater. In the 2010 and 2011 operations, we succeeded in pulling up and collecting the sensor modules by using the UAV. In the 2011 experiment, we installed two GPS receivers near the summit area of Sakurajima volcano. We also applied the UAV installation to another active volcano, Shinmoedake in Kirishima volcano group. Since the sub-plinian eruption in February 2011, entering the area 3km from the summit of Shinmoe-dake has been prohibited. In May and November 2011, we installed seismic sensors and GPS receivers in the off-limit zone. Although the ground coupling of the seismic modules is not perfect due to the way they are installed, the signal-to-noise ratio of the seismic signals recorded by these modules is fairly good. Despite the low antenna height of 50 cm from the ground surface, the location errors in horizontal and vertical GPS components are 1cm and 3cm, respectively.

For seismic signals associated with eruptions at Sakurajima from November 2010 to November 2011, we measure temporal variation of the amplitude ratio among the summit stations. In order to correct the amplitude variation due to the source amplitude variation, the amplitude of the recorded signals are normalized by using the amplitude of a permanent station, located on the western flank of Sakurajima 5km from the summit. The daily average of the normalized amplitude ratios among the summit stations shows clear temporal variation. The amplitude ratio variation can be classified to three stages. In the first stage, the amplitude ratios among the summit stations are nearly constant. The 2nd stage is characterized by a gradual increase in the amplitude ratio. The third stage is slightly difficult to define but we can say that the amplitude ratios are almost constant with fluctuations larger than that in the first stage. These changes strongly suggest a change in the source depth, probably migration of the source to the shallower portion in the volcanic conduit. Small change in the source position would have been observed as a big change in the observed amplitude ratio due to the closeness of the sensors to the source.