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Volcano observation using an unmanned autonomous helicopter: an experiment of seismometer installation at Sakura

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Observations in the vicinity of summit area of active volcanoes are important in understanding volcanoes. However, it is challenging to install observation sensors near the active vent because of the danger of sudden eruptions, and thus the summit area of active volcanoes are often left blank from the observational point of view. We are developing an observation system based on an unmanned autonomous helicopter combined with various types of observation devices. The helicopter system was already used for the aeromagnetic surveys in Izu-Oshima, and succeeded in detecting geomagnetic anomaly of short wavelength. In addition to the aeromagnetic survey, we aim at developing various types of volcano-observation tools based on the unmanned helicopter such as installing seismometers, sampling volcanic ash in the vicinity of active vents, obtaining both infrared and visible images from onboard camera etc.
We used the unmanned autonomous helicopter, model RMAX-G1 developed by Yamaha-Motor Co., Ltd. The payload of the helicopter is approximately 10kg, including the fuel and attached equipments. The autonomous aviation is available within 5km from the base station with meter accuracy using kinematic-differential GPS. This high positional accuracy makes it possible to conduct repeated observation. Real-time images taken from the onboard cameras are transmitted to the base station. This facility is a great advantage in installing sensors remotely.
The earthquake observation module (EOM) is carried just above the installation point, hanging on the wire of the onboard winch. Then, by sending out the wire gradually from the winch, EOM is dropped slowly and is installed without strong shock. The solar powered EOM is equipped with GPS timing and the communication board with a cellular-phone network. In order to reduce the total power consumption, the power consuming communication board is controlled by the timer. It is difficult to control the direction and inclination of EOM by the above mentioned installation method. It is also difficult to achieve strong coupling of EOM with the ground. These difficulties imposed restrictions on EOM design. Since, the solar panels cannot be directed to the south, the panels have to be arranged to cover all directions of the module, causing additional weight. Since it is difficult at the time of installation to take a horizontal, triaxial accelerometer is adopted. Furthermore, since the helicopters payload includes the weight of the onboard winch, onboard camera, and the fuel, we had to limit the weight of the module around 5kg. We had to reduce the capacity of the batteries onboard.
Sakurajima is one of the most active volcanoes in Japan. Since the reopening of the Showa crater at the eastern flank, eruptions are continuing at the Showa crater, and the annual number of explosive eruptions recorded the highest ever in 2009. Entering the area within 2 km from the summit craters is prohibited, and thus there is no observation station in the area. Seismic sensors in this area will significantly improve the accuracy of the locations of volcanic earthquakes. From November 2nd to 12th, 2009, we performed installation of EOMs in the summit area within 2km from the active craters. Before the installation, we carefully investigated geographical maps and high resolution aerial photographs to decide potential points for installation. Although we had to

give up one position due to bad wind condition, we could install successfully three modules at the planed positions. Although the communication state was not good since the installation points were outside of the service area of the cellular-phone network, we succeeded in retrieving the seismic waveform data accompanying eruptions. Although the recorded waveforms of the explosive eruptions are contaminated by the modules mechanical resonance above 30 Hz or more, they are good in the frequency band lower than 30Hz.

Keywords: Helicopter, Volcano observation, Seismometer