Low-altitude remote sensing of volcanoes using unmanned helicopter: an example of aeromagnetic observation at Izu-Oshima

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Satellite remote sensing has several prominent advantages, such as global access, spatial coverage and high efficiency of data acquisition, and thus it is extensively used in various fields of observation in earth sciences, including volcanology. However, in some cases, data from such high-altitude platforms offer very limited or almost no information, because of the distance between sensor and object, depending on the target or the types of measurements. In contrast, low-altitude remote sensing utilizing an airborne platform can offer extremely rich or exclusive information.

As an airborne platform, unmanned autonomous helicopters have distinct advantages compared to other platforms (Tsutsui et al. 1999). They can operate at a low altitude, a few tens of meters from the ground, because they are exempt from aviation laws in many cases, unlike airplanes or conventional helicopters. In addition, using onboard global positioning systems (GPS) and aviation systems, flights within meter accuracy can be made along a previously planned path. If required, they can even fly over volcanoes in a dangerous state.

We have worked on the development of a volcano observation system using an autonomous helicopter, on which various different types of sensors can be mounted. Recently, we succeeded in assembling a practical model of an aeromagnetic observation system. Low-altitude aeromagnetic observations using the autonomous helicopter are expected to contribute to the collection of critical information on the shallow level structure beneath volcanoes, which is difficult to obtain using conventional helicopter systems.

In this paper, aeromagnetic observations carried out at Izu-Oshima volcano using autonomous helicopter are reported in March and November 2008. The first objective of this study is to confirm whether the present system is capable of stably and efficiently observing a large area of a volcano under practical conditions, as required for research. The second objective is to ascertain the shallow level structure beneath the caldera area of Izu-Oshima based on the aeromagnetic data collected using this system. Izu-Oshima is thought to have been accumulating considerable amount of magma underneath (Watanabe 1998); therefore, collecting such aeromagnetic data ahead of a forthcoming eruption is important for comparison with post-eruption data, as well as for analysis of the present situation.

Through the observation of Izu-Oshima, it was confirmed that the proposed aeromagnetic observation system using an unmanned autonomous helicopter had sufficient performance for practical observations in volcanoes, and could also be utilized as a low-altitude platform for other sensors.Based on the data collated by this system, the shallow level structure beneath the caldera area could be detected for the first time.

On observation flight, total flight time is about 250 minutes and flight distance is about 67 km. We removed geomagnetic time variation and main field component from the data, using reference data and IGRF 10th model. Note that geomagnetic activity is very quiet during survey, that is, K indices at Kakioka are below level 1.

Before estimating magnetizaion, we resampled data to every 5 seconds, and added data obtained by another survey conducted at northern area in March 2008. Then magnetizaion distribution of 50m mesh blocks are estimated. For surface elevation, 10m mesh DEM data by GSJ are used. Bottom of blocks is assumed to be fixed to 2000m below sea level, and orientation of magnetizaion is also fixed to one of main field.

In the obtained magnetizaion model, high magnetizaion zone can be seen in NW-SE direction.On survey, helicopter flied at almost fixed altitude above ground, so model resolution at southern area is almost the same. Data residual is about 25 nT, and it is also almost the same as the mechanical error level. This high magnetizaion zone is considered to be due to solidified dykes.