Japan Geoscience Union Meeting 2013
(May 19-24 2013 at Makuhari, Chiba, Japan)

STT55-01 Room:203 Time:May 22 09:15-09:30

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

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STT55-02 Room:203 Time:May 22 09:30-09:45

A Development of Airborne Survey of Gravity and Magnetics on an Unmanned Helicopter and Its Data Processing

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It is important for the regional earthquake disaster prevention to make a model of ground structure and clarify the non-fairing nature of the ground in detail. For this purpose, gravity and magnetic surveys can be used to estimate the deep and vast velocity and density structures of the ground because of quick observations.

Nowadays, since these implements such as gyroscopes, accelerometers, computers and GPS measurement system are dramatically improved, observation system becomes much smaller and higher-performance. We now aspire to make observation system simple, which sensors installed directly on the career, then correct the observed data by post processing from the accurate posture data. Furthermore, the new accelerometer sensor "D-servo," which has enough dynamic range for the carrier disturbance and resolution for detection of gravity anomaly had been developed as shown in Yokoi et al.(2012).

To discuss the sensitivity and practicability of the exploration system, airborne survey has been carried out. We set the observation system on an autonomous-cruise-type uninhabited helicopter and navigate it over a huge concrete gravity dam, which makes large gradient in gravity, with some magnetic body as flood spillway. By means of GPS data of each cruise, theoretical gravity is calculated from terrain model made of 50m-mesh rectangular parallelepiped which height is altitude. Effects of stored water and dam itself are also considered.

As results from the observation, it is observed that sensitivity of the magnetic survey was quite well, though, inclination correction seems to be required for the gravity survey. For the accurate correction, we should consider some suitable way of the calibration of sensors. Improved method for gravity analysis is also proposed and the result has quite good agreement with theoretical gravity in phase and period of the signal. An mesurement and algorithm might be required to determine the accurate inclined angles for the correction as future development.

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Keywords: gravity survey, magnetic survey, airborne survey, unmanned helicopter, Hilbert-Huang transform (HHT)

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STT55-03 Room:203 Time:May 22 09:45-10:00

Aeromagnetic survey by a small unmanned airplane over northern part of Deception Island

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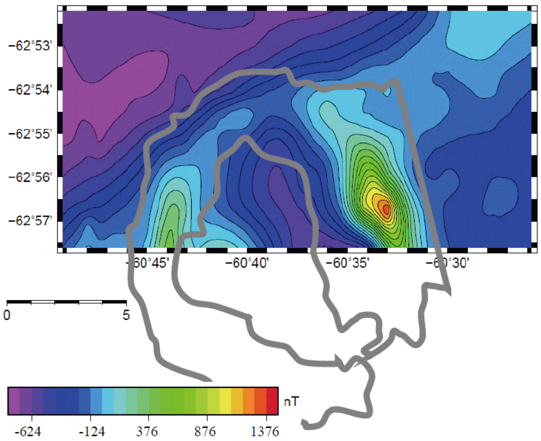
Part of the Scientific program incorporated with researchers in (Japanese) National Institute of Polar Research (NIPR), Korea Polar Research Institute, Chile Antarctic Institute, Bulgarian Antarctic research and Spanish Antarctic team, magnetic anomaly data were aquired over the Deception Island in Bransfield Strait. It was probably the first time to succeed to get the geophysical data by a long-flight unmanned aerial vehicle (UAV) in the area of Antarctica. Due to the severe weather the flight was only over the northern half of the Deception Island and its surrounding sae area.

Fig. 1 shows obtained magnetic anomaly, flight lines and coastline. The flight altitude is about 780m averaged. The main survey lines are directed east-west and the intervals of the lines are about 1000m. Longest length of the main survey line is about 18km. Probably due to the unstable atitude of the UAV body by strong wind, some east-west lines are shortcuted regardless of pre-programmed 18km length courses. The flight courses were overlapped on the survey lines along the latitude of 62deg53min and the longitude of -60deg28min. On these lines each direction of the flight is opposite. Some unnatural unduration can be seen around overrapped lines. These kinds of unduration are occurred due to the difference of the observed magnetic field on each line. These differences have to be corrected, now we have the torerable data for estimate the structure of the Deception Island.

Standing high magnetic anomaly is recognized over the eastern peak of the island. Although we don't have precise topographic data of the Deception Island and bathymetric data on surrounding sea area, we will try to estimate of the distribution and the length of magnetization.

Keywords: Deception Island, aeromagnetic survey, unmanned aerial vehicle, fluxgate magnetometer



Japan Geoscience Union Meeting 2013
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STT55-04 Room:203 Time:May 22 10:00-10:15

Repeated aeromagnetic survey of Shinmoe-dake, Kirishima volcano, Japan, after the 2011 eruption using unmanned autonomo

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We conducted the highly resolved aeromagnetic surveys around Shinmoe-dake, Kirishima volcano twice by using the unmanned autonomous helicopter, when it was after the magmatic sub-plinian eruptions.

First survey was carried out in the end of May covering 3 by 3 km area of western Shinmoe-dake. The flight altitude is as low as about 100 m above the ground and spacing of flight lines are as close as almost 100 m. Total flight distance is about 85 km. The cesium optically-pumping magnetometer was installed by hanging below the helicopter to measure the geomagnetic total intensity. Due to this survey, we detected a large geomagnetic total intensity anomaly as 1000 nT. Using these data, the horizontal map of magnetization intensity was obtained beneath the survey area. We found the followings;

1) The average value of the magnetization is as low as 1.5 A/m;

2) Northwestern Shinmoe-dake has lower magnetization than average;

3) Strong magnetization appears the area corresponding the lava at the foot of Karakuni-dake.

Second survey was carried out about 5 months later than the first survey, in the end of October to the beginning of November, in order to detect temporal change of geomagnetic total intensity. By comparing both data, we could detected a dipole-like change as large as about $\pm$ 100nT around the crater of Shinmoe-dake. This change can explain by magnetization enhancement with 2.3 x 10^7 Am^2 in the crater. In the 2011 eruptions of Shinmoe-dake, a large pancake-like lava was found in crater with 1.5 x 10^7 m^3 (Nakada et al., submitted), and the cooling of this lava probably causes this magnetization enhancement.

Keywords: repeated aeromagnetic survey, unmanned autonomous helicopter, Shinmoedake

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Airborne surveillance using an unmanned autonomous helicopter at Tarumae volcano

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1. Introduction

Volcanic eruptions generally prohibit humans from approaching active craters. Meanwhile, it is important during an eruption to perform visual surveillance, geophysical measurements, material sampling in the vicinity of the craters. Besides scientific purposes, these are also useful in deciding emergency actions such as evacuation or recovery plans considering the ongoing volcanic activity and possible subsequences. We started airborne volcano surveillance using an unmanned helicopter on a trial basis in co-operation with the Hokkaido Regional Development Bureau since 2011. We performed the experiments at Mt.Tarumae (1,041m) in 2011 and 2012. As of 2012, the volcano was not erupting but showed persistent fumarolic activity around the summit lava dome. In this study, we report the results of the repeated aeromagnetic survey and an operation test of a material sampler.

2. Aeromagnetic surveys

We performed the first airborne magnetic survey in Sep. 2011. The vehicle flew on the programmed route in the autonomous flight mode with the aid of GPS navigation. The same route was intended to be flown in the second survey in Sep. 2012 aiming for detecting temporal changes. Although we partly failed to fly due to an unfavorable weather in the second survey, we recovered the data from important part across the lava dome. We compared the actual flight paths between the two surveys and found that the deviation was mostly within 10m. Meanwhile, the field gradient along the flight paths was generally within +/-1nT/m. Then we considered that +/-10nT was an error range in a direct comparison of the magnetic field between the nearest points from the separate datasets. Through this procedure, we obtained a systematic pattern of temporal changes with a p-p amplitude of approximately 30nT. The spatial pattern implying the cooling remagnetization beneath the dome was consistent with the recent result from the repeated magnetic surveys on the ground by Hokkaido University and Sapporo District Meteorological Observatory, JMA. However, the observed amplitude was almost five times larger than the estimation from the ground-based remagnetization rate. Further careful investigations are necessary to identify the cause of this difference.

3. Material sampling

In the experiment in 2012, we also performed an operation test of a material sampling attachment in the vicinity of the base station. The gadget is reeled down from a winch on the fuselage. At a touchdown, the lock is released and the grab-bucket is shut. Because this system is originally designed for sampling solid pieces or muddy materials, we attached some double-stick tapes on the grab-bucket to collect ash grains, too. In our experiment, several pieces of pumice and lithic with a diameter of some centimeters were picked up as well as ash particles of some grams. Although we found some issues to improve such as the triggering sensitivity at a touchdown, the first test was generally satisfactory. When applied to a future eruption, the amount collected will be sufficient for analyzing the contribution of a fresh magma at an initial eruption stage.

4. Summary and conclusions

Through our two-year experiments, the unmanned helicopter was proved to be practically useful for volcano surveillance at Mt.Tarumae. In particular, autonomous flight proved a performance of positioning control within an accuracy of approximately 10m. This is an advantage in detecting volcano-magnetic changes from a direct comparison procedure. In application of this vehicle to a future volcanic unrest, it is practically important to find beforehand some candidate sites for a base station from which we control the helicopter, and to perform some preliminary operations to overview an undisturbed condition when a volcano is calm.

Acknowledgments: We express sincere thanks to Muroran and Sapporo Development and Construction Departments of the HRDB for the cooperation in the field experiments using their unmanned helicopter.

Keywords: Tarumae volcano, unmanned helicopter, airborne surveillance, geomagnetic field, temporal change, material sampling

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Case study of geotechnical estimation by GREATEM and a helicopter-borne magnetic survey over a tunnel construction site

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1. Introduction

Helicopter-borne geophysical explorations, such as a grounded electrical source airborne transient electromagnetic (GREATEM) method and a helicopter-borne magnetic survey (HMS), have recently become more common in surveys in geological investigation and monitoring of active volcano. These methods enable the rapidly and broadly measuring the characteristic values of the underground, and these methods allow the gathering of three-dimensional geological information. In this study, we used GREATEM and HMS to delineate the geological structures of long tunnel construction site planned in the northern side of Hokkaido pref., Japan and report the feasibility and effectiveness of these surveys to provide geotechnical information for tunnel construction.

2. Outline and Method

In this study, we conducted our surveys on a planned mountainous tunnel with a total length of 2.7 km long and maximum overburden is 380 m. Geological features of tunnel site is the Cretaceous sedimentary rocks extending north to south and is penetrated by serpentinite. The serpentinite is mostly distributed in the central part of the tunnel route, and sedimentary rocks are distributed in the eastern and western sides, respectively. Excavating through the serpentinite zone would raise various geotechnical issues, such as squeezing; therefore, it is very important that the distribution of serpentinite be detected. We describe the results of GREATEM and HMS, and compare them with those of geological ground surveys, two-dimensional electric resistivity prospecting (2DERP), controlled source magneto-telluric method (CSMT), magnetic survey at ground surface, borings, electrical logging (EL) and measured electrical resistivity (ER) of bore core samples performed in the same area by tunnel constructor.

3. Results

As the results of GREATEM, relatively high ER zones were mainly seen from the surface layer to a depth of 100 m and relatively low ER zones were distributed on tunnel elevation line. These tendencies are similar to results of 2DERP, CSMT and EL. As the results of ER by bore core samples, serpentinites, the massive type showed the highest resistivity value, followed by foliated and clayey types and sedimentary rocks in this order. Although relatively low ER zones were seen in the deeper section, high and low ER mixed layer zones and steep gradient part of ER zones, as the ER contrast zones, are present in the deeper section along the tunnel elevation line. These are estimated that low ER zones consist of a clayey layer or/and weak foliated serpentinite and sedimentary rocks. The massive serpentinites are probably distributed in relatively high ER zones. The geological conditions change at depths where correspond to existence of ER contrast zones were found in the GREATEM survey. When excavating a tunnel in these zones, one must pay attention to faults, fracture zones, unsymmetrical pressure zones due to geological condition changes, flowing groundwater, and similar factors.

As the result of HMS, magnetization map based on magnetic intensity (MI), applied upward continuing to 900 m above sea level, were delineated shown as low magnetization bodies (MB) on both sides of the tunnel site and high MB on its central part. The highly MB zones are almost identical to the distribution of serpentinites revealed in the geological map and the other geological investigation results. However, the MI distribution is not homogeneous in the direction of the geological structure underground. Therefore, it is only difficult to estimate the geological properties of underground based on MI.

The resistivity structure of deep sections determined by combination of GREATEM and HMS surveys are effective for the acquisition of basic data to predict potential geotechnical issues when excavating a tunnel. We will verify these results by comparison with clarified geological conditions after tunnel was excavated.

Keywords: GREATEM, HMS, Helicopter, Tunnel, Geological investigation