Japan Geoscience Union Meeting 2014
(28 April - 02 May 2014 at Pacifico YOKOHAMA, Kanagawa, Japan)

STT58-01 Room:313 Time:April 30 16:15-16:30

Regional Airborne Survey for the Evaluation of Geothermal Potential in Japan

SHIMADA, Tadaaki[1*] ; TAKAI, Katsumi[1] ; MIYAKE, Kazuhiro[1] ; HISATANI, Koichi[1] ; TOSHA, Toshiyuki[1]

[1]Japan Oil, Gas and Metals National Corporation

Japan Oil, Gas and Metals National Corporation (JOGMEC) supports smooth development of geothermal resources in Japan by providing assistance to geological, geophysical, and well-drilling surveys, equity capital or liability guarantees, and information and data on geothermal resources.

As part of them, we planned to conduct evaluation of geothermal potential with airborne technique of gravity gradiometer method and time-domain electromagnetic method.

The gravity gradiometer method measures the differential of gravity, and provides information of much detailed geological structures. The time-domain EM method provides deeper penetration data than the frequency-domain EM method.

Since these methods are state-of-the-art techniques, we demonstrated them first in a couple of area with relatively high geothermal potentials and a lot of surveys conducted.

We carried out airborne survey with the technique of the gravity gradiometer method in the Kuju and the Kirishima areas in 2013. We would like to introduce the result of the airborne survey.

The authors thank local municipalities and related organizations for their understanding and cooperation to conduct the airborne survey.

Keywords: airborne survey, geothermal resources, gravity, gravity survey, electromagnetic survey

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Study on the prediction of the deep catastrophic landslide using the Airborne Electromagnetic Survey

KAWATO, Katsushi[1*] ; KINOSHITA, Atsuhiko[2] ; TAKAHARA, Teruyoshi[2] ; ISSHIKI, Hiromitsu[2] ; ISHIZUKA, Tadanori[2] ; OKUMURA, Minoru[1] ; UCHIDA, Koichi[1]

[1]Nippon Engineering Consultants Co.,LTD., [2]Public Works Research Institute

Recently, the deep catastrophic landslides were occurred frequently including the disaster of the Kii peninsula by typhoon 12 in 2011. The risk evaluation is demanded to be carried out the measures that we can assume at the both sides of the method constructing sabo dams and evacuation method. Recently, the airborne electromagnetic survey is performed a close-up to evaluate the risk of them. Merits of the airborne electromagnetic survey include that a geological feature border in conjunction with the deep catastrophic landslides having possibilities to become clear, hydrological properties may become clear. On the other hand, there is the uncertain element such as the decision method of the ratio resistance level of the geological feature border and the groundwater not being clear. In this study, we have arranged the results such as in the airborne electromagnetic survey, a geological survey, the hydrological investigations for the points where the deep catastrophic landslides were occurred and where airborne electromagnetic survey was carried out so far. The study areas are Byutano river basin (is about 4.4km2), Fujikawa river basin (about 3.7km2), Himekawa basin (about 15.2km2), and Kumano river basin (about 10.1km2). In these areas, in the past, the deep catastrophic landslides were occurred and the airborne electromagnetic surveys were carried out.

First, we have examined ratio resistance properties every area by the airborne electromagnetic survey. The range of the ratio resistance level to appear in the area for showed 1-2400 Ω-m in 1-1200Ω-m, the Kumano river basin in the Himekawa river basin whereas it was 1-400Ω-m in Byutano river basin and the Fujikawa river basin, and the distribution of the ratio resistance level knew that there was a difference by a geological feature and an area. And we have found that there were three patterns of the distributions of the resistance when we have paid our attention to the ratio resistance pattern of the plumb directions from the surface of the slope at the point with the fear of the deep catastrophic landslides to the deep part. From this, the depth that a ratio resistance level changes in the plumb direction may become the fundus of the deep catastrophic landslide. Boring investigations were carried out in Byutano river basin, Fujikawa river basin, Himekawa river basin, and a weathering department and the geological feature border of the virginity part are authorized by the observation of the boring core. The ratio resistance level corresponding to this geological feature border indicates 100Ω-m in Byutano river basin, 70Ω-m in Fujikawa river basin, and in Himekawa river basin indicates 500Ω-m, 680Ω-m, 1000Ω-m.

From these, it was confirmed that the ratio resistance level to correspond to appearance frequency and the geological feature border of the ratio resistance level varied according to an area and a geological feature. Therefore, it is necessary to carry out the risk evaluation of the deep catastrophic landslide after carrying out a boring investigation in addition at a representative point when we carry out the airborne electromagnetic survey, and having arranged a geological feature and the relations of the ratio resistance level.

In addition, at the deep catastrophic landslide point of Kumano river basin, consecutive low ratio resistance zones and the low ratio resistance zone of the plumb direction are common to the valley part from the ridge and are confirmed and agree with the groundwater situation by the hydrological investigation. We need to accumulate data about the ratio resistance structure in conjunction with the deep catastrophic landslide and want to examine the extracting method of the point with the fear of the deep catastrophic landslide, an estimate method of the collapse depth and collapse volume in future.

Keywords: Airborne Electromagnetic Survey, deep catastrophic landslide

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Study on the prediction of the large landslides of the volcanoes using the Airborne Electromagnetic Survey

KINOSHITA, Atsuhiko[1*] ; TAKAHARA, Teruyoshi[1] ; ISSHIKI, Hiromitsu[1] ; ISHIZUKA, Tadanori[1] ; OODAIRA, Tomohide[2] ; OMORI, Tetsuji[3] ; YAMANE, Hiroyuki[3] ; ARAI, Kenichi[4] ; KIYONO, Koji[5] ; TSUJIOKA, Hideki[6]

[1]Public Works Research Institute, [2]Fukushima River and National Highway Office, [3]Fuji Sabo Office, [4]Asia Air Survey Co,. ltd., [5]Nippon Engineering Consultants Co,. ltd., [6]OYO Corporation

In the lower basins of the active volcanoes, there are always the risks that sediment disasters are occurred. Especially, when large landslides are occurred at the time of heavy rains, the landslide sediment become a debris flow and makes a big damage by the sedimentation and the flooding in a lower basin. In late years,the Airborne Electromagnetic Survey is performed a close-up of as means to predict these large-scale landslides. It is necessary to estimate establishing technique to estimate a collapse side, the water sentence process in the slope to predict the slope where there is possibility of the collapse in at the time of heavy rains, but is the situation that is hard to say to be considered about these enough currently.Therefore, in this study, we havetaken Mt. Azuma and Mt. Fuji examples and examined the estimate technique of the collapse side and technique to predict a water sentence process from the result of a geological survey and the quality of the water investigation that we carried out the airborne electromagnetic survey in addition.

First, we performed the documents investigation into the characteristics of the topography, the geological feature, results of the sediment disasters, volcanic activity history there. Next, we performed a field work and confirmed the quality of soil structure in conjunction with the landslides, hydrothermal alteration situation causing the landslides and the hot spring gush situations. We examined areas of the airborne electromagnetic survey in reference to these results.We decided that the top of the mountain body and the representative craters were included and did the investigation object with the area including inclines more than 15 degrees that landslides were possible.The exploration area of Mt. Azuma was about 18km2 and the exploration area of Mt. Fuji was about 120km2.We have arranged themevery depth two-dimensionally so that we could recognizethe result of the helicopter electromagnetic explorationregionally.And, at the area where sediment disasters were easy to be occurred, there were some craters and water level under the ground were high, we have arranged them every depth two-dimensionally so that we grasped ratio resistance levels of the depth direction for running. We have verified the result of the airborne electromagnetic surveyby Comparing with the investigation results of the topographic and geological features.In addition, we investigated hydrology and water quality of the water at 10 neighboring streams in Mt.Azuma for the purpose of confirming the result of the airborne electromagnetic survey in detail.The investigation items werewater discharge, electric conductivity, pH, water temperature and ion silica concentration. In addition, we have carried out the boring investigation for the purpose of checking the ratio resistance levels by the airborne electromagnetic survey and the relations with the geological feature in Mt.Fuji.

We have found that by using the airborne electromagnetic survey in volcano area we could roughly grasp the geological features and underground water levels.From this, wecouldroughly predict the slopes that may collapse at the time of a heavy rain by using the airborne electromagnetic survey. On the other hand, we cannot estimate the collapse depth and the collapse volume in detail when it is only the airborne electromagnetic survey.It is necessary to supplement the results of the in the airborne electromagnetic survey by carrying out other investigations which arethe boring investigations and physics explorations on the ground, the waterquality and hydrological investigation to estimate these.In the near future, we will carry out the investigations including the airborne electromagnetic survey for models in some volcanoes and want to establish the estimate technology of the collapse dangerous points in the volcano areas, estimate technique of the collapse depths and collapse volume by accumulating data.

Keywords: airborne electromagnetic survey, large landslide, volcano

Japan Geoscience Union Meeting 2014
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STT58-04 Room:313 Time:April 30 17:00-17:15

Verification of the tunnel geological structure based on the helicopter-borne magnetometry data analysis

OKAZAKI, Kenji[1*] ; ITO, Yoshihiko[1]

[1]CERI, PWRI

1. Introduction

More detailed geological information of tunnel ground is very important for its construction. Especially, geological complicated area, such as accretionary complex, is needed more accurate information for process control and avoidance of risk during construction of tunnels. The authors carried out helicopter-borne magnetic survey to verify its applicability for geotechnical evaluation of a mountainous planned road tunnel in east Hokkaido, Japan. We describe corresponds with the results of the geological profiles estimated from the outcomes of tunnel construction records and its analysis results of magnetic anomalies which was obtained by helicopter-borne magnetometry data.

2. Outline

The geology of the study area is mainly consists of greenstone, pyroclastic sedimentary rock and hyaloclastite, and is mixed with pillow lava, chert and limestone. Many faults are formed in the area around the survey site due to tectonic movements at the time of formation of the accretionary complex and after that. Surveyed tunnel is planed to 910 m long and maximum overburden is 150 m. The magnetic intensity was measured from a helicopter at low altitude using a cesium magnetometer, and a magnetic intensity map was compiled based on the scalar volume of the magnetic force after reduction to pole magnetism. The probable geological model of the tunnel profile was analyzed using the magnetic anomaly pattern. The forward modeling process for the magnetic data was conducted using Mag2dc software (Cooper, 2003) based on the Talwani algorithm for calculation anomalies. The forward modeling was carried out according to the type of magnetic anomaly over blocks/steps, dependence of anomaly on width, depth, susceptibility contrast and dip angle. The tunnel geological models that estimated using the magnetic anomaly pattern were verified by the geological properties from tunnel construction records.

3. Results of survey

Results of this survey, executed in a mountainous area where accretionary complexes are distributed, are summarized as follows:

1) Helicopter-borne magnetic survey was carried out for a tunnel in northeastern Hokkaido and magnetic intensity map was figured. By the correlation to the other results such as the geological survey or the observation of rock type and fracture shear and conditions in advanced core, high magnetic intensity zone corresponded to the sedimentary rock and the fracture and shear zone of hyaloclastite and massive basalt.

2) Two geological models were made by combining helicopter-borne magnetic survey results with geological survey results and magnetic intensity model. The models were correlated to the detailed data obtained by advanced boring core observation, and these distributions are roughly confirmed by advanced boring core observation.

3) In this case study, helicopter-borne magnetic survey provided useful information for effective interpretation. To analyze geological structure by helicopter-borne magnetic survey is very effective to evaluate potential geotechnical issues when excavating a tunnel.

Keywords: helicopter-borne magnetic survey, magnetic anomalies, accretionary complex, road tunnel

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STT58-05 Room:313 Time:April 30 17:15-17:30

Magnetic structure of the tsunami inundation area of the 2011 off the Pacific coast of Tohoku Earthquake

OKUMA, Shigeo[1*] ; UEDA, Takumi[1] ; NAKATSUKA, Tadashi[1] ; MITSUHATA, Yuji[1] ; JINGUUJI, Motohara[1] ; UCHIDA, Toshihiro[1]

[1]Geological Survey of Japan, AIST

In June 2012, the Geological Survey of Japan (GSJ) conducted an airborne EM and magnetic survey over the inundation area by the tsunami of the 2011 off the Pacific coast of Tohoku Earthquake, northeast Japan. The purpose of the survey was mainly to map the resistivity of the subsurface structure associated with sea water invasion by the tsunami. Airborne EM data were successful for revealing the subsurface resistivity distribution as an aid for groundwater assessment of the study area.

Aeromagnetic data were also observed by the survey and processed (Okuma et al., 2013). However, it turned out that the magnetic data seem to be contaminated by artificial noise with amount of ˜20nT probably caused by the survey helicopter. To mitigate directional errors (Herringbone effect), the generalized mis-tie control method (Nakatsuka and Okuma, 2006) was applied to the observed magnetic data and magnetic anomalies were reduced onto a smoothed observation surface. According to the compiled aeromagnetic anomaly map of the Southern Sendai Plain, magnetic highs lie over the Cretaceous granitic rocks with high magnetic susceptibilities (˜10^{-2} SI; PB-Rock 21) outcropping on the north-trending Wariyama Mountains, which may constrain the groundwater flow system. The magnetic highs also extend NE and reach the Pacific coast, implying the existence of Cretaceous granitic rocks. In a map of the Matsukawaura area, an obvious magnetic high lies over the northern edge of the lagoon without any signatures of magnetic sources on surface. To better understand the subsurface structures of the survey areas, we applied 3D imaging (Nakatsuka and Okuma, 2013) to the observed magnetic anomalies. The preliminary results of the imaging indicate magnetization highs lie below the Wariyama Mountains and coastal regions between the Torinoumi Lagoon and Ushibashi river mouth in the Southern Sendai Plain. An obvious magnetization high is present below the northeastern edge of the Matsukawaura Lagoon, corresponding to granitic rocks with high magnetic susceptibilities (˜10^{-2} SI; PB-Rock 21) at a depth of around 300m below the surface in a hot spring exploration well. The details of the 3D imaging will be shown in the presentation.

Keywords: airborne EM survey, tsunami, groundwater environment, aeromagnetic survey, magnetic structure, basement

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Repeated aeromagnetic surveys in Shinmoedake volcano, Japan, by using an unmanned helicopter

KOYAMA, Takao[1*] ; KANEKO, Takayuki[1] ; OHMINATO, Takao[1] ; WATANABE, Atsushi[1] ; TAKEO, Minoru[1] ; YANAGISAWA, Takatoshi[2] ; HONDA, Yoshiaki[3]

[1]Earthquake Research Institute, University of Tokyo, [2]Institute for Research on Earth Evolution, Japan Agency for Marine-Earth Science and Technology, [3]Center for Environmental Remote Sensing, Chiba University

After the 2011 eruptions of Shinmoedake volcano in Japan, we conducted three repeated aeromagnetic surveys around this area, by using an autonomously driven unmanned helicopter. Shinmoedake volcano had sub-Plinian eruptions in the end of January 2011 and its vent was filled by uprising intrusive lavas. After that, some Vulcanian eruptions followed, and then volcanic activities were decreasing gradually up to the beginning of April 2011.

After these events, we conducted aeromagnetic surveys in the end of May 2011, the beginning of November 2011, and the end of October 2013. The Yamaha RMAX-G1 unmanned helicopter was used for our surveys, which was usually used to spray the agricultural chemicals to fields, and can make flights following the programmed tracks within about 1 m precision. Availability of precise flights are a great advantage for repeated surveys in order to detect easily the changes of circumstances, such as, geomagnetic changes due to volcanic activities by measuring at the same positions. Almost 85 km flights in total were made in every survey with a flight speed of about 10 m/s. Flight heights above the ground were almost kept in 100 m.

As the result of some data processing, we clearly detected the change of the magnetic fields around the vent of Shinmoedake, which has a kind of a dipolar pattern with positive changes in South and negative changes in North. This indicates a region around the vent got magnetization due to cooling. The intrusive lava is supposed to be the source of magnetization, and 2.0x10ˆ7 Amˆ2 magnetization of lava is evaluated at the second survey (0.5yr) and 4.8x10ˆ7 Amˆ2 is evaluated at the third survey (2.5yr), compared with the first survey. This means the magnetizing rate is almost related to a square root of the elapsed time and it leads to an implication the lava cooling is dominantly made gradually by thermal diffusion, not by other cooling processes such as thermal convection. The common thermal diffusivity of rocks, however, is too small by one order of magnitude to explain this cooling rate, and intrusion of water in lava, say, rainfall water, may play an important role to raise the effective thermal diffusivity to make the lava cool.

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The 3D magnetic imaging using the L1 regularization and variable selection procedure.

UTSUGI, Mitsuru[1*]

[1]Graduate School of Science, Kyoto Univ.

Recently some new method to obtain 3D subsurface structure from the gravity or geomagnetic data were proposed. Some of them have a goal to obtain a stable and most simple model which reproduce the observed data in high accuracy. This is because, in generally, most of the traditional way of inversion for the potential data provides distorted or unfocused mages of real gravitational or magnetic structures. In this study, we propose a new method introducing a L-1 penalized least square procedure and tried to obtain a simple, and therefor high- resolution model.

Lasso(Tibshirani,1995) is a linear regression and variable selection procedure based on the L1 penalized least square. L1 penalty has a effect of shrinkage the value of regression coefficients which has only weak contributions to be 0. So, the Lasso does both continuous shrinkage and automatic variable selection simultaneously. On the other hand, Lasso has some limitations and restrictions. One of them is, at most Lasso algorithm can select nonzero variables of same number of observed data. So, in the case of p <<n problem, i.e. in the case of number of unknown regression coefficients (p) is larger than the number of observations(n), this algorithm cannot be adopted or overly shrinkage model will be obtained.To overcome this limitation, Zou and Hastie (2005) proposed a new L-1 penalized method named Elastic Net.This method is a compromise of the L-1 and L-2 regularization method with two control parameters. Using this method, we can treat p <<n problems in the framework of L-1 penalized method.

In our presentation, we will show the results of applying this method to the synthesized and real magnetic data.

Keywords: potential, geomagnetism, magnetic structure, L-1 norm regularization

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STT58-P02 Room:Poster Time:April 30 18:15-19:30

Magnetic structure of the north part of Deception Island based on the aeromagnetic survey by a small unmanned airplane

SAKANAKA, Shin'ya[1*] ; FUNAKI, Minoru[2] ; HIGASHINO, Shin-ichiro[3] ; NAKAMURA, Norihiro[4] ; IWATA, Naoyoshi[5] ; OBARA, Noriaki[6] ; KUWABARA, Mikio[7]

[1]Akita Univ., [2]NIPR, [3]Kyushu Univ., [4]Tohoku Univ., [5]Yamagata Univ., [6]Robotista, [7]RC Service

Aerial magnetic survey was carried out in the part of the flight project of the autonomous unmanned aerial vehicles (UAV). The project was incorporated with National Institute of Polar Research (Japan), Korea Polar Research Institute, Chile Antarctic Institute, Bulgarian Antarctic research and Spanish Antarctic team. Magnetic anomaly data were aquired over the northern part of Deception Island (within South Shetland islands) in Bransfield Strait. It was the first time to succeed to get the geophysical data by a long-flight unmanned aerial vehicle (UAV) in the area of Antarctica as already reported by our team. Due to the severe weather the flight was canceled over the southern half of the Deception Island and its surrounding sae area.

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 62 degree 53 minute and the longitude of -60 degree 28 minute. On these lines each direction of the flight is opposite. Some unnatural unduration was seen around overlapped 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.

Outstanding high magnetic anomaly is recognized over the eastern peak of the island. Preparing topographic digital data of the Deception Island and bathymetric data on surrounding sea area, we estimated the distribution and the intensity of magnetization.

Keywords: Antarctica, Deception Island, Unmanned Aerial Vehicle, Magnetic Survey, South Shetland Islands

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Three dimensional inversion for the Grounded Electrical-Source Airborne Transient Electromagnetic (GREATEM) data

ABD ALLAH, Sabry[1*] ; MOGI, Toru[1] ; KIM, Hee[2] ; FOMENKO, Elena[3]

[1]Institute of Seismology and Volcanology, Hokkaido University, [2]Departments of Environmental Exploration Engineering, Pukyong National University, Busan, Korea, [3]Nova Scotia Community College, Halifax, NV, Canada

Previous studies conducted by the Grounded Electrical-Source Airborne Transient Electromagnetic (GREATEM) have shown that, this system is a promising method for modelling 3D resistivity structures in coastal areas, in addition to inaccessible area such as volcano, mountainous area covered by deep forest. To expand the application of the GREATEM system in the future for studying hazardous wastes, sea water incursion,geothermal exploration and hydrocarbon exploration, a 3D-resistivity modelling that considers large lateral resistivity variations is required in case of large resistivity contrasts between land and sea in surveys of coastal areas where 1D resistivity model that assumes a horizontally layered structure might be inaccurate. In this abstract we present the preparation for developing a consistent three dimensional electromagnetic inversion algorithm to calculate the EM response over arbitrary 3D conductivity structure using GREATEM system. In forward modelling the second order partial differential equations for scalar and vector potential are discretized on a staggered-grid finite difference method (Fomenko and Mogi, 2002, Mogi et al., 2011). In the inversion method the 3D model discretized into a large number of rectangular cells of constant conductivity and the final solution is obtained by minimizing a global objective function composed of the model objective function and data misfit. To deal with a huge number of grids and wide range of frequencies in air borne datasets, a method for approximating sensitivities is introduced for the efficient 3-D inversion. Approximate sensitivities are derived by replacing adjoint secondary electric fields with those computed in the previous iteration. These sensitivities can reduce the computation time, without significant loss of accuracy when constructing a full sensitivity matrix for 3-D inversion, based on the Gauss?Newton method (Han, N.et al., 2008).

Firstly, we started testing the algorithm in the frequency domain electromagnetic response of synthetic model considering a 3D conductor embedded in uniform half space. In the second step we tested more complex synthetic model, considering vertical contact between two different high and low resistivity quarter-spaces and a conductor embedded in a high resistive quarter-space. Frequency-domain computation is executed at frequencies of five equal logarithm spacings in one decade in the frequency range of (10^{5}-10^{-2}) Hz. After the computation, we transformed into time domain using FFT and compared forward value with inverted value.The inverted results in case of the simple model, appear to highlight a conductive zone of potential interest within the resistive region. In addition, in case of two quarter spaces model, it was able to the reveal the clear resistivity contrast between the two quarters spaces and highlight a conductive zone within the high resistive quarter space. Both of the forward and inverted models have almost the same EM response which can confirm the accuracy of the inverted method. The next step for preparing this algorithm will be using the field data from previous GREATEM surveys to demonstrate this technique

Keywords: 3D EM inversion, GREATEM, Numerical approximations, Airborne Electromagnetic

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An Advanced Method of Data Analysis for Gravity Exploration System on a Mobile Vehicle

OGURA, Yumiko[1] ; MATSUDA, Shigeo[2] ; YOKOI, Isamu[3] ; SUDA, Haruo[3] ; KIMA, Sadaharu[3] ; MORIKAWA, Hitoshi[1*] ; SAEKI, Masayuki[4] ; SUZUKI, Takuya[4] ; KOMAZAWA, Masao[5]

[1]Tokyo Institute of Technology, [2]Clover Tech . Inc., [3]Tokyo Sokushin Co.,Ltd.,, [4]Tokyo University of Science, [5]OYO Corporation

A model of ground structure is very important to estimate earthquake ground motions. Gravity survey is one of exploration methods. We can estimate ground structure by using information of gravity anomaly which comes from heterogeneous density structure of the ground. Generally speaking, there are high correlation between density and velocity structure of the ground. Thus, the gravity survey is comparatively easier than other exploration method to estimate the ground structure, so that it is very suitable for the aspect of the seismic hazard projection.

For gravity survey, spring-type relative gravimeter is usually used. This type of gravimeter can provide accurate data, however, it is very expensive and difficult to handle. Furthermore, it takes much time to obtain adequate data. We, thus, began to develop a simple and inexpensive sensor which can measure gravity anomaly on a moving vehicle, such as air, land, and sea vehicles, that is, airplanes, motor vehicles, and ships. In a case where a gravimeter is used with a moving vehicle, we may survey the gravity over larger area in shorter time than using conventional survey techniques.

Generally, the gravity should be measured with resolution of 10 micro Gal at least for survey to estimate ground structure. However, the signal obtained from sensor is contaminated by various noise such as vibration of a moving vehicle etc. This means that a sensor with high resolution and large dynamic range is required. This is difficult to realize because resolution and dynamic range are conflicting requirement. To solve this problem, we have developed a sensor with a new feedback system, which has high resolution and large dynamic range.The performance of this sensor is examined in this study, and we also propose a technique of data processing based on the combination of second order blind identification (SOBI) and Hilbert Huang transform (HHT) technique.For this two different type of observations are carried out.

First, we set the sensor statically in a tunnel to confirm whether the sensor can respond to the gravitational effects caused by earth tides. From this observation, it is found that the sensor is affected by atmosphere. The effect is can be removed by applying second order blind identification (SOBI).

Second, the ship survey is carried out.Through a technique of data processing based,the observed data provide quite good agreement with theoretical gravity in phase and period of the signal.

Keywords: gravity survey, Hilbert-Huang Transform, Second Order Blind Identification