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

SGD22-01 Room:301B Time:May 22 14:15-14:30

About a small throw-up method absolute gravimeter under development

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The gravity measurement is used for resource exploration. The gravity map on the surface of the earth is used to estimate underground density distribution. In addition, the gravity exploration is used for investigating the magma movement of the volcano. We try to use an observed gravity change in an estimate of volcanic eruption predictions and underground density structure. For example, at first we perform absolute gravity measurements at the reference point of the foot for volcano observation. Then we measure gravity by carrying a relative gravimeter, and making a round trip to the reference point and to the observation point. This method requires great care and long time. At volcanic activity, it is dangerous to observe gravity.

Mr. Araya and others (2007) have developed a compact absolute gravimeter to improve these situations. If this compact absolute gravimeter was developed and we installed it in the volcano area, we could acquire data continuously even at the time of volcanic activity. In the future we will create the net work of absolute gravimeters, and we want to be able to observe absolute gravity at the same time. Then we come to understand a plane-like gravity change and be able to analyze activity of the magma precisely. In addition if we put it in a deep borehole and ocean bed of subduction zone, we could investigate seismic activity of deep underground and plate movement with gravity data. From these if the miniaturization of an absolute gravimeter advances, we enable various applications to an outdoor observation study and it will provide new observation technique. In existing device, we cannot measure repeatedly and quickly because the preparation for a free fall taken long time. However, in the case of a throw-up method, the measurement is enabled repeatedly because it is not necessary to lift a fall object. I replaced the free-fall device of the existing absolute gravimeter with the throw-up device which I developed. Then I checked accuracy and resolution of the measured acceleration of gravity of the throw-up device.

The throw-up device was able to detect a gravity change owing to earth tide. I realized that gravitational change resolution was 40 micro-gal. However, the absolute value of gravity has deviated from the expected one up to ?g 3mgal. This error occurred, when the reaction at the time of having thrown got across to the interferometer. In order to investigate the problem, I used different combinations of various vibration isolation materials. I expect to find a solution, when the vibration is minimized and fixed with a certain reproducibility. This should improve the accuracy of gravity measurements.

Keywords: geodesy, gravity, absolute gravimeter, throw-up method, earth tide, volcano

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SGD22-02 Room:301B Time:May 22 14:30-14:45

Development of a gravity gradiometer system for submarine gravity prospecting 3

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Gravity surveys are extensively conducted for profiling the underground density structure on land, while their application to sea area has been difficult because of either wide-area seafloor observation or poor accuracy caused by instability of the platform such as ships and airplanes. We propose a hybrid gravity survey method using an autonomous underwater vehicle (AUV) containing both a gravimeter and a gravity gradiometer. This paper describes the development of the submersible gravity gradiometer for this purpose.

As compared to a gravimeter, a gravity gradiometer is sensitive to localized density structure as a spatial derivative of its gravitational field, and hence it is suited to survey on concentrated sources such as submarine ore deposits. In addition, any common noise to the gravity sensors, such as translation acceleration of the platform, has little effect on gravity gradiometer as the differential gravity acceleration, and therefore a gravity gradiometers is preferable as an on-board instrument in the underwater vehicle.

We operated the developed gradiometer at a quiet site on land and estimated its self-noise to be 6 E (=6x10^{-9} /s^2) in (2-50) mHz where gravity gradient signal is expected to be dominant when an AUV passes above a typical ore deposit. To reduce centrifugal error associated with rotation of the underwater vehicle, the gravity gradiometer was mounted on a two-dimensional forced gimbal controlled to be vertical with reference to fiber-optic gyroscopes and tiltmeters.

A sea trial observation was carried out on 7-9 September, 2012, in Sagami Bay at a depth of about 1,300 m using the AUV Urashima (JAMSTEC). The gravity gradiometer and the forced gimbal operated stably onboard the moving platform unless it involves large motions during turning and pitching. Design and resulted resolution, as well as discussion for improvements, will be presented.

Keywords: ore deposit, gravity survey, gravity gradiometer, forced gimbal, AUV

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SGD22-03 Room:301B Time:May 22 14:45-15:00

Development of a free-fall interferometric gravity-gradiometer for volcanological studies in the Mt Aso area

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To improve our knowledge on the process of volcanic eruptions, it is essential to observe time and spatial variations of subsurface density in volcanic areas. Gravity measurements, using relative and/or absolute gravimeters, are one of the widely-used methods to observe such subsurface density variations. Measured values of gravity include other effects that are not related to volcanic activities, such as influences of groundwater and diastrophism. These non-volcanic effects have to be removed by careful modellings. However, uncertainties in the modelling make it difficult to accurately identify the volcanic effects in the measured values of gravity. In order to improve the accuracy of the identification of volcanic effects, we propose to carry out measurements of vertical gravity gradients, simultaneously with gravity measurements.

A new type of gravity gradiometer that employs the method of free-fall interferometer had been developed at the Institute for Cosmic Ray Research (ICRR) of the Tokyo University from 2009 to 2012. After confirming the working principle of the gravity gradiometer, its prototype was moved to the Aso Volcanological Laboratory (AVL) of the Kyoto University. Further improvements and trial measurements have been carried out at the AVL so that it can be used for continuous observations in volcanic areas. We report the current status of the development and future prospects of the gravity-gradients measurements in the Mt Aso area.

SGD22-04 Room:301B Time:May 22 15:00-15:15

Gravimetrical vertical array observation -A preliminary report-

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We carried out ”gravimeter array method” proposed in Tanaka et al.(2012, JpGU) experimentally for two months and will report the preliminary results and problems revealed by the experiment. All three gravimeters we used are made in Microg LaCoste Inc.: two continuous relative devices, gPhone (#78 and #90) and an absolute device, FG5(#225). Please refer to Tanaka et al.(EPS, in press) for data-processing procedure and observed precipitation responses.Though we name here ”vertical array” for convenience, the horizontal distance between gPhone#90 at 300m-depth belowground and gPhone#78 on the ground is approximately 100 m. Thus the institution, Mizunami Underground Laboratory (MIU) which enables to construct the gravimeter array is rare in the world. Such the gravity monitoring system may contribute to the studies of slab-subduction process and geological disposal because it suppresses rainfall responses and stacks signal from deep part of crust. We constructed the array system for two months from October, 2012 because of rental of the gPhone#78. Unfortunately, the data quality of gPhone#90 at 300m-depth belowground was very low because blasting for a horizontal gallery (the North gallery) excavation at 500m belowground performed frequently during this period. However, we found the following two points: 1) blastings at the South gallery at 500m-depth belowground were no effect to gPhone#90, 2) the accuracy of atmospheric correction of gPhone#90 was worse than the one of gPhone#78 approximately one digit (because gPhone#90 was installed at the end of 100m-length horizontal cave). We will improve the layout of array in consideration of blasting position and substitute the atmospheric pressure near the Main Shaft for in situ in future. On the other hand, it was suggested by the data at 300m-depth belowground during no blasting period before constructing the array that the rainfall responses were almost same amplitude the one of at 100m-depth belowground. This result insists that the acceptability of infinite plate assumption for unconfined aquifer distributed shallower than 100m-depth belowground. Though the same hourly rainfall depth at a rain gauge, the distributional area is not same. So that, it is necessary to check parallel gravity observations at different depth (i.e., 100m- and 300m- depth) in future. With regard to evaluation of the drift gPhone#78 by using FG5#225, we could not implement it because of a data-missing of gPhone#78 caused by earthquake vibration.

Acknowledgements: This work is supporting by a promotion grant for the establishment of the underground research facility of the Agency for Natural Resources and Energy, Minister of Economy, Trade and Industry. We wish to thank the JAEA for cooperation of observations (especially Y. Horiuchi, K. Kumada (now at Tokyu Construction Co.), and S. Hashizume). T. Tanaka, R. Honda and Y. Asai also wish to thank ERI for support of the special cooperative research grant ”2010-B001”.

Keywords: continuous gravity measurement, inland water, rainfall, measurement method

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Peculiar Gravity Change at the Kirishima Volcano during Vulcanian Eruption Phase in 2011

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1. Introduction

Mt. Shinmoedake of the Kirishima volcanoes woke from a 300 year long period of dormancy in 2011. Sub-Plinian eruptions on Jan. 26 and 27 were followed by formation of a lava dome and Vulcanian eruptions in February 2011. We carried out continuous absolute gravity measurement for 1 year since Feb. 8, 2011 and found peculiar gravity signals during the Vulcanian eruption phase in February 2011.

2. Absolute gravity measurement

We installed a gravimeter FG5 at the Kirisima Volcano Observatory, which is located just above the supposed inflation/deflation source before and after the 2011 eruption. FG5 is an absolute gravimeter that measures

acceleration of a free falling target in a vacuum chamber with a laser interferometer and a rubidium atomic clock. We usually average 50 measurements during a prescribed time window of 500 seconds to obtain a set gravity g_{set}; the bunch of 50 measurements is called a set. The time window is separated by either 30 or 60 minutes. Standard deviation of each measurement within a set is 10-30 microgal in normal condition. The precision of g_{set} is thus estimated to be 1-4 microgal.

The gravity record shows peculiar temporal changes before the Vulcanian eruptions in February 2011; gravity started to decrease from 8-10 hours before Vulcanian eruptions followed by quick recovery 2 hours before the eruption. We applied the F-test on the statistical significance of the gravity changes and found that they are significant on 1 % significance level. We shall discuss how these gravity changes occur before Vulcanian eruptions.

Keywords: absolute gravity change, volcano, vulcanian eruption, continuous measurement

SGD22-06 Room:301B Time:May 22 15:30-15:45

The postseismic gravity changes observed with GRACE satellite.

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There are several reports of the observations of gravity changes due to great earthquakes with data set of Gravity Recovery and Climate Experiment (GRACE) satellite, but only Release 02-04 data are used in them. I reanalyzed the co- and postseismic gravity changes due to the three M9 class earthquakes, the 2004 Sumatra-Andaman, 2010 Chile (Maule), and 2011 Tohoku-oki earthquake, using Release 05 data set. I found that the every gravity change due to a huge earthquake has three steps. The gravity decreases immediately at the moment a huge earthquake occurs, continues to decrease slowly for a few months, and increases slowly taking more than a year after decreasing. That is, postseismic gravity changes have short-term and long-term components. But the their mechanisms are not clear.

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SGD22-07 Room:301B Time:May 22 15:45-16:00

Precise gravity field determination around Syowa station, Antarctica, by combining satellite and in-situ gravity data

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We reported a preliminary result of the gravity field determination around Syowa Station, Antarctica, by combining GOCE (Gravity field and steady-state Ocean Circulation Explorer) EGM (Earth Gravity Model) and JARE (Japanese Antarctic Research Expedition) in-situ gravity data in the JpGU 2012 meeting. In the previous study, the area concerned was restricted almost same as that of the airborne gravity measurements conducted by JARE-47. Also we only employed limited number of preprocessed shipborne and land gravity data sets to skip bias corrections. And we estimated gravity anomalies and geoid heights by means of LSC (Least Squares Collocation) method using GOCE TIM (time-wise) RL (Release) 3 EGM as the long wavelength gravity fields. In this study, we have expanded the estimation area by including more in-situ gravity data and modified the procedure of the data processing.

Major improvements since the previous study are summarized as follows; 1) expanding the calculation area to 60-80S and 20-60E by including more shipborne and land gravity data, 2) including altimetric gravity data for the area with no shipborne gravity data, and 3) applying bias corrections for the shipborne and land gravity data. The gravity field has been calculated by LSC with the empirical covariance function estimated from the airborne gravity data. The formal errors estimate for the area with enough number of gravity data are several mgals and less than 10 cm for gravity anomalies and geoidal heights, respectively. This means that the accuracy of the gravity field is approaching toward the requirements for the future global height system unification. The airborne gravity data and the GOCE EGM show a good consistency in the long wavelength components and we may not need to apply any bias corrections. On the other hands, we observed clear biases between some of shipborne and land gravity data sets and the estimated gravity fields. Thus we may need careful bias corrections tracing back to the original data sets. Several EGMs including GOCE and other satellite gravity data such as GRACE have already been released and new EGMs calculated from updated GOCE data will be released soon. We plan to evaluate and utilize these EGMs for future improvements of the gravity field determinations in the area.

Keywords: GOCE, Gravity anomaly, Geoid, Syowa Station, Antarctica

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SGD22-08 Room:301B Time:May 22 16:15-16:30

Gravity observation using a superconducting gravimeter at Ishigakijima, Japan (part 2)

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About one year has passed since we installed a superconducting gravimeter at the VERA Ishigakijima Station, National Astronomical Observatory Japan, in February 2012, with the aim of detecting possible gravity changes associated with the slow slip events (SSE) taking place beneath the Yaeyama Islands. In the first month, the condition of the gravimeter was not very good because the temperature control was unstable. We solved the problem in March 2012. In the end of September, there was a power failure caused by the typhoon Jelawat, which lasted for about one day. Although the observation system was not damaged, the gravity signal indicated an instrumental offset before and after the power failure. On January 7, 2013 an earthquake (M=5.4) occurred near Yonagunijima island, which also caused a small instrumental offset in gravity. Except for these problems, the gravimeter has been producing an almost homogeneous and continuous dataset of temporal gravity changes.

Up to now, the gravimeter has experienced two instances of slow slip events, one from May 2012 to June 2012 and one from December 2012 to January 2013. In order to clarify the gravity changes related with the SSE, the gravity data must be corrected for the effects of atmospheric pressure, ocean tides, and groundwater. We have noticed difficulties in these corrections because of possible interactions between these parts, resulting in complicated responses of gravity. Our tentative conclusion with simple schemes of corrections is that the gravity indicated an increase (˜ 2 microGal) before the SSE and a decrease (˜ 2 microGal) during the SSE. This may reflect some movements of mass beneath the Yaeyama region in addition to the crustal deformations caused by the SSE.

Keywords: superconducting gravimeter, slow slip, Ishigakijima

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SGD22-09 Room:301B Time:May 22 16:30-16:45

Continuous gravity observation using a gPhone-133 at a hot spring area of Hachijojima, Japan

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Gravimeter is a useful tool for detecting subsurface mass variations. For elucidating groundwater variations in hot spring area, we carried out continuous gravity observation with a gPhone-133 in the Nakanogo gravity observation hut of Hachijojima (GOH) at the period from August to December 2012, following gPhone-109 observation in the last fiscal year. In addition to gravity measurements, we collected auxiliary data of atmospheric pressure, rainfall, soil moisture and the monitoring well (e.g. water level and temperature) in the vicinity of GOH. Using gPhone-109, in December 2011 and February 2012, we detected gravity decrease of an approximately 5 microGal that occurred about 3 days after groundwater temperature decrease of the monitoring well of an approximately 1 degree Celsius. By using gPhone-133, in this fiscal year, we also detected such a phenomenon. We calculated gravity effect of precipitation and/or soil moisture but the magnitude of the effect was smaller than 1 microGal. Although, at a period of a gPhone data analysis, sea level decreased about 1 m, we could not distinguish effects of mechanical drift of gPhone and sea level change.

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Keywords: gravity monitoring, soil moisture, ground water, sea level, rain fall, atmospheric pressure