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

Akito Araya[1*], Masanao Shinohara[1], Toshihiko Kanazawa[2], Hiromi Fujimoto[3], Tomoaki Yamada[1], Kokichi Iizasa[4], Takemi Ishihara[5], Satoshi Tsukioka[6]

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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

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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SGD22-05 Room:301B Time:May 22 15:15-15:30

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

Japan Geoscience Union Meeting 2013
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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.

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

Kazunari Nawa[1*], Mituhiko Sugihara[1], Yuji Nishi[1], Tsuneo Ishido[1], Kasumi Yasukawa[1], Keiichi Sakaguchi[1]

[1]AIST

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.

The authors wish to express their deep gratitude to the Tokyo Electric Power Services Corporation and to Hachijo Town local government for providing generous and courteous support to our field survey team. This study was supported by the competitive research fund of the Ministry of the Environment.

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

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SGD22-P01 Room:Convention Hall Time:May 22 18:15-19:30

Publication of new Japan Gravity Reference System 2011

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GSI constructed new Japanese gravity standardization net, JGSN2011, using latest gravity survey data. In Japan, the gravity reference had been published twice. The first publication was JGSN75 in 1976 which was based on IGSN71 and has been used as a Japanese gravity reference. The second was JGSN96 in 1997. While it is not connected to second order gravity stations which consist of 14000 points in Japan, it has 10 times higher precision than JGSN75's and has been used as an academic production.

JGSN2011 is composed of fundamental gravity survey (absolute gravity) data and first order gravity survey (relative gravity) data. Since we re-conducted gravity surveys in Tohoku region after the 2011 off the Pacific coast of Tohoku Earthquake, the seismic effects are included in JGSN2011.

In this third gravity reference, JGSN2011, more fundamental gravity stations are used and the gravity reference system are took into account by using higher precision of the position of the gravity stations and unifying a tidal correction, while it has the same precision as JGSN96. We aim to register JGSN2011 gravity data on AGrav and contribute to GGOS etc.

We present the outline of JGSN2011 and our future plan.

Keywords: Gravity Standardization Net, JGSN, Absolute gravimeter

SGD22-P02 Room:Convention Hall Time:May 22 18:15-19:30

Reprocessing of Shirase shipboarne gravity data

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In order to create consistent data sets of JARE (Japanese Antarctic Research Expedition) shipborne gravity data, we applied drift and offset corrections using the latest satellite altimetric gravity model as the reference for all the data sets so far obtained.

JARE has been conducting gravity measurements on board Ice breaker Shirase since 27th expedition (JARE-27) except JARE-31, 35, 36 and 50. The data sets obtained are divided into two groups, namely those obtained by the former Shirase during JARE27-49 and those obtained by the new Shirase after JARE 51. On board former Shirase, NIPRORI-1 surface ship gravity meter was employed for JARE-27 and 28 and NIPRORI-2 was employed after JARE-29. In addition, several improvements in the navigation system and instruments were conducted during the period.

Konishi et al. (2006) already conducted drift and offset corrections for the data before JARE-46 so that the shipborne data fitted to those of satellite altimetric gravity data of grav.img.11.1 (Sandwell and Smith, 2004). However the data sets after JARE-47 have been left unprocessed and they may contain drift and/or offset errors. On the other hand, after the release of grav.img.11.1, recent satellite altimetric gravity fields have been improved drastically by including CryoSat, Envisat and other satellite data and the newly released EGM2008 Earth gravity model. Therefore, in this study, we carried out drift and bias corrections again for all the shipborne gravity data obtained by JARE using the latest altimetric gravity model of grav.img.20.1 (Sandwell and Smith, 2012).

Practically, following Konishi et al. (2006), we first extracted the gravity values from grav.img.20.1 along the ship tracks, and then compared the values with those of shipborne gravity data. From the comparisons, we found some large discrepancies near the turning points of the ship tracks, also found some large drifts and offsets in the data sets after JARE-47 and even in same data sets before JARE-46.

In order to correct these errors, we first removed the data with large discrepancies, and assuming polynomial functions of time for the drifts, we applied drift and offset corrections for each leg. We will report the details of the data processing, comparison results and the corrected data sets as well.

Keywords: shipborne gravity, JARE, altimeter, drift correction, Ice breaker Shirase

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SGD22-P03 Room:Convention Hall Time:May 22 18:15-19:30

Sea surface gravity changes observed prior to March 11, 2011 Tohoku earthquake II

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[1]JAMSTEC

The 2011 Tohoku earthquake occurred via subduction of an oceanic tectonic plate, where we had no historical record of this size of earthquake. We have examined shipboard geophysical observations conducted above the rupture area for any indications before the earthquake. The location of largest slip along the fault surface coincides with gravity changes measured at the sea surface separated by three months all before earthquake. This gravity change cannot be explained by the local gravity gradient due to bathymetry along the cruise tracks. The measured gravity changes can be interpreted either as an uplift of ocean bottom or a density increase along the fault surface of which the time scale of evolution is about three months. This observation may constrain the physical mechanism by which this large and slow slip can be generated along this fault.

Keywords: 2011 Tohoku earthquake, shipboard gravity survey

SGD22-P04 Room:Convention Hall Time:May 22 18:15-19:30

Mass changes in polar ice sheets from low-degree gravity field by SLR

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The majority of the land ice on earth lies in Antarctica and Greenland as continental ice sheets. Recent climate changes have brought about the significant ice melting in these regions. The space mission of Gravity Recovery and Climate Experiment (GRACE), launched in 2002, enables direct measurements of such mass losses over extensive areas. According to the GRACE observation during 2003-2010, the polar ice sheets experienced mass loss at the rates ˜390 Gt/yr, amounting to ˜70% of the total ice loss globally in the same period (Jacob et al., 2012). These massive and extensive mass losses can also be detected by the Satellite Laser Ranging (SLR) technique. Although limited in spatial resolution, the SLR data have been available for a longer time span of 1991-2011. Here we calculated the changes in the earth's gravity field using the monthly Stokes coefficients up to degree and order 4 estimated from both SLR and GRACE. Then we corrected the results for the contributions of Glacial Isostatic Adjustment using the model of Paulson et al. (2007). Between 2003 and 2011, the linear trend map of the gravity field from SLR shows significant negative patterns in Greenland and Antarctica, agreeing well with that from GRACE. However, seen from SLR data, the gravity trend map between 1991 and 2011 shows different behaviors: near-balance in Greenland prior to 2002 and shifting to decreasing afterwards. The gravity in West Antarctica also shows similar trends as Greenland, but that in East Antarctica shows opposite trends. These results imply that the mass balances in the polar ice sheets might be affected by some decadal climate variability.

Keywords: Geodesy, Polar ice sheets, Gravity change

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SGD22-P05 Room:Convention Hall Time:May 22 18:15-19:30

Gravity change simulations of various environmental changes around TRIES gravity stations

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The Tono Research Institute of Earthquake Science (TRIES) has been operating absolute gravity measurement since 2004, with Micro-g LaCoste FG-5 absolute gravimeter. From the beginning of the observation, gravity values do not show variation larger than 10 micro Gals. The excavating of two vertical shafts and horizontal caves for research in Mizunami Underground Research Laboratory (MIU) is the largest action. It has been carried out by Japan Atomic Energy Agency (JAEA) since 2004. The shaft excavation site is vicinity of two gravity measurement stations, MGA and TGR. The drawdown of water depth level accompanying the excavation is observed around the site. Besides, the leveling which has been carried out since 2004 detected at most 17 mm subsidence near the TGR gravity station. The artificial topographic change might be also effective. We examined the gravitational effect of such environmental changes around our stations.

The effect of the tunnel excavation is estimated based on a detailed drift way model, which was provided by JAEA. The original model is prepared as a wire frame data. We arranged the wire frame model to the grid data. Then we adopted the method of Banerjee and Gupta (1977), which calculates the vertical component of the theoretical attraction force of rectangular prism.

The artificial topographic change took place near the TGR station. It was the elimination of crest and the infill of a channel. The effect of the topographic change is estimated by Digital Elevation Map (DEM). The latest DEM is provided by Geographical Survey Institute of Japan (GSI) as a 5 m grid model. We made an old DEM by digitizing altitude contours of the 1:1000 map of Mizunami city, which was published in 1986. The difference of the two DEM is employed to the attraction force calculation.

The detected subsidence was simply applied to a free-air gravitational effect. As a result, the total gravity change estimated for these various environmental changes was less than 5 micro Gals. The remaining problem is the change of the ground water level. We must explain the mechanisms of large ground water level change, which does not affect gravity values.

Banerjee, B. and S. P. D. Gupta (1977): Gravitational Attraction of a Rectangular Parallelepiped, Geophysics, 42, 1053-1055.

Keywords: gravity, gravity change

Japan Geoscience Union Meeting 2013
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SGD22-P06 Room:Convention Hall Time:May 22 18:15-19:30

Gravity changes around Ito campus, Kyushu University by using relative and absolute gravity measurement

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It is important to monitor the aquifer mass balance between discharge and recharge for the sustainable groundwater usage. The discharge of groundwater causes mass redistributions, which can cause measurable gravity changes. We carried out the repeat hybrid gravity measurements at some fields in order to detect the gravity changes associated with groundwater level changes. We used the instruments for the relative gravity measurement (CG-3M and CG-5 gravimeter: Scintrex Ltd.) and the absolute gravity measurement (A-10 gravimeter: Micro-g LaCoste, Inc.). The A10 absolute gravimeter is a portable absolute gravimeter produced by Micro-g LaCoste Inc. It operates on a 12V DC power supply (i.e. vehicle battery). We can measure the absolute gravity using the vehicle battery at the field.

We started repeat gravity measurement at Ito campus, Kyushu university Fukuoka city, Northern part of Kyushu, Japan, where the instrument is usually maintained, since 2008 in order to assess the A10 gravimeter's accuracy and repeatability. We measured 10 sets at each measurement, and 1 set consists of 100 drops. There are 3 groundwater level monitoring wells near the gravity station. It can be seen that there is a good correlation between gravity changes and groundwater level changes. We confirmed that the instrument is maintained good condition in general, although some bad data was included. It seems that the repeatability of A10 gravimeter is better than 10 micro gal. The A10 absolute gravimeter (Micro-g LaCoste Inc.) was introduced in order to monitor the gravity changes at base observation points since 2008. We observed seasonal gravity change (Maximum change was 26 micro gal), and we compared with the groundwater level changes. There are good correlation between the gravity changes and the groundwater level changes. We calculated the effect of groundwater level changes using Gwater-1D (Kazama et al., 2010). As a result of the calculation, we can explain the gravity seasonal changes were caused by the groundwater level changes. The gravity changes of the base observation were removed from each observation point. We can see the good correlation between the gravity changes and the groundwater level change in the almost observation point. The effect of the construction of the campus awaits future studies.

Keywords: A10 absolute gravimeter, Hybrid gravity measurement, Groundwater level monitoring, Gravity changes

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SGD22-P07 Room:Convention Hall Time:May 22 18:15-19:30

Numerical estimations of hydrological gravity changes at Cibinong, Indonesia with empirical and physical models

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Gravity measurement is one of the effective methods for probing mass changes and it enables us to monitor an earthquake deformation, a volcanic activity or a carbon dioxide reservoir performance. However, rainfall causes a gravity change of around 0.04 micro-gal/mm . Especially, heavy rainfall can cover over the fore mentioned gravity signals. Thus we should correct the gravity disturbance attributed to a rainfall, a soil water and an underground water as precisely as possible.

In this study, we empirically calculated and corrected the gravity response of underground water and soil water using continuous gravity data measured at Cibinog, Indonesia from March 2009 to January 2012. First, we calculated proportionality coefficient of gravity change to underground water level. It is estimated to be +0.12 micro-gal/cm, which is in the same range of that of Isawa, Japan (+0.16 micro-gal/cm; Hanada et al., 1990). Then, after taking the estimated gravity change of the underground water from the measured gravity data, we found the residual gravity change of 1.7 micro-gal in terms of RMS (Root Mean Square). This gravity change is considered that of soil water which sink in the underground after rainfall and is becoming underground water. Thus we found the response function of the residual gravity change to the rainfall.

As a result, we succeeded to replicate gravity change within a residual error of 0.51 micro-gal in terms of RMS after empirically correcting the effects of the underground water and the soil water between April 2011 and June 2011. However, the residual gravity change before April 2011 is calculated to be 1.8 micro-gal in terms of RMS, which means we could not precisely correct it even if we factor in the soil water. The cause could be attributed to the limitation of the empirical model with the assumption of linearity because the soil water flow may be dominated by non-linear physics. Then we will calculate more realistic and reproducible distribution of land water and gravity change using physical model (Kazama et al., 2012).

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SGD22-P08 Room:Convention Hall Time:May 22 18:15-19:30

Absolute gravity changes caused by long-term slow slip events in Ryukyu in May and December 2012

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Long-term slow-slip events (SSEs) have been observed in many plate-boundary zones along the circum-Pacific seismic belt. Previous studies have revealed that high-pressure fluids supplied from the subducted oceanic plate can generate SSEs. SSEs in different areas have different recurrence intervals. In general, the secular stress accumulation rate and the frictional property on a plate boundary controls the interval. Therefore, their differences are considered to cause the differences in the intervals. However, variations in fluid pressure can also change the intervals, because they affect the effective normal stress and the fault strength. Such variations in fluid pressure are predicted by an earthquake-cycle model based on a fault valve behavior of Sibson (1992). So far, variations in fluid pressure associated with SSEs had not been detected by field observations. If a massive fluid pressure change occurred, gravity change could be detected by the corresponding density redistribution in the underground. In the Tokai district in Japan, a long-term SSE had occurred during year from 2000 to around 2006, and gravity changes in 2004-2009 that could be explained by a fluid pressure variation were detected (Tanaka et al., 2010). However, the quality of the data was not good due to the lower temporal resolution of the campaign data and the observation period did not cover the whole cycle of the SSE. Therefore, a clear evidence of fluid-pressure change has still not yet been obtained. Since the end of year 2011, we have conducted a continuous gravity measurement using absolute gravimeters and a superconducting gravimeter in Ishigakijima and Iriomotejima Islands along the Ryukyu Trench where SSEs have occurred twice a year to observe a transient gravity change during the whole cycle of an SSE. In this presentation, we will report an observation result obtained by absolute gravimeters during the recent two slow slip events.

Keywords: slow earthquake, slow slip, fluid, gravity, earthquake cycle, subduction zone

SGD22-P09 Room:Convention Hall Time:May 22 18:15-19:30

Soil parameters and their heterogeneities at Yaeyama Islands for precise estimation of hydrological effects on gravity

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Superconducting and absolute gravity has been continuously observed at Yaeyama Islands in the southwestern Japan since 2012, in order to detect gravity changes due to slow slip events. However, the gravity signals can be masked by hydrological gravity disturbances, because the annual amount of rainfall reaches about 2200 mm/year, which is about 1.5 times more than that in Tokyo. The hydrological disturbances must be corrected precisely by utilizing hydrological models, so as to quantitatively discuss the slowslip-derived gravity changes.

We were thus motivated to measure physical parameters of soil at Yaeyama Islands for precise estimations of hydrological gravity disturbances. We first sampled soil cores at three gravity stations (listed below) on 13-15 November 2012. We then applied soil tests for the sampled cores, and measured porosity (n) and saturated permeability (ks) as follows:

At Ishigakijima Local Meteorological Observatory: n = 0.419 [m3/m3], ks = 7.2 E-6 [m/s]

At VERA Ishigakijima Station, NAO: n = 0.385 [m3/m3], ks = 4.9 E-6 [m/s]

At Iriomote Station, Ryukyu University: n = 0.387 [m3/m3], ks = 9.8 E-7 [m/s]

At the coming presentation, we will show modeled results of spatiotemporal hydrological distributions and gravity changes at three gravity stations with the above parameters. In addition, we will present soil parameters of sampled beach sand at Yaeyama Islands, in order to discuss spatial heterogeneity of the soil parameters.

Keywords: gravity change, slow slip event, Yaeyama Islands, soil parameter, hydrological modeling, maaji soil

SGD22-P10 Room:Convention Hall Time:May 22 18:15-19:30

Rough Estimate of P-wave Velocity beneath the VERA Ishigaki Island Station for Improving Accuracy of Gravity Analysis

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To detect gravity changes due to slow-slip events beneath Ishigaki Island, one superconducting gravimeter has been installed at a VERA (VLBI Exploration of Radio Astrometry) station in the island. Because this station is placed on sedimentary deposits in level land near a mountain, rainfall around the station may fluctuate nearby underground density distribution. One three-component short-period seismometer has also been installed at the station since March 5, 2012. To explore the variation beneath the station, differential arrival times of direct P-wave at the station relative to a nearby permanent (F-net) station are analyzed for three regional or teleseismic earthquakes. The seismometer at the permanent station, which is located about 1 km apart, is installed in a mountainside tunnel within the granite basement. By contrast, the VERA station is located on the sediment with a thickness of 15 m. Ray paths to the stations are almost same except for the structure just below them. Differential arrival times to the stations with epicentral distance correction thus depend on the differences of the station heights and of the velocity beneath the stations. In this talk, we obtain the P-wave velocity in the sediment beneath the VERA station and discuss its changes over time with rainfall.