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

SGD22-01 Room:413 Time:May 1 09:00-09:15

Gravity observation using a superconducting gravimeter at Ishigakijima, Japan (part 3)

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About two years have passed since we started gravity observation by means of a superconducting gravimeter at the VERA Ishigakijima Station, National Astronomical Observatory Japan in 2012, with the main purpose of detecting possible gravity changes associated with the long-term slow slip events beneath the Yaeyama Islands. Up to now, we have experienced three times of events, which took place in May 2012, December 2012 and July 2013. For the two events in 2012, gravity changes possibly associated with the slow slip events were recorded. The July 2013 event was not well recorded because of the damages by the typhoon. In addition, an earthquake swarm near the Yaeyama Islands in April 2013 may have also influenced the observed gravity. The next slow event is expected to take place around February 2014. Modeling and interpretation of the data will be presented in the paper.

Keywords: superconducting gravimeter, slow slip, Ishigakijima

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SGD22-02 Room:413 Time:May 1 09:15-09:30

Various drift rates of gPhone gravimeters obtained from short-term observations at geothermal fields

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We carried out short-term but continuous gravity observations using gPhone (spring type) gravimeters at geothermal fields. At hot spring area of Hachijojima, we obtained 1-4 months gravity data using several gPhone gravimeters at different sites and situations of the period between February 2011 and December 2012. Using the obtained data, we calculated and compared temporal variations of the drift rate. As a result, drift rates of gravimeters showed various characteristics according to location and elapsed time from installation. In many cases, it took about a month until initial drift stabilized, that is, dirift rate became quasi-constant. Even after stabilized, drift rate of gPhone gravimeters remained a few microGal/day (on the other hand, the nominal drift rate of iGrav superconducting gravimeter is 0.5 microGal/month), although the magnitude of the drift rates were considerabty smaller than several hundred microGal/day of CG-3M gravimeters. We will show the result of gPhone-133 replaced from Hachijojima to a geothermal power plant at Kyushu District in March 2013.

Keywords: relative gravimeter, temporal gravity change, Hachijojima, on-land observation

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SGD22-03 Room:413 Time:May 1 09:30-09:45

Gravimetrical vertical array observation -the 2013 fiscal year-

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A vertical array of gravimeters (Mizunami Underground Laboratory; MIU) is quite rare in the world, and this method that suppresses rainfall responses and stacks signal from deep part of the crust can contribute to leveling up the potential of gravimetry (Tanaka et al., EPS, 2013). This time (Nov. 2013~Jan. 2014), we have succeeded in getting higher quality data than before with almost same configuration; namely, using two gPhone gravimeters (#130 on the ground, #90 at 300m under the ground). Though blasting for construction works had performed frequently during last year, we can detect sub-microGal responses of rainfall this time in the frequency band from hourly to daily. In the longer band, the sensor temperature of #130 is still shifting slightly, which can affect drifting rate. Here, we describe the four time-series data: data of belowground, (1); data on the ground, (2); sum of the two, (3); difference between the two, (4). We have finally got residual gravity values without tidal and atmospheric responses by using the BAYTAP-G (Tamura et al., 1991), with assuming of linear drift. When it rains, (1) should show gravity decrease, (2) should show gravity increase, (3) should offset the response, and (4) should superimpose the response. Because, only the main part of the Akeyo formation, which overlies an impervious layer from the surface to approximately 80m depth, responds to precipitation (e.g. Tanaka et al., Gcubed, 2006). Actually, we have observed such responses of rainfall. These depend on the way of rainfall; however, it seems that the amplitude of the response of (1) is slightly larger than (2). If so, the infinite slab assumption of a groundwater layer caused by rainfall is unsuitable for this gravimeter layout. On atmospheric correction, (1) and (2) should be almost same, (3) should superimpose, and (4) should offset the response. Actually, we have observed such responses and confirmed that (4) is one-tenth the atmospheric response of that of (1) or (2).

In the future, we will aim to accumulate high quality data, survey the habit of these two gravimeters (i.e. sensor drift, sensor temperature, and tilt response), and finally construct a vertical array including an absolute gravimeter.

Acknowledgements: This work is supported 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 thank the JAEA for the cooperation of observations (especially Mr. Y. Horiuchi) and our colleagues.

Keywords: continuous gravity measurement, gravimeter, inland water, rainfall, atmospheric correction, measuring method

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SGD22-04 Room:413 Time:May 1 09:45-10:00

Huge uplift event of Iwoto: Estimation of gravity change based on the result of gravimeter calibration in Sapporo-Naha

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Ogasawara-Iwoto is the volcanic island located to 1200km south of Tokyo. It has a caldera with the diameter of 10km, and its central and southwestern part appears on the sea surface. One of characteristics for its volcanic activity is to have the large uplift rate, and National Research Institute for Earth Science and Disaster Prevention (NIED) has revealed occasional ×occurrence of huge uplift events and distribution of its crustal deformation (Ukawa et al., 2006). NIED started gravity survey from 1996, and Ukawa (2006) suggested involvement of magma in a huge uplift event. Though continuous subsidence had been observed from early 2003, it rapidly changed to uplift in mid-2006. Its uplift decelerated with time after 2007, but it rapidly re-accelerated in Feb. 2011. According to GNSS observation by NIED and GSI, the amount of uplift from re-acceleration to Apr. 2012 reached 2m. In late April of 2012, discolored water was found around Iwoto, and uplift activity slowed down after that. To investigate crustal deformation and gravity change associated with this event, we carried out GNSS campaign observation and gravity survey. We presented the result of GNSS campaign observation in fall meetings of the geodetic society of Japan and the volcanological society of Japan. We also presented preliminary result for gravity survey, but there was a problem on uncertainty for temporal change of scale factors of used gravimeters (Scintrex CG-3M #284 and #371). To estimate scale factors of their gravimeters, we carried out gravity survey between Sapporo and Naha. In this presentation, we show temporal change of scale factors revealed from this calibration and gravity change of Iwoto estimated using its result.

In gravimeter calibration, we measured gravities at NIED (Bosai-BS), GSI (Tsukuba-GS and Tsukuba-FGS), Haneda airport (Haneda-GS), Chitose airport (Chitose-GS), Hokkaido University (Sapporo-GS), and Okinawa Meteorological Observatory (Naha-GS and Naha-FGS). In estimation of relative gravity, we assumed that the drift rate was constant, and estimated gravities and the drift rate simultaneously. Then we estimated scale factors so that estimated gravities corresponded to those of JGSN96 (Geospatial Information Authority of Japan, Geodetic department, 1997). Since Sapporo-GS was moved to new benchmark, we used gravity measured by GSI. Estimated changes of scale factors from those in 2006 were $+2\times10^{-5}$ and -1×10^{-4} for #284 and #371, respectively. Temporal changes of scale factors are not orderly, and then obtained scale factor is different significantly from estimated value by the linear approximation. Therefore it indicates that consideration of temporal change of scale factor is important in survey of large gravity difference.

Estimating gravity at the benchmark in Iwoto (IWO101), estimated gravities from #284 and #371 were consistent within 0.027mGal, and its average was decrease of 0.734mGal from that in 2006. Uplift in this period was 3.05m, and then gravity change rate with respect to uplift was -0.241mGal/m. This gravity change rate is in good agreement with that for the 2001-2002 huge uplift event by Ukawa et al. (2006). This result suggests that the huge uplift event from 2006 has been caused by the magma with the similar density to that in the 2001-2002 event.

Acknowledgements. GNSS and gravity surveys were supported by JSDF. A part of survey and analysis for Iwoto was carried out by Ohba Co. Ltd. Gravity calibration was supported by GSI, Hokkaido University, and Okinawa Meteorological Observatory.

Keywords: Iwoto, gravity, scale factor, magma

Japan Geoscience Union Meeting 2014
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SGD22-05 Room:413 Time:May 1 10:00-10:15

Absolute gravity measurements near the Sor-Rondane Mountains, Antarctica

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In order to detect the gravity changes due to ice sheet mass changes, Glacial Isostatic Adjustment (GIA) and other effects, we have conducted absolute gravity measurements at Princess Elisabeth Station (PES) near the Sor-Rondane Mountains, Antarctica, as part of the 55th Japanese Antarctic Research Expedition (JARE-55). In addition, the first absolute gravity measurements using a field absolute gravimeter have also been conducted on the Seal rock near the Asuka station, where the gravity reference point (No.26-01) established by JARE-26 is located.

The absolute gravimeters employed were FG5#210 and A10#017, and a relative gravimeter LaCoste #805 was also used for dg/dz measurements and gravity connections. Using DROMLAN (Dronning Maud Land Air Network), we moved to PES with the instruments via Novolazarevskaya from Cape Town in South Africa. The length of our stay in PES was for 18 days from Nov. 29 to Dec. 16, 2013. Belgian researchers have already conducted absolute gravity measurements using a FG5 in North Shelter (NS), a small observation hut built on an outcrop a few hundred meters apart from the main base of PES. One of the main purposes of this project is to monitor long-term gravity changes by means of successive absolute gravity measurements at the same gravity point in NS. Since NS has not enough space for adjusting the gravimeters before measurements, we borrow a room in the main base for the purpose and test measurements as well. We established a tentative gravity point in the room and compared the gravity values measured by A10 and FG5. The result showed the discrepancy was within 2 micro-Gals. This means that A10 was well calibrated. Unfortunately a crucial fault arose in the dropping chamber of the FG5, and it could not be recovered to the last. For this reason, the measurements in NS were carried out using A10. The gravity value on the reference point was calculated to be 982302155.21 micro-Gals with the measured dg/dz of -4.4529 micro-Gals/cm. Although the exact comparisons with the gravity values obtained by the Belgian team have not been completed yet, the gravity values seem to be in agreement within several micro-Gals. Therefore the temporal gravity change would be very small, even if it existed.

The gravity measurements on the Seal rock have been conducted on Dec. 5th and 6th. Since No.26-01 is located near the summit of the Seal rock, where strong wind blows constantly, it is very difficult to conduct absolute gravity measurements even using A10. Therefore a tentative gravity point was set up at the foot of Seal rock, and measurements with A10 were conducted at the point. Then gravity connection to No.26-01 was conducted with the LaCoste gravimeter. The gravity value thus obtained at No.26-01 was 982406.109 mgal with the accuracy of about 15 micro-Gals including the errors due to the gravity connection.

The gravity values of No.26-01 so far obtained were 982405.33mgal by JARE-26 (GSI, 2002), and 982402.817mgal by JARE-27 (Fukuda, 1986). The new value is 0.779 mgal and 3.292 mgal larger than those of JARE-26 and JARE-27, respectively. In JARE-27, two sets of LaCoste gravimeters were employed for the gravity connection between Seal rock and Syowa Station. Since a large discrepancy between the values obtained by two gravimeters was found, Fukuda (1986) applied a step correction of 3.765mGals to the suspected gravimeter. However, judging from the present result, the correction could be applied to the wrong gravimeter. If the correction was applied to the other gravimeter, the difference of 3.292 mgal was set to about 0.5mGals, and it would be likely as the accuracy of the gravity connection. The gravity value of No.26-01 has been used as a reference value for the gravity surveys so far conducted in the Sor-Rondane area. Therefore the revisions of those values should be required from now on.

Keywords: absolute gravity measurement, Sor-Rondane, Antarctica, ice sheet movement, gravity changes, gravity reference point

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SGD22-06 Room:413 Time:May 1 10:15-10:30

Performance of the recoil-compensation mechanism used for a throw-up type absolute gravimeter

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Absolute gravimeters can measure gravity acceleration in the accuracy of 8 to 9 digits. They are accurate and useful for many applications, however the apparatus is too bulky and heavy. Therefore, in the field observation, their installation site is limited. As a result, for volcanic observations, a gravity value is usually measured by an absolute gravimeter at a reference point of foot, and then a gravity value of an observation point can be obtained from the gravity difference between a reference point and an observation point measured with a relative gravimeter; such a method is laborsome, and requires long time. Furthermore it is hazardous to approach the observation points when the volcano is active. This study is to minimize absolute gravimeter in order to improve these situations. The original point of our new apparatus is to incorporate a recoil-compensation mechanism to improve the measurement accuracy.

In the absolute gravity measurements, we adopted a rise-and-fall method, while conventional absolute gravimeters usually adopt a simple free-fall method. The simple free-fall method has several problems such as bulky mechanism to lift up a test mass, repeated measurements, and long time to take for the preparation. Hence, we developed a throw-up equipment that had no need for lifting up a test mass and could measure repeatedly. This enabled to minimize one of the biggest parts in the absolute gravimeter.

The equipment which we developed this time can throw up the test mass by 3mm in height simply by applying the signal to a piezoelectric element which is incorporated in the expansion mechanism. When the test mass was thrown up, it rotated by an anchoring effect and it may cause the error in the gravity measurement. We applied other piezoelectric elements which separate the stage from the test mass just before the test mass leaves the stage to cut off the anchoring force. At the end of 2012, we carried out a performance test of the throw-up equipment at Esashi Earth Tidal Station in Iwate. At Esashi, we replaced the free fall equipment of the existing absolute gravimeter with the throw-up equipment. As a result, the throw-up equipment was able to detect a gravity change of earth tides. The resolution of the gravity measurement δg was estimated to be 40μgal. However, the absolute gravity deviated from the value expected from the past measurements up to $\triangle$g= 3mgal. This big error was inferred from the recoil effect at the time of throw that induces vibration to the interferometer.

We developed the recoil compensation mechanism of the throw-up equipment to improve the measurement accuracy $\triangle$g. Specifically, we put the same piezoelectric element and the expansion mechanism on the other side of the baseplate to which the throw-up mechanism is attached. These expansion mechanisms move symmetric by applying the same signal to the piezos. When the test mass is thrown up, the counter mass fixed by springs is launched downward at the same time to compensate the recoil effect. We could observe the recoil reduction as much as 2.7% of peak acceleration without the compensation mechanism. After performing fine adjustment of the equipment, we plan to conduct gravity measurement by the same method to 2012, and the result and the development status will be reported.

Keywords: absolute gravimeter, throw-up equipment, miniaturization, recoil effect, compensation mechanism, gravity measurement

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SGD22-07 Room:413 Time:May 1 10:30-10:45

Development of a laser-interferometric gravity-gradiometer and its trial operation on the volcanic island of Sakurajima

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We have been developing a laser-interferometric gravity-gradiometer for volcanological studies. The gravity gradiometer measures differential accelerations between two test masses that are in free fall at different heights. Because its detection principle is based on the differential measurements, measured values are insensitive to the motions of observation points. That is to say, the gravity gradiometer is expected to have a good resolution even when it were used on an accelerating vehicle, such as an airship, or in an active volcanic area. Therefore, the gravity gradiometer could be useful for, for example, resource explorations and studies on volcanic activities.

The gravity gradiometer, to be used on an airship, had been developed at the Institute for Cosmic Ray Research (ICRR) of the Tokyo University from 2009 to 2012. A prototype of the gravity gradiometer was built up and tested at the ICRR. Their laboratory test showed that its resolution of measuring vertical gravity gradients was about a few μGal/m in two second measurements. However, large unexplained disturbances were observed in longer term measurements. In order to understand the sources of the disturbances, the prototype was moved to the Aso Volcanological Laboratory (AVL) of the Kyoto University in July 2012. Since then, its further development, to be used at an observatory in a volcanic area, has been carried out at the AVL.

We will report the current status of the development for volcanological studies and results of trial measurements performed at the Sakurajima Volcanological Laboratory of the Kyoto University, on the volcanic island of Sakurajima, Kyusyu, Japan.

Keywords: gravity gradients

SGD22-08 Room:413 Time:May 1 11:00-11:15

The two components of postseismic gravity changes and their mechanisms

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The time series analysis of the gravity changes of the three Mw9-class mega-thrust earthquakes (2004 Sumatra-Andaman earthquake; 2010 Chile (Maule) earthquake; and 2011 Tohoku-oki earthquake) gives the strong possibility that the gravity observation separates postseismic phenomena. There are three sensors for earthquake observations: the first sensor is seismographs, the second sensor is GNSS (Global Navigation Satellite System) or SAR (Synthetic Aperture Rader), and the third sensor is the gravity observation. Seismographs cannot be used to catch the signal of postseismic phenomena because they do not shake the ground. GNSS like GPS (Global Positioning System) and SAR catch the signal of postseismic phenomena but they cannot separate those phenomena because the phenomena move the ground with the same polarities. However, the polarities to gravity changes of postseismic phenomena can be different each other. This suggests that the gravity can become the first sensor to catch the separated signals of postseismic phenomena.

GRACE (Gravity Recovery And Climate Experiment), which is the twin satellites launched in 2002 by NASA and keeps on observing the gravity field of the earth, gives the two-dimensional gravity data and the insight into phenomena under the ground when and after earthquakes occur. The results of time series analysis of postseismic gravity changes with GRACE data show that the gravity which decreases coseismically keeps on decreasing for a few months and increases for a longer period; the postseismic gravity changes have two components (short- and long-term gravity changes). This is a new discovery and this also suggests that the gravity observation gets the different postseimic phenomena with different polarities.

The mechanisms of coseismic gravity changes are well known but those of short- and long-term postseismic gravity changes are not clear completely. They are explained with afterslip and viscoelastic mantle relaxation to some extent but each of them has each problem.

Although the mechanisms of postseismic gravity changes have rooms to be discussed, the gravity observation can do what the seismographs, GNSS and SAR cannot do; the gravity observation separates the postseismic phenomena.

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SGD22-09 Room:413 Time:May 1 11:15-11:30

High resolution mapping of ice mass trend in Greenland using GRACE GFZ solution

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The gravity satellite mission GRACE has been measuring monthly variations of the Earth's gravity field since its launch in 2002. The GRACE data has updated from RL04 to RL05 in May 2012, and have been provided in the form of spherical harmonic (Stokes') coefficients with degree and order up to 60 (d/o60) from CSR and JPL. In addition, GFZ has provided Stokes coefficients with d/o90 as RL05a product in December 2013. In this study, we examine the measurement error of GFZ RL05a product (d/o90). Then we attempt to delineate a high resolution map of ice mass trend in Greenland by making use of the full Stokes' coefficients.

First, we examine the measurement error. Following the method of Wahr et al. (2006), we derive temporal and spatial variation of the measurement error from error variance matrix of GRACE data. The global average of RL05a error is about 100cm in equivalent water thickness. Because RL04 error is about 300cm, RL05a achieves triple the precision improvement. The temporal variation of error in global average is about 200 cm from January 2003 to July 2003, and reduces to about 100cm afterwards. The spatial distribution shows large error in equatorial region (about 130cm) and small error in polar region (about 40cm). Considering these results, it can be said that the quality of RL05a is especially high in polar region after August 2003.

Next, we derive ice mass trend in Greenland from GFZ RL05a (d/o90) product. Here we apply de-striping filter (Swenson and Wahr, 2006) to alleviate the noise. In addition, we employ spherical Slepian Basis (Harig and Simons, 2012) to extract ice mass trend in Greenland effectively. In doing so, we can successfully delineate a clear ice mass trend map with about 200 km spatial resolution, which is 1.5 times as high as before. We confirmed very good agreement with ICESat result.

Keywords: Satellite gravimetry, Greenland, Ice sheet mass variation, Space geodesy, GRACE, ICESat