Japan Geoscience Union Meeting 2012
(May 20-25 2012 at Makuhari, Chiba, Japan)


SGD24-P01 Room:Convention Hall Time:May 25 13:45-15:15

# Absolute gravity measurement in coastal region of East Antarctica ? A preliminary report -

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We have started a project to implement absolute gravity measurements with GPS measurements on several outcropped areas along Prince Olav Coast and Soya Coast which locate in East Antarctica in the framework of the 53rd Japanese Antarctic Research Expedition (JARE53). The objectives of the measurements are precise determination of gravity field of Antarctic region and estimation of crustal movements associated with Glacial Isostatic Adjustment (GIA).

We planned to carry out the absolute gravity measurements with a portable absolute gravimeter A10 at 9 outcropped areas including Syowa Station during initial phases of the project. However, because of logistic restriction in JARE53 due to the impossibility of Icebreaker Shirase to come alongside Syowa Station, we have conducted the measurements at only just two areas, i.e. Syowa Station and Langhovde. Although the number of measured sites were much reduced, absolute measurements with A10 in the outcropped areas of Antarctica was the first trial of JARE and a lot of know-how were obtained through the measurements. The experiences including logistic preparation will bring many benefits to the next measurements in Antarctica.

The tentative absolute gravity value at Langhovde was 982 535 584. 57micro-Gal and its standard deviation was 2.4micro-Gal. In the presentation, we will show the outline of our project. We also show details of the measurements at Langhovde and Syowa Station and preliminary results of relative gravity measurements around the absolute gravimetric sites.

Keywords: absolute gravity measurement, GPS measurement, gravity field of Antarctic region, Glacial Isostatic Adjustment, A10

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# Frequency corrections of 10MHz atomic clocks in absolute gravimeters (A10 and FG5) at Syowa Station, Antarctica

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Absolute gravity values are estimated by precisely observing the drop distance and time of falling bodies in absolute gravimeters. Since the drop time is mostly observed with 10 MHz atomic clocks, the accurate clock frequency is needed in advance to estimate the absolute gravity values. However, the frequency of atomic clocks in absolute gravimeters often shifts slightly from 10 MHz, and some clocks have the time variation in the frequency. Therefore, in order to estimate the precise absolute gravity values, the correction for frequency values of the atomic clocks are needed, by comparing the clock frequencies with a reference clock.

We thus estimated the precise frequency values of 10 MHz atomic clocks in absolute gravimeters at Syowa Station in Antarctica during the 53rd Japan Antarctic Research Expedition (JARE53). We tested the following clocks: (1) Rubidium clock in the A10 absolute gravimeter (SN: #017), (2) Rubidium clock in the FG5 absolute gravimeter (SN: #210), and (3) the spare Rubidium clock for these absolute gravimeters. And we utilized the following clocks as references of 10 MHz signals: (4) Cesium clock and (5) Helium maser. First, we displayed the sine signals of a test clock and a reference clock in an oscilloscope, and recorded the movements of the sine waves with movie cameras. We then calculated the frequency difference between the test and reference clocks with the movie analyses. We conducted the above processes periodically for two months in January and February 2012, and finally we estimated the time variation in the absolute frequency values of the tested atomic clocks.

According to the results, the frequency of the Rubidium clock in the A10 gravimeter (No. 1) shifts by about +0.15 Hz from 10 MHz, and it changes in terms of time at a constant rate of -0.0018 Hz/day. These frequency shifts imply the artificial absolute gravity shifts by +30 micro-gal and -0.36 micro-gal/day respectively, which are larger than the gravity accuracy of the A10 gravimeter (~10 micro-gal). On the other hand, the frequency shifts of the FG5 and spare Rubidium clocks (No. 2 and 3) are smaller than +/- 0.002 Hz (+/- 0.4 micro-gal for gravity), which are significantly smaller than the gravity accuracies of the A10 and FG5 gravimeters.

We will utilize these results for the correction of absolute gravity values observed in Antarctica. And in the coming poster presentation, we will show and discuss the final results of the observed absolute gravity values in Antarctica.

Keywords: Absolute gravimeter, 10MHz atomic clock, Rubidium clock, Cesium clock, Helium maser, Antarctica

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# Improvement of the calculation system of the terrain corrected gravity anomaly using 1m mesh DEM and its application

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One of the purposes of the research of gravity anomaly is to obtain information on subsurface structure. The information enables to estimate the basement structure and the location of active faults, so the information of gravity anomaly is the basic one in the field of earth sciences and disaster prevention.

To use the data of gravity anomaly, we have to carry many correction processes. The terrain and the density data are required to correct the gravity data. However if their data include any errors, we cannot obtain the certain information of gravity anomaly. Therefore it is important to use accurate terrain data to obtain precise gravity anomaly data.

Honda and Kono(2005) developed and applied the 50m mesh terrain data that include land area and sea area seamlessly as the terrain data for the terrain correction. Recently the 1m mesh terrain data measured by Airborne Scanning Lidar are available. In the Noto peninsula, the 1m mesh DEM are developed by Hokuriku Electric Power Company. The development of the calculation system of the terrain correction using the 1m mesh DEM improves the accuracy of gravity anomaly distribution, leading better understanding of subsurface structure.

In this study, the main purposes are to improve the terrain correction calculation system with the 1m mesh DEM, and to obtain a higher accuracy distribution of gravity anomaly in the northern Noto peninsula. We compare and consider the difference between existing gravity anomaly distribution and improved one.

Keywords: Gravity anomaly, Terrain correction, 1m mesh DEM, Noto peninsula

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# Japan Gravity Standardization Net and Tohoku Region Pacific Coast Earthquake

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The Geospatial Information Authority of Japan (GSI) carried out hybrid gravity survey (absolute observation + relative observation) to detect gravity change caused by Tohoku Region Pacific Coast Earthquake in Sendai, Hachinohe, and Ohsyu area. GSI surveys Sendai and Hachinohe area every 5 years. Because crust change of those areas are very active. Fortunately we carried out gravity survey in Sendai and Hachinohe half year earlier than Tohoku Region Pacific Coast Earthquake. By comparing gravity of last year and this year, we find gravity change in absolute observation.

We inspect change of Japan Gravity Standardization Net (JGSN75 and 96) that have been provided from GSI.

Although, land subsidence was detected in those areas, gravity value decreases at some observation station. We intend to inspect those gravity changes by using formularization of gravity change that is bases on dislocation theory(Okubo, 1994).

We will report results of gravity change of JGSN and model calculation.

Keywords: Gravity, Gravity Standardization Net, Tohoku Region Pacific Coast Earthquake

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# Miniaturization of absolute gravimeter by means of the throw-up method

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When carrying out the field survey of movement of magma in a volcano, change of gravity acceleration provides very important information. We are studying miniaturization of an absolute gravimeter.

Absolute gravimeters are equipment which can measure gravity acceleration in the accuracy of 8 to 9 digits. They can observe not only static gravity field but also groundwater flow and movement of magma which provide significant information of volcanic activities. Absolute gravimeters are accurate, but the equipment is too large and heavy for field observation. 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 of a reference point and an observation point measured with the relative gravimeter. Therefore such an observation is troublesome, and time resolution was bad. Furthermore it is dangerous to observe at reference point when a volcano erupts. In order to improve these situations, Araya et al. (2007) has developed a compact absolute gravimeter. If this equipment put to volcanic body, we will find out information when the volcano is active. By observing with absolute gravimeters which are arranged simultaneously as a multi-point network, we will be able to analyze magma activity as 2D gravity changes. By installation to a deep borehole or the deep sea of a plate subduction zone, the seismic activity and plate motion of the deep underground can be investigated using gravity. In conclusion, miniaturization of absolute gravimeters will enable various applications and offer the different observation techniques. Since the present equipment had the problem in rapid measurements because of a fall method, I am studying throw-up method.

Our new equipment throws up a corner cube mirror approximately 3mm high by a flexure-based piezoelectric actuator. It generates small vibration because of short raising distance without using a motor. Current equipment took time to lift the corner cube 10cm up to the release point. By the new one with the throw-up mechanism consecutive measurements become possible within a short time. The equipment need to throw vertically without rotating the corner cube mirror.

Keywords: absolute gravimeter, throw-up method, miniaturization, gravity, volcano, magma

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# Gravity tectonic map of Kofu district

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The low gravity anomaly of the Kofu basin is a part of large low gravity anomaly belts which exist in the east side of Itoigawa-Shizuoka Tectonic Line which goes Fujigawa north and reaches the Suwa basin. The west edge and southeast edge of the basin are a steep slope, and correspond to reversed fault structure. Gravity is the minimum not in the lowlands along Fujikawa but in the steep range of hills of several kilometer west, and especially near the Kajikazawa town which is an exit of the south of a basin is having structure where the low density substance is collapsed under the hill. The regional gravity basement of Kofu basin correlates with topographical feature. In detail, the deepest part deeper than -2000m above sea level does not exist in the central part of the basin, but in the west edge, which corresponds to the foot of Minami-Alps.

Keywords: Kofu basin, gravity tectonic map, Itoigawa-Shizuoka tectonic line, Bouguer anomaly, gravity basement

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# A Gravity Measurement at the Reference Station of Osaka City University and its Variation

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The gravity exploration is a useful method in pushing forward basement structural analysis for city disaster prevention. The comparison measurement of the gravity value was obtained on the station according to the transfer in Osaka City University, and reported on the change of passing year from the measurement value before this time.

A presented gravity reference station (A station) is in front of the entrance of the Faculty of Science. A new gravity reference station (B station) is in the general education district north end. The gravity values at the temporary reference station in Kinki Polytechnic University (C station) and in Hattaso Geoscience Institute (D station) were also measured respectively. C station was used by Ryoki (2010) and Ryoki (2011). The standard station for the comparison of the gravity values was Kyoto FGS. The gravimeter was LaCoste & Romberg G-308.

The gravity values on the reference stations were obtained; A station:979707.69 mgal, B station:979707.91 mgal, C station:979688.49 mgal, D station:979699.18 mgal. These values were determined from 979707.68 mgal which was measured absolutely in Kyoto FGS on May 12, 2003 (Geographical Survey Institute, 2004).

The gravity value on A station measured March or April, 1973 was 979721.86 mgal in 1930 Potsdam system (Nakagawa and Satomura, 1973).This value was converted to 979708.03 mgal in 1967 gravity system. Moreover, it was 797707.59 mgal in the measurement on July 30, 1981 (Ryoki, 1982). When the value in 1981 and the value in 1973 are compared based on the measurement value in 2011, the gravity value is -0.10 mgal and + 0.34 mgal. The height is -0.092 m (after Ryoki(1982) and Mitamura(2011)).

The height in A station is 0.092 m rises from about 1981 to present, and the gravity value is 0.10 mgal increases. A rise of 0.092 m makes a gravity effect of almost -0.03 mgal in Free-Air reduction. But the measurement value increases. An increase in the height is thought to be a result which considered how to cope with the ground subsidence in the whole area of Osaka plains, and yet an increase in the gravity value in A station is a problem which should be examined more in detail including the activity signs such as Uemachi Fault Zone.

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Keywords: gravity station, KyotoFGS, reference method, ground subsidence, basement structure, gravity survey

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# Gravity observation using a superconducting gravimeter at Ishigakijima, Japan

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We have started gravity observation using a superconducting gravimeter (SG) at the VERA Ishigakijima Station, National Astronomical Observatory Japan, with the aim of detecting possible gravity changes associated with the slow slip events taking place in the Iriomotejima/Ishigakijima region. The gravimeter (serial number CT36) used in this project was in operation at the Inuyama Observatory, Nagoya University for about ten years. We have chosen to refurbish and reuse the instruments to move them to Ishigakijima island. Refer to Tanaka et al. (this session) for the objectives of the whole project, and Ikeda et al. (this session) for the preparation of the instruments at Inuyama and Tsukuba.

Installation work of the SG at Ishigakijima took place from January 30 through February 4, 2012. The gravimeter pier in the VERA Ishigakijima Station is 2m x 1.5m wide, about half of which is occupied by the SG. The other half of the pier is reserved for future regisration of an absolute gravimeter. The three granite blocks as the gravimeter base are placed on the pier with rubber sheets inserted underneath them, and are anchored to the pier using L-shaped angles. We have not fastened the refrigerator support frame to the pier but simply adjusted it for the alignment with the Dewar. The gravimeter is housed inside a plastic cover so that airflows from the air-conditioner do not hit it directly. Gravimeter controllers as well as data acquisition equipments are placed outside the pier. We have built a new hut next to the building where an air-cooled compressor is housed. We have installed a soil moisture gauge outside the building, and several meteorological sensors such as a rain gauge will be added in the near future.

As of this writing, we are aware of electronic problems in the gravimeter system, including noise contamination associated with the operations of the VLBI antenna. Further adjustment of the instruments is needed to improve the quality of recordings. We will characterize the first data obtained at Ishigakijima, and also introduce gravity data to be acquired in the next slow slip event, which is predicted to take place in March 2012.

Keywords: superconducting gravimeter, slow slip, Ishigakijima

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# Refurbishment of the SG-CT36 at University of Tsukuba for a new challenging observation at Ishigakijima, Japan

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We started a superconducting gravimeter observation to elucidate relationships between slow slip events and gravity changes at Ishigakijima near Ryukyu trench, southwestern Japan in February 2012 (Tanaka et al., and Imanishi et al., this meeting). Before the installation of the superconducting gravimeter (CT36) at Ishigakijima, we refurbished the CT36, installed at the Inuyama observatory of Nagoya University originally, so that the system can operate reliably at such a remote island. Specifically, for the planed observation, we replaced compressor for the coldhead from 'water-cooled' type to 'air-cooled' type. In addition, at University of Tsukuba, we warmed up the Dewar to room temperature to remove the 'clogs' inside it. This has resulted in eliminating strange behaviors in the temperature and tilt controls of the gravimeter, as well as solving the problem in transferring liquid helium into the Dewar.

This work was supported by KAKENHI (23340125).

Keywords: superconducting gravimeter, liquid helium, slow slip

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# Gravity changes at Hachijo island caused by the displacement of the Kuroshio current

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A three-year research project has been begun since fiscal year 2010 (FY2010). The final goal is to develop a reliable monitoring system that can detect small effects on a hot spring caused by geothermal exploitation (Yasukawa et al., 2011). We have started gravity monitoring by means of continuous measurement and time-lapse measurement for the project at southern Hachijo Island, where a 3.3 MWe geothermal power station has been in continuous operation since March, 1999 and several hot spring wells were drilled. We aim to detect a change in groundwater and hot spring water level with a resolution of 10 cm with continuous gravity measurement (Nawa et al., 2011). Roughly it is equivalent to a resolution of 1 microGal. On Hachijo Island we must distinguish local gravity changes occurring in connection with hydrothermal process of hot spring, from those of geothermal power generation, groundwater, and tidal current around the island. Regarding the tidal current the displacement of the Kuroshio current may cause gravity change on Hachio island.

We set a new type of metal spring sensor gravity meter gPhone-119 at the gallery of the broadband seismic station HJO of the F-net networks operated by NIED, in 2010FY creating a continuous 34-day record. Removing tidal component and air-pressure response from the continuous record we detected the gravity variation whose amplitude is about 20 microGal. The displacement of the Kuroshio current was reported by Japan Coast Guard that the current axis was northwest off the island at first then moved to southeast off the island during the period. Observed gravity change is reproduced by calculating the effect of the dynamic topography of the Kuroshio current. Removing the tidal current effect from the observed record we can evaluate the local gravity changes occurring in connection with hydrothermal process of hot spring and others.

The authors wish to express their deep gratitude to NIED (National Research Institute for Earth Science and Disaster Prevention) 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: Hachijo island, Kuroshio current, gravity change, gPhone, dynamic topography

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# Gravity changes around Ito campus, Kyushu University by using hybrid gravity measurement

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Ito campus, Kyushu University is located in the western end of Fukuoka city, Northern part of Kyushu, Japan. There are 30 wells in order to monitor the groundwater level. Repeat gravity measurements using Scintrex CG-3M gravimeter around Ito campus were conducted before construction of the campus. The seasonal gravity changes were observed and there were good correlation between the gravity changes and groundwater level changes. We started the repeat gravity measurement using Scintrex CG-5 gravimeter since 2009. We established 12 observation points, because almost observation points of previous study were destroyed by the construction of the campus.

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 25 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 change, Gravity changes