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

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

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

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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

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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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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

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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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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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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

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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

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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.