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

SGD24-01 Room:105 Time:May 25 09:00-09:15

A study on Antarctic ice-sheet mass changes using satellite data

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Total ice sheet on Antarctica is said to consist of about 90 % of the earth's entire Ice sheet, which is equivalent to almost 60 meters of sea level rise. Nevertheless, because of the difficulties of in-situ observations, it has been difficult to estimate the mass change rate of the whole of Antarctic ice mass. GRACE (Gravity Recovery and Climate Experiment) has been observing time-variable gravity fields and succeeded to estimate the mass change rate for the whole of Antarctica, which was difficult to conduct by other means. However the GRACE observation is the total mass change of the earth including the Glacial Isostatic Adjustment (GIA) and therefore, suffers from the discrepancy between GIA models. In addition, the uncertainties of lower degrees of Stokes coefficients have particularly large impacts in Antarctica.

On the other hand, ICESat (Ice, Cloud, and land Elevation Satellite) is a satellite with GLAS (Geo-science Laser Altimeter System), which can observe ice-sheet elevation changes. In principle, the combination of GRACE and ICESat can yield comparisons between ice-sheet mass change estimates and volume change estimates. Nevertheless, ICESat datasets of 90 days have 180 days of interval time, and therefore, not appropriate to compare with monthly GRACE data. Equipped with RA2 radar system, EnviSat (Environmental Satellite) is useful to compensate ICESat data, for its datasets are available in 35-day repeat cycle from the same period as GRACE. Although the precision of EnviSat RA2 is not as high as ICESat GLAS, continuous observation of height changes in a longer period are considered useful. In this study, therefore, we used EnviSat data as well as GRACE and ICESat, to estimate the Antarctic ice-sheet mass change rates as a whole. In addition, we divided Antarctica into 27 drainage systems, and compared the results of EnviSat with those of GRACE.

The Antarctic ice-sheet mass change rates from GRACE show mass decrease of -174 ˜ -48.4 Gt/year in total, which is consistent with previous studies. GRACE and ICESat are in good agreements in their spatial patterns, and a large mass/volume decrease can be seen in Amundsen Sea Sector (ASE) and Antarctic Peninsula (AP). Due to the scarce measurement densities, the spatial patterns of volume changes from EnviSat does not agree well with those of GRACE or ICESat. Nevertheless, the time-series of volume changes from EnviSat show good agreements with mass changes from GRACE for the whole of Antarctica as well as some of the drainage systems, especially in the regions where the slope magnitude is low. This study shows by making use of EnviSat data, the volume changes in shorter time-scale can be detected for the whole off Antarctic as well as its regions.

Keywords: Satellite geodesy, GRACE, ICESat, EnviSat, Altimeter, Antarctic ice sheet mass change

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SGD24-02 Room:105 Time:May 25 09:15-09:30

Gravity field determination around Syowa station, Antarctica, by combining GOCE and in-situ gravity data

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GOCE (Gravity field and steady-state Ocean Circulation Explorer) satellite launched in March 2009 by ESA (European Space Agency) aims at improving static gravity fields, in particular at short wavelengths. In addition to its low-altitude orbit (250km), the sensitive gravity gradiometer installed is expected to reveal 1 mgal gravity anomaly and 1cm geoid at the spatial resolution of 100km (half wavelength). On the other hand, due to instrumental drifts, lack of reference points, and other reasons, the accuracy of in-situ gravity data (land, surface ship and airborne gravity data) is decreasing toward the longer wavelength more than several tens km. In particular in Antarctica where very few gravity reference points are available, the long wavelength accuracy and/or consistency among the data sets are quite limited. The Japanese Antarctic Research Expedition (JARE) has been conducting in-situ gravity measurements around the Japanese Antarctic stations for a long period. These measurements also suffered from such influences and they cause large errors in the long wavelength gravity fields, and, consequently, errors in geophysical and geodetic applications. This study aims at improveing the accuracy of the JARE gravity data using GOCE gravity models (level 2 EGMs). There are three different approaches for estimating the GOCE gravity models, namely, direct solution (DIR), time-wise solution (TIM) and space-wise solution (SPW). Among these, TIM never uses any a-priori information other than GOCE. Therefore we mainly employed TIM models (RL 1-3). We also employed EGM2008 as a reference. In this talk, we present the comparisons between the gravity models and each of in-situ gravity data sets, and a preliminary result of the improved gravity field around Syowa station, Antarctica.

Keywords: GOCE, Gravity Model, Antarctica, Syowa Station

SGD24-03 Room:105 Time:May 25 09:30-09:45

Towards improvement of geoid model in Japan by GOCE data: Case study of Shikoku area

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The performance of the recently released global geopotential models (GGMs) based on 2, 8 and 12 months of data collected by the Gravity field and steady-state Ocean Circulation Explorer (GOCE) is evaluated using geoid undulations and free-air gravity anomalies over Japan. The evaluated GOCE and related GGMs include; direct solution (DIR, release 1, 2 and 3), time-wise solution (TIM, release 1, 2 and 3), space-wise solution (SPW, release 1 and 2) and Gravity Observation Combination (GOCO, release 1 and 2). Further evaluations are carried out in each of the four Japanese main islands. The performance of EGM2008 and GOCE-related GGMs over Japan is generally comparable indicating possible improvement of geoid model in Japan by GOCE data at the end of the mission. The comparisons over the four main islands reveal that EGM2008 performs better than GOCE and related GGMs in Hokkaido, Honshu and Kyushu. However, GOCE and related GGMs perform better than EGM2008 in Shikoku. GOCO02S, GOCE-DIR3 and GOCE-TIM3 have the best and similar performance in Shikoku. Given that GOCE-TIM relies exclusively on GOCE data, it is considered for geoid determination in Shikoku for further assessment. To evaluate the actual improvement of the geoid model in Shikoku area by GOCE-TIM3, the geoid over Shikoku is determined from EGM2008 and a combination of GOCE-TIM3 with EGM2008 (GOCE-TIM3/EGM2008). In both cases the same terrestrial gravity data sets are used and all the necessary reductions are applied. The Stokes-Helmert scheme in a modified form is adopted for the computations. The first improvement of geoid model over Japan by GOCE data is evident in Shikoku.

Keywords: Geoid model, Gravity, EGM2008, GOCE, Shikoku

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SGD24-04 Room:105 Time:May 25 09:45-10:00

Search for geoid height changes due to the Tohoku Oki earthquake (Mw9.0) by satellite altimeter Jason-2

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On March 11, 2011, The Tohoku Oki earthquake (Mw9.0) occurred, and the accompanying crustal deformations and gravity changes detected by SAR, GPS, and GRACE have been reported (e.g., Matsuo and Heki, 2011). While these results are very important to reveal the mechanism of the earthquake, if we detect coseismic changes of geoid height over the ocean, we can exploit the data to constrain the earthquake mechanisms immediately above the epicenter because the co-seismic geoid height changes would be one of the few near-field data for the earthquake offshore. However, no successful report of the detection of coseismic geoid height changes have been reported yet.

Geoid height changes link with mean sea surface height changes, and one of the most useful ways to calculate them is to use satellite altimeter. In this study, we used GDR (Geo Physical Record) SSHA (Sea Surface Height Anomaly) data of satellite altimeter Jason-2 and searched for geoid height changes due to the Tohoku Oki earthquake. Although we don't think about sea bottom changes, water load and so on, we estimated the geoid height changes by the fault model reported by Geospatial Information Authority of Japan before this research. Then, it is expected that coseismic geoid height was changed to 3.5cm at most at latitude 38 degrees north and longitude 144 degrees east. And the Jason-2 pass 238 is running around this point, so that it is possible to observe those changes by Jason-2 (measuring precision of 2 ˜3cm). The biggest problem to search the geoid height changes is how to eliminate sea surface height changes due to ocean tide, oceanic currents and so on. In this study, we use SSH (Sea Surface Height) data from JCOPE2 (Japan Coastal Ocean Predictability Experiment) oceanic circulation model in order to correct those sea surface height changes, and this experiment is provided by JAMSTEC (Japan Agency for Marine-earth Science and Technology). Jason-2 GDR SSHA data and JCOPE2 SSH data have similar trends of these changes. We thought the differences between those two data suggest the geoid height changes and we compared these differences.

We stacked and compared these differences of each year (2009˜2011) and there is the about 20 cm peak around latitude 38 degrees north in pass 238 data across the earthquake. But it is far from the theoretical value. And although we applied High Pass Filter on this result, we couldn't get any useful information about the geoid height changes.

This study has room for us to consider contributions for the geoid height changes by sea bottom changes, water load and so on. In point of fact, many kinds of changes which must not be ignored have been found: the local more-than-10m sea bottom changes by the fault model reported by Geospatial Information Authority of Japan, about 5m mean sea surface changes around latitude 38 degrees north in Jason-2 pass 238 obtained by Jason-2 observation, and so on. Our future works are to consider these things. Furthermore, to check the noise properties on other passes, we are going to use SSHA data of Jason-1, the conventional model of Jason-2.

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SGD24-05 Room:105 Time:May 25 10:00-10:15

Postseismic gravity changes of the 2010 Chilean earthquake from GRACE gravimetry

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The Earth's gravity field is known to change after earthquakes. The changes occur instantaneously in the earthquake (coseismic gravity change) and/or slowly after the earthquake (postseismic gravity change). The coseismic gravity change was first observed after the 2003 Tokachi-oki earthquake by an array of superconducting gravimeters (Imanishi et al., Science 2004). Using the data of GRACE (Gravity Recovery And Climate Experiment) satellites, which is the twin satellite launched in 2002 to measure gravity field and its changes, Han et al. (Science, 2006) observed the two-dimensional distribution of coseismic gravity changes associated with the 2004 Sumatra-Andaman earthquake. In the present study, using the GRACE data, we try to detect co- and postseismic gravity changes of the 2010 Chile (Maule) earthquake. We found coseismic gravity decrease and its slow recovery. The coseismic gravity changes were mostly negative, and the maximum decrease was about 4 microgal. The postseismic gravity recovery had a time constant of about a year. The coseismic changes are already reported by Heki and Matsuo (GRL 2010).

Three mechanisms are known for postseismic gravity changes: afterslip, viscous relaxation of the upper mantle, and pore water diffusion. Afterslips would change the gravity in the same sense as the coseismic changes, and viscous relaxation would take a few years or more. These two mechanisms cannot explain the observed postseismic gravity changes, and consequently the pore water diffusion seems the most likely mechanism. Similar postseismic gravity changes were found after the 2004 Sumatra-Andaman earthquake (Heki and Ogawa, GRL 2007), and they suggested that the diffusion of supercritical pore water is responsible for the changes. In addition, the 2004 Sumatra-Andaman and the 2010 Chile earthquake show common features in the amount, time constant of the postseismic gravity changes. I also compared the 2011 Tohoku-oki earthquake, but the time elapsed after this earthquake is not long enough (the GRACE data available only up to 2011 October) to enable detailed discussion on the postseismic gravity changes. One unique point in the Tohoku-oki event is that the postseismic gravity increase occurs in the same region as the coseismic increase. In spite of such differences, overall tendency of the co- and postseismic gravity changes of the 2011 Tohoku-oki earthquake is similar to the other two earthquakes. Recently, its coseismic gravity change is published by Matsuo and Heki (GRL, 2011).

Keywords: coseismic gravity changes, postseismic gravity changes, 2010 Chile earthquake

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SGD24-06 Room:105 Time:May 25 10:15-10:30

Determination of earth gravity field from SLR analysis

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Determination of earth gravity field is newly implemented in our geodetic analysis software "c5++" (Otsubo, et al, JPGU, 2011). Satellite laser ranging (SLR) data are used to retrieve the gravity field, and its sensitivity is dependent on the SLR targets, especially in its altitude. Although the two LAGEOS satellites arecommonly used for terrestrial reference frames and earth orientation parameters, the low SLR satellites such as AJISAI, STARLETTE and STELLA are more sensitive to the earth gravity. Combining those multiple satellites, the long-term trend and the periodical variation will be presented for the J2 term and low degree/order terms up to 2 or 3.

Keywords: satellite laser ranging, earth gravity field, space geodesy

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SGD24-07 Room:105 Time:May 25 10:45-11:00

Development of a gravity gradiometer system for submarine gravity prospecting 2

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Gravity surveys are useful in profiling the underground density structure. We propose a hybrid gravity survey method using gravimeters and gravity gradiometers to detect submarine ore deposits. This paper describes the development of a submersible gravity gradiometer for this purpose. As compared to a gravimeter, a gravity gradiometer is sensitive to localized density structure, and hence it is well suited to survey on concentrated source such as ore deposits. The required resolution is estimated to be finer than approximately 10E (=1x10^{-8}/s^2), considering typical dimensions of submarine ore deposits and survey altitude from the seafloor. To attain the required resolution, we newly developed a gravity gradiometer comprising two vertically-separated accelerometers with astatic reference pendulums. Because any common noise to the gravity sensors, such as translation acceleration and thermal drift, is canceled by taking the differential signal, the gravity gradiometer is preferable as an onboard instrument in the underwater vehicle.

The instrument should be installed on a gimbal to reduce rotational motion when the gradiometer is mounted in an underwater vehicle to survey around the seafloor. We have demonstrated a one-dimensional forced gimbal on which the orientation is precisely controlled to be vertical referred to both a fiber-optic gyroscope and a tiltmeter. Laboratory measurements show that the gravity gradiometer attains the required resolution and the forced gimbal reduces expected rotational disturbances to required level. By combining the gravity gradiometer with a two-dimensional gimbal based on this experiment, detectability of the typical ore deposit can be obtained.

A sea trial observation is scheduled in Suruga Bay using an AUV in September, 2012. Details of the design, the instrument performance, and the trial plan are presented.

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

SGD24-08 Room:105 Time:May 25 11:00-11:15

Hydrological gravity response detection using a gPhone -aboveground, and 100- & 300-m belowground-

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Inland water fluctuations are one of the most important source of disturbance for gravity monitoring which monitors density change of the underground. We have proposed the gravimeter array method as the technique of removing the disturbance due to inland water fluctuations. Namely, the effect of rain-/snow-fall should be cancelled using two continuous gravimeters with a free water plane between them. We have performed three gravity observations; aboveground (Ontake volcano), 100-m deep belowground (Mizunami Underground Laboratory (MIU)), and 300-m deep belowground (MIU). Although the data of 300-m deep are still under analysis, we have succeeded in approximately 1 ~ 4 microGal of gravity responses due to inland water variations in the data of both aboveground and 100-m deep belowground. However, the data of 100-m deep belowground also contained unknown gravity variations (real signal from the deep part of crust or non-linear spring sensor behavior). Our absolute gravity measurements have doubled as a calibration tool for the gPhone and a detector of rainfall response itself (Tanaka et al., 2011, JPGU abstract). However, even the rainfall over 20 mm/hour could not be detected with the usual operation policy (100 drops/hour, 10-second drop interval). Based upon the foregoing, the following strategy is realistic as gravity monitoring: (1) two relative continuous gravimeters both above- and belowground are in charge of detections of the response of inland water fluctuations. (2) absolute gravity measurements are repeatedly carried out to calibrate the sensor-drifting of relative gravimeters when atmosphere and ocean are under calm conditions.

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Keywords: continuous gravity measurement, gravimeter, inland water variations, groundwater, rainfall, snow depth

SGD24-09 Room:105 Time:May 25 11:15-11:30

Long-term slow slip events along the Ryukyu Trench as seen from high-precision continuous gravity observations

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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 tectonic stress accumulation rates and the frictional properties on the plate boundaries control the intervals. Therefore, their differences are considered to cause the differences in the intervals. However, variations in fluid pressure will also change the intervals, because they affect the effective normal stress. Variations in fluid pressure are predicted by the earthquake-cycle model based on the fault valve behavior of Sibson (1992). So far, variations in fluid pressure associated with SSEs have not been detected by field observations. If a massive fluid pressure change occurred, gravity change could be observed since the corresponding density redistribution in the underground occurred. In the Tokai district in Japan, the SSE occurred during the years 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. So, a clear evidence of fluid-pressure change has not been obtained yet. In this study, we conduct 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 (Heki and Kataoka, 2008) to observe a transient gravity change during the whole cycle of an SSE. Such a continuous measurement to elucidate processes of an SSE has never been carried out in the world due to technical difficulties. In this presentation, we will report an observation result obtained by absolute gravimeters.

Keywords: slow slip, subduction zone, gravity, crustal deformation, geodesy, seismology

SGD24-10 Room:105 Time:May 25 11:30-11:45

Continuous gravity observation using a gPhone-109 at a hot spring area of Hachijojima, Japan

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Gravimeter is a useful tool for detecting subsurface mass variations. For elucidating groundwater variations in hot spring area, we carried out continuous gravity observation with a gPhone-109 in the Nakanogo gravity observation hut of Hachijojima (GOH) at the period from November 2011 to February 2012. We also measured absolute gravity values with a FG5-217 gravimeter for a drift correction of gPhone gravimeter. In addition to gravity measurements, we collected data of atmospheric pressure, rainfall, soil moisture and the monitoring well (e.g. water level and temperature) in the vicinity of GOH. A preliminary result is that, in the late of December 2011, 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. In addition to the case, several small gravity changes of microGal level are observed in the observation period. Therefore we will compare gravity changes with estimated precipitation effects and/or observed sea level changes for extracting a gravity signal related to mass variations of a hot spring reservoir.

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: hot spring, geothormal power, groundwater, monitoring