Japan Geoscience Union Meeting 2011
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SGD022-01 Room:201A Time:May 23 14:30-14:45

Proposal of Japan Gravity Reference System 2010

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GSI is constructing new gravity standardization net, ”Japan Gravity Standardization Net 2010 (JGSN2010)”, to improve former one and contribute to research for the earth’s internal structure. Constructing it requires to conform JGSN2010 to a gravity reference system.

In this presentation, we will report the proposal of Japan Gravity Reference System and the plan of future construction of JGSN2010.

Keywords: Gravity Standardization Net, Gravity, JGSN, IAGBN

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SGD022-02 Room:201A Time:May 23 14:45-15:00

Sea Floor Gravity Survey of Offshore Area of Fukuoka prefecture

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A sea floor gravity survey was carried out from September to October in 2010 along the offshore of fukuoka prefecture in order to understand a shallow and whole underground structure. The measurement points were arranged within 5km offshore at every 2km interval and the number of measurement points became 100 points. The characteristic Bouguer anomalies are that the gravity steep gradients continue to the offshore area. But, the continuity to the sea of Kego Fault is not so clear.The low Bouguer anomalies are found out in the Epicenter area of 2005 Fukuoka earthquake, it may correspond to the fracture structure.

Keywords: Sea floor gravity, offshore of fukuoka prefecture, 2005 Fukuoka earthquake, Kego fault

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SGD022-03 Room:201A Time:May 23 15:00-15:15

Development of a gravity gradiometer for precise on-board measurements

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We have been developing a gravity gradiometer that could measure vertical gravity gradients on a moving vehicle, such as an aircraft and a ship, to a level of a few microgal. This target sensitivity of a few microgal is about two orders of magnitude better than the sensitivity of mechanical gravimeters, which are typically used on aircraft and ships. This gravity gradiometer would allow us to carry out on-board measurements in inaccessible areas, with an unprecedented high sensitivity.

This gravity gradiometer employs the concept of the free-fall interferometer, developed for tests of the Weak Equivalence Principle. Two test bodies are put in free fall and their differential displacements during the free fall are monitored by a laser interferometer. Unlike the tests of the Equivalence Principle, the centres of mass of the test bodies are separated along the vertical direction before free falls. This separation allows us to obtain the vertical difference in the gravitational fields. Because of the differential measurements, the obtained gravity gradients are, in principle, insensitive to the motion of the vehicles on which the measurements are carried out.

We will introduce the concept of the gradiometer and present the current status of the development.

Keywords: Gravity gradiometer

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SGD022-04 Room:201A Time:May 23 15:15-15:30

Development of a gravimeter for underwater hybrid gravimetry

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Gravity profiling has been an important geophysical method combined with seismic profiling. For example, it has been recognized from dense gravimetry in Japan that a belt of large gravity gradient coincides with an active fault. After several destructive earthquakes occurred in coastal areas of Japan, gravimetry has been carried out on the shallow seafloor using an ocean bottom gravimeter to detect an unrecognized active fault. However, it requires considerable time to make a detailed gravity map in such a way of gravimetry. While a surface ship gravimeter can carry out continuous gravity measurement with precision of about 1 mgal, or 10∗∗(-6) G, required precision for such field works is 0.05 to 0.1 mgal. In this way a gravimetry system onboard an underwater vehicle has been required to carry out continuous gravity measurement with one-order better precision than a sea surface gravimetry.

We once tried to develop an underwater gravimeter onboard a large AUV (autonomous underwater vehicle) powered with a diesel engine developed under a fund from the MEXT to Institute of Industrial Science, University of Tokyo. The basic design was to keep the gravity sensor, a static gravimeter Scintrex CG-3M with some modifications, vertical with the aid of the signal from a gyro. The system was not completed due to limited specifications of the gyro and mechanical parts for the system as well as limited chances of sea trials. In 2009 we improved on the system with the doubtful parts replaced, and examined its performance on a test bed simulating pitching and rolling as well as strong vibration. The gravity sensor remained unchanged. The revised system worked fairly well under a condition of pitching and rolling of the amplitudes 3 degrees and the period several seconds. Averaged gravity values under such conditions were observed with a precision of 0.2 mgal. Because the mechanism of the forced gimbals was not fully rigid, tilt of the gravity sensor was larger than a theoretical value by about 20 percent, and the averaged gravity values fluctuated by about 0.2 mgal. The strong vibration was successfully cut off with double-layered shock absorbers.

We began to build a brand-new hybrid gravimetry system in 2010 with another fund from the MEXT to Earthquake Research Institute, University of Tokyo. It consists of a gravimeter and a gradiometer both for underwater gravimetry. The former aims at quantitative mapping of density anomalies below the seafloor, and the latter can be more sensitive in detection of density variations. The hybrid system can estimate the subterranean structure more accurately than a gravimeter alone. The gradiometer consists of a pair of high precision accelerometers that have been developed for an absolute gravimeter (Araya et al., this meeting). Both of the sensors will be kept vertical with each gyro. We plan to carry out a sea trial onboard the AUV Urashima, JAMSTEC, in the near future.

The new underwater gravimeter of the hybrid system was designed considering the results of the examination of the old one in the previous year. While the concept of design remains unchanged; a gravity sensor is kept vertical with forced gimbals by use of a gyro, the gravimeter has adopted a newly developed dynamic gravity sensor, a high precision gyro, and a highly rigid mechanism for the gimbals in order to improve the precision. The sensor unit of the system is installed with batteries in a pressure-tight Ti sphere. A logging unit is contained in a smaller housing. The whole system is being assembled and will be examined indoors as was carried out for the older gravimeter.

Keywords: gravimeter, underwater, hybrid gravimetry, gradiometer, forced gimbals, AUV

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SGD022-05 Room:201A Time:May 23 15:30-15:45

Development of a gravity gradiometer system for submarine gravity prospecting

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Gravity prospecting is the method to detect underground density structure, and it is one of the most useful prospecting techniques on the seafloor where drilling is difficult to perform. We are working on development of a underwater hybrid gravimetry system including a gravimeter and a gravity gradiometer. In this paper, a gravity gradiometer system for submarine gravity prospecting is described.

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 gravity gradiometer comprises two vertically-separated gravity sensors, and the gravity gradient can be obtained from the differential signal between them. 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. In this case, rotation of the instrument would be a major noise source and is controlled to keep it vertical as in the case of the gravimeter.

Along with design and performance of the gravity gradiometer being developed for the submarine gravity prospecting, the verticality control system to be installed in an AUV will be presented.

Keywords: gravity gradiometer, gravity prospecting, gravimeter, underwater, AUV, hybrid gravimetry

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SGD022-06 Room:201A Time:May 23 15:45-16:00

An attempt of the local gravity field estimation using GOCE satellite gradiometer 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 in short wavelength. 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). Since 2010, ESA has begun to release GOCE data to those who submitted research proposals. Using the GOCE data, it is highly expected that applications for local gravity fields as well as global gravity field determinations are widely conducted right away.

Finishing with the six months of the CAL/VAL period after the launch, GOCE moved to the repeat orbit of 979 cycles /61days in September 2009, and has started the full-scale measurement mode. Afterward, Level 1B and Level 2 data has been released in May and July 2010, respectively.

GOCE is designed to determine the gravity fields with HL-SST (High-Low Satellite to Satellite Tracking) and the 6 gravity gradients (the second derivatives of the gravity potential) measured by the gradiometer. The Level 1B data (GOCE.EGG.NOM_1b) include the gravity gradients in the gradiometer reference frame, SST, and the Star Tracker data which show the attitude of the satellite. On the other hand, in addition to the gravity gradients with several corrections in the gradiometer reference frame (EGG.NOM_2), the Level 2 data include the gravity gradients in the local north oriented frame (EGG.TRF_2), precise orbit of the satellite (SST.PSO_2) and spherical harmonic coefficients of the gravity fields (EGM.GOC_2).

Among these data sets, level 1B data are not necessary for many applications. Thus, in this study, the applicability of the level 2 EGM and EGG.TRF has been examined mainly from the view point of local gravity field estimation. As of January 2011, using the 2 months data of Nov-Dec 2009, three EGMs (direct solution, time-wise solution, space-wise solution) with different estimation methods are available. In addition, EGG.TRF data from September 2009 to April 2010 have been released.

Although the direct solution uses EIGEN5C model as a-priori information, space-wise solution uses only quick-look model of GOCE as a-priori information and time-wise solution does not use any a-priori information. Comparing the gravity anomalies calculated from those solutions, the direct solution shows the most smooth anomalies even with all the coefficients upto the maximum degree of 240. However both space-wise and time-wise solutions show almost same smooth results with all the coefficients upto degrees of 210 and 224, respectively. Given that those models use only two months of GOCE data, the accuracy of the final GOCE model is the great expectations.

The EGG.TRF consists of along-track 1 sec sampling data of calibrated gravity gradients, the GPS time of each epoch and the geocentric coordinates (latitude, longitude, r). Among 6 components of the gravity gradients, the global plot of Tzz clearly shows the large structures such as subducting plats, Himalayan collision zone. The present 1 second sampling data could not be used directly because of their large noises. However, if properly processed, the high sampling data are expected to improve the spatial resolution of the local gravity fields, in particular in the areas with poor gravity data, such as polar regions.

Keywords: GOCE, satellite gradiometer, local gravity field

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SGD022-07 Room:201A Time:May 23 16:00-16:15

Estimation of ice-sheet trend over Antarctica using GRACE, ICESat, and EnviSat 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, by conducting continuous measurements of the distance between the twin satellites. GRACE has 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 Post Glacial Rebound (PGR) effect. Therefore, to estimate the actual ice-sheet mass trend in Antarctica from GRACE data, a precise PGR model is required. 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. By combining the elevation changes observed by ICESat with mass changes by GRACE, a better PGR model can be obtained. Although ICESat data has sufficient coverage of the higher latitudinal area, its data sets 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, because its data sets are available monthly from the same period as GRACE, and it has a better precision at East Antarctic coastlines. In this study, we present the data processing using ICESat and EnviSat altimeter data combined with GRACE data, and the result of the ice-sheet trend over Antarctica.

Keywords: Antarctica, ice-sheet change, altimeter, GRACE, ICESat, EnviSat

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SGD022-08 Room:201A Time:May 23 16:30-16:45

Underground fluid flow monitoring using a A10 absolute gravimeter

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It is important to monitor the aquifer mass balance of pumping up and recharge to use the ground water for a long term. The pumping up of ground water causes mass fluid movement and mass redistributions, which can cause measurable gravity changes and ground deformation at the ground surface. We carried out the repeat gravity measurement at some fields in order to detect the gravity changes caused by groundwater level changes. We combined the Absolute gravity measurement and the relative gravity measurement. 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.

First, we started repeat gravity measurement at Ito campus, Kyushu university Fukuoka city, 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 microgals.

After checking the A10 gravimeter's condition, accuracy and repeatability, we have started repeat gravity measurement in Jakarta and Bandung, Indonesia since 2008. These 2 cities observed a large amount of subsidence caused by a large amount of pumping the groundwater. We cannot get the gravity data in 2008 survey because of the instrument troubles. Although we got only limited number of gravity data, we learned a lot of technical and logistic viewpoints. There are some problems (high temperature and humidity, ground noises caused by heavy traffics) to get the good gravity data. In particular the measurement in high temperature condition caused a problem in vacuum and laptop computer. We installed 2nd Ion pump for upgrading the vacuum capacity. We detected gravity increase from July 2009 to July 2010 at 7 stations in Jakarta. We can see the large gravity increase (30 - 50 microgals) in the coastal area where the large subsidence was observed by GPS.

Keywords: Groundwater level monitoring, A10, Absolute gravimeter

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SGD022-09 Room:201A Time:May 23 16:45-17:00

Detection of rainfall response by a gPhone gravimeter installed at 100 meters under the ground

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The absolute gravity measurement is the instrumentation which can monitor underground density variation one after another even if the generation of the operator and the device change. However, for the argument of the microGal-order, the disturbance caused by atmospheric/oceanic and hydrological variations can easily mask signals from the deep underground. The former has become able to discuss microGal-order by recent improvements of global/regional physical model, the latter model must be constructed properly at each observation point. We have started to wrestle with the establishment of the correction method by parallel gravity measurements both underground and on the ground. In the beginning, we have installed the gPhone gravimeter (serial number 90) in the depth 100 m stage of MIzunami Underground laboratory (MIU) and then tried to detect gravity response by rainfall. The past pore water pressure data observed in the MSB-3 borehole showed that no pressure change by rainfall occurs at the depth the gPhone installed (in the main part of Toki Lignite-bearing Formation, Mizunami Group), on the contrary the pore water pressure in near surface (in the main part of Akeyo Formation, Mizunami Group) shows clear fluctuations by rainfall. Therefore, the gPhone should observe gravity decrease when it rains heavily because mass excess occurs in its overhead. In the first observation term (Jul~Nov 2010) we succeeded in detection of several rainfall responses about 1 microGal amplitude, but some problems, such as the gravity disturbance result from instability of the floor face under the gPhone sensor and from abrupt air temperature change and the way of evaluation of non-linear drift fated to spring sensor, became clear. In the planned second observation term, we will improve the gPhone sensor setting floor face and then aim at the simultaneous detection of rainfall response with an absolute gravimeter. If it is proved that the validity of this correction method, we can promote the development of borehole-type relative gravimeter which can run long term stably and propose it as an infrastructure for hydrological gravity correction.

Acknowledgment: The authors thank H. Asai (now at Maeda Corp.), Y. Horiuchi, K. Kumada, and S. Hashizume from Tono Geoscience Center, Japan Atomic Energy Agency for the installation of the meter.

Keywords: continuous gravity measurement, gravimeter, hydrology

SGD022-10 Room:201A Time:May 23 17:00-17:15

Effect of underground water on gravity at Matsushiro, Japan (part 2)

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The superconducting gravimeter station at Matsushiro, Japan, is housed in a tunnel dug inside Mt. Maizuru (560m). At this station, observed gravity decreases after rainfall due to the effect of underground water. Imanishi et al. (2006) modeled the effect as (i) the gravity decrease is proportional to the amount of rainfall, and (ii) the gravity change due to underground water decays linearly with time to the original level. This model describes the effect of underground water above the tunnel empirically, and works well for the short term effects. However, there has been no theoretical explanation on why the gravity shows such a response, and also it has been unknown what determines the decay rate of gravity.

The inside of the tunnel where the gravimeter is installed is always wet everywhere, and water often drops from the ceiling at particular points. A rain gauge is installed at one of such points (about 90 m below the surface) to measure the amount of water drops. Comparing the water drop data with the rainfall data outside the tunnel, it is found that (i) water begins to drop about 3 hours after the onset of rainfall, (ii) the drop rate is almost constant, and (iii) the amount of water drops is approximately proportional to the rainfall amount.

The rate of the underground water, which is assumed to descend inside the mountain steadily, is about 30 m per hour. On the other hand, the rate of osmosis in the soil was found to be lower than the rate of the underground water by about one order of magnitude from our measurements of soil moisture near the summit of Mt. Maizuru. The thickness of soil may be some tens of centimeters at most near the summit and negligibly small at the base of the mountain. Also, assuming a Hagen-Poiseuille flow in a vertically oriented round tube, the observed rate of underground water flow gives 0.5 mm as the radius of the tube.

Combining these observations, we can conclude that the water supplied by rainfall is first preserved by the thin layer of soil on the surface, and then percolates downward into the rocks at a steady rate. In this picture, the soil and the rocks behave as a tank and capillary, respectively. This gives a theoretical justification to the model of Imanishi et al. (2006), in which the gravity decay rate is determined by the flow rate in the capillary. It is also found that the amount of water drop inside the tunnel is not exactly proportional to the surface rainfall, implying that some part of the water does not percolate into the soil but escape to the sky by evapotranspiration.

Keywords: superconducting gravimeter, underground water

SGD022-11 Room:201A Time:May 23 17:15-17:30

Hyper-hybrid gravity measurements: case studies on volcanic activities of Asama 2004 and Sakura-jima 2010 events

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Recent advance in imaging with cosmic-ray muons provides us with density profiles of the interiors of gigantic bodies. Resultant images enable us to estimate the dimensions and configuration of a volcanic conduit in a quantitative way (Tanaka et al. 2007). The imaging called Muon Radiography also provides us with rough measure of porosity of magma in the conduit.

Once these parameters are predetermined, we may interpret temporal gravity change g(t) in terms of magma head height H(t) based on a line mass model. We apply the idea to two active volcanoes, Mt. Asama and Mt. Sakura-jima. Long term variations of the magma head height H(t) derived from absolute gravity observations g(t) are consistent with the volcanic activity of the two volcanoes: frequent explosions occur when H(t) is high and vice versa. H(t) also explains the temporal variation of SO2 flux well: high SO2 flux when H(t) is high and vice versa.

These results clearly shows that continuous gravity monitoring with geometrical constraint from the Muon Radiography is quite useful to trace the rise and fall of magma in a volcanic conduit.

Keywords: gravity, magma head, muon radiography, Asama, Sakurajima

SGD022-12 Room:201A Time:May 23 17:30-17:45

The estimation of FCR parameters by the gravimetric tidal factors corrected through optimal ocean tide model, TPXO7.2

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Superconducting gravimeters at Metsahovi, Strasbourg, Sutherland, Canberra and Syowa Stations were used to estimate the FCR (Fluid Core Resonance) parameters using the Bayesian method (Tarantola and Valette, 1982) with an priori information. We obtained the probability density function with the most probable value by integrating the probability for a reasonable parameter range (Florsch and Hinderer, 2000). One of the primary motivations of this study was to find the effectiveness of optimal ocean tide model for each station located globally on the estimated FCR parameters. From a statistical test on the error in K1, PSI1 and PHI1 waves, increasing the percentage error of the imaginary part of gravimetric factor in each wave separately, we found that the PSI1 wave was most sensitive to the correlation between the quality factor and imaginary component of the resonance strength, and to the standard deviation of quality factor. The ocean loading effect was estimated using TPXO7.2, which gave the smallest combined misfit for every station in diurnal bands. The obtained results are as follows: the quality factor of Metsahovi, Sutherland and Syowa stations were found to diverge, i.e., non-symmetric probability density functions (PDFs). The quality factor at Strasbourg and Canberra showed the symmetric PDFs and the most probable values by integration were 37762+-4452 and 3311+-607, respectively. Strasbourg was the only station which showed the good correlation between quality factor and imaginary part of resonance strength. Eigenperiods of 430+-5 and 428+-1.6 days at Metsahovi and Strasbourg, are close to the result of the theoretical prediction by Mathews et al. (2002) and the observed values at Europe by Rosat et al. (2009) within the margin of error. However, the results of eigenperiod of 435+-8 days for Sutherland, 432+-6 days for Canberra, and 433+-43 days for Syowa have discrepancies as compared with the most probable value of 430.2+-0.28 days by Mathews et al. (2002). Employing the stacking method, the parameters of FCR were found to have a normally distributed PDF: the mean values were 432+-2days for the eigenperiod, 0.6362+-0.006degree x10-3degree/ h for the real component of resonance strength, -0.1967+-0.0236degree x10-4degree/ h for the imaginary component of resonance strength, and 35897+-4230 for the quality factor.

Keywords: FCR parameters, ocean tide model, Superconducting gravimeter, Syowa Station, ocean loading effect

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SGD022-13 Room:201A Time:May 23 17:45-18:00

High-resolution gravimetric geoid model for Japan from EGM2008 and local gravity data

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A high-resolution geoid model covering four main Japanese islands (Hokkaido, Honshu, Shikoku and Kyushu) has been developed on a 1 by 1.5 arc-minute grid from EGM2008 and terrestrial gravity data over Japan. The Stokes-Helmert Scheme in a modified form is applied for the determination of the geoid using an empirically determined optimal spherical cap and Kriging technique is used for gridding residual gravity anomalies. Comparisons between the gravimetric and geometric geoid undulations are carried out using 816 GPS/levelling points. In comparison with the previous geoid model for Japan (JGEOID2008), there is a slight improvement in the standard deviation from 8.44 cm to 8.29 cm. The standard deviation reduces to 5.81cm about a mean of 0.00 cm after planar fit.

Comparisons between the gravimetric and GPS/levelling geoid undulations are also carried out in each of the main islands except Honshu which is divided into three parts (North Honshu, Central Honshu and West Honshu) because of its size and geometry. The following is a summary of the comparisons in each area: Hokkaido 163(6.71), North Honshu 171(6.41), Central Honshu 163(7.34), West Honshu 158(5.16), Shikoku 56(8.69) and Kyushu 105(5.58), where the numbers outside the brackets represent the number of GPS/levelling points while bracketed ones are the corresponding standard deviations in cm. It is noted that although the determined gravimetric geoid represents the geoid over Japan fairly well, there is still need for more gravity data especially in the northern part of Japan to obtain a precise geoid model.

Keywords: geoid model, gravity, Kriging, EGM2008, GPS/levelling

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SGD022-14 Room:201A Time:May 23 18:00-18:15

Measuring local tilts of Geoid with a GPS meteorological approach

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Atmospheric delays estimated by GPS together with station coordinates are known to provide valuable information for meteorological studies. We report climatological behaviors of the atmospheric water vapor over the last 12 years using zenith wet delays (ZWD) at ˜1000 receivers of GEONET GPS stations in Japan (the F3 solution). ZWD can be converted to precipitable water vapor (PWV), and long-term changes of PWV presented climatological signals including interannual changes due to El Nino/Southern Oscillation (ENSO), longer-term changes such as Pacific Decadal Oscillation (PDO). We also studied time series of the tropospheric delay gradients (azimuthal dependence of atmospheric delays) 2004-2010, and found that (1) almost all stations had time-averaged gradient of ˜1 mm toward south, and (2) southward gradients are stronger in winter. The point (1) simply indicates higher temperature (i.e. more water vapor) in the south, and the point (2) would reflect stronger north-south temperature gradient in Japan in winter. On the other hand, the gradient vectors showed significant time-averaged east-west components in some regions. GPS data analysis software packages calculate satellite elevation angles relative to the reference ellipsoid. On the other hand, atmosphere stratifies in parallel with the local geoid. Therefore local tilt of geoid relative to the reference ellipsoid may give rise to permanent components in atmospheric delay gradients. Such gradients may amount up to a few times of 0.3 mm in the Japanese Islands.

Keywords: geoid, GPS meteorology, atmospheric delay gradient

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SGD022-15 Room:201A Time:May 23 18:15-18:30

Reconstruction of the selenoid 4 billion years ago using altimetry data in lunar maria

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Observations by the Japanese first lunar explorer "SELENE (Kaguya)" made a great progress in lunar geodesy e.g. gravity and topography (Namiki et al., 2009; Araki et al., 2009). An unsolved problem on the lunar shape is the odd degree-2 shape of the Moon. If the Earth-Moon system has maintained synchronous rotation throughout its history, the ratio of the centrifugal potential due to the lunar spin to the tidal potential by the earth is 1:3. As for the degree-2 spherical harmonic coefficients, the ratio between C_{20} (=-J_2) and C_{22} should become 10:3. However, the J_2/ C_{22} observed by Kaguya is 9.09 (Namiki et al. 2009), i.e. J_2 is too large relative to C_{22}. Garrick-Bethell et al. (2006) tried to explain this odd ratio by postulating that the Moon used to be in a 3:2 resonance just like Mercury. However, their hypothesis would break down if the present lunar degree-2 gravity coefficient were only 20 percent different. Therefore, their conclusion is far from being robust.

Degree-2 gravity coefficients are often discussed in relationship to "fossil bulge". In our study, we evaluate how much of the current lunar degree-2 coefficients are random components irrelevant to the lunar spin or the terrestrial tide. We take two approaches; (1) extrapolating the Kaula's law fit for degrees > 3 to the degree 2, and (2) calculation of the influence of the formation of major impact basins. Both approaches showed that the random components account for 20-30% of the degree-2 gravity coefficients, i.e. the hypothesis of Garrick-Bethell et al. (2006) lost its ground.

Next we tried to reconstruct the past selenoid (lunar geoid) to discuss the evolution of the Earth-Moon system. The laser altimeter (LALT) and the terrain camera (TC) on board Kaguya greatly improved the lunar global and regional topographic map. First we examine the topography of the mare basalts filling the mascon basins, and estimate tilt angles of their surfaces using the LALT grid data (Araki, et al., 2009). The low viscosity of the basaltic lava might retain information on the past selenoid when they solidified. In our study, we used the least squares method to fit altitude profiles of the surfaces of four mascon basins, Mare Imbrium, Serenitatis, Humorum and Nectaris (they satisfied the requirements that lava covers the whole maria with small undulations), and estimated the combination of C_{20} and C_{22} which best explains the observed tilts. In comparison with the present degree-2 coefficients of the gravity and topography, the inferred combination showed the ratio J_2/ C_{22}, much closer to the theoretical value of 10/3. In the future, we would compare the TC topographic data and flow directions of sinuous rilles, to further discuss differences between the present and the past selenoid.

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Japan Geoscience Union Meeting 2011
(May 22-27 2011 at Makuhari, Chiba, Japan)
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SGD022-P01 Room:Convention Hall Time:May 23 10:30-13:00

Compilation of the Gravity Database of Japan, DVD Edition.

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Geological Survey of Japan, AIST has compiled new Gravity Database of Japan, DVD edition in 2011. This DVD includes gravity measurement point data, mesh data and image map data.

The mesh data consist of Bouguer anomalies with assumed densities of 2.00, 2.30 and 2.67 g/cm3 and free-air gravity anomaly. The mesh data size is 500m x 500m. The image maps are Bouguer anomaly map, free-air anomaly map and geological map.

Keywords: Japan, Gravity, Database, CD-ROM, DVD

Japan Geoscience Union Meeting 2011
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SGD022-P02 Room:Convention Hall Time:May 23 10:30-13:00

Latest Gravity Database of Japan (CD-ROM) and new Bouguer gravity maps of Tohoku District, northern Japan

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In 2001 we published the gravity database CD-ROM of Southwest Japan (Shichi and Yamamoto, 2001; hereafter referred to as CD2001), in which the absolute gravity values and their coordinates of 90,298 net gravity data were digitally included. CD2001 consists with gravity data by Nagoya University (NU) (DB1, 54.3% of total) and those by organizations other than NU (DB2, 45.7% of total). Besides this database, we archived more than 100,000 net gravity data (DB3) by other sources that were not published in CD2001. DB3 contains a part of published database by Geological Survey Japan (GSJ, 2000, 2004) and unpublished database by Geographical Survey Institute and private companies. At that time we focused our attention to Southwest Japan in order to collect and compile gravity database from many organizations, because many blank-areas of gravity data have been left untouched in Northeast Japan. After the publication of CD2001, we have performed extensive gravity surveys especially in the regions with sparsely-measured gravity data (chiefly in Northeast Japan) until the Autumn of 2010. Consequently, we obtained about 23,689 new gravity data (DB4), which may fill most of the blank-areas of gravity data in Northeast Japan. DB4 consists with gravity data by Chubu University (CU) (22,406, 94.6% of total) and those by Nagoya University (NU) (1,283, 5.4% of total). Finally we archived more than 214,000 original gravity data (DB1+DB2+DB3+DB4).

DB1: 49,615 (published in CD2001, data by NU+CU)
DB2: 40,683 (published in CD2001,
data by 35 organizations other than NU+CU)
DB3: 100,000 (unpublished data)
DB4: 23,689 (new data by CU+NU)
DB1+DB4: 73,304 (CD2001 and new data by CU+NU)

We have carefully revised and/or updated previously-measured data (DB1) in CD2001. Here we publish the updated version of DB1 and newly archived database DB4 with their coordinates, gravity, and related values in a digital form. Most of this updated database has not yet been published in a tabulated list nor in computer-readable form. We present new Bouguer gravity maps of Tohoku District, northern Japan, which were created using gravity data compiled from this CD-ROM and other sources.

Keywords: gravity anomaly, database

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SGD022-P03 Room:Convention Hall Time:May 23 10:30-13:00

Gravity measurement at segment boundary of Yamasaki fault zone

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A high dense gravity measurement composed of 336 points was carried out at segment boundary of Yamasaki fault zone, in order to reveal the depth distribution of basement. The measurement was conducted with two CG-3 type gravimeters.

The obtained distribution of gravity shows the negative anomalies ranging from 0.5 - 1.0 mGal parallel to Hijima and Yasutomi fault. On the other hand, there are no negative anomalies around western part of Kuresakatouge fault.

We assume that the negative anomalies are from distribution of fracture zone, from which it is deduced that Hijima and Yasutomi fault are connecting, and Kuresakatouge fault is independent fault.

Keywords: active fault, gravity measurement

SGD022-P04 Room:Convention Hall Time:May 23 10:30-13:00

Support mechanism for a relative gravimeter using two-axes gimbal on a mobile carrier

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Modeling ground structure is one of the most important topics for the estimation of seismic hazard these days. It is said that there are high correlation between the density structure of the ground and the seismic velocity structure of the ground. The gravity survey is comparatively easier than other exploration method to estimate the density structure, so that it is very suitable for the aspect of the seismic hazard projection.

For the measurement of gravity, development of a simplified relative gravimeter is ongoing, in which a force-balanced-type accelerometer is applied as a sensor. Because these accelerometers are simple and inexpensive, the observation can be performed much easier than by using a conventional spring-type relative gravimeter which is usually used. The gravimeter is also expected to perform the observation on a mobile carrier, such as vehicle, ship, and so on, so that we can obtain gravity anomaly at the place where is difficult to measure by using other sensors.

In such a situation, we decided to use a two-axes gimbal system to support the gravimeter on a carrier. There are two main purposes: to maintain the gravity meter horizontally and to attenuate a vibration caused by the body. The 2D and 3D numerical model of the supporting system are proposed, and the equations of motion are derived by means of the Lagrange equations. By using the leap-frog method, frequency response functions of the gimbal model are obtained numerically from the equations.

Furthermore, we made an actual prototype of the gimbal. By using the support system, we conducted an excitation test. Results of the test are compared with that of the numerical analysis. Numerical model can explain the behavior of the actual gimbal partially. However, the degree of freedom of model is not enough to represent responses of the gimbal. Furthermore, the effects of cables may not be neglected to follow the real behaviors.

Keywords: gravity survey, gimbal, force-balanced accelerometer, frequency response function

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SGD022-P05 Room:Convention Hall Time:May 23 10:30-13:00

Gravity change associated with local land-water redistributions: its observations and modeling at Isawa Fan

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Gravity observation is one of the powerful tools in detecting mass redistributions in the solid earth, such as earthquake deformations and magma transfer in volcanoes. Many previous studies have detected the above solid-earth gravity signals, by correcting ”hydrological disturbances” (i.e. gravity change associated with spatiotemporal land water redistributions) with empirical models in advance. However, physical hydrology should be taken into account in order to correct the hydrological disturbances with high accuracy. We were thus motivated to utilize a physical groundwater flow solver ”Gwater-1D” (Kazama, 2010) to model the hydrological disturbance observed by a superconducting gravimeter at Isawa Fan (Iwate Prefecture). We found the following results:

(1) The local soil moisture change can be reproduced within the observation error, if soil parameters observed by soil tests are applied to Gwater-1D.

(2) The hydrological disturbance during 50 days (amplitude: 5 micro-gals) can be reproduced within about 0.4 micro-gals in RMS, because Gwater-1D models the local-scale groundwater distribution and the consequent short-term (˜< several months) gravity change.

(3) The annual component of the hydrological disturbance (amplitude: about 1.3 micro-gals) cannot be reproduced, because Gwater-1D does not model regional and/or global land water redistributions, such as snow loading and ocean height change.

In the coming presentation, we will explain details about estimating the hydrological disturbance, and discuss how to reproduce hydrological disturbances with higher accuracy.

Keywords: gravity change, Isawa Fan, superconducting gravimeter, groundwater, soil water, snow cover