Seismic gravity changes of the 2004 Sumatra-Andaman earthquake and static gravity anomaly

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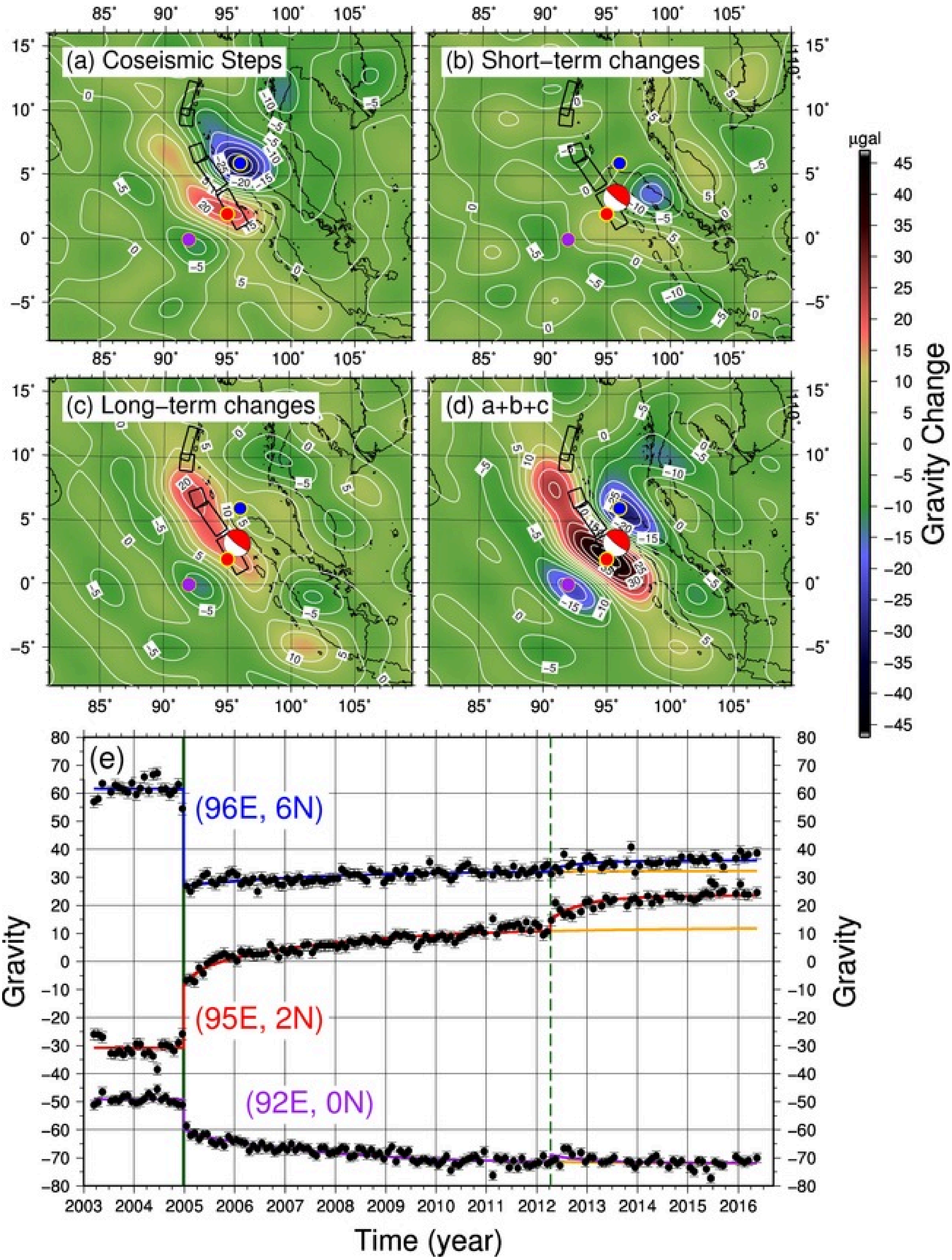
The 2004 Sumatra-Andaman earthquake (Mw9.1-9.3) is the first very large earthquake after the launch of the GRACE satellites in 2002. The results of the time series analysis of postseismic gravity changes indicate that those of the 2004 Sumatra-Andaman earthquake have almost ended. This is the first two-dimentional observation result of total seismic gravity changes.

These observation data may also allow us to research interseismic gravity changes because (1) the static gravity anomaly is formed by the repeat of inter-, co-, and postseismic gravity changes and (2) the data of the static gravity anomaly have been given and co- and postseismic gravity changes of one earthquake have been observed.

In my presentation, I will show several observation results and explain the details of what I wrote above.

Keywords: coseismic gravity changes, postseismic gravity changes, interseismic gravity changes, GRACE, The 2004 Sumatra-Andaman earthquake, earthquake cycle


(a) Coseismic Steps
(b) Short−term changes
(c) Long−term changes
(d) a+b+c
µgal
Gravity Change
(e)
(96E, 6N)
(95E, 2N)
(92E, 0N)
Gravity
Time (year)

Water mass variation in the Japan Sea from satellite gravimetry: Comparison with seasonal movements of GNSS stations

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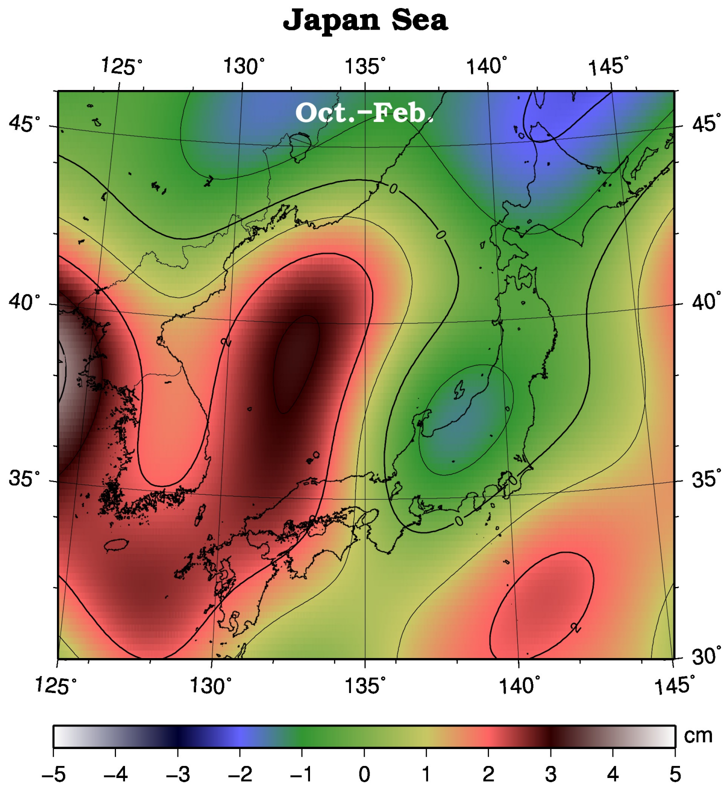
Fifteen years have passed since the gravity satellite GRACE (Gravity Recovery and Climate Experiment) was launched by NASA/DLR in 2002. Most of the past researches focused on the land area, but it is gradually becoming possible to discuss the time-variable gravity in the ocean. The Red Sea is located between the Arabian Peninsula and Africa. Wahr et al. (2014) studied seasonal gravity changes there by combining the seasonal gravity change from GRACE with satellite altimetry and various in-situ data, and found that the seasonal ocean mass changes are driven by wind stress exerted near the strait connecting the Red Sea with the Indian Ocean. We also analyzed seasonal changes around the world oceans using GRACE data 2002-2016, and found significant seasonal variability in the Arctic Sea, Hudson Bay, Arafura Sea, Japan Sea, etc. Here, we focus on the Japan Sea.
To analyze the gravity changes, we used of the Stokes’ coefficients with degrees and orders complete to 60 from the Level-2 RL-5 data released by CSR, University of Texas, and applied the de-striping filter and the Gaussian filter with average radius of 300km. In our previous report (Doto & Heki, Geod. Soc. Japan, Fall Meeting, 2016), we analyzed data from GSM files, in which the oceanic and atmospheric mass changes are supposed to be removed using various geophysical models. In the present study, however, we added back the values in GAD files to recover the originally observed gravity changes in the ocean. In the GSM files, the gravity maximum occurred in November and the minimum occurred in June in the Japan Sea, and the peak-to-peak amplitude was ~10 cm in equivalent water depth. In the GSM + GAD files, however, the maximum and the minimum moved to October and February, respectively, and the amplitude decreased to ~4 cm (Fig.1). This means that the non-tidal mass change model used to make the GAD files is wrong at least in the Japan Sea.
We compared the GRACE data with the average seasonal variation of the sea surface height using the tide gauge data at the Tobishima and Okushiri (both in Japan Sea) observatories. The tide gauge showed the amplitude ~5 times as large as the GRACE data with maximum in August and September. This result suggests that the sea surface height changes mainly reflect thermal expansion of warm water above the thermocline rather than the real change of the amount of sea water.
Seasonal gravity changes also occur above the land area of Northeast Japan, and its maximum (February to March) suggest that it comes from snowpack in winter. GNSS stations in NE Japan often show clear seasonal movements, and a large part of them comes from the seasonal load, i.e. snow on land and sea water in the Japan Sea. We try to validate the GRACE results by comparing them with the GNSS data on land.

Figure 1: Gravity deviation in October compared with February, converted to equivalent water depth from the GRACE data. We can see the positive deviation in the Japan Sea.

Keywords: GRACE, Water mass variation, Japan Sea, Crustal deformation, GNSS


Japan Sea
Oct.–Feb.
125°
130°
135°
140°
145°
45°
40°
35°
30°
cm
–5
–4
–3
–2
–1
0
1
2
3
4
5

Distributions of elevation-gravity anomaly of subduction zones its mechanical implication

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We classified the global subduction zones based on their gravity and topography distribution to consider the possibility of huge earthquakes.

We used elevation data of Global Bathymetric Chart of Ocean (GEBCO) and Free-air gravity anomaly of World Gravity Map (WGM) by International Gravimetric Bureau (BGI), and volcanic eruption catalogue by National Oceanic and Atmospheric Administration (NOAA).

First, we divided all global subduction zones into shallow and deep ones.

The subduction zones with their trench depth shallower than 6000 m generate M8 or greater earthquakes everywhere. Spatial variation of the gravity anomaly and the elevation around these trenches are so small that further classification based on gravity and topography is difficult. Gravity anomaly is suppressed for the buoyant young lithosphere with shallow trench because Isostasy would be easily established due to its relatively flexible lithosphere.

In contrast, the subduction zone where the trench is deeper than 6000 m does not cause frequent great earthquakes of M8. However, we experienced two M9-class huge earthquakes at off the coast of Tohoku and off Kamchatka Peninsula included in this group. It is impossible to classify the possible source area of huge earthquakes only by the depth of the trench. We divided variation patterns of gravity anomaly around the deeper trenches into four types: 1-a. Steep and monotonic increase from trench toward arc (1 deg or less before reaching the maximum value). 1-b Slow and monotonic increase (larger than 1 deg to reach the maximum value). 2. A small peak with a trough behind it before increase toward arc. 3. Mismatch of trench and gravity minimum: Minimum gravity occurs at arc-side of the trench. Among these four groups, slow and monotonous increase include subduction zones that have ever caused earthquakes of M8 or greater (Japan, Kamchatka, Tonga, northern and middle Chile).

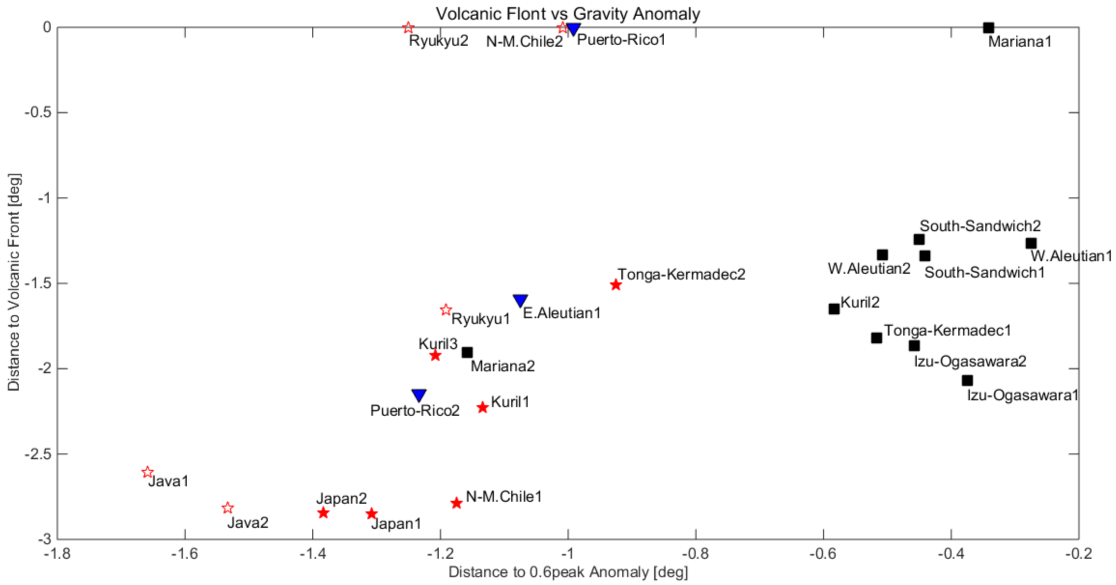
Scatter plot between distances of gravity maximum and volcanic front from trench shows a positive correlation between them. Since the trench distance of volcanic front corresponds to inverse subduction angle, distant gravity peak corresponds to gentle subduction angle of the slab.

Bassett and Wasst (2015) proposed a trench-parallel fore-arc ridges (TPFRs) induced from gravity anomaly and topography. They used deviatoric values of gravity (TPGA=Trench parallel gravity anomaly) and topography (TPTA=Trench parallel topography anomaly) from trench-distance ensemble average for each subduction. They proposed that the down dip limit of inter-plate seismogenic zones corresponds to location of TPRF. This is because stress concentration at the down-dip limit by inter-plate coupling during inter-seismic period cumulate a plastic deformation just above it, which develops TPFRs. They advocate that TPRF is useful as an index for evaluating earthquake potential. Some of the peak gravity locations obtained in this study correspond to that of their TPFRs. This suggests that TPFRs can be seen even in the case of absolute value and there was no big difference as distribution. Furthermore, in our study, the peak of gravity anomalies appears in the fore arc in all of the subduction zones deeper than 6000 m in contrast

that Basset and Wasst (2015) do not necessarily show TPFR for all the trench. Although their subtraction of ensemble average should well emphasize along-trench perturbation for relatively uniform angle subduction zone, subduction zone whose slab angle varies laterally may generate apparent variation of TPGA and TPTA preventing to see actual perturbation due to inter-plate coupling.

As a future research, I will investigate the relationship between the peak of gravity anomaly and seismic activity.

Keywords: subduction zones, huge earthquakes, Free-air gravity anomaly, Elevation, TPFRs



Major earthquakes resulting in gravity changes detected by GRACE

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The twin-satellite mission - Gravity Recovery and Climate Experiment (GRACE) launched in 2002 measure the time-variable gravity (TVG) field. We analyze the GRACE data to study the TVG due to earthquake faulting and the associated mass dislocations in the Earth. Most GRACE TVG signals are directly related to changes in surface processes, primarily the water cycle. So we first strive to remove the terrestrial water signal using the Global Land Data Assimilation System model outputs and the seasonal (annual and semi-annual) signals by the least-squares estimation. Then we apply the method of Empirical Orthogonal Function (EOF) analysis to extract the earthquake-induced TVG signals in the epicentral region in terms of change pattern and time evolution. Our EOF results corroborate past findings of the GRACE TVG signals caused by the greatest recent earthquakes not only for co-seismic but also post-seismic behavior. We do so notably for the 2004 Sumatra-Andaman (Mw 9.1), 2010 Chile (Mw 8.9), and 2011 Tohoku (Mw 9.0) events, as well as somewhat smaller earthquakes including the 2005 Nias (Mw 8.5) event otherwise largely masked by the 2004 Sumatra-Andaman signals, the 2007 Sumatra (Mw 8.5) event, the 2012 Sumatra (double event of Mw 8.2 and 8.6 in one day) event which is largely strike-slip, and even possibly the 2013 deep-focused Okhotsk (Mw 8.3) event. We also conduct least-squares fitting with a co-seismic step function representing the earthquake for every grid point in the considered region, to augment to and confirm the EOF results. Furthermore, assuming a point-source double-couple dislocation and a spherically symmetrical Earth, the earthquake-induced displacement field is expanded by spherical harmonics where components of order greater than 2 vanish. We transform the epicenter to the North Pole in the canonical coordinates and could duplicate the whole TVG signal by spherical harmonics up to degree 60 but only order 2, which accentuates the EOF and least-squares fitting results that are approximated by co-seismic double-couple phenomena.

Keywords: earthquake, gravity change, Gravity Recovery and Climate Experiment (GRACE), Empirical Orthogonal Function (EOF)

Implementation of Domestic Comparison of Absolute Gravimeters Ishioka Geodetic Observing station and construction of Japan Gravity Standardization Net 2016 (JGSN 2016)

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1. GSI of Japan

Geospatial information authority of japan (GSI) has held the Domestic Comparison of Absolute Gravimeters (DCAG) annually since 2002 with several domestic organizations which own absolute gravimeters. By comparing with the results of the FG5 absolute gravimeters, which is operated by the National Institute of Advanced Industrial Science and Technology (AIST) and routinely participate in International Comparison of Absolute Gravimeters supported by BIPM, we could expect to confirm the consistency of our equipment with international standard.
While DCAG had been held at a hotel located in Mt. Tsukuba area until 2015, it was done at GSI's new Ishioka Geodetic Observing Station (Ishioka city, hereinafter referred to as Ishioka station) in 2016. Since Ishioka station has a special room for DCAG as described later, it is expected that we can conduct DCAG much more precisely under better environment.
The gravity measurement facility of Ishioka station is very unique in several respects. It is firmly coupled to the support layer with a plurality of concrete piles and its base plate is isolated from the building in order to reduce the effect of ground vibration. It is designed to set up six absolute gravimeters simultaneously on each points which have precise coordinates decided by GNSS and leveling before the construction. Since Ishioka station also has the VLBI facility, we can utilize the distributed hydrogen maser 's signal to minimize clock errors between absolute gravimeters. Of course, we can expect less artificial noise because of its suburban location. Thanks to those improvements, we successfully achieved good results in the latest DCAG within the range of instrumental error.
GSI has released a new Japan Gravity Standardization Network (JGSN) 2016 in March 2017 for the first time in 40 years. It was composed of both absolute and relative gravity measurement data carried out by GSI between 2002 and 2016. On the course of its measuremments, we used our FG5 calibrated by DCAG to determine the absolute gravity values. DCAG obviously played a key role in making JGSN2016 highly reliable and consistent with the global gravity standards.
We will report the results of past DCAG and its contribution to the JGSN2016.

Keywords: Domestic comparison of Absolute Gravimeters, FG5 Absolute gravimeter, Japan Gravity Standardization Net 2016

Improvement of method that makes Japanese old and dense gravity data consistent with Japan gravity standardization net 2016

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1. GSI of Japan

Geospatial Information Authority of Japan (GSI) have established a new gravity standardization network of Japan, named the Japan Gravity Standardization Net. 2016 (JGSN2016) that is constituted of about 30 absolute measure stations and 200 relative measure station, from the latest land gravity measurements covering the whole country. The accuracy of JGSN2016 is evaluated around 10 micro Gal for absolute measurement and 20 micro Gal for relative measurement in standard deviation. GSI also had conducted relative gravity measurements at benchmarks and some of triangular control points from 1967 to 1993 in order to obtain dense spatial distribution of surface gravity and also utilize them for orthometric height correction of levelling survey. The data obtained by the measurements comes to 14,000 in total, refers JGSN75 and has been utilized for calibration of measurement devices etc. as nationally authorized gravity standard. But these dense gravity data are not consistent with recent measurements referring JGSN2016 and the difference sometimes exceeds range of the measurement error. The maximum difference between JGSN75 and JGSN2016 at the gravity station of GSI is over some 100 micro Gal.
GNSS-derived orthometric height determination has been recently developed. As a result, the importance of land gravity data densely covering the whole country has been gradually increasing because the data has been increasingly utilized as fundamental data for modeling of geoid, a reference surface for orthometric height. The latest, Highly-reliable land gravity data covering the country are essential for improving accuracy and reliability of geoid model. However, it is almost impossible to obtain new data referring JGSN2016 with in short period by newly conducting time- and cost-consuming land gravity measurement for the whole country.
To resolve these problems, we have developed a method that makes Japanese old and dense gravity data consistent with JGSN2016. We reported a solution for that problem in JpGU2016. In the method, we estimated uplift/subsidence displacement of observation station due to crustal deformation, mass redistribution caused by earthquake event and system offset that has existed since establishment of each gravity reference individually. Consequently, we achieve to convert old gravity data to new gravity data in about 40 micro Gal precision. In the method, however, vertical gravity gradient value which is used for convert uplift/subsidence displacement of station to gravity change is assumed that all station have same vertical gravity gradient (Bouguer) value. Therefore spatial variation of vertical gravity gradient is abbreviated.
We newly developed gravity terrain correction program that use 10m mesh DEM data provided by GSI. And we calculated vertical gravity gradient of each station for more precise estimation. In addition, we will present method for calculating displacement of station that takes into account fault geometry and estimation for system offset using data assimilation.
By this research, gravity change that are caused by crustal deformation is estimated. And relation of old and new gravity data is revealed. Thus old and dense gravity data recover accuracy. Consequently, basic data for developing more precise geoid are provided.

Keywords: Japan Gravity Standardization Net. 2016 (JGSN2016)

Absolute gravity measurements in New Zealand (2nd report)

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To enhance and extend the absolute gravity (AG) measurements in New Zealand, we had conducted AG measurements using a FG5 (#210 of Kyoto University) in January and March 2016 as reported in 2016 JpGU meeting. The measurements were made at three points in North Island and five points in South Island. To compliment the AG measurements, we also conducted relative measurements using a LaCoste & Romberg G-meter (#680) at five points from Bilham et al. (2016) in Southern Alps. Among them, two points are located near the summits and only accessible by a helicopter. Thus we could conduct a single loop measurement only, due to restricted time and weather condition in 2016.
Although we have not conducted AG measurements in 2017, relative measurements using two LaCoste & Romberg G-meters (#680 and #805) have been conducted at four points near the summits including the two points occupied in 2016, and conducted two loops of the measurements for those points. In addition to these, we conducted the measurements at most of the AG points occupied in 2016 and some additional points from Stagpoole et al. (2015) for the calibration of the scale factors of the gravimeters, and the gravity connections to the spare points near the AG points. Moreover, for planning the AG measurements in the area of 2016 Kaikoura earthquake (Mw 7.8), we conducted test measurements at a few points where huge uplifts have been observed. In this talk, we present the results in 2017, and the future observation plan particularly in the area of Kaikoura earthquake. This study was partially supported by JSPS KAKENHI Grant No. 15H05205.

Keywords: New Zealand, absolute gravity measurements, gravity network, gravity changes, NZ Southern Alps, Kaikoura earthquake

Comparison of Superconducting and Spring Gravimeters at the Mizusawa VLBI Observatory of the National Astronomical Observatory of Japan

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Continuous microgravity monitoring is utilized to gain new insights into changes in the subsurface distribution of magma and/or fluid that commonly occur beneath active volcanoes. Rather new superconducting and spring gravimeters, iGrav#003 and gPhone#136 are collocated with a superconducting gravimeter, TT#70 at the Mizusawa VLBI Observatory of the National Astronomical Observatory of Japan, since the end of September, 2016 in order to evaluate those performances before field deployment planned in 2017.
Calibration of iGrav#003 was carried out by collocation with an absolute gravimeter FG5 of the Earthquake Research Institute, University of Tokyo (Okubo, 2016, personal comm.) at a Fundamental Gravity Station in Sendai in July, 2016. Based on the scale factors of iGrav#003 obtained by the calibration and of gPhone#136 provided by the manufacturer (Micro-g LaCoste, Inc.), tidal analyses are performed by means of BAYTAP-G (Tamura et al., 1991, GJI). Amplitudes and phases of each major tidal constituent mutually agree well within ±4 % and ±3 degrees, respectively.
The instrumental drift rate of iGrav#003 is very low, about 5 micro-Gal/month, whereas that of gPhone#136 is very high, about 500 micro-Gal/month. The high drift rate of gPhone#136, however, is well approximated by a quadratic function at present and can be removed. The detrended time series of gPhone#136 shows good agreement with iGrav#003 time series in the overall feature: gravity fluctuations with amplitudes of about a few micro-Gal and with durations of a few days, which may be due to variations in the moisture content of the topmost unsaturated sedimentary layer and the water table height. It suggests that both instruments may capture volcanic signals associated with pressure changes in magma chambers, dike intrusion/withdrawing, and so on.
iGrav#003 will be installed in the Zao volcanological observatory of Tohoku University located at about 3 km from the summit crater, and gPhone#136 will be deployed in the Jododaira Astronomical Observatory located at about 0.5 km from Oana crater of Azumayama volcano in the spring of 2017. Both of the volcanoes, Zao and Azumayama show minor volcanic activity with frequent shallow earthquakes, changes in the total magnetic force, pressure changes at depth, and so on in 2014 and 2015.

Keywords: Gravity measurement, Superconducting Gravimeter, Spring Gravimeters, Collocation

Development of a new portable gravity gradiometer for field measurements

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Laser interferometric gravity gradiometers have been expected to be a useful tool for geophysical observation and the basic concepts have been discussed and patented since 1970s. However, they have not been practically applicated to field measurements yet. This is mainly because of the technical difficulty in carrying out repeated measurements with precision sufficient for laser interferometry. To overcome the technical difficulty, a new interferometric gravitygradiometer has been developed [1]. In this gravity gradiometer, a pair of test masses located at different heights (the separation is about 70 cm) is thrown up at the same time in a vacuum tank. The differential acceleration between the test masses in free fall is measured by a Mickelson interferometer. This gravity gradiometer is designed to release the test masses quickly and precisely by applying a mounting method developed for an earth orbiting free-fall experiment (Satellite Test of the Equivalence Principle) [2]. This release mechanism was found to be effective for the realisation of precise repeated measurements [1].

The first prototype of the gravity gradiometer was tentatively operated at the Sakurajima Volcanological Observatory of Kyoto University, located on the active volcanic island of Sakurajima, Kyusyu Japan. From this tentative operation, it was found that the instrument was robust against seismic vibration; the resolution was ±0.3 μGal/m, which is the same level as that operated at a quiet observation station. This result indicates that this gravity gradiometer could detect local underground activities, which are buried in seismic noise and have not been detected by previous gravimeters. However, the first prototype is heavy (weighs about 200 kg) and it was difficult to install it at the local observatory without crane equipment. We are developing a new laser-interferometric gravity-gradiometer that is designed to be portable and more practical for field measurements. In this presentation, I will report the status and prospects of the development.

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Keywords: gravity gradiometer

Monte Carlo Simulation of Gravity Gradient for Observing Volcanic Activity

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Attempts to detect mass distribution changes, associated with volcanic activity, by measuring gravitational fields have been done since the 1920s in Japan. Measurement was done by using the gravity-variometer, such as the torsion balance on the Sakurajima volcano. In the early 1990s, Absolute Gravimeter (FG 5) of Micro-g LaCoste Company, which is simple to use and lightweight, became popular in field measurements. The absolute gravimeter has a resolution of 10^{-8} m/s^2 level when used at a quite observation station. When observing volcanic activity with an absolute gravimeter, it is possible to estimate the height of the magma head from gravity change. However, the absolute gravimeter is sensitive to environmental disturbances, and the error is thought to mislead the height of magma head by several hundred meters.
The instrument we are developing is a new gravity gradiometer. The gravity gradiometer can measure vertical gravity gradients with a resolution of 10^{-9} 1/s^2 level at an observation station with seismic vibration. In this gravity gradiometer, two test bodies are thrown upward at different heights in a vacuum tank at the same time, and the difference between the free fall acceleration of the two test bodies is obtained by a Michelson interferometer. Gravity is proportional to $1/r^2$ and the gravity gradient in the vertical direction is proportional to $1/r^3$, where r is the distance between the gravitational source and the instrument. Therefore, the gravity gradiometer has a better sensitivity to nearby gravity sources, and is suitable for observation of the environmental disturbances, such as rainfall and groundwater fluctuation. Simultaneous observation of the absolute gravimeter and gravity gradiometer at the same observation station could allow us to estimate the displacement of the magma head more accurately.
Assuming a simple volcano model, we have calculated the gravity change by Monte Carlo simulation for Mt. Asama and Sakurajima volcanos, and examined the usefulness of the simultaneous observation of the absolute gravimeter and gravity gradiometer. In this presentation, I will report the results of the simulation and discuss the optimum observation station for the absolute gravimeter and gravity gradiometer.

Keywords: gravity gradient, volcano

Physical modeling of hydrological gravity changes observed by the iGrav-003 superconducting gravimeter in Southeast Alaska

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Crustal uplift of 3 cm/year at a maximum has been observed in Southeast Alaska, associated with glacier melting (Larsen et al., JGR, 2007). The crustal uplift includes (1) the Earth's viscoelastic deformation due to past glacier melting and (2) the Earth's elastic deformation due to present-day glacier melting, and the two effects can be separated by simultaneous observations of crustal deformations and land gravity changes (Wahr et al., GRL, 1995). However, the land gravity data is often disturbed by hydrological variations such as soil water infiltration and groundwater flow, so they need to be corrected from the original gravity data in order to understand the gravity signals due to glacier melting quantitatively. In particular, spatiotemporal water distributions near gravity sites should be modeled accurately, because most of the hydrological gravity disturbances are dominated by time variations in attraction force due to water mass around gravimeters.

We thus modeled the local water balance and consequent gravity changes at the EGAN gravity site in Juneau, Southeast Alaska, and compared the modeled gravity with the hydrological gravity disturbances observed by the iGrav superconducting gravimeter (serial number: 003). We first estimated the spatiotemporal distributions of soil water and groundwater around EGAN using the G-WATER [3D] software (Kazama et al., JGR, 2015), and calculated the time variation in attraction force ($g_1(t)$) by the spatial integral of the water mass distributions. We also estimated the attraction effect of lake water in Auke Lake (120 m from the gravimeter; 0.65 km^2) and accumulated snow on the site facility ($g_2(t)$ and $g_3(t)$, respectively), using the observed data of lake water level and snow depth. We finally calculated the total gravity value to be $g_{cal}(t) = g_1(t) + g_2(t) + g_3(t)$, and compared $g_{cal}(t)$ with the gravity change collected by the iGrav gravimeter ($g_{obs}(t)$).

The gravity change due to underground water ($g_1(t)$) had the highest amplitude of about 4 microGal in peak-to-peak, whereas the amplitudes of both $g_2(t)$ and $g_3(t)$ are about 1 microGal. The sum of the three effects (i.e., $g_{cal}(t)$) agreed with $g_{obs}(t)$ observed from September to December 2012, in terms of rapid gravity increase during precipitation events and gradual gravity decrease after the events. However, the amplitude ratio of $g_{cal}(t)/g_{obs}(t)$ was only 30% if the small value of ~10^{-8} m/s was chosen for soil permeability in modeling underground water variations; strong capillary force in the low-permeability soil leads to high steady water content, and all of precipitation cannot infiltrate into the soil during the precipitation events because of little porosity left. We thus re-calculated the underground water distributions and consequent gravity changes ($g_1(t)$) using six different permeability values, and found that the amplitude ratio of $g_{cal}(t)/g_{obs}(t)$ became the highest value of 55% when the permeability value of $1.5*10^{-6}$ m/s was used in the G-WATER modeling. The permeability value is consistent with that of glacier silt, which is assumed to spread around the EGAN gravity site. The remaining 45% difference between $g_{obs}(t)$ and $g_{cal}(t)$ may lie in soil heterogeneity and/or regional hydrological variations, so direct measurements of soil parameters around EGAN are needed in the future, in addition to gravity calculations utilizing wide-area hydrological model such as GLDAS and WaterGAP.

Keywords: hydrological gravity change, superconducting gravimeter, iGrav, glacier, soil water, groundwater

Constraining the focal mechanism of the 2015 Gorkha earthquake by using the continuous gravity observations

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The amplitudes of the Earth's free oscillations have a close relationship to earthquake focal mechanisms. Focal mechanisms of large earthquakes can be well analyzed and constrained with observations of long period free oscillations.On 25 April 2015, a magnitude Ms 8.1 interplate thrust earthquake ruptured a densely instrumented region of Gorkha. After Earthquake, the focal mechanism solutions of Gorkha earthquake were provided by well-respected international earthquake research institutions based on different data and methods, which were different. We compared free oscillations observed by 18 spring gravimeters of continuous gravity stations with synthetic normal modes corresponding to 3 different focal mechanisms for the Gorkha earthquake, and the focal mechanisms solutions of Gorkha earthquake were analyzed and constrained by spherical normal modes in a 2 to 5 mHz frequency band. Based on the best focal mechanisms solution, the accurate magnitude was searched. The results show that the focal mechanism of Gorkha earthquake can be estimated by spherical modes in the 2 to 5 mHz frequency band. The synthetic modes corresponding to the focal mechanism determined by the Gcmt Moment Tensor Solution showed agreement to the observed modes, the average of misfit factors F was 0.03, and the average of scaling factors was 1.04, which was closest to 1, suggesting that earthquake magnitudes predicted in this way can reflect the total energy released by the earthquake. Based on the focal mechanisms solution provided by Gcmt, keeping the strike, dip, slip, depth constant, adjusting the scalar moment, the real scalar moment was searched. When the average of scaling factors was 1, the average of misfit factors F was only 0.03. After calculation, the scalar moment of Gorkha earthquake was 8.09×10^{20} Nm, and the corresponding magnitude was Mw7.91.

Keywords: Gorkha earthquake, Focal mechanism solutions, Earth's free oscillations, Gravimeter observations