Japan Geoscience Union Meeting 2015
(May 24th - 28th at Makuhari, Chiba, Japan)

SGD21-01 Room:303 Time:May 28 11:00-11:15

Re-examination of absolute gravity changes observed in Southeast Alaska

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Ground gravity measurement is one of the most effective methods to monitor mass variations due to glacial isostatic adjustment (GIA) and present-day ice melting (PDIM). Meanwhile, observed gravity data often contains environmental disturbances such as the effects of spatiotemporal mass variations associated with land water, atmosphere, and oceans, which should be corrected accurately to retrieve the GIA/PDIM gravity signals.

For example, the GIA/PDIM-derived linear gravity decrease of the maximum of -5.6 micro-Gal/year was found from absolute gravity data, obtained at Southeast Alaska every summer in 2006-2008 (Sun et al., 2010). However, the new gravity data measured at the same gravity sites in 2012-2013 was greater than expected from the regression lines of the linear gravity decrease suggested by Sun et al. (2010) by up to 20 micro-Gal (Kazama et al., 2013), because of the excess snow loading associated with the heavier-than-average snowfall in the wintertime of 2011-2012. Although Kazama et al. (2013) corrected the hydrological gravity disturbances (including the excess snow loading effect) from the observed gravity data using the synthetic ground gravity data created by the time series of satellite gravity (GRACE) and ground deformation (GPS), they did not take into account the atmospheric/oceanic gravity disturbances, which might distort their final results about the GIA/PDIM-derived gravity signal.

We were thus motivated to quantitatively evaluate the hydrological/atmospheric/oceanic gravity disturbances in the absolute gravity data measured at Southeast Alaska, in order to re-examine the gravity decrease rate due to GIA and PDIM. We first estimate the atmospheric/oceanic gravity disturbances using the global model AOD1B (Flechtner, 2007), and the hydrological disturbances using the satellite gravity time series collected by GRACE and some hydrological models (such as GLDAS (Rodell et al., 2004) and G-WATER [3D] (Kazama et al., 2015)). We then retrieve the GIA/PDIM-derived gravity changes in 2006-2013 from the observed absolute gravity data by correcting for the above gravity disturbances, and compare the retrieved gravity changes with those of the previous study (Sun et al., 2010).

Keywords: absolute gravity, Southeast Alaska, glacial isostatic adjustment, glacier, snow, soil moisture

Japan Geoscience Union Meeting 2015
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SGD21-02 Room:303 Time:May 28 11:15-11:30

Measuring the Difference between Two Local Vectors: the Gradient of Earth's Gravity Field and the Earth Surface Normal

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Even though concrete support is not yet available, it is widely believed or hoped, that earth quakes, which are generally accidental events on our Earth surface, could be predicted by analyzing historical signals from kinds of geodetic measurements. Directly or indirectly for such a purpose, many comparative analyses have been carried out for constructing an implicit or explicit correlation between the temporal variations of selected measurements and the recorded earthquakes. For instance, in [1] the locally co-seismic and post-seismic variations of the Earth's gravity field for three giant earthquakes (2004, 2010 and 2011) are compared, with a frustrating but just normal conclusion that the observed discrepancies of gravity changes reflect the difference in the settings of the studied earthquakes.

On another hand, based on the development of measurement techniques, geodetic measurements are continually reported with high quality. As an example, ITRF2008 [2] claims a believed origin accuracy at the level of 1 cm over the time-span of 26 year of SLR observations. Integrating four measurement techniques, ITRF2008 provides an accuracy of 8 mm over more than 20 years. With latest technical improvements, it is reasonable to expect even better accuracy in the coming release of ITRF2013 [3].

It seems that a gap between the high quality of geodetic measurements and the relatively less achievement by analyzing them does exist. Normally an accidental event like an earthquake is a local event which happens at a particular time moment covering a close neighborhood of its epicenter. Geodetic measurements are often suffering from densely sampling the dynamical behaviors on Earth. A typical velocity of plate tectonic movements which varies from 1-10 cm/year is indistinguishable from noise in most of daily measurement systems, if the time span is set to be seconds, minutes, or even hours; The system reference of geodetic observation is often set either as man-made satellites, or as natural space objects like lunar or extragalactic reference. These references help us constructing a global coordinate system for geodetic observations with great successes. But still, they are neither convenient nor flexible for densely local observations.

In this paper a new geodetic measurement concept is suggested for local and short time-span observations. Other than going to space pursuing a comparable scale than Earth radius, the suggested concept looks into the atomic scale, while a velocity of 1-10 cm/year is roughly equivalent to 317-3171 pm/s, which is the same scale for observing atomic structures. In this concept a microscope for nano scale observation, e.g., scanning tunneling microscope [4], is required. The observation arm and the sample holding arm are separately assembled as that the observation arm is fixed on the ground, and the sample holder is floating in the air. The sample holder is designed as a long pendulum which keeps pointing to the earth gravity center. The local earth surface normal, and the local gradient of the earth gravity field, are two vectors in the system. Within short time span like seconds it is possible to measure the different temporal variations between them, based on the different earth dynamics of lithosphere and earth mass distribution.

Without systematic ambiguities like non-modeled forces in space, signal delay in ionosphere, as well as the troposphere distortions, the suggested concept physically is promising for a new geodetic measurement.

References:

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[2] Z. Altamimi etc.: ITRF2008: an improved solution of the international terrestrial reference frame, 2011;
[3] Z. Altamimi etc.: Status of ITRF2013 and early results, 2014;
[4] C. J. Chen: Introduction to Scanning Tunneling Microscopy, 1993.

Keywords: Geodetic Measurement, Atomic scale, Plate movement, Velocity, Gradient of gravity field, Microscope

Japan Geoscience Union Meeting 2015
(May 24th - 28th at Makuhari, Chiba, Japan)

SGD21-03 Room:303 Time:May 28 11:30-11:45

VLBI application for Frequency Transfer and Development of GALA-V System (V)

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1. Introduction

NICT is conducting a development of the new broadband VLBI system for distant frequency comparison. This project, named GALA-V, is intended to make precise frequency comparison between atomic frequency standards by VLBI observation of celestial radio sources with 3 ? 14 GHz. Advantages of using VLBI technology with respect to the two way satellite time and frequency transfer (TWSTFT) are simultaneous multi station comparison by single VLBI session and freedom of from availability of communication satellites. Additionally VLBI method is not affected by precision of orbit information of GNSS satellites. From the view point of broadband observation system, ours is semi-compliant with the VGOS (VLBI2010 Global Observing System), which is under development as next generation geodetic VLBI system in international VLBI community. Thus this system is not only useful for distant frequency comparison, but also for precise geodesy.

NICT has originally developed broadband feed for Kashima 34m radio telescope. And small diameter broadband VLBI antennas and data acquisition systems were installed at NICT Koganei and National Metrology Institute of Japan (NMIJ) in Tsukuba, where standard time UTC[NICT] and UTC[NMIJ] are maintained, respectively. By joint use of the 34m antenna and two small antenna systems, measurements of UTC[NICT]-UTC[NMIJ] have been performed.

For contribution to geodesy, we have made a series of test experiments between Ishioka VGOS station, which is established by GSI in 2014, and Kashima 34m antenna. In January 2015, we have successfully observed super broadband signal over 8GHz frequency range and cohelently synthesized for the first time. Additionally, the first international broadband VLBI experiment was successfully performed among Kashima 34m, Westford 18m antenna at MIT Haystack observatory, and GGAO station at NASA/GSFC.

2. VLBI Frequency Comparison between NMIJ and NICT.

Small diameter antenna systems of GALA-V have been installed at NICT Koganei, where Japan Standard Time (JST) is maintained, and NMIJ, where atomic time standards are developed. Since accurate measurement result of difference between UTC[BIPM] and UTC[NICT], UTC[NMIJ] are regularly reported to BIPM (Bureau International des Poids et Mesures), thus NICT-NMIJ is good test bed for development of VLBI system for frequency comparison. Further long term comparison and employment of broadband system will be tested in this year.

3. Super broadband VLBI observation with Ishioka VGOS Geodetic Station of GSI

The GSI has established a new VGOS 13m diameter antenna (hereafter Ishioka 13m antenna) at Ishioka geodetic station in 2014. This antenna is domestically the second largest telescope with broadband receiver. We have conducted a super broadband VLBI experiments between Kashima 34m antenna and Ishioka 13m antenna. Signal from celestial radio source was observed by six observation bands (1GHz bandwidth) allocated in 6-14GHz frequency range. The data was acquired by newly developed direct-sampling technique. After correlation processing of the data, signal was synthesized coherently over 8GHz bandwidth. This was the first achievement and theoretical delay precision reaches to several tens of femto seconds! Of course precision in real measurement is degrade by a number of causes. Further evaluation of actual delay precision will be made.

4. The First International VLBI Experiment with Broadband Systems.

The GALA-V project is not only developing original new technology such as direct-sampling data acquisition technique, but also keeping compatibility with VGOS system is in the scope for joint international observation. In January 2015, we have successfully made the first international VLBI experiment with broadband feed between Kashima 34m antenna, and Westford 18m antenna, and GGAO 12m antenna. The observation data were exchanged between Japan and U.S.A. through high speed network of JGN-X, APAN, and Internet2.

Keywords: Very Long Baseline Interferometory, Time and Frequency Transfer

Japan Geoscience Union Meeting 2015
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SGD21-04 Room:303 Time:May 28 11:45-12:00

Improvement of the accuracy in seafloor acoustic ranging by estimating the spatio-temporal temperature variation

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Direct-path seafloor acoustic ranging is widely used to detect crustal deformation. The idea is simply to monitor a baseline length by multiplying sound speed to the round-trip time between transducer and transponder installed on the seafloor. A transducer transmits the acoustic wave and a transponder record. Sound velocity is a function of temperature, pressure and salinity, among which the temperature is most effective on seafloor. Thus, evaluation of temperature field plays a key roll on this measurement.

In the past studies, time-varying uniform temperature field is assumed employing a simple average of measured temperature at the both ends of the baseline. This results in large apparent fluctuation in measured baseline length, especially during rapid temperature change. So, we tried to infer the spatio-temporal temperature field by applying a simple advection model of temperature field..

We proposed an equation of temperature T(x,t) which linearly interpolates between measured temperature data for both x (space) and t (time). Typical change in the temperature is thought to be associated with the semidiurnal tide, so field advection is postulatedas simple 12-hours harmonic oscillation with arbitrary phase and amplitude. Measured temperature at both ends are basically in coherent with certain time-lag. Any individual deviation at each site can be consistently formulated by linear interpolation in time and space. We assessed the formulation by inverting a given temperature field using synthetic temperature data. If there are temperature data at three sites, the formula can be easily expanded to 2-D temperature field by linear interpolation between the two baselines..

We also tried to apply the formula to real data. In 2007, the acoustic ranging test was conducted at Kumano-nada [Osada, Y., M. Kido, and H. Fujimoto, *Ocean Engineering*, 2012]. Significant improvements in the stability of apparent baseline length were found when the advection vector is clear from the original temperature data. Base on this result, the formula is effective if the sampling frequency of temperatures is high enough (about 30 min. to 1 hour), while the acoustic ranging itself can be infrequent.

Currently, we only verified the formula for the time windows in where the advection vector is clear. Without knowing advection, the formulation cannot be applicable. The advection is estimated based on coherency and time-lag between the temperatures at the both ends of the baseline, however, it is not possible to estimate it for time window with smaller temperature variation or non-coherent behavior. The best way to know temperature field is dense measurement along the baseline. Although the advection of temperature field is not always equivalent with flow of water, it should be valuable to introduce currently meter or to make rough estimate from time varying attitude of the instrument. In the different point of view, it could be worth to utilize the fine-scale assimilated ocean model, JCOPE-T (provided by Application Laboratory, JAMSTEC), which can predict local temperature variation.

Keywords: Seafloor geodesy, Acoustic ranging, Seafloor temperature, Tidal current, Extensometer

SGD21-05 Room:303 Time:May 28 12:00-12:15

Noise assessment of the kinematic GNSS analysis for GPS/Acoustic observation by precisely controlled movable table data

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The seafloor geodetic observation techniques are extremely important for understanding of the spatial and temporal heterogeneity of the interplate coupling. Especially, GPS/Acoustic (hereafter GPS/A) techniques have been developed for practical use in the past ten years, which allowed offshore measurement just above the expected strong coupling region in the plate boundary. The conventional observation style of the GPS/A is campaign style, which repeatedly observed by the research vessel. Recently, several groups have proposed continuous style GPS/A observation based on the moored buoy system.

The one of key technique of GPS/A observation is high-rate sampling precise/accurate positioning of floating section (e.g. research vessel, moored buoy) based on kinematic GPS analysis. A required precision/accuracy is typically smaller than several tens mm in the horizontal components even though it depend on the required precision by user. On the other hand, true position of such moving body is generally unknown.

Based on these backgrounds, we developed the precisely controlled movable table for the assessment of the precision/accuracy of the kinematic GPS (GNSS) analysis. The developed precise movable table consists of uniaxial small electric actuator device and its control unit. The maximum movable stroke of the actuator is 200mm, and the resolution of moving step is 0.1mm/pulse. We implemented a several moving pattern to the developed table. One of the moving patterns is modeled upon the research vessel. We used the velocity data obtained by 10Hz GPS Doppler measurement in the actual research vessel. We applied high-pass filtering after the integration of velocity data to the displacement. Obtained displacement strongly reflects the ship rolls and/or pitches, so we used this data as true value of the moving body. Based on the developed movable table, we tested the precision of the kinematic GPS analysis. We used the dual-frequency GNSS (GPS and GLONASS) receiver with 10Hz sampling for the test. For the test, we compared with real-time kinematic PPP time series and known movable table motion. As a preliminary result, obtained 10Hz time series by real-time kinematic PPP time series shows the good agreement with known movable table motion during the short period of time ($<$several hundred seconds). In contrast, the large discrepancy clearly appeared between both time series in the long period of time. It caused by the high noise level of kinematic PPP time series in the low frequency band. These experiments should be important for understanding of the noise property of the kinematic GNSS analysis for the moving body.

Keywords: kinematic GNSS, moving body

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SGD21-06 Room:303 Time:May 28 12:15-12:30

The effect of snowfall on the solution of GEONET (2)

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The routine solutions of geodetic coordinate of observation stations of GEONET, F3 solution, are fundamental data for the studies of crustal deformation and tectonics and widely utilized for a variety of purposes. As GEONET data is available freely, researchers can discuss the crustal deformation or tectonics without carrying out GNSS observation or baseline analysis. However, it should be noted that the coordinates provided by GEONET may include errors caused by various noise sources or factors. One of the significant error sources is the effect of snowfall, especially the stuck of the snow on the radome of GEONET sites. We reported that the effect of heavy snow fall on the February 2014 caused notable perturbation on the GEONET solution in Yamanashi prefecture, on the 2014 fall meeting of the Geodetic Society of Japan. We investigated other GEONET sites on same date and those sites on other heavy-snowy days with abnormal F3 solution. We will report how snowfall affected the GEONET solution on those cases, combining the GEONET solutions and he meteorological data in time series.

Keywords: GEONET, GNSS, positioning, error, snowfall

Japan Geoscience Union Meeting 2015
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SGD21-07 Room:303 Time:May 28 12:30-12:45

Development of a new precise positioning technique using multi-GNSS signals

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Geospatial Information Authority of Japan (GSI) is developing and standardizing new precise positioning techniques which deal with multiple GNSS constellations, GPS, QZSS, GLONASS, Galileo, and Beidou, in order to mainly encourage effective surveys at places where it is currently difficult to carry out them using only GPS satellites.

In FY 2014, we examined analysis methods to correct Inter System Bias and to using single/double differences between Beidou and other GNSS. Moreover, in case of using Beidou, we need to correct Inter-satellite-type Bias which is 1/2 cycle shift between GEO and MEO, IGSO. In addition, we obtained multi-GNSS data in five cities and evaluated the effects and problems using multi-GNSS signals.

This presentation shows results of FY 2014.

Keywords: GNSS, Geodetic Survey, Beidou

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SGD21-P01 Room:Convention Hall Time:May 27 18:15-19:30

Gravity variations and vertical displacements over the Japanese islands

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We are going to analyze satellite gravity data for the Japanese islands and discuss the characteristics of gravity variations in each region. To corroborate our results of gravity analysis, we shall show the comparison results with vertical crustal deformation from GNSS observation.

Keywords: time-variable gravity, vertical displacement, GRACE, GNSS, cryology, hydology

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SGD21-P02 Room:Convention Hall Time:May 27 18:15-19:30

Verification of the separation precision between tropospheric and coordinate parameters in kinematic PPP analysis

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Recently, kinematic GNSS analysis is generally used for crustal deformation phenomena within the day such as postseismic deformation after the large earthquake. The kinematic GNSS analysis, however, have a fundamental problem for the separation precision between unknown parameters such as the coordinate and tropospheric parameters, because of the both parameters have strong correlation between each others. In this study, we focused on the improvement of the separation precision between coordinate time series of kinematic GNSS and wet zenith tropospheric delay (WZTD).

We used GIPSY-OASIS II Ver. 6.3 software for the processing of whole sites of the GEONET in 10th March 2011. We applied the kinematic PPP strategy for the coordinate estimation. In the processing, we applied the every 6 hours nominal WZTD value as a priori information based on the ECMWF global numerical climate model. We also processed the data without a priori information for the comparison. In the processing, we assumed the white noise and random walk stochastic process for the coordinate time series and tropospheric parameters, respectively. These unknown parameters are very sensitive to assumed process noise parameters for each stochastic process. Thus, we also evaluated the effect of process noise value for WZTD parameter. We changed the value for the WZTD as (1) 1×10^{-8}, (2) 1×10^{-7} and (3) 1×10^{-6} (unit: km/sqrt(sec)).We named the model applied a priori information of WZTD as "A" , and named the A1, A2, and A3 model for the each different process noise parameter result. In the same way, we named the result without a priori value as "N" and named N1, N2, and N3 model represented the each process noise result.

Based on these results, we found that clear offset in estimated WZTD value appeared between result with or without a priori information. It suggests that the a priori information of WZTD may give the impact to the accuracy of the vertical coordinate time series. Furthermore, the standard deviations of estimated coordinate time series did not depend on the with/without a priori value of the WZTD. It strongly depends on the assumed process noise of the WZTD. For example, the standard deviations of UD component at 0430 (Imabari) site in each model of A1, A2, A3, N1, N2, N3 are 20.9, 26.0, 44.2, 20.8, 26.0, 44.2 (unit: mm), respectively. This results suggest that the assumption of optimal process noise may be important for the precision. In the presentation, we will propose the optimal value of process noise in order to obtain time series of kinematic GNSS analysis with high accuracy and precision from more data sets.

Keywords: GPS, kinematic PPP analysis, tropospheric delay

SGD21-P03 Room:Convention Hall Time:May 27 18:15-19:30

The formation of equatorial flattening of the Earth

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The supercontinent Pangea is formed 330 Ma ago and followed with a sequence of breakup after 100 My. During the supercontinent Pangea occuured, the mantle convection of very long-wavelengths at spherical harmonic degree-1.After the African continent is formed a degree-2 structure,the Africa and Pacific superplumes show major upwellings(Zhong et.al.,2007;Zhang et al.,2010).The degree-2 structure for the present-day mantle with the Africa and Pacific superplumes is shown as the equatorial flattening of the present Earth. The evolution from the degree -1 to the degree-2 is due to change of the convective flows from a downwelling to a upwelling under the Pangea supercoontinent.Here we attempt to explain the formation of the equatorial flatterning by considering that chemical diffusion of a light element FeO compared with Fe into the OC(outer core) from the IC(inner core) through the ICB(inner core -outer core boundary)and from the mantle through the CMB(core-mantle boundary) respectively in the eastern hemisphere (40 deg.E-180 deg.E).Mass loss of the degree-1 in the mantle and the IC causes anisotropic mass distributions relative to the center of the Earth's gravity. The center of gravity of the mantle and the IC shift towards the western hemisphere(180 deg.W-40 deg.E).These shifts induce additional modes of Y221 to the Earth's geopotential. The fluid OC keeps an axially symmetric form. The Earth has an equatorial flattening form for a long time.The rotational speed of the mantle will be increase,but the rotational speed of the IC and OC will be decrease because of the radius of the IC increases and mass inflow from the mantle repectively.The thermal stable stratification near the CMB and the ICB increases thermal transport to the mantle.

Keywords: Pangea supercontinent, Africa continent, FeO diffusion, Earth's equatorial flattening, rotational speed, thermal transport