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

SGD23-01 Room:105 Time:May 25 13:45-14:00

A Robust and Wide Area GPS Monitoring System by PPP-AR

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Real Time Kinematic (RTK) solution is usually applied to monitor Earthquake, Volcano, Landslide, Buoy and any real time events. When strong earthquakes occur, RTK has possibilities of getting not accurate coordinate because the reference station may move together. Precise Point Positioning (PPP) is other method for real time solution and it works without reference station. But the accuracy is not enough to monitor such events.

To solve this problem, we have developed new GPS real time monitoring system by PPP with Ambiguity Resolution (PPP-AR). PPP-AR needs correction data from reference station network. We do not have to set up the network close to client station because it can apply to almost 1000km area. And the accuracy is almost equal to RTK.

We designed several local reference networks in Japan in our system. We run parallel solutions for one client station with each correction data from these networks in real time. When any movements happen in a network, our system selects other area's data automatically. Therefore, we can get accurate results robustly.

Keywords: PPP-AR, GPS Monitoring system

Japan Geoscience Union Meeting 2012
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SGD23-02 Room:105 Time:May 25 14:00-14:15

Estimation of precipitable water by way of analysis of all sites of nation-wide GEONET network

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In NIED for the study to improve the accuracy of heavy rainfall nowcasting in the Tokyo metropolitan area, we run the CReSS high-resolution atmospheric model assimilating the observation data of multi-parameter (MP) radar network. To accurate the model assimilating the accurate precipitable water observation data to the model, we run the automated system to calculate near-realtime hourly GPS precipitable water of about 150 GEONET network sites in the area every three-hour applying the RINEX file downloaded from GSI ftp server.

In addition, since 2011 fiscal year for the area of Osaka and Nagoya metropolitan areas and major local cities where flood disasters attacked before, we run the CReSS high-resolution atmospheric model when heavy rainfall attacks to clarify the atmospheric rainfall mechanism assimilating the observation data of the MLIT MP radar network. To accurate the atmospheric model assimilating the accurate precipitable water observation data it is required to calculate the accurate GPS precipitable water of the GEONET sites in and around the regions.

On the other hand, NIED established the automated system to estimate accurate site coordinates of all of nation-wide GEONET network sites applying the IGS ultra-rapid ephemeris and RINEX files automatically downloaded from GSI ftp server every day just after the observation for the development of the dynamic geodetic coordinates control system.

Thus in this study we have developed the system to calculate the accurate site coordinates of all of the GEONET network sites applying IGS rapid and final ephemerides and using the RINEX files obtained above, and to estimate the accurate vertical coordinate of all GEONET network sites automatically every day using the latest 30 days vertical coordinate solutions, and to calculate the GPS precipitable water of the sites in and around the region of the heavy rainfall anywhere domestic Japan immediately when flood disaster attacks, assimilating the GPS precipitable water to the CReSS model.

Keywords: GPS precipitable water, analysis of all GEONET sites, mechanism of heavy rainfall precipitation

Japan Geoscience Union Meeting 2012
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SGD23-03 Room:105 Time:May 25 14:15-14:30

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

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GSI is developing and standardizing a new precise positioning technique which deal with multiple GNSS constellations, GPS, QZSS, GLONASS and Galileo, in order to mainly encourage effective surveys at places where are currently difficult to carry out them by only GPS satellites. This project is composed of 1)Development of suitable analysis methods with multi-GNSS, 2)Evaluation of the methods, and 3)Standardization of the precise positioning technique.

In fiscal year 2011, we examined existed analysis methods which cope with both classic GPS signals (L1 and L2) and modernized signal (L5) or multi-GNSS signals. Then we designed basic outline of the new software by integrating and expanding those ideas. In addition, we carried out preliminary experiments by using real multi-GNSS signals.

This presentation shows a blueprint of the project, results of FY 2011 and future plans from FY 2012.

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SGD23-04 Room:105 Time:May 25 14:30-14:45

GLONASS-R: A novel GNSS reflectometry solution based on software defined radio

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Other than GPS or Galileo, the Russian GLONASS system uses frequency-division multiple access (FDMA) to transmit the signals of the satellites to the user. This feature can be used to develop a GNSS-R system which works without the knowledge of replica codes and enables cross-correlation of direct and reflected signal in a simple and straightforward way. By applying this processing strategy any arbitrary coherent integration length can be achieved without knowledge of the navigation bits. We are going to summarize this novel method and present first results taken with our prototype system.

Keywords: GNSS, GLONASS, Software defined radio, Reflection

Japan Geoscience Union Meeting 2012
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SGD23-05 Room:105 Time:May 25 14:45-15:00

Extraction of the vertical seafloor movement recorded on ocean bottom pressure data by applying ICA

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In order to extract the vertical seafloor movement from ocean bottom pressure data obtained by the multi-point observation, we introduced Independent Component Analysis (ICA). The Ocean Bottom Pressure (OBP) change due to the predicted amount of seafloor vertical movement is comparable to or slightly less than that due to dynamic ocean processes. Therefore, it is needed some new methods that enable us to separate and/or extract the slow-slip component from the OBP data. ICA is one of the multivariable analysis techniques, which have been applied in the field of the speech processing and the electroencephalogram analysis [e.g., Common, 1994]. Since the spatio-temporal scale and the distribution of the slow-slip component is likely significantly different from those of oceanic components, ICA is expected to be a powerful method to separate them. In this study, we used FastICA algorithm developed by Apro Hyvarinen (see http://www.cs.helsinki.fi/u/ahyvarin/papers/fastica.shtml). To evaluate the practical performance of FastICA, we performed some experiments using the test data. The test data is a sum of the OBP data and the simulated slow slip event. The OBP data was obtained on 2009, which is a quite time in earthquakes, in Miyagi-Oki region [Hino et al., 2009]. The slow slip event was generated based on the result of numerical simulation shown in Hino et al. [2009]. Before ICA, tidal components were eliminated from OBP data by using BAYTAP-G. Also, sensor drifts were corrected by linear fitting function in advance. We applied FastICA to the test data on the assumption that the number of significant sources is 3. As a result, the artificial slow slip event was successfully extracted as the first independent component. The second and third independent component was likely corresponding to oceanic components. For comparison, we also applied Principal Component Analysis (PCA) to the test data described above. The result clearly showed the superior performance of FastICA for extracting the slow slip event from OBP data.

Keywords: slip event, ocean bottom pressure observation, seafloor movement, Independent Component Analysis, Principal Component Analysis

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SGD23-06 Room:105 Time:May 25 15:00-15:15

Warkworth geodetic station as a potential GGOS core site in New Zealand

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Auckland University of Technology (AUT) has constructed a 12-m radio telescope (WARK12M) in New Zealand near Warkworth, 60 km north of Auckland. It was launched October 2008 as New Zealand's first research capable radio telescope for the purpose of both astronomy and geodesy. Prior to that, GPS was the only space geodetic technique in New Zealand. WARK12M is collocated with GNSS station WARK belonging to the PositioNZ network operated by Land Information New Zealand. Warkworth is currently the only geodetic station in New Zealand that has the capability to become the national GGOS (the Global Geodetic Observing System) core site. Currently VLBI coverage of the Southern Hemisphere is low so Warkworth is an important new addition for the GGOS project.

The GGOS goal is an origin definition at 1mm accuracy or better and a temporal stability of the order of 0.1mm/yr, with similar numbers for the scale and orientation components. As a GGOS core site has to provide stable and high quality outputs, here we reconsider the geodetic analysis procedure at Warkworth, including ocean tide loading at the site. The displacements due to ocean tide loading calculated for Warkworth are up to +/-10mm for the horizontal components, and +/-40mm for the vertical component. A high-resolution land-sea data grid representation of the coastline is one of the important components for calculation of an accurate site-dependent ocean tidal coefficient. We compare the ocean tide loading displacements calculated using different grid data. One of the site-dependent coefficients was calculated by the Ocean Tide Loading Provider maintained by the Onsala Space Observatory. Another was calculated using GOTIC2 software with the Shuttle Radar Topography Mission data set, which provides 3 arc-second grid data all over the world. Differences between the ocean tide loading displacements in the two models were less than 1mm for the East-West component, +/-1mm for the North-South component, and +/-2mm for the vertical component. These differences are significant for the goal of 1mm target accuracy, demonstrating the importance of the right choice of coastline grid data.

Here we will discuss what is necessary to become a GGOS core site. In addition, we show the progress on the experiment we are conducting jointly with Japanese VLBI stations to provide ultra-rapid EOP result.

Keywords: VLBI, GNSS, GGOS, ocean tide loading

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SGD23-P01 Room:Convention Hall Time:May 25 10:45-12:15

Green's function in the non-integer dimensional space: the fractional Laplacian for the fault zone

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Generally, the crust materials have a various scale of the discontinuous property. Since the effect of the discontinuity can be described quantitatively by the non-interger property of the space (e.g., Fractal geometry), we consider the Green's function in the non-interger space. Especially, we take up the fractional Laplacian as follows:

(-¥Laplacian)$^{a/2}$ $f(r)$=-$g(r)$ (1)

where a is the order of the differentiation and the real number. When a=2, this is the ordinary Laplacian, therefore, f is, for instance, the volumetric strain or the trace of the stress tensor and so on; g is the perturbative force. Except when a is an even number, the distance dependence of the Green's function is given by the Riesz potential:

$G \sim r^{a-2}$ (2)

From this relationship and the Laplacian of the dimension D, we obtain

D+a=4 (3)

except when a is an even number. For instance, when a=1 and 3, we have $G \sim 1/r$ and $G \sim r$, respectively. These are the well-known results in the thee-dimensional and the one-dimensional space. Note that since a is the real number, Eq. (3) shows that the dimension D can also take a non-interger values. For instance, when a=1.5, i.e., D=2.5 dimensional space, the Green's function take the form: $G \sim r^{-0.5}$.Since a itself is defined as the order of the differentiation, the larger number of a means that the problem, described by the fractional Laplacian, becomes more non-local. Eq. (3) shows that the order of the differential is inversely proportional to the number of the dimension of the space. In fact, as the D grows larger, the problem becomes more local. This is a phenological interpretation of Eq. (3).Our conclusions are as follows: (1) In the discontinuous space such as a fault zone, the order of the fractional differentiation has a relationship with the number of the dimension of the space. (2) This relationship determines the concrete form of the distance dependency for the Green's function in the non-integer dimensional space.

Keywords: non-integer dimension, Green's function, Fractional Laplacian, Fault zone

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SGD23-P02 Room:Convention Hall Time:May 25 10:45-12:15

Crustal deformation monitoring in the Asia-Pacific region

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Geospatial Information Authority of Japan (GSI) has been operating continuous GPS observation in the Asia-Pacific region and analyzing the data combined with IGS data obtained in the region. Purpose of the observation and analysis is to monitor crustal deformation in the region and establish regional reference frame consistent with ITRF. In order to establish analysis strategy for estimating enough stable coordinates for the purpose, we performed past data analysis and evaluate the stability of the estimated coordinate of the network composed of long baselines up to several thousand kilometers. This time series also includes gaps caused by events such as earthquakes. Therefore, we also evaluate detection capability of this analysis for crustal deformation.

Keywords: Asia-Pacific region, GPS, Long baseline, Crustal deformation, Bernese

Japan Geoscience Union Meeting 2012
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SGD23-P03 Room:Convention Hall Time:May 25 10:45-12:15

Ultra-rapid EOP measurement with e-VLBI system

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Earth Orientation Parameter (EOP) is essential data for orbit control of an artificial satellite, space exploration or analysis of GPS data. Although the EOP values are calculated by international VLBI observations operated by International VLBI Service for Geodesy and Astrometry (IVS), IVS needs a lot of time (from several hours to several weeks) to obtain EOP values, because it takes a lot of time to process the VLBI data.

Although we conduct some data analysis, we use the final solution of EOP which is calculated using the observed EOP values on VLBI observation. The final solution includes the prediction EOP values, of which accuracies decrease with time. Therefore, many users of the EOP solution require submission of observed UT1 value as soon as possible after the observation.

Geospatial Information Authority of Japan (GSI) has implemented a number of experiments for quasi real-time estimation of UT1 value, which is one of parameters of EOP, since 2007. We introduced the system for quasi real-time estimation into an international VLBI session, and it enabled us to obtain and submit the UT1 results within a few minutes after the observing session of regular VLBI session. In 2011, we have implemented test observation on East-West and South-North baseline and succeeded in ultra-rapid measurement of XY coordinate of polar motion as well as UT1. We will report our recent activities in the presentation.

Keywords: VLBI, UT1, EOP, e-VLBI

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SGD23-P04 Room:Convention Hall Time:May 25 10:45-12:15

Fully automated multi-baseline VLBI analysis with c5++

HOBIGER, Thomas[1*], OTSUBO, Toshimichi[2], SEKIDO, Mamoru[1]

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Automated processing of UT1 single baseline session has been demonstrated by Hobiger et al. (2010) and is currently applied to regular INT2 sessions as well as ultra-rapid test sessions. We have extended the concept of fully unattended session analysis to multi-baseline sessions and applied it successfully to three station EOPs experiments. Thereby the ambiguity resolution is the crucial part which needs to be handled by a robust and straightforward algorithm before the estimation of the geodetic target parameters could start. Based on our software c5++, we will present a simple multi-baseline ambiguity resolution approach and demonstrate its effectiveness. Moreover we discuss results from real-time EOP estimation experiments and give an outlook how this would affect VLBI2010 operation.

Keywords: VLBI, analysis software, EOP

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Development of the space-time information justification verification system of the GNSS satellite using VLBI correlation

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We challenged the new GNSS justification observation to verify the space-time information using CUDA GPU. For this purpose we have to develop the two-dimensional FFT search software for the VLBI-type delay and delay rate using very long FFT chip data longer than 32M points. It consumes very long time such as 2.6sec for 1 line of FFT even using Core i7 CPU. Thus we developed CUDA GPU FFT technology and got the dramatically improved results of 0.0141sec. We also developed the 2D visual verification software from many kinds of GNSS satellite group by calculating the orbit of GNSS and we successfully linked with CUDA FFT system. Using this system we succeeded to verify the GNSS justification.

Keywords: CUDA, GNSS, VLBI, Correlation processing, FFT, GPU

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SGD23-P06 Room:Convention Hall Time:May 25 10:45-12:15

Radio Environment Survey for the Development of Wideband Receiver Antenna of VLBI2010 Specification.

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The VLBI2010 specification, which is under the development in the international geodetic VLBI community as the next generation observation system, is targeting to improve the measurement precision by increasing sensitivity through wide radio frequency observations. VLBI group of NICT has developed 2.4m diameter radio telescope with wide band receiver system (MARBLE), and we are going to use it for 10km baseline validation and for a tool of time-frequency transfer over the long distances. Furthermore, upgrading of MARBLE for the new VLBI antenna of Antarctica is being considered.

However wideband receiver system has disadvantage of vulnerability to radio frequency interference (RFI) such as increasing number of base stations of mobile phone. We have made radio environment survey at Kashima and Koganei sites, where MARBLE1 and 2 are placed, with another type of wideband receiver system. Its results indicated that radio frequency range lower than 3GHz was suffered from strong interference of mobile phone, wireless LAN, ground-TV broadcasting and so on. Thus VLBI systems of VLBI2010 specification need workaround to avoid these radio signals. MARBLE systems at NICT are suffered from these RFI and we are going to introduce high-pass-filter (HPF) to cut radio signal below 3GHz. This paper will present the results of radio environment survey and will show some test observation results after the workaround of the RFI.

Keywords: VLBI2010, Wideband Receiver, Radio Frequency Interference

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SGD23-P07 Room:Convention Hall Time:May 25 10:45-12:15

Variations in the equatorial flattening of the inner core

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[1]none

The inner core shows degree one hemispherical variations between the eastern hemisphere and the western hemisphere, and beneath the middle Africa. In the cylindrical coordinate frame of which axis is coincide with the rotation axis,deformation of the inner core is expressed as variations of the equatorial flattening of the inner core. Here we discuss gravitational coupling between the inner core and the mantle associated with deformation of the equatorial flattening of the inner core. The motion of the outer core is characterized by a velosity potential. The velosity components must vanish at infinite distancs and the normal velocity at any point of the surface on the ICB (the inner core boundary) must be equal to the velosity of the surface at that point normal to itself. Heat flow due to phase changes from the fluid to solid is assumed to be distributed as an axially symmetric around the rotation axis. The flow generates a thermal wind and relative rotation of the inner core. The density gradient in the eastern and western hemispheres in the top 400 km of the inner core induces the equatorial flattening to be 1.69 x 10 -5. This value shows about 2.8 times larger than Szeto and Yu's value 6 x 10 -6 (1997).The local variations of the equatorial flattening can excite the mantle and inner core libration (Bufffett,1996; Zu et al.,2000;and Aurnou and Olson,2000).

Keywords: inner core, equatorial flattening, mantle, gravitational coupling, outer core, libration

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SGD23-P08 Room:Convention Hall Time:May 25 10:45-12:15

Evaluation of coordinate correction parameter of the 2011 off the Pacific coast of Tohoku Earthquake

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The 2011 off the Pacific coast of Tohoku Earthquake with a moment magnitude of 9.0 occurred on 11 March, 2011. Remarkable crustal deformation associated with the earthquake was observed by the GPS-based control stations in an extensive area of eastern Japan. Geospatial Information Authority of Japan (GSI) suspended the publication of survey results of control points located in eastern Japan on 14 March, 2011, because these control points largely moved and the survey results needed to be revised.

The most desirable method to revise the survey results of control points is to conduct observations at all the control points in order to improve the accuracy of the coordinates. However, it is not realistic because the number of control points which were affected by the earthquake was more than 40,000.

Crustal deformation associated with the earthquake was relatively uniform, so GSI carried out observations at about 2,000 control points, and revised the coordinates of the other control points by calculation using coordinate correction parameter.

In this presentation, we will report the method of calculation and the result of evaluation of coordinate correction parameter of the 2011 off the Pacific coast of Tohoku Earthquake.

Keywords: the 2011 off the Pacific coast of Tohoku Earthquake, survey results, coordinate correction parameter

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SGD23-P09 Room:Convention Hall Time:May 25 10:45-12:15

Simultaneous Observation of GPS and Radiosonde

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Bangladesh is one of the countries of very heavy rain in the world. National mean of annual rainfall is as large as 2000 mm and the rainfall exceeds 5000 mm/yr locally in the northeastern part of the country. In this study we compare precipitable water estimated from fixed continuous GPS observations (GPS-PW) with that obtained from radiosonde measurements (sonde-PW) and also with the daily precipitation at the surface. GPS observations were conducted at Bangladesh Meteorological Department in Dhaka (DHAK) and Sylhet (SYLT) for about 100 days from May to August, 2011. SYLT is located about 200 km northeast of DAHK. GPS data were processed with the precise point positioning method of GIPSY-OASIS II Ver.6.0, and zenith tropospheric wet delay (ZWD) was estimated every five minutes together with three components of coordinates. The ZWDs were converted to GPS-PWs by using a constant coefficient of 0.16 and then averaged to produce an hourly mean. Radiosonde systems were provided by International Met Systems. iMet 1-AA radiosondes were launched at 0000UTC at DHAK, and iMet 1-AB radiosondes were launched at 0600UTC and 1200UTC for one week in the beginning of May. GPS-PW and sonde-PW are consistent with each other at SYLT; the difference of them is about 2.6 mm in rms. On the other hand sonde-PW is systematically larger by about 10 mm than GPS-PW at DHAK. Since two GPS-PW estimates at DAHK and SYLT are very similar, the difference is smaller than 5 mm in rms, we need to check sonde-PW measurements at DAHK. GPS-PW time series at two sites show an increase of about 20 mm in the first one month during the pre-monsoon and then remain almost flat at around 60 mm during the monsoon. This change represents a transition from the pre-monsoon season to the monsoon season. GPS-PW shows spike-like peaks synchronizing to the rainfall.

Vertical component of the coordinates at DHAK shows a subsidence of about 4 cm in about three months. The subsidence may be caused by a decrease of groundwater level near DHAK (Steckler et al., 2010). The term of GPS observation corresponded to a rainy season from pre-monsoon to monsoon but there is a time-lag between rainfall and increase of groundwater level. We interpret that ground uplift that occurred in the dry season before the observation turned to a delayed subsidence. In contrast no subsidence was observed at SYLT. It can be explained that heavy rainfall at SYLT throughout the year preserves a high groundwater level without a significant fluctuation. Steckler et al. (2010) have reported annual variation of vertical component with amplitude larger than 6 cm near DAHK. The subsidence of about 4 cm in three months at DAHK may show a partial seasonal variation. Observations in longer time span are needed to quantify seasonal to annual variation.

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Diagnosis of troposphere-induced positioning errors using high-resolution numerical weather model

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In the routine analysis of GEONET, positioning errors caused by the tropospheric delay have been occasionally observed, which make the crustal deformation monitoring a difficult task. In the case study, we found that the characteristic positioning errors observed in the routine analysis of GEONET were reproduced using numerical weather model and the induced mechanism of errors was clarified.

In this research, we investigated which the numerical weather model is useful for diagnosis of troposhpere-induced positioning errors in various typical weather conditions such as seasonal rain front, typhoon, extratropical cyclone, and so on. For this purpose, we used the numerical weather model with 1.5km horizontal resolution and 30-minute temporal resolution computed by the Weather Research and Forecasting (WRF) model while assimilating JMA meso-scale analysis data. We produced simulated GPS observation datasets using Satellite Positioning System Simulator (SPSS) developed by GSI with the numerical weather model data. Then, we analyzed simulated GPS data by the PPP method using GIPSY-OASYS ver.6.1 to estimate positioning errors due to troposheric delay. In presentation, we will report on these results.