Japan Geoscience Union Meeting 2011
(May 22-27 2011 at Makuhari, Chiba, Japan)

SGD021-01 Room:201A Time:May 23 08:30-08:45

Degree one motion of the inner core and Earth rotation

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The Earth's inner core shows degree one hemispherical variation of anisotropy in the eastern hemisphere(40 degE-180 degE) and in the western hemisphere(180 degW-40 degE).The hemispheical difference may be explained by unequal growth of the inner core. Wen(2006) showed that the Earth's inner core radius enlarged locally beneath middle Africa by 0.98 to 1.75 kilometers from 1 December 1993 to 6 September 2003. In this report we add the gravitational torque of the outer core caused from the surface deformation of the inner core to the gravitational coupling between the mantle and the inner core.We express the form of the outer core to be a cylinder of elliptic cross section in the elliptic coordinate frame. The volume of the outer core is assumed to be the same volume as the outer core excluding the volume of the tangent cylinder of the inner core. By taking account of Wen(2006) results the semimajor axis of the outer core is assumed to be increase 100 m.. The elliptic form of the inner core also depends on the one dimensional gravitational coupling torque between the mantle and the inner core. We assume the outer core to be a rigid body. If the directions of the semimajor axes of the outer core and the inner core do not coincide, the axial gravitaional torque acts to restore the outer core and the inner core to the gravitaional equilibrium position. This torque relates to the figure of the inner core and the motion of the outer core is transferred to the motion of the mantle. The results show that the free oscillations of the mantle and the outer core, and that the free oscillation period of the mantle (92 years in the previous result) is shorter than the previous value,due to variations of the semimajor axis of the inner core.

Keywords: inner core, outer core, mantle, gravitaional torque, degree one motion, Earth rotation

Japan Geoscience Union Meeting 2011
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SGD021-02 Room:201A Time:May 23 08:45-09:00

Polar motion due to the 2010 earthquake in Central Chile and long-term polar motion due to earthquakes

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Mass redistribution associated with earthquake faulting causes the shift of the Earth's rotation axis and changes in LOD (Length of day). In Chile, the great earthquake occurred on 27 February 2010. GRACE gravity observations showed a negative jump with the largest drop of ˜5 micro gal, and this corresponds to ˜8 cm shift of the Earth's inertial axis (Heki and Matsuo, GRL 2010). In the meetings in the last autumn, we reported our attempt to detect this polar motion by geodetic observations. Atmosphere and ocean are the main factors to excite polar motions. We tried to remove their contributions (both motion and mass terms) using NCEP data and ECCO model, respectively. However, the 2010 ECCO model was not available then, and we could not correct the oceanic contribution before and after the 2010 Chilean earthquake. Hence, the discussion on the polar motion was not adequate. In the present meeting, we hope we can correct for the oceanic excitation during 2010 and discuss the issue fully.

In addition to this topic, we will also discuss the excitation of long-term polar motion due to earthquakes. We calculated the earthquake-induced polar motion excitation. Seismic excitation of the polar motion is smaller than the observation by two-orders of magnitude, and in the opposite direction to the observed motion toward Greenland. It was pointed out that the seismic excitation has a strong tendency to move the pole towards ˜140E (Chao et al., 1996, Spada, 1997). Large earthquakes in subduction zones generally makes dent in geoid, and move the pole (the north pole if the earthquake occurred in the northern hemisphere) toward the epicenter. The preferred direction would reflect the occurrence of such earthquakes in the northwestern (˜140E, mid-latitude) and southeastern (antipodal to it) rims of the Pacific Ocean.

Keywords: The 2010 Chilean earthquake, polar motion, mass redistribution, earth rotation parameters

Japan Geoscience Union Meeting 2011
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SGD021-03 Room:201A Time:May 23 09:00-09:15

Ultra-rapid dUT1 measurement with high-speed network

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UT1 (Universal Time 1) is essential data for orbit control of an artificial satellite, space exploration or analysis of GPS data. Although the UT1 value is calculated by international VLBI observations operated by International VLBI Service for Geodesy and Astrometry (IVS), it takes several hours or several days to obtain UT1 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 UT1 which is calculated using the observed UT1 value on VLBI observation. The final solution includes the prediction UT1 values, which accuracies decrease with time. Therefore, many users of the UT1 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 since 2007. In 2008, we introduced the system for quasi real-time estimation into an international VLBI session, and it enables us to obtain the UT1 results within a few minutes after the observing session of regular VLBI session. GSI became an IVS analysis center in April, 2010. Since then, we have improved the system and checked the qualities of the results. I will report our recent activities in my presentation.

Keywords: VLBI, UT1, EOP, High-speed network, ultra-rapid

Japan Geoscience Union Meeting 2011
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SGD021-04 Room:201A Time:May 23 09:15-09:30

Results of Geodetic VLBI Observations by Compact Antennas

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[1]GSI of Japan, [2]NICT, [3]AES

The Geospatial Information Authority of Japan (GSI) has carried out experiments of geodetic VLBI observations by using a compact antenna with a diameter of about 1.5 m, in collaboration with the National Institute of Information and Communications Technology (NICT). The compact antenna can be removed from its basement which is also available for the basement of GPS antenna. Thus we can directly compare the results of VLBI observation with those of other geodetic technique. Moreover the compact antenna is so portable that it enables us to carry out VLBI observations everywhere. Hence we study the compact antenna as a new generation of VLBI techniques.

Large antenna with a diameter over 30 m is necessary for us to obtain high precision geodetic results with the compact antenna. We carried out geodetic observations by using two compact antennas, first prototype at NICT Kashima Space Research Center and second prototype at GSI, and two large antennas, Kashima 34 m and Tsukuba 32 m. Then we obtained geodetic results of seven observations since December 2009. These observations include a wideband observation on 12 November 2010 in which we directly sampled intermediate frequency signals (500 MHz bandwidth) of S and X band with a sampling rate of 2 Gbps in order to obtain a higher precision result. We will report on the results of experiments of the compact antenna.

Keywords: VLBI, geodesy, compact antenna

Japan Geoscience Union Meeting 2011
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SGD021-05 Room:201A Time:May 23 09:30-09:45

VLBI2010 and GGOS

Shinobu Kurihara[1*], Jiro Kuroda[1], Misao Ishihara[1], Kensuke Kokado[1], Ryoji Kawabata[1]

[1]GSI of Japan

The International VLBI Service for Geodesy and Astrometry (IVS) had been considering the next generation VLBI system named ”VLBI2010”. The IVS approved the specification of the VLBI2010 system in the IVS General Meeting held in France in March 2009, and the member organization of IVS proceeded in working toward VLBI2010. VLBI2010 is necessary for the Global Geodetic Observation System (GGOS) proceeded with the International Association of Geodesy. In this report, I'll talk about the outline of VLBI2010, the situation of the effort for VLBI2010 in the world and the relationship with GGOS.

Keywords: VLBI, VLBI2010, IVS, Global, IAG, GGOS

Japan Geoscience Union Meeting 2011
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SGD021-06 Room:201A Time:May 23 09:45-10:00

Combining different types of data for inverse ill-posed problems

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Data assimilation theory for geophysical inverse problems

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The method of generalized cross-validation (GCV) has been widely used to determine the regularization parameter, because the criterion minimizes the average predicted residuals of measured data and depends solely on data. The data-driven advantage is valid only if the variance?covariance matrix of the data can be represented as the product of a given positive definite matrix and a scalar unknown noise variance. In practice, important geophysical inverse ill-posed problems have often been solved by combining different types of data. The stochastic model of measurements in this case contains a number of different unknown variance components. Although the weighting factors, or equivalently the variance components, have been shown to significantly affect joint inversion results of geophysical ill-posed problems, they have been either assumed to be known or empirically chosen. No solid statistical foundation is available yet to correctly determine the weighting factors of different types of data in joint geophysical inversion. We extend the GCV method to accommodate both the regularization parameter and the variance components. The extended version of GCV essentially consists of two steps, one to estimate the variance components by fixing the regularization parameter and the other to determine the regularization parameter by using the GCV method and by fixing the variance components. We simulate two examples: a purely mathematical integral equation of the first kind modified from the first example of Phillips (1962) and a typical geophysical example of downward continuation to recover the gravity anomalies on the surface of the Earth from satellite measurements. Based on the two simulated examples, we extensively compare the iterative GCV method with existing methods, which have shown that the method works well to correctly recover the unknown variance components and determine the regularization parameter. In other words, our method lets data speak for themselves, decide the correct weighting factors of different types of geophysical data, and determine the regularization parameter. In addition, we derive an unbiased estimator of the noise variance by correcting the biases of the regularized residuals. A simplified formula to save the time of computation is also given. The two new estimators of the noise variance are compared with six existing methods through numerical simulations. The simulation results have shown that the two new estimators perform as well as Wahba estimator for highly ill-posed problems and outperform any existing methods for moderately ill-posed problems. More details on this topic can be found in Xu et al. (2006, J Geodesy, 80, 69-81), Xu (2009, Geophys J Int, 179, 182-200) and Shen, Xu and Li (2011, submitted).

Keywords: inverse problems, data assimilation

Japan Geoscience Union Meeting 2011
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SGD021-07 Room:201A Time:May 23 10:00-10:15

Development of a compact absolute gravimeter (6)

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Absoute gravimeters can measure gravitational acceleration with an accuracy of 10{sup}-9{/sup}, and are useful for detecting crustal deformation and transfer of underground fluid, especially expected for diagnosing volcanic activity.

We have developed a prototype of a compact free-fall absolute gravimeter by means of new fringe-signal processing, correction of ground vibration using an active control of the reference mirror, and miniaturizing a free-fall mechanism. We are working on further reduction of its size and improvement of portability in the field. The details of the improvements, the performance including accuracy, and its practicality will be presented.

Keywords: geodesy, gravity, absolute gravimeter, laser interferometer, free fall

Japan Geoscience Union Meeting 2011
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SGD021-08 Room:201A Time:May 23 10:15-10:30

Compact and highly sensitive tiltmeter

Akiteru Takamori[1*], Alessandro Bertolini[2], Riccardo DeSalvo[3], Toshihiko Kanazawa[1], Masanao Shinohara[1], Akito Araya[1]

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The details of a novel compact tiltmeter will be reported as well as the results of test observations.

Keywords: tiltmeter, folded pendulum, optical transducer, ocean bottom, borehole

Japan Geoscience Union Meeting 2011
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SGD021-09 Room:201A Time:May 23 10:45-11:00

Towards the Utilization of QZSS for GPS surveying: Test observation at Tsukuba Baseline Field

Hiromichi Tsuji[1*], Hiroshi Yarai[1], Tomoo Toyoda[1], Tomohiro Yahagi[1], Kenji Yoshida[1], Yuki Hatanaka[1], Hiroshi Munekane[1], Satoshi Kogure[2], Jiro Yamashita[2], Motoyuki Miyoshi[2], Hiroaki Tateshita[2], Yaka Wakabayashi[2], Tomoji Takasu[3]

[1]GSI of Japan, [2]JAXA, [3]TUMSAT

Geospatial Information Authority of Japan (GSI) and Japan Aerospace Exploration Agency (JAXA) jointly conduct a test observation of Quasi Zenith Satellite System (QZSS) at Tsukuba Baseline Field of GSI. This is one of the first technical evaluations of GPS availability enhancement of QZSS.

We obtained GPS and QZSS data using JAXA's GNSS receivers manufactured by JAVAD at 14 stations for 24 hours. GPS baseline solutions with/without QZSS will be compared under various elevation cutoff angles using RTKLIB software developed by Tokyo University of Marine Science and Technology and GAMIT software modified by GSI.

Towards the early realization of multi-GNSS surveying environment, GSI will take necessary steps in collaboration with JAXA, including a new 4 year R&D project for multi-GNSS analysis method from 2011FY.

Keywords: QZSS, GPS augmentation, surveying

Japan Geoscience Union Meeting 2011
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SGD021-10 Room:201A Time:May 23 11:00-11:15

Development and availability of a new positioning technique using GPS augmentation information from QZS-1 'Michibiki'

Toshihiro Yahagi[1*], Kenji Yoshida[1], Tomoo Toyoda[1], Hiroshi Yarai[1], Hiromichi Tsuji[1], Yuki Hatanaka[1], Hiroshi Munekane[1], Yuki Kuroishi[1]

[1]GSI of Japan

The first satellite of the Quasi Zenith Satellite System (QZSS) named 'Michibiki' was launched on September 11th 2010 successfully. Michibiki has a unique orbit in order to stay long hours above Japan region and provide services even under non-open sky environment like urban areas and mountainous regions. Michibiki transmits two types of signals. Ones are completely compatible and interoperable with existing and modernized GPS signals (L1-C/A, L1C, L2C and L5). By transmitting those signals, Michibiki is expected to improve GPS satellite constellation by working as an additional GPS satellite. And the others are Michibiki's original signals, L1-SAIF and LEX, which are used for broadcasting augmentation messages.

GSI has developed a new precise positioning technique by using the augmentation parameters on the LEX signal. The goal of this method is the realization of cm-level positioning by a single-frequency GPS receiver with about 15minites observation. The parameters on LEX signal are generated from real-time data collected by the GPS Earth Observation Network system (GEONET). We carried out experimental surveys by using data from Michibiki and drafted the geodetic surveying specification to encourage a use of this technique in Japan.

This presentation shows the details of the new developed technique, evaluation results of experimental surveys and drafting specification.

Keywords: QZSS, GPS augmentation, surveying

Japan Geoscience Union Meeting 2011
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SGD021-11 Room:201A Time:May 23 11:15-11:30

Comparison of Ka-band Rainfall Attenation Measurement between radio interferometery and Nowcast data for WINDS satellite

Hirokazu Sato[1]*

[1]Yokohama National University

A rain attenuation on the Ka band has been measured with weather data by Japan Meteorogical Agency and with their own rainfall meters.

We have developed Ka band radio interferometer to measure the complex fringe data of WINDS satellite radio wave.

We compared the estimated rainfall attenation with the NowCast data of Japan Meteorological Agency and conventional data of rain attenuation.

Keywords: WINDS, Rainfall Attenation

Japan Geoscience Union Meeting 2011
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SGD021-12 Room:201A Time:May 23 11:30-11:45

Mass loading contribution for seasonal variation of GPS time series in southeast Alaska

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We assess contributions of mass loading effects to GPS time series seasonal variation in southeast Alaska.

In southeast Alaska shows very rapid uplift, with peak rates exceeding 30 mm/yr based on the mainly campaign GPS observation, which are mainly caused by GIA due to the effects of past and present-day ice melting [1]. The almost continuous sites, however, clearly shows the strong seasonal variation in vertical components. It may be interfered with precise vertical velocity estimation. In this study, we consider well-known mass loading for the GPS time series correction, which contain atmosphere, snow and soil moisture loading effect.

We re-analyzed the PBO (Plate Boundary Observatory) GPS data in and around Alaska region using PPP (Precise Point Positioning) approach implemented in GIPSY-OASIS II Ver. 6.0. We applied VMF1 mapping function and reproduced JPL precise orbit and clock products (flinnR products). Obtained GPS vertical component time series clearly show seasonal variation. The Green's function approach is adopted to calculate site displacements from various mass loads [2]. We used the NCEP/NCAR reproduced product as atmospheric pressure data for loading calculation. Mass redistribution from variations of snow cover (snow water equivalent, SWE) and soil moisture is derived from the assimilated model of GLDAS (Global Land Data Assimilation System [3]). Compared with GPS and synthetic displacement time series generated by all loading component, both time series are basically agreement with each other. The synthetic time series, however, underestimate seasonal variation amplitude. The mass loading can explain only 30 % of annual signal amplitude. The one of the inconsistency reason include the inaccurate GLDAS SWE data set because of GLDAS SWE amount is not consistent with ground observation result.

[1] Larsen et al. (JGR, 2005)
[2] Farrell (Rev. Geophys. Space Phys, 1972)
[3] Rodell et al. (Bull. Amer. Meteor. Soc., 2004)

Japan Geoscience Union Meeting 2011
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SGD021-13 Room:201A Time:May 23 11:45-12:00

Performance Comparison of High-Rate GPS Receivers for Seismology

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High-rate GPS observations with higher than once-per-second sampling are getting increasingly important for seismology. A number of reports have shown that high-rate GPS receivers are capable of capturing the ground vibration due to earthquakes. Unlike a traditional seismometer which measures short period vibration using accelerometers, the GPS receiver can measure its antenna position directly and record long period seismic wave and permanent displacements as well. The high-rate GPS observations are expected to provide new insights in understanding the whole aspects of earthquake process.

The ground vibration due to an earthquake is composed of a wide spectrum of frequencies. In general, the seismic energy in frequency spectrum decreases toward higher frequency, and the corner frequency is around several to tens of hertz depending on the earthquake magnitude. In order to grasp such a wide frequency range, the GPS receiver is required to provide higher data sampling rate. The receiver also needs to maintain lock to the GPS signals under high acceleration and high jerk environment due to the earthquake.

In this study, we investigated dynamic characteristics of the high-rate GPS receivers capable of outputting the observations at up to 50Hz. This higher output rate, however, doesn't mean higher dynamics range of the GPS observations. Since many GPS receivers are designed for low dynamics applications, such as static survey, personal and car navigation, the bandwidth of the loop filters tend to be narrower in order to reduce the noise level of the observations. The signal tracking loop works like a low-pass filter. Thus the narrower the bandwidth, the lower the dynamics range. In order to extend this dynamical limit, high-rate GPS receivers might use wider loop bandwidth for phase tracking. In this case, the GPS observations are degraded by higher noise level in return.

In addition to the limitation of the loop bandwidth, higher acceleration due to earthquake may cause the steady state error in the signal tracking loop. As a result, kinematic solutions experience undesirable position offsets, or the receiver may lose the GPS signals in an extreme case.

In order to examine those effects for the high-rate GPS observations, we made an experiment using a GPS signal simulator and several geodetic GPS receivers, including Trimble Net-R8, NovAtel OEMV, Topcon Net-G3A, and Javad SIGMA-G2T. We set up the zero-baseline simulation scenario in which the rover receiver was vibrating in a periodic motion with the frequency from 1Hz to 10Hz around the reference station. The amplitude of the motion was chosen to provide up to 10G acceleration to emulate high frequency and high acceleration earthquake motion.

The simulation results showed that the amplitude was too small when the frequency was higher than 5Hz, and kinematic solutions were buried under the noise level. The jerk was also too high in such high frequency region, and no receiver was capable of maintaining signal lock. Many receivers lost signal under the acceleration higher than 4G. We also found that the accuracy of high-rate GPS observations was independent of sampling rate of the receivers, and the 50Hz sampling rate provides better resolution to the kinematic solutions.

Our experiment suggested that, in the given environment and receiver sets, higher sampling interval was recommended to measure the ground motion in higher resolution. On the other hand, the dynamic characteristics of the signal tracking loop put a limit on the frequency and the acceleration of the antenna motion, and it would be quite difficult to capture the ground vibration with higher than 5Hz in frequency and 4G in acceleration. We will further continue our experiments to find the optimal configurations of the high-rate GPS receivers to monitor seismic events.

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SGD021-14 Room:201A Time:May 23 12:00-12:15

Evaluation of real-time PPP performance with IGS real-time precise ephemerides

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PPP (precise point positioning) is a precise positioning technique by using carrier-phase observables of GNSS satellite signals. Compared to general baseline analysis, PPP has a merit that it does not need any reference station. Conventionally, PPP is utilized in post-processing mode which needs precise ephemeris provided by IGS (International GNSS service). IGS had been have the activity to provide its products in real-time as RTPP (real-time pilot project) since about 10 years ago. The RTPP already started to broadcast the real-time ephemeris products via Internet with RTCM ver.3 SSR (state space representation) format and NTRIP (Networked Transport of RTCM via Internet Protocol). The ephemerides contain not only for GPS but also for GLONASS. The performance of PPP much depends on the quality of used ephemerides and has not been well evaluated. In this study, we continuously collected IGS real-time ephemeris via Internet for about half year and evaluated real-time PPP performance with such IGS real-time products. For the experiment, we used RTKLIB version 2.4.0 which provides real-time and post-processing PPP modes. The evaluation results include accuracy of solutions, convergence time, comparison between with GPS only and with GPS/GLONASS.

Keywords: Precise Point Positioning, IGS, precise ephemeris, real-time

Japan Geoscience Union Meeting 2011
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SGD021-15 Room:201A Time:May 23 12:15-12:30

A GNSS-R system based on software defined radio

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[1]NICT

The remote sensing community has an increasing interest in analyzing GNSS reflections as they provide valuable information about the physical characteristics of the reflection area. This technology operates usually with two antennas in order to monitor direct and reflected signals. One up-looking (RCHP) and one down-looking (LHCP) antenna is deployed at the same site and analysis of the differential delay and/or the cross-correlation function w.r.t. to delay and Doppler shift allows to deduce the physical properties of the scattering surface. In order to develop a GNSS-R off-the-shelf system RHCP and LHCP L1 active patch antennas are utilized together for this purpose. Signals are sampled directly in the RF and sent to a PC over a Gigabit ethernet connection. This allows us to implement the system as a software radio using readily-available, low-cost RF hardware and commodity processors. Field tests are carried out on a 60m high telecommunication tower located NICT's headquarter in Koganei, Tokyo.

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SGD021-16 Room:201A Time:May 23 12:30-12:45

Evaluation of IGS reproduction precise ephemeris applying the analysis of Japanese domestic GPS network data (Part 2)

Seiichi Shimada[1]*

[1]NIED

International GNSS Service (IGS) revised the conditions to calculate GPS precise ephemerids after 1400 GPS week (November 5, 2006) and 1410 GPS week (January 14, 2007). IGS recalculates precise ephemerides for the weeks before 1410 GPS week applying the same conditions with those after 1410 week (IGS reproduction ephemeris).

Shimada (2010) evaluates IGS reproduction orbit analyzing about 90 GEONET and 5 NIED GPS network sites in Tokai-Izu area for the period during 1997 and 1998 with about 15 IGS network sites in and around Eastern Asia applying the IGS reproduction orbit and the IGS final orbits and comparing the site coordinates repeatability of the Tokai-Izu sites obtained using those two orbits. In the analysis site coordinates, zenith delay parameters, tropospheric gradients, and ambiguities of Tokai-Izu and IGS sites, orbit parameters, and the EOP parameters are estimated. By the comparison there is very little difference between the repeatabilities applying those two orbits. The little difference may be caused by the orbit relaxation approach in the analysis adopting the ITRF2005 site coordinates and velocities (Altimimi et al., 2007) for the IGS fiducial sites, and the approach makes very little difference between those two improved orbits.

Therefor in this study we fix those two orbits and analyze the same datasets with the same conditions but fixing orbits, and compare the site repeatabilities of the Tokai-Izu sites applying the IGS reproduction and final precise ephemerides. In the result the averages and standard deviations of the sites repeatabilities of Tokai-Izu sites applying the IGS reproduction orbit are 2.0 +- 0.9 mm, 2.6 +- 0.8 mm, and 6.4 +- 1.3 mm for N-S, E-W, and U-D components respectively. On the other hand, those applying the IGS final orbit are 2.1 +- 0.9 mm, 3.0 +- 0.8 mm, and 7.1 +- 1.2 mm respectively. Judging with the standard deviation the difference is not significant, but especially for E-W and U-D components the repeatabilities of the reproduction orbit seem to improve compared with those of the final orbit.

Keywords: IGS reproduction precise ephemeris, site coordinates repeatability