Activities of the United Nations for the enhancement of Global Geodetic Reference Frame

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The United Nations General Assembly adopted its resolution, “A Global Geodetic Reference Frame for Sustainable Development”, on February 26, 2015, recognizing that Global Geodetic Reference Frame (GGRF) is essential fundamental infrastructure for social, economic and scientific activities. This resolution is the first resolution on the importance of a globally-coordinated approach to geodesy and urges Member States to jointly develop and maintain sustainable GGRF under globally-coordinated multilateral cooperation. The resolution includes six Operational Paragraphs which urge Member States to establish a Roadmap for the enhancement of GGRF, enhance technical assistance and capacity building on geodesy, and maintain and improve their geodetic infrastructure and so on. Working Group established by the United Nations Committee of Experts on Global Geospatial Information Management (UN-GGIM) for drafting the resolution also drafted the Roadmap and the Roadmap was adopted by UN-CCIM at its sixth session in August 2016. In the roadmap, the Working Group clarifies current issuers for maintenance of sustainable GGRF, then suggests the possible solutions and finally presents future vision for the further enhancement of GGRF on the five items indicated in the resolution, that is Geodetic Infrastructure, Data Sharing, Policies, Standards and Conventions, Education, Training, and Capacity Building, Communication and Outreach, and Governance. In the sixth session, the committee also decided to officially escalate the WG to sub-committee and asked the sub-committee to develop an implementation plan which encourages further implementation of recommendations in the Roadmap. The sub-committee will start drafting the implementation plan on the five items and take over the activities of the WG as a key player for cooperation on sustainable GGRF. The Geospatial Information Authority of Japan (GSI) has contributed to drafting of the Roadmap as a member of the WG and will participate in the sub-committee and contribute to drafting of the implementation plan.
In the presentation, I will report on recent activities of the group of geodetic experts under the United Nations on development of sustainable GGRF.

Keywords: Global Geodetic Reference Frame (GGRF), the United Nations, GGRF Roadmap

Preparatory research on the development of rapid and accurate GNSS routine analysis system

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The Geospatial Information Authority of Japan routinely analyzes GNSS data obtained by GEONET and monitoring crustal deformation all over Japan. The results, crustal deformation data and seismic fault models associated with main shock or postseismic movement, are used to evaluate earthquake activity by the Earthquake Research Committee (ERC) of the Headquarters for Earthquake Research Promotion and the Assessment Committee for Areas under Intensified Measures against Earthquake disaster. Also, the crustal deformation data are used by the Coordinating Committee for Prediction of Volcanic Eruptions as fundamental data for monitoring deformation of mountain body of active volcano and, when eruption occurred, monitoring eruptive activity.
However, even up-to-date routine analysis result sometimes do not have enough rapidness or time resolution. At present, even the result of the most rapid routine analysis, Q3-solution, needs three hours after GEONET data acquisition. In case of the 2016 Kumamoto Earthquake occurring at the night of April 14, crustal deformation information by Q3-solution is obtained on the morning of April 15. Special meeting of the ERC is usually held half a day after the large earthquake occurred. So for the case of the Kumamoto Earthquake, it had possibility that the crustal deformation information offered by GSI would have been late for the meeting and understanding of the earthquake would have got delayed.
Another problem is the time resolution of the solution. For even Q3-solution, which has highest time resolution, the time resolution is six hours. In case of the Kumamoto Earthquake again, three hours after the shock of M6.5 on April 14, an aftershock of almost same magnitude occurred and it also seemed to cause crustal deformation in addition to those caused by the first shock. However, the crustal deformation information using Q3-solution given to the special meeting of the ERC on the afternoon of April 15, cannot distinguish between the crustal deformation caused by the first shock of M6.5 and those caused by the aftershock, which had some difficulties in the understanding of the earthquake. Moreover, present routine analysis do not have enough time resolution for monitoring inflation and deflation of volcanic body before and after eruption. It may have difficulty in evaluating volcanic activity.
These days the GNSS analysis method called Precise Point Positioning (PPP) gains publicity, which is more rapid, has high time resolution and has comparable accuracy to the routine analysis method of GEONET. The principle of PPP is that using precise orbit and clock information of GNSS satellites, GNSS point positioning is performed on each station. The feature of PPP is that the position of the stations in every epoch can be calculated with small calculation load. Moreover, adding corrective information called Fractional Cycle Bias (FCB), which differs for each satellite, enables ambiguity resolution in PPP (called PPP-AR), which is likely to result in the accuracy almost same as GNSS interferometric analysis. In addition, PPP-AR does not need fixed reference station which has advantage when crustal deformation occurs over wide area by large earthquake and it is difficult to find the point that is not subjected to the deformation.
On the background above, GSI has started a three-year research project since the April of 2017. In the project, we will develop more rapid and accurate GNSS analysis method based on PPP-AR and make prototype system implementing this method envisioning future GEONET routine analysis. The goal of this research is routinely and stably obtaining the solution of one-second interval within about two hours after data acquisition with typical repeatability of about 1cm in horizontal component.
In this presentation, I introduce a framework of the system under consideration and the result of the

preparatory research.

Keywords: GNSS, PPP-AR, GEONET routine analysis, GEONET

Technical development for expanding availability of GNSS precise positioning in urban environment

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Geospatial Information Authority of Japan (GSI) is developing new software-based techniques mitigating multipath effects in order to expand availability of GNSS precise positioning in urban environment.
In FY 2015, we have selected four promising techniques from previous studies related to mitigating multipath effects, and developed validation programs as follows.
1) Selecting line-of-sight satellites with cutoff masks generated by fish-eye lens photos taken at observation stations
2) Selecting line-of-sight satellites with cutoff masks generated from 3D maps
3) Quality check of observation data based on phase differences of Doppler observables
4) Improvement of precision based on velocities from Doppler observables
In FY 2016, we conducted 12 hour observations under severe conditions in Kobe city, Hyogo prefecture for examining the effects of satellite constellations. We also conducted 5 minute observations at various stations for examining the effect of obstruction of the sky. We validated the four selected techniques by applying them to observation data.
In this presentation, we report the result of FY 2016 and future plan.

Keywords: GNSS positioning, multi-path, urban environment

Analysis of GEONET network data applying ITRF2014 reference frame and IGS14 antenna PCV model

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On the meeting of the Geodetic Society of Japan in 2016 fall, we have introduced the difference of coordinates of IGS fiducial sites in and around Japan from ITRF2008 to ITRF2014 coordinate system, as well as the preliminary result of the analysis of GEONET sites applying the ITRF2014 coordinate system.
On the other hand, IGS switches reference frame from ITRF2008 to ITRF2014 staring GPS week 1934 (29th January 2017). Actually IGS adopts the reference frame IGS14 closely related to ITRF2014 (IGSMAIL-7399). At the same time IGS introduces a new SV and ground antenna model, IGS14.
Mainly because of the SV antenna offset, scale differs by around 0.4 ppb by this revision. In addition, the revised calibrations for numerous ground antennas causes 10mm in height and 5mm in horizontal coordinates solutions (King, private communication).
Before IGS switched reference frame from ITRF2005 to ITRF2008 from 1632 GPS week (11th April 2011), as well as the SV and ground antenna PCV models from IGS05 to IGS08. At that time also mainly according to antenna PCV offset causes around 1 ppb scale and 3mm vertical and 1.2mm horizontal coordinates offset (IGSMAIL-6354). On the other hand, in the analysis of the GEONET network sites in Kanto-Tokai district applying GAMIT/GLOBK program, around 2ppb scale and around 2mm in height and 3mm in horizontal coordinates offset are detected (Shimada, 2011, 2012). The difference between the analysis of the global and the GEONET networks may be caused because GEONET adopts original antenna radome, and the PCV models of GEONET sites are determined by the original field test carried by GSI. Moreover, GSI determines only IGS05 PCV model, thus we determined ourselves GEONET sites IGS08 PCV model using the GEONET IGS05 PCV model and the difference between the IGS05 and IGS08 PCV models released by IGS.
In this paper, we present the scale and coordinates offsets of the GEONET network sites, determined applying the analysis of eight weeks GEONET network observation before and after 29th January 2017, when IGS switches reference frame to IGS14.

Keywords: ITRF2014, ISG14 PCV model, GEONET

Soft Computing and Conventional Interpolation Methods in Geoid Modelling: A Case Study in Istanbul

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Geoid is the fundamental geodetic infrastructure for rational use of Global Navigation Satellite System (GNSS) technology. For this reason, definition a "cm geoid" is an actual subject in all countries. Development of geoid modelling is based on geodetic, gravimetric and astrogeodetic techniques, which are maintained using the geopotential models produced by the combination of gravity measurements, astrogeodetic vertical deflections, GNSS/Levelling data, satellite gravity data, satellite altimetry data and the combination of these data. GNSS/Levelling geoid determination has great importance with regard to the transformation of GNSS-derived ellipsoidal height (h), into the orthometric height (H), which is used in engineering projects and determined by levelling. Instead of levelling, which is an expensive and time-consuming method, orthometric heights can be calculated by using a well-defined geoid models. These geoid models enable us to compute the geoid height (N), which is the difference between ellipsoidal and orthometric height values (N=h-H). Then orthometric heights can be computed using these geoid heights and known ellipsoidal heights. Therefore, this will reduce the measurement work in the basic land surveying to a great extent and make economic contribution. In geoid modelling several methods can be employed. Such a geoid model has been developed for the metropolitan area of Istanbul city. In this context, Istanbul GPS Triangulation Network (IGN) and the Istanbul Levelling Network (ILN) provided reliable data, ellipsoidal and orthometric heights, respectively. This study focuses on the development of Istanbul geoid model with soft computing techniques and its comparison with conventional interpolation algorithms used for modelling. For this purpose, geoid heights in Istanbul metropolitan area have been computed by soft computing methods, namely Adaptive Network based Fuzzy Inference System (ANFIS) and Artificial Neural Networks (ANN) and modeled by twelve different interpolation methods. For computations and modelling in the study area, homogenously distributed 1005 model and 178 test points were selected. These are the common points in IGN and ILN whose latitude, longitude, ellipsoidal heights and orthometric heights are known to construct ANFIS and ANN models in Istanbul. To construct these models in model and test points, latitude and longitude are taken as inputs and geoid heights are taken as outputs. The results obtained from ANFIS and ANN methods are quite satisfactory. The model derived orthometric heights were compared with the known orthometric heights for model and test points. The standard deviation has been obtained in ANFIS as ±4.3cm and ±4.0cm for model and test areas, respectively. On the other hand, the standard deviation in ANN model are ±4 cm and 3.1 cm, for model and test areas, respectively. In addition, conventional interpolation methods as modified Sheapard’s method, radial basis function, Kriging, Nearest neighbor, minimum curvature, inverse distance to a power and local polynomial yield better results than ANFIS and ANN in model and test areas. The others interpolation methods such as polynomial regression, moving average, triangulation with linear interpolation, natural neighbor and data metrics yield worse results than ANFIS and ANN in each area.

Keywords: geoid modelling, soft computing, interpolation methods

The Geoid High and Temperature Variations near the CMB

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1. none

Anderson(1982)showed that the 40m geoid high near the African super plume after the Pangea supercontinent formation(330 Ma),and suggests upwelling heat flow under the African super plume. Heat flow flux in the mantle relates to Joule heating in the Earth and the inner core growth. The age of the inner core is studied to be 2.7 Ga(Hale,1987;Kumazawa et al.,1994).But Labrosse et al.(2001) pointed out that the age of the inner core is most likely around 1 Ga. It is interesting that both ages of formation of the seismic anisotropy layer 235 km and 375 km in the inner core from the ICB (inner core boundary) and the African supercontinent formation may be close each other, if the inner core age is young. In this report the effects of heat flux from the CMB(core mantle boundary) on the African geoid high are studied. This problem has been reported that periodic supercontinent cycles are unlikely if thermal instabilites originating at the CMB are of sufficient strength (Phillips and Bunge,2001).Here,however,we revisit this problem in consideration of the inner core growth. Effects of variations of heat flux from the CMB on the mantle geoid high are small,but heat flow changes rapidly depending on the rate of decay (1/e decay),that is changes of convective patterns.The rate of decay,which consists with the geoid high as shown by Anderson (1982),is about 1/500km.

Keywords: geoid high, Pangea supercontinent, heat flow in the mantle

Design and operation of a 1.5-km laser strainmeter installed in the KAGRA underground site (II)

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Laser interferometers are widely used for precise measurement in experimental physics, engineering, metrology, etc. In geophysics, as one of its applications, laser strainmeters are used for measuring deformation of the ground based on accurate wavelength of a highly frequency-stabilized laser. The advantages of the laser strainmeter over conventional strainmeters using mechanical references are high resolution with a long baseline, resonance-free response with optical reference, and low-drift detection using absolutely stabilized laser wavelength.
A laser strainmeter with a baseline of 100m was constructed in Kamioka underground site (Gifu Prefecture in Japan) and has been operated since 2003. The observation results were reported in Refs. [1-4]. Construction of a new laser strainmeter, having a longer baseline (1.5km), was reported in [5]. The strainmeter is located in a new tunnel for the large-scale gravitational-wave detector, KAGRA [6]. Along one of the arms of the KAGRA detector, the laser strainmeter is formed by an asymmetric Michelson interferometer with two retro-reflectors and other optics in vacuum. A frequency-doubled Nd:YAG laser, emitting wavelength of 532nm and frequency stabilized at a level of ~10^{-13}, is used as a light source. Fringe signals are converted to displacement between the retro-reflectors with a separation of 1.5km using a quadrature fringe detection [7].
A test run of the new laser strainmeter started in August 2016, and strain data were obtained. Earth tides were clearly observed and were almost consistent with theoretical waveforms, except for slight reduction in amplitudes likely due to topographic effect [2]. Strain detectability was estimated to be ~10^{-12}, which is better than the 100-m strainmeter. Estimated performance of the 1.5-km laser strainmeter in comparison with the 100-m strainmeter and other conventional straineters will be presented based on the results of the test run.

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Keywords: strainmeter, laser, crustal deformation, KAGRA, Kamioka, gravitational wave

Simulation study for crossover orbit analysis of Hayabusa2 (2)

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The asteroid explorer "Hayabusa2" launched in 2014 is currently sailing towards the target asteroid, Ryugu, and will arrive there in the middle of 2018. Hayabusa2 will stay there for one and a half years, and perform various observations.
For mapping of acquired observation data, precise orbit determination of Hayabusa2 is very important. Further, Ryugu's geodetic parameters, which will be simultaneously estimated with Hayabusa2 orbit, are also required to be determined in high precision for understanding of Ryugu. However, such precise determinations are difficult by using radiometric tracking data only, because of current limited knowledge of Ryugu's ephemeris and physical parameters. To overcome this problem, in Hayabusa2 mission, crossover orbit analysis using laser altimeter (LIDAR) data between Hayabusa2 and Ryugu is planned, in addition to radiometric tracking data analysis.
In this study, we performed offline simulation of Hayabusa2 orbit analysis. We developed a simulation program for Hayabusa2 orbit analysis, including crossover orbit analysis. Test data of Hayabusa2 orbit, Ryugu ephemeris, and Ryugu shape model were also created for the simulation. From these test data, input observation data to the simulation program were prepared. After adding some errors to Ryugu ephemeris and the observations, recovery of "true" Hayabusa2 orbit from these data sets were simulated in the following order: 1) Hayabusa2 orbit determination with range and range rate observations from ground tracking stations to Hayabusa2, 2) Determination of Hayabusa2 orbit with respect to Ryugu center by crossover orbit analysis using LIDAR-observed ranges between Hayabusa2 and Ryugu, 3) improvement of Ryugu ephemeris using 1) and 2) results, 4) improvement of Hayabusa2 orbit by performing 1) again with updated Ryugu ephemeris, and 5) iteration of 1) to 4). We discuss how much the precision of determined Hayabusa2 orbit changes by changing error magnitudes of each observations and Ryugu ephemeris.

Keywords: Hayabusa2, Orbit Analysis Simulation

