持続可能な開発のための地球規模の測地基準座標系（GGRF）に関する国連総会決議

The United Nations General Assembly Resolution on A Global Geodetic Reference Frame for sustainable development

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国連総会は，2015年２月26日，地球規模の測地基準座標系（GGRF）が社会，経済，科学に不可欠な基盤インフラであることを認めて，決議「持続可能な開発のための地球規模の測地基準座標系」を採択した．この決議は，測地学の分野で地球規模の連携した取り組みを行う重要性を初めて認めた国連総会決議で，加盟国に連携してGGRFの構築，維持を行うことを求めている．決議では，ロードマップを作成して決議を実行すること，途上国の技術，能力開発を強化すること，各国が責任を持って自国の測地観測を改善することなど，６つの決議文が採択された．決議に基づき，国連地球規模の地理空間情報管理に関する専門家委員会（UNCE-GGIM）が設置した作業部会がロードマップを作成し，ロードマップは，2016年8月には，第６回のUNCE-GGIM会合において承認された．ロードマップでは，決議で示された５つの項目，測地インフラ，基準・標準，教育・能力開発，広報・アウトリーチ，ガバナンスに関して，確実なGGRFの構築と維持を行ううえで，現状でどのような課題があるかを分析するとともに，その課題を解決する方策を提案している．国土地理院は，作業部会のメンバーとしてロードマップの作成に貢献するとともに，引き続き順位委員会に参加して実施計画の作成に貢献していく．

発表では，持続可能なGGRFに関する国連総会決議の概要を解説するとともに、実質の世界標準のGGRFである、国際地球基準座標系（ITRF）の現状について報告する．

キーワード：地球規模の測地基準座標系、国際連合、GGRFロードマップ
Keywords: Global Geodetic Reference Frame (GGRF), the United Nations, GGRF Roadmap

SLR continuous observation at the Shimosato Hydrographic Observatory after 1982

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Satellite Laser Ranging (SLR) plays an important role for the Global Geodetic Observation System (GGOS). The Hydrographic and Oceanographic Department of the Japan Coast Guard (JHOD) has conducted the SLR observation at the Shimosato Hydrographic Observatory (SHO) since 1982. For 35 years, the SLR observation at the SHO made a great contribution to establishing a world geodetic system as a national geodetic system in Japan in 2002. The Shimosato station also observed crustal movements of the 2004 Kii Peninsula earthquakes and the 2011 Tohoku-oki earthquake. In addition, the Shimosato station also plays a role as the mainland reference point of the marine geodetic control network based on MGC2000. In this presentation, we review results of the SLR observation at the SHO. The fact that the SLR observation was continuously performed at the same point for 35 years is significant for not only a framework of a national geodesy in Japan but also a global geodetic framework. It is also valuable to discuss a framework of the future GGOS.

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キーワード：SLR、レーザー測距
Keywords: SLR, Laser ranging

Satellite Laser Ranging Network: Where Should a New Station Be Placed? [Part II] For Better Satellite Orbits

Satellite Laser Ranging Network: Where Should a New Station Be Placed? [Part II] For Better Satellite Orbits

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Precise orbits of artificial satellites are not only useful for flight dynamics and geodetic products but also important for monitoring the phenomena of the changing Earth such as sea level rise and ice melting. Satellite Laser Ranging (SLR) is one of the most precise techniques to determine the orbits of satellites. About 35 SLR stations are being operational all over the world but the distribution of the current station network is not uniform. In particular, there are only 7 stations in the Southern hemisphere and there is no stations below 37 degrees latitude. It is found that this results in relatively less accurate orbit determination in the southern hemisphere.
A virtual station is added to the existing SLR network to evaluate the impact of a future station. The simulation procedure is similar to our previous study (Otsubo et al., EPS, 2016). Combining a simulated data set of a virtual station to the real existing data set, orbit determination procedures are simulated. For instance, assuming an active SLR station at Syowa (69S, 39E), the time-varying formal errors of Jason-2 and Cryosat are improved in the southern high latitude region by 20 to 30%.

キーワード：GGOS、衛星レーザ測距、精密軌道決定
Keywords: GGOS, Satellite Laser Ranging, Precise Orbit Determination

Time variation of solar radiation pressure acceleration acting on geodetic satellites

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Solar radiation pressure is one of the major error sources in satellite geodesy. Solar radiation pressure acting on a satellite varies in accordance with how sunlight illuminates its surface and how it is reflected. The cannonball model widely applied for spherical geodetic satellites rests on the following assumption: the satellite is a perfect sphere and the optical properties of its surface is spherical symmetry. Applying this model, a solar radiation pressure coefficient C_R is often adjusted as a scale factor. This study focuses on the time variation of the C_R solutions.
We use the geodetic analysis software "c5++" (Otsubo, 2016) to estimate the C_R coefficients of the six geodetic satellites: Ajisai, LAGEOS-1, LAGEOS-2, LARES, Starlette and Stella. Satellite laser ranging data for the past 20 years are analyzed where the C_R coefficients are estimated per 30 days.
An interesting behavior is observed in the time series of Ajisai’s C_R estimates. It ranges from 1.022 to 1.064, and shows a clear semiannual pattern maximizing in summer and winter. The 0.04 variation of Ajisai’s C_R value is equivalent to a 1.0 nm/s^2 difference in the acceleration acting on the satellite (Hattori, 2016).
Sengoku et al. (1995) constructed a solar radiation pressure model of Ajisai based on its surface materials. The C_R is predicted to vary in a range from 1.020 to 1.035 and show a dominant annual pattern with a maximum in summer. This does not agree well with our solutions above.
We attribute the reason of the discrepancy to the following two facts. One is that a 5-cm-height metallic ring is attached to one of the pole the satellite and the effective cross-section area becomes larger when the satellite is illuminated from inclined angles in summer and winter. This seasonal variation of the effective cross-section area results in a semi-annual variation of the C_R estimates. The other is that the difference of optical reflectivity between its equatorial region and the polar regions are found to be more than the difference between the two polar regions.

キーワード：衛星レーザー測距、太陽輻射圧、Ajisai
Keywords: satellite laser ranging, solar radiation pressure, Ajisai

SLR monthly gravity solutions using the C5++ software

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This study presents monthly gravity solutions up to degree and order 4 for the period 1993-2015 derived by Satellite Laser Ranging (SLR) data using the C5++ software [Otsubo et al., 1994]. Here, we apply the following modifications to the previous solutions by Matsuo et al. (2013). First, Range bias is estimated for per station and per satellite. Secondly, station coordinates are solved for using no-net-rotation constraints. Thirdly, non-tidal effects for atmosphere, ocean, hydrology are corrected using geophysical fluid models. Last, one-per-rev empirical accelerations are estimated in along-track and cross-track. Consequently, our new SLR solutions exhibited better consistency with those from Gravity Recovery And Climate Experiment (GRACE) than the previous solutions in the degree 3 and 4 components. The improvements of SLR gravity solutions provides further insight into the mass variability of the earth prior to the launch of GRACE in 2002.

キーワード：重力時間変化、衛星レーザ測距、宇宙測地学
Keywords: Time-variable gravity, Satellite Laser Ranging, Space geodesy

Activities of the Asia-Oceania VLBI Group for Geodesy and Astrometry (AOV)

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The Asia-Oceania VLBI Group for Geodesy and Astrometry (AOV) was established in 2014 as a subgroup of the International VLBI Service for Geodesy and Astrometry (IVS) in order to foster regional collaboration of VLBI. AOV coordinates six regional sessions in a year on regular basis by sharing resources of scheduler, stations, and correlators. AOV members are also enhancing their close collaboration by sharing information of recent activities in several face-to-face meetings. Successful broadband VLBI experiments with telescopes in Australia and Japan in August 2016 marked the start of VGOS in this region under the collaboration of AOV. We talk on the recent activities of the AOV.

キーワード：VLBI、IVS
Keywords: VLBI, IVS

The GSI contribution to the IGS

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Geospatial Information Authority of Japan (GSI) has started GNSS continuous observation in tracking stations since 1991. Five years later, GSI started operation of nationwide continuous observation system called GEONET (GNSS Earth Observation Network System), which now consists of more than 1300 stations.
Some stations of GEONET operated by GSI are registered as International GNSS Service (IGS) stations. GSI has participated in IGS since the establishment of the IGS and has played an important role as an operational data center and Regional Network Associated Analysis Center (RNAAC).
GSI operates 7 IGS stations including 6 stations in Japan, and SYOG station located in Antarctica. Some equipment satisfying IGS specification are installed at these stations, e.g. atomic clock to keep precise time stamp at each station. We have also participated in recently launched M-GEX project and RTS Service for further contribution to IGS. These data support the high-quality IGS products and construction of International Terrestrial Reference Frame, which also benefit us to conduct coordinate analysis of GEONET stations in Japan. We will continue to cooperate with IGS.
We show the GSI contribution to IGS from beginning of continuous GNSS observation.

キーワード：GEONET、国際GNSS事業、GNSS
Keywords: GEONET, IGS, GNSS

Verification of accelerated vertical crustal movements in the Tohoku region prior to the 2011 Tohoku-Oki earthquake by reanalysis of GEONET data using Precise Point Positioning

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Homogeneous coordinate time series data over a decade from GNSS analysis is essential for investigation of various phenomena preceding massive earthquakes such as the Tohoku-Oki earthquake. Kurokawa (2016) found a significant difference between vertical velocities obtained from GNSS and those from tidal record during 2003~2011. This suggests that the long-term homogeneity of the GNSS result is questioned. Routine processing of GEONET, the GNSS continuous observation network in Japan, currently adopts the network analysis strategy (F3 solution). However, such strategy may generate bias in analysis result because the combination of baselines has changed in response to the increase of the number of stations. In this study, we reanalyze the daily coordinate of 30 GEONET stations along the coast of Tohoku region for the last 20 years by using Precise Point Positioning method (PPP) in order to get rid of bias due to network analysis. We compare the velocities obtained from the F3 solution and our PPP result. In the horizontal components, the differences are about 1~1.5 mm/yr before the Tohoku-Oki earthquake. In the vertical component, large differences of about 2~3 mm/yr are found before 2003, and gradually decrease to smaller than 0.5 mm/yr just before the Tohoku-Oki earthquake. Even if the difference is small, there exist systematic differences in many cases. We estimate the vertical acceleration before the Tohoku-Oki earthquake. Our PPP result shows no significant change along the Japan Sea coast, and accelerated subsidence along the Pacific coast (about -0.3 mm/yr^2). This result is consistent with the horizontal acceleration indicated by Mavrommatis et al. (2014) and the accelerated subsidence by Kurosawa (2016). Furthermore, this suggests that the construction of a network for the F3 solution is one of the causes of the common mode error, because Mavrommatis et al. (2014) and Kurokawa (2016) eliminated such errors by using spatial filtering technique.

キーワード：単独精密測位、加速的地殻上下変動、GEONET
Keywords: Precise Point Positioning, accelerated vertical crustal movements, GEONET

石岡測地観測局における絶対重力計の国内比較観測の実施及び日本重力基準網2016（JGSN2016）の構築

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

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国土地理院は，国際標準に整合した絶対重力値を取得するため，我々及び国内関係機関が有するFG5絶対重力計と，国際度量衡局（BIPM）の後援による国際比較観測に参加している産業技術総合研究所が所有する同機器との間でキャリブレーションを目的とした比較観測を実施している．この国内比較観測は2002年から2015年まで毎年1回国民宿舎「つくばね荘」（茨城県石岡市）にて実施されてきたが，より良い環境で高精度な比較観測を実現するため，2016年からは新たに開設された国土地理院石岡測地観測局（同市．以下，「石岡局」という．）の重力測定室で実施することとした．

石岡局の重力測定室は、建物と絶縁された基台を有し，複数のコンクリートパイルで支持層と堅固に結合されている．また，市街地から5kmほど離れているため経済活動による人工的なノイズも比較的小さい．比較観測は同時に6台可能で，建物が完成する以前にGNSS測量及び水準測量を実施し，測点の位置情報を高精度に決定している．さらに，石岡局のVLBI観測施設から水素メーザの信号を分配し，比較する絶対重力計に統一した周波数信号を用いることで時計の誤差を最小限にする方法も試みた．その結果，参加した全ての絶対重力計で器差の範囲内で十分に整合する結果が得られた．

これまで国内では、国土地理院が1976年に公開した「日本重力基準網1975（JGSN75）」が重力の基準として使用されてきた。構築から40年以上が経過し、地殻変動の影響や重力値の測定精度の向上等により、JGSN75が与える重力基準と実際の重力値の乖離が大きくなったことから、国土地理院では，2017年3月に新しい日本重力基準網2016（JGSN2016）を公開した。JGSN2016では，2002年から2016年までに実施した最新の絶対および相対重力測定のデータを使用しているが、国内比較観測で国際標準との整合が確認された絶対重力計を用いて絶対重力値を測定することで、世界標準と整合した高精度で信頼性の高い重力網が実現されている．

本講演では，これまでの国内比較観測の結果とともに，JGSN2016構築に果たした役割について報告する．

キーワード：日本重力基準網2016、絶対重力観測、絶対重力計国内比較観測
Keywords: Japan Gravity Standardization Net 2016 (JGSN2016), Absokute gravity measurement, Domestic comparison of Absolute Gravimeters

On-site Frequency Measurements of a Rubidium Oscillator for Gravimeters

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It is important for precise gravity measurement to calibrate the frequency of a rubidium oscillator as a time frequency standard. We demonstrate simple on-site frequency measurement by using a time frequency calibration tool (FT-001A) with a GPS common view method. We equipped one at F-net IGK station, Ishigaki, Japan and measured frequency variation of the internal rubidium oscillator of gPhone gravimeter (S/N 133). As a result, we could measure its frequency with uncertainty of approximately 10^{-12} (0.01 mHz) on the gravity station 2,000 km apart from AIST Tsukuba where UTC(NMIJ) is maintained.

