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

MTT05-01 会場:203 時間:5 月 27 日 09:00-09:30

Low-cost multi-constellation GNSS receivers for Earth observation
Low-cost multi-constellation GNSS receivers for Earth observation

REALINI, Eugenio[1*]
REALINI, Eugenio[1*]

[1]Geomatics Research & Development (GReD) srl
[1]Geomatics Research & Development (GReD) srl

Low-cost, multi-constellation GNSS receivers that output raw data (i.e. at least code pseudorange and carrier phase observations) have been introduced on the market in the last three years, enabling several advanced applications in the field of Earth observation, including atmospheric measurements, in a cost-effective way. Such receivers, in fact, combine the benefits of using low-cost hardware with those of multi-constellation receivers. The former include, for example, the possibility to make the densification of existing GNSS networks more practical in terms of cost, or to deploy receivers in hazardous locations that might put at risk the integrity of the hardware itself. The latter are at least twofold:

· the increased redundancy provided by satellites belonging to constellations other than GPS makes the estimation process more robust, and increases the available slant measurement directions at any given epoch;

· new signals can be exploited that may prove beneficial for specific applications.

As regards the first point, the number of available multi-GNSS satellites can already be increased to about 2-3 times that of GPS satellites alone, depending on the region of observation, only considering those already in orbit and functioning. This number is going to be further increased when taking into account the new launches scheduled for the next few years.

The second point includes new signals, on frequencies other than L1 or L2, which could be used to obtain more precise measurements (e.g. by the precise code of the Galileo E5 signals) or to provide a second frequency at affordable cost (e.g. exploiting the L2C or L5 signals).

As an example, the advantage of using a cost-effective dual-frequency receiver could be significant for GNSS/MET analyses. In fact, GNSS-based tropospheric estimation and water vapor retrieval are typically performed by using high-grade dual-frequency GPS receivers. A densification of existing GNSS networks is beneficial for precipitable water vapor (PWV) monitoring at a local scale, which is expected to be useful to improve the nowcasting and forecasting of localized heavy rain. However, such a densification would have a high economic impact when standard dual-frequency receivers are involved. On the other hand, when dealing with single-frequency receivers one has to take into account the ionospheric delay, which has to be removed in order to retrieve the tropospheric delay (and consequently the PWV). A second frequency onboard a low-cost GNSS receiver would allow to compensate the ionospheric delay by linear combination of the two frequencies, excluding the need of performing complex interpolations from available dual-frequency stations surrounding the single-frequency receiver.

In general, all the applications requiring the processing of GNSS observations by PPP (precise point positioning), or by relative positioning over long baselines, would benefit from the availability of cost-effective dual-frequency receivers.

This presentation will give an overview of the current status of low-cost receivers and multi-GNSS, describing experiments and test cases related to the combination of the two technologies. Details about the feasibility of designing cost-effective dual-frequency receivers will also be investigated and reported.

キーワード: GNSS, low-cost, multi-GNSS
Keywords: GNSS, low-cost, multi-GNSS

MTT05-02 会場:203 時間:5月27日 09:30-09:45

新しい大気天頂遅延量推定方法とその評価　－観測点座標値推定との分離－
Impact of advanced ZTD estimate method - Separation from site coordinates estimation -

島田 誠一 [1*] ; 清水 慎吾 [1] ; 坪木 和久 [2]
SHIMADA, Seiichi[1*] ; SHIMIZU, Shingo[1] ; TSUBOKI, Kazuhisa[2]

[1] 防災科学技術研究所, [2] 名古屋大学
[1]NIED, [2]Nagoya University

In this paper we introduce the new procedure to estimate ZTD to obtain GPS PWV for numerical weather models. In general the major systematic error source of the ZTD estimation is the trade-off between the ZTD and the coordinate solutions usually simultaneously estimated in the GNSS analysis. In the analysis of the ZTD estimation, we fix the accurate site coordinates and exclude the trade-off systematic errors.

In the first step of the procedure, we estimate site coordinates as well as hourly ZTD, every four-hourly atmospheric gradient, and ambiguities of all of the GEONET network sites as well as the IGS fiducial sites applying the GAMIT program. In the second step, we estimate the accurate present-day site coordinates of the GEONET sites, estimating from the recent 30-days site coordinates solutions time series applying the Kalman filtering of the GLOBK program, constraining the IGS fiducial site coordinates. Then in the final step of the procedure, we estimate every hourly ZTD and every four-hourly gradients of the GEONET sites fixing the site coordinates obtained in the second step.

To evaluate the advanced ZTD estimation, we compare the PWV values calculated from the three kind of ZTDs obtained by three different analysis procedures. We assimilate the PWVs to the CReSS numerical weather model, and examine the impact of the PWVs in the heavy rain in the Southern Gifu Prefecture, Central Japan, on July 15 2010. The ZTDs are estimated by the following three procedures; (a) in the near real-time analysis applying the GAMIT program and estimating site coordinates, hourly ZTDs, four-hourly atmospheric gradient, and ambiguities simultaneously using IGS ultra-rapid orbit, (b) in the post-processing analysis applying the Bernese software and estimating site coordinates, three-hourly ZTDs, atmospheric gradient, and ambiguities simultaneously using IGS final orbit calculated by GSI (F3 solution), (c) in the post-processing analysis and applying the procedure mentioned above in this study (advanced ZTDs) using IGS final orbit. Examining the wide area distribution of water vapor in the objective analysis, (a) and (b) indicate the almost same distribution and (c) only shows the sharp contrast of the mixing ratio, dry in the north-western area in contrast with wet in the south-western area, in Central and Western Japan. The heavy rain phenomena calculated using (c) only significantly coincides with the observation.

We also introduce the impact of the heavy rains applying PWVs obtained by the advanced ZTDs in the cases of the heavy rain in the Niigata Prefecture, Central Japan, in July 2011, and the thunderstorm in the Tokyo metropolis on July 15 2006.
Keywords: Zenith Total Delay, GNSS precipitable water, GEONET, Numerical weather model, CReSS model

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

MTT05-03 会場:203 時間:5 月 27 日 09:45-10:00

Preliminary studies on the integration of GPS and ECMWF to derive high spatial and temporal resolution water vapor maps

Preliminary studies on the integration of GPS and ECMWF to derive high spatial and temporal resolution water vapor maps

CAPPONI, Martina[1*] ; CRESPI, Mattia[1] ; COLOSIMO, Gabriele[1]
CAPPONI, Martina[1*] ; CRESPI, Mattia[1] ; COLOSIMO, Gabriele[1]

[1]University of Rome ”La Sapienza”
[1]University of Rome ”La Sapienza”

The development of Global Navigation Satellite Systems (GNSS), since middle 1980s, has led to a significant change in the life of world's community. One of their most important and known application for the mass market is navigation systems for automobiles but also for aircrafts and ships. They play an important role also in several technical and scientific activities such as surveying, mapping and geographic information systems (GIS). In geophysics, the high precision measurements of multiple stations can be used to find strain and ground movement. Actually the most common system, operational and globally available, is the US Global Positioning System (GPS).

Recently studies are in place to evaluate GPS application for meteorology. The atmosphere affects the GPS radio signals transmissions from space since the index of refraction is variable along the ray path. This index is a function of pressure, temperature, and moisture so GPS can be directly used for sensing properties of the atmosphere. Water vapor, located in the lowest layers of the atmosphere, significantly affects the GPS signal propagation velocity and, at the same time, plays an important role in atmospheric processes, from global climate change to micrometeorology. The information derived from GPS, which allows to quantify water vapor, is the Zenith Total Delay (ZTD) that summarizes the increase of the optical path length between GPS satellites and receiver. It has two components: the Zenith Hydrostatic Delay (ZHD), primarily affected by hydrostatic gasses, and the Zenith Wet Delay (ZWD), directly related to water vapor. While the ZHD can be modeled with high accuracy, the ZWD has a large temporal and spatial variability so it is rather difficult to model and predict.

The comparison between water vapor estimated from GPS ZTD and the results obtained from other well-known technics (radio-sounding with water vapor radiometers, ground or space-based, or Numerical Weather Models) has shown the reliability of GPS data for the estimation of this atmospheric parameter.

This work describes the results of preliminary studies on the integration between GPS and European Centre for Medium-Range Weather Forecasting (ECMWF) data to derive high spatial and temporal resolution water vapor maps. The data from ECMWF, characterized by high spatial resolution but low temporal resolution (3 hours), can be used to calculate the covariance function, which quantify their spatial variability. Knowing this function, ZTD values obtained from GPS, which have a low spatial resolution but high temporal resolution (15 minutes) could be regionalized and high resolution water vapor maps, almost in real time, could be obtained.

The work has been developed in the contest of a three year international program between Italy and Argentina (2011-2013). In the first two years, different analysis have been conducted, focused on the assessment of the capabilities of the SIRGAS permanent network, which is the densification of the International Reference Frame (ITRF) in South America and Antarctic continent. The ZTD derived by the SIRGAS permanent network has been compared with those obtained from the International GNSS Service (IGS) products and from the radiometer on Jason-1 altimeter satellite. The results showed the reliability of SIRGAS permanent network. The accuracy of SIRGAS ZTD values was analyzed also in terms of consistency with ZTD values obtained from the ECMWF ERA-Interim database. ERA-Interim is an “interim” reanalysis to the period 1979-present of all the data stored in the ECMWF database.

The work done consists in a detailed study of the consistence of the results (in terms of ZTD) obtained from ECMWF and GPS, considering two small areas of South America. The areas chosen were characterized by different features (e.g. orography) in order to better understand their influence on the spatial variation of ZTD. A procedure is also proposed to optimize the management of data.

キーワード: GPS meteorology, high resolution water vapor maps, ECMWF
Keywords: GPS meteorology, high resolution water vapor maps, ECMWF

MTT05-04 会場:203 時間:5月27日 10:00-10:15

GNSS視線遅延データにより捕捉された桜島火山における噴煙柱の移流拡散
Advective diffusion of eruption column captured by GNSS slant path delay in Sakurajima volcano

太田 雄策[1*] ; 井口 正人[2]
OHTA, Yusaku[1*] ; IGUCHI, Masato[2]

[1] 東北大学大学院理学研究科, [2] 京都大学防災研究所
[1]Graduate School of Science, Tohoku University, [2]Disaster Prevention Research Institute, Kyoto University

We assess the ability of GPS data to detect volcanic plumes at Minami-dake of Sakurajima Volcano. In this study, we describe the July 24, 2012 activity at Minami-dake of Sakurajima Volcano. We analyzed the data from more than 20 continuous GPS stations, which located on the volcano flanks, and neighboring region. We used GIPSY-OASIS II version 6.3 software. We extracted the post-fit phase residual in the ionosphere-free linear combination for each pair of GPS satellites and ground stations for the detection of eruption column. The wet zenith tropospheric delays and its gradient at all the GPS sites were estimated at all processing epochs (30 seconds). Firstly, we analyze the all of the GPS data in July 23, 2012 for the reference. Obtained post-fit phase residual of the reference days showed the noise-level for the path delay effects caused by the volcanic plume. This reference post-fit phase residual contained many noise sources such as multipath effects. The noise level of the post-fit phase residual strongly depends on the each GPS satellite and ground station pair. Finally, we analyzed the data of the July 24, 2012. The post-fit phase residual clearly shows large disturbance just after the eruption. For example, the phase residual between SVN34 satellite and GEONET 0720, which located in the east coast of Sakurajima, suddenly increased just after the eruption. The obtained residual amount reached 80mm. It is clearly larger than the noise level measured on the reference days. Furthermore, other GPS satellite and ground station pairs also clearly showed significant amounts of disturbance. These results suggest that the eruption column moved to the westward by the wind after the eruptive event.

キーワード: GNSS
Keywords: GNSS

MTT05-05　　会場:203　　時間:5 月 27 日 10:15-10:30

直接波と反射波の干渉を利用したGNSS積雪計：2014年2月の山梨豪雪の観測
Observation of the 2014 February heavy snow fall in Yamanashi with the GNSS snow depth meter

日置 幸介 [1*] ; 小司 禎教 [2] ; 吉本 浩一 [3]
HEKI, Kosuke[1*] ; SHOJI, Yoshinori[2] ; YOSHIMOTO, Koichi[3]

[1] 北海道大学・院理・自然史, [2] 気象研究所, [3] 気象庁
[1]Dept. Nat. Hist. Sci., Hokkaido Univ., [2]Meteorological Research Inst., [3]Japan Meteorological Agency

GNSSの「マルチパス」を利用した観測によってアンテナ周囲の積雪深度を求めた事例について報告する。GNSS衛星からの直接波と地面等で反射した電波の干渉によって生じる様々な現象を総称してマルチパスと呼ぶ。衛星の公転周期である恒星日に同期した繰り返し測位誤差などが良く知られるが、昨今では、マルチパスを積極的に利用して、土壌水分、植生、海面高等のアンテナ周辺の様々な状況を推定する手法が開拓されつつある。Larson et al. (2009) は、GNSS受信信号のSN比の変動から、積雪に伴う見かけ上のアンテナ高の変動を求める手法を提唱した。一方Ozeki & Heki (2012) は、L1とL2の搬送波位相の差 (L4) の振動からも同様に積雪深度を推定できることを示した。Ozeki & Heki (2012) は、国土地理院の連続観測網GEONETの北海道新篠津村のGNSS点のデータを用いて、L4とS N比の双方を用いて求めた積雪深度を近傍のアメダス積雪計と比較することにより、それぞれ約6 cmおよび約4 cmの確度があることを示した。

本研究では山梨県北杜市小淵沢町にあるGEONET点950263の2014年一月から三月にかけてのデータを用い、複数の衛星が北東の地平線に沈む直前のSN比のマルチパスによる変動を解析した。北杜市では2014年二月の大雪で交通の遮断等による物流や農業施設への被害等が発生している。同観測点は小学校校庭の南西部に設置され、北東方向は平坦なグランドであるため、直接波と反射波の干渉の観測に条件が良い。衛星はGPS衛星の12, 20, 32の三衛星を用い、それぞれが北西に沈む前約二時間のSN比データを用いた。観測時間窓は毎日約4分ずつ早くして、衛星の方向を毎日同じに保った。無積雪時のマルチパスによるGPS 12番衛星のL2のSN比変化の周波数は4.6 mHz程度であるが、これが本来のGNSSアンテナの高さである約6 mに相当する。その周波数は雪が深くなるに従って低くなり、1 m程度の積雪でL2のSN比変動周波数のピークは約0.75 mHz下方にシフトする。様々なアンテナ高で理論的に予測されるSN比変化の周波数を計算してあらかじめ校正曲線を作っておき、日々の周波数ピーク値から積雪深度の推移を求めた。

本研究の結果、小淵沢ＧＮＳＳ点で二月の七日と十四日の二回にわたる大雪で積雪深度が約1 mに達したこと、その後徐々に融雪により深度がゆっくり小さくなる様子が再現できた。大雪直後は時折データの乱れが見られるが、現地は誰でも自由に出入りできる学校の構内であり、電波が反射する部分の雪面がしばしば人為的に乱されるのだろう。積雪が1 mを超えた時点からは、人為的な擾乱が無くなったためかデータは綺麗になる。アメダスには、例年積雪があまりない地点では積雪計が装備されていないことが多いが、GEONET点を利用することで、それらを補完する積雪データが得られることが期待される。

文献

Ozeki, M. and K. Heki, J. Geodesy, 86, 209-219, doi:10.1007/s00190-011-0511-x, 2012.
Larson, K. et al., GRL, 36, L17502, doi:10.1029/2009GL039430, 2009

キーワード: GNSS, GPS, 積雪深度, マルチパス, 干渉, 2014山梨豪雪
Keywords: GNSS, GPS, snow depth, multipath, interference, 2014 Yamanashi heavy snowfall

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

MTT05-06 会場:203 時間:5 月 27 日 11:00-11:30

複数GNSS時代の到来に向けたMADOCAの研究開発
MADOCA(Multi-GNSS Advanced Demonstration Tool for Orbit and Clock Analysis) development status for Multi-GNSS Era

小暮 聡 [1*]
KOGURE, Satoshi[1*]

[1] 宇宙航空研究開発機構第一宇宙利用ミッション本部衛星測位システム技術室
[1]Satellite Navigation Office, Space Applications Mission Directorate I, JAXA

For past two decades, U.S. Global Positioning System (GPS) has been almost sole reliable operational system for space based Position, Navigation and Timing. Recently, other countries, Russia, China, EU, India and Japan, are competing in the efforts to establish their own Global Navigation Satellite System (GNSS) or Regional one in order to seek secure and effective social infrastructure, and economical growth.

In present, two GNSS, U.S. GPS and Russian Glonass, are operated and China is pushing their national program strongly, BeiDou has started regional service with 14 satellites in Asia pacific region since December 2012. European Galileo is progressing to launch its initial service in 2015-16, though their latest two Full Operational Capability (FOC) satellites could not reach planned orbit slots due to the upper stage failure of launch vehicle, unfortunately. India has just started their regional satellite navigation system, IRNSS, three satellites has being launched already. As for Japanese QZSS, adding QZS-1 orbiting since 2010 to three additional satellites, Japan will provide GPS interoperable signal for Eastern Asia and Oceania region as well as augmentation service for Japan in 2018.

Forecasting the situation in 2020, more than 120 navigation satellites will orbiting around the Earth and more than 30 satellites are to be available to use even in town in this coming multi-GNSS era. The utilization of multiple GNSS constellation is expected to resolve one of the drawbacks of satellite navigation which is difficult to use in dense urban area. Especially, carrier phase positioning in urban canyon is still big challenge, since surrounding building can easily block satellite signals, cycle slip and signal loss occur frequently. However, multi-GNSS signals can facilitate to get positioning solution even in the such severe condition. In addition, use of multiple system contributes to more dense atmospheric delay measurement such like Slant Tropospheric Delay (STD) which is useful to monitor the distribution of precipitable water rather than conventional ZTD estimation with only GPS observation.

Toward the future multiple GNSS environment, Multi-GNSS Advanced Demonstration Tool for Orbit and Clock Analysis (MADOCA) has been developed by Japan Aerospace Exploration Agency (JAXA) which supports all usable GNSS constellations. The current version of MADOCA can estimate precise orbit and clock offset for GPS, GLONASS, Galileo and QZSS. The final product for GPS and GLONASS generated by post processing analysis with more than 80 observation at Multi-GNSS Monitoring Network (MGM-Net) and IGS sites is comparable to IGS final product within a couple of centimeters. Supporting BeiDou will come in near future update in 2015. In parallel with MADOCA development, the development of its applications on Precise Point Positioning (PPP), which we call ”MADOCA-PPP” are being conducted. The first satellite of QZSS, Michibiki, has an experimental signal (LEX) which can transmit 2000 bps data stream on 1278.75 MHz with BPSK(5) radio signal. JAXA is routinely generating error correction message for MADOCA-PPP, broadcasting it via LEX signal and evaluating its performance. Current performance of MADOCA-PPP is sub-decimeter accuracy (RMS) for both horizontal and vertical direction in real time processing.

The latest status of the MADOCA and MADOCA-PPP development is described with performance test results. In addition, current technical challenges are introduced and how to resolve them are also discussed in the presentation.

キーワード: 複数 GNSS, 精密軌道クロック推定, 準天頂衛星システム, MADOCA, PPP/PPP-AR
Keywords: Multi-GNSS, Precise Orbit and Clock estimation, Quasi-Zenith Satellite System, MADOCA, PPP/PPP-AR

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

MTT05-07 会場:203 時間:5 月 27 日 11:30-12:00

GNSS ionospheric anomalies following recent big earthquakes: Results and statistical analysis

GNSS ionospheric anomalies following recent big earthquakes: Results and statistical analysis

JIN, Shuanggen[1*] ; JIN, Rui[1]
JIN, Shuanggen[1*] ; JIN, Rui[1]

[1]Shanghai Astronomical Observatory, Chinese Academy of Sciences
[1]Shanghai Astronomical Observatory, Chinese Academy of Sciences

Up to now, it is still difficult to well understand and predict Earthquake from traditional seismometer and space geodetic deformation measurements. Ionospheric disturbances following the earthquake may provide new insights. In this paper, GNSS seismo-ionospheric anomalies are presented following recent bigger earthquakes, e.g., 2008 Mw 8.0 Wenchuan (China) earthquake, 2011 Mw 9.1 Tohoku (Japan) Earthquake and 2011 Mw 7.2 Van (Turkey) earthquake. Significant pre-seismic, co-seismic and post-seismic ionospheric disturbances are observed with about 0.2˜0.5TECU from continuous GPS measurements. Furthermore, different seismo-ionospheric behaviors and patterns are presented and discussed as well as statistic analysis.

キーワード: Seismo-ionosphere, TEC, Earthquake, GNSS
Keywords: Seismo-ionosphere, TEC, Earthquake, GNSS

MTT05-08 会場:203 時間:5 月 27 日 12:00-12:15

稠密 GNSS 受信ネットワークによる電離層遅延量の時空間変動に関する研究
An observational study on the time and spatial variations of the localized ionospheric delays with a dense GNSS receiver

竹田 悠二[1*] ; 津田 敏隆[1]
TAKEDA, Yuji[1*] ; TSUDA, Toshitaka[1]

[1] 京都大学生存圏研究所
[1]Research Institute for Sustainable Humanosphere,Kyoto University

The integrated amount of water vapor along the zenith angle, or PWV (Precipitable Water Vapor) can be estimated by GPS (GNSS) meteorology, which is a method to compute atmospheric parameters from troposphere-induced delays in signals of GPS (GNSS). We deployed a dual-frequency (DF) GNSS network around Uji campus of Kyoto University, Japan, with inter-station distances of few kilometers. By using this dense network, we built a basic system to observe PWV fluctuations occurring within a small horizontal scale (less than 10 km), which were then analyzed to identify possible precursors of local torrential rain.

To utilize this network as a practical heavy rain early warning system for urban area, using inexpensive single-frequency (SF) receivers would be better for economic reasons. However, Using SF receivers occurs error in computing PWV because we cannott eliminate the ionospheric delay by using SF receivers. So we investigate and estimate ionospheric delay within this dense network system in many cases. From this investigate, we aim to find the appropriate method to correct the effect of ionospheric delays on SF observations in this dense GNSS network system.

キーワード: ジーピーエス, ジーエヌエスエス, 電離層, 稠密観測網
Keywords: GPS, GNSS, ionosphere, dense network

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

MTT05-09 会場:203 時間:5 月 27 日 12:15-12:30

Development of GNSS tomography for ionospheric electron density and tropospheric water vapor distribution

Development of GNSS tomography for ionospheric electron density and tropospheric water vapor distribution

服部 克巳 [1*] ; 廣岡 伸治 [2] ; 廣木 暁充 [1]
HATTORI, Katsumi[1*] ; HIROOKA, Shinji[2] ; HIROKI, Akimitsu[1]

[1]Graduate School of Science, Chiba University, [2]National Central University, Taiwan
[1]Graduate School of Science, Chiba University, [2]National Central University, Taiwan

The GNSS signal contains the information on electron density distribution of water vapor along the line of sight. Therefore, it is possible to develop the electron density tomography and the water vapor tomography to visualize the 3D structures in time and space. For this aim, we use the algorithm of residual minimization learning neural network (RMTNN) without any models (Ma et al., 2006; Hirooka et al., 2011). Tomographic algorithms have a tendency to fall into ill-posed problems. Therefore, in general a regularization is required. In this study, we use the data observed by Ionosonde and AMeDAS to restrict data for electron density and water vapor reconstruction, respectively. We performed the numerical simulation to investigate the ability of the developed RMTNN algorithm and carried out the practical application for actual data. .

The results provide following capacities of the RMTNN algorithm; (1) for the electron density visualization, transient disturbances can be reconstructed successfully without any model assumptions, (2) the reliability of the lower edge of the ionosphere is a little bit weak, and (3) for the water vapor, if adequately restricted data are given, the water vapor disturbance can be reconstructed successfully. These facts show that the developed RMTNN tomography algorithm on GNSS/GPS data for electron density and tropospheric water vapor has the capacity to reconstruct disturbance without any model dependence.

Keywords: GNSS tomography, ionospheric electron density, tropospheric water vapor distribution, RMTNN

MTT05-10 会場:203 時間:5 月 27 日 12:30-12:45

Chiba University Microsatellite for Ionospheric Monitoring
Chiba University Microsatellite for Ionospheric Monitoring

SRI SUMANTYO, Josaphat tetuko[1*]
SRI SUMANTYO, Josaphat tetuko[1*]

[1]Chiba University
[1]Chiba University

Chiba University develops two microsatellites called GAIA-I (50 kg class) and GAIA-II (100 kg class). GAIA-I payload is GNSS Radio Occultation (RO) sensor and Electron Density - Temperature Probe (EDTP) for Ionosphere monitoring, and GAIA-II payload is Circularly Polarized Synthetic Aperture Radar (CP-SAR, Patent Pending 2014-214905) for global land deformation monitoring. In the near future, we will employ these microsatellites to investigate relationship of total electron content (TEC), electron density and temperature, and global land deformation to observe precursor of earthquake. This paper focuses to discuss the development progress of GAIA-I microsatellite.

キーワード: Ionospheric Monitoring, GNSS-RO, EDTP, Microsatellite
Keywords: Ionospheric Monitoring, GNSS-RO, EDTP, Microsatellite

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

MTT05-11 会場:203 時間:5 月 27 日 14:15-14:30

海洋 GNSS ブイアレイを用いた総合防災システムの提案
Proposal of GNSS Buoy Array in the Ocean for a Synthetic Disaster Mitigation

加藤 照之 [1*] ; 寺田 幸博 [2] ; 田所 敬一 [3] ; 小司 禎教 [4] ; 瀬古 弘 [4] ; 石井 守 [5] ; 西岡 未知 [5] ; 山本 伸一 [6] ;
豊嶋 守生 [6] ; 岩切 直彦 [6] ; 越川 尚清 [7] ; 本橋 修 [8] ; 和田 晃 [9] ; 今田 成之 [9]
KATO, Teruyuki[1*] ; TERADA, Yukihiro[2] ; TADOKORO, Keiichi[3] ; SHOJI, Yoshinori[4] ; SEKO, Hiromu[4] ;
ISHII, Mamoru[5] ; NISHIOKA, Michi[5] ; YAMAMOTO, Shin-ichi[6] ; TOYOSHIMA, Morio[6] ; IWAKIRI, Naohiko[6] ;
KOSHIKAWA, Naokiyo[7] ; MOTOHASHI, Osamu[8] ; WADA, Akira[9] ; IMADA, Naruyuki[9]

[1] 東京大学地震研究所, [2] 高知工業高等専門学校, [3] 名古屋大学環境学研究科, [4] 気象庁気象研究所, [5] 情報通信研究機構，電磁波計測研究所, [6] 情報通信研究機構，ワイヤレスネットワーク研究所, [7] 宇宙航空研究開発機構，衛星利用推進センター, [8] 宇宙航空研究開発機構，衛星測位システム技術室, [9] 日立造船株式会社
[1]Earthquake Research Institute, Univ. Tokyo, [2]National Institute of Technology, Kochi College, [3]Graduate School of Environmental Studies, Nagoya Univ., [4]Meteorological Research Institute, JMA, [5]Applied Electromagnetic Research Institute, NICT, [6]Wireless Network Research Institute, NICT, [7]Satellite Applications and Promotion Center, JAXA, [8]Satellite Navigation Office, JAXA, [9]Hitachi Zosen Corporation

GNSS ブイによる津波の早期検出の手法が 15 年以上にわたって開発されてきた．この方式は GPS 津波計として 10cm 程度の津波の検出に成功したほか，国土交通省の NOWPHAS システムに採用され，全国に設置が進められている．2011 年 3 月東北地方太平洋沖地震の際にもこのシステムで津波が検知されて通報にも使われた．本講演ではこのシステムを拡張し，海洋に GNSS ブイのアレイを設置し，津波だけでなく海底地殻変動，大気中の水蒸気量，電離層の総電子数などを計測することによって，さまざまな自然災害の軽減のための監視に活用しようとする試みを提案する．

現在の GNSS ブイを用いた津波の計測では陸上に地上局を設置し，リアルタイムキネマティック（RTK）方式を用いることでブイの位置を高精度に推定するという方式を用いている．この方式では陸上に基地局を置く必要があり，基線距離もせいぜい 20km までであった．しかし，最近の GNSS 技術の発達により，基線方式ではなく，単独測位で 1cm 程度の精度でリアルタイムに移動体測位を行う手法が開発されてきた．この方式を用いることで，遠距離の沖合でも GNSS ブイの位置計測を行える可能性が出てきた．

GNSS ブイの応用としては，第一に海底地殻変動計測への応用が考えられる．現在，海底地殻変動計測は船舶を用いて行われているが，GNSS ブイを用いて実施することができれば海底地殻変動を連続して実施できることになり，海溝型巨大地震の発生メカニズムの解明に大きく寄与することができると期待される．また，ブイ上でのデータ解析により，大気中の可降水量や電離層の電子密度を陸上での計測と同程度の精度で推定できれば，気象や電離層の擾乱の把握や将来予測に大きな貢献ができると期待される．なお，このために必須の開発研究としては，大深度・遠洋でのブイの安定的な運用方式の開発と共に，陸上からの精密衛星暦・時計情報のブイへのリアルタイム伝送及びブイから陸側局への安定したデータ伝送などの問題を解決する必要がある．このための衛星を用いた実験を行うことを計画中である．

この方式が実用に供されれば，例えば西太平洋の日本の排他的経済水域内に数十点の GNSS ブイアレイを設置して観測を実施することで上記に挙げたような総合的な防災システムが構築できると共に，基礎的な固体・気象・電離層研究のためのインフラとしても活用できることになると期待される．

キーワード: GNSS, GNSS ブイ, 津波, 海底地殻変動, 気象, 電離層
Keywords: GNSS, GNSS buoy, tsunami, ocean bottom crustal movement, meteorology, ionosphere

MTT05-12 会場:203 時間:5 月 27 日 14:30-14:45

GPS^3: 革新的衛星技術実証プログラムへの提案
GNSS occultation & Plasma Small Satellite Systems (GPS^3)

児玉 哲哉 [1*]
KODAMA, Tetsuya[1*]

[1] 宇宙航空研究開発機構　地球観測研究センター
[1]Earth Observation Research Center, JAXA

平成 27 年度より実施される革新的衛星技術実証プログラムに提案した掩蔽観測小型衛星構想について発表する。

キーワード: GNSS 掩蔽観測, 数値気象予測, 国際標準電離層, 地震前電離圏変動, 宇宙天気, 宇宙状況認識
Keywords: GNSS-RO, Numerical Weather Prediction, International Reference Ionosphere, Seismo-Ionospheric Precursor, Space Wearther, Space Situational Awareness

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

MTT05-13　　会場:203　　時間:5 月 27 日 14:45-15:00

GPS/GNSS 気象学 -概要と将来展望-
GPS/GNSS Meteorology in JAPAN - Overview and future scope -

小司 禎教[1*] ; 瀬古 弘[1] ; 佐藤 一敏[2] ; 加藤 照之[3] ; 津田 敏隆[4]
SHOJI, Yoshinori[1*] ; SEKO, Hiromu[1] ; SATO, Kazutoshi[2] ; KATO, Teruyuki[3] ; TSUDA, Toshitaka[4]

[1] 気象研究所, [2] 宇宙航空研究開発機構, [3] 東京大学地震研究所, [4] 京都大学生存圏研究所
[1]Meteorological Research Institute, [2]Japan Aerospace Exploration Agency, [3]Earthquake Research Institute, The University of Tokyo, [4]Research Institute for Sustainable Humanosphere, Kyoto University

日本における GPS/GNSS 気象学をレビューし、将来を展望する。

水蒸気は GPS（Global Positioning System：全地球測位システム）測位には誤差をもたらすノイズだが，天気予報にとっては精度向上をもたらす重要なシグナルである．1997-2001 年度に取り組まれた科学技術庁科学技術振興調整費「GPS 気象学：GPS 水蒸気情報システムの構築と気象学・水文学への応用（以下「GPS 気象学」と記す)」は，この「水蒸気」をキーワードに，測地研究者と気象研究者が，GPS という研究資源を介して学際協力を行い，相互の発展を図ることを基本概念として実施された．

「GPS 気象学」プロジェクトは，世界に類を見ない稠密な国土地理院の GPS 観測網，GEONET (GPS Earth Observation NETwork) から得られる水蒸気情報を天気予報の根幹である数値気象予報に活用すること，および数値予報データを用いた測位精度の向上という２つの目標を掲げ，測地研究者と気象研究者が参加する学際的なプロジェクトであった．1996 年の実現可能性を探る予備研究 (Feasibility Study: FS) を経て，①GEONET から解析された可降水量（PWV）の精度検証，②数値予報へのデータ同化実験，③視線情報を用いたトモグラフィーによる 3 次元水蒸気構造の解析，④測位誤差をもたらす水蒸気の非一様性に関する研究等が取り組まれた．2000 年，2001 年にはつくば市周辺 20km 四方の領域に 75 箇所の GPS 観測点を設置する世界初の稠密観測実験が取り組まれ，積乱雲の発達に伴う水蒸気の 3 次元構造とその変動を捕らえることに成功した．低軌道衛星に搭載した受信機に，大気を貫いて到達する電波の屈折を利用した掩蔽 (Radio Occultation: RO) 法により得られた気温の全球構造の解析から，重力波の鉛直伝播の様子が明瞭に捉えられた．さらに，富士山頂に設置した受信機を用いた掩蔽解析により，大気境界層内部の気温や水蒸気の構造解析に成功した．

プロジェクトの終了後も研究は進み，気象庁では 2007 年 3 月にドイツの掩蔽観測衛星 CHAMP の観測した屈折率データの全球解析（Global Analysis: GA）への利用を開始した．さらに 2009 年 10 月には，GEONET から解析された PWV のメソ解析 (Mesoscale Analysis: MA) での利用を始めた．測地学の分野では高解像度数値気象モデルを用いた mm 測位精度向上の研究が進展している．

2013 年 5 月，国土地理院では GEONET 全点で，米国の GPS に加え，ロシアの GLONASS，JAXA の準天頂衛星 (QZSS) の観測データの公開を開始した．加えて欧州の GALILEO や中国の COMPASS 等，現在は GPS から Multi-GNSS(Global Navigation Satellite System) の時代が始まっている．加えて，NTRIP ストリーミングプロトコルを利用した観測や解析結果のリアルタイム配信により，GNSS による地震，津波の観測，豪雨や突風の監視等，新たな研究が始まっている．反射波を用いた海面上の風の観測，積雪深，土壌水分の解析等新たな学問分野も創出されている．

この報告が，GPS/GNSS 気象学の展望を議論する機会となれば幸いである．

キーワード: GPS/GNSS 気象学, 衛星測地学, 水蒸気
Keywords: GPS/GNSS Meteorology, Satellite Geodesy, Water vapor