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

MTT05-01 Room:203 Time:May 27 09:00-09:30

Low-cost multi-constellation GNSS receivers for Earth observation

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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.

Keywords: GNSS, low-cost, multi-GNSS

MTT05-02 Room:203 Time:May 27 09:30-09:45

Impact of advanced ZTD estimate method - Separation from site coordinates estimation -

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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

MTT05-03 Room:203 Time:May 27 09:45-10:00

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

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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.

Keywords: GPS meteorology, high resolution water vapor maps, ECMWF

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MTT05-04 Room:203 Time:May 27 10:00-10:15

Advective diffusion of eruption column captured by GNSS slant path delay in Sakurajima volcano

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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.

Keywords: GNSS

MTT05-05 Room:203 Time:May 27 10:15-10:30

Observation of the 2014 February heavy snow fall in Yamanashi with the GNSS snow depth meter

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Here we report the case in which we estimated the snow depth by using multipath of Global Navigation Satellite System (GNSS). Multipath is the interference between direct microwaves from GNSS satellites and those reflected somewhere, such as the ground surface, and causes, e.g. measurement errors repeating every sidereal day (the orbital period of the satellites is a half sidereal day). Recently, several attempts have been made to utilize multipath to measure various quantities around the antenna, such as soil moisture contents, vegetation, and sea surface height. Larson et al. (2009) estimated the apparent height of the antenna (which is lowered by snowpack) by analyzing the frequencies of periodic variation of S/N ratio of the received signals caused by multipath. On the other hand, Ozeki and Heki (2012) showed that the fluctuation of the phase differences (L4) between L1 and L2 carriers could also be used for snow depth measurements. They analyzed both L4 and S/N ratio at the Shinshinotsu GNSS stations, one of the GEONET (GNSS Earth Observation Network) station in Hokkaido, and showed that they are accurate to ˜6 cm and ˜4 cm, respectively, by comparing them with the conventional snow depth meter records at a nearby AMeDAS station.

In this study, we used data at GEONET site 950263 in Kobuchizawa, Kitamori-city, Yamanashi, from January to March in 2014, and analyzed periodic changes in S/N ratio immediately before satellites set beneath the horizon. In this city, 2014 February heavy snowfall has caused cutoffs of public traffic lines and damages on agricultural facilities. This GNSS antenna is installed at the SW corner of the playground of an elementary school, and there is an extensive flat terrain in the NE direction. This is a good condition for observing the interference between the direct waves and those reflected by the ground. We used GPS satellites #12, #20, and #32 sinking in the NE horizon, and analyzed S/N ratio changes during two hours period before the disappearances of the satellite signals. We shifted the time window by ˜4 minutes earlier every day to maintain the same geometry of the antenna and the satellites. The frequency of the S/N ratio changes of L2 carrier is normally ˜4.6 mHz, and this corresponds to the original antenna height of ˜6 meters. This frequency peak lowers by ˜0.75 mHz by one meter snow depth (5 meter antenna height). We first prepared the calibration curve by calculating the theoretical S/N ratio changing frequencies for various antenna heights, and we inferred the snow depths by correlating the daily S/N ratio change peak frequencies with the calibration curve.

In the present study, we could reproduce the two heavy snowfall episodes, first on February 7th and second on February 14th, which eventually resulted in snow depth exceeding one meter at the Kobuchizawa GNSS station. The snow depth data become noisy occasionally at the beginning of increasing snow depth, possibly by artificial disturbances by the reflecting snow surface (which is located within a playground of a school). As the snow depth increase, the data became less noisy, which would mean decrease of human disturbances in a meter thick snow pack. AMeDAS snow depth meters are not densely deployed in the region where it snows little in normal years, and GNSS snow depth meters using GEONET are expected to complement the AMeDAS network.

References

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

Keywords: GNSS, GPS, snow depth, multipath, interference, 2014 Yamanashi heavy snowfall

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MTT05-06 Room:203 Time:May 27 11:00-11:30

MADOCA(Multi-GNSS Advanced Demonstration Tool for Orbit and Clock Analysis) development status for Multi-GNSS Era

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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.

Keywords: Multi-GNSS, Precise Orbit and Clock estimation, Quasi-Zenith Satellite System, MADOCA, PPP/PPP-AR

MTT05-07 Room:203 Time:May 27 11:30-12:00

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

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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.

Keywords: Seismo-ionosphere, TEC, Earthquake, GNSS

MTT05-08 Room:203 Time:May 27 12:00-12:15

An observational study on the time and spatial variations of the localized ionospheric delays with a dense GNSS receiver

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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.

Keywords: GPS, GNSS, ionosphere, dense network

MTT05-09 Room:203 Time:May 27 12:15-12:30

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

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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

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MTT05-10 Room:203 Time:May 27 12:30-12:45

Chiba University Microsatellite for Ionospheric Monitoring

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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.

Keywords: Ionospheric Monitoring, GNSS-RO, EDTP, Microsatellite

MTT05-11 Room:203 Time:May 27 14:15-14:30

Proposal of GNSS Buoy Array in the Ocean for a Synthetic Disaster Mitigation

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A system of GNSS buoy for detecting tsunami has been developed for more than 15 years in Japan. The buoys deployed around the Japanese coasts have successfully detected tsunamis with amplitudes of about 10 centimeters or bigger, including a large tsunami due to the 2011 Tohoku-Oki earthquake. The present study tries to extend the GNSS buoys for a wide variety of applications for monitoring disaster related signals in the ocean, such as ocean bottom crustal deformation, atmospheric water vapor detection for weather monitoring, and ionospheric disturbance detection for space weather monitoring as well as tsunamis.

One problem of the GNSS buoy system that we have developed is the limitation of baseline distance to at most less than 20km, as the system uses so-called Real-Time Kinematic algorithm which requires a base station on land. Recent developments of real-time GNSS technology enabled us to estimate position of a moving platform like buoy in a few centimeter accuracy in real-time without a base station on land, so that the buoy is now able to be deployed at much far offshore.

Combination of precise point positioning with acoustic ranging to the ocean bottom transponder stations enables positioning of the ocean bottom station in continuous manner. Moreover, GNSS data on the buoy provide us with accurate estimation of atmospheric water vapor and total electron content in the ionosphere. These geophysical data on the ocean surface, together with land based sensors, will serve us with unprecedented invaluable datasets for better understanding of ocean bottom crustal deformation, atmospheric and ionospheric disturbances as well as sea surface disturbances. Combined this GNSS buoy technology with satellite data transmission and long-term safe and secure operation of GNSS buoy in outer ocean is a key for materializing the capability of GNSS buoy. We propose to establish an array of GNSS buoy in the Japanese EEZ area for a synthetic geodetic and geophysical infrastructure of earth science and as well as disaster mitigation.

Keywords: GNSS, GNSS buoy, tsunami, ocean bottom crustal movement, meteorology, ionosphere

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MTT05-12 Room:203 Time:May 27 14:30-14:45

GNSS occultation & Plasma Small Satellite Systems (GPS^3)

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The outline of GNSS occultation & Plasma Small Satellite Systems (GPS^3) will be presented. The GPS^3 has proposed for the Innovative Satellite Technology Demonstration Program.

Keywords: GNSS-RO, Numerical Weather Prediction, International Reference Ionosphere, Seismo-Ionospheric Precursor, Space Wearther, Space Situational Awareness

MTT05-13 Room:203 Time:May 27 14:45-15:00

GPS/GNSS Meteorology in JAPAN - Overview and future scope -

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The Global Positioning System was developed during 1970-80 in the United States. In 1994, The Geographical Survey Institute of Japan (GSI) (the official english appellation is changed to "Geospatial Information Authority of Japan" in April 2010) began partial services of the nationwide GPS network named GEONET (GPS Earth Observation NETwork). Prior to the start of the GEONET service, Japanese geodesists and meteorologists held the first workshop on "GPS Tropospheric Delay" at the National Astronomical Observatory Mizusawa and recognized the importance of GPS meteorology with a suggestion of N. Mannoji from the Japan Meteorological Agency (JMA).

After one year feasibility study based on a concept proposed by H. Tsuji of GSI, Japanese GPS meteorology project "GPS/MET JAPAN" was launched in 1997. This five year project from April 1997 to March 2002 was aiming at two birds with one stone; an application of precipitable water vapor (PWV) from the GEONET to data assimilation system in numerical weather predictions (NWP), and an improvement of geodetic accuracy of GPS based on NWP data. At the dawn of the project, accuracy of PWV from GEONET was statistically tested, and GEONET vividly monitored various atmospheric phenomena. All these analyses, however, attested critical necessity of knowing a few km-scale water vapor variations to improve the accuracy of GPS positioning and PWV retrieval. This led us to conduct a dense GPS network campaign with 75 receivers in a 400 km2 area. A tomography analysis of slant path delays (SPD) of GPS signals revealed a 3-D distribution of water vapors. Improvement of geodetic accuracy of GEONET was also tried using high resolution NWP data. GPS radio occultation (RO) method applied to GPS data observed by space-borne GPS receivers yielded a global-scale distribution of temperature and humidity, which shed light on a vertical propagation process of atmospheric gravity waves in the tropics. GPS RO technique was also applied to mountain-based GPS downward-looking observation and succeeded in obtaining fine vertical temperature structure in the lower troposphere.

The researchers of the "GPS/MET JAPAN" sustained their researches after the project period and practical usage of GPS data in weather prediction model was started in the late 2000s. German GPS RO satellite CHAMP data was began to be used in JMA's global analysis (GA) in March 2007. A near-real-time (NRT) retrieval procedure of PWV retrieved from ground-based GPS observations was developed and confirmed its benefits for mesoscale NWP. On October 28, 2009, JMA started the operational use of PWV derived from GEONET in its mesoscale DA system. In the field of geodesy, researches which aiming to achieve mm accuracy using high resolution NWP model has been advancing.

Currently, we are in multi-GNSS (Global Navigation Satellite System) era. Not only U.S. GPS, but also Russian GLONASS, and JAXA's QZSS are available in GEONET. Also, development of streaming data exchange protocol has been creating new research fields and ideas in GNSS meteorology. GNSS reflexology should also be highlighted. Several applications, for example retrieval of snow depth, soil moisture, and wind over the ocean, have been conducted worldwide.

In this presentation, we summarize results of the "GPS/MET Japan" project, review subsequent relevant researches, and look at the future. We hope that this paper will encourage new studies aiming for further progresses not only on numerical weather prediction but also on the interdisciplinary sciences for understanding the global changes.

Keywords: GPS/GNSS Meteorology, Satellite Geodesy, Water vapor