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

AAS001-01 Room:202 Time:May 25 16:30-16:52

Atmospheric Remote Sensing for Meteorology in Southern Hemisphere and Antarctica -Recent Australian Initiatives

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Recent developments in both ground-based and space-borne geospatial infrastructure have opened exciting opportunities for geodesists to contribute to "big issues" such as atmosphere, climate changes, global warming, and environmental sustainability. GNSS atmospheric remote sensing using GNSS and low Earth orbit (LEO) satellites such as CHAMP, GRACE and COSMIC is a new technique for profiling the atmosphere. Research has demonstrated that GNSS radio occultation technique is capable of measuring the Earth's atmospheric parameters with a high accuracy, unprecedented high resolution and global coverage. It is expected that this new technology will significantly advance our knowledge of Earth's atmospheric structure and processes.

Australia and Antarctica are characterized with a large continent, sparse population and a long coastline. The lack of variety and density of reliable meteorological observations over Australia and Antarctica poses a major challenge for operational weather prediction, long term climate studies, and optimal usages of satellite data. Since the successful launch of the six COSMIC satellites in April 2006, approximately 2,500 global daily GPS radio occultation events (ROEs) and over 100 daily GPS ROEs in Australia have been obtained which represents six times more observations in comparison with CHAMP. Such a large number of retrievals have brought unprecedented opportunities for in-depth regional studies and operational usage of the GNSS RO retrievals in southern hemisphere. The planned new launches in the next a few years from South America, Europe and Asia are offering exciting opportunities for geodesists to tackle big issues such as climate and environment globally.

Recent significant Australian research initiatives along the GNSS positioning, meteorology/climate and space debris tracking will be outlined. We start with a brief introduction of the SPACE Research Centre established at RMIT University including key research directions and projects, and recent international collaborations, particularly in the areas of GNSS atmospheric sounding, weather and climate. The recent Australian government initiative of its space research program scheme will be then outlined. The multiple million dollars space research project in the areas of in-space tracking and navigation, precise satellite positioning, space weather, atmospheric modelling and climate monitoring awarded to a research consortium led by SPACE will be introduced. Key issues related to the research work and challenges confronting Australian space research and space industry will be discussed and some preliminary outcomes will be shown to facilitate discussion and possible international collaboration in atmospheric remote sensing, GNSS and geodesy.

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AAS001-02 Room:202 Time:May 25 16:52-17:14

New scientific and operational application with real-time GNSS monitoring of atmosphere

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GPS has been widely used as new unique sensor for accurate atmospheric sensing. The method is based on the measurement of the atmospheric delay of the phase of a microwave transmitted from a GPS satellite and received at a GPS antenna. This time delay (converted to excess path delay by multiplication with the speed of light) is determined by comparing the observed propagation delay with the computed vacuum delay based on the know positions of transmitting and receiving antennas. The primary part of the delay is caused by the ionosphere, and its contribution can be corrected (observed) with dual frequency observations due to the nature of dispersion of the ionosphere. We can retrieve the integrated refractivity of the neutral atmosphere after removing the contribution of the ionospheric delay.

Improvements in the GNSS processing strategy, geophysical/instrumental models, and satellite orbit/clock products has led to improved GNSS atmospheric sensing. Availability of real-time data has made true real-time solutions that are available within a few seconds of data collection possible. For GPS Earth Observation NETwork (GEONET) in Japan, the most antennas and receivers were replaced around 2003, and real-time data streaming of 1Hz data has been implemented since then. Many other global GPS networks with real-time data streaming have also come on line. Such real-time GPS networks enable new GPS application of monitoring the atmosphere in true real-time and make previous near-real-time (NRT) applications obsolete.

The primary GNSS product in the neutral atmosphere is the zenith tropospheric delay (ZTD). ZTD can be mapped to represent the averaged precipitable water vapor (PWV) in the surrounding of the GPS antenna. NRT ZTD and PWV have been used for operational numerical weather forecast, and the impact of ZTD data has been reported for many severe storm cases globally. The primary impact of real-time PWV can be seen in short-term forecasts with frequent updates. It has also been shown to provide useful information for nowcasting of precipitation. Real-time slant path delay which contains information on the inhomogeneity of the water vapor distribution in active weather conditions can be used for water vapor tomography. All the products mentioned above are now available also for moving platform such as ships and buoys with kinematic processing. Such products can be helpful to improve precipitation forecast if the observation data are transmitted in real-time from ocean platforms. A new application of GNSS environmental monitoring is the determination of soil moisture. This is done by analyzing S/N ratios which fluctuate due to multipath reflections from the ground near the GNSS station. These S/N fluctuations are affected by soil moisture and we attempt to use GEONET data for soil moisture monitoring. The data are potentially useful for farming, as input to flood models and for research of the water cycle.

Monitoring of the ionosphere is also possible under the assumptions of a thin ionospheric layer and stable differential code biases in the GPS receivers on the order of a few days. The vertical and slant total electron content (TEC) is used for monitoring of space weather and ionospheric disturbances. With real-time capability, it is possible to monitor the current status of ionosphere to issue warning, and detect tsunami and rocket launches. We can also use ionospheric model generated from dual frequency network for processing of relatively low cost L1 receiver network to get denser information on water vapor and slant path delay.

The paper briefly introduces the background of neutral and ionized atmospheric sensing with GPS, and reviews the current status of global and Japanese GNSS research on atmospheric sensing. It then introduces new real-time application of GNSS for atmospheric research, and concludes with a near future perspective of GNSS meteorology under consideration of Japan's QZSS and radio occultation.

Keywords: GNSS, Water Vapor, Numerical Weather Forecast, Nowcast, Ionosphere, Soil moisture

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AAS001-03 Room:202 Time:May 25 17:14-17:29

A proposal of GPS occultation receiver system for the ionsphere and atmosphere

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Status feasibility study of GPS occultation/reflection receiver system for ionosphere-atmosphere research will be reported.

Keywords: GPS occultation, GPS reflection, GPS receiver

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AAS001-04 Room:202 Time:May 25 17:29-17:44

Ionospheric tomography using ground-based GPS receiver networks in Japan, America and Europe

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An ionospheric tomography algorithm using the GPS Total Electron Content (TEC) data was developed to reconstruct the plasma density distribution from 80km altitude to 20,000km. Observation of the dual frequency radio wave from the Global Positioning System (GPS) can provide the Total Electron Content (TEC) data between satellites and receivers. The set of data from the array of the ground-based GPS receivers and the constellation of the GPS enables to derive the electron density distribution in the ionosphere and the plasmasphere by tomography algorithm. We developed an algorithm to derive the three dimensional distribution of the plasma density using GPS-TEC. We applied this tomography algorithm to the data in Japan, the North America and Europe. The distribution of the ground-based GPS receivers in Japan is denser than that in the North America, and the size of the observational area is wider in the North America than in Japan. Therefore the tomography in Japan is suitable to study the ionospheric structures whose scale is a few hundreds kilometer, and that in the north America is suitable to study the structures whose scale is a few thousands kilometer. The ionospheric plasma density was reconstructed for the cases of the geomagnetically quiet and disturbed times. The spatial and temporal variations of the reconstructed electron density was compared with the observation of the IS radars and satellites.

Keywords: GPS, Ionosphere, Tomography, Plasma density

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AAS001-05 Room:202 Time:May 25 17:44-17:59

Airborne GPS Radio Occultation

Naoto Yoshida[1], Toshitaka Tsuda[1]*

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GPS Radio Occultation (GPS RO) techniques use GPS receivers on board LEO satellites, there is another type of GPS RO techniques called the downward-looking (DL) RO. This technique uses a GPS receiver placed inside the Earth's atmosphere such as on an airplane and a mountain top, and provides atmospheric profiles below the altitude of the receiver by the inversion algorithms for GPS DL. DL RO measurements on the top of Mt. Fuji in Japan were carried out in 2001 and succeeded in deriving temperature profiles and water vapor profiles.

We calculate the data distributions of airborne GPS RO measurements with the flights of Garuda Indonesia Airplane between Jakarta and Surabaya in Indonesia on December 1, 2010. There are 11 flights from Jakarta to Surabaya, and 12 flights from Surabaya to Jakarta. Total number of profiles of the flights from Jakarta to Surabaya is 35, from Surabaya to Jakarta is 53. The length of a tangent point trajectory is different between these opposite direction flights. The frequencies of occultations are also different. This may be explained by the characteristics of the orbit of GPS satellites. Because the inclination angle of GPS satellites is 55 and their speed is greater than that of the Earth's rotation, all GPS satellites moves from west to east with respect to the Earth's surface. Therefore, the relative velocity between an airplane and a GPS satellite is low when the airplane flies from west to east, and is high when the airplane flies from east to west. This effect is more marked at low latitudes than at mid or high latitudes.

The effect of the GPS orbit cannot be seen in a GPS RO mission with a LEO satellite. This may be explained by a difference of speed between an airplane and a satellite. While the speed of a normal airplane is approximately 900km/hours, the speed of a satellite at an altitude of 700 km is 22000 km/hours relative to the Earth's surface. Because the speed of GPS satellites is 3000 km/hours, a GPS RO mission with a LEO satellite is not sensitive to this effect.

Next, we compute the airborne GPS RO data distributions over Japan. Here we select nine major airports, and use JAL flights between each selected airports on February 1, 2011. Total number of these flights is 210 and observation data is 1114. For this case the data density near Japan is roughly 5 events/(100 km x 100 km) in a day. This result suggests that airborne GPS RO measurements with commercial flights will produce a number of atmospheric profiles in particular region. So, such measurements are expected to contribute to improve the accuracy of weather forecast around there remarkably.

Keywords: GPS Radio Occultation, LEO, Airborne, downward-looking

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AAS001-06 Room:202 Time:May 25 17:59-18:14

Mesoscale Data Assimilation of Tropical Cyclones with GPS Atmospheric Information

Yoshinori Shoji[1*], Masaru Kunii[1], Hiromu Seko[1], Toshitaka Tsuda[2], Kazuo Saito[1]

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A four-dimensional variational (4D-Var) mesoscale data assimilation (DA) system in low latitudes was developed and impacts of GPS derived atmospheric information on tropical cyclone prediction was investigated through two case studies.

Prediction of tropical cyclones (TC) including typhoons is one of the most important issues in meteorology. Although accuracies of the operational numerical weather prediction (NWP) in world forecast centers have been considerably improved in recent years, there are still many difficulties in the TC prediction. Resolution and physical processes of NWP model together with mesoscale DA is a key factor for the issue. However, the most mesoscale regional DA systems operated routinely are designed for mid-latitudes.

In this study, to prepare high-resolution (10 - 20 km horizontal grid spacing) initial fields for the simulation of tropical cyclones, the mesoscale 4D-Var DA system (meso 4D-Var) for the JMA hydrostatic meso-scale model (MSM) is modified in order to optimize to use in low latitudes where TCs generate and develop. In addition, the impact of GPS derived atmospheric information such as refractivity profile or precipitable water vapor (PWV) on TC prediction is also investigated thorough the following two case studies.

1. DA of GPS radio occultation (RO) data for typhoon USAGI in 2007

The assimilation period of the experimental meso 4D-Var is 24-hour and typhoon bogus data is not assimilated. Numerical predictions are attempted using JMA non-hydrostatic model (NHM) with 10km horizontal resolution. When the global analysis is used for the initial field, the typhoon is not formed in the forecast. By contrast, when the global analysis is replaced by the meso 4D-Var analysis in the experiment, the generation of the typhoon is successfully predicted. With GPS RO refractivity assimilated, the simulated typhoon intensity is closer to the best-track data.

2. DA of GPS PWV for TC NARGIS in 2008

NHM predictions using initial fields produced by DA experiments that used only ordinary observational data (without GPS PWV) exhibited a large variation of predicted maximum TC intensity (958 to 983 hPa) according to DA period (12, 24, 36, and 48 h). In these experiments, a longer assimilation period did not necessarily result in better prediction. The DA of GPS PWV yielded a smaller variation of predicted maximum TC intensity (964 to 974 hPa), and a longer assimilation period tended to bring deeper depression of TC central pressure. Overall, TC intensities determined by DA experiments with GPS data were closer to the best track produced by the Regional Specialized Meteorological Centre (RSMC) New Delhi than the DA experiments without GPS data.

In those two experiments, it was confirmed through the close inspection that implementation of GPS data contributed to create a more favorable environment for the generation and development of the TCs.

Keywords: Numerical Prediction, Data Assimilation, GPS Meteorology, Remotesensing, Cyclone Nargis

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Improvement of rainfall forecast by assimilations of ground-based GPS data and radio occultation data

Hiromu Seko[1*], Masaru Kunii[1], Yoshinori Shoji[1], Kazuo Saito[1]

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Impacts of three kinds of GPS-derived water vapor data, i.e., precipitable water vapor (PWV), slant water vapor (SWV) and radio occultation (RO) data, were investigated using the Meso 4D-Var system of Japan Meteorological Agency (JMA) for a heavy rainfall case on 16 July 2004. When PWV or SWV data were assimilated individually, water vapor in the rainfall region was increased and on the northern sides was decreased, and then the shape of the rainfall region became similar to the observed one. However, the reproduced rainfall amount remained smaller than the observed one. Compared with PWV, SWV made the horizontal contrast of water vapor larger. When RO data were assimilated, the low-level water vapor was increased so that the rainfall amount was largely increased. However, the rainfall region became wider than the observed one. When SWV and RO data were assimilated simultaneously, low-level water vapor in the rainfall region and on its southern side was increased, and then both shapes of rainfall region and of rainfall amount became similar to the observed ones.

Keywords: Data assimilation, GPS-derived precipitable water vapor, GPS-derived slant water vapor, Radio cccultation data, Heavy rainfall

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AAS001-P01 Room:Convention Hall Time:May 25 15:45-16:15

Water vapor distribution during the heavy rain estimated with InSAR and GPS

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Interferometric Synthetic Aperture Radar (InSAR) phase signals allow us to map the Earth's surface deformation, but are also affected by earth's atmosphere. In particular, the heterogeneity of water vapor near the surface causes unpredictable phase changes in InSAR data. InSAR can therefore provide us with a spatial distribution of precipitable water vapor with unprecedented spatial resolution in the absence of deformation signals and other errors. On 2 September 2008, a torrential rain struck wide areas over central Japan, and Japan Aerospace exploration Agency (JAXA) carried out an emergent observation of the heavy rains by PALSAR, an L-band synthetic aperture radar sensor. On January 2010, JAXA has carried out another PALSAR measurement of the very areas, so that we could generate InSAR image of the area and examine the detailed snapshot of the regional troposphere; the weather on January 21 2010 was dry and stable. Near Ibi River, we could detect localized signals, which changed 12.2 cm in radar line-of-sight over a spatial scale on the order of 8 km, and were unlikely to be an artifact of either ground deformation or DEM errors, or ionosphere. In the previous report (Kinoshita et al., 2010 AGU Fall Meeting), we validated this point, having shown other InSAR images as well as azimuth component of pixel-offset data. Then we concluded that the signal was due to neither ground deformation nor DEM errors, and we considered that the signal was probably not due to ionospheric effect.

Now we newly try to model the ionospheric effect using azimuth offset data with the method proposed by Meyer et al. (2006). As a result, we concluded again that the ionospheric effect hardly correlated with the signal (Kinoshita et al., SAR session this meeting). In addition, we compare the tropospheric delay in InSAR data with that derived from the GEONET data, the Japanese GPS network. The principle of atmospheric propagation delay in GPS is inherently same as that of InSAR, therefore it is worth to compare of tropospheric delay between GPS and InSAR. We will discuss what we can learn from the InSAR image and GPS zenith wet delay data.

References

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Keywords: InSAR, heavy rain, propagation delay, GPS

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Assimilation experiment of the GPS-drived water vapor observations on the local heavy rainfall event in Okinawa

Takuya Kawabata[1*], Yoshinori Shoji[1], Hiromu Seko[1], Kazuo Saito[1]

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A meso convective system was initiated around 14 h on 19 August 2009 on the south sea of Naha, Okinawa island. After that, a small cumulonimbus, about 2 km x 2 km square, was initiated on the north of that system. This cloud rapidly induced freshet in small Ga-bu river in Naha. This freshet swept away 5 persons who constructed a bridge and 4 persons of them were passed away.

For the prediction on this heavy rainfall event, it is necessary to use the initial field with precise water vapor information, especially in the sourth sea of Naha. To modify the initial field, we conducted the assimilation experiment which assimilated the grand based GPS-derived water vapor observations. In this experiment, we assimilated 3 types of observations, i.e. precipitable water vapor on the GPS observation point, zenith total delay observations, and slant total delay observations to the GPS satellites (STD), and investigated the impact of the 3 h rainfall forecasts. The results showed that the assimilation of STD provided the best rainfall forecast, because the assimilation modified the water vapor distribution of the sea around Okinawa island.

Keywords: Data Assimilation, GPS, slant delay

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Data assimilation of GPS precipitable water vapor to NWP model and its impact on ray-traced atmospheric slant delays

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We have developed a state-of-art tool to obtain atmospheric slant path delays by ray-tracing through the meso-scale analysis data from numerical weather prediction (NWP) provided by the Japan Meteorological Agency (JMA). The tool, which we have named 'KAshima RAytracing Tools (KARAT)', is capable of calculating total slant delays and ray-bending angles considering real atmospheric phenomena. One advantage of KARAT is that the reduction of atmospheric path delay will become more accurate each time the numerical weather model are improved (i.e. time and spatial resolution, including new observation data). Shoji et al. [2009] presented the GPS PWV data assimilation can improve the prediction of a heavy rainfall. On October 27, 2009 the JMA started data assimilation of zenith wet delay obtained by the GPS Earth Observation Network System (GEONET) operated by Geospatial Information Authority of Japan (GSI) for meso-scale NWP model. The improved NWP model data assimilating the GPS PWV data has the potential to correct the atmospheric path delay more precisely. Meteorological Research Institute (MRI) of Japan has evaluated the impact of ground-based GPS precipitable water vapor (GPS PWV) derived from the GEONET on meso-scale NWP model under the localized heavy rainfall event in Tokyo, Japan on 5 August 2008. A terrific thunderstorm occurred across the Kanto area of Japan, and it caused flooding in downtown Tokyo. During the event, the rainfall intensity increased to over 100 mm per hour within thirty minutes. We are now processing the atmospheric slant delays using KARAT through the MRI NWP model during that event. We will also perform the same analysis using the conventional NWP model (i.e. the model without assimilating GPS PWV data). We will present the preliminary results of the comparison study.

Keywords: GNSS, ray tracing, numerical weather prediction, data assimilation, GPS precipitable water vapor, mesoscale

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Development of the high-resolution horizontal distribution of water vapor monitoring system using by GNSS

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The GPS meteorology that began in 1990's produces many results of research. It was demonstrated that the accuracy of the weather forecast improved greatly by assimilating GPS data in a numerical weather prediction model. As a result, It understood that information of the quantity of water vapor included in GPS data was very effective.

In the case of concentrated downpour, it is important to grasp a change of increase and the horizontal distribution of the water vapor to appear in real time. But, it did not utilize the water vapor information in a true real time because it used GPS data for an initial value by the present data assimilation technique every 3 hours.

Therefore we develop the system which finds the water vapor with high time resolution using only the ground GPS meteorology.

The estimated water vapor was the stability means of a radius of 20 km to use all GPS satellites. However, if it uses a satellite staying in the high position for a long time, such as Quasi Zenith Satellite System (QZSS) "Michibiki" which was launched in September, 2010, it is thought that the horizontal resolution of the estimated water vapor is improved to less than 1 km. In addition, it is necessary to locate a lot of GPS receivers on a network to get the wide-area distribution of the water vapor. So, it generates the ionospheric correction model by the data obtained from the double frequency receivers and must maintain the accuracy by applying to the single frequency network.

We are going to carry out the experiment using the roof of public schools around the Uji campus, Kyoto University to solve these problems.

In this presentation, we report the estimated accuracy of the water vapor that we analyze only with the high positioning satellite that assumed QZSS using by data of past density observation campaign in 2001 and an example of concentrated downpour in Kyoto city on August 8, 2005.

Keywords: GPS, water vapor, dense network, QZSS

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Effects of quasi zenith satellite on the reduction of positioning error

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Signals from GPS satellites are delayed by atmosphere between GPS satellites and GPS receivers, and then cause positioning error. Then, delays are estimated by assuming linear distributions of atmospheric delays over GPS receivers, and removed from signals, to reduce positioning error. However, GPS satellites do not stay over the receivers and their paths shift in nonuniform atmosphere. Thus, there is the limit of the reduction of positioning error. On the other hand, Quasi-zenith satellite (QZS) stays over receivers, with providing the continuous data over the GPS receiver, and then it is expected to have the potential of the reduction of positioning error.

In the actual estimation of positioning error, discussion on influence of atmosphere is difficult because other factors also cause errors. Thus, delays produced from outputs of numerical models were used in estimation of positioning error so that positioning error only due to atmosphere can be discussed. In this presentation, the complicated distribution of atmosphere in mountain lee wave case event was reproduced by Non hydrostatic model (NHM) of Japan Meteorological Agency with the horizontal grid interval of 250 m, and positioning error was estimated from delays produced from outputs of NHM.

We estimated positioning error at GPS sites of 4111, 5105 and KWN. The paths from the GPS receivers were determined by a ray-tracing method, and the delays were obtained from the water vapor, temperature etc. of NHM outputs. Positioning error was estimated by the non-gradient model, linear gradient model and quadratic function model with GPS data or GPS and QZS data. When quadratic function model was used, the positioning error became small and effect of QZS data was limited. However, when the non-gradient model or gradient model was used, positioning error was large but reduced by QZS. These results show that the delay provided from QZS has the potential to reduce positioning error.

Keywords: Positioning error, Quasi zenith satellite, GPS

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Environmental Remote Sensing by GPS -Section3- Action of wind

Shouji Aoto[1]*

[1]None

The previous studies of this series of studies have suggested that GPS radio wave (L1) is influenced by atmospheric pollution, atmospheric tide, solar radiation and geomagnetism, which have lead up to the presumption that wind influences to GPS radio wave, too.

The data of wind direction and wind velocity, which were incited from Soramame-kun of NIES web-pages, were used to transform to NS and EW components, which were analyzed in direct correlation with GPS point positioning data, and in indirect correlation with atmospheric pollution, atmospheric tide, solar radiation and geomagnetism, i.e. double correlation with direct correlation between GPS data and those factors.

As a result, NS and EW components have specific distribution of correlation. The correlation distributions of atmospheric pollution had high values in the area of 250~300km distance. Those of wind have similar rings but different patterns. NS components have a zero correlation belt, in each side of which there are observed inverse correlations. EW components do not have such patterns, but only have ring-shape correlation.

Therefore, it is clear that wind influences to GPS radio wave in cooperation with other factors. But, the mechanism of wind action to GPS radio wave is left unclear. It is necessary to study the geoelectromagnetic mechanism of wind occurrence from the meteorological viewpoint.

Keywords: GPS, wind, atmospheric pollution, correlation coefficient, Soramame-kun