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


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

[1] Meyer, F., R. Bamler, N. Jakowski, and T. Fritz (2006): Methods for small scale ionospheric TEC mapping from broadband L-band SAR data, in Proc. IGARSS, Denver, CO, Jul. 31-Aug. 4., 3735-3738.

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

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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

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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