IUGG2011@Melbourne

IAG/JG01-66 #4010

Data assimilation of ground-based GPS precipitable water vapor to the mesoscale numerical weather prediction model and its impact on ray-traced atmospheric total slant delays for GNSS positioning

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Introduction

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 [Hobiger et al. 2008a, 2008b]. 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/**Figure 1**). Shoji et al. [2009] have already 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 the meso-scale NWP model under the localized heavy rainfall event in Tokyo, Japan on 5 August 2008 (see **Figure 2**). 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 have assessed the impacts of GPS PWV assimilation into the NWP model on the KARAT correction by comparisons of the precise point positioning (PPP) solutions. We have compared the precise point positioning (PPP) processing results using KARAT correction via NWP model assimilating GPS PWV with those obtained by 5 other different schemes as shown below in order to assess the impacts of GPS PWV assimilation into the NWP model on the KARAT correction.

Our processing schemes for the comparison:

1. KARAT (MRI+GPS/PWV): Ray tracing through the 5 km MRI NWP model with GPS PWV derived from GSI/GEONET.
2. KARAT (MRI): Ray tracing through the 5 km MRI NWP model w/o GPS PWV data assimilation.
3. Ray tracing through the 10 km meso-scale analysis (MANAL) data by Japan Meteorological Agency (JMA).
   a. KARAT (MANAL/Eikonal): ray tracing using Eikonal solver
   b. KARAT (MANAL/Thayer): ray tracing using Thayer model [Thayer, 1967]
4. Mapping function (VMF1) [Boehm and Schuh, 2004].
   a. VMF1 + gradient: ZWD estimation using VMF1 and linear gradient estimation [Chen and Herring, 1997]
   b. VMF1: ZWD estimation using VMF1

PPP processing

In order to compare NWP schemes we performed precise point positioning (PPP) processing for GPS data sets of GEONET, which is a nationwide GPS network operated by GSI. We have used the data sets of about 1220 GEONET stations during Aug. 3-6 of 2008. The PPP processing were carried out using GPSTOOLS [Takasu and Kasai, 2005].

Results and concluding remark

In the nationwide scale of Japan, the short time repeatability of the PPP results for both horizontal and height positions applying KARAT correction through the MRI NWP model with GPS PWV assimilation are about several percent better than that through the conventional MRI NPW model w/o GPS PWV assimilation. On the other hand, the best result is based on the atmospheric delay correction using VMF1 with gradient model. We need further investigations to evaluate the capability of ray tracing technique to reduce atmospheric path delays under various meteorological regimes. In spite of the present model imperfectness and coarse time resolution, we can concluded that the GPS PWV data assimilation is effective to improve the NWP model for applying the GNSS positioning.

ACKNOWLEDGMENTS
We would like to thank the Geographical Survey Institute, Japan for providing GEONET data sets. We also thank the Japan Meteorological Agency for providing data and products. This study was supported by a Grant-in-Aid for Scientific Research A (No. 21241043) from the Japan Society for the Promotion of Science.

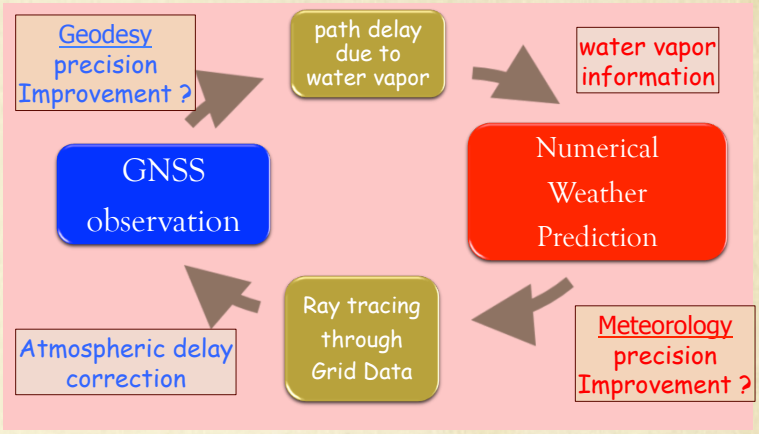


Figure 1. Schematic image of our motivation.

Is this concept promising ?

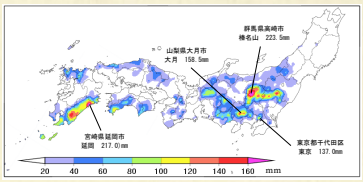


Figure 2. Heavy rain fall event during Aug. 3-5 of 2008.

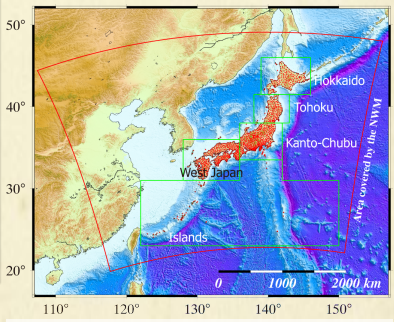
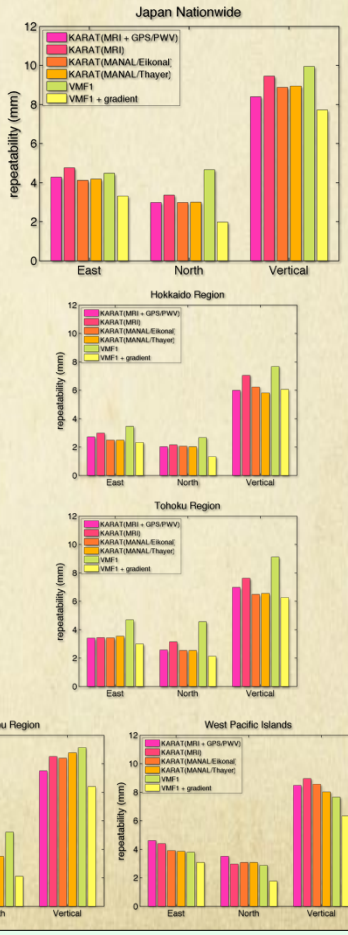
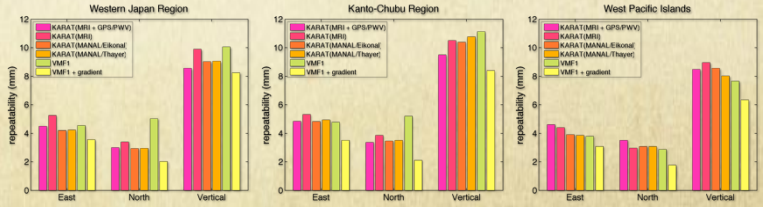


Figure 3. Short time repeatability of PPP processing results (daily averaged repeatability during Aug.3-6 of 2008) Red stars in the map denote the GEONET stations operated by the GSI. Elevation cut off angle is 5 degrees.





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