Optimal estimation of GNSS PWV over the Korean Peninsula and its applications

Jungho Cho*, Han-Earl Park*, Ha-Soo Yoon*, and Sung-Moon Yoo*
* Space Geodesy Group, Korea Astronomy and Space Science Institute

Abstract

Atmospheric precipitable water vapor (PWV) based on GNSS network in South Korea was estimated in near real time. For an optimal estimation of the information, a couple of local mean temperature models and mapping functions were investigated in terms of best fitting to Radiosonde measurements. The optimal estimation enables the GNSS PWV to being reliable and practical for numerical weather predictions particularly for heavy rainfall events.

Introduction

Atmospheric water vapor is one of crucial gases for energy transfer and greenhouse effects. Nowadays GNSS meteorology enables continuous monitoring of atmospheric water vapor in near real time. In order to apply near real time GNSS PWV to numerical weather predictions, the information has to be verified in terms of reliability. Before the verification, we improved the precision of GNSS precipitable water vapor (PWV) to be optimized to the Korean Peninsula. The optimization consists of two parts which are finding an optimal mean temperature model and a mapping function. Then we verified the reliability of the information compared to Radiosonde measurements. Finally, the optimized GNSS PWV information was applied to a numerical weather prediction model for a sample event of heavy rainfall. As the result, the heavy rainfall event was successfully predicted both in time and in space.

The optimization of GNSS PWV

Atmospheric mean temperature is one of key factors in PWV retrieval from GNSS Zenith Total Delay (ZTD) estimates. For precise ZTD estimation based on Precise Point Positioning (PPP) of Bernese 5.2, Vienna Mapping Function (VMF1) was investigated comparing with Global Mapping Function (GMF). As shown in figure 1, VMF1 is slightly better than GMF in terms of bias and deviation with respect to CODE.

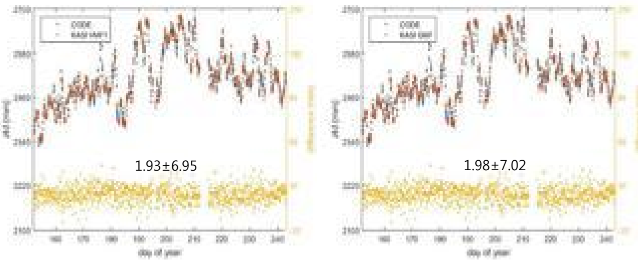

Figure 1. The ZTD comparison between VMF1 (left) and GMF (right) with respect to CODE at DAEJ from June to August 2015.

As a further investigation of the mapping functions, PWVs from Radiosonde and GNSS in 2006-2014 were compared with each other for Sokcho GNSS station in which Radiosonde is launched regularly. As shown in figure 2, VMF1 is also slightly better than GMF in terms of R^2.

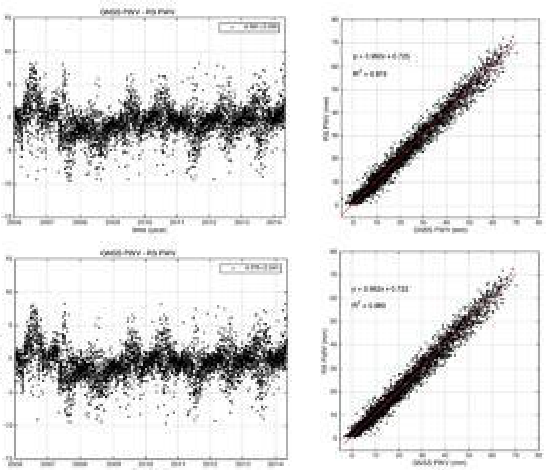

Figure 2. GNSS PWV Comparisons to Radiosonde (RS) measurements by using VMF1 (top) and GMF (bottom).

Several local mean temperature equation models (MTEs) had been developed and were compared with each other including a regional (Bevis, 1992) and a global (Mendes, 1999). Detailed information of the models are summarized in table 1. Unlike the other annual models, Song I and Song II are seasonal corresponding to summer and winter respectively. As shown in figure 3, each MTE shows different inclination. Thus, each MTE is separated big particularly in summer and winter range of the surface temperature.

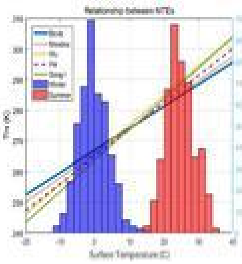

Table 1. Summary of details of the MTEs.

Models	a	b	RS Sites	Periods
Bevis (1992)	0.72	70.2	U.S.	1989-1991
Mendes (1999)	0.789	50.4	Global	1992
Wu (2003)	0.968	1.056	South Korea	1998-2004
Ha (2008)	0.884	23.4	South Korea	1998-2005
Song (2009)	0.98 (Summer) 0.76 0.92 (Winter) 0.97	6.21 (Summer) 72.91 22.49 (Winter) 8.67	South Korea	2003-2005

Figure 3. Comparisons between the MTEs with respect to surface temperature.

To check the effects of the MTE biases in summer and winter, GNSS PWV estimated from each model were compared to Radiosonde measurements during the period from 2009 to 2014 over the Sokcho. The comparison results are shown in figure 4. Although the local seasonal models, which are Song I and Song II, are best fitted to Radiosonde PWV, local annual model Wu was selected as an optimal model because boundaries of the seasons are not clear. In addition, the annual model is proper to maintain consistency of near real-time GNSS PWV.

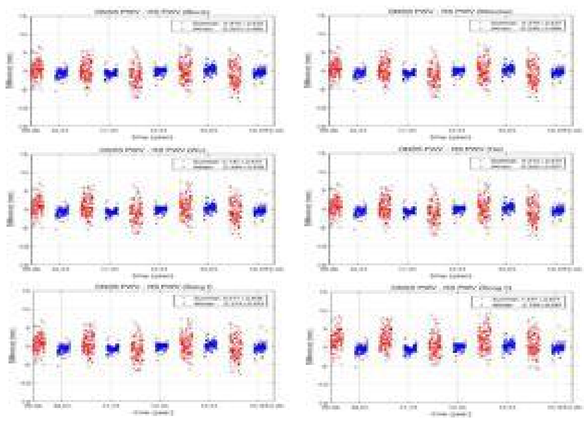

Figure 4. GNSS PWVs applied different mean temperature models were compared to RS particularly in summer and winter for Sokcho site from 2009 to 2014.

Application to Numerical Weather Prediction

To check the applicability of the GNSS PWV to weather forecast, a heavy rainfall event in August, 2014 was chosen. The GNSS PWV estimates based on VMF1 and Wu MTE were applied to WRF 3D-Var assimilation. Figure 5 shows optimal estimation of the GNSS PWV over South Korea for the event period. While weather forecast at that time failed to heavy rainfall in southwest part (dashed circles), WRF prediction including the GNSS PWV information was improved particularly in the area of dashed circles in figure 6.

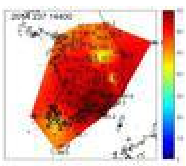

Figure 5. GNSS PWV for Heavy rainfall in Aug. 25, 2014.

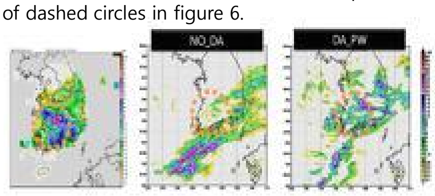

Figure 6. To test of the optimal GNSS PWV and applicability to numerical prediction model, the heavy rainfall event was selected and figures are corresponding to precipitation contour map of the heavy rainfall events (left), weather forecast at that time with no the optimal GNSS PWV data assimilation (middle), and WRF prediction with 3D-Var assimilation of the optimal GNSS PWV.

Outlooks

Based on the optimal estimation of GNSS PWV over South Korea, a couple of experiments are planed such as application to Typhoon cases and fog forecast. After further proof tests and network densification from now 80 sites to 120 sites, 5 to 10 minutes interval GNSS PWV information would be used for improvement of weather forecast particularly for severe rainfall events.

Acknowledgements

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