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Comparison of GNSS tropospheric products obtained by two processing strategies

G. Guerova[1], Ts. Simeonov[1,2], K. Vassileva[3,4]

[1]Faculty of Physics, Sofia University, St. Kliment Ohridski, Bulgaria,
[2] GFZ, Potsdam, Germany
[3]National Institute of Geophysics, Geodesy and Geography, BAS, Bulgaria
[4]European Polytechnical University, Bulgaria

Сравнение на ГНСС тропосферни продукти получени по два метода на обработка

Г. Герова[1], Ц. Симеонов[1,2], К. Василева[3,4]

[1]Физически факултет, СУ "Св. Климент Охридски", България
[2]Център Науки за Земята, Потсдам, Германия
[3]Национален институт по Геофизика, Геодезия и География, БАН, България,
[4]Европейски политехнически университет, България

Abstract

The use of Global Navigation Satellite Systems (GNSS) for atmospheric remote sensing began in the 90s of the 20th century. A widespread method for the obtaining of the tropospheric products is the processing of the GNSS network as a whole called Precise Network Processing (PNP). Over the last decade processing based on the Precise single Point Positioning (PPP) is rapidly developed. In this work a comparison between the tropospheric products obtained by the two methods for GNSS data in December 2013 is reported. Seven GNSS stations from BULiPOS network are processed and results show very high correlation at 5 locations (over 0.95). At station Varna and Rozhen a monthly mean difference of 2.2 and 1.9 kg/m2 is reported.

Резюме

Използването на Глобалните Навигационни Спътникови Системи (ГНСС) за атмосферно сондиране започва през 90те години на 20ти век. Широко разпространен метод за получаване на тропосферните продукти е обработката на ГНСС мрежата като цяло (network solution). През последното десетилетие бързо развитие получиха и обработки базирани на прецизно единично точково позициониране (Precise Point Positioning — PPP). В тази работа е направено сравнение на тропосферните продукти, получени по двата метода за GNSS измервания през декември 2013 г.

1. Introduction

Tropospheric water vapour is the highly variable source of error for the Global Navigation Satellite Systems (GNSS) signals. Global and regional GNSS Analysis Centers (AC's) and projects, such as IGS and EUREF, estimate tropospheric delays to increase the accuracy of their positioning solutions. The Sofia University GNSS Analysis Center (SUGAC) is the first analysis center to provide meteorological tropospheric products from GNSS networks for Bulgaria. The first campaign for estimation of troposphere parameter (Zenith Total Delay – ZTD) for the purposes of evaluation of Integrated Water Vapour (IWV) in 2013 was processed at SUGAC for 7 stations on the territory of Bulgaria by applying the Precise Point Processing method (Simeonov et al. 2016). Later, in 2015 the data only from December 2013 were processed by using the scientific Bernese software, version 5.0. The results obtained from two processing methods were compared.

2.1. GPS data processing

GNSS tropospheric products from the BULgarian intelegent POSitioning System (BULiPOS) GNSS network in Bulgaria (Milev et al., 2009 http://www.bulipos.eu/), are used in this work. GPS data for the period December 1-31, 2013 are processed with the two approaches (PNP and PPP). PNP is based on data of total 20 GNSS permanent stations. All 13 GNSS stations (BLAG, BURG, LOVE, MONT, PLOV, RAZG, ROZH, SHUM, SRED, STAR, TARN, VARN, YAMB) (*Figure 2.1*) of the Bulgarian reference network BULiPOS and 7 IGS GNSS permanent stations (BUCU, GLSV, GRAZ, ISTA, MIKL, ORID, SOFI) have been involved (*Figure 2.2)*. The GPS data with sampling rate of 30 seconds have been processed with Bernese software, Version 5.0 in coordinate system ITRF2005 with 3 degrees elevation cut-off angle for satellites. 31 daily solutions and 5 session solutions have been processed corresponding to the DoYs from 1 till 31 of December, 2013 as station Graz (GRAZ) has been used for datum definition of daily solutions. For modelling the atmosphere have been applied the following models. For the ionosphere – global model with estimated CODE's European ionospheric coefficients of the respective DoYs. The tropospheric zenith delay for each GNSS station has been estimated every 1 hour of the DoY. The a priori tropospheric model used is dry Niell model. For standard atmosphere model the values of required input parameters are: reference height - 0.00 m; temperature at reference height - 18.00° C, the pressure at reference height is 1013.25 mbar and the humidity at reference height is 50.00 %. Wet Niell mapping function is applied for estimation of the site-specific tropospheric parameters of the delay and tilting mapping is applied for troposphere gradient estimation. The estimated daily troposphere parameters (Zenith Total Delay - ZTD) are used as input data in weather modelling of the WFR model.

For the PPP approach GPS data of 7 GNSS BULiPOS stations (BURG, LOVE, MONT, SHUM, STAR, TARN, VARN) have been used (Simeonov et al., 2016). The GNSS tropospheric products (ZTD) have been computed with the NAvigation Package for Earth Observation Satellites (NAPEOS, http://www.positim.com/napeos.html (2016)) software. NAPEOS is developed and maintained by the European Space Operations Centre (ESOC) of the European Space Agency (ESA). NAPEOS is used at ESOC since January 2008. The NAPEOS version 3.3.1 was used for the processing in this study.

The processing has been performed at the University of Luxembourg using the GMF (Global Mapping Function) (Boehm et al., 2006) and 10° elevation cut-off angle. The data have been processed using the PPP approach employing IGS satellite orbits and clocks. The computed ZTDs are with a temporal resolution of 300 s (5 min).

Figure 2.1. BULiPOS GNSS permanent stations involved in the PNP

Figure 2.2. IGS GNSS permanent stations involved in the PNP.

2.2. Integrated Water Vapour derivation

The full description of IWV derivation from PPP is available in Simeonov et al. (2016). A schematic presentation of data flow used in this work is presented in figure 2.3. The tropospheric product Zenith Total Delay (ZTD) derived with PPP and PNP strategy is archived in GNSS_IN table of the Sofia University Atmospheric Data Archive (SUADA, Guerova et al., 2014). Numerical Weather Prediction (NWP) Weather Research and Forecasting (WRF) model simulations are conducted for December 2013 and surface pressure and temperature are archived in NWP_IN_1D table. The WFR model pressure and temperature are used to derive Integrated Water Vapour (IWV) from ZTD following the described in Simeonov et al. (2016) method. It is to be noted that for both PPP and PNP ZTDs the same surface parameters are used to derive IWV.

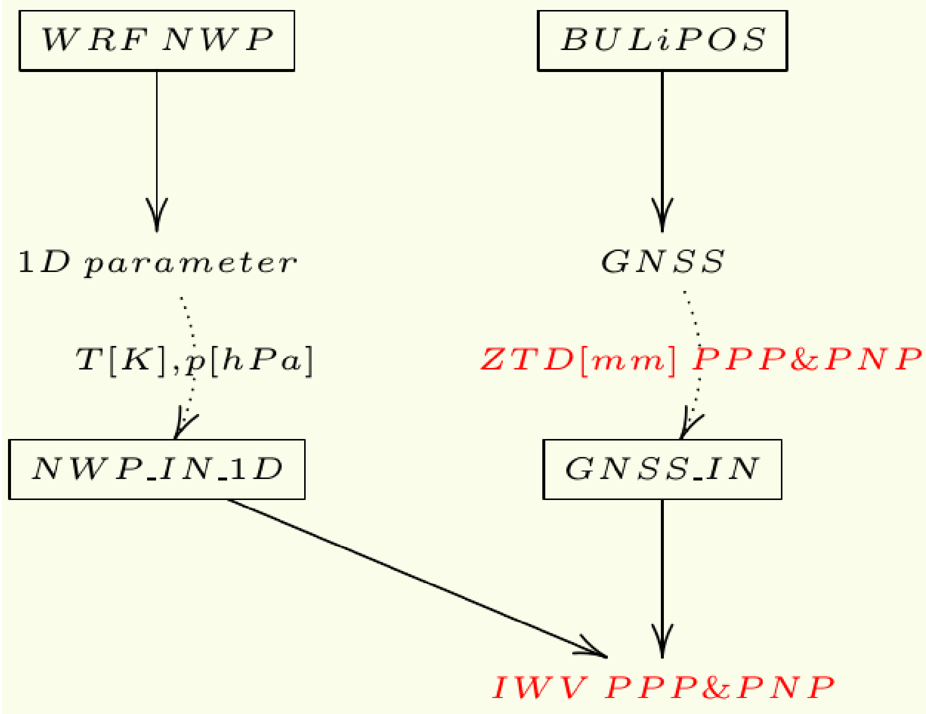

Figure 2.3. SUADA data flow

3. Results

3.1. Comparison of IWV from PPP and PNP at Burgas, Lovech, Montana, Shumen and Stara Zagora

In figure 3.1 is presented the IWV with PPP (red line) and PNP (blue line) at Burgas station for December 2013. Clearly seen is the very good agreement with correlation of 0.96 and the monthly mean IWV of 10.8 and 10.9 kg/m2 for the PPP and PNP respectively. The standard deviation of the two data-sets is 4.6 and 4.5 kg/m2.
The IWV at the stations Lovech, Montana, Shumen and Stara Zagora from PPP and PNP also show very good agreement with maximum monthly mean IWV difference of 0.3 kg/m2 and correlation in the range 0.95-0.97. On figure 3.2 it can be seen that IWV difference is mostly within ± 2 kg/m2 range but at all stations outliers up to 8 kg/m2 are visible. The outliers are predominately at 00 UTC, which coincides with the start of the data processing window by both strategies.

3.2. IWV at Varna and Rozhen

Simeonov et al. (2016) report drop of IWV at station Varna and Rozhen in April and March, respectively. Thus special attention is devoted to those two stations. The manual data inspection at station Varna showed incorrect antenna type of the station in the header of the RINEX data files which was corrected before the PNP processing. The resulted improvement is clearly seen in figure 3.3. The monthly mean IWV from PNP increased by 2.2 kg/m2.
At station Rozhen the manual data inspection did not show problems with the raw data but the PNP processing resulted in 1.9 kg/m2 higher monthly mean IWV (*Figure 3.4*). This is an interesting result which is likely linked to the different tropospheric models used in the PPP and PNP processing strategy. It is to be noted that Rozhen station is at altitude of 1780 m above sea level and that can be the reason for the large differences between the two prepossessing strategies.

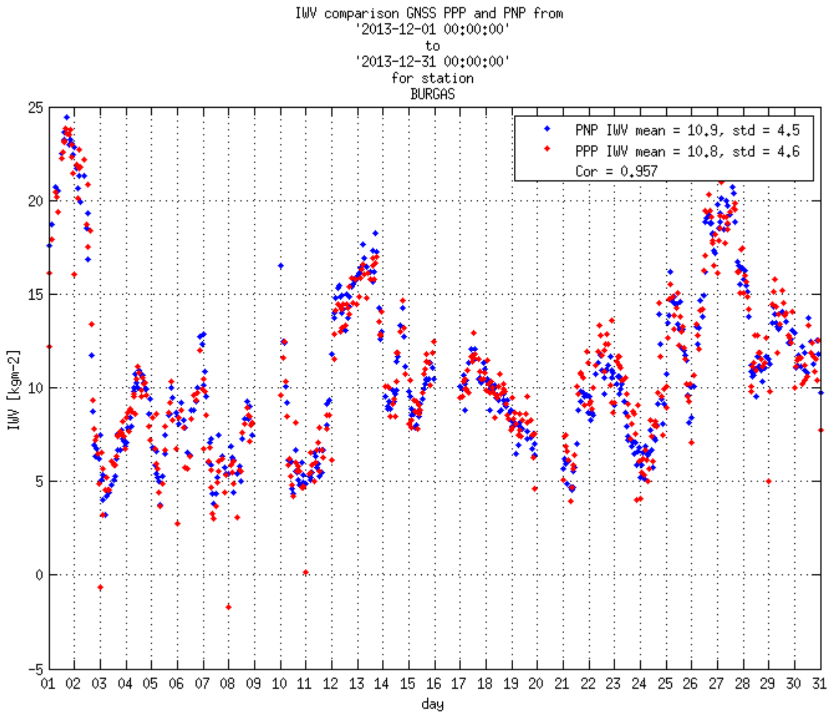

Figure 3.1. IWV with PPP (red line) and PNP (blue line) at station Burgas for December 2013.

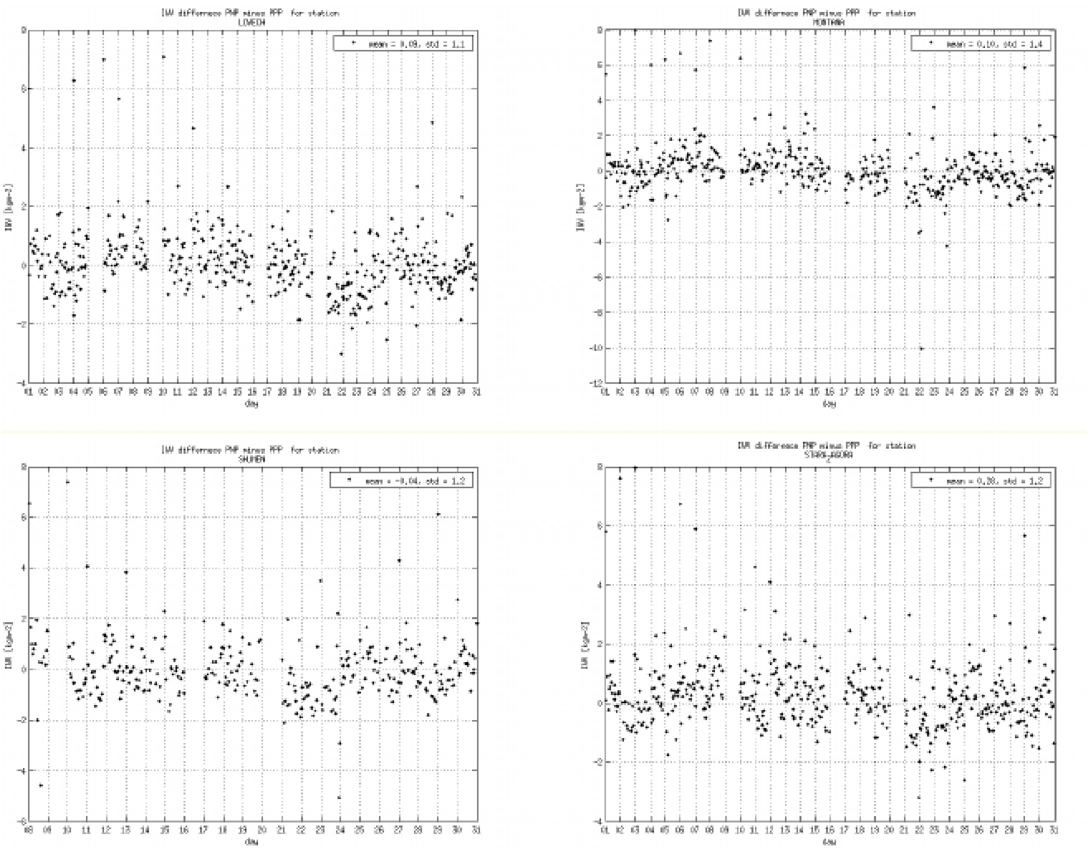

Figure 3.2. IWV difference (PPP minus PNP) at Lovech (top left), Montana (top right), Shumen (bottom left) and Stara Zagora (bottom right).

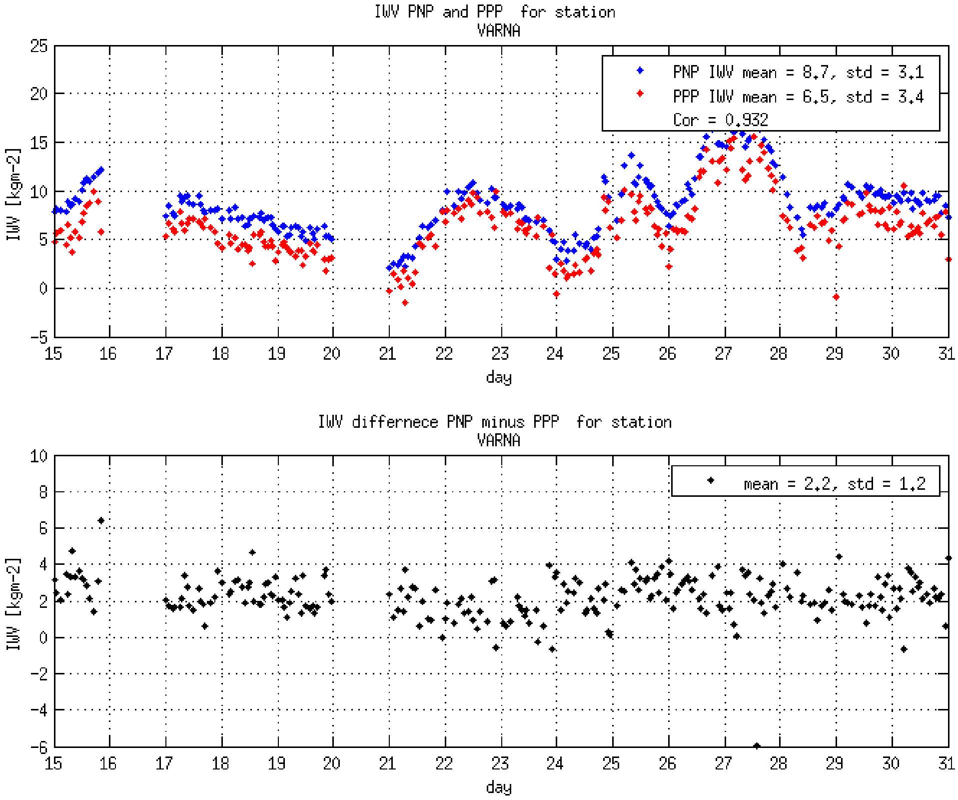

Figure 3.3. IWV (top) and IWV difference (bottom) at Varna.

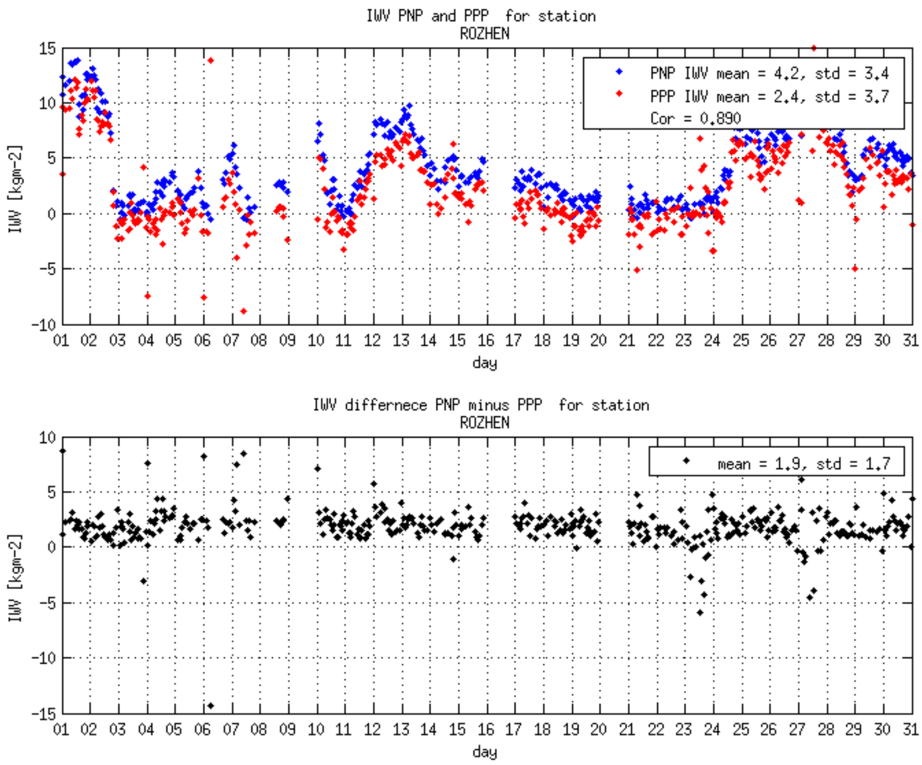

Figure 3.4. IWV (top) and IWV difference (bottom) at Rozhen

Conclusion

In this work the PNP and PPP derived IWV from 7 BULiPOS stations is compared in December 2013. For stations Burgas, Montana, Lovech, Shumen and Stara Zagora very high correlation (0.59-0.95) between the two data sets is obtained. The monthly mean IWV difference at 5 stations is in the range 0-0.3 kg/m2 but it can reach up to 8 kg/m2 at 00 UTC, which reflects the processing window used. At station Varna a manual RINEX file header investigation and change of antenna type resulted in the monthly mean IWV from PNP strategy with 2.2 kg/m2 higher than PPP. At station Rozhen the monthly mean difference is 1.9 kg/m2, which remains to be explained.

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Contacts

[1]Assoc. Prof. Guergana Guerova, PhD
Faculty of Physics, Sofia University, St. Kliment Ohridski, Bulgaria
guerova@phys.uni-sofia.bg

[1, 2]Tzvetan Simeonov
[1] Faculty of Physics, Sofia University, St. Kliment Ohridski, Bulgaria
[2] GFZ, Potsdam, Germany
simeonov@phys.uni-sofia.bg

[3, 4] Prof. Keranka Vassileva, PhD
National Institute of Geophysics, Geodesy and Geography, Bulgaria
Bulgarian Academy of Sciences
European Polytechnical University, Pernik, Bulgaria
Keranka.vassileva@gmail.com