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Interactive comment on "Evaluation of IWV from the numerical weather prediction WRF model with PPP GNSS processing for Bulgaria" *by* Tzvetan Simeonov et al.

Tzvetan Simeonov et al.

simeonov@phys.uni-sofia.bg

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Dear reviewer,

Thank you for the time invested in helping us improve the presentation of our work! Please find below our response to the your recommendations underlined.

1) Although the subject of the manuscript is of scientific interest, the approach followed is quite shallow. In particular, the analysis of results does not go in depth and refrains to simply presenting statistics, either in tables or figures.

This work is a first step in application of GNSS for atmospheric remote sensing in Bulgaria in particular for validation of the NWP model WRF. We agree that NWP model

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evaluation with GNSS has been performed in other regions but for Bulgaria such studies are not available. The dominant features of the atmospheric circulation in Bulgaria and South-east Europe are the Mediterranean cyclones which have complex interaction with topography. Thus it is mandatory to evaluate the model performance. Our experience with simulation of intense summer precipitation has shown that the WRF model has high sensitivity to the convective parameterisation for example and this was the reason to perform an yearly check of the performance of the selected set-up. A detrending using annual and semiannual components was done for all stations. Stations Varna and Rozhen have inhomogenities in the datasets, so the detrending for those stations is highly dependent on the jumps. Stations Stara Zagora, Burgas and Montana have gaps in the beginning or the end of the year, so the estimated trends are not representative. Only stations Lovech and Shumen have long enough datasets for annual trend analysis, so the data for them is included into the manuscript.

The following paragraph is added to section 3.2 with supporting figure 7: The datasets of Lovech and Shumen have the shortest gaps among the studied stations. These two stations were detrended using the following annual fitting function, as proposed by Ning (2012) : $y = at + b\cos(2\pi t) + c\sin(2\pi t) + d\cos(4\pi t) + e\sin(4\pi t)$ where b and c are the annual coefficients and d and e - the semi-annual, while a is a linear trend component. These coefficients were determined using least-square analysis. The correlation between the datasets is high (0.913 for Lovech and 0.901 for Shumen) after subtracting the seasonal variation (Fig. 7). This analysis could not be performed for the other 5 stations, because of the gaps in the datasets, which influence the trend analysis of both the annual variation and the monthly change in IWV.

2) A discussion on the causes of the computed differences is almost absent, while there is no discussion relevant to the available literature.

The following paragraph is added to section 3.2: Further work was carried out to investigate the possible reasons for reported drop in GNSS-IWV values at station Varna and Rozhen. The manual investigation of the raw GNSS data showed that at station Varna

wrong antenna model as reported in the raw data. After the antenna model correction the processing resulted to an IWV increase by 2 mm in December 2013. For station Rozhen the manual investigation did not show any mistakes thus the problem remains there.

The following paragraph is added to section 3.3: The WRF model has an underestimation of diurnal IWV cycle at all stations in the range of 0.5-1.5 mm Guerova and Tomassini (September 2003) report a systematic underestimation of the diurnal IWV cycle between 6 and 21 UTC in COSMO analysis and forecast for Germany and Switzerland. It is not possible to link our study with the one done with COSMO model as each NWP model has its own characteristics (Guerova et al., 2016). NWP models are set up differently, and have different performance, depending on selected region, resolution, season and parametrisation schemes. Our experience with simulation of intense summer precipitation in Bulgaria during 2012 has shown that the WRF model has high sensitivity to the convective parameterisation scheme used and this prompted the present study to a full year check of the the model performance of the selected set-up.

3) A simple verification exercise is certainly important, especially for new "products", but is it enough for supporting a publication?

The GNSS tropospheric products derived from PPP have the advantage of providing high temporal and spatial resolution, which is in high demand for short range weather forecasting and nowcasting application. PPP is a new product for atmospheric analysis using the GNSS Meteorology method. This is one of the first studies, using PPP processing in high temporal resolution, intending to observe IWV variations.

With kind regards, Tzvetan Simeonov on behalf of co-authors

Please also note the supplement to this comment:
http://www.atmos-meas-tech-discuss.net/amt-2016-152/amt-2016-152-AC1-

supplement.pdf

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