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Atmospheric Measurement Techniques Discussions

Interactive comment on "4DVAR assimilation of GNSS zenith path delays and precipitable water into a numerical weather prediction model WRF" *by* Witold Rohm et al.

Anonymous Referee #2

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This manuscript presents Observing System Experiments (OSEs) with assimilation of GNSS Zenith Total Delay (ZTD) and Precipitable Water (PW) in the Weather Research and Forecasting model (WRF) over Poland for the period May-June 2013. The period was selected for a GNSS benchmark campaign during COST Action GNSS4SWEC and reported in the paper by Dousa et al (2016). To the best of my knowledge this is the only assimilation experiment conducted for this period and this makes the contribution of particular interest to the community. However, the benefits of the GNSS dataset collected during the benchmark campaign are not exploited fully (see 2) bellow), which is likely reflected in the results from OSEs.

Major comments/questions:

1) In the paper are used the "International GNSS Service (IGS) ultrarapid orbits, clocks and Earth rotation parameters are used." Please justify the selection of those products as their quality is likely having substantial impact on the OSEs. Please, provide a comparison to high quality near-real time estimates.

2) The quality control of GNSS ZTD is a vital part of the assimilation process. Please, include a section covering the quality control and "black listing" strategy you used. The benchmark quality controlled data-set can be used as a reference.

3) In section 4 is missing the model performance for PW (ZTD). It is not expected to improve the model if it has a very good PW (ZTD), which is likely the case for most of the time. Please, consider including a section with PW comparison of reference (REF) model (without assimilation) and GNSS PW.

4) The reported OSE impact do not cover assessment of PW improvement/degradation. It is important to access both individual positive and negative PW assimilation cases as they can provide valuable insight about the model and the ways to improve it.

5) The assimilation of GNSS data is limited to Poland while there are a large number of GNSS stations in the surrounding countries like Germany (over 500). For the large scale frontal processes the westerly flow modification (through data assimilation) is likely to be more valuable than the local modifications thus the question is if this has been considered. It is recommended to conducted OSEs for selected number of days with assimilation of GNSS data from the neighbouring countries.

Minor comments/questions:

1) Please consider revising the following paragraph in the abstract as it is not fully in line with the state of the art: "The GNSS data assimilation is currently widely discussed in the literature with respect to the various applications in meteorology and numerical

weather models. Data assimilation combines atmospheric measurements with knowledge of atmospheric behavior as codified in computer models. With this approach, the 'best' estimate of current conditions consistent with both information sources is produced. Some approaches allow assimilating also the non-prognostic variables, including remote sensing data from radar or GNSS (Global Navigation Satellite System). These techniques are named variational data assimilation schemes and are based on a minimization of the cost function, which contains the differences between the 15 model state (background) and the observations."

2) Page 1 line 27: Please specify if "20% improvement in bias of humidity forecast," is at surface or in 3D.

3) Page 2 line 21: Please correct "Authors".

4) Page 4 line 13: Please correct the colloquial language use in "PW into the very popular WRF model using the WRFDA package".

5) In section 4 it can be suggest to use the widely accepted terms REF run and OSE1, OSE2 etc instead of "base run".

6) It is not really clear what is displayed and how probability of detection and success ratio are computed in figure 3, 6, 7 and 8. The figures can be combined in one figure and referred as figure a), b), c) and d) as they show similar information. Figure captions are not of sufficient detail.

7) Page 16 line 10: Please explain why is ZTD impact much higher (43%) compared to PW (2%). "Relative humidity MEs are reduced by assimilation of PW by 2% and up to 43% while ZTD is used."

8) Page 18 line 9: "Adding SYNOP stations and radiosonde did not bring any further improvements in forecasting humidity or rain but reduced the errors in wind speed and temperature data." One reason can be that the driving initial and boundary conditions are with assimilated SYNOP and RS data. Please comment on this.

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