Interactive comment on "EPN Repro2: A reference GNSS tropospheric dataset over Europe" by Rosa Pacione et al.

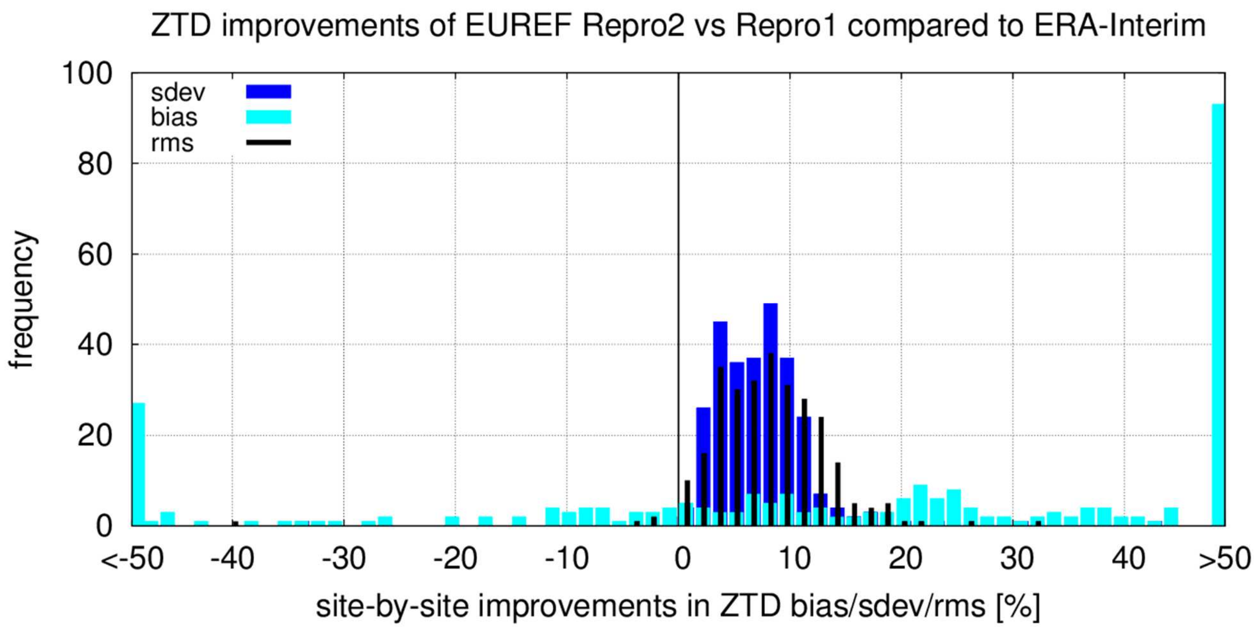
Response to Review #1 (addendum to the response uploaded on 1st February 2017)

Reviewer # 1

Fig. 11: I would recommend to add some quantitative numbers, such as the reduction of biases and SDs, in the text (or Fig.) and the discussion. Based on visual examination, it looks like that it is mainly a shift 3.

Authors' Response

Taking into account what reported in the first response, we have decided to add the additional figure reported below. In the revised text it is Figure 12.



Reviewer # 1

It would be great to show how the processed data improve the detection of PW trends, even just with a few examples.

Authors' Response

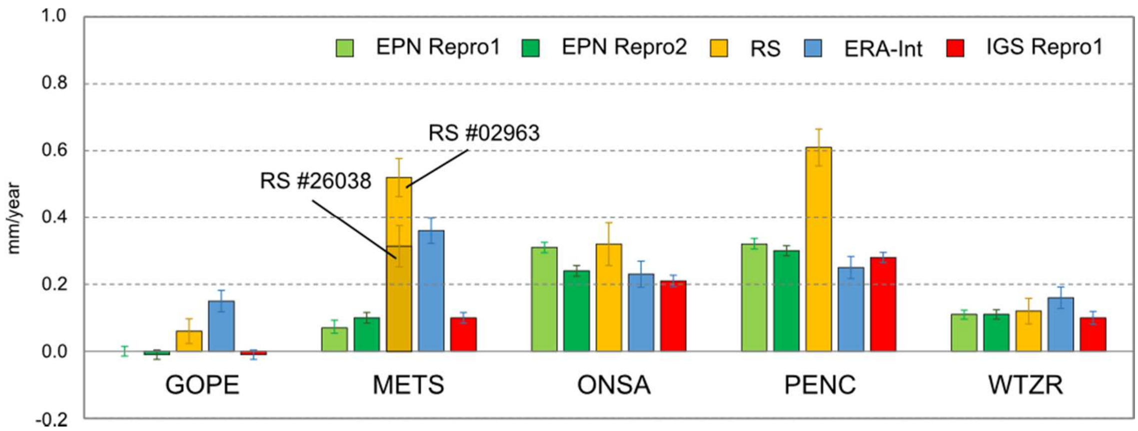
We have reviewed section 5 'Conclusion' and have added examples available in the literature. As an example of application of EPN Repro2 data, we cited, in addition to the assimilation trial ongoing at UK Met Office, comparisons with regional climate model simulations ongoing at Sofia University and Hungarian Meteorologic Service.

As requested, we have computed ZTD trends at five EPN stations: GOPE (Ondrejov, Czech Republic, integrated in the EPN since 31-12-1995), METS (Kirkkonummi, Finland, integrated in the EPN since 31-12-1995), ONSA (Onsala, Sweden, integrated in the EPN since 31-12-1995), PENC (Penc, Hungary, integrated in the EPN since 03-03-1996) and WTZR (Bad Koetzting, Germany, integrated in the EPN since 31-12-1995) using EPN Repro2, EPN Repro1 completed with the EUREF operational products, radiosonde and ERA-Interim data. All of them are also in the IGS Network, for which IGS Repro1 time series is available. IGS Repro1 data completed with the IGS operational products have been extracted from the GOP-TropDB.

We have screened all data sets (classical 3 sigma). Then for all GPS ZTD data sets (EPN Repro2, EPN Repro1 + operational and IGS Repro1 + operational) we have estimated and removed shift related to the antenna replacement. No homogenization has been done for radiosonde since we do not have radiosonde metadata to do this properly. However, we think that this will affect the comparison of ZTD trends in the same way. A LSE method is applied to estimate trends and seasonal component.

Finally, we received trends for EPN Repro2 (GOPE=-0.01+/-0.014 mm/year; METS=0.10+/-0.016 mm/year; ONSA=0.24+/-0.016 mm/year; PENC=0.30+/-0.015 mm/year; WTZR=0.11+/-0.014 mm/year) and other data sets.

ZTD trends for all three GPS ZTD data sets are consistent, as soon as the same homogenisation procedure is applied. The overall RMS is 0.02 mm/year. Among all five ZTD sourced, we find the best agreement for ONSA (RMS=0.04mm/year) and WTZR (RMS=0.02mm/year). For PENC we have good agreement with respect to ERA-Interim (0.05 mm/year), but a large discrepancy versus radiosonde (-0.31 mm/year). This large discrepancy is probably due to the distance to the radiosonde launch site (40.7 km, radiosonde code 12843) and to the lack of the homogenisation stage. Over the five considered stations the agreement with respect to ERA-Interim (RMS = 0.11 mm/year) is better than that with respect to radiosonde (RMS = 0.16 mm/year). An additional figure (included in the revised text as Figure 15) shows the ZTD trend comparisons, the error bars are the formal error of the trend values.



For the considered stations EPN Repro2 do not change significantly the detection of ZTD trends as compared to EPN Repro1 + operational or IGS Repro1 + operational. However, it has generally a better agreement w.r.t. radiosonde and ERA-Interim data than EPN Repro 1 + operational. It has also the best spatial resolution than IGS Repro1 and radiosonde data, which are used today for long-term analysis over Europe. Taking into account the good consistency among trends, EPN Repro2 can be used for trend detection in areas where other data are not available.

Lines 391-395 changed:

> "However, this data set is quite sparse over Europe (only 85 stations over the 280 EPN stations) and covers the period 1996-2010. According to Wang et al. (2007) IGS ZTD products are valuable source of water vapor data for climate and weather studies. The GPS PW is useful also for monitoring the quality of the radiosonde data. However, a better spatial coverage of the GNSS PW data is needed to investigate and reduce systematic biases in comparison with the global radiosonde humidity data (Wang and Zhang, 2009). On the other hand extending the observation period and complement of temporal coverage is necessary to calculate more reliable mean values and trends. As it was pointed by Baldysz et al. (2015,

2016) additional two years of ZTD data can change estimated trends up to 10%. Therefore, data after 2010 and with a better coverage over Europe are required for improving the knowledge of climatic trends of atmospheric water vapour in Europe. In this scenario, EPN-Repro2 can be used as a reference data set with a high potential for monitoring trend and variability in atmospheric water vapour. Considering five EPN stations, among those with the longest time span, GOPE (Ondrejov, Czech Republic, integrated in the EPN since 31-12-1995), METS (Kirkkonummi, Finland, integrated in the EPN since 31-12-1995), ONSA (Onsala, Sweden, integrated in the EPN since 31-12-1995), PENC (Penc, Hungary, integrated in the EPN since 03-03-2096) and WTZR (Bad Koetzting, Germany, integrated in the EPN since 31-12-1995), we have computed ZTD trends using EPN Repro2, EPN Repro1 completed with the EUREF operational products, radiosonde and ERA-Interim data. All of them are also in the IGS Network, for which IGS Repro1 completed with the IGS operational products are available and extracted from the GOP-TropDB. First we have removed annual signal from the original time series and marked all outliers according to 3-sigma criteria. Then for all GPS ZTD data sets we have estimated all well-known and recognized shifts related to the antenna replacement. No other unexplained breaks has been removed to be sure that we not introduce any artificial errors. Based on the cleaned and filtered data we have used linear regression model before and after the considered epoch independently. The difference between those two models in specific epoch is considered as a shift. Then, we have removed all the estimated shifts from the original time series. Generally, the size of the shifts is much lower than noise level and depends on the applied method of its estimation. Therefore, the final results are affected by used methodology and cannot be considered as an absolute values. No homogenization has been done for radiosonde since radiosonde metadata are not available. Finally, a LSE method have been applied to estimate linear trends and seasonal component. ZTD trends (Figure 14) for all three GPS ZTD data sets are consistent, as soon as the same homogenisation procedure is applied. Then overall RMS is 0.02 mm/year. Among all five ZTD sourced, we find the best agreement for ONSA (RMS=0.04mm/year) and WTZR (RMS=0.02mm/year). For PENC we have good agreement with respect to ERA-Interim (0.05 mm/year), but a large discrepancy versus radiosonde (-0.31 mm/year). This large discrepancy is probably due to the distance to the radiosonde launch site (40.7 km, radiosonde code 12843) and to the lack of the homogenisation stage. Over the five considered stations the agreement with respect to ERA-Interim (RMS = 0.11 mm/year) is better than that with respect to radiosonde (RMS = 0.16 mm/year). Even though for the five considered stations EPN Repro2 do not change significantly the detection of ZTD trends, it has a better agreement with respect to radiosonde and ERA-Interim data than EPN Repro1.It has also the best spatial resolution than IGS Repro1 and radiosonde data, which are used today for long-term analysis over Europe. Taking into account the good consistency among trends, EPN Repro2 can be used for trend detection in areas where other data are not available.

Comparisons with regional climate model simulations is one of the application of EPN-Repro2. Ongoing at Sofia University is comparison between GNSS IWV, computed from EPN-Repro2 ZTD data for SOFI (Sofia, Bulgaria), and ALADIN-Climate IWV simulations conducted by the Hungarian Meteorological Service, for the period 2003-2008. The preliminary results show a tendency of the model to underestimate IWV. Clearly, larger number of model grid points need to be investigated in different regions in Europe and the EPN-Repro2 data is well suited for this."

Baldysz, Z., Nykiel, G., Figurski, M., Szafranek, K., and Kroszczynski, K.: Investigation of the 16-year and 18-year ZTD Time Series Derived from GPS Data Processing. Acta Geophys. 63, 1103-1125, DOI: 10.1515/acgeo-2015-0033, 2015

Baldysz Z., Nykiel G., Araszkiewicz A., Figurski M. and Szafranek K.: Comparison of GPS tropospheric delays derived from two consecutive EPN reprocessing campaigns from the point of view of climate monitoring. Atmos. Meas. Tech., 9, 4861-4877, DOI: 10.5194/amt-9-4861-2016, 2016