Interactive comment on "Tropospheric products of the 2nd European GNSS reprocessing (1996-2014)" by Jan Dousa et al.

Responses to Review #2.

RC1: The manuscript presents results of the 2nd reprocessing of the EPN network performed by GOP analysis centre. Seven variants of processing were carried out and compared to GOP-Repro1 and combined EUREF Repro 1 solutions. Moreover, independent data from the ERA-Interim global reanalysis were used to validate tropospheric products from GNSS processing. Authors assessed all solutions in term of repeatability of station coordinates and also analysed biases and standard deviations of the derived ZTDs and horizontal gradients. They also discussed the relationship between tropospheric gradient bias and antenna tracking. In my opinion this paper is well written and will be of interest of AMT readers. However, I have some concerns and questions before it can be accepted for publication.

1. Did you do any screening of coordinates and ZTD/gradients obtained from your processing? If so, what was the screening procedure?

Within the processing, we screened station coordinate repeatabilities from weekly combined solutions and we identified any problematic station for which north/east/up residuals exceeded 15/15/30 mm or RMS of north/east/up coordinate component exceeded values 10/10/20 mm. Such station was a priori excluded from the tropospheric product for the corresponding day. There were other standard control procedures within the processing when individual station could have been excluded, e.g. if a) less than 60% of GNSS data available, b) code or phase data revealed poor quality, c) station metadata were found inconsistent with data file header information (receiver, antenna and dome names, antenna eccentricities) and, d) phase residuals were too large for all satellites in the processing period indicating a problem with station. Tropospheric parameters were estimated practically without constrains (sigma greater than 1 m) thus parameter formal errors reflect relative uncertainties of estimates. Large errors usually indicate lack of observations contributing to the parameter. During the tropoposheric parameter evaluations, we applied filter for exceeding formal errors of estimated parameters (ZTD sigma greater than 3 mm, normal cases stay below 1 mm). In monthly statistics we also applied iterative procedure for excluding residuals exceeding 3-sigma of standard deviation calculated from the compared differences (Gyori and Dousa, 2016). The description was added (end of Section 2).

2. In this paper almost all analysis and statistics (expect interesting case with MALL station) are quite general. You may want to try to analyse the results in more details and try to find cases when change of the processing parameters had the clear influence on the estimated coordinates and tropospheric parameters. E.g. you could do more careful analysis and consider possible dependence on the on the localization of stations, antenna models, etc. (for example maybe for stations in high mountains or closer to equator some variant are better than others). This would improve the content of the manuscript.

We performed spatial and temporal analyses of all processed variants in order to assess the impact of different settings on tropospheric products. Zenith tropospheric delays from all variants were compared in such a way to enable assessing impact of any single processing change: 1) GO1-GO0 for mapping function and more precise a priori ZHD model, 2) GO2-GO1 and GO3-GO1 for different elevation angle cut-off, 3) GO4-GO1 for non-tidal atmospheric corrections, 4) GO5-GO4 for higher-order ionospheric corrections and, 5) GO6-GO4 for temporal resolution tropospheric horizontal gradients. Station-specific behavior is out of this paper and will be studied in future. New subsection (4.4) was added to the manuscript. However, we believe more detailed study on site-specific behaviour is out of the scope of this paper as it would require more time for analysis and additional space for text and figures. We will certainly use the dataset for it in future.

3. Section 2, line 106, Figure 1:
a) You wrote that the network was split into 10 sub-networks. In Figure 1 based on different colours I can distinguish only 6 clusters. It is better to change the markers and e.g. some clusters mark as squares.

The number of clusters was fixed (8 instead of 10) and Figure 1 was enhanced to distinguish station colours.

b) Did you use common stations to link the clusters in the network solution?

Nothing was fixed in the processing, while clustering and fiducial station definitions were dynamically adapted in the processing system.

c) How did you choose the clusters of stations? Based on the localization of the stations? I can see in Figure 1 that clusters are regional – stations which are located close to each other are in the same cluster, and the stations of each sub-networks are always the same. Is it an optimal solution of the sub-networks design?

Geographic clusters were only defined a priori while still possibly adapted dynamically within the processing. Number of used clusters, their size and selection of stations varied in different processing steps, e.g. sometimes using geographic clusters, sometimes random number of stations, sorted or conditioned for specific selections etc. The use of common station or other fixed cluster definition could lead to problems in combined solution when few or poor data at some station are available for linking the clusters. For linking clusters we always used baselines of maximum number of observations.

Santamaría-Gómez (2010) showed the results of processing of global network clustered into “dynamic subnetwork”, where closer stations were distributed in different sub-networks in order to obtain a regular distribution based on station baseline geometry. They showed a noticeable improvement in the percentage of fixed ambiguities, especially before the year 2000, and also improvement of position repeatability and transformation parameters with respect to a “static sub-networks” solution. Did you test maybe this kind of clustering in your processing?
- Santamaría-Gómez, A. (2010), Estimation of crustal vertical movements with GPS in a geocentric frame, within the framework of the TIGA project, doctoral dissertation of the Observatoire de Paris.
- Santamaría-Gómez, A.; Bouin, M.-N.; Wöppelmann, G. (2009), Impact of subnetwork configuration on global scale GPS processing, EGU General Assembly 2009.

We haven’t tested such a clustering, but our clustering approach is based on our long-term experience in developing daily and hourly (near real-time) processing in regional or global scope for estimating tropospheric parameters, coordinates or orbits. We suppose that suggested method might be of interest in a global network processing mainly for orbit determination, however, in a regional network such as EUREF Permanent Network, we prefer prioritizing shorter baselines for reducing the impact of orbit errors and for easier initial phase integer ambiguity resolution. We never use static sub-networks as it is risky and can not generally guarantee a high quality. We process clusters keeping a reasonable reference datum and other parameters for careful pre-elimination of unresolved ambiguities. The final IGS frame was then realized within the combined solution.

4. Section 4.1, lines 202-223: You wrote that you used an interactive procedure of validation of the fiducial stations. Can you be more specific on what this procedure was and how it works? Did you choose stations based on daily repeatability of their coordinates? What was your set of fiducial stations? IGS stations?

For validating a priori defined fiducial stations (IGS stations with precise IGS08 coordinates and velocities) we used the iterative procedure exploiting coordinate residuals at all active fiducial stations when applying Helmert transformation between the IGS08 coordinates and 7-day GOP combined solutions. The criteria for rejection of particular fiducial station were set 15, 15 and 30 mm for north, east and up components, respectively.

5. Section 4.2:
a) lines 233-253: It's a quite long paragraph about comparison of ZTD obtained from GOP Repro2 reprocessing to EUREF Repro1 products. We can expect that EUREF Repro 1 is worse than each version of Repro 2. The fact that some variant of the reprocessing is closer to EUREF Repro 1 does not mean that it is better. So, is it really useful to show such results? Does it bring any meaningful statistics? I think comparison to any external data (for instance ERA-Interim what is shown in next paragraph) is more interesting and conclusive.

We have removed this part suggested by other comments too. Thank you for suggestion.

b) lines 260-274, Figure 5: GNSS ZTD from each reprocessing compared to ZTD from ERA-Interim is characterized by a negative bias. We can also notice it in the EPN solution. Can you explain why the bias is negative?

Actually, we cannot explain it preciously. We expect the mean bias of about -1.8 mm (with uncertainty of 2-3 mm) is coming mainly from the ERA-Interim re-analysis. It means ERA-Interim is drier which could be related to the water vapour content underestimates. Such bias for the ERA-Interim has not been observed in a small dense network in Central Europe of the GNSS4SWEC Benchmark campaign in May-June 2013 (Dousa et al., 2016), but for the same dataset, a larger bias (- 4.9 mm) was observed for NCEP's Global Forecasting System. The mean bias -1.8 mm in Europe over 1996-2014 revealed to be rather stable (see Figure 6) and, it has been observed in all GNSS re-processing results in Europe (Pacione et al. 2017). Alternatively, the bias could be attributed to the numerical weather data processing method, however, within the GNSS4SWEC Benchmark campaign we processed ERA-Interim with two different software and methodology for calculating ZTD, compared them with two different GNSS processing methods while haven't found significant differences in results. The description was added (Section 4.2).

6. References, line 472: Please, change reference Pacione et al. (2017) to: Pacione, R., Araszkiewicz, A., Brockmann, E., and Dousa, J.: EPN Repro2: A reference GNSS tropospheric dataset over Europe, Atmos. Meas. Tech. Discuss., doi:10.5194/amt-2016-369, in review, 2016.

The reference has been corrected.

Finally, we would like to thank the anonymous reviewer for all the comments which helped us to improve the manuscript significantly.

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