Answers to the Interactive comments on „Noise characteristics in Zenith Total Delay from homogenously reprocessed GPS time series" by Anna Klos et al.

Answer to the comments added by O. Ge

Dear Authors, Thank you for interesting paper. Below you can find a few remarks.

Dear O. Ge,

Thank you very much for your remarks. We appreciate for your careful reading, and comments of the manuscript. The answers are added below in italics.

1. I have two general comments to the first part of the paper: a. In the introduction you have written a lot about IWV and its usage as a product for, e.g. climate studies. Why you don't analyses it instead of ZTD? b. I think that you should write more about homogenization of ZTD. You have written themselves about how much important it is, but you didn't write which method/algorithm did you use in for discontinuities detection, why this one, what criteria you take on. The same remarks relating to their removal. I would be grateful for more information about it.

Following the comments of the other reviewers, the ZTD time series have now changed into ZWD time series, and we re-ran the entire analysis again. More details about homogenisation are also added. We employed the epochs we found in the GPS position time series and validated them manually in ZWD data. We ran the least-squares analysis few times for each station, found the amplitudes of offsets and applied only to those whose amplitudes were significant and also, numerically unbiased. We ended with a number of 337 offsets in our selected set of 120 stations. The time series were then homogenised based on the amplitudes estimated with LSE and corrected data was analysed further.

2. The performed analyses look quite good but I have some doubts about the noise nature. Is it stationary? I'm familiar with statistical analyses and I know, that usage of AR models is possible and properly methodically, when the character of the noise is stationary. In your paper I have not found any information about it. if so I would ask you to give some statistics which confirm the stationarity.

Thank you for this comment, indeed, we should have put the statistics into the text to confirm the stationarity. We estimated the values of skewness and kurtosis for each individual ZWD data. The skewness ranged between 0 and 0.6 whereas the kurtosis between 2.7 and 3.1, meaning that we might expect that the ZWD data is stationary.

We run also the so-called Dickey_fuller test where the null hypothesis assumes non-stationarity of the time series. Based on the test statistic, the null-hypothesis fails and meaning the ZWD time series shows stationarity properties.

3. I suggest to change Figure 9, the bottom one, and provide the percentage change. I think that it would be more readable and easier for interpretation.

Figure 9 is now changed. We estimated the significant and insignificant trends of ZWD data and marked them with, respectively, green and red. Significant trends mean when the magnitude of trends are larger than 3 times the error of trend.

4. I have also some remark about result presentation. You estimate trend values for long time series of ZTD. Whether the observation time for all sites was the same? In your paper I could not find clear information about it. As it was mentioned by the e.g. Baldysz et al 2016 (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) or Nilsson and Elgered 2008 (Nilsson, T. and Elgered, G.: Long-term trends in the atmospheric water vapor content estimated from ground-based GPS data, J.Geophys. Res., 113, D19101, 2008) adopted length of the time series can have significant effect on the statistic parameters like a trend. So please, if you can, write more information about it. I think that all analysis of any global characteristics (e.g. Fig 4, Fig 5 etc.) can be presented only on homogeneous data of a similar period of time. Only such results can be used for reliable interpretation of tropospheric changes in case e.g. climate studies.

The time of observations we employed in this research, differed for each individual station. However, this approach is justified by the fact that we do not focus on the interpretation of trends in terms of climate studies. We just propose the new approach using the AR(1)+WH noise model, which should be widely used to decide on the significance of trends instead of a pure white noise. We prove that ZWD trends (but also IWV or ZTD, what can be easily checked) which have already been interpreted in climate studies, might not be significant. A great care needs to be taken when analysing trends especially with WH only model.

5. Moreover I think you should compare your results of trend or amplitude with other studies (e.g. mentioned above, Baldysz et al. 2016). Are there large differences, are they significant and which results are more reliable?

We did not compare the values of trends with previous studies, as we do not focus on their interpretation. We propose a method which should be applied to assess the reliability of trends with values of their errors describing the significance of the estimates.

6. For most stations your trend estimation are similar, both for WH and AR+WH, regardless which noise model was adopted. The only difference can be seen in the error values. Why do you think that greater value is more reliable? I think that you should extend your discussions / comment just on such elements. Currently, I get the impression, it focuses more on the applied some method but without any meaningful statements.

We do not expect significant differences in the trend estimates themselves but the error bounds need to accurately represent the stochastic properties of the time series. This is a requirement for any further interpretations.

The larger error value (or the uncertainty delivered with AR+WH) is more realistic, as AR+WH noise model was proved to be preferred for ZWD/ZTD series. Up until now, a pure white noise model was used to estimate the errors of parameters. In this research, we show that the stochastic part of ZTD/ZWD data follows the evident AR noise with some amount of white noise which makes the power spectra to flatten in high and low frequencies. Based on that, we employ the AR+WH noise to describe what is really happening in the stochastic part of ZTD/ZWD data. Therefore, we characterize the series with the AR+WH which is the preferred noise model for all stations we analysed.

I wish you success in further work.

Thank you very much for your comments.