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Atmospheric Measurement Techniques Discussions

Interactive comment on "Comparison of GPS tropospheric delays derived from two consecutive EPN reprocessing campaigns from the point of view of climate monitoring" *by* Zofia Baldysz et al.

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The authors would like to thank Referee#2 for the comments. In respond to the comment, we changes most of points exactly as suggested by the referee. Detailed answers and comments can be found below:

General comments:

- Referee#2: The authors conclude that the trend differences are caused by the differences in the data processing strategies applied in two campaigns. However, they have only investigated one factor, the mapping function, further and found out that it has insignificant impact in terms of the resulting ZTD trends. Although they suggested

for further works, I still strongly recommend that more works should be carried out (at least using a few sites) for this paper where the authors can introduce the updated models (i.e., application of atmospheric loadings, elevation cutoff angle, and high order of ionospheric correction) one by one in order to figure out which factor has the largest impact on the resulting ZTD trends. By doing so, they can give some primary results and recommend dations for future work.

Authors: In this work only contributions to the EPN reprocessings were analyzed. They were prepared according to the EPN guidelines, conducted according to EPN guidelines, on the respective time. The main objective of this study was to compare data sets which are somehow official and open to the community. The mentioned mapping function is only one of possible factors, which could causing these differences. Nowadays authors working on precise investigation of another factors, which could be responsible for changes in ZTD secular variations. Several another campaign of recalculating of selected 30 EPN stations are finished and another ones are still processed. Therefore authors would like at first finished all planning reprocessings and then analyze them precisely. The results of these investigations will be published.

Detailed comments: - Referee#2 Page 1 line 11: "the trends values were generally higher than the values from the other one". Is this same for both two lengths of the ZTD time series (16 yrs and 18 yrs)

Authors: the second part of the Introductian was changed to be more precisely about general results. This is the same for both lengths of the ZTD time series: "All these analyses were conducted for two lengths of the ZTD time series: a shortened 16-year series and a full 18-year one. In case of spectral analysis, amplitudes of the annual and semiannual periods were almost exactly the same for both reprocessing campaigns. Exceptions were found for only a few stations and they did not exceed 1 mm. The estimated trends were also similar. However, in case of reprocessing performed in 2008, the trends values were usually higher than the values from the other one. In general, shortening of the analysed period of time resulted in decrease of the linear

trends values of about 0.7 mm/decade. This was confirmed by analyses based on two data sets."

- Referee#2 Page 2 line 19-25: It is true that the inconsistencies due to the data processing-related changes, i.e., updates of the reference frame and applied models, different elevation cutoff angle, mapping functions, and processing strategies, can be signficantly reduced by reprocessing the whole data series homogenously. However, there are also site-related changes, e.g., antenna changes and/or radome changes, which can cause inconsistencies in the data time series. Have authors considered those types of changes in their study? What would be the impact on their results if such changes exist in their network? Some more discussion regarding this issue is necessary.

Authors: Reference to the discontinuities related to the antenna changes was added in the end of section 3, in which data preparation for further analysis is presented. "Final step in preparing data for further analysis was removing all discontinuity. Usually they were related to the antenna changes and therefore occured in both sets of data. Due to the fact that discontinuity could disturb proper analysis and trend detection, they were remove for the same epochs in both data sets."

- Referee#2 Page 4 line2-6: Depending on different applications, the requirement on the accuracy of the estimated ZTD is different. For climate research, it is crucial to have high accurate estimates with minimized biases in order to obtain correct long-term trend. Therefore a higher elevation cutoff angle is recommended in the study carried out by Ning and Elgered (2012) for the data processing in order to minimize the impact of the multipath. A few sentences are good to be added here in order to discuss this issue and address which parameters (mapping function? elevation cutoff angle? or others?) are interested to be investigated, in term of the impact on the resulted ZTD trends, in this study.

Authors: we cited Ning and Elgered paper, in which detailed description about

elevation-dependent errors is given. However, we avoid description of them at this point due to the fact that changes between these two reprocessings were only 2 degree (in elevation mask) and it is difficult to estimate its influence on secular variations. However, in Discussion section probably reasons of such differences in ZTD trends are mentioned.

- Referee#2 Page 5 line 6-7; he parameters which are elevation dependent (mapping functions, PCV, and elevation cutoff angle) will have immediate impact on the resulted ZTD. How can the authors be sure that the biggest differences between two reprocessing occurred in mapping functions? Has any investigation regarding this issue been carried out? Can you present any values regarding resulting ZTD differences?

Authors: we agree with Referee#2 and changed in manuscript sentence "Parameters which are directly related to the state of troposphere have more immediate impact." was changed to "In frame of factors directly related to the state of troposphere, the biggest differences between Repro1 and Repro2 occurred in mapping functions and adopted ZHD a priori".

- Referee#2 Page 6 line 11: What is reason to choose two standard deviations as the up limit of the outliers? Why not use one or three standard deviations?

Authors: we added information about percentage of the rejected data and detailed description of screening (by giving literature: Bock et al. A high quality reprocessed ground-based GPS dataset for atmospheric process studies, radiosonde and model evaluation, and reanalysis of HyMeX Special Observing Period): ' 'Therefore, ZTD data screening was conducted in both data sets: all outliners that exceed two standard deviations were removed' changed to 'Therefore, ZTD screening was conducted in both solutions sets, according to approach described by Bock et al. (Bock et al. 2015). For all the stations, the percentage of all rejected solutions was on the level of 0,42%. The largest number of rejected solutions was in case of SFER station and amounted to 4,18%. ' The previous version was simplified form of describing of screening process.

- Referee#2 Page 9 line 5: Do you mean that the maximum of ZTD occurred for ALL 52 stations at the same day or you mean that for each station, the maximum of ZTD occurred at the same day for both campaigns, and it is true for all 52 stations?

Authors: the sentence: 'In both campaigns the maximum of ZTD at 52 stations occurred on the same day of the year' was changed to 'For each from 52 stations, the maximum of ZTD occurred on the same day of the year for both campaigns' to be more precisely

- Referee#2 Page 10 line 1: For a given ground-based GPS station, the ZTD value actually is more decided by the height of the station and the ground pressure. The sentence "Consequently, high values of the ZTD mean are correlated..." is true only when we compare GPS sites having the same height as well as the same ground pressure.

Authors: according to Referee suggestions authors described factors with which ZTD is correlated in more appropriate form: "Consequently, despite the station height and ground pressure, high values of the ZTD mean are correlated with high content of water vapour in the atmosphere."

- Referee#2 Page 10 line 28-32: I am confused by the results from the Mann-Kendall trend test. When looking into Table 2, the ZTD trend for TRO1 from Repro2 is 0.05 mm/decade and the mean ZTD is 2329 mm while the one from Repro1 is 0.02 mm/decade and the mean ZTD is 2354 mm. No matter we compare the ZTD trend in absolute value or in relative value (in percentage to the ZTD mean), the ZTD trend from Repro2 is more signiïňĄcant than the one from Repro1. How come the trend from Repro1 passed the test while the one from Repro2 did not? Can the authors explain on this?

Authors: Mann-Kendall Trend Test is a statistical test in which all observations from all period of time, are taking into account. However, the size of the trend is not possible to determine. This test was conducted mostly due to the fact, that we wanted to confirm

the presence of a trend estimated using LSE approach. Obtained trends value were really small compared to the ZTD values. For some stations these values are close to zero. In such case, we do not know that this effect is caused by existing trend, ZTD estimation errors or numerical errors. Therefore we used verification method which gave us another information about existence of a trends. In case of station mentioned by Referee#2 (TRO1), both in Repro1 and Repro2 estimated trend was very small and we could not be sure that this trend really exist. Therefore another method was conducted and only in those cases for which both LSE and Mann-Kendall gave positive results of trends, we confirm its existing. Authors knows, that this is only one of many methods which could be used here, and studies related to different methods are in process.

- Referee#2 Page 11 line 9: In the text, the ZTD trends are 5.5 and 5.8mm/decade for the stations BZRG and GLSV, respectively. However, in Table 2, the corresponding values are 0.55 and 0.58 mm/decade. Which are the correct values? The same question refers to the station GOPE.

Authors: incorrect notation in the table header (mm/decade/ was changed to proper form (mm/year)

- Referee#2 Page 12 figure 5 and also figure 7: Make the map in black and white. Otherwise, it is dificult to see the green arrows.

Authors: Maps was changed from full color to black/white.

- Referee#2 Page 16 line 1-17: If the choice of mapping functions is not critical for the ZTD trend estimation, the authors could try to do more tests in order to see if the trend differences come from other parameters, e.g. elevation cutoff angle. At least you could try tests for one or two sites where you reprocess the data for the whole time period for one campaign but using exactly same elevation cutoff angle from the other campaign and then compare the resulting ZTD trend one more time. The authors conclude that the trend differences are caused by the differences in the data

processing strategies applied in two campaigns. However, they have only investigated one factor, the mapping function, further and found out that it has insignficant impact in terms of the resulting ZTD trends. Although they suggested for further works, I still strongly recommend that more works should be carried out (at least using a few sites) for this paper where the authors can introduce the updated models (i.e., application of atmospheric loadings, elevation cutoff angle, and high order of ionospheric correction) one by one in order to figure out which factor has the largest impact on the resulting ZTD trends. By doing so, they can give some primary results and recommendations for future work.

Authors: As authors mentioned earlier in response to the Referee - we're going to analyze and published detailed investigation about probably reasons of the impact of each factor (mapping function, a priori ZHD, HOI, ATL etc.) on the ZTD and estimated trends. Especially in case of different elevation masks we do not want to analyze this problem on the basis of few stations due to the fact that local conditions can affect them. Therefore we would like to conduct analysis on the basis of about 30 stations in order to obtain information about possible site-dependence impact.

- Referee#2 Page 22-24 – All estimated ZTD trends have corresponding uncertainties which however are never mentioned and discussed in the text. In addition, all trends have almost same value of the uncertainty (0.02 mm/decade) and which is really insignficant compared to the trends. How did the authors get these uncertainties? When calculating the trend uncertainty, have the authors considered the short term variations of the water vapour which are not correctly presented by the model used for the trend estimation (see Nilsson and Elgered, 2008)? Some more texts regarding this issue should be added.

Authors: Most of the estimated ZTD trends have the same value of a corresponding trend error of about 0,02 mm/year. This errors are correct and results from the fact, that during estimation process of ZTD trend all hourly observations were taken into account. Despite of analyzed period of time (16 year or 18 year) for most of the station

it was between 140 000 and 157 000 observations which number significant affected estimated error. Information about general value of trend estimation error was added in the beginning of section 5, as well as explanation of its size

- Referee#2 Page 23 (Table 2) – Compared to others, there are some sites, i.e. TERS, VIS0, WTZR, ZECK, and ZIMM having larger differences in ZTD mean between Repro1 and Repro 2 where TERS has a difference of 242 mm. What is reason to cause such signficant differences?

Authors: there was an error in the table (value shift of one row) – it has been corrected

- Referee#2 Page 24 (Table 3) – Table 3: Four sites (JOZE, KIRU, METS, and RIGA) have extremely large ZTD trends (over 70 mm/decade) from Repro2. Are these values correct? In addition, Table 3 has never been mentioned in the text.

Authors: there was an error in the Table 3 – it has been corrected

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