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Atmospheric Measurement Techniques Discussions

Interactive comment on "Decadal variations in atmospheric water vapor time series estimated using ground-based GNSS" *by* Fadwa Alshawaf et al.

Anonymous Referee #2

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Review of manuscript amt-2016-151 "Decadal variations in atmospheric water vapor time series estimated using ground-based GNSS" by Fadwa Alshawaf and co-authors.

General comments

The authors compare PWV from 3 data sources: GNSS, ERA-Interim and surface measurements of dew point temperature. They estimate trends in various parameters and find correlated positive trends in PWV and temperature in the last 30-years. The topic of this paper fits well the scope of AMT. However, I recommend major revision before publication.

My main objections are: - The use of dew point temperature as a proxy of PWV is

highly questionable when small variations and trends are to be extracted. To demonstrate the validity of this approach, a more comprehensive inter-comparison should be performed (not only for 2 sites), including daily data (since these are used to compute the trends) and also PWV trends. - Trend estimates are compared and interpreted but nothing is said about the significance of the values. It is mandatory to include uncertainty estimates and significance tests to conclude on the agreement of trend estimates and on the physical relationship between trends of different variables (e.g. PWV and temperature). - In order to strengthen the methodology and conclusions, data from more GNSS sites with homogeneous data should be included (only 3 sites are used in the inter-comparison and trend analysis whereas the authors claim they have 84 such sites).

The rationale and scientific questioning of the paper should be better introduced and data usage should be made accordingly (e.g. it is not clear why meteorological data back to 1900 are shown when only trends over the last 30-years are analysed).

Why are dew point temperature measurements used to extend the PWV series back into the past when ERA-Interim goes back to 1979 and other reanalyses exist which go further back in the past? Several global XXth century reanalyses have namely been released recently by ECMWF and NOAA.

It is not clear if the PWV comparisons in Section 2 are used to assess the accuracy of the GNSS PWV data or to highlight problems in the ERA-Interim data. A similar remark holds for the surface P and T measurements compared to ERA-Interim.

Nothing is said about the homogeneity of the meteorological data.

Specific comments

P2L15: The results of Bengtsson et al., 2004, are not used in a proper way. First, the trend value of +0.36mm/decade (global mean for the period 1979-2001) is deemed inconsistent by these authors who suggest it is an artefact caused by the changes in

the global observing system. They provide a more reasonable value after correction of +0.16mm/decade (global mean for the period 1958-2001). Second, it is mandatory to indicate the spatial and temporal domain when quoting such estimates because regional trends can be quite different (in sign and magnitude) from the global trend.

P2L18: The concluding sentence from this paragraph is wrong. The two quoted studies evidence strong limitations in the reanalysis data for characterizing long term trends and conclude on the necessity for better understanding and reducing the uncertainties in the long term trends from reanalyses.

P2L27-29: How can the current normal period be calculated until 2020 from observations? This slicing of time periods in the future makes only sense for model projections. When dealing with observations, the period of period should be present. Please correct the sentence accordingly.

P3L10: How is the homogeneity of the data from the 84 sites established or achieved? If any correction is applied to the data to homogenize them it should be explained here.

P3L11 & L20: Meteorological observations are used to calculate ZDD. The accuracy and homogeneity of these data and subsequent ZWD and PWV should be discussed.

P3L23: Equation (1): this formulation for ZDD, as an approximation of ZHD, is usually not used in the GNSS community. The commonly used formulation for ZHD is the one given by Davis et al., 1985, which based on Saastamoinen's earlier work of 1972/1973. Why is a different formulation used here? A consequence of using this formulation is place of ZHD is that the subsequent ZWD and PWV determined from equations (6) and (7) are not consistent with the commonly used formulations for these variables. Please justify your choice, assess the difference with standard formulations, or revise accordingly.

P5L3-10: The PWV data from GNSS and ERA-Interim are compared and it is concluded that the bias increases with height. Are the data corrected for height difference?

Please comment.

P5L10: what is the shadowing effect in mountainous regions? Please explain and quantify.

P5L20: To which extent is the bias at station 0285 explained by the pressure difference shown in Figure 3? Please provide an estimate of this effect.

P5 Table1: if altitude is a determining variable, please add it in the Table. Indicate also over which period the data are compared and at which temporal resolution (monthly?).

P8L4: section 2 lacks a conclusion on the PWV, surface pressure and Tm comparisons.

P9L3: equation (13) is a very poor formula to convert rh to Td as emphasized by Lawrence (2005). Either account for the related uncertainty and propagate it to the PWV and trend estimates or use a more elaborate formula from Lawrence (2005).

P9 Table2: specify the temporal resolution (monthly?)

P10L1-3: Why citing statistical methods used in econometrics? A reference from the climate literature would be more in the scope of this paper.

P10: Equations (15) and (16): how are the trends calculated near the edges of the time series?

P11L15 & P12L2: compare the PWV – T relationship to the Clausius-Clapeyron equation.

Add uncertainty estimates to the trends.

Include regression results for more sites to assess the spatial variability.

Why is only the last 30-year period analysed? The change compared to previous periods is also of interest.

Figure 7 & 8: there are quite large biases between the different datasets. Please comment and assess the impact on the trend estimates.

P12L8: it is a very quick and hazardous conclusion that the observed temperature increase (0.28°C/decade) causes faster melting of snow or that precipitation is more in form of rain. Please justify or revise.

Revise the conclusions (section 5) accordingly.

Technical comments

Please put all the figures at the end of the manuscript (see the AMT author guidelines for more details). Indicate the period of comparisons and temporal resolution of the data in all figures presenting data. Figure 3: wrong labelling: (a,c) PWV and (b,d) surface pressure. Add station ID in the title of plots. Add station altitude in the captions. Figure 3 & 4: Add statistics of differences in the plot (mean, std.dev., correlation). P1L18: PWV is the amount of water *that would* result from condensing... P1L23: define GPS acronym P7L1: The numeric value for Rw (specific gas constant of water vapour) is wrong. P7L6: specify if model-level or pressure-level data are used. P8L3: for which site is the difference of 0.048 mm found? Give the numbers for both sites.

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