Response of the authors:

The authors would like to thank the editor and the reviewers for the time investigated to review this paper. We addressed the suggested points. The current version contains all changes according to the reviewer suggestions.

Referee#2	**Response of the authors**
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).	We also thought that using these data might be critical; however, when comparing the PWV time series obtained based on the dew point temperature, we found a small bias to the PWV measured for example radiosondes. Of course we need to test more sites. This paper presents the concept and preliminary results (title is changed) and we are working on the whole network and will in future work be more able to give more specific conclusions.
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).	That is right, that you. We need to analyze more sites, which what we are currently doing; however, it is quite early to make conclusions about the entire region. Fig. 1 below shows a first results for all available 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).	We want to consider longer time periods than 30 years; however, according to the availability of the GNSS data we compared the last 30 years of the time series.
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.	That is because we want to rely on measurements and not the model data in their current spatial resolution. And because we think there is a large potential in these homogeneous measurements for the analysis of atmospheric variables. Of course more effort has to be put on evaluating the quality of the data.
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.	Since the GNSS PWV time series are not long enough for trend analysis, it was necessary to find another data set, which was the ERA-Interim. So, we compare the GNSS and ERA-Interim to show that it is reasonable to use PWV time series from ERA-Interim for PWV trend analysis as well as

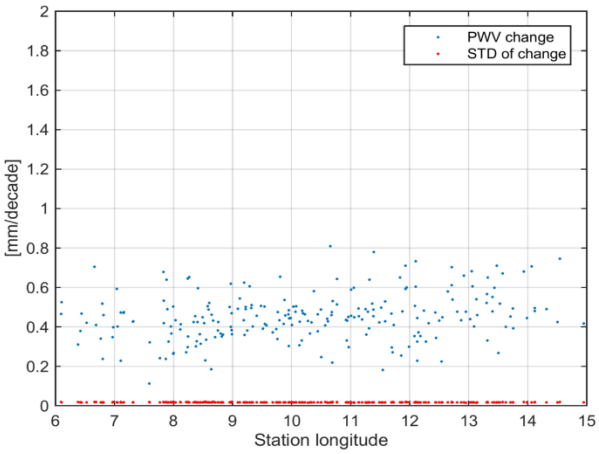
	temperature. Added to text.
Nothing is said about the homogeneity of the meteorological data.	Yes, this is unintentionally missing! We added that in text. They are provided by the German weather service for climate studies and they are homogeneous.
Specific comments	
P2L15: The results of Bengtsson et 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 reanalyzes.	Text is modified
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.	According to the climatologists, the current normal goes from 1991-2020. We, however, are still in 2016, so we defined the interval from 1984-2014 depending on the availability of archive data. It was given in text (now modified).
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.	We had this paper on homogeneity of global GNSS sites. Ning, T.,Wickert, J., Deng, Z., Heise, S., Dick, G., Vey, S., and Schöne, T.: Homogenized time series of the atmospheric water vapor content obtained from the GNSS reprocessed data, Journal of Climate, 2016. For the sites in Germany, we did not detect any change points in the analyzed sites. We are working on a paper that goes into details for all 278 sites in the research region. We calculated the difference between GNSS time series of PWV and radiosonde

	and model data to detect sudden disconnect in the time series.
P3L11 & L20: Meteorological observations are used to calculate ZDD. The accuracy and homogeneity of these data and subsequent ZWD and PWV should be discussed.	That is a good point. We did not describe the GPS data processing in this paper and for more details, we refer to the following papers: Gendt, G., Dick, G., Reigber, C., Tomassini, M., Liu, Y., and Ramatschi, M.: Near real time GPS water vapor monitoring for numerical weather prediction in Germany, J. Meteor. Soc. Japan, 82, 361–370, 2004. Bender, Michael, et al. "Development of a GNSS water vapour tomography system using algebraic reconstruction techniques." Advances in Space Research 47.10 (2011): 1704-1720. If not measured at the GPS site, the pressure and temperature are interpolated from 3 neighboring stations and are accepted with an error of ±1 hPa and ±1 K.
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.	Indeed there have been different works in the GNSS community that aimed at improving the estimation of PWV from GNSS and this formula was used, see for example, 1. Troller, Marc. *GPS based determination of the integrated and spatially distributed water vapor in the troposphere*. Vol. 67. 2004. 2. Luo, X., B. Heck, and J. L. Awange. "Improving the estimation of zenith dry tropospheric delays using regional surface meteorological data." *Advances in Space Research* 52.12 (2013): 2204-2214. 3. Alshawaf, F., T. Fuhrmann, A. Knöpfler, X. Luo, M. Mayer, S. Hinz, B. Heck (2015). Accurate estimation of atmospheric water vapor using GNSS observations and surface meteorological data. Transactions on Geoscience and Remote Sensing. 53 (7), pp. 3764–3771, IEEE Journals & Magazines. However, in this work, we used the traditional Saastamoinen model and the text has been modified.
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.	This conclusion is made for the mountainous region where a cell of ERA-Interim data of 70 km in each direction averages the topography around the Zugspitze. So this sentence is not precise for other area with a rather smooth topography. It is modified

	in text to avoid misunderstanding. And yes, we interpolate the ERA-Interim data at the GNSS site for the sake of comparison.
P5L10: what is the shadowing effect in mountainous regions? Please explain and quantify.	Due to the presence of mountains, the visibility of satellites might be limited. Also, there might be multipath effects in the observed signal. This will have an impact on the estimated tropospheric parameters. This is added to text.
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.	According to what we understand from the questions: The site 0285 is located within the ERA-Interim cell that contains the Zugspitze and a variable surface elevation over 70 km × 70 km. Therefore, the atmospheric variables in this cell are inaccurate, e.g., pressure, temperature, and PWV. To determine the PWV at the GNSS site, we use the measured pressure at from meteorological stations. How the PWV is provided in the ECMWF model or how the pressure might affect it is beyond the scope of this paper. Did we get your point correctly?
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?).	The site altitudes are added to the table, too. In the figure the time period is given on the x-axis at a temporal resolution of one day (x-label).
P8L4: section 2 lacks a conclusion on the PWV, surface pressure and Tm comparisons.	Text added
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).	That is right, thank you. Using this formula to obtained the Td results in 0.38 mm mean difference in PWV. We replaced it with the most accurate formula in Lawrence 2005.
P9 Table2: specify the temporal resolution (monthly?)	Yes, monthly. Added to caption.
P10L1-3: Why citing statistical methods used in econometrics? A reference from the climate literature would be more in the scope of this paper.	Thank you. However, Science is indivisible, so we think what important is to add the right citation.
P10: Equations (15) and (16): how are the trends calculated near the edges of the time series?	We estimate one trend for the entire interval without putting a difference near the edges.

P11L15 & P12L2: compare the PWV – T relationship to the Clausius-Clapeyron equation.	Please refer to Fig. 2 and table 1). We checked the rate of change of the PWV, vapor pressure, and saturation pressure, first using the total values and then looking only at the trend (seasonal and irregular component removed). For the first case, the rate of change in the saturation pressure follows Clausius-Clapeyron relation and the two sites show roughly consistent values. (For Garmisch, the values tend to be smaller, we think because it is located higher). If we look only at the trend component, however, we could not make conclusions, the sites behave differently. If the analysis we did does not answer the question of the reviewer, we would kindly ask him/her to recommend a reference we can refer to do the required analysis.
Add uncertainty estimates to the trends.	Added
Include regression results for more sites to assess the spatial variability.	We agree with the reviewer on this point. However, we do not think that adding more sites will give enough indication about the spatial variability of the trends. Therefore, we make use of the spatial properties of atmospheric variables to provide 2D trend estimates over time. This topic has to be well-described and it will be submitted as an independent paper.
Why is only the last 30-year period analysed? The change compared to previous periods is also of interest.	Yes, it is of interest; however, we wanted to compare the three data sets and the period of GNSS as well as Era-Interim are limited. By the end of this year the ERA-Interim data will be available for the entire century, so we can do more analysis. Moreover, we considered the shortest time period the climatologists suggest.
Figure 7 & 8: there are quite large biases between the different datasets. Please comment and assess the impact on the trend estimates.	As we can see from table 2, the bias for both sites does not exceed 1 mm. It increases for the site IFU1 between ERA-Interim and the other 2 data sets because as we explained above the ERA-Interim data for this mountainous cell are not adequately accurate even if interpolated and downscaled. The bias, however, has little to do the slope of the regression.
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.	This part is removed from this paper

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



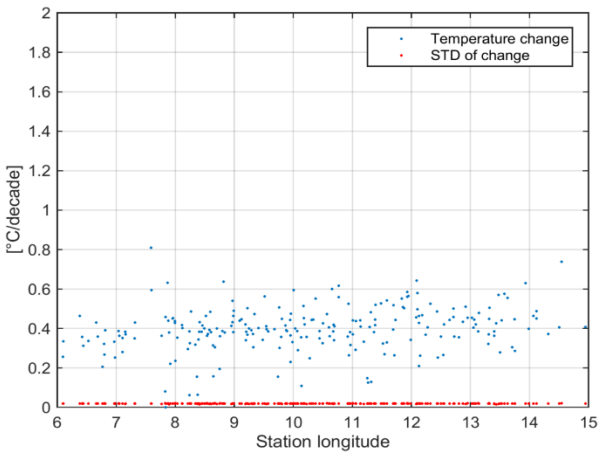


Fig.1: The change of PWV and temperature over the previous 30 years

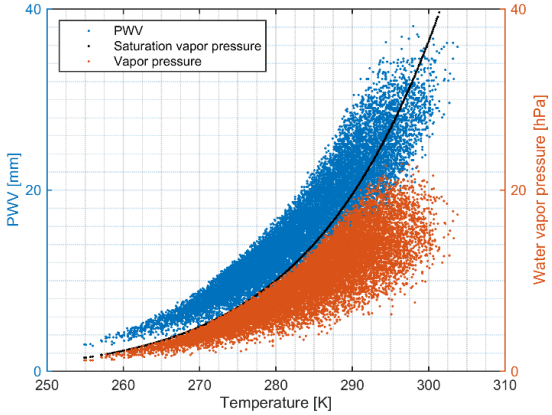


Fig.2: PWV and water vapor pressure against temperature

Table 1: Comparison of the rate of change of PWV and water vapor pressure for sites Berlin and Garmisch

	Site Berlin [%/K]		Site Garmisch [%/K]	
	Total	Trend only	Total	Trend only
Saturation vapor pressure	7.5	4.7	7.3	3.7
Vapor pressure	6.7	8.9	6.6	4
Column water vapor	5.9	9.3	5.6	6.5