# Editor review of "Development of time-varying global gridded Ts-Tm model for precise GPS-PWV retrieval" by Jiang et al.

## Major remarks

Unfortunately, the major remark addressed by David Adams has still not be addressed fully in your final revision of the manuscript: "how much is the error reduction in the GPS-PWV retrieval by using a more accurate Tm parameterization, compared to the other uncertainties in the GPS-PWV retrieval"? Or in other words, you must state that, when using your varying Ts-Tm model, the improvement of x% with respect to e.g. the Bevis equation will be translated in an improvement of y% in the GPS-PWV retrieval. Therefore, since you are using the Ning et al. (2016) formula (your Equation 10), you should give some typical values for the contributions of the different terms in Eq. (10) to the total uncertainty $\sigma_{PWV}$: the first term $\sigma^2_{ZTD}$ accounts typically for around ..% of the uncertainty $\sigma_{PWV}$, the second term (with $\sigma_{Ps}$) accounts for ..% of the uncertainty $\sigma_{PWV}$, the third term (with $\sigma_C$) accounts for ..% of the uncertainty $\sigma_{PWV}$, and the fourth term ( with $\sigma_Q$) accounts for ..% of the uncertainty $\sigma_{PWV}$ (do this for different, typical values of PWV, Ps, etc.). Those different relative contributions of those terms to the total uncertainty are much more meaningful than the values shown in Table 4. By doing this, you will give the reader an idea of the importance of improving the $\sigma_Q$ for the total uncertainty $\sigma_{PWV}$ for the GPS-PWV retrieval. Up to now, this issue (raised by David Adams) has not been addressed satisfactorily by you (**and should be before the manuscript can be accepted for final publication**). So, this aspect (and calculations) should be definitely added to your "uncertainty analysis" described in section 4.3 (lines 289-327).

I also have the feeling that this "uncertainty analysis" (lines 289-327) + the additional assessment I asked for in the previous paragraph does not fit within section 4.3 (Assessment Ts-Tm models), but better at the beginning of section 5 (GPS-PWV retrieving experiments): in section 4.3 you are comparing the differences between the different Ts-Tm models (also in Fig 9.), while in your "uncertainty analysis" you are assessing the impact of the different Ts-Tm models on the GPS-PWV retrieval. I would therefore suggest to move your "uncertainty analysis" (lines 289-327) + the additional assessment I asked for in the previous paragraph to the beginning of section 5.

I have also some remaining problems with the discussion in lines 305-312 (shown in Fig. 8). It starts with the sentence: "Then $\sigma_{PWV}$ results were generated from the different $\sigma_Q$ estimates using equation 10." But, these important calculations to which this sentence alludes to, have never been described or shown in your manuscript, if I understand it correctly. Instead, you are focusing primarily on the uncertainty of Q itself in equation 10 (the so-called pQ, for which a formula should be provided as well), as the $T_m$ errors propagate through the determination of Q. I think that you should treat both error sources of the Tm calculation, so both the $\sigma_Q$ and the pQ, to assess the improvement of Tm varying with respect to other models (this is what an interested reader would see, instead of Fig. 8).

## Minor remarks

- Page 1, line 17: replace to "can remove the large biases in the Bevis equation (Bevis et al., 1992) and …"

- Page 1, lines 22-23: replace “This performance is superior to the other Tm estimation models” to the percentages you find for the other models.
- Page 1, lines 23-25: rewrite after doing the assessment of how much is the error reduction in the GPS-PWV retrieval by using a more accurate Tm parameterization, compared to the other uncertainties in the GPS-PWV retrieval (see major remarks).
- Page 2, line 44: replacing “deducting” by “subtracting”
- Page 3, after line 52: give the definition of Tm here (your equation 5).
- Page 3, line 57: “It usually takes considerable amounts **of** time …”
- Page 3, line 61: “Therefore, such methods are appropriate for climate research or …” (drop “the”)
- Page 3, line 69: “Many studies indicated that **the** Tm parameter has **a** relationship … “
- Page 4, lines 72-73: Change to “For example, Bevis et al. (1992) introduced the equation Tm = 0.72 Ts + 70.2 [K] after analyzing 8712 radiosonde profiles collected at 13 sites in the U.S. over two years.”
- Page 4, line 75. Change to “According to Rohm et al. (2014), GPS-ZTD …”
- Page 4, line 79: “However, it is not precise enough to apply “: I do not understand what you mean here. Please rephrase.
- Page 4, lines 85-86: Change to “A global gridded Ts-Tm model has been established in Lan et al. (2016). In this model, the …”
- Page 4, lines 87-88: Change to “However, the Ts-Tm relationship is varying in time (Yao et al., 2014a), while the Lan et al. (2016) model is static.”
- Page 5, line 98: “Tm is defined as a water vapour weighted mean temperature” → put this sentence and the equation (5) after line 52, page 3.
- Page 6, line 118: profiles instead of profile.
- Page 7, line 132: drop “operation”.
- Page 7, line 140: Change to “However, Tm is also found not being closely related to Ts…”
- Page 7, lines 143-144: Change to “We first carried out a linear regression analysis on four years of Ts and Tm data generated from the radiosonde data and the global gridded ERA-Interim datasets, with data covering the period 2009.01 to 2012.12.”
- Page 7, line 146: Change to “both analyses agree well with each other”.
- Page 7-8, lines 149-151: Change to “and reach a maximum in the polar regions. The correlation coefficients drop dramatically at low latitudes. This is because Tm is stable there, showing independency of the other parameters. “
- Page 8, line 153: “… Tm varies to a lesser degree than Ts at low latitudes.”
- Page 8, line 154: coefficients instead of coefficient.
- Page 8, line 154: Replace “Analyses even demonstrate …” by “We even found that …”
- Page 8, line 155: give again a reference to your figure after “Arabian Sea”.
- Page 8, line 157: here, and at different other locations in the manuscript: geographical locations are denoted as 0.35°N 180°E (so the wind directions are put after the degrees, not before!!!).
- Page 8, lines 158-159: “… near the equator, because the entire variation ranges of Ts and Tm are both within 10 K. This results in a meaningless linear regression (see magenta line).”
- Page 10, line 173: change section title to “4. Development of global-gridded Ts-Tm models”.

- Page 10, line 174: change to “Since the Ts-Tm relationship has large spatial variations, a global gridded Ts-Tm model is preferred for precise GPS-PWV estimations.”
- Page 10, line 178: Change to “A linear formula Tm = aTs + b for the relation between Tm and Ts has been adopted in may studies.”
- Page 10, line 179: please mention the time period for which you performed linear fittings of Tm versus Ts (not Ts versus Tm, I assume).
- Page 10, line 181: please add “(e.g. land, ocean)” after underlying surface.
- Page 10, lines 183-187: Change to “Constant a is smaller (approximately 0.5 to 0.7) over land in the mid to high latitudes over the Southern Hemisphere. Especially, there are abrupt changes in the values of constants a and b from land to ocean in the mid to high latitude due to different variation features of Ts and Tm (see Fig. 2). At the low latitudes, the a value is smaller than over the other regions, because of the low variations of Ts and Tm. The fitting RMSEs are within 2-4K over the mid to high latitude bands, and lower values are obtained over the oceans or at the lower latitudes. “
- Page 11, lines 189-190: Can this be rephrased to “As we did not perform any spatial or temporal smoothing of the data during the data processing, both the precision and resolution of our static model is better than other models (e.g. Lan et al., 2016)”?
- Page 12, line 197: “a precise Ts-Tm model” instead “the precise Ts-Tm model”.
- Page 12, line 201: drop “of corresponding formula items”. Further change “formula items” with “equations”.
- Page 12, lines 203-204: Change to “Our new regression model found similar values for the coefficients a and b (of its static term) as for the static model in section 4.1, except for some differences over the oceans. In Fig. 5, besides these constants a and b, we also illustrate the amplitudes …”
- Page 13, line 209: change to “over water than over land. The estimated Tm RMSE …”
- Page 15, line 222: change to “To further assess the precision of the Ts-Tm models using …”
- Page 15, line 224: change to “independent of our model”.
- Page 15, line 228: add “respectively” after “from”
- Page 15, lines 229-231: change to “When the global gridded models are employed, the radiosonde station may not be located at a grid node. Therefore, we interpolated the coefficients in the Ts-Tm equations from the …”
- Page 16, line 235: change to “$w^i$ are the interpolation coefficients, which are determined using the equation”
- Page 16, lines 238-239: change to “$\psi^i$ are computed using following formal (with latitude $\varphi$ and longitude $\theta$)”
- Page 16, line 240: please be consistent and use superscripts for the indices i, not subscripts in the equation.
- Page 16, line 241: “Considering the fact that the reanalysis grids are definite”.
- Page 16, line 242: are you really referring to equation 5 here?
- Page 16, line 245: change to “Obviously, in many regions, the Bevis equation has a bad precision with the absolute bias and RSME both larger than 5 K.
- Page 16, line 245: last word: RMSEs instead of RMSE
- Page 16, line 250: at many occasions in the manuscript: bad usage of ‘s. Just drop them after bias and RMSE here.

- Page 16, line 254: Tm_varying ‘s RMSE is so awkward. Use “The RSME of Tm_varying” instead.
- Page 16, line 254: add s to second RMSE in this line.
- Page 19, in caption of Figure 7: drop ‘s (two times).
- Page 19, line 272: “the assumption of a normal distribution of the estimated Tm error:”
- Page 19, line 273: drop ‘s
- Page 20, line 283: “All the models are believed to have equivalent performances”.
- Pages 20-21-22, lines 289-326: this uncertainty estimation on the GPS-PWV retrieval is out of scope here and should be moved to section 5, apart from adding different calculations (see major remarks) and rewriting.
- Page 22, line 328 and line 331: be consistent for the IGRA station names or numbers, not only here but throughout the entire manuscript. Either use the entire code EGM00062378 (like in Fig. 9) or mention just the IGRA number like IGRA station number 62378. When you give the latitude and longitude, there is no need to give them up to 4 digits after the comma. Put N and E after the number. And mention the place and country of the station as well.
- Page 23, lines 333-335: “performs as well as the Tm calculated from the radiosonde data, with small biases and capturing the variations well. The time series of Tm_GPS are smoother and cannot capture the fluctuations of the Tm time series, causing a worse accuracy than Tm_varying.”
- Page 23, lines 336-337: Change “It is because” with “This can be explained by the fact that our fitting analyses are based …”
- Page 23, lines 338-339: Drop “Improvements on the reanalysis data should be performed in future”.
- Page 24, line 345: “It is complicated to evaluate the GPS-PWV uncertainty here due to the lack of collocated additional…”
- Page 24, line 347: drop this sentence.
- Page 24, line 350: replace “several” by “74” and write out CDDIS (what does it stand for?).
- Page 24, line 352: add “that” after “so”
- Page 24, line 353: replace “deducted” by “subtracted” and “through” with “with”.
- Page 24, line 356: add “leading to over one hundred compared points for each GPS-PWV series” after “estimates”.
- Page 24, line 357: “the impact of other errors is excluded.”
- Page 24, line 359: We “therefore took” instead of We “regarded”. Drop “Finally, the GPS-PWV … “ until “over one hundred compared points.”
- Page 24, line 361: add “are” before illustrated.
- Page 24, line 362: “At most of the sites” → how many?
- Page 24, line 365: “at ALIC site (Australia), with a mean PWV of …”
- Page 25, line 369: change to “larger only in the summer season (when the PWV values are highest). Apparently, the Tm variations in summer …”.
- Page 25, line 370: Drop the sentence “Furthermore, …”
- Page 25, line 371: rewrite to “some residual errors, which are removed by more than 1.0 mm in $PWV_{VTm}$.
- Page 26, line 382: “within 5 km to a nearby IGRA radiosonde station”.
- Page 26, line 385: “It is worth noting that”. Further on this line: drop ‘s after IGS site.

- Page 26, line 389: replace “occupied” with “make up the bulk of”
- Page 26, line 393-394: please be consistent in naming the radiosonde site and adapt the latitude and longitude notations (too many digits, wind direction after the numbers).
- Page 27, line 397: Some differences can reduce 1-2 mm during the wetter months. It is absolutely not clear what you mean by this statement.
- Page 27, lines 397-398: Drop the sentence “The accuracy of …”, as it has not at all any added value to the analysis here.
- Page 27-28: summary and conclusion. I guess that some of the results of the extra calculations you have been asked for in my major remarks will have to be added to the summary and conclusion section.
- Page 27: you start your summary with a kind of chronological resume of your analysis. This is not how it should be done. You should first say what the major outcome of this study is (the development of your varying Tm-Ts model) and then write how can came to it (analyzing the Tm-Ts relationship based on the Ts and Tm from radiosondes and ERA-Interim).
- Page 28, line 423: “large errors”: how large? Please quantify! Or at least, mention the order of magnitude.
- Page 28, lines 428-429: here again, you do not specify by how many % the errors are reduced in the GPS-PWV retrieval by using your Tm model. This is the major deficiency of your manuscript in your current form, as pointed out several times by David Adams already, and has not been adequately been taken into account. The second sentence of these lines is also too vague and should be assessed, as I’ve asked for.
- Page 28, line 431: drop “as well as the Ts observations”.
- Page 29, line 433: drop the sentence “It could be useful for …”.