

## Review on Manuscript No. ACP-2022-660

Shao et al.: Characterizing the tropospheric water vapor spatial variation and trend using 2007-2018 COSMIC radio occultation and reanalysis data

The manuscript has significantly improved, but still lacks in the quality of the language and a clear writing. There are lot of small errors. It would have been good if the authors would have spent more effort in a careful check of the manuscripts before submission. To list all this small errors is for me as referee really time consuming and distracts me from really focusing on the contents of your study.

### General comments:

The abstract is a bit too long and detailed on the results. I would suggest to skip the explicit numbers of the trend and rather qualitatively state if the trend is positive or negative (and give the order, i.e a few percent). Further, it should be more clearly stated which comparisons have been made instead of writing in detail which differences where derived in which area. I also think mentioning that the El Nino water vapor increases are visible in the data is rather obsolete in the abstract. Write down some key points and make out of these a clear structured abstract.

I don't understand the difference between slope and trend. Isn't the slope of the linear fit the trend?

The result session is still too descriptive and lacks explanations.

The term trending should be replaced by trend, wetter should be replaced by moister, heights by altitudes.

There is still too much data analyses shown in the result section. It is not clearly motivated what the intention is of picking all these sites and looking at them. The paper is in my opinion somewhat overloaded and hard to follow. Especially since you have trouble expressing yourself it makes following the discussion really difficult. In this case a shorter more concise study would be more beneficial.

Section 5 should either significantly improved or omitted. At the moment it makes only the paper longer, but does not provide any knowledge gain.

For example Section 5.3. Why is this studied? It's just a listing of trend estimates without explaining or discussing the cause or consequence of these increasing trends.

Section 5.4 is quite confusing. Here you refer to Figure 7, but this Figure has already been described in Section 5.1. Are you using this figure for both sections? Is the reference really correct? You should more clearly state here what is shown in this figure and refer to Section 5.1.

Further, I am not satisfied with your answer why you selected the altitudes 500 and 300 hPa. You should provide a motivation with respect to atmospheric processes or a certain atmospheric region, e.g. stating that you with these levels cover the entire troposphere (lower, middle, higher troposphere) would be fine with me. However, how can you know what differences and uncertainties to expect? Isn't that what you derive from this study? I think you should improve this paragraph (Sect. 2). Further, you should provide an explanation why you expect this differences.

I think also the conclusion and discussion should be improved. You just squeezed in there some answers to my comments, which however feel there rather lost and out of context.

I have listed my specific and technical comments below.

### **Specific and technical comments:**

P2, L25: qualities -> quality

P2, L59: skip "and" before microwave

P2, L63: skip "and others". I would say that this is obsolete since you already write in the beginning of the sentence "mainly"

P3, L65: in -> for, so that it reads "for long-term....."

P3, L66: I would not use the term "monitoring" for reanalysis data. This is a term that should be rather used with measurements. Thus, I would suggest to write: These atmospheric reanalysis data have been used for understanding (or investigating) long-term atmospheric water vapor variability and trends (or more general changes).

P3, L82: the rise -> the increase

P3, L88: data -> datasets

P3, L90: add "ERA" before Interim

P3, L90: better than reanalysis from -> better than the reanalysis data (add "the" and "data")

P3, L92: What exactly do you mean with "other sensor data"? Please clarify and rephrase.

P3, L94: assure the climate community with -> provide to the climate community (replace assure by provide to and delete with)

P4, L101: microwaves -> microwave

P4, L102: Add "Further," before "RO-derived".

P4, L108: skip comma and add "for" and "and", so that it reads "for climate and meteorological research"

P4, L110: distribution -> distributions

P4, L111: from 2007 to 2018 -> for the time period from 2007 to 2018

P4, L121: replace "As supplementary" by "Additionally"

P4, L122: add "the" -> in the Appendix

P4, L122: .....with introduction to estimating the water vapor trend -> you mean with introducing (or rather describing) the estimation of the water vapor trend? Please check and rephrase (correct English grammar)

P5, L138: occulted by the Earth's atmosphere -> not correct, please rephrase.

P5, L140: Start the sentence with "From" replace "data" by observations and write "are derived", thus "From the retrievals ..... first the bending angle.....are derived"

P5, L144: profile -> profiles

P5, L146: 2007 to 1028 \_> 2007 to 2018

P6, L166: before the study? Please rephrase? Do you mean before the analyses has been performed?

P6, L169: add "the" -> For the RO

P6, L173: could -> may

P8, L231: troposphere -> tropospheric

P8, L233: small -> low

P8, L233: skip "also" and rephrase the next sentence as follows: "The main cause that at 300 hPa higher water vapor from ERA5 than from COSMIC is derived is due..... estimating water vapor....." You can retrieve data, but from a model the data is simulated or estimated.

P9, L247: delete "model"

P9, L248: in consistently -> is consistently

P9, L249: not the "retrieval", but the "retrieval data", thus change "retrieval" -to "retrieval data"

P10, L262: 20-degree-latitude-bin-averaged -> please rephrase and write averaged over 20 degree bins, thus you could write "averaged over 20 degree latitude bins at the three selected pressure levels (300, 500 and 850 hPa).

P10, L266: in Fig. 3 -> shown in Fig. 3 or just write Fig. 3 in parentheses -> (Fig. 3)

P10, L272: a wetter what? A wetter atmosphere? Skip? Rephrase?

P10, L278: wetter -> moister

P10, L279: Sentence not clear. Please rephrase.

P10, L281: Which factors? Clearly state what you are referring to.

P11, L282-283: What do you mean with "warmer NH" and "colder SH"? The winter and summer hemispheres?

P11, L286: grow -> increase

P11, L286-287: Sentence is not clear. Something is missing here.

P11, L289: These factors? Do you mean these conditions? Not clear what you exactly mean .

P11, L289: How or why? How can temperature differences affect water vapor? You just described temperature differences. How is temperature connected to water vapor?

P11, Figure 3 caption: skip "20-degree-latitudinal....." Just write in the first sentence what is compared and then in the second sentence how the data has been treated.

P11, L291: retrieval -> observation or retrieved data

P11, L295: over all months in 12 years -> for all months of the considered 12 year period

P12, L297: add "shown" before "in the middle....."

P12, L310: put Fig 3h and 3f in parenthesis

P12, L311: Fig 3h shows -> From Fig 3h it can be seen.....

P12, L314: Same here: From Fig 3j it can be seen.....

P12, L316: add "differences" before being

P12, L3198-319: Skip "after sampling.....". You don't need this in the section title. It is enough to mention this in the text part.

P12, L323: Sampling removed water vapor -> rephrase. Rather write COSMIC water vapor data where sampling errors have been removed.

P12, L323: in the rest of this paper -> in the remainder of this paper, but better would be to write in the following.

P12, L325: This section compares. Not the section is doing the comparison, but you. Correctly it should read "In this section.....are compared".

P13, L335: Change "It is noted" to "It becomes visible" or "It can be seen"

P13, L341. What is NINO3.4 and NIN4? An explanation should be given in the text.

P13, L342: add "the" before April

P13, L346: Add "the" before seasonal

P13, L346: change "as seen" to "as visible" or even better skip this and put Fig 4a in parenthesis at the end of the sentence.

P14, Figure 4 caption: Needs to be improved. Too much repetition. First sentence obsolete? Trending should be replaced by trend (throughout the manuscript).

P1, L366: trending -> trend and put Fig 4a in parenthesis

P15, L366: Add time period after water vapor concentration.

P15, L369: with -> using, delete of ECMWF data or write ECMWF ERA-40 data

P15, L369, 370 and 371: delete "in" and put references in parenthesis.

P15, L373: were trended -> were used to derive the trend

P15, L378: move the time period behind paper

P15, L379: at three -> at the three and replace from by considered in

P15, L384: add "the" -> the three

P15, L386: trends -> trend, with -> for the and move the time period data

P15, L387: is -> are

P15, L388: overlapped -> overlapping

P15, L390: Just write "a positive water vapor trend of " or " a positive water vapor trend of 1.44%". If you write positive or negative you do not need to give a number. Vice versa, If you give the number then you do not need to write positive or negative.

P16, L404: trending -> trend

P16, L408 and 411: What do you mean with trending slope? Is not the trend the slope of the linear fit?

P16, L409: in -> at and delete "latitude range" at the end of the sentence.

P16, L416: in should be replaced by at or for

P17, L426: "mixed with" should rather read "composed of" or "consisting of".

P17, Figure 5 caption: Comparing -> Comparison of (two occasions)

P17, Figure 5 caption L437: skip retrieval.

P17-18: Figure 5: The sentence starting with "The bar ....." is not clear and needs to be rephrased.

P18, L445ff: In most occasions you can skip writing northern and southern. IF you provide the coordinates with plus and minus signs this is enough.

P18, §49: within -> of

P18, L453: Put Fig 5f in parenthesis and delete "in"

P18, L454: Why -60 to 80? Is that correct? Or should it be -60 to -80?

P19, L457: Put "Figure 5g and Table 2" in parenthesis and delete "show that"

P19, L460: high -> higher

P19, L461: estimations -> estimated

P19, §63: with latitude bins needs to be rephrased.

P19, L460ff: I thought you made a separation into 20 degree bins, Why are in this section larger bins discussed?

P19, L466-467: Sentence not clear. Needs to be rephrased.

P19, L475: interval -> period

P19, L476: the period -> this time period

P19, L476: delete distributed and write "mostly fond over the ....."

P19, L377: above -> greater than

P19, L478: Sentence not clear. Please correct.

P19, L478:trending -> trend

P20, Figure 6 caption: no monthly data missing? What do you mean here? With no data or with missing data? I guess the grids with missing data are shown as white blanks.

P20: I do not understand what you mean here with interface.

P21, Figure 7 caption: In two occasions trending should be replaced by trend.

P22, General: Move the latitudes und longitudes behind the respective region, e.g Laccadive Sea

P22, L533: Here you write this region, but two different latitude and longitudes are given. Do you mean “these regions”? And which regions are you talking here about? The text would be much easier to read if you would put the coordinates at the end and not always after “region”.

P22, L544: “These established sites are in 10 by 10 longitude/latitude grids”. Not clear what you mean since sentence not grammatically correct. What do you mean with established?

P23, L550 and 552\_ heights -> altitudes

P23, L550: delete “being driven by”

P23, L553: cloud -> cloud layer

P23, L564: show -> show that

P23, L565: Increasing with what? With time? With space?

P24, L574: heights I -> altitudes from

P24, L575: cloud -> clouds

P24, L576: water trends -> water vapor trends

P24, L580 and 581: add “located” -> are located in the ocean, are located on the land

P24, L580: Delete “In” and move Table 4 in parenthesis at the end of the sentence and start sentence with “Both”.

P24, L581-582: What do you mean with substantial water vapor? High concentrations?

P24, L590: Still the connection between water vapor and temperature has not been explained. Why should or does higher temperature cause higher water vapor?

P26, L523: add located (twice) before over the ocean and over land, respectively.

P28, L630: What do you mean with “on the west”? The West Pacific?

P26; L531: from 2007 to 2018 -> for the timer period 2007 to 2018

P26, L632: Change to “From the linear trend study of global.....”

P26; L634 to 635: singular or plural? A nearby cloud or nearby clouds? Why nearby? How do you know that a cloud was nearby?

P26, L636: in -> at

P26, L639: delete “area”

P26, L646: paper -> study

P26, L649: move “better” before “resolve”, so that it reads “better resolve.....”

P27, L654: The section “Conclusions and Discussions” should be renamed to “Discussion and Conclusion”.

P27, L664: I don’t agree. Only because the COSMIC data agrees better to ERA5 it does not mean that it is closer to the true state of the atmosphere. The reanalysis is, although data is assimilated, still a

model. I also do not understand why the assimilation impacts are negligible. This discussion should not be squeezed to the major conclusion bullet, but rather discussed beforehand.

P27; L696: Also mentioning here SPARC feels a bit lost. The mentioning of the efforts of the SPARC community would rather fit into the first paragraph of this section to highlight why such intercomparisons are important.

P27; L675: this paper -> here

P28; L694: estimating from 2007-2018 -> estimates for the time period from 2007 to 2018

P28; L704: have substantial variabilities -> show substantial variability

P28, L707: slopes?

P29, L711: with -> between

P29, L717: move the latitude/longitude coordinates behind the respective areas

P29; L729: What can be better characterized?

P29, L737: Not clear, if you mean here in general or in specific areas. Before good quality of RO data mentioned, here now deficiencies discussed, but is not made clear that this is a correction of the data.

P29, L738: Here it could be stated that ERA5 data has significantly improved compared to ERA-interim.

P29, L739: trending -> trend

P30, L746: times of what. Please be more precise.

P38, L921: trending -> trend

P38, L933, Figure A6 caption: Delete distributions