

Manuscript Number : amt-2017-250-RC2
Associate Editor : Dr. Jens Wickert
Manuscript Title : Comparisons of the tropospheric specific humidity from GPS radio occultations with ERA-Interim, NASA MERRA and AIRS data

Dear Referee #1,

We would like to thank reviewer #1 for taking the time to review our manuscript. We greatly appreciate all comments, which we address and implement in the revised manuscript. The manuscript has now become stronger and presents additional results for discussion reflecting the reviewer's comments.

General Comment #1: The paper is long and it is a little difficult and tiresome to read because there are three regions and these are discussed in great detail with two figures and one table for each region. All of this takes 16 pages and the reader may get lost. Perhaps the number of regions could be reduced to two? It is not clear to me that the difference between +/- 15NS and 15-30NS are important. I become lost in the details of all these comparisons.

Answer: Agreed. However the 500 hPa and 400 hPa show the same behavior in all three regions. The only difference is found at the 700 hPa and 600 hPa, which are most influenced by convection. Thus, although we agree that analyzing three different regions is tiresome, we want to be inclusive and decided not to merge the results from the +/- 15NS and 15-30NS regions into one. This is because we would have missed seeing the different behavior of the data at 700 hPa and 600 hPa in the two regions. However, we took the following actions to make the results easier to read:

Actions taken:

1. We only show the monthly zonal mean time series of the specific humidity and their interannual anomalies and the accompanied table for the deep tropics (+/- 15NS) and moved the rest of the figures and tables into the supplementary material. However, we kept their discussion in the text.
 2. We written more concisely the analysis for each region and avoided repetitive discussion at 500 hPa and 400 hPa pressure levels, focusing only in the lower troposphere.
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General Comment #2: Most importantly, because a major point of the paper is a comparison of the JPL and UCAR retrievals of specific humidity it is worth mentioning in the abstract the significant difference between the JPL and UCAR estimation of q given refractivity N . JPL uses a "simple" method (using T from ECMWF TOGA database in Eq. 1) while UCAR uses a 1DVAR method (using ERA-Interim for the a priori). This difference between these two methods is likely the main reason for the different results, and not a property of RO in general. This reason should be verified by also comparing the JPL and UCAR refractivities that were used in computing q .

Answer: The reviewer is correct.

Actions taken:

1. We added relevant text in the manuscript to explicitly state this. **See Abstract lines 31–33, and lines 148–153.**
2. We performed additional data processing and data analysis for the refractivity climatologies and included the results in the manuscripts in a new section and discussion. **See new Section 3.4.**

General Comment #3: Finally, it would be helpful if the authors could say something about what all these differences mean in terms of accuracy of water vapor compared to the estimates of accuracy in q from other papers. Perhaps this discussion could go in the conclusions.

Answer: Done. We included background information about the accuracy of RO q retrievals and compare them with the accuracy of other data sets. Based on this discussion, we explicitly discuss about the statistical significance of our results throughout the manuscript (when comparing the different climatologies). **See new added Section 3.4 and lines 235–236.**

Specific Comment #1: SH is not a common abbreviation for specific humidity. I suggest using the more common letter “ q ”.

Answer: Agreed. We removed the abbreviation SH from the manuscript. Instead, we explicitly write “specific humidity”.

Specific Comment #2: Line 32. Something is missing here? “as well as” perhaps?

Answer: Done. Sentence was modified. No need to act on this any more.

Specific Comment #3: Page 10, lines 206 – 215. The quoted accuracies of 10-20% below 7 km and 0.1 g/kg seem inconsistent. For a typical lower tropospheric q of 5-10 g/kg, an error of 0.1 g/kg (1-2%) is far better than 10% (1-2%). The JPL quoted accuracies of 0.2-0.4 g/kg in the tropics (2-4% for a typical value of q of 10 g/kg) are also very high compared to the quoted values of 20% for MERRA and 25% for AIRS. Can the authors comment on these large differences? In general, it is very important for this paper to precisely define previous studies of the accuracy of water vapor (specific humidity) estimates from RO.

Answer: Done. We devoted a separate section establishing the RO specific humidity accuracies based on previous studies. **See Section 2.6**

Specific Comment #4: It would be helpful to know why the author’s study extends downward only to 700 hPa? Most of the atmospheric water vapor is below 700 hPa. Yes, there is negative N bias associated with super-refraction and other issues in the lower troposphere, but still it is important to characterize the errors in retrieved q in this region.

Answer: This is the same comment with that of Reviewer #2 Minor Comment #5. The reason is exactly what the reviewer mentions above. Also, the spherical symmetry approximation and signal tracking issues could also play a role here. In this preliminary climatology analysis, we wanted to focus on the pressure range that we are confident the RO humidity is well established, and then we would focus on the boundary layer and higher up in the troposphere. **We have added relevant text to clarify this. See lines 121–127 and Conclusion section.**

Specific Comment #5: The Vergados et al. 2016 paper is in the list of references, but I could not find it mentioned in the paper.

Answer: Done. We removed the references.

Specific Comment #6: Lines 285-287. It says that the wet bias in JPL-RO may be due to the warm bias in the ERA-Interim (We. 1). But they use ECMWF TOGA analysis for the T in Eq. 1, not the ERA-Interim (lines 150-151). Please clarify. Similarly, lines 420-422 say the JPL retrieval technique uses “ECMWF” as a-priori temperature information. What ECMWF, TOGA or Interim?

Answer: Done. See line 165 and lines 495–500.

Specific Comment #7: Figure 3 is not referred to in text. It looks like it should be in line 291, i.e. “...we estimate the respective SH anomalies (Figure 3).”

Answer: Done. Due to re-arranging the figures, Figure 3 now shows the specific humidity anomalies at the deep tropics and is discussed throughout the manuscript.

Specific Comment #8: Lines 372-373. I suggest rewording to “...defines the subtropics where dry air descends from the Hadley cell.”

Answer: Done. See lines 423–424.

Specific Comment #9: Lines 474-475. Reword to say “moistest of all data sets” and “driest of all datasets”.

Answer: Done. See lines 519–520.

Specific Comment #10: Lines 490-492: All the pressure levels lie above the PBL not just the 700 hPa level. Do the authors mean that the 700 hPa level is the closest to the PBL?

Answer: Yes. Please, see modified lines 522–523.

Panagiotis Vergados

THIS IS THE END OF REVIEWER #1 REPORT