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Atmospheric Measurement Techniques Discussions

Interactive comment on "Comparisons of the tropospheric specific humidity from GPS radio occultations with ERA–Interim, NASA MERRA and AIRS data" *by* Panagiotis Vergados et al.

Anonymous Referee #2

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General comments:

The paper compares specific humidity derived from GPS RO and different weather model reanalysis. Although the results might not be ground-breaking, they provide valuable information. I have some minor comments and questions.

Minor comments:

Abstract:

P2, L38: '...together with the retrieval uncertainty of the SH products from all data sets, we conclude that RO observations are a valuable independent observing sys-

tem.' What do you mean by 'independent'? RO SH is not independent from weather model data. JPL-RO SH makes use of the temperature from ECMWF. UCAR-RO SH is obtained by variational data assimilation utilizing ECMWF as the background. I suggest to remove the word 'independent'. Also, ECMWF depends on RO, because UCAR-RO bending angles were assimilated.

Introduction:

P3,L48: '...Hence, we ought to quantify and understand the degree of agreement of the water vapor concentration throughout the vertical extent of the troposphere among different sensors, in order to improve the representation of the Earth's atmospheric humidity content that is key to predicting future climate [Hegerl et al., 2015].' In the present study you consider the altiude range 700 -400 hPa ($\sim$2 – 8 km). The troposphere extents from $\sim$0 – 15 km. In fact, most of the water vapor is contained in the lowest 2 km. In the present study you do not try to quantify and understand the degree of agreement of the water vapor concentration throughout the vertical extent of the troposphere. I suggest to remove the word 'throughout'.

P4,L38: '...and full diurnal cycle sampling.' This is approximately true for COSMIC but not true in general. This depends on the LEO orbits.

P5,L102: '...Of importance is the fact that we use MERRA, instead of MERRA-2, because MERRA does not assimilate ROs (unlike ERA–Interim), providing an independent data set when comparing the RO SH observations.' This sounds interesting. Does this mean that you expect big differences when you use MERRA-2 instead of MERRA? Would it be a lot of effort for you to add MERRA-2 as well? I recommend to do so. This would be very interesting, because it would show the impact of RO on weather model SH.

Methodology:

P6, L114: '...We study the tropics and subtropics ($\pm$40o, in three distinct latitudinal

regions) from 700 hPa up to 400 hPa, because this region is key to climate research [IPCC, 2007], but models and observations have large SH differences in the middle and upper troposphere [e.g., Jiang et al., 2012; Tian et al., 2013; Wang and Su, 2013], and we select this pressure range because the RO SH retrievals are most robust.' I can imagine what you mean by 'most robust' but some other interested readers do not know what this means. Please, explain in brief what you mean by 'most robust'. E.g. signal tracking in the lower troposphere is somewhat problematic, the assumption of a spherically layered atmosphere, critical refraction (Ao et al., 2003) etc.

P7, L144: '...air temperature'. I suggest to remove the word 'air'.

P7, L145: Please add (for completness) the equation that you use to convert water vapor pressure to SH.

P7, L154: '...air refractivity'. I suggest to remove the word 'air' here and in the following.

P9, L188: '...The AIRS physical retrievals use an IR–microwave neural net solution [Blackwell et al., 2008] as the first guess for temperature and water vapor profiles based on MIT's stochastic cloud-clearing and neural network solution described in Khan et al. [2014].' I have very little idea of AIRS retrieval. In short, does the AIRS retrieval at any point make use of data from a climatology or a weather model?

P9, L192: The section 'Data Sources' can be moved to the Acknowledgments.

P10, L207: '...GPS-RO air refractivity accuracy of <1.0% at 2.0 km altitude [Schreiner et al., 2007] reduces to $\sim$0.2% above 5.0 km [Kuo et al., 2005].' Schreiner et al., 2007 provides an estimate for the precision and not the accuracy. They measure the degree of the reproducibility of the GPS RO technique. Kuo et al., 2005 provide an estimate for the accuracy. As you focus on the altitude range 2 – 8 km, I suggest to simply write: 'GPS-RO refractivity accuracy is about 1% at an altitude of 2 km and decreasing to about 0.2% at an altitude of 8 km [Kuo et al., 2005].'

Results and discussion:

P10, L223: I suggest to remove '...We do not extend our analysis at higher altitudes due to the small contribution of water vapor on to the RO observations.' as you already mention in the 'Methodology' section that your focus is 700-400 hPa.

P11, L226: '...and the differences between the JPL and the UCAR time series serve as a guideline of an estimate of the SH structural uncertainty.' One of the most interesting points in your study are the differences between JPL SH and UCAR SH. Where do the differences come from? Are those differences due to differences in the raw (=non-optimized) bending angles, the refractivity or are they mainly caused by the different SH retrieval method? I strongly recommend to add (in an Appendix) a one-to-one comparison (mean and one-sigma) for bending angle and refractivtiy profiles for the altitude range 0-8 km.

P12, L240: '...SH time series over the entire observational record for all data sets throughout the vertical extent of the troposphere'. Remove the word 'throughout'.

P18, L332: '...Overall, this suggests that over less convective regions different data sets tend to agree better, signifying that convection is a limiting factor in properly sensing the amount of water vapor in the atmosphere.' Weather models are known to be less accurate in regions with convection. Do you mean that RO SH is less accurate there aswell? For example there is one study by S. Yang and Zou, 2017 showing (positive) RO biases in cloudy conditions.

S. Yang and Zou (2017) Dependence of positive refractivity bias of GPS RO cloudy profiles on cloud fraction along GPS RO limb tracks, GPS Solut, 21:499–509 DOI 10.1007/s10291-016-0541-1

P26, L421: Remove 'in the forward operator'.

Conclusion:

P28, L467: I suggest to remove the word 'independent'. RO (non-optimized) bending angles are independent, however RO SH is not independent.

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