

## ***Interactive comment on “Climate intercomparison of GPS radio occultation, RS90/92 radiosondes and GRUAN over 2002 to 2013” by F. Ladstädter et al.***

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Title: “Climate intercomparison of GPS radio occultation, RS90/92 radiosondes and GRUAN over 2002 to 2013”

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We thank the reviewer for the affirmative comments and the helpful list of recommendations and comments. Please find our response below:

C5171

- a. *“Section 2.1 Suggest to add a discussion of WEGC GPSRO dry temperature intercomparison with other products to gain confidence of the RO climate quality.”*

The climate quality of GPS RO is discussed in the Introduction, citing many publications underlining the GPS RO data quality (page 11738, line 26 to page 11739, line 10), and including publications with temperature intercomparisons. To stress that these references include further discussions about the climate quality of GPS RO, we changed Page 11739, line 5 to: **“The value of GPSRO to act as reference measurements with climate quality has been demonstrated in several publications, [...]”**.

- b. *“Page 11745, around Line 11. Can you discuss more about the solar activity related error? What is the impact of this error on RO dry temperature on diurnal scale or at different phase of solar activity cycle?”*

We added the following sentence to this paragraph to state some numbers: **“At 30 km the residual ionospheric error can amount to up to 0.3 K (up to 0.1 K at 20 km) (Schreiner et al., 2011; Steiner et al., 2011).”**

- c. *“Figures 7-9. I believe the statistics shown in those figures are reliable (I got very similar results, by the way). I know GRUAN data points are much denser than GTS vertically. But, do we also expect to see the vertical discontinuities shown in the RS92-minus-GRUAN plots? Why do not those strange discontinuities show up in the GRUAN-minus-RO or GTS-minus-RO plots? I recommend these confusions to be clarified in the paper.”*

We added the following sentence to Sect. 3.4 to clarify this point (starting at Page 11748, line 12): “Remaining differences are partly related to the different vertical sampling delivered in the two data products, and to the small number of remaining sample points at high altitudes. **The distinct vertical discontinuities in standard deviation and bias of temperature differences indicate that at**

C5172

**the significant levels reported by GTS the difference between GRUAN and RS becomes negligible.”**

- d. *“Page 11740, Line 16. ‘The optimal estimation is applied up to an altitude of 16 km, with a half-sine-weighted transition to physical to dry parameters between 14 and 16km for temperature and pressure’. Does this weight apply to everywhere globally? Does this mean that the physical temperature is the same as the dry temperature above 16 km everywhere? If not (most probably not as discussed in Section 3.6), then the above cited sentence needs to be modified to reflect that.”*

The weight is applied globally in the same way. Physical temperature is essentially the same as dry temperature above 16 km. To clarify this point, we added the following sentence to Sect. 2.1.: **“This signifies that at 14 km and below only information from the optimal estimation retrieval enters the profiles, while at 16 km and above physical and dry parameters are identical to within 0.01 K (the physical temperature being only very slightly larger due to stratospheric water vapor).”**

- e. *“The authors used ‘radiosonde-minus-dry T’ vs ‘radiosonde-minus-physical T’ to compare RO dry vs physical T as displayed by Fig.11. Unfortunately, it is very hard to see the differences (described in the text in Section 3.6) from the figure. I recommend the authors to draw the plots of ‘RO physical T-minus-RO dry T’ for this discussion to replace the existing Figure 11.”*

We added an additional panel to Fig. 11 (now Fig. 13) with the difference plot ‘RO Tphys – RO Tdry’.

- f. *“Page 11753 Line 10. I would not say ‘excellent’ basic agreement of the products intercompared. The upper tropospheric and low stratospheric temperature difference of 0.2 K noticed in this study is not a trivial number given that the upper air temperature change discovered by many publications is around 0.2 K/decade.”*

C5173

We consider the agreement at least “very good” and changed the sentence to something more modest: **“Overall very good agreement is demonstrated by this multi-year intercomparison of GPSRO and radiosonde reference datasets.”**

1. *“Page 11738 Line 2. You may explain a bit about the ‘structural uncertainty’. What does it mean?”*

We added a sentence to better introduce the concept of structural uncertainty, which is elaborated in the cited publications: “These challenges point to the need for additional datasets of reference quality in order to better account for measurement biases, and to be able to estimate the structural uncertainty involved. **Such structural uncertainty inevitably arises from differences in the chosen approaches, and is decreased by increasing the number of datasets (Thorne et al., 2011a, 2005; Santer et al., 2008; Karl et al., 2006).**”

2. *“Page 11739 Line 6. Change ‘several’ to ‘some’. You listed 10 articles.”*

We changed the phrase to: **“a range of publications”**.

3. *“Page 11740 Line 22. Suggest to indicate the percentage of profiles that are quality ‘bad’ and not used in the study.”*

We added this information: **“In this intercomparison we only use GPSRO profiles which passed the OPSv5.6 quality control (these amount to approximately 70 % of all profiles), which includes plausibility checks for bending angle, refractivity, and temperature profiles.”**

4. *“Page 11741 Lines 4-9. 0.2 K and 0.3 K errors are inconsistent. Need to clarify this.”*

The overall uncertainty bound of 0.3 K is estimated from both the statistical observational error of 0.1 K and the systematic errors of 0.2 K. We explicitly stated

C5174

this now: "To sum up, the overall uncertainty bound for a sample of 100 GPSRO or more profiles, **including the statistical observational and the systematic errors**, is generally  $< 0.3 \text{ K} \dots$ "

5. "Page 11742 Line 26. What about mandatory level data? Are they included in the GTS raobs?"

Yes. We added this information: "**The radiosonde data from the ERA-Interim archive (denoted RS in this study) include all mandatory and significant levels reported by the GTS.**"

6. "Page 11743 Section 2.3. Suggest to expand a bit about the way to do the collocation. Do you use lat/lon and time at raob launch site and at RO occultation point to compute the collocation mismatch?"

We added the following sentence to Sect. 2.3: "**We collocated RS and GPSRO profiles by matching the position of the RS launch site to the mean tangent point of GPSRO, and the launch time of RS to the mean event time of GPSRO.**"

7. "Figure 3. Three vertical pressure labels on the y-axis of this figure are too few and it is hard to pin down where certain pressure values discussed in Section 3.1 are. Suggest to use the y-axis of any figures of 6-11 for this figure."

We updated Fig. 3 to indicate the 200 hPa and 400 hPa levels by dashed lines, improved labeling of the pressure axis, and added a pressure altitude axis.

8. "Figures 4-5. I am confused by the symbols. What is the difference between 'RS9092vsCHAMPOPSv56' and 'RS92vsCHAMPOPSv56' for example? If the former is the combination of RS90 and 92, then I suggest to delete all those combination symbols in the plots since RS90 and 92 are separately included in the plots already. If not, I think these symbols need to be explained in figure legend."

C5175

'RS9092vsCHAMPOPSv56' is the difference between the combined RS90/RS92 dataset and CHAMP-only GPSRO. In our view this information is valuable in addition to the separate RS90 and RS92 symbols, because the respective weight of RS90 and RS92 in the mean becomes clearly visible. To avoid confusion concerning the term RS90RS92, we added the following sentence to the figure caption: "**RS90RS92 indicates the combined set of RS90 and RS92 instruments.**"

9. "Page 11745, Line 6 and some other places as well. Change 'between GPSRO and RS' should be 'between RS and GPSRO'."

We changed the phrase from "between GPSRO and RS" to "between RS and GPSRO" in the text and in the figure caption of Fig. 4.

10. "Page 11746, Line 13. What does ECMWF 'IFS' stands for?"

We added the full form of the acronym: "**IFS (Integrated Forecasting System)**".

11. "Page 11750 Line 13. Add parenthesis before 'See' and after '2014'."

Thanks for pointing this out, we assume that this comment actually refers to the next sentence where the reference was wrongly formatted. We corrected the sentence to: "**An initial illustration based on monthly climatological fields was included in Scherllin-Pirscher et al. (2011a).**"