Manuscript number acp-2017-669

Interactive comment on "Tropical convection regimes in climate models: evaluation with satellite observations" *by* Andrea K. Steiner et al.

Response to Referee#2

We thank the reviewer for the constructive review, the interesting questions, and very valuable comments.

Please find our detailed response below the reviewer's original comments.

1 General Comments:

This article demonstrates the use of radio occultation (RO) satellite data for the verification of climate models. In particular, radio occultation from a combination of satellites is used to evaluate tropical temperature and humidity profiles for five atmosphere-only climate simulations.

The research described in this article is original and technically sound, making it suitable for publication in Atmospheric Chemistry and Physics. The quality of the writing is adequate and I think can be improved upon. I did find some sentences difficult to understand, some of which I've highlighted below. However, the article is well organised.

2 Specific Comments:

Comment 1: I don't understand why it is necessary to collocate the RO observations and the climate models. Are there gaps in the spatial/temporal coverage of the RO observations that make this necessary? As co-location requires daily model output, this will make using RO observations a challenge simply in terms of data volumes. How different would the results be without co-location?

Response 1:

Radio occultation observations are based on a limb sounding technique, which provides discrete measurements in form of vertical profiles. The observations are globally well distributed. For the reviewer's convenience we show the global coverage with RO measurements for one exemplary day in Fig. A1 below. One of the strengths of RO is the good vertical resolution.

In this study we use individual RO profiles and compare them to atmospheric models at the best available vertical resolution. We want to compare the same conditions in observations and atmospheric models, which have sea surface temperature prescribed. Thus, it is important to match the location and time of the day of updraft and downdraft occurrences in order to compare for the same conditions.

This requires, as the reviewer noted, a daily/6-hourly model output and data files get quite large. Thus, the comparison is computationally intensive in our current study setup.

However, besides individual profiles, RO data can also be sampled and averaged to climatological fields. Thus, another approach for model comparison could be gridded RO fields, which are regularly used in form of monthly-mean zonal-mean fields available for the whole RO record. From 2006 onwards, the data amount is large enough for a finer gridding because data from more than a single RO satellite are available. Daily climatologies of 2.5° x 2.5° in latitude and longitude are possible but require a weighted averaging in space and time (weighting over +/-1 day). The use of such higher resolved daily RO climatological fields has been demonstrated for the investigation of atmospheric blocking recently (see Brunner et al., 2016; Brunner and Steiner, 2017).

As these higher resolved RO climatological fields are available only from 2006 onward (and only since recently) and the AMIP data are available only until 2008, we decided to use individual profiles for model comparison in this study. Furthermore, a daily to sub-daily resolution is a prerequisite to resolve and compare for different atmospheric conditions, as done in this study.

In section 5, we added the following paragraph:

"RO data are available as individual profiles and gridded climatological fields. The latter are commonly available in form of monthly-mean zonal-mean climatologies for the whole RO record. From 2006 onward, the data amount is large enough for a finer gridding because data from more than a single RO satellite are available. Daily climatologies of 2.5° x 2.5° in latitude and longitude are possible but require a weighted averaging in space and time. The use of such higher resolved daily RO climatological fields has been demonstrated only recently for the investigation of atmospheric blocking (see Brunner et al., 2016; Brunner and Steiner, 2017)."

Comment 2: Given that ERA-Interim is quite widely used to evaluate temperature and humidity in climate mode, it would be interesting (and presumably fairly straightforward) to compare the ERA-Interim temperature and humidity profiles to the OR observations.

You mention that a different reanalysis "might give a slightly different distribution of observed RO profiles". Could you try actually redoing this analysis using a different reanalysis?

Response 2:

We agree that this might be interesting. However, there are already several studies which compare temperature and humidity from RO observations with analyses or reanalyses and which we cite in our manuscript, e.g., Rieckh et al. (2017) use ERA-Interim, Vergados et al. (2016) use MERRA, and Pincus et al. (2017) provide an overview on the representation of tropospheric water vapor in analyses and reanalyses.

We find a comparison to reanalyses beyond the scope of this study. In the current study setup, 6-hourly gridded fields and high vertical resolution are required. For a reasonable comparison with ERA-Interim one would choose a vertical gridding comparable with RO. The size of files including a few years of data gets very large, reaching more than 80 GB, which is hard to handle in the current setup of the study and would require a redesign.

For the reviewers convenience we show in Fig.A2 below temperature differences of ERA-Interim minus RO which are based on monthly-mean zonal-mean climatological fields and a vertical gridding of 200 m. There are distinct differences in the tropopause region and in the stratosphere, which stem from a known bias of ERA-Interim (Poli et al. 2010; S. Healy (ECMWF) pers. comm.).

2 Technical Corrections:

Comment P1 L18: "and only partly represent high updraft or downdraft velocities". I only under-stood what you meant by this once I'd read the paper once. Consider rewriting.

Response P1 L18: We rephrased the sentence to make it clearer. The sentence now reads: "and only partly represent strong vertical wind classes."

Comment P2 L14: "Its proper representation. . ." It's not clear what it is here.

Response P2 L14: We rewrote the sentence to make it clearer. It reads now: "The proper representation of the tropospheric structure in climate models is of central importance since it has more impact than other regions of the atmosphere.

Comment P2 L18: "Bony et al. (2015). . ." This sentence doesn't make sense.

Response P2 L18: We changed the sentence to: "Bony et al. (2015) point in particular to enhance the understanding of cloud feedbacks and convective organization."

Comment P3 L2: Change "has shown" to "have shown".

Response P3 L2: We changed it and write "have shown".

Comment P4, L1: You say (paraphrasing) that the quality of RO measurements is best in the upper troposphere and lower stratosphere, but that the uncertainty of individual profiles is about 0.7 K in the tropopause region and decreases towards the low troposphere. This seems contradictory to me.

Response :

In section 2.1 of the manuscript we explain the retrieval of dry and physical atmospheric RO parameters in some detail. In a dry atmosphere, where water vapor is negligible, RO dry temperature profiles can be retrieved without further background information. In the troposphere, temperature and humidity are retrieved based on optimal estimation of RO and background profiles.

For RO profiles the uncertainty is lowest in the upper troposphere and lower stratosphere region. Above this region the observational error increases into the stratosphere. For dry temperature profiles, the observational error increases also in the lower troposphere (see Scherllin-Pirscher et al., 2011a). For physical temperature profiles (mainly used in this study), the observational error slightly decreases in the troposphere. The reason for decreasing RO temperature errors in the lower troposphere is the increasing influence of background information in the blended product. RO error estimates for physical temperature are given by Scherllin-Pirscher et al. (2017) for the Wegener Center RO data.

P4, L1: We removed "and slightly decreases toward the lower troposphere". We agree that it is confusing. We refer to the work of Scherllin-Pirscher et al. (2017) instead. The sentence reads now:

"The observational uncertainty of individual temperature profiles is about 0.7 K in the tropopause region and detailed estimates are given by Scherllin-Pirscher et al. (2017)."

Comment P5, L4: I think you mean "Extensive" rather than "Excessive" here.

Response P5, L4:: We corrected the sentence and write "Extensive".

Comment Table 1: I think there are some inconsistencies between the resolution and the number of latitude/longitude points. E.g. BCC-CSM1 with a longitudinal resolution of 1.875 degrees has 192 longitude points, not 128.

Response Table 1: Thank you for pointing to this error. The resolution of BCC-CSM1 is 2.8125 degrees in longitude and 2.8125 in latitude, which corresponds to 128 x 64 points. We thoroughly checked all other numbers in Table 1 and found them correct.

We made the following corrections in the manuscript:
Table 1, line BCC-CSM1.1, column 2: We corrected the horizontal resolution to 2.8125° x 2.8125° (126 x 64).

P5, L25: We changed the sentence on the models' horizontal resolution ranges accordingly: "The models' horizontal resolution ranges from near 1.25° x 0.95° to 2.8° x 2.8° in longitude and latitude."

Comment P17, L32: I would change "Model profiles are clustered narrower from. . ." to "Model profiles are clustered over a narrower pressure range from. . ."

Response P17, L32: We changed the sentence as suggested.

References:

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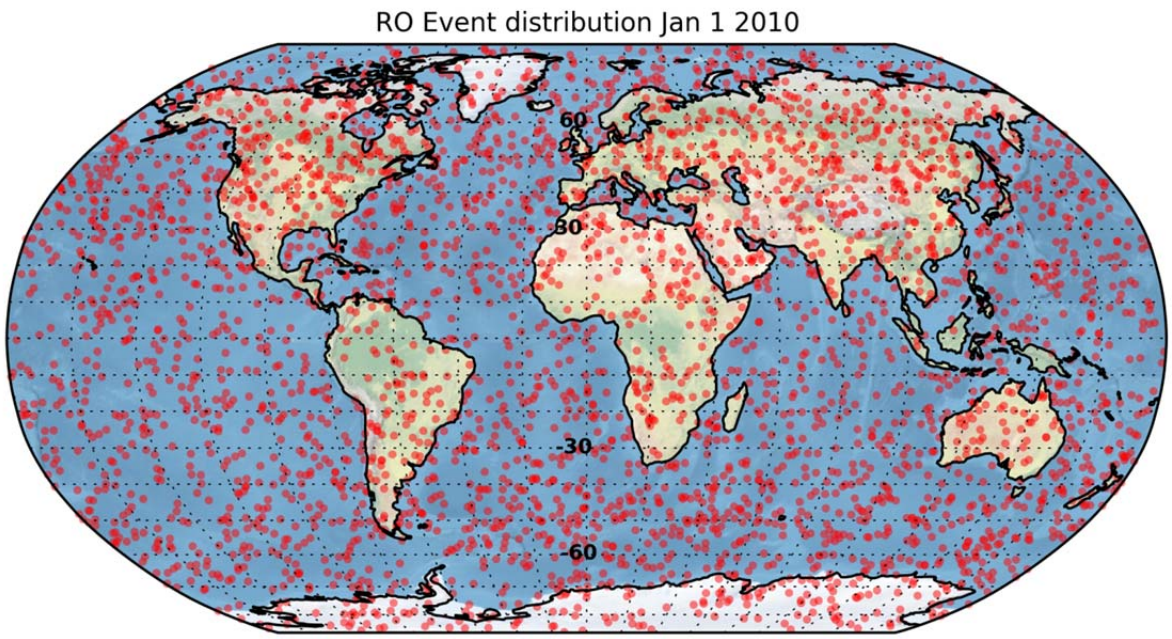

Fig. A1 Global distribution of radio occultation measurements on January 1, 2010.

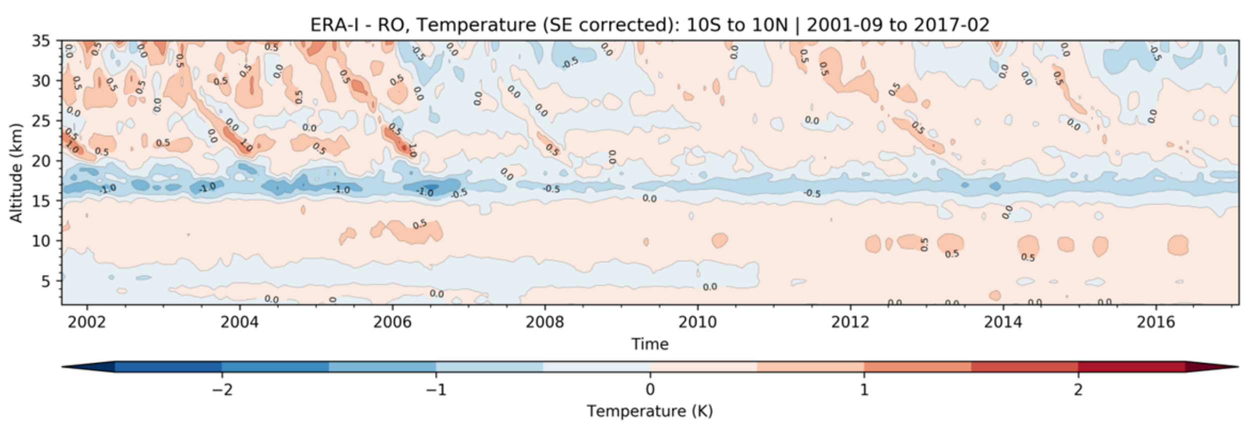

Fig.A2 Monthly mean temperature differences or ERA-Interim minus RO.