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Atmospheric Measurement Techniques Discussions

Interactive comment on "Processing of GRAS/METOP radio occultation data recorded in closed-loop and raw-sampling modes" *by* M. E. Gorbunov et al.

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(1) Please provide an example illustrating the merging of the CL and RS data.

We added such an example. It also illustrates a tropical event.

How were the data gaps in the GRAS data handled? What are the possible errors from filling the gaps?

Upon the request of Reviewer #1 we have already added the following description of our procedure for handling gaps: *For each gap its length is evaluated. If the gap length exceeds some pre-specified threshold the data after the gap for setting events*

or, correspondingly, the data before the gap for rising events are discarded. It the gap length does not exceed the threshold, the deviation of the phase excess from the phase model and the amplitude inside the gap are linearly interpolated to the uniform time grid between the two surrounding points where the signal is present. This fill-in procedure introduces some additional uncertainty. However, if the gap length threshold is chosen small enough, the uncertainty will also be insignificant. In this study the threshold was 0.04 second.

Errors from filling the gaps may require some further investigation. But we observe the following: 1) the perturbations of bending angle profiles due to gaps are small, (2) The gap length is smaller than the typical filter width we use, and (3) the resulting GRAS–ECMWF statistics is very close to the COSMIC–ECMWF statistics. This allows for a conclusion that gaps do not constitute a serious problem.

(2) Examples of spectrogram are from mid-to-high latitudes: why not include a tropical occultation?

We added a tropical occultation (see answer to remark 1).

(3) Sec 3, 1st para: "The bending angle profile below 2 km is not related to the atmosphere, because it is obtained from the phase model used to fill in the area where the receiver was unable to track the signal." I don't understand this. Please elaborate.

This part of the text was re-written as follows: *The bending angle profile below 2 km is not related to the atmosphere, because below 2 km there are no rays reaching the receiver. The profile here is obtained from the phase model used to fill in the area where the receiver made attempts to track the signal and generated small portions of data separated by gaps. This part of the profile is discarded in the inversion.*

(4) Sec 3, 2nd para: "This behavior is explained by the sharp tropopauses unresolved by the filter window of 2 km used in our data processing." I read this to mean that the

RO bending angles being smoothed over 2 km windows near the tropical tropopauses. Why is such a large window being used? What is the filter window for the lower troposphere?

This window was chosen to be consistent with UCAR processing. For more details see: M. E. Gorbunov, A. V. Shmakov, S. S. Leroy, and K. B. Lauritsen, COSMIC radio occultation processing: Cross-center comparison and validation, Journal of Atmospheric and Oceanic Technology, 2011, in press.

(5) Comparing between bending angle and refractivity biases in the tropics: is the refractivity bias consistent with the bending angle bias? As is well known, there could exist additional bias going from bending angle to refractivity in the presence of super-refraction layers (e.g., Xie et al.,Geophys. Res. Lett., 37., L11805, doi:10.1029/2010GL043299).

Superrefraction as a possible source of systematic retrieval error has been known long before the work by Xie et al. See: L. Bengtsson, M. E. Gorbunov, and S. V. Sokolovskiy: Space Refractive Tomography of the Atmosphere, Modeling of Direct and Inverse Problems. Report No 210. Max-Planck Institute for Meteorology, Hamburg, 1996. Another possible mechanism of the negative bias inovolves horizontal gradients as discussed by M. E. Gorbunov, K. B. Lauritsen, S. S. Leroy, Application of Wigner distribution function for analysis of radio occultations, Radio Science, 2010, V. 45, RS6011, doi:10.1029/2010RS004388.

The input of superrefraction is typically overestimated as far as its estimate involves the assumption of the spherical symmetry. The statement made by Xie et al. (2010) that the superrefraction is the main cause of the negative N-bias, in our opinion, does not comply with the fact that we see a significant negative bias in bending angles both in COSMIC and GRAS data. Note, superrefraction does not result in any bias in bending angles. In the tropics the maximum negative bias of bending angles is about 6% and it is concentrated in the lowest 2 km, while the characteristic vertical scale

of the atmosphere is about 8 km. The resulting negative bias of refractivity (due to systematic error in bending angles) is then estimated as $6\%\sqrt{2km/8km} = 3\%$, which is close to (or even slightly exceeds) the observed maximum bending angle bias in tropics, which reaches 2.5%. This does not leave much place for the error due to superrefraction, but, of course, this estimate is rough. Superrefraction must give some input into the negative N-bias, but we can be positive that superrefraction cannot be its main source. However, we think that the discussion of relative input of different mechanisms of the negative bias is beyond the scope of this paper, and this topic requires a further thorough investigation.

(6) Fig. 7: please describe how the lowest altitude of a retrieved profile is determined in your processing.

The lowest altitude of a retrieved bending angle profile is determined as the maximum of the correlation of the CT2 amplitude with the step function (Gorbunov et al. 2006). This brief remark has been added to Section 2 “Data Processing”.

Please also note the supplement to this comment:
http://www.atmos-meas-tech-discuss.net/4/C540/2011/amtd-4-C540-2011-supplement.pdf

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