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Atmospheric diurnal variations observed with GPS radio occultation soundings

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We thank all reviewers for the very insightful and detailed comments. Following the reviewers' suggestions, we made some major changes:

- (1) Remove the semi-diurnal variation component from the paper.
 - a. New title: "Atmospheric diurnal variations observed with GPS radio occultation soundings"
 - b. Remove Fig.2 showing semi-diurnal variations in tropics.
 - c. Remove Semi-diurnal amplitude plots in Fig.4

We agree with the reviewer#1 and review#3 that the phase of the semi-diurnal variations derived from COSMIC RO in the tropics is rather noisy and might not be statistically significant due to weak semidiurnal signal and possibly the lack of sampling. Although, we believe some significant semi-diurnal amplitude over high-latitude stratosphere and the lower troposphere could be realistic, we decide to leave it out, since it could be better supported with model simulations, which is currently not available.

- (2) Different colors are added into Fig-1a,c to distinguish different seasons in the diurnal tidal amplitude.
- (3) Fig.3 is changed to color version.
- (4) Change the title of Section 3 from "*Tropical Tidal Waves*" to "Tropical Diurnal Variations – the Tidal Waves". Also "Section 3.1" title is removed.
- (5) Remove the less relevant information in "Discussion" section related to the PBL retrieval in RO observations.

The reviewer's specific comments are addressed as follows.

Replies to Referee #1

Specific Comments:

1) The semi-diurnal tide is investigated in addition to the diurnal tide. From the Figures presented (especially Figure 2), it seems that the amplitude and phase measurements are too small to examine with the resolution of COSMIC. I am not convinced of the robustness of the semi-diurnal tidal results presented here and in later figures. The phase structure in Figure 2 is very noisy. How did you obtain the annual median phases? Were the phases unwrapped before determining the medians? The phase of the semi-diurnal tide should show a coherent structure in height. See the results for the three wind components in this altitude region by Riggins et al. (J. Geophys. Res. 2002, doi: 10.1029/2001JD001216). I would expect something similar for the temperature component. Based on the results presented in the manuscript, I suggest removal of the semi-diurnal tidal results.

We agree with the reviewer that the tropical semidiurnal variation derived from COSMIC/RO (Fig-2 in the former draft) doesn't show coherent phase structures. Also the derived semidiurnal amplitude is generally small (<0.2% from 5~42 km) in tropics and might not be significant. Therefore, we follow the reviewer's suggestion and remove the figure and modify the text in the manuscript accordingly. The semi-diurnal results in Fig.4 are also removed.

2) What is the uncertainty of the COSMIC temperature and refractivity data at various altitudes? Do these uncertainties exceed the amplitudes of the semi-diurnal tides at certain altitudes? (It may also be that the uncertainties exceed the amplitudes of the diurnal tides around the upper troposphere as well, although at least here the phases show consistent values)

There are three major factors limiting the precision of the RO refractivity and temperature retrievals. Kursinski et al. (1997) show the refractivity retrieval errors at 55 km, due to (a) ionospheric residual (~ 0.12% in solar minimum, e.g., in year 2007 & 2008 of this paper); (b) thermal errors (~3%); and (c) Abel boundary errors (0.8%) (Table-2 & Fig-10). All errors decay exponentially at lower altitudes. Moreover, the random thermal error can be reduced by averaging. Given that the monthly mean diurnal/semidiurnal sampling over 5°-latitude band to be 37 (at 75N). The RO refractivity retrieval error is estimated to be around 1.4% ($=0.1\%+0.8+3\%/SQRT(37)$) at 55 km, but quickly decreasing to ~0.16% at and below 40 km. Note also that at lower latitudes, the larger samples further reduce the refractivity measurement errors.

In Fig-3,&4, the diurnal amplitude with contour levels over 0.2% refractivity are generally statistically significant as shown by the SNR in Fig-4.

3) Throughout the manuscript, the approximate altitudes of given pressure levels are presented in parentheses afterwards which becomes distracting. I suggest plotting the approximate altitudes on the right hand y-axes of the appropriate Figures and then refraining from giving the altitudes in the text.

Thanks for the suggestion. The altitude coordinates are shown in the right-hand y-axes in Fig.1 and Fig.4. Only the geometric altitude is used in most of the discussion.

4) P25419, line 26. Where are seasonal (winter / autumn) profiles of diurnal amplitude shown, or how are they distinguishable in Fig 1a?

The colors are added onto the lines in Fig.1a,c to distinguish the diurnal amplitude in four seasons, e.g., DJF: green; MAM: blue; JJA: cyan; SON: black.

5) P25426, line 11. A reference is needed for the CMAM tides.

Reference added: [McLandress, 1997]

Technical Corrections:

- 1) p25410, line 18 'solar'*
- 2) p25410, line 24, 'by persistent daily'*
- 3) p25415, line 4 'the cold, dry upper troposphere: : :'*
- 4) p25418 line 9 'among tropical: : :'*
- 5) p25418 line 13 'against some earlier: : :'*
- 6) p25419 line 17 'showing local minima'*
- 7) p25422 line 5 'two maxima'*
- 8) p25426 line 19 'COSMIC'*
- 9) p25427 line 3 'Although the six COSMIC satellites: : :'*

All the above suggestions are included in the new draft. Thanks.