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Atmospheric Measurement Techniques
Discussions

Interactive comment on "A new approach to global gravity wave momentum flux determination from GPS radio occultation data" *by* A. Faber et al.

A. Faber et al.

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Dear Reviewer No.1,
Thank you very much for your suggestions and comments.
Please find below the detailed response to your comments:

MC1:
The horizontal spacing of 10-15deg is chosen way too large! Therefore the shown distributions of horizontal wavelengths and momentum fluxes are not reli- able! Of course, it makes sense to show these results as a demonstration of the newly introduced method. It should however be stated more clearly that the statistics of the currently available data is still too sparse to

produce more reliable results.
It is true, that spacing is rather big, but we feel, that this is due to the available data density. This will change with the upcoming COSMIC-2 mission which should provide up to 12,000 profiles daily. However, the displayed results show already interesting signatures especially in the tropical region.

MC2:
No measure or reference is given to judge whether the 3-point method works satisfactorily, especially regarding MC1. As a reference, in Figs.6–9 the authors should also provide results of a standard 2-point method for the same data set, but using small horizontal spacings of $< 300km$ between the 2 points. The 2-point data set can be used as a reference, because 2-point methods will systematically overestimate the horizontal wavelength. If successfully applied, the 3-point method should provide always shorter horizontal wavelengths than the 2-point method. If no such reference is given, the reader is left alone and is unable to decide whether, for a given data set, applying the 3-point method is an improvement over the 2-point methods currently used.
Thank you for this suggestion. This graphic shows a comparison for the 2-point and 3-point

[width=10cm]figure-1

method for the horizontal wavelength with a 10° spacing (left and middle figure) and $< 300km$ spacing (right figure) and the same for the momentum flux (d,e and f). Clearly the shortest wavelength are derived when applying the 3 point method, even though the 2-point method with $< 300km$ spacing has a higher resolution in the raw dataset. These results prove, that the 2-point method systematically overestimates the horizontal wavelength as expected. This comparison will also be included in the revised paper.

Specific Comments

1: *p.2, l.14 and further on: The expression "triad" might be somewhat misleading, because in atmospheric physics it is also used for cases of resonant wave-wave interactions (Wuest and Bittner, JASTP, 2006). Maybe, this expression should be replaced throughout the paper, for example by "3-point method".*
The term triads has been exchanges in the revised paper.

2: *p.3, l.14/15: "footprint" is not a good expression here Suggestion: "the sampling of GPS is more irregular in space and time than other techniques, such as limb or nadir scanning of atmospheric emissions from satel- lite."*
Footprint is exchanges.

3. *p.4, l.24: λ_h is not explained! Suggestion: ... λ_h, the true horizontal wavelength of a gravity wave, at least...*
The explanation of λ_h is added.

4. *p.5, eq.3: It looks like a factor 2 is missing in this equation! Also the momentum fluxes in Fig.9 could be too low by this factor of 2! Please check!*
The momentum flux like determined by Wang and Alexander 2010 uses the temperature fluctuation and not the amplitudes, therefore is no 2 missing in the equation.

5. *p.6, l.5: Please add the reference Preusse et al., AMT, 2009. In this paper the geometry of gravity wave detection from satellite is illustrated in more detail.*
Preusse et al. 2009 is added.

6. *p.6, l.23: What is the advantage of a CTW over performing simply a FFT to determine zonal wavenumbers 0-6 from the gridded data?*
The continuous wavelet transform (CWT) is used, since we used it before for the vertical

wavelength analysis. The results are similar to those of a FFT. Wang and Alexander 2010 used a S-transform, which is also a continuous wavelet-like analysis.

7. *p.6, l.23: How many data points are typically falling into one of the 10x15 deg fields? If these are too few, a clear separation of planetary and gravity waves might no longer be possible. I suppose there is enough statistics outside the tropics. However in the tropics the COSMIC data coverage is strongly reduced, and the quality of the finally obtained gravity wave variances might be worse. At least a cautionary note should be added in the text!*
The number of data points is not large, but internal comparisons of this one day griding to a 15 days griding and to the application of a vertical filter show, that this is the most sufficient way to exclude planetary waves in the extra tropics and especially in the tropics. This will be improved with higher data density in the COSMIC-2 mission (should provide about 12000 profiles daily).

8. *p.7, l.16: See also Major Comment MC1 The horizontal spacing of 15deg (1500km at the equator!) is much too coarse! Most gravity waves will be severely under-resolved (aliasing). Horizontal wavelength distributions derived by using such large spacings will be almost meaningless! Several studies suggest spacings $< 300km$. For example, in McDonald, JGR, 2012, Fig.6, the gravity wave occurrence frequency in COSMIC observations strongly increases at horizontal spacings $< 300km$. Because of its relevance, please add this reference to your paper!*
Answer is given in the MC1 and 2. The horizontal spacing cannot be chosen smaller due to the data density. We know that there are many alignments included in the displayed results but this might change with a higher data density as will be provided with the COSMIC-2 mission. A $< 300km$ spacing is not operable with the available dataset.

9. *p.8, l.4: Why is the vertical wavelength difference chosen so low? I suppose this must have something to do with the range of vertical wavelengths that is covered in your study. This*

range is however never mentioned. Please state clearly which interval of vertical wavelengths is investigated!
Information about the vertical wavelength window is added. It ranges between 2 and 12 km.

10. *Fig.1d: Please provide a color bar with units! In the caption of Fig.1: horizontal! vertical and one "(d)" should be removed in the caption*
Color bar and caption are changes.

11. *p.9, l.3: The phase shifts are also known, no information on xi,yi and dx is needed for that. Suggest to rewrite as follows: "... are known, and also the phase shifts..."*
Changed the sentence.

12. *p.10, l.2ff: This formulation confuses me, please rewrite!Suggestion (is this more correct?): "When displacing the black sinusoidal along the line connecting the brown and blue points into the same direction as before, we would obtain the grey sinusoidal line. The resulting slope..."*
Paragraph rewritten.

13. *General comment regarding section 3: Although everything may be correct, the problems arising from the evaluation of phase differences for different groupings/arrangements of points is written down in a very complicated way. I do not know whether I got the key point right, but if so, please add a statement like the following: "When evaluating the phase differences, inconsistencies may arise from wraparound effects. Depending on the reference point, due to the periodicity of the problem, the same phase difference could be regarded, for example, as either very small, or close to 2π . This effect is accounted for by evaluating all possible combinations of a considered group of three points, and sorting out the inconsistent combinations."*
Added in the text at the end of Sec. 3: When evaluating the phase differences, inconsistencies

may arise from wraparound effects. Depending on the reference point, due to the periodicity of the problem, the same phase difference could be regarded, for example, as either very small, or close to 2π. Also the inner angle at the reference point must be obtuse to determine a valuable horizontal wavelength. These effects are accounted for by evaluating all possible combinations of a considered group of three points and sorting out the inconsistent combinations.

14. *p.10, l.17: To make sure that the same wave is observed, probably one should be more worried about the dx criterion than about the dt criterion (see also Mc- Donald, 2012). The main limitation of the dt criterion is the phase progression caused by the wave frequency within this time difference. This effect could easily bias the phase differences between two soundings of the same wave! Please change the text accordingly.*
Text is changed as suggested.

15. *p.10, l.24ff: Why are very long values of h sorted out before forming the groups of three points? This could be a valid solution! It could easily happen that two of the three points are aligned along a line of constant phase of a real wave. The "true" horizontal wavelength would then be available from the information added by the third point.*
It is true, that the result might be a valid result, but the changes that the phase shift results from an alignment effect (2nd, 3rd. . . phase maximum) are bigger and this should be excluded. Therefore the phase difference is limited, which automatically excludes these very long horizontal wavelengths.

16. *p.11, l.4ff: Why are so small (5x5 deg) grid boxes used for the global maps, given the facts that: (a) the number of points is very small (b) the horizontal resolution inherent in the method is much worse: For defining groups of 3 points regions of 10x10 or 15x15 deg were used! Possibly, using larger 10x10 deg grid boxes would solve many problems. Anyway, many of the horizontal patterns are larger than 5 deg, probably because of the large regions used for grouping 3 points.*

Every result of one 3-point group determines a solution for their middle point. These middle points can then be presented in the $10x10^{\circ}$ resolution. Not all groupings (in the extra tropics but also in the tropics) exhaust the $15x15^{\circ}$ search window. There are also groupings with smaller distances. Choosing the small resolution also increases the details in the final results.

17. *p.11, l.9ff, about Fig.6: A statement commenting the sensitivity of the horizontal wavelength on the size of the lon/lat regions is missing and should be added! See also Major Comment MC1. Suggestion: "The fact that the horizontal wavelength is strongly dependent on the maximum distance limit shows that the global distribution of gravity wave horizontal wavelengths cannot be reliably determined with the large distances required to obtain sufficient statistics."*
Added in the text: The fact, that the horizontal wavelength is strongly dependent on the maximum distance limit shows, that the global distribution of gravity wave horizontal wavelengths cannot be reliably determined with the large distances required to obtain sufficient statistics.

18. *p.11 and in the following: As a reference, please always show corresponding results of a 300 km 2-point method in Figs.6–9. See also Major Comment MC2!*
Comparison 2-point verses 3-point method
As a reference, that the 3-point method works right, the results of the horizontal wavelength should always be shorter then those derived by the 2-point method from Ern 2004. Therefor the determination of λ_h^p and the true λ_h is shown in Fig. a and b for a 10° spacing and the λ_h^p for a $< 300km$ spacing in Fig. c. Corresponding to these horizontal wavelengths, the momentum flux is displayed in Fig. d-f. First the comparison for the 10° spacing is discussed (Fig. a and b). Th detected projected (a) and true (b) horizontal wavelength show clearly, that the 3-point method decreases the horizontal wavelength. The 2-point method delivers wavelengths between 3000 and 5000 km, whereas the 3-point method with the same spacing decreases the detected wavelengths down to values between 1000 and 2500 km. This effect of detecting shorter wavelengths is also found, when decreasing the spacing for the 2-point method down

to a maximum value of 300 km (Fig. c). Here the determined projected wavelengths vary between 2000 and 5000 km. This states clearly, that even though the spacing of 15° is rather big, the results are more realistic than those from the 2-point method. For the momentum flux, the determined horizontal wavelength plays an important role. The detection of shorter wavelengths leads to higher values in the momentum flux distribution. Therefore the results from the 3-point method (Fig. e) show higher values than those of the 2-point method with both spacings (10° and $< 300km$ in Figs. d and f, respectively).

19. *p.13, l.5–7: How does Ep compare with the distribution shown in John and Ku- mar, GRL, 2013, accepted? In John and Kumar (2013) there is no maximum of Ep at the equator if planetary waves are removed from COSMIC by a similar horizontal fitting procedure. Instead, maximum variances during NH summer are observed at around 15N. This discrepancy suggests that there is still some uncertainty in removing planetary waves, at least in the tropics. This should be mentioned in the revised manuscript.*
The potential energy results are in good agreement to those of John and Kumar 2013 (method 2). The difference in the absolute value comes from the difference in the analyzed altitude region (20-30 km our work and 20-40 km for John and Kumar). The structure with high values in the tropical region and along the south end of South America is also comparable, even thought the analyzed time period is not the same (JJA 2006 compared with JJA 2007). I n addition to the low data density in the equator region, which make it hard to properly determine the background, the maximum at 15N in northern summer could also be related to the ITCZ with strong convection above land as GW source.

20. *p.13, l.8–19: It makes no sense to discuss details of the λ_h distribution, because λ_h is too strongly high-biased! For instance, the mentioned regions of short λ_h over land coincide with regions of shorter 3-point distances dx on average (see Figure 7c). Obviously variations in the distribution of λ_h rather reflect variations in dx than variations of λ_h in the real atmosphere! Because most of the features seen in the λ_h distributions are probably not robust, this again*

shows the requirement of a kind of reference! Please include according figures for a short-dx 2-point method and discuss the differences. See also Major Comment MC2.
Already included in the new section.

21. *p.14, l.14: The first sentence of the Conclusions section is somewhat out of place. Momentum fluxes have been derived before from GPS RO data (Froehlich et al., 2007; Wang and Alexander, 2010).*
Changed the sentence to: This study provides information about the determination of momentum flux using three co-located RO profiles.

22. *Figure 7a: In this figure the "number of triads" in the tropics is usually very low. But at (0,0)deg lon/lat there is a spot of very high values. This really looks strange! Please check whether this is an artifact. If this is not the case, please add a short explanation why there is an enhanced number of RO.*
The misprint in Fig. 7 a is corrected now.

All the editorial comments and the reference are included in the new version.
Thank you very much again.
Best regards,

Antonia Faber

Please also note the supplement to this comment:
http://www.atmos-meas-tech-discuss.net/6/C1988/2013/amtd-6-C1988-2013-supplement.pdf

Interactive comment on Atmos. Meas. Tech. Discuss., 6, 2907, 2013.

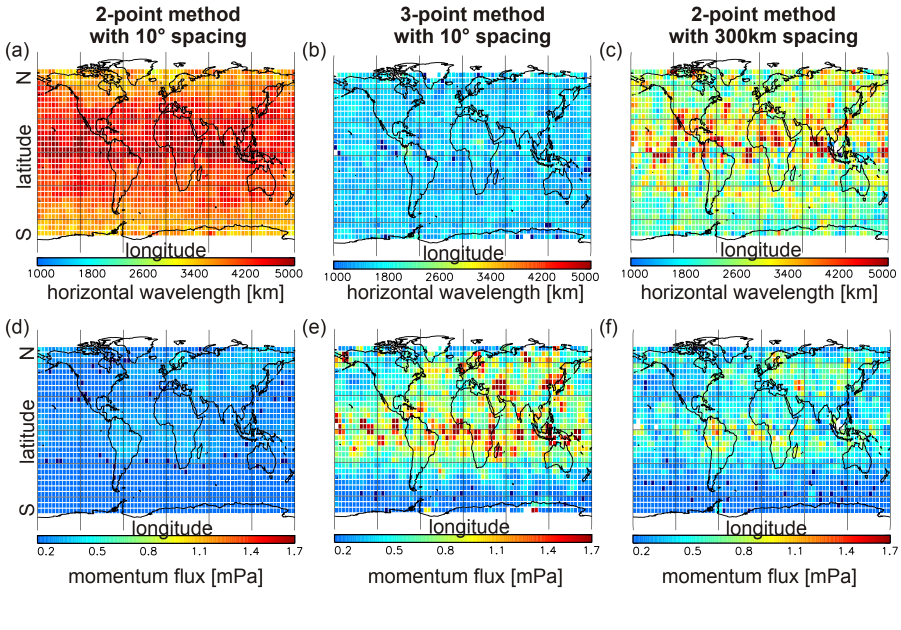

Fig. 1. Projected horizontal wavelength (a and c) and true horizontal wavelength (b) with spacings of 10° (a and b) and <300 km (c) and the corresponding momentum flux d-f.