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Atmospheric Measurement Techniques Discussions

Interactive comment on "Evaluation of atmospheric profiles derived from single- and zero-difference excess phase processing of BeiDou System radio occultation data of the FY-3C GNOS mission" *by* Weihua Bai et al.

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We thank the referees very much for the constructive comments and recommendations and for the overall positive rating that this is a significant scientific paper. We thoroughly considered all comments and carefully revised the manuscript accounting for most of them. In addition, we carefully complemented these revisions with a range of further improvements throughout the manuscript text in the spirit of the comments.

(Please read the amt-2017-177-supplement.pdf by the link at end of this document, in

which you can find the response to all the referees and the revised manuscript)

1 General Comments

This article presents atmospheric profiling results derived from radio occultation of satellites in the BeiDou constellation over three months, as processed by single- and zero- differencing algorithms. The derived bending angles and refractivity profiles are compared to results from the ECMWF and radiosondes collocated geospatially and temporally with the profiles from the GNOS instrument. This paper is well organized and does a good job of describing the processing methodologies. The resulting BDS profiles are fairly consistent with both other radio occultation measurement results from the ECMWF and localized radiosondes. The results are encouraging in both the use of ultra-stable oscillators for radio occultation collection instruments (zero-differencing), and the use of the BeiDou signals as remote sensing sources for future atmospheric sensing satellite missions. I only have a few specific comments and suggestions that I'd like to see further expanded upon in the revision.

Thank you.

2 Specific Comments

The authors mention, early in the paper, that the GNOS receiver is capable of collecting both GPS and BDS data. However, I am slightly confused as to whether any GPS data were used in your single/zero-differencing studies. You make a distinction on Page 6 that the term "GNSS" refers to both GPS and BDS satellites, but it seems like only BDS satellites are used for the occultation measurements, and perhaps GPS is just used for timing? It would be interesting to the reader to compare occultation results from your same algorithms, but with GPS data over the same time and spatial intervals.

Ok, though it is a challenge to get sufficient co-located BDS and GPS radio occultation (RO) profiles in our current setup, we now performed some comparative RO data processing of BDS vs. GPS satellite observations by using the single-/zero-differencing

algorithms as well. We note that evaluations of the retrieved GPS-only RO data using single-differencing algorithms have been presented by some previous papers already, so that is why this paper focuses on the BDS RO data validation. We included one BDS vs. GPS intercomparison figure now in section 3.2., which we find to exhibit reasonably high consistency. Of course, further improvements and a detailed intercomparison analysis of the GPS and BDS RO data is a very interesting study for us as well, and we plan to do it by an extra paper. And yes, the GPS is used for timing in the BDS data processing, as described in section 2.1.

Another related point, I am curious as to why your results are negatively biased from both the ECMWF and radiosondes. The authors make a comment as to the differences in the vertical geo-locations of the profiles in comparison to the reference data, but it is odd that all the different types of BDS satellites (GEO, IGSO, MEO) are negatively biased. Again, if the authors were to process GPS data from the same times/locations with their single/zero-differencing algorithms, it could be another way to validate their methodologies and results. The negative biases are already quite small but, yes, we agree we should be able to further reduce them in future. Currently we consider they are likely caused by a residual error in the excess phase processing and we work to further improve this processing.

The authors use radiosonde measurements within a +/- 1 deg lat-lon/ +/- 1 hour collocation criterion to validate an RO event for part of their analysis. This range can be on the order of a 200 km x 200 km box, over the course of an hour. Do the authors have an explanation or reference to the stability of the atmosphere over these spatial and time ranges?

Thanks, its a good question. Actually, the $\pm$1 degree lat-lon and $\pm$1 hour criterion was our initial collocation implementation, and we used it at the beginning of GNOS data validation. We have re-checked our programming codes, and confirmed that the temporal and spatial criterion of comparison between the GNOS BDS RO observations and the radiosonde reference data is within $\pm$1 hour and a circle with radius of 200

km around the radiosonde location. So we have corrected the explanation of the collocations accordingly. Regarding the reasonable stability of the atmosphere over such collocation distances, we have now included Hajj et al. (2004) and Anthes et al. (2008) as references, since therein some discussion of representativity errors as a function of collocation distances is conducted.

3 Technical Corrections

Page 3, lines 13-14: the word “satellites” is repeated Ok, corrected.

Page 3, lines 20-21: These new GNSS navigation satellites, together with planned LEO missions, will offer many more RO observations. Ok, done.

Page 3, line 22: : : : onboard for the first time: : : Ok, done.

Page 3, line 29: will have GNOS on board as well, similar : : : Ok, done.

Page 3, line 30: The definition for the acronym GRAS is defined on page 16, should be where it is first used. Ok, done.

Page 4, line 1-3: This description is a bit confusing. You mention three antennas on the instrument, then an antenna for the processor that has a stable phase center. Is this one of the three antennas? Or an additional antenna? Please consider rewording. It is one of the three antennas, but not an additional antenna. The ’as well as’ has been revised as ’in which’.

Page 4, line 6: Can you quantify “large”? Perhaps by the number of days or occultations Ok, done. The ’large’ has been revised as ’4-year’.

Page 4, line 16: Should “ GPS” be changed to “GNSS”? Single differencing may have been limited to GPS in your references, but here you use GNSS elsewhere in the same sentence. Thanks, it should be ’GPS’, since this specifically refers to the GPS ’selective availability’ (SA).

Page 4, line 21: Can you reword “started to be used”? Ok, we now say “was started to

be used”

Page 4, line 24-25: : : :by an ultra-stable oscillator that, so far, was only available for GRACE : : : Ok, done.

Page 4, line 29: So far, BDS can provide good regional coverage : : : Ok, done.

Pages 4-5, lines 31, 1-2: : : : GNOS satellite received signals from five geostationary orbit (GEO) satellites, five inclined geosynchronous orbit (IGSO) satellites, and four medium earth orbit (MEO) satellites to conduct the radio occultation measurements. Ok, done.

And throughout the paper, don’t redefine GEO, IGSO, and MEO. Define the first time, and use the acronyms thereafter. Ok, done.

Page 5, line 7: Remove the word “anyway” Ok, done.

Page 8, lines 6-7: : : :as the basic equation and adopt Eq. (2) as the auxiliary equation. Ok, done.

Page 9, line 2: Reword “comparing with” (could use “as compared to”) Ok, done.

Page 9, line 6: : : : constellation, as with the current BDS. In addition, zero differencing will likely : : : Ok, done.

Page 9, lines 6-10: Please consider splitting this sentence into multiple sentences. Ok, done; split into two sentences.

Page 9, line 11: In the zero-differencing approach, we employ: : : (the term Zero-Differencing is used previously in the paper. If you want to use it as an acronym, please define earlier). Ok, done. Page 9, line 12: “GPS” should be “GNSS”, right? Ok, corrected.

Page 9, line 21: When you say that the processing chooses the GNSS satellite with highest elevation angle, are you using both GPS and BDS satellites for single-

differencing? Please clarify. Currently, in our single-differencing data processing, only BDS satellites are used as reference satellites for BDS occultation, similarly only GPS satellites for GPS occultation. We clarified this in the text now. Page 10, line 4: For both B1 and B2, the elevation angle appears to be more like 12 deg where the carrier phase errors are less than 2 mm. Right, as shown in Figure 3, for both B1 and B2, the elevation should be 12 deg, where the carrier phase errors are less than 2 mm. As well as, at 10 degree both the B1 and B2 carrier phase errors are less than 2.2 mm. Actually, we use the elevation 10 degree as the reference satellite selection criterion, so we have revised the 2 mm to 2.2 mm in the manuscript.

Page 13, line 10: It looks like you might be missing a reference here. Thanks, was left as a typo, corrected.

Page 13, line 12: MEO is already defined previously in the paper. Ok, corrected.

Page 16, lines 4-5: Should be Allan deviation (ADEV), not Allen variance. Ok, corrected.

Please also note the supplement to this comment:
https://www.atmos-meas-tech-discuss.net/amt-2017-177/amt-2017-177-AC1-supplement.pdf

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