

Interactive comment on “Application of Fengyun 3-C GNSS occultation sounder for assessing global ionospheric response to magnetic storm event” by Weihua Bai et al.

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Dear Editor and Referee #1,

Thank you for your comments concerning our manuscript entitled “Application of Fengyun 3-C GNSS occultation sounder for assessing global ionospheric response to magnetic storm event” (Manuscript Number: doi:10.5194/amt-2016-291-RC1). Those comments are all valuable and very helpful for revising and improving our paper, as well as the important guiding significance to our researches. We have studied comments carefully and have made correction which we hope meet with approval. The responds to the comments are as flowing:

Referee #1:

General comments:

1, Figure 4 compares NmF2 measurements from the GNOS GPS occultation and Figure 5 shows those produced by GNOS BDS occultation. The comparison between these two figures is the only thing I find in this paper that could be called a “new finding.”

Response: We would like to explain our purposes and meanings in this paper: (1) It's a first demonstration for the application of the FY3-C GNSS occultation sounder (GNOS) for assessing global ionospheric response to magnetic storm events. These results coincide with previous studies (e. g. Habarulema et al. 2014, 2016 and references therein), which just right proves the reliability of FY3-C GNOS radio occultation measurements for analyzing statistical and event-specific physical characteristics of the ionosphere. (2) Using the one year GNOS data, we showed that the Correlation coefficients NmF2 derived from GNOS GPS and BDS products with ionosonde data were higher than 0.9, and standard deviations were less than 20 %. It's important for the Multi-GNSS occultation application, which proves the precisions of the different GNSS occultations are consistent and comparable. (3) We analyzed the variation of the daily and zonal average of the NmF2 and hmF2 values during the whole geomagnetic storm, and confirmed the negative effect of this space weather event on the ionosphere. In the zone of geomagnetic inclination between 40–80°, average NmF2 during the geomagnetic storm showed the same basic trends in GNOS measurements, and in observations from 17 ground-based ionosonde stations (4) We believe that our study makes a significant contribution to the literature because this paper is just a little case and first step for the application of the GNOS. As a new member of the family of the occultation missions, the data of the GNOS will have significant potential application in space weather monitoring and forecasting, as well as modeling and research in the future, especially, with datum from other GNSS occultation missions.

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2, The differences between these two figures should be discussed in details.

Response: Well, we have added some discussion in this part. For the description of the two figures, we think that it's adequate in original manuscript, we complement the NmF2 errors comparison between GPS and BDS "The bias and standard deviation of the NmF2 derived from the GNOS BDS occultation and GPS occultation are consistent and comparable. However, the bias and standard deviation of the NmF2 from BDS are slightly larger, it could be caused by the larger position errors of the BDS satellites, especially for the GEO satellites, and the different distribution of the occultation events". In my opinion, the reason of why BDS is worse than GPS is because of the larger position errors of the BDS satellites, because the BDS consists of three types of the navigation satellites, GEO, IGSO, and MEO, it's impossible to get the precise (cm level) orbit determination for the GEO satellites, usually, the errors of the GEO are meter level (in Lou Y., et al. 2016, Fig.7). In figure 5, the statistic results include all type of BDS satellites. Moreover, the distribution of the BDS occultation events is different, you can find out some information from the reference Fig2 of the Liao M. et al. 2016, where we can see most of the GEO occultation events appeared on the particular high latitude region, the IGSO events concentrated on the edge of two big circle, and MEO events were evenly distribution. Different location distribution should be different error feature. Therefore, the reason would be very complicated, considering the length of this paper and our purpose (to discuss the ionospheric response to magnetic storm event using the GNOS ionosphere products), we would not like to discuss more in this paper, but we have planed to study it using more BDS products (two years).

Reference: Liao, M., Zhang, P., Yang, G. L., Bi, Y. M., Y., Liu, Bai, W. H., Meng, X. G., Du, Q. F., and Sun, Y. Q.: Preliminary validation of refractivity from a new radio occultation sounder GNOS/FY-3C. *AMT*, 9: 781-792, 2016. Lou Y., Liu Y., Shi C., Wang B., Yao X., Zheng F.:. Precise orbit determination of BeiDou constellation: method comparison. *GPS Solut.*, 20:259–268, 2016.

Specific comments:

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1, The authors do not adequately describe the Beidou constellation, signals or frequencies. Beidou is still a relatively new system and has not been well-referenced in the literature yet. Why are the results between Beidou and GPS different? The authors should discuss this in detail and provide more background introduction to Beidou.

Response: Yes, it's a good suggestion, we have added the basic information of the BDS in the third paragraph of the introduction section in upload manuscript: "BDS is China's global navigation satellite system, which can provide coverage in the Asia-Pacific region with 5 geostationary orbit (GEO) satellites 5 inclined geosynchronous orbit (IGSO) satellites and 5 medium earth orbit (MEO) orbit satellites, currently (China satellite navigation office, 2016)", and gave the BDS official document (BeiDou document,2016) as a new reference. We also complement the dual-frequencies information in the second paragraph in section 2 : "The ionospheric occultation antennas are single unit, micro-strip, dual-mode, and dual-frequency, and they can simultaneously receive BDS dual-frequency (B1I 1561.098MHz and B2I 1207.140MHz) and GPS dual frequency (L1 1575.420MHz and L2 1227.600MHz) ionospheric occultation signals."

Reference: BeiDou navigation satellite system signal in space interface control document open service signal (Version 2.1): <http://en.beidou.gov.cn/>, last access: November, 2016.

2, Not enough background material was provided. In particular, the paper by Hararulema and Carelse (2016). Their paper was published before yours and discusses the first long-term comparison between RO and ionosonde NmF2 and hmF2 data during storm conditions. They also provide results (a similar finding to yours) that NmF2 and hmF2 agree to within 21% and 9% (1 standard deviation), respectively. They also saw that maximum deviations for both NmF2 and hmF2 occur during high solar activity periods

Response: Thank you for your good suggestions. We have supplemented some background material in introduction and other necessary sections. Please see them in the

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fourth paragraph in the last paragraph of the section 2, and the first paragraph in section 4. We would like to complement the differences between the paper Hararulema and Carelse (2016) and our manuscript. For example, the data we used is in the zone of geomagnetic inclination between $40\text{--}80^\circ$ in the north hemisphere, including the GNOS ionosphere products (GPS and BDS) and the observations from 17 ground-based ionosonde stations; the ionosonde data of the paper Hararulema and Carelse (2016) is just one station in Grahamstown, south Africa, in the south hemisphere. Moreover, in our paper, we discuss the daily changing process of the Nmf2 and hmf2 during the whole geomagnetic storm. We showed the variation of the daily, daytime, and nighttime average of the NmF2 and hmF2 in the zone of geomagnetic inclination between $40\text{--}80^\circ$ (in Fig.8 and Fig.12). Finally, we confirmed the negative effect of this geomagnetic storm event on the ionosphere.

3, I do not think that equation 1) eliminates all the biases. There are both satellite and receiver biases (differential delay differences between the two frequencies) that are not eliminated in this equation. Please discuss. Add or discuss these references in the paper.

Response: Yes, the referrer is right, the equation (1) can not eliminates all the biases, but, in original manuscript (in the fourth paragraph of the section 2) : “This type of dual frequency TEC inversion method (Syndergaard, et al., 2000; Datta-Barua, et al., 2008) eliminates clock differences and other instrumental biases, and also allows information on bending angle and impact height to be obtained”, what we said is “other instrumental biases”. In our opinion, the instrumental biases mean the biases or delay caused by the instrument (or payload or receiver system). The receiver clock offset and differences belong to the instrumental biases, and “other instrumental biases” includes the delay cause by cable connecting the RO antenna and receiver, and the delays or biases caused by the electronic components in the receiver (e.g. amplifiers, filters, and mixers). All of the instrumental biases could be considered the same for both two frequencies (L1,L2 of GPS, and B1I,B2I of BDS). I’m sorry for the expression

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“instrumental biases” might be cause the misunderstanding, so we revised this sentence to “This type of dual frequency TEC inversion method (Syndergaard, et al., 2000; Schreiner, et al., 1999) eliminates clock errors (Jin S. et al, 2014), and also allows information on bending angle and impact height to be obtained”, and we also added a reference (Jin S. et al, 2014), in which : P114, “The phase difference cancels out the orbit and clock errors automatically and”

Reference: Jin S., Estel C., Xie F. (Eds.): GNSS remote sensing theory, methods and applications, EARSel Series, Springer, Freck D., Netherlands, 2014.

4, Others mentioned papers:

Thanks for the referee to supply the valuable references, we studied them and appended them in the suitable place. Garcia-Fernandez, et al., 2003, Habarulema, et al., 2014 and 2016 appended in the last paragraph of the section 2 to enhance the background introduction. Yue, et al., 2010, 2011 have been used to explain the Abel inversion in the first paragraph in section 4.

We appreciate for your warm work earnestly, and hope that the response will meet with approval.

The references and the new update version paper are enclosed in supplement.

Thank you very much.

Yours sincerely,

Bai Weihua, Wang Guojun and orther co-authors

Please also note the supplement to this comment:

<http://www.atmos-meas-tech-discuss.net/amt-2016-291/amt-2016-291-AC1-supplement.zip>

Interactive comment on Atmos. Meas. Tech. Discuss., doi:10.5194/amt-2016-291, 2016.