

Observed impact of the GNSS clock data rate on Radio Occultation bending angles for Sentinel-6A and COSMIC-2

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Summary

The authors provided a revised version of the manuscript addressing the comments from the previous review. One major improvement is the inclusion of an analysis investigating the effects of different GNSS clock rates at single-occultation level. Additionally, Section 3.1, which covers precise orbit determination of the Sentinel-6A (S6A) satellite, was strengthened with a comprehensive comparison of different orbit solutions presented in Figure 4. To provide a better overview in support of the reader, the authors added a table summarizing the different sets of GNSS products used in the study. Furthermore, the final combined Discussion and Conclusions section was separated and expanded, now also including considerations on the Galileo and BeiDou GNSS systems.

General comments

In response to feedback from the initial review, the authors included an additional figure and corresponding discussion regarding the expected performance of Galileo and BeiDou occultations in the Conclusions section. While the addition of this content and the insights on these GNSS systems is valuable and enriches the publication, the introduction of a new figure and content in this final manuscript section is not common practise. It is required that the authors restructure the last two sections of the manuscript and move their main considerations on Galileo and BeiDou, along with Figure 12, to the Discussion section. Since the final Conclusions section is generally intended to be self-contained, it is further recommended to minimize figure references unless they are considered essential.

The paper primarily focuses on S6A and utilizes only a small batch of COSMIC-2 data. Section 4.2 points out a larger standard deviation in the bending angle statistics for COSMIC-2 compared to S6A, attributed to a POD solution of lower quality. It is argued that this is caused by the absence of a satellite macro-model, the lower orbit altitude, and increased solar activity in 2023. While Section 3.1 extensively discusses S6A POD, there is a lack of discussion on COSMIC-2 POD in this dedicated POD section. It is advised that the authors add a short discussion of COSMIC-2 POD, including relevant numbers or references, in order to provide a complete analysis and to support their assessment of lower COSMIC-2 POD quality in Section 4.2.

Line per line and figure specific comments:

Figures (general): Please use intermediate minor tick-marks and provide major tick-marks with shorter intervals to support the reader with the identification of relevant values in the figures (applies basically to all bending angle statistics figures).

--- Abstract

L2: In the first review I noted the following: *“Space-based RO experiments ...”. For my understanding this sounds a bit too “experimental”, RO is a proven and well advanced remote-sensing measurement technique, but maybe this is commonly recognized designation.*

We just had in mind RO experiments on other planets, where the receiver sits on ground and not on a LEO. But indeed in the context of this special issue, there's no need to specify it.

What I was referring to in my comment above was not “space-based” but the wording “experiments”. I suggest to replace it by “measurements”. Note that this applies to other occurrences in the text as well.

--- 1 Introduction

L20: Remove “an” in “requires an accurate knowledge ...”.

L33: The wording “some information” gives the impression that Table 1 is somehow incomplete. I suggest to rephrase.

--- 2 Motivation

L59: Please introduce OPE at its first usage in the text, independently from Figure 1. In Figure 1 be consistent with the introduction of OPE and STC.

L65: Start new paragraph with: “The comparison of the statistics ...”.

L68: Note the mission: “..., using recent S6A data ...”.

L70: You state that different POD SW and different GNSS auxiliary data are responsible for a 3 % difference in total number of BA profiles obtained by the OPE and STC processors. The OPE uses GNSS products from JPL-EUM (GPS: 15 min/30 s; GLONASS: 15 min/1 s) and the STC GNSS products from COR (GPS: 15 min/30 s; GLONASS: 15 min/30 s). I wonder how the different POD SW and GNSS auxiliary data (used by JPL and CODE) affect the number of processed BA. I assume both analysis center deliver GNSS orbit and clock data products covering the entire test period and that for each retrieved profile a matching modeled profile exists. Is it rather the different quality of the provided orbit and clock data which differs and therefore leads to rejection or failure to process some of the occultations? Or are there differences between the OPE and STC processors leading to different numbers of successfully processed BA profiles?

L72: Please stick with OPE here instead with NTC. It is easier to relate to the following text and occurrences of OPE therein.

L76: Start new paragraph with: “Previous work has pointed out ...”.

L79: Plural and hyphenation: “Less stable clocks would require a higher-rate correction to compensate their noise, ...”.

---- 3 Set-up of the experiments

L109: At the beginning of Section 3.1 you state that LEO orbit and clock solutions are obtained with Bernese 5.4, with the exemption that the OPE embedded Bernese 5.2 in 2021 and thus also has been used with the OPE processor in Fig. 1 (L109). To clarify, apart from the OPE analysis in Fig. 1, which used Bernese 5.2, in all other cases Bernese 5.4 was used?

L106: Better: “Integer-ambiguity fixing has been shown to perform better ...”.

L120: “etc.” instead of “ect.”

L120: Please correct: “As a result, the reduced-dynamic versus kinematic orbit comparison ...”.

L124: Introduce hyphenation for “cross-check”. Also for all further occurrences (e.g., L128).

L150: Sentence structure: “In Fig. 4, we use the CPOD QWG combined solution as the reference solution... ”.

L153: Add missing space between value and unit: “JPL 30 s GNSS products”.

--- 4 Results

L165: Plural: “GNSS clock data rates”. Maybe even better to rephrase: “... using GNSS clock products with different data rates in the BA data processing”.

L172: Remind the reader once more of the selected data rates and specify the five data sets used.

L197: Do the three-days of COSMIC-2 test data comprise data from all flight models and have they been processed from level 0 data from UCAR? Please add this information, in particular the origin of the data, to the manuscript.

L199: Sentence structure: “For GPS occultations we only present results for GPS clocks at 30 seconds (Fig. 9), ...”.

--- 5 Discussion

L206: Better: “... points to the importance ...”.

L207: Please correct to “... in terms of ...”.

L212: Use numerals rather than spelling out numbers (e.g., about 110k occultations).

L234: Plural: “these data”.

L237: Plural: “... set of bending angle profiles.”

L238: I think you intend to refer to Fig. 7 here. Also, I would rather say that there is no obvious trend in the standard deviation across the GPS blocks with respect to different clock rates.

Figure 10: I suggest the following adaptations to the figure caption: Move second part of the first sentence to the beginning of the sentence to improve the word order; Move the note on the different

vertical axis ranges in brackets to a separate sentence. Furthermore, in my opinion the interpretation rather belongs in the text than in the figure caption. In any case you should elaborate which decrease is very evident for GLONASS and rather talk about phase variations or differences instead of lines for GPS.

--- 6 Conclusions

Please see the general comments section for remarks on the content and structure of the Conclusions section. Besides that, line per line comments follow.

L241: Remind the reader once more what was the main focus of the study: “This work focused on the implications of different GPS and GLONASS clock rates on occultations recorded by ...”.

L243: Word order: “... S6B, will start collecting Galileo signals on the RO antennas, in addition to GPS and GLONASS signals.”

L245: Plural: “... modern RO missions also exploit ... ”.

L248: Standard deviation of what? Elaborate and provide more context.

L249: “vertical error correlation (Fig. 11)”

L253: Add figure number and adequate commas.

L256: So there are no BeiDou clock products available with a rate higher than 30 seconds? Especially the shorter averaging intervals of the AD would be of interest.

L262: As you pointed out in your response to the initial review I also consider “sweet-spot” an informal definition because it varies among different studies. I recommend not overemphasizing it: for example, you may consider stating “...is expected in the 5 to 30 km range (Kursinski et al., 1997), also referred to as the so-called 'RO sweet-spot'.”, and avoid the repetition of the term in the following sentence.

L264: Remove comma before “Recently ...”.

--- References

L298: Remove space from article number: “112395”.