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Atmospheric Measurement Techniques Discussions

Interactive comment on "Integrating uncertainty propagation in GNSS radio occultation retrieval: from excess phase to atmospheric bending angle profiles" *by* Jakob Schwarz et al.

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General Comments

As most of remote sensing techniques, uncertainty analysis is essential to quantify the retrieval credibility in a GNSS-RO system. This article describes the uncertainty propagation of GNSS-RO with step by step approach. From excess phase to bending angle, the propagation process of both random and systematic uncertainties at each step are introduced in details. While the description of the uncertainty propagation is nearly complete and the validation results are very impressive, I recommend this article published after minor revision on several issues:

1. The "estimated system uncertainty" is not well-defined and needs more explanation.

What are the sources of the system uncertainty in excess phase? Why can we model it with eq. 8? Are these estimated system uncertainty totally uncorrelated with random uncertainties in each step so that we can treat them separately? What if the bias actually comes from the signal randomness (e.g. the bending angle bias caused by signal noise as depicted by [Sokolovskiy et al., 2010])? Should we count it as system uncertainty or random uncertainty?

2. Although the MC simulations validate the propagation process, whether the propagation results can reflect how real data behave is questionable:

(i) One thing I concern the most is the modeling of random uncertainty as normal distribution. While the "residual phase" of the RO signal suffered by thermal noise could be normally distributed (strictly speaking it is not), the excess phase calculated by unwrapping residual phase can contain cycle slips (even bias if the used model is biased) due to signal noise. Obviously the nonlinear unwrapping process is ignored in this article, and I'm wondering if it could impact the uncertainty propagation results? If this has already been considered in the eq. 6, then author should explain how this model is derived rather than simply providing a technical report reference.

(ii) The random uncertainty is highly related to the signal SNR. However, the linear extension used below 30 km removes all the corresponding SNR information. The reason of using a linear gradient model below 30 km instead of the calculated ddL_{rm,k} should be given.

(iii) A key element this article lack of is the verification of the propagated uncertainty using the actual data. The direct comparison in random uncertainty might be difficult, but the system uncertainty, or bias as you defined in P.4, could be observed statistically through the comparison between RO and ECMWF (or other measurement like RAOB). We may have more confidence on the propagated system uncertainty if it matches the comparison results.

[Sokolovskiy, S., C. Rocken, W. Schreiner, and D. Hunt (2010), On the uncertainty of radio occultation inversions in the lower troposphere, J. Geophys. Res., 115, D22111, doi:10.1029/2010JD014058.]

Specific comments

*** P7, eq. 6 & eq. 8 ***

These two equations should be better explained: why linear and where are these constants (3e6 and 3e7) come from? Why eq. 6 is better than the original ddL_{rm,k} in modeling the random uncertainty below 30 km?

*** P7, L23 – L26 ***

Why 0.1 mm and 0.2 mm for simMetOp? Why 0.2 and 0.4 mm for the other two? Why are they constants over 8 km to 80 km? What are the causes of the modeled systematic uncertainty?

*** P11, L18 ***

F_{c2} is set noise dependent – How to determine the filter bandwidth? Do you have to check the spectrum first?

*** P14, L8 ***

What is the criteria used for discarding 5% of the processed profiles?

*** P20, L7 ***

Although the conclusion is the same but shouldn't the BWS filter be 41 points as you stated in P. 16?

*** P23, eq. A33 ***

Why the systematic uncertainty of bending angle is not related to the open angle?

*** P41, Fig. 6(b) ***

When comparing Fig.5(b) and Fig.6(b), it surprised me that the Doppler systematic

uncertainty increase at the bottom of the profile vanished in the one of bending angle. In figure 6, it's just a constant all the way down. Is there any specific reason for this? The Doppler uncertainty is too small compared to the orbit uncertainties? So most of the systematic uncertainty of the bending angle comes from the orbit instead of the measured Doppler?

*** P45, Fig 10(g) ***

Can you provide an explanation why several cases in simMetOp have larger L_f uncertainty between the impact altitude of 40 and 60 km?

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