Abstract recommendations

>>>>>*On first reading my impression was that the use of openIFS is the novel thing, but on a second reading, remembering what I have read before, my opinion changed. Now I believe that it is the use of the ray-tracing instead of the mapping functions that is the new aspect here. I suggest that this should be made clearer so that the reader gets it on the first reading.*

We would like to thank the referee for pointing this out. After some debate we consider that the abstract focuses on the use of OpenIFS data as the novel thing in the coupling of weather models and orbit determination solvers, as it was intended. The use of the ray tracer allows us to bypass the creation of the mapping function, that will be the continuation of this work, but we could use RADIATE (ray tracer used by Vienna to create their mapping functions) to get to the same results, although losing some information due to the mapping functions.

>>>>>*I am also a bit surprised that the whole paper deals with a-priori estimates only. Perhaps it is my ignorance of this field, but why do you compare only a-priori estimates instead of final ones?*

Thanks to the referee for this question, as it is important to understand the reason to using ‘a priori’ estimates and it has not been clearly explained. From the perspective of GNSS orbit determination, the troposphere is a major source of perturbations of the GNSS signals. Hence, we try to remedy this by modeling the signal delay caused by the troposphere so we can subtract/remove it from the observations. This is what we call the "a priori" troposphere model. Unfortunately, these models are so far not able to represent the wet component of the troposphere sufficiently well. Therefore, we have to estimate certain tropospheric parameters during the orbit determination process that account for the remaining (unmodeled) wet tropospheric signal delay. These are referred to as a posteriori. In short, comparing a-priori estimates is the most straight-forward method to assess the performance of the two ways to process the input data for precise orbit determination.

>>>>>*A minor issue was the notion "midnight discontinuity" which was puzzling on first reading. Later it became clear. Please try to find a short but simple circumscription of what is meant so that the reader does not get lost already in the abstract.*

The referee is right about this issue and we appreciate the notification as it is important to state what we meant with ‘midnight discontinuity’. A comment from another referee suggested to remove the sentece and, after some consideration, we decided to remove it, so this ‘minor recommendation’ needs no further revision.

Section 2.1 recommendations

>>>>>*It is astonishing to me that 30 sec of data per day are sufficient to compute the orbit for a complete 24 hours period. Is this, because it is essentially celestial mechanics (i.e. almost negligible perturbations) or is there a misunderstanding?*

We think that there has been a misunderstanding here. The observation samplig is done in epochs of 30 seconds, so over one day we have 2880 observation epochs with which we compute the orbits. The perturbations are in fact important. We assume the responsibility of the misunderstanding and we would like to thank the referee for noticing this error.

>>>>>*What do you mean with "pseudostochastic pulses are estimated"? Don't repeat the quoted paper here, but a few simple words for explantion would be fine.*

As the perturbations of the satellites are important and the modelling is not perfect, an additional ‘force’ needs to be added as a correction for these deficiencies in the orbit. This force is included as an increment of the velocity of the satellite in the center of the 24-h period. As the force is not a real factor and has just been introduced to make a correction, we call it pseudostochastic.

>>>>>*I understand that you are computing a-priori delays, but in lines 99 ff you compare them with actual delays and the difference or discrepancy is determined (or estimated). To me it is unclear from where you have the actual delays and whether you need an a-priori estimate at all if you have the actual delay. Or is the a priori for orbit prediction and the actual positions can be measured after the event?*

This question is directly related to ‘Abstract recommendations, issue number 2’. In this paragraph of the manuscript (lines 99 ff) the explanation of the impact of the troposphere is explained. As all the other factors in the orbit determination process are well modelled, the discrepancies over the slant delays are assumed to come from the troposphere measurement and thus we can estimate how large the discrepacies are. The tropospheric delay is divided in two parts, dry and wet. Whereas the dry part is well modelled, the wet part is not so easy to model as it changes rapidly, so the discrepancies of the slant delays can be attached to this second part, the wet delay. Even though the objective is to get rid of the a-posteriori calculations, we can actually use them now to see deficiencies in our model (OpenIFS) and our ray-tracer (LTT).

The actual tropospheric signal delay affecting a GNSS observation is not known during orbit determination. GNSS signals are affected by several perturbations (ionosphere, tropsphere, signal biases etc.). Each perturbation is modeled as well as possible. The remaining discrepancy between the measured total signal delay and the modeled signal delay can then be analyzed with respect to unmodeled effects. For example, it can tell us about un-/mismodeled tropospheric effects.

<u>Section 3.2 recommendation</u>

>>>>>*I wonder why the Deltas (to my understanding, the difference between the a-priori estimate and the actual delays) are compared for the two methods instead of the a-priori parameters directly. It should make no difference, of course, since the actual delay must be the same for both methods and must thus cancel out. But it is puzzling. I would expect instead two tests here: 1) the comparison of both methods using the a-priori parameters only and 2) the distribution of the deltas in the new version, to see whether the difference of the two methods is significant in comparison to the difference between model and measurement. While the first of these steps are given, the second is missing and should be given.*

We appreciate this question from the referee as the procedure is tricky to understand and we may have not explained it correctly. In this section the fitted parameters, that are the differences obtained from the measurements and the total delay, are compared for both systems, experimental and default (explained in previous replies). The discrepancies between measurements and real delays come from mathematical methods, and are assummed to come solely from the troposphere. Knowing these discrepancies and extending them to the fitted equation posted in Section 2.1, we can get an idea of where these discrepancies are being produced (the wet component or the gradients) and spot deficiencies in the model and or data.

Section 4 recommendation

>>>>>For the VMF3 method you use the operational weather forecast, and for the new method the openIFS. Your interest is not to demonstrate the differences arising from using one set of weather data that has millions of observations assimilated with another data set without data assimilation. Instead your interest is to compare the use of the ray-tracing method with the mapping method, if I undestand it correctly. But of course, the atmospheric states should be different in the two weather data sets, and the one using the actual forecast should be more realistic. So it is surprising that this does not lead to a significantly better performance of the mapping method. I would like to see your comments on this issue.

Although OpenIFS itself does not have the data assimilation capability, the observation data has already been assimilated beforehand during the creation of the initial condition files for OpenIFS. Similarly, in the creation of the Vienna mapping function coefficients, the observation data assimilation is done beforehand during the operational forecast production. VMF3 then uses the forecasts and the RADIATE ray tracer to produce their mapping function coefficients. However, we are trying to avoid some steps by directly using the ray tracer over OpenIFS data. The atmospheric states are somehow different in each forecast system, but in this manuscript the idea was coupling the weather model to the orbit determination solver as we expect to improve our results. In fact a new study is being carried out to analyze the improvements in both, the ray tracer and the orbit determination solver, with outstanding results that are leading to a new paper.