GNSS-RO Residual Ionospheric Error (RIE): A New Method and Assessment

Dong L. Wu et al., amt-2024-51, AMT-Review

General Comments

1. This paper presents a new residual ionospheric errors (RIE) in bending angles based on the GNSS RO excess phase measurement for each RO event. The excess phase gradient method, is self-sufficient and based on the vertical derivative of the RO excess phase profile. Specifically, a linear fit was applied to the excess phase data at heights above 65 km, then calculate the RIE using the vertical derivative of the linear fit excess phase profile, finally the derived RIE is extrapolated to the RO measurements at the lower heights by assuming that $\Delta\alpha$ has the same impact on the entire α profile.

If I understand correctly, in this method the RIEs in bending angle are considered as the slopes of the linear fit excess phase profiles (as the red lines shown in the sub-figure (c) of figures 1-4). Then use this slopes as the RIE values for the entire bending angle profiles.

According to the sections "*2.1 Atmospheric Bending Angle (α) and Excess Phase (ϕex)*" and "*2.2 RIE and Detection Method*" this mothed has 3 assumptions:

(1) "*For a rising/setting occultation, $V\perp$ is the ascending/descending rate of RO sampling with respect to ht, or the GNSS–LEO straight line height (SLH), which yields $V\perp \cong dht/dt$. The get equation (6).*" **Which uses the $V\perp$ of the LEO satellite as the tangent point velocity. In the GNSS-LEO RO, this assumption will induce errors.**

(2) "*In the upper atmosphere where there is little atmospheric bending (i.e., $\alpha c \approx 0$), a significant value that is not zero in $d\phi/dht$ (indicates the existence of αRIE, which can be both positive and negative.*" **Define the α calculated by equations (4) and (6) as bending angle RIEs. Actually, the equations (4) and (6) calculate the ionospheric bending angles above ~80 km, physically this variable is different from the bending angle RIEs defined in the previous studies.**

(3) The equation (6) is used for the linear fit excess phase profiles (as the red lines shown in the sub-figure (c) of figures 1-4). Then use this slopes as the RIE values for the entire bending angle profiles. **As discussed in the manuscript, the fit excess phase profiles depend on the local time, season, solar cycle, solar activity, and RO receiver type, RO top height. Maybe also geomagnetic field, the RO plane direction and so on. While this method only use equation (6) to calculate the ionospheric bending angles as bending angle RIE. This will induce problems in the application.**

2. Regarding the quality control (QC) on the excess phase data as shown in Table 1, how to determine the QC flags and thresholds? It does not according to the previous bending angle RIE definition and characteristics. To "Retain only realistic $\Delta\alpha$ values", set $|\Delta\alpha| < 2000$ μrad,

this threshold is too large. (As shown in your figures, most of the $|\Delta\alpha|$ are less than 2 μrad).

3. Regarding the $\Delta\alpha$ statistics with the latitude: Figures 5-9 show that most of the $\Delta\alpha$ values for day and night from Jan 2013 are positive, while Figure 19 shows most of the $\Delta\alpha$ values for day and night MetOp RO data from 2020 are negative. Why?
It also shows that this mothed is very sensitive with the RO top height. When the height increases the ionospheric bending angle will become larger and non-linear, this may be a reason.

4. Regarding the $\Delta\alpha$ statistics with the local time: As shown in figure 10, the $\Delta\alpha$ statistical behaviors are very strange (not reasonable). (1) from -60 to 60 latitude degree, at local time 8 and 20, where the ionosphere has large horizontal gradient since the morning and dusk change, and the magnitude of the RIEs are very large, however in figure 10 in this area the $\Delta\alpha$ is around zero. (2) the $\Delta\alpha$ magnitudes at night time are larger than the daytime. (3) generally, the night time RIEs are near zero, however in figure 10 they relatively larger than that in the daytime and with positive sign, which indicated that the positive $\Delta\alpha$ values in Figures 5-9 mainly come from the night time data.

5. As this is a new method and can be used for each individual RO profile, therefore it's better to show the profile-by-profile RIEs and their vertical statistical variables of biases and stdev, which is easier for readers to understand the results, also easier for comparing with previous studies.

Specific comments:
Please update the figures by providing proper units, using uniform color bars in one figure. It's better to combine the same layout figures like figures 1-4 into one figure, since there are so many figures in this paper.

There are lots of typos in the manuscript, please revise them, for examples:
L27: "RIF"
L141: "wehre"
L406: "(2),"
…