Author response to comments of Referee #1

Thank you very muchfor theconstructive comments and recommendations.Our responsesto the comments are as follows:

Referee 1
Scientific questions:
p. 765, line 3: Can you shortly describe the difference between Liu et al. 2013 and Liu et al. 2014 Maybe summarize core results of Liu et al. 2013?
Generally, our 2013 paper characterized&quantified the bending angle RIEs mainly by simulating individual RO events. We agree that a very brief summary at this point in the text may be useful and we therefore expanded the single sentence into the following, accounting now also for our associated recent 2014 paper:
"Recently Liu et al. (2013) performed an initial study on quantifying bending angle RIEs based on end-to-end simulations, complemented by Liu et al. (2014) who looked at the effects in subsequently retrieved temperature profiles. This work found, based on a limited set of individual occultation events, that the RIEs can significant affect bending angles and retrieved temperatures, in particular when ionospheric disturbances occur such as during periods of active space weather (bending angle RIEs can exceed 0.5 μrad, temperature errors 1 K in the upper stratosphere). These initial results provided the encouragement and formed the basis for the present much more advanced study on bending angle RIEs based on much larger ensembles."

Why are the bending angle RIE maximum values (-0.03 to -0.05 mu rad) so much smaller than values by Danzer et al. 2013 (from min to max: -0.05 to -0.4 mu rad), or Rocken and Schreiner (0.1 mu rad at 60 km, solar max; presentation at WCRPworkshop 2011)?
This is a relevant point of current discrepancy between the simulation-based results and the results from analyzing real RO data, which (we agree) is not yet fully understood and reconciled. Roughly speaking, the real-RO-data work such as Danzer et al. finds about twice as much bias (i.e., estimated systematic error) in the RIEs compared to our simulations.
The reason is likely twofold: On the one hand our simulations are based on a large-scale ionospheric model, which is somewhat realistic but still does not represent all effects of the real ionosphere (e.g., potential small systematic RIE effects from asymmetric small-scale irregularities, or from the geomagnetic higher-order term). This will tentatively lead to an underestimation of the "true" RIEs by the simulations. On the other hand the analyses of the real RO data may in part attribute also bias contributions from non-RIE observational errors into the empirically estimated RIEs (e.g., from residual clock correction, or multipath errors). This will tentatively lead to an overestimation of the "true" RIEs by the real-RO-data work.
In summary, reconciliation of this, and further improved quantification of RIEs, needs additional work in the future (which we plan to do as part of follow-on work to this study). In order to better reflect this current uncertainty in the RIE bias quantification we have improved the text by adding the following small paragraphs at two places as follows:

In section 2.1 Ionospheric correction and bending angle RIE: "We suggest that further refined RIE studies should revisit the role of the geomagnetic term again, however, since it remains unclear whether small residual biases (possibly within 0.01 to 0.1 μrad) may arise under high ionization levels in some geographic regions despite the general smallness of the term. Such a quantification will be one useful element for helping reconcile a current discrepancy in bending angle RIE bias estimations from simulations like here and RIE estimations from real RO data such as by Danzer et al. (2013); see further comments in Section 4 below."

In section 4 Summary and conclusions: "Compared to RIE studies using real RO data, such as the recent one by Danzer et al. (2013), the magnitude of the negative biases found from our simulations is roughly only half the one estimated from real data. One reason may be that our simulations are based on a large-scale ionospheric model, which is somewhat realistic but still does not represent all effects of the real ionosphere (e.g., possible contributions to RIE biases from asymmetric small-scale irregularities or from the geomagnetic higher-order refraction term are not included). On the other hand, the analyses of real data may in part attribute bias contributions from non-RIE observational errors into the RIE estimations (e.g., from residual clock correction or multipath errors). Either way, further work to reconcile current bias estimations from simulations and real-data analyses will be needed."

We have also amended one sentence in the abstract to point to these smaller bias magnitudes from the simulations compared to the real-data work.

Technical corrections:

p. 760, line 16: please introduce SD as standard deviation

Agreed; and we have corrected it, now avoiding this unexplained acronym.

As far as I have seen, Fig. 10 has not been explicitly discussed or referred to.

Fig. 10 has been introducedand discussed in p.776 line10 and p.777 line 19, to illustratethe relative RIEs in bending angles. Actually, the relative RIE values for different simulation conditions and different impact height levels have been shown in the tables, but haven't been discussed as detailed as the absolute ones, since they have similar variance principles. The main purpose of showing alsoFig. 10 is to show overall characteristics of the relative RIEs in bending angles and we think this is useful for some readers.