

## ***Interactive comment on “A modification to the ionospheric correction method used in GPS radio occultation” by S. B. Healy and I. D. Culverwell***

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Author's response to referee 2

The reviewer's original comments are given first, using their numbering. The response is denoted by "»>".

The changes in the manuscript are given in red. See supplement.

1) Title: Suggest to say "...to the standard ionospheric correction method used..."; the added word "standard" will help to indeed make most (expert) readers think of the dual frequency correction of bending angles according to Vorobev-Krasilnikova-1994, otherwise it remains a bit vague.

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»> We have added "standard" to the title, as suggested.

2) Introduction section: This section is well done, however, two aspects should receive better citation: 2a. the important ROTrends work on structural uncertainty was so far published by Ho et al. (2009), Ho et al. (2012), Steiner et al. (2013) - and since the AMT journal has no number-of-references restrictions clearly all three should be cited. It is therefore suggested to add also the Ho et al. (2009) and Ho et al. (2012) references in line 48. (Note, all additional references suggested here are listed at the bottom of this review, see below.)

»> The two Ho et al. papers have been cited, as suggested.

2b. lines 87 to 98 give a good brief intro on recent work on residual ionospheric errors (RIEs) but do not include any reference to the recent work by Liu et al. 2013 and 2015 based on simulations, which was somewhat complementary to the cited work of Danzer et al. (2013); I am just checking also this Liu et al. work, it could be added such like "Complementary to Danzer et al. (2013), Liu et al. (2013) and Liu et al. (2015) performed end-to-end simulations to investigate residual ionospheric errors remaining after the dual-frequency bending angle correction. They also found clear evidence for negative residual bending angle bias, although smaller in size than the observation based studies, likely since higher order ionospheric terms were not included in their simulation setup."

»> We have added a reference to the two Liu et al. papers as suggested, and added the following statement:

"Complementary to Danzer et al. (2013), Liu et al. (2013) and Liu et al. (2015) performed end-to-end simulations to investigate residual ionospheric errors remaining after the dual-frequency bending angle correction. They also found clear evidence for negative residual bending angle bias, although smaller in size than the observation based studies."

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2c. as a side note, also in line 176, in section 2, Liu et al. (2015) should complement the Danzer et al. (2013) reference cited there.

»> Reference to Liu et al. (2015) has been added.

3) Title of section 2:

Suggest better say "Ionospheric correction of GPS RO measurements" (and see also bullet 5 below)

»> The title of this section has been modified to "Modified ionospheric correction of GPS-RO bending angles".

4) Section 2, lines 196 to 198:

While the section 2 math derivation is mostly done in a concise yet still sufficiently understandable manner (with complementary details in appendix A), the formulation "...expand the denominator of the left hand side of equation 4 to estimate the second-order term for both the L1 and L2 frequencies." appears a bit too brief. Readers can figure out with some more thinking, but please try to have a bit more clarification what exactly is done here to Eq.(4) - by improving this sentence to be more informative and/or by adding one more sentence (readers should not be forced to look back to VK94).

»> This section has been rewritten so that it is easier to derive Eq. 5 directly from the information in the text. Eq.4 has been modified so that it is now an expression for the bending angle that is second order in the electron density. The relevant binomial expansions used to derive Eq.4 are noted. The text now states that the standard ionospheric correction using Eq.3 on Eq.4 will produce the residual error, Eq.5.

5) Section, 2, end of section: Here is - or rather is missed in fact - what I see as the only more severe structural weakness of the paper: it appears that the key formula, the new advanced correction formula Eq.(9), is only introduced in the discussion and conclusions section 4! This is awkward given that section 2 is the intro to the "iono-

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spheric correction" and section 3 is "Results", all done before the key formula enters stage close to the end. I would suggest to extend section 2 and have Eqs (8) and (9) introduced here; I perceive it would be quite easier in this order to clearly comprehend what is demonstrated then by sections 3 and 4. Maybe, even name section 2 "Advanced ionospheric correction of GPS RO bending angles", making clear that here the advanced methodology is coming one-stop, as the key is extending the standard Eq. (3) to the advanced Eq. (9) (then becoming Eq.(7) after re-order).

»> Equation 9 has been moved into section 2 (now equation 6), as suggested. We now explicitly state that this is the new model we are proposing, and the physical justification for the new term will be given in section 3. We have kept Eq.8 in section 3.

6) Sections 3 and 4: Apart from what I said under bullet 5, I like these sections which give a pretty good account of what to expect from the advanced correction (including caveats), plus pointing to the companion paper by Danzer et al. Therefore I suggest just to implement bullet 5 above - extracting Eqs (7) and (9) plus proper text context forward to section 2, becoming Eqs (6) and (7) there - but otherwise keep this flow.

»> We have removed Eq.9 from Section 4, and modified the text accordingly.

7) Appendix and general remark:

7a. the equation in line 434, Eq.(A7), contains the term "TEC" which is awkward since one never should use multi-character symbols for a mathematical variable. Please substitute "TEC" by a mathematical symbol (typical candidates are an uppercase greek  $\tau_e$ , or using Ne; cf. e.g. Syndergaard (2000) which you cite). Note, this "TEC" as well appears in other places such as Eq.(A8) and in surrounding texts.

»> We have replaced TEC with  $\tau_e$  throughout the paper.

7b. finally there are also a couple of small typos, punctuation weaknesses, etc, especially throughout the Appendix, but also at a few places throughout the paper. Please give the full paper a very careful final copy-editing before it is published.

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»> We will try to find the remaining typos.

Please also note the supplement to this comment:

<http://www.atmos-meas-tech-discuss.net/8/C1476/2015/amtd-8-C1476-2015-supplement.pdf>

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Interactive comment on Atmos. Meas. Tech. Discuss., 8, 1177, 2015.

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