

# ***Interactive comment on “Systematic residual ionospheric errors in radio occultation data and a potential way to minimize them” by J. Danzer et al.***

## **Anonymous Referee #2**

Received and published: 23 April 2013

### General comments

This paper discusses the radio occultation retrieval errors caused by residual ionospheric errors. The motivation is mainly possible climate applications of RO data. It is shown that the residual ionospheric errors are function of solar cycle, season and day/night. It is suggested that the errors can be corrected for, and the impact of such a correction on the dry temperature retrievals is discussed. The possibility of a time varying residual ionospheric error signal in RO climate records is an area of interest, and the paper will be a useful contribution when published. However, some revision is required before publication.

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Firstly, I believe there is a lot of material in the original Vorobev and Krasilnikova (1994) paper that could be related to the main results given here. They discussed the origin of the residual ionospheric errors in their approach, provided integral expression for it, and tested it in simulation. Their expression shows that the residual error is proportional to the electron density, and it would seem that the variation of with solar cycle etc. shown here follows naturally from that insight. I would also suggest that the magnitude of the residual errors (up to  $\sim -0.4$  microradians) could be estimated from a 1D calculation assuming a Chapman layer ionosphere, with appropriate time varying peak electron density. Are the more complex simulations presented here adding more insight?

It would also be useful to put the magnitude of the residual ionospheric errors in some context. The largest errors at solar maximum conditions is or order  $\sim 0.4$  microradians. Ringer and Healy (2008) (Monitoring twenty-first century climate using GPS radio occultation bending) angles, Geophys. Res. Lett., 35, L05708, doi:10.1029/2007GL032462) suggested that climate trends in bending angle space might be  $\sim 0.5$ -1.0 microradians per year near 20 km in the tropics, where the signal is large (see their table 1). Further, the bending angles values at 20 km are typically 1700 microradians. When viewed in this context, the residual ionospheric error does not appear particularly problematic. Please discuss this and the noise amplification in the dry retrieval, noted in the specific comments.

If these points and the specific comments below are dealt with, I believe this will be a useful contribution and should be published in AMT.

#### Specific comments

Page 1982, Line 23. "The second order term ... shows almost no influence to a changing solar activity." Some clarification is required here, because elsewhere in the paper ignoring higher order terms is seen as a limitation. EG, last line page 1983.

Is ignoring higher order terms acceptable or not? Please be clear throughout the paper.

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Page 1984, equation 5. I think it should be noted that Vorobev and Krasilnikova (1994) actually provide an integral expression for the residual error in their correction (their equation 22), and it depends on the electron density. The error arises because of the assumption that the refractive index is unity in the denominator of the bending angle integral. It will arise even in the simplest case of a spherically symmetric plasma, neglecting the earth's magnetic field.

It would be useful to see how the magnitude of their error estimate compares with the residual errors presented in this paper, given similar peak electron densities. I believe their error term gives  $\sim 0.3$  microradians near 60 km for solar-max, day time conditions.

It is also worth noting that Vorobev and Krasilnikova (1994) claim that their method is adequate whether the ionosphere is spherically symmetric or not (Their paper Page 608, paragraph starting "Note also ...")

Page 1986. Generating the simulated data. I'm not clear whether the magnetic field term in equation 2 is included when the data is simulated. Please clarify.

Page 1986 (end of). I think the three main points are saying the residual bias increase with the ionization state, but this point is also clear analytically from Vorobev and Krasilnikova (1994), equation 22. Please consider relating this study to their work here.

Page 1995. The dry temperature biases at 35 km are  $-3.9$  K for Jan 2002. The temperature at 35 km is  $\sim 240$  K, so the bias in percentage terms is  $-1.6$  %. It is interesting to note that the bending angle values at 35 km will be  $\sim 130$  microradians, and the largest residual bias is  $\sim 0.4$  microradians above 60 km. It appears that the fractional error in bending angle space is likely  $\sim 0.3$  % or lower. This appears to illustrate the noise amplification in the dry retrieval. Please discuss.

### Typos

Page 1981, Line 7. "Consequential" should be "Consequently".

Please consider changing "model world" throughout.

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Interactive comment on Atmos. Meas. Tech. Discuss., 6, 1979, 2013.

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