

We would like to thank referee #1 for the review of our paper and his/her appreciation of our work and the constructive and useful comments. We have answered all comments below. Changes in the manuscript will be implemented in the revision. The referee's comments are included in *italic*.

This work is a careful study of the impact of large-scale, solar cycle and diurnally dependent ionospheric residual on radio occultation atmospheric profiles. The study combines actual data and simulation. A correction factor is derived to correct for the ionospheric residual. This is a high quality study that is a significant contribution to the literature.

#1: Thank you for your appreciation of our work.

Additional information and analysis should be provided prior to final publication. This is a plot of the MSIS bending angle, since the correction is derived relative to that.

#2: Since our study focuses on relative **differences** of the day to night time bending angle bias, the absolute difference of the RO bending angle to the reference climatology cancels out. We showed that the bending angle bias difference shows the same characteristic in the WEGC and the UCAR data, even though different reference climatologies are used (MSIS and NCAR climatology, respectively). If the reference climatology had diurnal variations, such as e.g., ECMWF analysis fields, or would depend on the solar activity, the absolute difference of the bending angle to the reference climatology would play a further role in our study. However, we modeled the MSIS climatology with fixed local time and fixed F10.7 index, so there are no diurnal variations and no solar variations. Since the MSIS climatology itself is therefore not of importance in this context we did not add such a plot in the paper, but we see that we should have described the MSIS climatology more thoroughly and we will emphasize this in the revised paper.

p. 3: refractivity is defined, preferable to "obtained".

#3: We followed your suggestion.

p. 4: the statement that the second order term is weakly dependent on solar activity is hard to justify since it depends on Ne. Either provide a reference or clarification, or consider revising the sentence.

#4: Thank you for this comment. According to Melbourne et al., 1994, there is a splitting term, second-order term, third-order term and a bending term, which act as residual error sources after applying a linear combination which removes the $1/f^2$ ionospheric terms. Furthermore the authors write that for a year near solar maximum, the day time second-order term results in a propagation delay residual between 0 to 20mm and for the night time between 0 to 3 mm, while the third-order term is in the region of sub-millimeter and can be ignored. However, since we did only discuss the second-order term in our manuscript, we decided to remove the sentence completely on page 4.

p. 6: What does this sentence refer to? Smallest compared to what? Smallest in a fractional sense compared to refractivity of temperature? "Their studies show that the effect of the residual error is smallest in the bending angle data."

#5: Thank you for bringing to our attention that there is a need for clarification. We will write: Their studies show that the effect of the residual error is smallest in bending angle data and that it increases through the retrieval chain. At 60 km altitude they found day time bending angle errors of about $-0.02 \mu\text{rad}$ in 2007 (solar minimum) and of about $-0.1 \mu\text{rad}$ in 2002 (solar maximum). For the bending angle the residual ionospheric error at 20 km altitude is about 0.003 %, increasing to about 0.015% at 30 km altitude. While it amounts to 0.010 % (20 km) and 0.045 % (30 km) in refractivity, it is up to 0.045 % (0.1 K) at 20 km altitude and 0.2 % (0.5 K) at 30 km altitude in temperature, during day time (Schreiner et al., 2011).

p. 7: Are the results of the present work consistent with Foelsche et al. 2008? This question should at least be considered. That work accounts for ionosphere but does not separate the ionosphere contribution from others. Is the magnitude of the residual in this work consistent with the prior simulation (e.g. 0.2 K combined observation and sampling errors)? This can be discussed here or somewhere else in the paper.

#6: The results of Foelsche et al. 2008 indicate a mean observational error (dominated by the bias) and a sampling error of 0.2K each (not combined), averaged over many profiles, for low solar activity in the northern summer 1997. In Fig. 8 we studied only day time data (which show a higher ionospheric influence than when averaging over the diurnal cycle). Taking into account the different approaches, we regard the results for the profiles simulated with low solar activity (in Fig. 8) as consistent with the results by Foelsche et al. 2008.

p. 10: It would be very helpful to plot the MSIS bending angle separately to help interpret these results (Fig. 3). Plotting the MSIS results over the cycle would provide great insight into these results and help the paper overall.

#7: Fig. 3 shows the bending angle bias relative to the reference climatology used at WEGC and UCAR (MSIS and NCAR climatology, respectively). Therefore the absolute MSIS bending angle does not provide additional insight. We again want to emphasize that our MSIS model does not contain diurnal variations and is simulated with constant solar activity. But we see there is a need for clarification and we will modify the manuscript accordingly.

p. 11: Bullet 3. I don't see this summer maximum except for the northern latitudes. Is this also true in the Southern latitudes?

#8: We found the seasonal cycle for northern and southern mid latitudes (20° to 60°) for WEGC data. Fig. 3 clearly shows largest bending angle biases in the southern hemisphere in December and January (orange and dark blue line) and smallest bending angle biases in June and July. Seasonal characteristics are best seen for COSMIC data, beginning in 2006.

p. 13, paragraph 2: It is interesting to know how the ECMWF result compares to MSIS, another reason to plot the MSIS contribution separately.

#9: We are not completely sure to what the referee is referring to in his/her question. However, if the

idea is to study the bending angle bias via the difference of the bending angle to ECMWF fields, we provide a similar answer as in #2. ECMWF fields have no fixed local time and show solar variations. Hence they are not of interest for our application. The reference climatology cancels out in the study of the day to night time bending angle bias difference, where our focus lies. In fact, in our study we could alternatively use no reference climatology at all, and simply sum up the bending angle in the altitude range of interest. The reference climatology acts simply as a shift of the summed up bending angle profile to a value around zero.

p. 14: Why is the correction factor based on simulation and not the actual data (possibly smoothed)? Please explain this choice.

#10: The model simulation served as a test bed to determine if the idea of a climatological ionospheric correction works. For the satellite data the goal is to use the actual bending angle bias difference as a correction factor. However before applying this methodology to real observational data further studies have to be applied, such as a detailed study of the local time dependence of the ionospheric residual and its geographic dependence.

p. 14: Please justify why it is appropriate to shift the entire profile by a single number. Can this be justified via simulation or another means? A recent publication by Mannucci et al. (Atmos Meas Tech, 2011) suggests that orbital altitude can affect ionospheric residual error. Would this be a factor also?

#11: We thank the reviewer for his or her excellent comment regarding the fact that orbital altitude of the GPS receiver plays a role for the ionospheric residual, as published by Mannucci et al., 2011. We will add a discussion about it in the outlook.

For our simulations we used a receiving satellite in an orbital height of 800 km. As Manucci et al. show, spacecrafts at higher altitudes show less residual ionospheric errors than spacecrafts at lower altitudes, comparing COSMIC orbital heights (~780km) to CHAMP (~400km). We will not repeat their analysis but point out, that our simulated receiver height is comparable with the COSMIC height, which shows less residual ionospheric errors, due to partial cancellations of the ionospheric bending, than e.g. the CHAMP satellite.

As mentioned in our discussion, we want to wait for further satellite data of the currently evolving solar maximum for a first correction of observational satellite data. In a first step the correction will be based on COSMIC RO data only, and no mixing of satellite data will take place for the correction factor. However, when we include different satellites we will regard their orbital altitudes as a further factor in our correction.

Regarding the point about shifting the entire profile by a single number we want to emphasize that the goal is to apply the correction factor to an ensemble of many profiles, and certainly not to correct single profiles, where the actual measurement geometry in connection with the Ne distribution is of much higher importance. For our climatological approach we expect that the average influence of the day to night time change in the ionosphere is the small systematic shift in the bending angle as determined. The simulation results in Fig. 8 indicate that this simple approach actually reduces the systematic residual error to a high degree.

P. 22: A color bar would aid readability.

#12: We agree with the reviewer, but Fig.2 should just illustrate the difference between a day and night

time electron density distribution as a function of latitude and height. We do not want to focus on details. We are confident that the information of increasing electron density during the day compared to the night is clearly visible without a colorbar, since the labeled contour lines provide the quantitative information.