This is the reply to the report from Referee #1.

Our replies are written in *italics* after the referee's comments.

We would like to thank the referee for taking the time to review our paper.

I am referring in my review to the 2 column version I got of the manuscript, not the usually shown version on the website! In particular, the page/line numbers are different.

General Comments:

- the manuscript is well written, presents interesting results of the GRAS SAF processing of GRAS data to refractivity. I have a few minor comments for improvement, clarification.

Specific Comments:

- Page 1, Line 31: "Using satellite observations ... applications." Please give a reference for these sentences, maybe the latest Anthes one?

We will include the suggested reference in the updated manuscript.

- Page 1, Line 49: "One of the key advantages ... (Dee, 2008))." Suggest to move this up to where NWP is discussed, after the Cardinali reference. Currently the text jumps from NWP to climate and then back to NWP. Although I agree this is a grey area, where NWP "meets" climate.

We will follow the suggestion by the referee.

- Page 2, Line 144: For a reader unfamiliar with GPS signals, the L1, L2, LC comes a bit out of the blue. Suggest to introduce them in a sentence.

We will add a sentence with the definition of these quantities.

- Page 2, Line 149: "For the processing in the upper ..." Suggest to include refractivity here to make the distinction between bending angle and ref.

We will reformulate the sentence to read:

"For the processing to the refractivity in the upper ..."

- Page 3, Line 164: "However the fit is not performed..." I am unclear to what this means. What happens in this case, is the profile disregarded?

Or the fit just based on other altitude intervals? Why does it deviate this strongly even after the 2 parameter fit?

First, the overall number of samples that fall into the pre-specified fitting height interval is checked. If the number is less than 100 ($\sim 10\,km$), then the profile is discarded. The 30% deviation defines then the upper boundary of the actual fitting interval. If the number of samples in this interval is less than 50 ($\sim 5\,km$), then the profile is also discarded. We will make this clear in the text. More than 30% deviation can be explained by ionospheric residual noise in the LC bending angle and stronger noise in the L2 channel.

Figure 1 below shows two examples, one profile which was automatically discarded because of such variations between 40 and 60 km (20101203_000128), and one that looks more like the norm (though this case still with large variations, but mostly above 60 km), which was processed (20101203_000110). We hope to improve our algorithm to be able to process more profiles reliably, but currently some are discarded because of such variations. This happens in about 6% of the cases, and this will be mentioned in the text.

- Page 3, Line 179: "Linear interpolation to a fixed..." Why is this linear, the bending angles are exp?

It may seem to be advantageous to linearly interpolate $\ln \epsilon (p)$. *But here we are dealing with L1, L2 and LC bending angles before the statistical optimization. These profiles may take negative values at some points, due to the ionosphere.*

- Page 3, Line 190: Could you actually write down the equation for how the fit is performed, e.g. epsilon_model beta + alpha? I am confused on the ln alpha, multiplication, all in log-space.

Given the background bending angle profile $\epsilon_M (p_i)$ *and the LC bending angle profile* $\epsilon_{LC} (p_i)$ *at the impact parameter grid* p_i, *we take their logarithms* $\ln \epsilon_M (p_i)$ *and* $\ln \epsilon_{LC} (p_i)$ *and compute the linear regression coefficients* $\ln \alpha$ *and* β *in the regression height interval such that the quantity* $\sum \left(\ln \alpha + \beta \ln \epsilon_M (p_i) - \ln \epsilon_{LC} (p_i) \right)^2$ *is minimized, where the summation is spread over the regression height interval. Because* $\epsilon_{LC} (p_i)$ *does not deviate from* $\epsilon_M (p_i)$ *by more than 30% here, it must be positive.*

- Page 3, Line 203: "Calculation of the relative mean deviation ..." Is there actually a bias left in this, and if yes, how is it handled?

We just compute the square relative deviation and average it over the

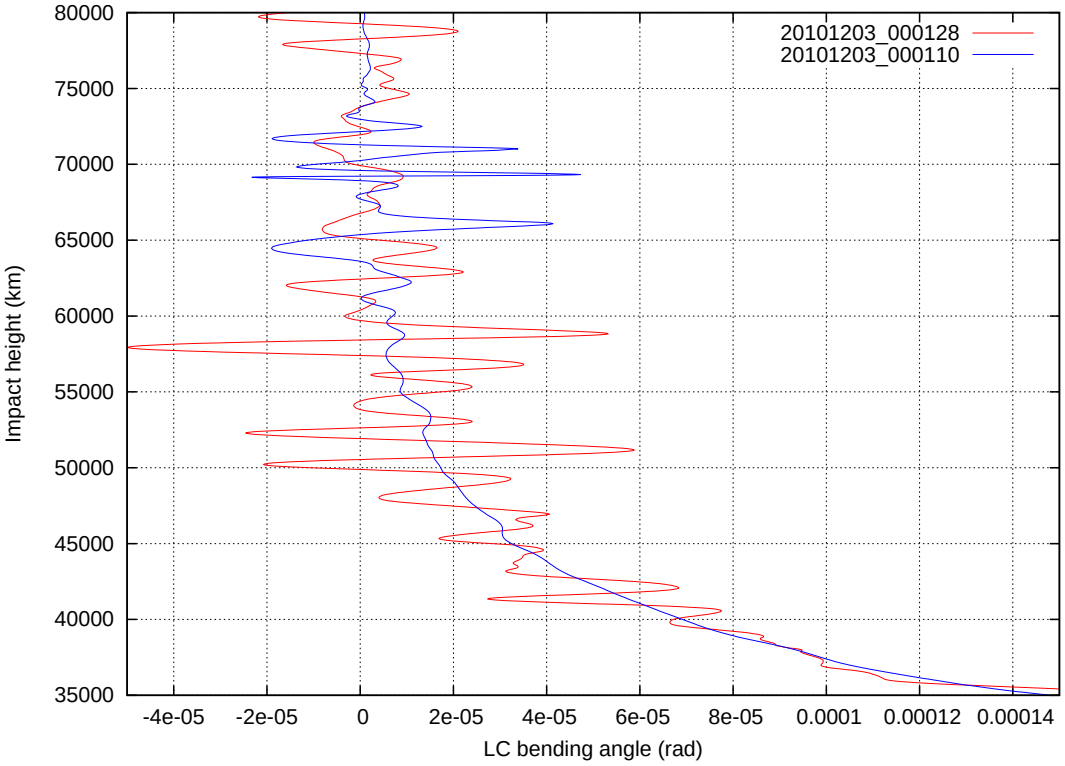

Figure 1: Two examples of LC bending angle between 35 and 80 km.

height interval specified. The bias, if any, will be also included into this variance estimate. The reason is that this estimate is performed dynamically for each event, and the amount of data is insufficient for a reliable bias estimate, which should also depend on the altitude.

- Page 4, Line 215: How many occultations are removed in this quality control? Would also be nice to give them by the criteria.

The number of occultations that are flagged as 'bad' will be indicated in the text to read:

"The refractivity profiles are quality-controlled and flagged as 'bad' (and does not appear in the validation results shown in Section 4 if one of the following is true: i) Refractivity profile does not reach below 20 km (4 - 5% of profiles); ii) One or more points in the refractivity profile below 35 km dif-

fer by more than 10% from the corresponding profile obtained from ECMWF fields (1 - 1.5% of profiles); iii) Refractivity profile reach below the ECMWF model surface (0.8 - 1.0% of profiles); iv) Refractivity is negative (0.05 - 0.1% of profiles). These criteria flag about 7% of all profiles (percentages for each criteria are shown in parentheses).”

- Page 4, Line 289: ”... a bias may be introduced ...” Isn’t it actually a good sign that a bias persists? If all biases are removed with this approach, any climate monitoring up there would be useless. Suggest to rephrase this.

What is meant here is that additional biases could be introduced, and this is what the approach seeks to avoid. Biases already in the data relative to the climatology are allowed with this approach since we are trying to find a ’nudged’ MSIS model profile that fits the data (using global search and scaling/offset as described). To clarify, we will modify the text slightly to read:

“Although the approach implemented for statistical optimization at the GRAS SAF seeks to avoid introducing biases (by finding a climatological profile fitting the data between 40 and 60 km), a bias may nevertheless be introduced at this level of processing, possibly because of limitations in the approach and limitations in the MSIS90 climatology.”

- Figure 2, left plot: Why are there actually no observations at 9:30/21:30 over the equator? I know why, but might be good to mention this briefly.

We will update the figure caption (of the right plot) and corresponding text to read as follows:

Latitude, longitude, and local-time distribution of occultations observed by the GRAS instrument onboard Metop-A during December 2010.

The overall distribution is largely governed by the orbit of the Metop-A satellite whereas the detailed structure also depends on the GRAS instrument observational characteristics and on the transmitting GPS satellite orbits. The gaps around local times 9:30 and 21:30 - which is when the Sun-synchronous Metop-A satellite passes the equator - are due to the fact that the GRAS instrument observes the horizon at a distance of around 3000 kilometers. The GPS satellites are predominantly setting and rising in certain azimuths as viewed from Metop-A, and due to the instrument characteristics observations are done most efficiently in the forward and backward directions. The equatorial region cannot be observed from directly above the equator.