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Interactive comment

Interactive comment on "Middle atmospheric ozone, nitrogen dioxide, and nitrogen trioxide in 2002–2011: SD-WACCM simulations compared to GOMOS observations" *by* Erkki Kyrölä et al.

Erkki Kyrölä et al.

erkki.kyrola@fmi.fi

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We want to thank Reviewer 1 for his/her useful review of the paper. The answers to individual comments are shown below.

In addition to changes demanded by the reviewers we have updated all figures in order to increase their information content. In Figs. 5-7, 11-12, we have shown only 2 altitudes (earlier 3) for clarity. We have removed Fig. 14 because its content overlaps with Fig. 13. For Fig. 13 we have added also the WACCM-GOMOS difference plot. Figure 20 is redrawn. Instead showing the NO3/O3 ratio from theory, WACCM and GOMOS, we show the relative differences of this ratio from theory and WACCM to the ratio from

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GOMOS. For readers' delight we have added one new figure (Fig. 21 of the paper, Fig. 1 in this response) that shows the vertical column differences between WACCM and GOMOS for our three gases.

We have changed our interpretation of the WACCM-GOMOS difference in the Arctic in the lower stratosphere. We assumed earlier that it could be a consequence of the NO2 increases from protons and downdrafts. Now the more plausible reason is that GOMOS sees larger ozone destruction during Arctic winters than what WACCM simulates. This can seen in new Figs. 6-7.

Specific answers to comments:

1. In equation (2), page 7, the scaling factor is computed using GOMOS data fkG(z). It may cause some problems when GOMOS values are small compared to their uncertainty with the problem of negative values within the error bars. Why not to use WACCM data fkW(z) instead?

Answer: We have experimented with both scaling factors. After a vote GOMOS was selected. In our analysis negative density values from individual occultations are included, but negative average values (from averaging over time and geolocation) are removed from the comparisons (both GOMOS and corresponding WACCM profiles). It does not make sense to include unphysical values for the comparison.

2. Page 7, line 13, from where is coming the factor 3x1.4826 for the elimination of outliers. Does it correspond to 3 sigma in the median statistic? This is not the same factor that the one given in equation (1) in Kyrölä et al. (2010a).

Answer: In the reference mentioned the quantity was the median-world 's analogue to the error of the mean. Now we are using median world's analogue to the 3*sigma-limit. For the sigma (standard deviation) a median absolute deviation, MAD, is used: MAD=median(|x-median(x)]). In order that MAD is a consistent estimator for the normal distribution, the MAD value needs to be multiplied by a factor 1.4826. For more detail

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can be found from https://en.wikipedia.org/wiki/Median_absolute_deviation.

3. Page 7, lines 22-27, the discussion on regions defined with t_value > 2 is not clear. Please try to reformulate it.

Answer: This part is reorganised and rewritten.

4. Page 13, figure 8, do you have any explanation for the larger inter-annual NO_2 variability in WACCM than in GOMOS? In general observations exhibit a larger variability than model outputs.

Answer: It is important to notice that these Sirius occultations take place only during August-September, most of the cases are from September. It is also important to note that the latitudinal region is partly inside the strong Antarctic vortex. In Fig.2 of this response we have shown three altitudes in this latitude region from all available stars (solid curves, GOMOS=blue, WACC=red) and the Sirius occultations by crosses (a gentle smoothing in time for all curves). Data cover from August 2002 to the end of September 2004. Around 2 hPa and above WACCM is usually slightly larger than GOMOS and this can be seen in Fig. 8 of the paper for 2002 and 2004. In August 2003 a remnant from an increased NO_2-event during the summer 2003 is seen by a high peak in the two uppermost GOMOS curves and it temporarily lifts GOMOS above WACCM. When it returns back to the level below WACCM it crosses the WACCM level and this happens just at the time when Sirius measurements take place. Therefore WACCM and GOMOS agree during 2003 when Sirius data is used. We have modified the text after Fig. 8 as follows: The yearly variation in profiles and differences is large. Notice that the reason for this variation is the location of Sirius occultations near the Antarctic vortex where sporadic NO_2 enhancements are not totally contained in the polar latitudes.

5. Page 20, line 14, there is an extended discussion in Marchand et al. (2007) on the relation between GOMOS NO_3 concentration and temperature with the same conclusion that NO_3 is a good proxy for upper stratospheric temperature. Please cite this

paper: Reference: Marchand et al., 2007, Temperature retrieval from stratospheric O3 and NO3 GOMOS data, Geophys. Res. Lett., 34, L24809.

Answer: We apologise for this omission. Two articles by Marchand et al. (2004, 2007) have been added to references. We have also added a reference to Hakkarainen's thesis where the NO3-temperature relation was used in the assimilation.

6. Page 21, figure 20, it would be better to plot the NO3-temperature diagram with NO3 in log-scale in order to show the exponential relation.

Answer: A very good suggestion! The plots are now much more interesting. Because of the re-plotting, we discovered a bug in our software that caused corruption in the temperature data. All figures including temperature data are now corrected. There was also error in the caption. Hopefully everything is now correct in Fig. 20!

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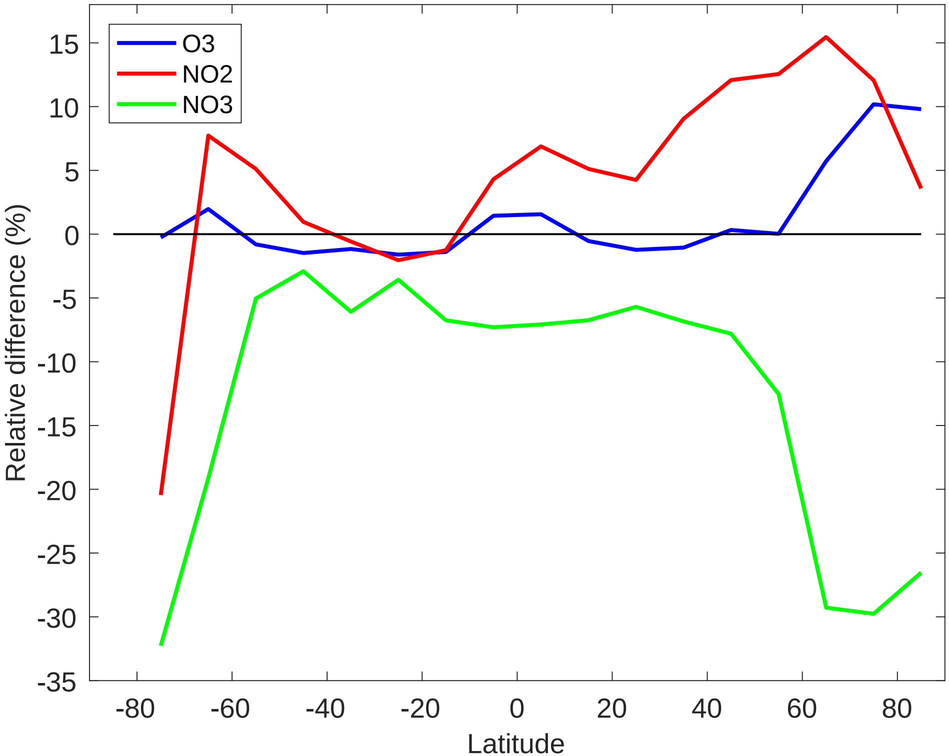

Fig. 1. The relative difference of WACCM and GOMOS vertical columns of ozone, NO2 and NO3.

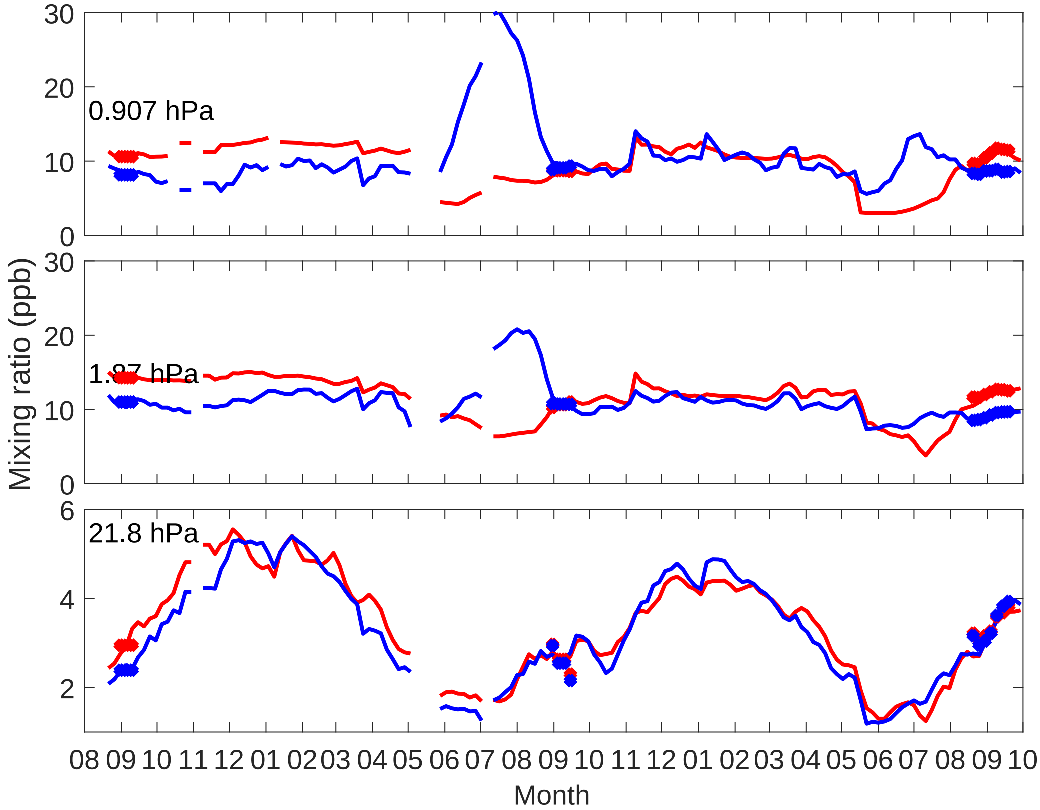

Fig. 2. Response to comment 4 of the reviewer 1.