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Interactive Comment

Interactive comment on "Enhancement of N_2O during the October–November 2003 solar proton events" *by* B. Funke et al.

B. Funke et al.

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We thank Reviewer #1 for his/her very helpful comments and suggestions. The "Reviewer Comments" are noted first and then we give our "Reply:" to the comment. We are submitting a revised manuscript that includes all the actions noted below.

The figures were also quite clear, although the font size in the contour labelling in Figs 4-6 was somewhat small at places.

Reply: The reviewer is right. We were expecting most figures to appear as "two-columns" figures, which would make them larger and more readable. Action: We have re-made all figures enlarging all labels, fonts, and removing unnecessary information of the title head. We will also ask the editor to increase the size of the figures in the revised version to make them more readable.

Page 5, second full paragraph. Why is the NO data used only for one day but NO_2 for the full study period? Is this due to NO data availability?

Reply: Yes, it is due to lack of NO data availability. NO data is only processed for 1 November 2003. Note however that, as suggested by other reviewer, Figure 7 does not add any further information than already given by the previous figures and we have removed it. Thus, NO data is not used in the revised version.

Page 7 and Figure 4. The authors write that there seems to be and indication of aurorally enhanced N_2O in the October 26 MIPAS observations. This is not the focus of this paper but still I wish to point out that this enhancements appears to extend to very high latitudes, far beyond the the location of the auroral oval where auroral particles would cause in situ ionization. Also the altitude (60 km) is quite low for auroral energy particles.

Reply: The referee is right. Auroral electron precipitation would not lead to atomic nitrogen production (needed to form N_2O) at altitudes around 50-70 km but in the lower thermosphere. Also, we expect that polar winter descent of atomic nitrogen from the thermosphere is negligible due to the short photochemical lifetime of N. Thus, the required N seems to be more likely produced in situ by energetic electron precipitations (EEP). These EEPs would also supply NO_2. Alternatively, NO_2 could also be produced at higher altitudes (in the upper mesosphere/lower thermosphere) some weeks before by auroral electrons and then transported downwards. We have changed the manuscript accordingly and make a reference to the manuscript by Funke et al. (2008) that describes the mesospheric N_2O enhancements observed by MIPAS during several polar winters.

B. Funke, M. López-Puertas, M. García-Comas, G. P. Stiller, T. von Clarmann, and N. Glatthor, Mesospheric N_2O enhancements as observed by MIPAS on Envisat during the polar winters in 2002-2004, ACPD, accepted, 2008.

Page 8, first para In addition to atomic nitrogen production EEP should surely also lead to NO_2 production. Is the descent from the MLT needed to have enough NO_2 for the N_2O production or might EEP production on it´s own be enough?

Reply: The reviewer is right, EEP also contribute to local productions of NO_2. However, for this particular case, most of the NO_2 observed after 16 November above 60 km was attributed to a strong descent of mesospheric air, very rich in NO_x, produced by EEP in the mesosphere (see López-Puertas et al., 2006). Thus, answering the reviewer question, yes, the descent from the MLT is needed to explain the 3 ppb enhancement in N_2O at 60 km observed by MIPAS in that period. No action is taken since this explanation is already given in first full paragraph (line 5 and ff.) of page 4679 (page 11 for the reviewer), including the reference above-mentioned.

Ionization by particle precipitation would also produce the exited state of nitrogen. Does the exited state of nitrogen (N2D) play any role in the proposed N_2O production?

Reply: Based on previous research we assume that N(2D) goes primarily into the formation of NO by reacting with O_2 and does not destroy NO_y significantly (Rusch et al., 1981; Jackman et al., 2005). Thus, in the CMAM chemistry scheme N(2D) is not explicitly included as production of N_2O but its production from ionization is treated as a source of NO.

Page 10, last para The NO_x production by EEP is not included in the CMAM modelling presented in this paper. However, Semeniuk at al. have published CMAM modelling results for the Halloween events showing that for sufficient enough NO_y production for these events the enhanced thermospheric ionization source is required. Why not include this source also in the modelling done for this paper?

Reply: We did not include an auroral ionization source since these simulations were done for SPEs with the region of interest in the lower mesosphere. An auroral NO_x source could have been included but we cannot capture the weather of 2003 so the descending NO_x anomaly at the end of November would likely not have been reproduced.

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Page 11, last para of section 3 "The ratio of both is about a factor of 5-6, very similar to the NH/SH ratio for N2O of (6-7)/(1-1.2)." I am not sure what this should mean. Should it be "The NH/SH NO2 ratio is about 5-6, very similar to the NH/SH ratio for N2O of (6-7)/(1-1.2)."

Reply: The reviewer s interpretation is right. The manuscript has been changed accordingly.

Figure 1 and 2 Some of the diamonds show rather large values but similar values do not show in the smoothed field. Is this simply due to the 700 km smoothing?

Reply: Yes, that is the reason.

Figure 6 Are the MIPAS averaging kernels used to produce the CMAM time series? I assumed so but the text does not mention it.

Reply: The averaging kernel was not applied originally. We have applied it now. The changes are negligible below around 60 km and slightly increase (˜10%) the modelled values (a priori effect) from 60 to 70 km.

Figure 7. There is a clear peak in the MIPAS NO2 at around 53 km above which the values decrease but the model values do not show this peak. The authors write that there is model overestimation at altitudes 55-65 km (i.e. the observed low values are close to the reality), is this verified by some other means?

Reply: We have checked GOMOS observations (see, e.g., Top panel in Fig. 2 of Seppala et al., 2007) and they also show a small decrease in the altitude range of 55-65 km in the very first days after the SPEs.

Seppala, A., P. T. Verronen, M. A. Clilverd, C. E. Randall, J. Tamminen, V. Sofieva, L. Backman, and E. Kyrola (2007), Arctic and Antarctic polar winter NOx and energetic particle precipitation in 2002-2006, Geophys. Res. Lett., 34, L12810, doi:10.1029/2007GL029733.

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Typos: All typos have been corrected. Thank you very much.

Interactive comment on Atmos. Chem. Phys. Discuss., 8, 4669, 2008.

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