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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Energetic particle precipitation in ECHAM5/MESSy – Part 2: Solar Proton Events" *by* A. J. G. Baumgaertner et al.

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We would like to thank the referee for his valuable comments, which we address below.

The first main comment of the referee concerns the expected temperature decrease from the SPE. The manuscript contains a discussion of the expected temperature effect using model simulations. A separate set of simulations was performed for this purpose. The results indicate a cooling in the SH lower mesosphere of up to 3 K. This is of the same order of the natural variability on this timescale (caused e.g. by gravity waves, tides, or planetary waves) and can therefore unfortunately not be detected from the MIPAS observations. For further discussion see the replies to the specific comments below.

The second main comment concerns the total ozone column and will be discussed in detail below in the discussion of the corresponding detailed comment.

Replies to specific comments:

Page 4503, line 22 Clarified as suggested: "Northern Hemisphere polar total ozone reduction greater than 0.5% was predicted to last for 8 months."

Page 4505, line 11 We have clarified this as suggested. "SPE-induced cooling up to 2.6 K in the lower mesosphere and heating up to 2 K at 90 km were found. Background wind velocities changed up to 25%." The temperature effects are very likely to be largest directly after the SPE, which was most intense on 29 October; therefore, the Figures shown by Jackman et al. (2007) for 30 October are very likely to show the maximum response. This is confirmed by our Fig. 18.

Page 4505, line 15 corrected as suggested.

Page 4505, line 19 spelled out in the revised manuscript.

Page 4506, line 13 "Range in meters". As stated in the manuscript, we follow the method presented in the Vitt and Jackman (1996), their Appendix describes the procedure in detail and therefore we do not see the necessity to repeat this description, but we will cite Vitt and Jackman (1996) again where referring to "range in meters". "Column mode": We added the following paragraph to the section describing the submodel: "A column version of the submodel was also implemented which uses the same submodel core layer files (for a discussion of the MESSy structure see Jöckel et al. (2005)) but a separate interface and a simple time control. It is not coupled to any other MESSy submodels."

Page 4507, equation (2) As suggested we added the following sentence: "Note that f (h) cannot become negative, therefore Eq. 2 cannot be used for altitudes greater than approx. 87.2 km."

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Page 4508, section 3 The revised manuscript will include a table of measurement errors as well as vertical resolution (see replies to Referee 1).

Page 4510, first paragraph, NO_2 comparison This was also pointed out by Referee 1 and we have mentioned the fact that both day and night observations were used in the appropriate locations of the revised manuscript.

Page 4510, line 15 Adapted as suggested.

Page 4511, line 2 Corrected as suggested.

Page 4511, equations (R2) and (R3) We added “chosen such that the model better reproduces the observations”.

Page 4513, line 22/23 we removed “and above 65 km,”

Page 4514, lines 15-18 The enhancements around 6–7 November and 12–13 November, which give the impression that MIPAS measured a slower reduction of NO_2 than found by the model during the first two weeks after the SPE are based on only very few measurements, therefore we added the following statement: “Also note that on 6 and 7 November only 5 profiles were obtained by MIPAS in this area, with an ensemble mean precision of 1.5 ppbv and standard error of 21 ppbv at 50 km. Similarly, on 12 and 13 November only 6 profiles were obtained, with an ensemble mean precision of 1.0 ppbv and a standard error of 11 ppbv. Therefore the enhancements during both these periods are probably not representative for the full polar cap, given that ïňĆux measurements did not show any anomalies during these times.” Later in November the situation gets more difficult because there is a potential contribution by the NO_x produced by geomagnetic activity. However, we cannot exclude that the model has deficiencies concerning the NO_y partitioning and we added the statement: “Note, however that especially in the second half of November in the upper stratosphere the model appears to underestimate NO_2. Geomagnetic-activity related NO_x enhancements are at this

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time mainly found in the mesosphere, indicating that there might be problems concerning the model NO_y partitioning, see also Sec. 4.3."

Page 4514, lines 23-25 we added "as expected."

Page 4515, lines 19-20 Both simulations were nudged toward observed meteorology (see also replies to referee 1, the nudging technique and relaxation times are now described in more detail). This means that short-term deviations (below and at the e-folding times of 6 to 48 hours) of all model variables are possible, but the simulations will not drift apart. This explains the difference of 2-3 DU around 22/23 October; the fact that this difference is eliminated after less than three days is therefore not by chance but a consequence of the nudging. Therefore, the authors are confident that the deviations after the SPE are a result of the altered chemistry. To clarify this, we added to the relevant paragraph the following statement: "Deviations such as around 22 October are eliminated by the nudging on the relaxation e-folding timescales."

Page 4517, lines 26-28 "Looking at the change from October 29 to October 30, or 30 to 31 in Fig. 18, the difference is significantly smaller than 2.6 K". Fig. 18 depicts the changes relative to the S-NOSPE simulation, therefore from this figure the change should not be considered from October 29 to October 30 but absolute. This change reaches its maximum of 2.6 K on 30 October at 60 km. If the region is constrained to the south pole, the maximum temperature change is 3.0 K. It is not entirely clear how Jackman et al. (2007) computed the temperature changes presented in their Figure 2. However, it is very likely that they refer either to the undisturbed period before the SPE or to a reference simulation. Therefore, the cooling of 2.6 K at the south pole on 30 October can be directly compared to the south pole cooling found from the difference of the two EMAC simulations with and without the SPE, which amounts to 3.0 K. Therefore, the magnitude of the cooling is comparable, although there is a five kilometer altitude offset between the areas of the largest response. We have clarified this and modified the paragraph as follows: “The associated temperature changes in the area 70° S–90° S relative to the simulation without the SPE are depicted in Fig. 18a. An average cooling of up to 2.6 K in the lower mesosphere is evident during the first week after the SPE. The cooling is strongest at 60 km. Jackman et al. (2007) found a cooling up to 2.6 K at 65 km altitude and 90° S from their model simulations. If the EMAC analysis is restricted to 90° S as in Jackman et al. (2007), the maximum cooling amounts to 3.0 K at 60 km. Therefore, the magntitude of the cooling is comparable, although there is a five kilometer altitude offset between the areas of the largest response.”

Page 4517, same sentence The temperature effect from the SPE as seen in Fig. 18 is only evident because we can compare two simulations starting with identical dynamics. If the temperature is shown with respect to a time before the SPE, the effect is not visible anymore because of the dominating natural variability which is of the same or larger magnitude. This can be seen from Fig. 1 attached to this reply, which shows the temperature change with respect to 26 October from the model simulation.

Page 4517, section 4.4 We have included the studies listed by the referee.

Page 4519, lines 15 and Page 4502, line 19 As mentioned above, the applied nudging prevents the simulations from drifting apart, therefore the stated values are very unlikely to be overestimated.

Page 4524 The relevant paragraph was amended by the following statement: “The differences between the employed baseline versions are small and generally simply cover different days of the concerned period.“

Page 4529: Fig. 5 We have added the labels “MIPAS” and “EMAC” to the relevant figures as suggested.

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Page 4533: Fig. 9 In order to show the employed values for the altitudes above 66 km we have left this figure as is. We believe that the empty squares/circles indicate sufficiently that these values stem from inter/extrapolation.

Page 4533, caption of Fig. 9, line 2 Caption changed as suggested.

Page 4537, Fig. 13 We have added labels as requested.

Page 4540: Caption of Fig. 16 For the revised manuscript we applied the averaging kernel for every species.

General comment on Figures We have adjusted the font size for the revised manuscript.

References

Jackman, C. H., Roble, R. G., and Fleming, E. L.: Mesospheric dynamical changes induced by the solar proton events in October-November 2003, Geophys. Res. Lett., 34, L04 812, doi:10.1029/2006GL028 328, 2007.

Jöckel, P., Sander, R., Kerkweg, A., Tost, H., and Lelieveld, J.: Technical Note: The Modular Earth Submodel System (MESSy) - a new approach towards Earth System Modeling, Atmos. Chem. Phys., 5, 433–444, 2005.

Vitt, F. M. and Jackman, C. H.: A comparison of sources of odd nitrogen production from 1974 through 1993 in the Earth's middle atmosphere as calculated using a two-dimensional model, J. Geophys. Res., 101, 6729–6740, doi:10.1029/95JD03386, 1996.

Interactive comment on Atmos. Chem. Phys. Discuss., 10, 4501, 2010.

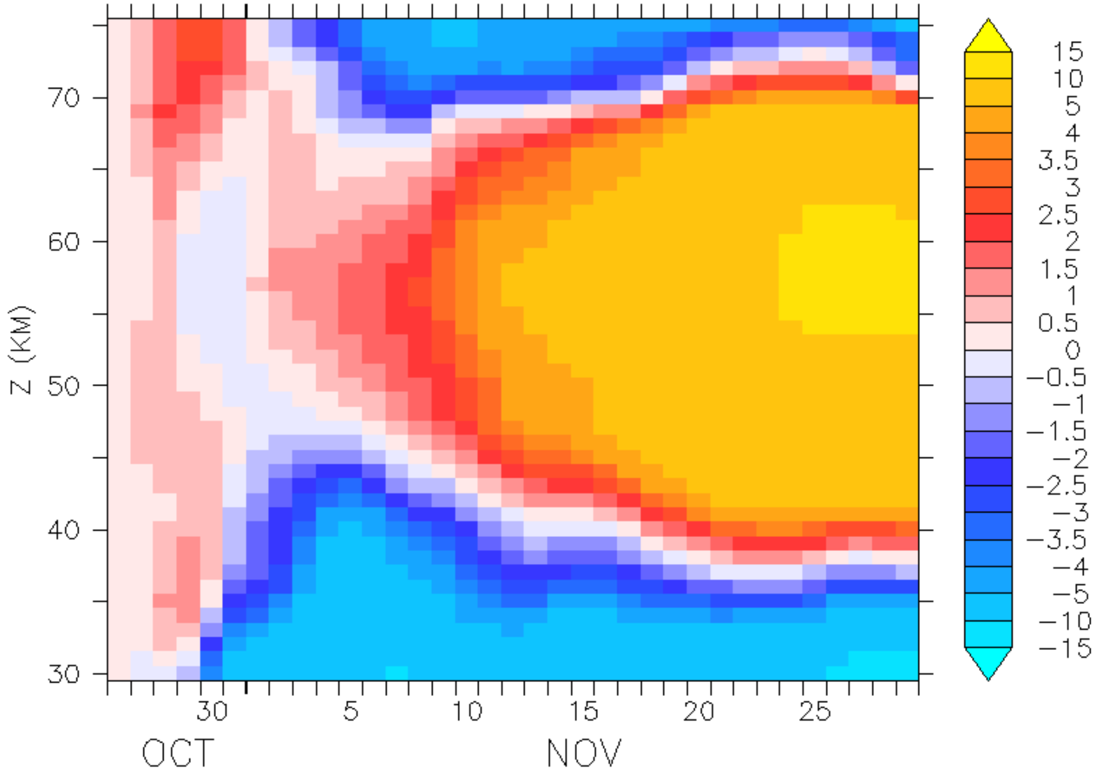

Fig. 1. Temperature (K) change for 70S-90S with respect to 26 October (simulation S-NNOSPE).

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