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Atmospheric Chemistry and Physics Discussions

Interactive comment on “Northern Hemisphere atmospheric influence of the solar proton events and ground level enhancement in January 2005” *by* C. H. Jackman et al.

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We thank Referee #1 for helpful comments and suggestions. The “Referee’s Comments” are noted first and then we give our “Reply:” to the comment.

This article provides quite a comprehensive analysis of the January 2005 SPE events, combining both model (WACCM3) results and satellite observations (from different platforms). In addition to the SPE, the authors have also looked into the Ground Level Enhancement (GLE) event that took place on January 20th, 2005. The analysis is focused on the Northern Hemisphere as longer lasting effects are expected in the winter hemisphere. I think the paper is well written and interesting but I have some comments

that I would like the authors to consider before the paper is published in ACP.

1. The different model simulations are discussed in the paper as A, B, and C, but also as "no SPE, and no GLE", "SPEs-only" and "SPEs+GLE". At times this is difficult to follow, particularly as the latter has "SPE" in all cases. I think it would help the reader if a uniform naming of the model simulations would be adapted.

Reply: We apologize for the confusion in the model simulation descriptions. We now rely on Table 1, which classifies and identifies the groups of model simulations. The model simulations’ designations of A, B, and C are then used in the discussion of the model results.

2. It wasn’t clear to me whether the results shown in the figures were daily averages or something else (individual observations, model time grid?). I think this should be clarified as it can effect how you interpret the variability and model-data agreement for some constituents.

Reply: The results shown in the figures are daily averages. We have tried to make this clearer in the manuscript (see paragraph 6 of section 4 and captions for Figures 3-8 and 10-14).

3. The use of Averaging Kernels. Clearly when comparing with some satellite observations is important to take the averaging kernels into account. I’d like the authors to clarify the use of averaging kernels a little in the text. At the moment it’s unclear if Averaging Kernels are used throughout the analysis when comparing the satellite data to model results. I understood that they are only used for MIPAS data, what about when the model results are compared with two different satellite instruments? Also, the use of AKs is mentioned for some of the gases, but not others. Does omitting AKs not affect some of the comparisons?

Reply: We appreciate the comment. The reviewer is correct that Averaging Kernels (AKs) were only used for MIPAS data in the ACPD manuscript. AKs do exist for MLS data and we have now applied those to the WACCM3 output in the revised Figures 4, 5, 6, and 7. There is only a modest difference in the results shown for the comparison between MLS and WACCM3 for the constituents OH and ozone, however, the application of the AKs does make a noticeable difference in the HO2 comparison between MLS and WACCM3 (see Figure 6). The agreement between MLS and WACCM3 has been improved for HO2 with the application of the AKs on WACCM3 output. There are no AKs for the SCISAT-1 ACE instrument because optimal estimation is not used in the ACE retrievals. The vertical resolutions of WACCM3 and ACE are nearly equivalent in the mesosphere ($\sim$3 km). WACCM3 vertical resolution is slightly finer than ACE in the upper stratosphere (2 km vs. 3 km), however, these values are certainly comparable. Since the WACCM3 and ACE resolutions are so similar, comparison between the usual WACCM3 output and ACE measurements should be satisfactory for the analyses of NOx changes presented in this paper. This is now discussed in paragraph 2 of section 5.2.3. There is a difference in the AKs between MLS and MIPAS for the HNO3 observation. Thus, we have not used any AKs on the WACCM3 output in Figure 11 involving the comparison of MLS, MIPAS, and WACCM3.

4. Of the different model simulation realizations occasionally only one is shown, (WACCM3 B1) other times average of the different realizations (average of B's - average of A's). Why not the show the average of all B instead of just B1?

Reply: There is no reason not to use the average of all B realizations instead of just B1 or the average of all A realizations instead of just A1. We have redone Figures 4, 5, 6, 7, 8, 9, 10, and 11 with the average of all A and B realizations. The general findings of the paper have not changed as a result of this, however, the specific discussion for the figures has been changed appropriately.

5. I was expecting to see more results from the GLE simulations, although I appreciate that the effects from the GLE are very small. Even so, at the moment only NOy is discussed and shown. I think it would be interesting to add at least some statements of the GLE effects, or lack thereof, on other stratospheric constituents (HOx, Ox, etc:

?). It would also be interesting to know if the GLE SH effect was as insignificant as the NH effect, although I appreciate that the article is focused on the NH. Seppala et al. (2008) have also modelled the Jan 2005 SPEs but they focused on the short term effects of the Jan 20 event on both hemispheres and, like here, concluded that the stratospheric effects were small. But they did not include the GLE forcing. One difference in stratosphere seems to be that their results (Fig 7) show HOx production down to 30 km from the SPEs, but this does not seem to take place in the MLS and WACCM3 results (Fig 5-6.) Is this difference likely just due to the relatively low amounts of HOx at those altitudes?

Reply: We focused on the NOy changes, since it would be through the longer lasting NOy that extended impacts on ozone would be manifested. We have looked at HOx and ozone impacts as well as the GLE SH effect and have found the following: 1) HOx can be impacted significantly (>20% in the 20-100 hPa range) by the GLE in the 60-90N region on January 20, 2005. As the reviewer has suggested in the last question of their comment, the very significant enhancements in HOx due to the GLE are because of the very small amounts of ambient HOx in the polar winter low sun conditions at this time of year. Ambient HOx values in the 60-90N region range from 0.002-0.3 pptv at 100 hPa to 1.2-1.9 pptv at 20 hPa. This HOx enhancement is reduced to less than a 0.1% increase within 48 hours due to the short lifetime of HOx constituents in the stratosphere. 2) Ozone decreases of a maximum of about 0.007% by the GLE were computed on January 21, which appear to be connected to the NOy enhancements ($\sim$0.09%) that also peak on the same day. 3) Southern Hemisphere polar (60-90S) impacts – a) NOy is enhanced by a maximum of about 0.18% on January 21 due to the GLE. This larger enhancement in the polar SH compared with the polar NH is due to the fact that the ambient NOy is somewhat smaller in the SH compared with the NH. b) The HOx is enhanced by a maximum of about 2% on January 20 due to the GLE. This enhancement is reduced to zero within 24 hours. c) Ozone was reduced by a maximum of about 0.05% in January due to the GLE, which appears to be connected with the NOy enhancements. We have added some discussion of these additional results into the manuscript (see paragraphs 2 and 3 in section 6). Also, we did find an error in the x-axis of Figure 14. A corrected figure is provided with the revised manuscript.

6. I also have a question about the GLE ionization rates. Do the GLE ionization rates vary with time or is just one ionization rate profile applied for the GLE in the model. This would seem perfectly acceptable, but it's not clear if this is what was done. How long in duration is the GLE ionization burst? This wasn't clear from the text either.

Reply: The GLE ionization rates are daily average values, just like the SPE ionization rates. The daily average GLE ionization rates were constructed from the GLE ionization burst information, which indicated that the most substantial increase in the high energy protons lasted only about 90 minutes [see G. M. Simnett and E. C. Roelof, Timing of the relativistic proton acceleration responsible for the GLE on 20 January, 2005, 20th International Cosmic Ray Conference Pune, 1, 233-236, 2005]. We have now added discussion in paragraph 1 in section 6 about this. Hopefully, it is clearer now.

Minor: Page 7721, line 1: "Odd nitrogen (NOy) is also produced: : :" -> "Odd nitrogen (NOy) is produced: : :"

Reply: Yes, this has now been changed.

Figure 1. Could you add to the caption that this ionization is from 1-300 MeV protons only and not GLE?

Reply: Yes, this has now been added to the caption.

Interactive comment on Atmos. Chem. Phys. Discuss., 11, 7715, 2011.