Atmos. Chem. Phys. Discuss., 11, C4885–C4887, 2011
www.atmos-chem-phys-discuss.net/11/C4885/2011/

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.

C. H. Jackman et al.

Charles.H.Jackman@nasa.gov

Received and published: 13 June 2011

We thank Referee #2 for helpful comments and suggestions. The "Referee's Comments" are noted first and then we give our "Reply:" to the comment.

This paper provides an interesting comparison of WACCM simulations of the January 2005 SPEs with three observational datasets. Only a few points should be addressed before the paper can be accepted for publication:

1) p. 7723-5: The horizontal distribution of SPEs ionization is assumed to be uniform over a disc between 60N and 90N in geomagnetic coordinates. Surely this is an approximation and the true distribution is more complex as suggested by Figure 3 com-

pared to Figure 4. Aside from chemistry issues (Canty et al., 2006) the overestimation of HOx may be due to overestimation of total ionization.

Reply: The referee is certainly correct about the ionization from the January 2005 SPEs being more complicated than assumed in the manuscript. Verronen et al. [2007] show that the geomagnetic boundary can vary with the proton forcing ranging from none to a full effect between about 57 and 64N geomagnetic latitude. Thus, there can be proton influences at geomagnetic latitudes less than 60N (down to 57N) and the full proton influence may not be reached until 64N. Our assumption of a uniform forcing over the entire polar cap (60-90N) is an approximation, which may slightly overestimate the affected area. It does appear from the Verronen et al. study that the proton forcing is nearly a full effect at geomagnetic latitudes greater than about 62-63N. If the affected polar cap is 62-90N, rather than 60-90N, then the impacted area would be decreased by about 13%. The proton flux's impacted region is variable with time and there appears to be some influence during certain periods at latitudes lower than 60N. Given this variability of the impacted area, we assumed a non-changing polar cap area for ease of computation. We discuss this briefly in paragraph 4 of section 4.

2) p. 7727, l. 13: At stratospheric altitudes formation of HOx from ionization is more involved than the simple H and OH production parametrized in the model. According to Verronen et al. (2006), the ionization production should be H + OH + HNO3. The HNO3 production via ion-ion recombination reactions is more important at stratospheric altitudes. It is difficult to tell from Figures 5 and 6 how well the model does in generating OH and HO2 in the stratosphere due to the contour interval. Figure 8 suggests that there is significant overestimation of HOx production. The authors discuss ion chemistry in section 5.2.2, but it is also relevant for this section.

Reply: We have simplified the HOx production from ionization to be only H + OH and use the lookup table from Jackman et al. [2005a, Table 1], which is taken from the work of Solomon et al. [1981] and explained in the text. The HOx production of Solomon et al. [1981] involved complex positive ion chemistry, which is not included in WACCM3.

The referee is correct that the ionization products should probably include HNO3, as well as H + OH [see Verronen et al., 2006]. We have considered the possibility of including HNO3 through a lookup table, but to date the attempted methodologies have not been totally satisfactory. We now mention in the manuscript that the production of HNO3 is not included (see paragraph 1 of section 3). We also now include contour levels of 0.01, 0.02, and 0.05 ppbv in Figures 5 and 6 so that readers can see the model production of OH and HO2 in the stratosphere.

3) p. 7729, l. 11-12: It appears that the version of the model used for this study does not have medium energy electron precipitation (section 4 refers to 2007 papers). There were significant medium energy electron fluxes measured by the MEPED instruments during January 1-8, 10-13 and 16-23 of 2005. Given the peak ionization rates around 75 km from these fluxes were between 500 and 4000 ion pairs per cc per second, this is a substantial missing source of NOx in the upper mesosphere. Some clarification in section 4 or here should be included about this missing NOx source.

Reply: The referee is certainly correct that there were significant medium energy fluxes in January 2005. We have started work on including medium energy electrons (MEEs) in WACCM3 computations. There appears to be a large uncertainty in the impacted geographic region by the MEEs. Currently, the inclusion of MEEs is beyond the scope of the present study. We now mention the lack of MEEs in the WACCM3 computations in paragraph 2 of section 4.

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