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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Model simulations of stratospheric ozone loss caused by enhanced mesospheric NO_X during Arctic Winter 2003/2004" *by* B. Vogel et al.

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General comments:

The authors discuss the results of model computations, which are used to estimate the Arctic stratospheric ozone loss in the winter of 2003/2004, caused by the downward transport of the enhanced mesospheric charged particle produced-NOx. They use the Chemical Lagrangian Model of the Stratosphere (CLaMS) in their computations with different NOx boundary conditions at 2000 K potential temperature (∼50 km), the top of CLaMS. They found that mesospheric NOx can affect the stratosphere down to about 400 K (∼17-18 km). The CLaMS predictions are compared with ACE-FTS and

MIPAS data and an upper limit for ozone loss caused by the enhanced mesospheric NOx is derived. They found that the stratospheric column loss caused by the solar proton-produced NOx at levels above 55 km due to SPEs in Oct-Nov 2003 is about 3.3 DU with an upper limit of 5.5 DU through the end of November. They also found that the transport of mesospheric NOx-rich air in 2004 up to the end of March resulted in about 10 DU stratospheric ozone loss. About 3.5 DU ozone is computed to have been lost in the lower stratosphere (350 -700K,∼14-27 km) due to mesosphere NOx-rich air.

The manuscript is generally well-written and provides valuable information about the influence of mesospheric NOx-rich air on the stratosphere. The use of horizontal and vertical transport driven by ECMWF winds helps to insure that the Arctic winter 2003/2004 is well simulated. The model results from three simulations, 'ref', 'no NOx', and 'max NOx', are presented which help quantify the influence of the mesosphere on the stratosphere during this very disturbed time period, both from solar particles and the meteorological conditions. There are a few places in the manuscript where I think some clarification is necessary about the results and their meaning (see 'Specific comments' 1, 5, 7, 8, and 9). I have provided some information about the computed total ozone loss from the Oct-Nov 2003 SPEs given in an earlier study (see 'Specific comment' 6) that the authors might want to consider. In total, I have listed nine 'Specific comments' and thirty-three 'Technical corrections'. I also have a brief 'Note to authors' at the bottom. The paper should be ready for publication in ACP after minor revision.

Specific comments:

1) p. 4912, lines 24-28: I suggest a rewrite of the sentence 'In the lower stratosphere...until the end of March.' to 'The solar proton-produced NOx above 55 km due to the SPEs of October-November 2003 have a negligibly small impact on ozone loss processes through the end of November in the lower stratosphere (350-700 K, ∼14-27 km). The mesospheric NOx intrusions in early 2004 yield a lower stratospheric ozone loss of about 3.5 DU, but clearly lower than 6.5 DU, through the end of March.'

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2) p. 4914, line 4: Regarding the phrase 'and of HOx' I suggest changing to 'and of HOx and ozone depletion signatures associated with HOx'

3) p. 4914, line 5: Possibly add 'Verronen et al., 2006' after 'von Clarmann et al., 2005'

4) p. 4922, line 27: It appears that there is a reference to 'Fig. 7' before there is any reference to 'Figure 6' (referenced first on p. 4923, line 26). If the authors want to keep Fig. 5 and Fig. 7 together, I suggest relabeling them as Figs. 5a and 5b.

5) p. 4926, lines 22-23: I think this sentence needs to be modified as the authors only include the NOx from the solar protons at altitudes above 55 km - I suggest rewriting 'The column ozone loss caused by the SPEs in October-November 2003 in the stratosphere is up to 3.3 DU with an upper limit of 5.5 in mid-November.' to 'The column ozone loss caused by the solar protons producing NOx at altitudes above 55 km in October-November 2003 in the stratosphere is up to 3.3 DU with an upper limit of 5.5 DU in mid-November.'

6) p. 4928, lines 6-10: The Jackman et al. (2005b) manuscript ONLY considered the October-November 2003 solar proton fluxes, thus comparison to results in that study are more appropriate to this paper than the Jackman et al. (2005a) manuscript. I suggest that it would be more consistent with this paper to compare with Figure 13 of Jackman et al. (2005b). I recommend rewriting the three sentences 'The impact of...Jackman et al. (2005a).' At present, I do not have a suggestion for how to rewrite.

I do not see how the phrase 'whereas we derive a column ozone loss about 2.5 DU, but lower than 4.5 DU caused by the October-November 2003 SPEs (p. 4928, lines 9-10)' was derived. On page 4926 (lines 22-23) it is indicated that the NOx produced above 55 km from SPEs in Oct.-Nov. 2003 caused an ozone loss of 3.3-5.5 DU. Is there something I am missing in the paper?

I have looked back at the 2-D CTM results that were presented in Figure 13 of Jackman et al. (2005b) and calculated a total column ozone loss of 0.4% (1.5 DU) in mid-November 2003 increasing to about 1.1% (4.1 DU) between mid-February and

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the end of March 2004 for latitudes >70N, which is caused by the October-November 2003 SPEs.

7) p. 4928, line 24: I think the authors might want to clarify and change 'by SPEs in October-November 2003' to 'by solar protons only for altitudes above 55 km in October-November 2003'.

8) p. 4930, lines 10-13: I suggest rewriting the sentence 'Due to the SPEs of the Halloween sunstorm event an additional accumulated ozone loss of approximately 3.3 DU (36%) but below 5.5 DU (48%) was simulated until mid-November 2003.' to 'Due to the solar protons producing NOx above 55 km during the Halloween solar storm event, an additional accumulated ozone loss of approximately 3.3 DU (36%) but below 5.5 DU (48%) was simulated through mid-November 2003.' See, also, Specific comment 5.

9) p. 4930, lines 19-22: I believe that the methodology used by the authors in simulating the enhanced NOx from the October-November SPEs only includes that produced above 55 km. Please correct my misunderstanding if I am wrong. I would suggest rewriting the sentence 'Thus, owing...by October-November SPEs.' to 'Thus, owing to the meteorological conditions, NOx enhancements caused by the mesospheric NOx intrusion in early 2004 have a stronger impact on ozone loss processes in the lower stratosphere than the solar proton-produced NOx at altitudes above 55 km caused by the October-November 2003 SPEs.'

Technical corrections:

1) p. 4913, line 22: Very minor. Suggest changing 'Halloween sunstrom' to 'Halloween solar storm'

2) p. 4916, line 24: Change 'refer this' to 'refer to this'

3) p. 4918, line 11: Change 'to quantify' to 'the quantification of'

4) p. 4918, line 17: Change '0.5 ppmv accumulated' to '0.5 ppmv of accumulated'

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5) p. 4919, line 2: Change ‘originate’ to ‘originating’

6) p. 4919, line 6: Change ‘loss also halogen-induced and HOx-induced ozone loss’ to ‘loss, halogen-induced and HOx-induced ozone loss also’

7) p. 4919, line 8: Change ‘plays’ to ‘played’

8) p. 4919, lines 22-23: Change ‘by the absence of PSCs in the middle stratosphere the destruction of ozone is mainly driven by NOx,’ to ‘the destruction of ozone is mainly driven by NOx in the middle stratosphere with the absence of PSCs,’

9) p. 4920, line 10: Change ‘small about’ to ‘small at about’

10) p. 4920, line 11: Change ‘is increasing’ to ‘increased’

11) p. 4920, line 25: Change ‘longterm’ to ‘long-term’

12) p. 4921, line 9: Change ‘longterm’ to ‘long-term’

13) p. 4921, lines 18-19: Change ‘for the KASIMA simulations NO2 mixing ratios are derived form’ to ‘NO2 mixing ratios for the KASIMA simulations are derived from’

14) p. 4921, line 24: Change ‘equal 60N’ to ‘equal to 60N’

15) p. 4923, line 7: Change ‘depends’ to ‘depend’

16) p. 4924, line 2: Change ‘expect’ to ‘except’

17) p. 4924, line 20: Change ‘reporting’ to ‘reports’

18) p. 4925, line 22: Change ‘rations’ to ‘ratios’

19) p. 4926, line 8: Change ‘midlatitude’ to ‘mid-latitude’

20) p. 4926, line 19: Change ‘have still’ to ‘still have’

21) p. 4927, line 10: Change ‘yield’ to ‘yields’

22) p. 4927, line 15: Change ‘until end’ to ‘until the end’

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23) p. 4927, line 26: Change ‘of enhanced’ to ‘due to enhanced’

24) p. 4927, lines 27-29: Change ‘Moreover Fig. 9b (bottom panel) shows that first from Mid-February during the period of the very strong upper stratospheric vortex enhanced mesospheric NOx values have an impact on ozone loss below 700 K. ’ to ‘Moreover, Fig. 9b (bottom panel) shows that enhanced mesospheric NOx values have an impact on ozone loss below 700 K from mid-February during the period of the very strong upper stratospheric vortex. ’

25) p. 4928, line 21: Change ‘longterm’ to ‘long-term’

26) p. 4929, line 20: Change ‘provide so an’ to ‘provide an’

27) p. 4930, line 7: Change ‘until end’ to ‘until the end’

28) p. 4930, line 10: Change ‘found end’ to ‘found at the end’

29) p. 4930, line 11: Very minor. Suggest changing ‘Halloween sunstorm’ to ‘Halloween solar storm’

30) p. 4930, line 17: Change ‘negligible’ to ‘a negligibly’

31) p. 4930, line 19: Change ‘until end’ to ‘until the end’

32) p. 4930, line 24: Change ‘form’ to ‘from’

33) p. 4947, 4th line of Fig. 9 caption: Change ‘addition’ to ‘additional’

Note to authors:

If it is desired to include the direct NOx production from solar protons below 55 km, the ionization rates and suggested NOx production from solar protons for the years 1963-2007 (including the October-November 2003 period) are given at the website: http://www.geo.fu-berlin.de/en/met/ag/strat/research/SOLARIS/ under ‘Input data’

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