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Interactive Comment

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.

B. Vogel et al.

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Reply to the Review by Referee 2

acpd-2008-0010 by Vogel et al. 'Model simulations of stratospheric ozone loss caused by enhanced mesospheric NOx during Arctic Winter 2003/2004'

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We thank Referee 2 for a very helpful review. The referee listed 4 minor comments. We think that points 1 to 3 are very good questions and comments that have led to an improvement of the paper; point 4 required only minor modifications. We discuss all these points in detail below. Reviewers comments are cited in *italics*.

1) It is unclear what in-homogeneities in NO_x (at 1600K) the authors refer to, when discussing Figure 7. It is apparent that the satellite NO_x observations are higher than in the model at 2000K, but at 1600K the plot is cluttered by the superposition of satellite data (circles) on the model field, which indeed seems to show localized enhancements. What is the origin of these inhomogeneities? This needs clarification and possibly an improved or additional figure (e.g. scatter plot?). It is also very difficult to see the ACE observations (diamonds) in these figures.

We agree that the the plots of Figure 7 contain a lot of information. Nevertheless, if the plots were shown much larger than in the ACPD version, the different symbols would be distinguishable very well. Thus we would like to ask again the production office of ACP whether these Figures could be printed out much larger (similar as in the originally submitted manuscript). We suggest only 2 plots of Figure 7 on one ACP page.

To the inhomogeneous spatial distribution: In CLaMS the spatial distributions of NO_x and ozone are very homogeneous at 2000 K caused by the upper boundary conditions taken from KASIMA results (see Fig. 7, top panel). In contrast NO_x and also ozone are distributed very inhomogeneous at levels below (see Fig. 7 middle and bottom panels). Even if these spatial distributions are highly inhomogeneous, these inhomogeneities enhance during the downward transport mainly within the polar vortex [Ray et al., 2002]. The corresponding patchy CLaMS distribution of NO_x and ozone at levels below 2000 K (see Fig 7 middle and bottom panels) are mainly to a strong differential descent, i.e., adjacent air parcels experience different diabatic

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descent due to strong and spatially inhomogeneous descent rates at these altitudes. The CLaMS mixing algorithm preserves these inhomogeneities that is consistent with satellite observations as shown in Fig. 7.

Further scatter plots are submitted as supplementary material.

2) In Figure 5, there are discrepancies between MIPAS and the model below 750 K in November and December 2003. Are these consistent (in time and altitude) with satellite observations of the NO_x enhancements following the SPEs of late October 2003.

That is a very good question. The NO_x enhancements following the SPEs of October and November 2003 caused by in-situ stratospheric NO_x production were found mainly in altitudes between 35 km and 60 km end of October and November 2003 [e. g. Lopéz-Puertas et al, 2005a, Seppälä et al., 2004]. Significant ion pair production rates caused by SPEs in October and November 2003 were found down to approximately 25 km altitude ($\approx$ 650 K potential temperature) (Jackman et al., 2005b). Significant enhancements of HNO_3 cause by NO_x-chemistry were found around 25 km (between approximately 20 km and 30 km) end of October and in November 2004 [e. g. Lopéz-Puertas et al., 2005b]. Caused by the low statistics of simultaneous measurements of NO and NO_2 for altitudes between 400 K and 800 K and equivalent latitudes greater than 70° N is it difficult to answer this question. Nevertheless, for this region NO_x measurements exist at November 1st, 11th, and 21th and December 24th. An intercomparison between MIPAS measurement and CLaMS shows that the regions with the largest difference between measurements and CLaMS are mainly located in the vortex region (see additional plot in supplementary material), where due to local production of NO_x caused by SPEs an enhancement of NO_x would be expected. Further, observations on November 1st and 11th show that the regions with

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the largest difference between measurements and CLaMS results are located at the same longitude and latitude range where enhanced HNO_3 was found in MIPAS measurements at 650 K potential temperature (see Lopéz-Puertas et al., 2005b, Fig. 3). This is an indication that differences below 800 K potential temperature in November and December may be caused by the fact that in CLaMS the local production of NO_x by ion chemistry is not considered. However, definite conclusions are difficult because of low statistics.

3) In Fig. 9, the depletion shows up in column ozone from February (roughly), presumably due to the ozone change in the 350K-700K layer. The NO_x anomalies do not seem to penetrate that low. Is the rate of descent of the NO_x anomalies in the model throughout the winter consistent with other studies and observations? The authors should discuss this point.

In our studies we found enhanced NO_x of about 20 ppbv transported downwards to approximately 1200 K potential temperature ($\approx$ 38 km) until end of March 2004 for equivalent latitudes greater than 70 °N. Randall et al. [2006] analyze NO_x enhancements in early 2004 measured by ACE-FTS. They found NO_x enhancements in the range of 20 ppbv transported downwards until the end of March 2004 in altitude regions around 40 km poleward of 50 °N (Randall et al., 2006, Fig. 1). Further a study by Randall et al., [2005] based on numerous satellite measurements (mainly HALOE, SAGE II, POAM II & III) show that a systematic descent of NO_x-rich air occurred in the vortex that led to NO_x-enhancements in the upper stratospheric vortex from March to May 2004. The anomalies declined as the vortex broke up, but where still evident even in July 2004. The model simulations presented here show similar results shown in Fig. 1c and Fig. 8a. Thus experimental results confirm the descent rate of NO_x-rich air masses in the model simulations presented here.

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4) The paper discusses only the effect of NO_x injection at the top of the stratosphere, not the in-situ stratospheric NO_x production due to the SPEs. This is mentioned in the text, but should be re-emphasised in the Abstract and Conclusions.

We certainly agree, but believe we already mentioned this point clearly enough in the Abstract and in the Conclusions. Nevertheless, we have tried to clarify this point even better; the relevant sections read now:

see Abstract line 11 – 13:
In our study we focus on the impact of the non-local production of NO_x which means on the downward transport of enhanced NO_x from the mesosphere to the stratosphere. The local production of NO_x in the stratosphere is neglected. . . .

see Conclusions page 4929 line 7 – 13:
We emphasize that the enhancements of different NOy species below 55 km downward to 30 km altitude due to local production of NO_x observed immediately after the SPEs (e.g. Lopez-Puertas et al., 2005b) caused by particle precipitation down into the stratosphere are not considered in our simulations as well as the local production of HO_x. Thus, in our simulations only the transport of enhanced NO_x from the mesosphere (upper boundary condition) to the stratosphere is considered and the local production of NO_x and HO_x below 55 km altitude is neglected.

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