Reply of the *Anonymous Referee #2*'s comments on "Modelling the Effect of Denitrification on Polar Ozone Depletion for Arctic Winter/Spring 2004/05" by W. Feng et al.

GENERAL COMMENTS

This article investigates the effect of denitrification on polar ozone loss in the Arctic winter 2004/05. Although similar works were reported earlier, this work uses three different scenarios of denitrification within the same model. The ozone loss deduced from the recommended version of the model runs, with DLAPSE scheme, agrees well with the measured ozone loss. These experiments are quite interesting. Therefore, the article should be published after addressing the following comments.

Thank your for the review and the positive comments.

SPECIFIC COMMENTS

1. In order to emphasise the results, the authors need to present a few sentences or a short paragraph describing how DLAPSE in SLIMCAT helps to simulate better, as compared to other results. A comparison with previous results with DLAPSE or similar studies with other models will do (for e.g.: Carslaw et al., Davies et al., Grooss et al., Tripathi et al., etc). Though other studies cannot be compared directly with EXP_B, a reasonable comparison with EXP_A and EXP_C is possible, as the other modellers usually conduct those experiments to study the sedimentation/denitrification effect in their models. Its is better to put the results in the context of previous related works rather than restricting them to a single year experiment.

Thank you for the suggestion. We have now added a few sentences to emphasise the results in the discussion: "Kleinböhl et al. (2005) and Schoeberl et al. (2006) also used ASUR and MLS measurements to study the denitrification for Arctic winter 2004/05. Kleinböhl et al. (2005) showed that the observed HNO_3 deficit from ASUR measurement in January/February 2005 is about 6 ppbv at 475 K. Schoeberl et al. (2006) also confirmed that there is large HNO_3 decrease in late January 2005 and the net HNO_3 changes roughly correspond with the coldest temperature based on Aura MLS measurements. Manney et al. (2003), Goutail et al. (2005) and Feng et al. (2007a) have shown large year-to-year variations of polar Arctic ozone loss due to different meteorological conditions. There have been extensive studies about denitrification for cold Arctic winters (e.g., Carslaw et al., 2002; Davies et al., 2002; Grooß et al., 2002; Kleinböhl, 2004; Kleinböhl et al., 2005; Jin et al., 2006; Davies et al., 2006; Schoeberl et al., 2006). Some of these studies also included the SLIMCAT model run with the equilibrium denitrification scheme or DLAPSE schemes. The results showed that the model using the DLAPSE microphysical denitrification scheme is able to produce denitrification and in good agreement with observations for the previous Arctic winters (e.g., 1999/2000, 2003/04). The simulation from the model run without denitrification process (EXP_C) underestimates the Arctic polar ozone depletion by ~30%, i.e. 40–60 DU partial column ozone loss for Arctic winter/spring 2004/05, which is slightly larger than the inferred contribution of denitrification of polar ozone loss for previous Arctic winters. For example, Davies et al. (2002) showed that denitrification induced an extra 21-30% maximum ozone loss at 460 K for Arctic winter 1999/2000 using the SLIMCAT model. Grooß et al. (2002) also used the Lagrangian CTM model CLaMs to study the ozone depletion in spring 2000 and they showed that the denitrification contributed to strong chlorine deactivation and

ozone depletion starting in March 2000. The enhanced ozone loss due to the denitrification was 0.3 ppmv (about 18%) at 450 K from 10 Feburary to 20 March 2000. Tripathi et al. (2010) estimated the contributions of denitrification on Arctic ozone loss were about 23% for Arctic winter 1999/2000 and 17% for Arctic winter 2002/03 using the high resolution CTM MIMOSA-CHIM model."

2. There are three different studies on Arctic denitrification using various measurements for this particular winter (Jin et al., Kelinboehl et al., and Schoeberl et al.). These studies include measurements from both ASUR and MLS. Comparable results from these studies are to be discussed (e.g. winter conditions, HNO3 values, what they say about denitrification in this winter, etc). These are to be cited. This will also justify the usage of ASUR and MLS data in this study, as the above mentioned studies clearly show the strength of these measurements for this kind of work.

OK. We have now added this in the paper.

3. Since the title itself deals with ozone loss, the discussion regarding ozone loss in 2004/05 should be strengthened with all available results for the winter. Some studies are obviously missing in this regard: El Amaroui et al., Tvsetkova et al., Kuttippurath et al., etc. Those are to be cited and discussed in the relevant section with respect to the model experiments performed. Because the difference between EXP_A and EXP_B is about 20 DU, and the uncertainty of the measured loss (that compared with) is also about 20 DU. So it would be good to compare with other results (even if there are slight differences in the column range) to corroborate the author arguments! Abstract and Conclusion should be modified with respect to the comments #1, #2 and #3.

Thanks for these references. We have added them and updated Table 2. We have modified the the paper now based on the whole range of comparison with previous Arctic 2004/05 ozone loss studies.

4. How was this 30% (see abstract and conclusion) overestimation calculated? Compared to the measured loss or the difference between the experiment results (EXP) ? Please explain this in the text.*

This was based on the maximum ozone loss between EXP_A and EXP_C. Now we have explained this in the paper. We revised the sentences as "Overall, denitrification is responsible for a ~30% enhancement in O_3 depletion compared with simulations without denitrification for Arctic winter/spring 2004/05.

5. Retrieval techniques of ASUR, and the vertical range, vertical resolution and accuracy of the trace gases are to be explicitly mentioned. Resolution of the compared trace gases is a very important aspect of these comparisons. I am pretty sure that if the simulated/MLS profiles are convolved with the respective ASUR trace gas averaging kernels, the agreement will be much better. So it should be mentioned in the relevant section with some references (Kleinboehl et al., von Koenig et al., Bremer et al.).

Thanks. We have added more information about the retrieval techniques, vertical resolution and uncertainty of the reacer gases of ASUR and MLS.

6. As for ASUR, please provide a few more sentences about the MLS instrument, retrieval features and trace gas details relevant to this study. The v1.5 is almost 4 years old and now v3.3 is available.

So give some more details about the improvement in the new versions and state what will bring those improvements in your comparison results.

Thank you. Yes, the MLS V1.5 is now old and there are improvements in MLS v3.3. Therefore, we have used MLS V3.3 data in the revised paper.

7. Always use EXP_A, EXP_B and EXP_C to mention the respective model runs. For example: Sometimes it is referred to as standard model run, model runs with DLAPSE, etc. This makes confusion about the model runs.

OK. We now take care to more clearly mention these experiments in the text.

TECHNICAL CORRECTIONS
Page 3858, Line 13: 5-10% is not small
Page 3859, Line 10: give reference after chemistry
Page 3859, Line 13: give reference after components
Page 3859, Line 21: a latest version of the SLIMCAT is it the same model used here, as defined by the standard model run ?
Page 3859, Line 22: delete chemical transport model and use CTM. It is already there in Line 10. Put the CTM in bracket there.
Page 3859, Line 28: More details OF
Page 3859, Line 28: delete the bracket for the references and delete thereafter
Page 3860, Line 02: coma after effect
Page 3860, Line 03: Airborne Submillimeter Radiometer (ASUR)
Page 3860, Line 04: Microwave Limb Sounder (MLS)
Page 3860, Line 07: ASUR is enough, already given the expanded form in Line 3
Page 3860, Line 13: MLS is enough, no need to repeat the expanded form in Line 4
Page 3860, Line 22: delete the website address and cite the validation papers.
Page 3861, Line 01: Here the authors can mention that ASUR measurements have been successfully used to quantify denitrification in the Arctic winters 2000 and 2005 (Kleinboehl et al. 2002 and 2005). Similarly, cite Schoeberl et al., from the MLS side. If there is a bias in the MLS data, it has to be mentioned.
Page 3861, Line 05: Ozone cannot be used as a dynamical tracer at all altitudes!
Page 3861, Line 14: NCAR CCM: expand it. Is it better than the MIDRAD scheme?
Page 3862, Line 01: determination; may be another word calculation or simulation ?
Page 3862, Line 0104: Rephrase the sentence.
Page 3862, Line 05: radius ?
Page 3862, Line 07: the cold ARCTIC winter
Page 3862, Line 13: put DLAPSE in brackets instead of its expanded form
Page 3863, Line 02: introduce Table 1 properly (not in bracket)
Page 3863, Line 13: State why these dates are selected for the comparisons.
Page 3863, Line 19: denitrification having occurred at what altitude? Write the altitude to make it more clear.
Page 3863, Line 20: between 18 and 24 km
Page 3864, Line 04: no ClO measurements available from ASUR ?
Page 3864, Line 05: no other (nearby) ASUR HCl measurements available ?
Page 3865, Line 02: delete percent to make it consistent with The relative o3 differences

Page 3865, Line 05: Is there any reason for the selection of 456 K ? if yes, state that in the text.
Page 3866, Line 12: , which IS consistent
Page 3867, Line 03: This paragraph should be modified, as discussed in Specific comments #3.
Page 3867, Line 07: However, there are still large differences . Consider the altitude and time of ozone loss estimations for the comparisons. The method of estimation and vortex definitions will definitely play a role in deciding the amount of ozone loss. So add the altitude level and time of estimation in the table.
Page 3867, Line 08: The table should be introduced properly and not in bracket.
Page 3867, Line 09: SubMillimetre Radiometer (SMR)
Page 3867, Line 11: What sort of measurement is from Geophysica? Is it a local/single day measurement? If so, it has to be mentioned. In this case the comparison holds only for the particular day and location.
Page 3867, Line 12: place von Hobe et al. in the previous line after aircraft data
Page 3867, Line 12: the lower limit of the ozone loss estimation from Jin et al. was 1.8 ppmv? They have used several methods for the loss computations. Which one is selected for this comparison?
Page 3867, Line 19: Give experiment name if applicable here (EXP_A, B, C)
Page 3867, Line 20: slightly lower, give the value
Page 3868, Line 03: 121+/20 DU (delete the space)
Page 3868, Line 05: It would be good to compare the results with other estimations too (e.g. Jin et al., Singleton et al., Tvsetkova et al., Kuttippurath et al., etc).
Page 3868, Line 16: . The partial , delete coma and put fullstop
Page 3869, Line 20: acknowledge ASUR data
Table 1: Instead of none, no denitrification ?
Table 2: Add other available studies (El Amaroui et al., Tvsetkova et al., and Kuttippurath et al.) Add time and altitude of the loss estimation too.
Figures 1-2: The latitude and longitude of which measurement is given here, ASUR or MLS? Write that in the caption.
Figure 7-8: Write the experiment names in appropriate places, as did in Figures 5 and 6. Is 25 km too high for 550 K? It depends though! May be 21-23 km?
General: minus is used instead of hyphen in some places. Please change that.

Thank you for these. We have corrected the text.