Reply of the Dr. Kleinboehl's comments on "Modelling the Effect of Denitrification on Polar Ozone Depletion for Arctic Winter/Spring 2004/05" by W. Feng et al.

I am very pleased to see that you are using ASUR data for studying denitrification in the Arctic winter 2004/05. As one of the originators of these data I have three short remarks:

1. Concerning the comparison of model data with ASUR data I would like to point out that ASUR data have a vertical resolution of about 5 km in the lower stratosphere. As you are comparing vortex averages rather than individual profiles and the features have a rather large vertical extent even in HNO3 and HCl, a direct comparison is probably justified. However, features like the difference between ASUR and the model in HNO3 around 25 km are likely related to the limited resolution of the ASUR measurement and it might be worth pointing this out. Also, the negative values in the HCl measurement are likely caused by the retrieval not quite being able to follow the steep slope from high HCl VMRs in the middle stratosphere to virtually no HCl in the lower stratosphere. This might be worth mentioning, too.

Thank you for the suggestions. In the revised paper, we now add the vertical resolution of ASUR information "The vertical resolution of these measurements is given by the width of the averaging kernels (∼6–20 km), decreasing with altitude from the lower to upper stratosphere (e.g, Kleinböhl, 2004; Kuttippurath et al., 2011)." Based on your suggestion, we also add the following sentences in the paper: "Please note the differences between ASUR and the model in HNO_3 around 24 km are likely related to the limited resolution of the ASUR HNO_3 measurement (A. Kleinböhl, personal communication, 2011)." and "The negative values in the ASUR HCl measurement are likely caused by the retrieval not quite being able to follow the steep slope from high values in the middle stratosphere to zero HCl in the lower stratosphere (A. Kleinböhl, personal communication, 2011)."

2. In extensive intercomparison studies by Kuttippurath et al. [2007] it has been established that the ASUR O3 data product tends to be biased high by about 12%. This bias seems to be consistent over many campaigns, however, it has not been considered in data submitted to public archives. As you probably downloaded the ASUR data for your study from a public archive, I suggest to reduce the ASUR O3 VMRs shown in your study by 12% with reference to the paper by Kuttippurath et al. [2007]. This will also bring measurements and model results into better agreement in Figs. 1-3.

Thank you for the reference and suggestion. We have changed the ASUR O3 data uncertainty up to 12% in the plots.

3. My final remark concerns some work on denitrification I had done for the Arctic winter 1999/2000. In my paper [Kleinböhl et al., 2002] I derived denitrification inside the vortex from an NOy budget largely based on ASUR HNO3 measurements. The results were compared to output from the Slimcat model run with the NAT equilibrium denitrification scheme (equivalent to your run "Exp A"). It was shown that the model overestimated denitrification particularly at low equivalent latitudes, close to the vortex edge. The DLAPSE scheme was not available by the time this paper was published. However, I followed up on this issue shortly after the development of DLAPSE, and performed a comparison with output from the DLAPSE microphysical model, which was not coupled to a chemistry model at that time. It turned out that the overall denitrification and its dependence on equivalent latitude was much better reproduced by DLAPSE than by the equilibrium model. This finding did not make it into a standalone paper, however, it was published in my PhD thesis [Kleinbhl, 2004] (which is available

for purchase at the German branch of a large online book retailer, but I would also be happy to provide the relevant chapters upon request). As these results can be considered as corroborative evidence for the case you are making I think it would be appropriate to mention them in a relevant section of your paper.

Thank you for sending your PhD thesis. We have updated the description of ASUR as: "The ASUR (Küllmann et al., 1999; Kleinböhl, 2004) is an airborne radiometer measuring the thermal emission of trace gases in the stratosphere. The profile retrieval is performed on equidistant altitude levels of 2 km spacing (Kleinböhl, 2004). The instrument was successfully operated on board the NASA DC-8 research aircraft in the Polar Aura Validation Experiment (PAVE) over the period of 24 January to 9 February 2005 remotely measuring the trace gases HCl, O_3, ClO, N_2O and HNO_3 in the altitude range 14 to 40 km (Kleinböhl et al., 2005; Kuttippurath et al., 2004). The vertical resolution of these measurements is given by the width of the averaging kernels (∼6–20 km), decreasing with altitude from the lower to upper stratosphere (e.g, Kleinböhl, 2004; Kuttippurath et al., 2011). The total typical retrieval error is ∼ 20 % for HCl, ∼ 10% for ClO, and less than 15% for N_2O and 12% for O_3 e.g., von König, 2002; Bremer et al., 2002; Kleinböhl, 2004; Kuttipurath et al., 2007)."
and also put your denitrification work in the Conclusion section:
"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)."

I hope you will find these comments helpful and I would appreciate if they were taken into account.

Thank you again. These comments were certainly helpful.