Atmos. Chem. Phys. Discuss., 4, S3586–S3592, 2004
www.atmos-chem-phys.org/acpd/4/S3586/
European Geosciences Union

Atmospheric Chemistry and Physics Discussions

Interactive comment on "2002–2003 Arctic ozone loss deduced from POAM III satellite observations and the SLIMCAT chemical transport model" *by* C. S. Singleton et al.

C. S. Singleton et al.

Received and published: 8 February 2005

We would like to thank the anonymous referee and Dr. M. Rex for their helpful suggestions.

Responses Referee # 1

Specific Comments: p.7015, line 6: We also believe that this is a limitation with the Match technique and we are planning to explore how mixing affects the ozone loss calculations specifically when you compare the calculations with the CTM-PS technique. We have added your suggestion to the discussion by changing our previous discussion to: "Two large sources of uncertainty in the Match method are errors in the trajectory

calculations (Rex et al., 1999) and neglect of mixing. Many Match pairs are required in order to reduce errors sufficiently to produce statistically significant ozone loss estimates, and the Match technique assumes that the sampled air parcel does not mix with its surroundings along a trajectory."

p.7015, line 16: In the calculations conducted for this work vortex-averaged descent rates were used to descend a passive ozone profile; thus for this work, uniform descent within the vortex was assumed. We have clarified the text that pertains specifically to the Hoppel et al. method to, "The Vortex Average method as applied by Hoppel et al. [2002] uses vortex-averaged descent rates, tantamount to assuming uniform descent within the vortex, and does not account for lateral mixing across the vortex edge. Lateral mixing across the vortex edge is particularly important to consider in winters when the vortex is disturbed."

p7018, line 18: We do mean mixing between vortex and ex-vortex air. We revised the sentence (see previous comment).

p7018, line 28: We removed this sentence from the text. The wording of the sentence made it sound as if inside the vortex we have both diabatic descent and mixing with subtropical extra-vortex air occurring. We have replaced the sentence with, "At 500 K vortex and extra-vortex ozone are nearly identical in early December. This is because enhanced diabatic descent increases 500 K ozone mixing ratios sampled by POAM inside the vortex by about the same amount that mixing with subtropical extra-vortex air increases 500 K mixing ratios sampled by POAM outside the vortex." The new text should make it clear that the mixing of subtropical extra-vortex air occurs outside the vortex.

Comment on zonal cross-sections: Figure 4 shows the daily average POAM observations inside and outside of the vortex and while potential temperature vs. equivalent latitude cross-sections would be interesting, we feel that they would be redundant with Figure 4. We also believe that it is easier for readers to infer quantitative information

ACPD

4, S3586–S3592, 2004

from the explicit time series rather than contour plots.

p.7020: Only the ozone fields are reinitialized due to the lack of global measurements of other constituents. The other model fields are determined by a multiannual 3D CTM simulation. This could lead to a potential inconsistency when using results from the Pseudo Passive or Active model runs (this would not be the case for the Pure Passive model run because ozone is treated as just a tracer), depending on the error in the CTM run. However, we feel that it is better to use the ozone fields to constrain the model.

We have also inserted the following sentences, “Only the ozone model fields were reinitialized in the model because of the lack of global observations of other constituents. There is thus the potential for inconsistencies in runs when ozone is not treated as a passive tracer, because the other constituents were determined from the multiannual run as described above. This needs to be considered when interpreting model and measurement differences; however we feel that it is better to use the ozone fields to constrain the model.”

We have also added the following sentences where we discuss differences between the Pseudo and Pure Passive, “It is also important to consider that there may be a potential inconsistency in the Pseudo Passive, since only the ozone fields were reinitialized from observations. The Pure Passive ozone would not be affected since ozone is treated as a completely passive tracer. Additional work will be required to quantify the potential inconsistency.

p.7021, line 18: For this analysis vertical descent in the SLIMCAT model was calculated from heating rates. When heating rates are used global mass balance must be applied to the model because, in this configuration the model does not balance horizontal and vertical mass fluxes. SLIMCAT can be run with vertical motion from the analyses, which does allow for the balance of both fluxes, but the ‘age of air’ is not as realistic. Studies have shown that the best way to handle long term circulation is to use the heating

ACPD

4, S3586–S3592, 2004

rates. A new paper, Chipperfield, 2005, describes a range of tracer experiments with the TOMCAT/SLIMCAT CTM and our study uses the model which gives the overall best simulation of the stratosphere.

We also inserted the following sentence, “Radiative heating rates were used because they provide the best simulation of stratospheric transport.”

Chipperfield, M. P., New Version of the TOMCAT/SLIMCAT Off-Line Chemical Transport Model, Q. J. Roy. Met. Soc., (to be submitted), 2005.

p.7021, line 25 to p.7022, line 18: We also believe that it is important to look at both the Pure and Pseudo Passive results because they help us to understand different questions. However, we feel that when you are trying to isolate loss due to heterogeneous reactions using the CTM-PS technique it is important to use the Pseudo Passive. We state in the paper when air is passively advected for long periods of time the local NOx chemistry at the polar latitudes is not accounted for and the low-latitude ozone source will not be maintained. Therefore, in order to descend the proper amount of ozone within the polar vortex and correctly quantify ozone loss due to heterogeneous reactions it is important for gas phase reactions to be activated. We have shown ozone loss results using the Pure Passive (POAM - Pure Passive) and the Pseudo Passive (POAM-Pseudo Passive) in Figure 8. In terms of heterogeneous processes the results where the Pseudo Passive run was used in the calculation are probably more credible.

We have added the following sentence to the paper: “Results from both calculations are shown below to quantify the net change in ozone (production - loss, with the caveat that this could be influenced by errors in the transported ozone as described above) as well as the change due to heterogeneous processes alone.”

p.7022, lines 25-28. The wording was confusing. We have decided to replace it with the following sentence, “It is interesting that differences between the Pure and Pseudo Passive calculations decrease in magnitude above 600 K in late February and March. This results from an increase in competition between catalytic ozone loss at high lati-

ACPD

4, S3586–S3592, 2004

tudes and production at lower latitudes (which was then followed by advection to high latitudes), so that the net effect of photochemistry is less significant."

p.7024, line 28: We have reworded the sentence to, "POAM ozone decreases by about 0.4 ppmv in January, but then remains relatively constant or declines slightly through mid-March, perhaps an indication of diabatic descent of air from above that has experienced heterogeneous loss."

p. 7025, line 6 and Figure 9 (also Figure 8): If transport and chemistry is accurately represented in the model the left panel of Figure 9 would show net production minus net loss. However, the figure does not really represent net production minus loss because it has an error due to the transport of incorrect ozone in the middle stratosphere where gas phase chemistry is relevant. We know near 650 K and above gas phase chemistry should be the only chemistry that occurs; therefore, the Pseudo Passive should be approximately equal to the observations. Although the Pseudo Passive is not equal to the observations at these altitudes we present the figure because it is the more conventional way of looking at CTM-derived ozone loss, and because the comparison between it and the differences using the Pseudo passive are instructive. We suggest a possible reason why there are the discrepancies at 600 K on page 7027 (line 26): "However, above 600 K in February and March model ozone is too low, possibly suggesting an underestimate of descent rates or an underestimate of mixing." Your concerns about these problems are valid; however, understanding the model results at these levels is beyond the scope of this paper, so we prefer to not go into any more detail at the current time. However, this is a problem which we will be examining further.

We have made changes to the text and the captions of Figure 9 and 10 to specify that negative differences signify ozone loss.

Responses Referee # 2 (M. Rex)

p.7016, line 21: This is a very good point, therefore we have inserted the following sentence into the text, "SLIMCAT uses the Prather (1986) advection scheme which

ACPD

4, S3586–S3592, 2004

has very low numerical diffusion."

p.7018, line 8: Validation results indicate that there is very little difference in ozone between the two versions. We have added the following sentences to the paper, "Version 4.0 POAM data became available after the analysis for this work had been completed. Comparisons between version 3.0 and version 4.0 POAM ozone data indicate differences of less than 1% on average, however, so the results presented here are not expected to change significantly with the new version."

p.7022, line 28: We have modified the text to now read, "It is interesting that differences between the Pure and Pseudo Passive calculations decrease in magnitude above 600 K in late February and March. This results from an increase in competition between catalytic ozone loss at high latitudes and production at lower latitudes (which was then followed by advection to high latitudes), so that the net effect of photochemistry is less significant."

p7023, last line: We mention on page 7027, line 26: "However, above 600 K in February and March model ozone is too low, possibly suggestion an underestimate of descent rates or an underestimate of mixing." This is a problem in the model that we are looking into and will be the focus of future research; however, we feel that understanding the model results at this level is beyond the scope of this paper.

p.7026, line 18: We have included your suggestion and modified the text to read, "A likely explanation is horizontal transport or mixing across the vortex edge, which is not included in the vortex average approach (Hoppel et al., 2002)".

Figure 1, caption: We have modified the caption to read, "Temperatures are the minimum temperatures inside the polar vortex and were obtained from Met Office analyses."

Figure 2: We have made the changes that you suggested to Figure 2.

Figure 3. We have made the change to Figure 3.

ACPD

4, S3586–S3592, 2004

Interactive comment on Atmos. Chem. Phys. Discuss., 4, 7011, 2004.