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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Quantifying transport into the Arctic lowermost stratosphere" *by* A. Werner et al.

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to Referee 4, Eric Ray:

Section 4.2: Since N2O was used to define the vortex and non-vortex data it would be useful to see a profile of N2O similar to Fig. 3 or refer to Fig. 7 in this section.
Section 6: It would be interesting to see the average profiles from Figs. 8 and 9 overlaid on each other to more clearly see the progression over the winter.

Yes, an extra Fig. would be nice, but the no of figures is already quite high. In the first case I will include the reference to Fig 7. and figures 8 and 9 will be re-designed.

In 3 out of 4 cases shown the majority of tropospheric fractions above 370 K are negative. This seems to be a flag that you need to adjust your tropospheric boundary condition. You could either separate the boundary condition as a function of theta for all species as you did for H2O, or you could make an adjustment for all theta. Perhaps your latitudinal sampling in the troposphere wasn't sufficient to establish the boundary condition. I realize that you mention earlier the troposphere is assumed to be well mixed and the variations are small compared to the difference between the stratosphere and troposphere boundary conditions, but there is clearly something that needs to be adjusted to avoid all of the negative results.

Good point - the discussion of boundary conditions is certainly a long one:

Concerning their tropospheric boundary, N2O, CFC11 and H1211 have such a long lifetime, that I feel "on the safe side", concerning their latitudinal behaviour; especially as I compared mid-latitude data from autumn and high-latitude data from winter and could not derive major differences.

The choice of boundary condition is definitely a problem for H2O, O3 and CH4. For troposhperic H2O I might not really capture the correct theta or latitude adjustment. Here, cross-isentropic transport or mixing provides another source of error. However, I account for these errors with large error margins for the tropospheric H2O boundaries. The same is basically done for CH4 (error: 2%) and O3 (error: 16%). However, this boundary describes the observed variability from mid to high latitudes in autumn to winter 2002/2003 quite well. See attached Pic.

Anyway, the bigger problem or error arises, in my point of view, from the dynamic vortex boundary that I assume, where horizontal inhomogeneties are neglected. In some cases the measurements in the LMS lie below (above for O3) their referring vortex boundary. Thus, the equation system can only solve the problem by adding a negative fraction. And the equation system reacts very sensitive to errors in the boundary condi-

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tions (see section:5.2). I played around with the boundary values and by this you can of course influence the results. However, the reaction of the equation system to changes in the boundary is not always straight forward, as the tracers do not strictly provide sufficient constraints for the solution. Maybe the results could be improved by adding other tracer data, providing more constraints to the equation system. Unfortunately, other tracers were not available from these flights.

Furthermore, these negative fractions maybe a hint on the not explicitly considered transport pathways from the tropical stratosphere region.

Finally, justifying an adjustment of the boundary values in order to "fit" the data into the expected frame feels quite arbitrary to me. Obviously, I could adjust all boundary conditions to a point, where all results are within the physical range of 0 and 1, however, this cannot be the aim of this study.

Section 7: I was expecting a comparison of your results with the model studies that examined mixing of vortex air into the mid-latitude stratosphere mentioned in the introduction. Have you done comparisons with model studies?

Only with the study of Günther et al. (see Conclusions) as the other studies that were mentioned focus on potential temperatures above 400 K (so does Günther) and describe late spring. Furthermore, these studies do not provide comparable fractions in the LMS region.

Pg. 1412, lines 2-7: You say the same thing just below this paragraph so it doesn't seem necessary here.

ok.

Pg. 1415, line 19: the "K" should be removed from "60 K ppb".

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ok

Pg. 1416, line 16: "exemplarily" should be removed.

ok

Pg. 1420, line 3: This is an awkward sentence and I would suggest removing "As the tracer data were gathered" and begin with "In the vortex..."

ok

Pg. 1425, line 7: "lead" should be "led". Pg. 1429, line 10: "criterium" should be "criterion".

ok

Pg. 1429, line 12: How was the vortex edge located below 400K of 67N chosen?

Since the criterion for the vortex edge is not applying below 400 K, the average position of the vortex edge above 400 K was used and extended to theta levels below 400K. I have clarified this in the revised version.

Figures 8 and 9: It would be useful to use the same x-axis scale on all of the plots in order to more easily see the relative contributions from each region.

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The Figs will be changed and the X axis adjusted.

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