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Atmospheric Chemistry and Physics Discussions

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

A. Werner et al.

anja.werner@dwd.de

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to Anonymous Referee 2:

P1409 L3-8: This is just one side of the coin. There are a couple studies showing that isentropic transport is not the only way to influence tracer distributions in the LMS. Diabatic processes through convective events (Poulida et al. 1996, Hegglin et al. 2004), pyro-convection (Fromm et al. 2006), or radiative processes (Zierl and Wirth 1997, Bourqui 2006) are as well important, although their relative importance has not yet been quantified. Please complete this discussion in the manuscript.

I agree. This has been included.

p1411 L3: see previous comment, add 'cross-isentropic' to 'quasi-isentropic' in i)

Actually, this simple mass balance model does not separate between all possible transport processes across the tropopause. Nevertheless, the dominant transport process for air masses that entered the LMS will be fast quasi-horizontal transport from the tropopause region, especially at higher theta levels. Further winter time processes are regarded - a time when convective processes are only weak.

P1411 L17-20: except for H2O, since air parcels are being dehydrated when crossing the tropical cold-point tropopause.

Yes, the referee is right. That is why H2O is considered in an extra section (sec 4.4 , p.1418f). As the here mentioned section is the part where the basic equation system is described, I a skipped detailed discussion here. However, I included " ... which exhibits a similar chemical composition as the upper troposphere for **most** of the tracers considered here (**see section 4**)."

P1415 L4-11: I don't understand this point. Do you try to say that although the latitudinal and therefore spatial variability is high (which is due to strongly changing innervortex values), the temporal variability at least at mid-latitudes is small?

The referee refers to the section, where a constant boundary condition is motivated. Of course due to ongoing descend of air from above 380 K there is a seasonal change of air masses between autumn and winter. But comparisons of several in-situ mea-

surements of the regarded tracers (as described in the paper p.1415, l.8) at 400 K in the mid-latitudes (but well southward of the vortex edge!) in autumn and winter show relatively small differences in the mixing ratio for ie. N2O:4%, CFC-11: 9%, CH4: 3% (plot for CH4 attached;), For the more sensitive tracers like O3 (35%) or H-1211 (12%) this change is more severe. Nevertheless, the inter-seasonal variability is of the same magnitude (average of the January O3 data: 614 ppb $\pm$ 200 ppb, H-1211: 3.28 ppt $\pm$0.3 ppt). Thus the this boundary is described with a constant mixing ratio, however, considering the variability (temporal and spatial) with a very conservatively estimated error (see p.1415,l.22,23 and Table 1 on p. 1436).

I re-formulated this paragraph.

P1415 L21: How did you determine the natural variability with a limited data set?

I did not; however at this point I assume that the variability captured by our measurements (though well distributed over several degrees of equivalent latitude and span a time interval from autumn to winter) will certainly not describe the total atmospheric variability. Thus, I tried to be as conservative as possible with the determination of the error and included the total span of the respective measurements.

P1416 L10-11: Which observations do tell you this? For example, a compilation of O3- N2O correlation slopes in the lowermost stratosphere by Hegglin and Shepherd (2006) shows changes in the slopes of around 15

Correct, the correlation slope changes indeed (also seen in Hegglin et al., 2006). What I really intended to say was the following: The compact, nearly linear correlation of O3 and N2O in the LMS is conserved. This shows that O3 is not effected by local chemistry, otherwise the correlation to a long-lived tracer like N2O would not stay linear.

I changed that paragraph - thanks for pointing out the weak explanation!

P1427 L14-15: I'm wondering about the consistency between your results which indicate that tropospheric influence is close to zero above 360K and the results from Hoor et al. (2004) which shows that there is substantial influence from the tropical troposphere during autumn and winter, i.e. between 30 and 50%, at altitudes up to 370K.

The main reason is due to the fact that both studies regard different boundary conditions and a different frame of reference (i.e. Hoor does not regard the vortex). Additionally, I only consider the time between autumn and winter, thus any tropospheric influence that already exists in autumn is neglected: The composition of the air masses at the stratospheric boundary at 400 K (average of autumn an winter data) might of course be influenced by tropospheric air. Thus, the here presented fractions refer to the time frame autumn/winter and to the changes since then. I have clarified this point in the conclusions.

Figure 8: The tropospheric fraction above 360K is negative, which is unphysical. Doesn't this imply an error in the boundary conditions or a missing transport process?

As pointed out in section 5.2., p. 1422, the boundaries especially at 400 K exhibit rather large error bars (especially the dynamical vortex boundary, the data point might be below the referring vortex boundary value) and the available tracers do not provide sufficient constraints to fully solve the equation system.

Missing transport processes maybe inhomogeneous descent. And of course the lacking ability to really separate between the tropical stratosphere and troposphere with the available tracer set and coverage.

P1408 L1-3: suggest rewriting this sentence (it sounds awkward) and starting next

sentence with 'The LMS...'. P1409 L3: correct 'Haynes and Shepherd'

ok!

P1412 L12-13: Please spell out and shortly explain 'QR' and 'QL'. Not everybody knows what these acronyms mean.

QR and LQ - Algorithms are the established names for the below given matrix decomposition and not really an abbreviation. I still think a more detailed description is not necessary as the referring cites were given in the paper.

QR: Here a Matrix A(nxm) can be written as, i.e. A = Q * R, where Q is the quadratic nxn matrix and R the upper right triagonal nxm matrix. LQ: A = L * Q, here the L ist the lower (left) triagonal (nxm) matrix.

P1412 L25: Please provide the campaign period or flight days.

A table containing this information has been added!

P1413 L15: What is the accuracy of the FISH measurements?

precision of the measurements is roughly 0.2 ppm, the accuracy 4% (Zöger et al, 1999)

P1415 L19: delete 'K' in between '60' and 'ppb'.

ok

P1420 L24: Could you say already here on what the normalization and the weighting factor are based on (just in a couple words)?

Indeed, I originally had it written this way but after some test reading it was banned into the appendix as "a couple of words" led to more confusion than clarification and still prefer to keep it there.

P1423 L10: change 'lead' to 'led' Figure caption 9: rather write 'Same as in Fig. 8, but for the AVC campaign.'

ok.