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Interactive Comment

Interactive comment on “The impact of mid-latitude intrusions into the polar vortex on ozone loss estimates” *by* J.-U. Grooß and R. Müller

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General:

The paper addresses the potential impact of mixing across the vortex edge on ozone loss estimates for the Arctic polar vortex. It focusses on two different approaches to quantify Arctic ozone losses. These are the "vortex average approach" and the "Match" approach. To estimate how mixing accross the vortex edge impacts these empirical approaches, the lagrangian model CLAMS is used to quantify the mixing.

The degree of mixing accross the vortex edge and its impact on empirical estimates of Arctic ozone loss are subject to ongoing scientific discussions. The lagrangian model CLAMS with its unique capabilities to adjust the model mixing to the real atmosphere

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Interactive Discussion

Discussion Paper

is a perfect tool to study these processes and the paper is a valuabe contribution to the discussion.

However, the paper generally suffers from a mixing between parts that address potential biases of the vortex average approach and of Match. These two approaches are completely different, but during large parts of the paper the reader can easily get confused about whether the respective paragraph or sentence applies to the vortex average approach or to Match. This can be fixed easily, perhaps by some reorganisation of the paper.

The parts addressing the impact of mixing on the vortex average approach are generally in relatively good shape. The choosen approach is sound and the results are reliable upper limits for the impact of mixing. They are upper limits, since there is an important difference between the vortex average approach and the calculations presented in this paper: Here the vortex edge has been defined by a constant PV value, but for the the vortex average approach it is crucial to rely on a defintion for the vortex edge that follows the mixing barrier, i.e. a varying PV value has to be used (more details are given in the specific comments).

The parts addressing the impact of mixing on the Match approach are somewhat more problematic. The Match approach goes a long way to avoid air masses that have been influenced by mixing. An automatic filter mechanism sorts out matches based on various criteriae that identify air masses that may have been influenced by mixing and excludes them from the analysis. This is completely ignored in the "virtual Match" calculations, which are the basis for this part of the paper. If anything, the results can be interpreted as upper limits, which probably largely overestimate the impact of mixing on Match results. Nonetheless I find the results interesting and important. The main message is, that even these large upper limits are sufficient to demonstrate that the discrepancy between Match and model calculations of chemical ozone loss cannot be explained by a mixing induced bias in the Match calculations.

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The paper focusses on just two weeks in January 1992. This is a period when the vortex was highly disturbed by a strong warming event. The degree of mixing during this period is perhaps larger than during any other mid-winter time period during the past decade, perhaps only comparable to late January 2003. It is definitely not representative for normal vortex conditions. The paper would largely benefit from looking at other winters and time periods to come up with more representative result. Unless this is done, it must be clearly mentioned (in the abstract and the conclusions), that the period studied is not representative for "normal" vortex conditions, but rather quantifies the mixing induced bias under the worst conditions.

I think the paper makes a valuable contribution and it should be published based on the current calculations. But it is important to point out the above mentioned differences between the calculations based on the model and the empirical approaches and to clearly note that the calculated biases are upper limits, which for Match probably largely overestimate the true impact of mixing.

Specific comments:

2490, 10 - 14:

This needs to be rewritten, based on the comments below. For me the defendable message of the paper seems to be: If there is any influence of mixing on the Match results, it is smaller than the stated one sigma uncertainty of the results. The paper basically shows that mixing is not a major concern for Match. Specifically any mixing bias cannot explain the discrepancy between Match results and modelled chemical ozone loss for January 1992.

2490, 18:

... and by mixing ...

2491, 7:

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Since the paper discusses the potential impact of mixing on the Match analysis, I think the measures that are taken in Match to avoid mixed air masses need to be mentioned here. E.g.: ...analysis. A selection procedure based on parameters like the local vertical ozone gradient and the dispersion of trajectory clusters is used to avoid regions of strong mixing.

2493, 15-24, Figure 3:

The discussion here and the violet circle in the Figure are very misleading. They suggest a sounding anywhere within the match radius (or the circle in the Figure) could result in a match. This is not the case. Filament structures like the one seen at the left hand side of Figure 3 are tilted layers of extravortex air. In vertical ozone soundings they appear as pronounced narrow layers of low ozone (below ˜500 K, above ˜550 K they usually appear as layers of high ozone), the well known lamina structres. These can be clearly identified by the steep vertical ozone gradients below and above the lamina. The automatic selection procedure that is part of the match analysis scans the ozone profiles in the vertical region of the match and discards matches that are impacted by laminae.

2493, 25 - 2494, 20:

These two paragraphes describe how the "mixing error" impacts the vortex average approach and the Match approach respectively. The first paragraph focusses on the vortex average approach, the second on Match. I have a few problems with these paragraphs:

- The first paragraph obviously addresses the impact of mixing on the vortex average approach and concludes that mixing can have a major impact on ozone losses derived with this approach. This is well known and is the main reason why the Match approach was developed. But this paragraph starts with "To be comparable with the Match analysis ..." and seems to suggest that the mixing problem described here relates to Match, which I find confusing.

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- In principle the first paragraph and Figure 4 could be used to quantify the impact of mixing on the vortex average approach. However, for the vortex average approach the vortex edge definition is crucial, which is not the case for Match. In this paragraph the authors have mixed elements from Match (the vortex edge definition from Match, i.e. constant PV) with the vortex average approach and have quantified the error due to mixing for this hypothetical approach. This is not really helpful since published ozone loss analyses from the vortex average approach rely on a vortex edge definition that follows the mixing barrier, e.g. the strongest PV gradient. Hence, these studies are less influenced by mixing. Nonetheless the results from the analysis in the paragraph are very useful, since they put an upper limit on the "mixing error" of vortex average studies.

- The "virtual Match" calculation described here ignores three basic features of the real Match approach, which sort out matches that are impacted by dynamical processes. These are (a) the "lamina scan" (three height dependend thresholds for the maximum vertical gradient of the ozone mixing ratio profile for three theta intervals around the Match level), (b) a threshold for the maximum change of PV along the trajectory, and (c) the "cluster trajectory analysis" that basically gives the integrated horizontal divergence and the integrated wind shear along the trajectory and is a good measure for the precision of the trajectory and for the degree of mixing expected for this individual air mass. I think the results from the "virtual Match" analysis are very useful upper limits for the bias of the Match results due to mixing. But it must be clearly stated that these estimates are upper limits and are probably largely overestimating the true bias.

2495, 21-23:

Why is this paragraph related to Match ? I think mentioning Match here easily confuses the reader, since the paragraph is really only applicable to the vortex average approach.

2495, 27 - 2496, 2:

This would be a good place to point out that the real vortex average approach (using

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a variable definition for the vortex edge, that follows the maximum PV gradient) would probably result in even smaller biases and that the results presented here should be interpreted as an estimation of the upper limit of the bias.

2496, 15:

Why "... in a similar manner" ? Even when ignoring the additional measures in Match to avoid mixing, this should read " ..., however, to a lesser extend", since intrusions that are larger than the matchradius are avoided.

2496, 13 - 2497, 5:

The main features of Match that are designed to avoid mixed air masses and impacts from streamers (points (a), (b), and (c) above) are ignored. So this discussion only makes sense if right from the beginning it is explained that the goal of the calculations is to come up with an upper limit for the bias due to mixing.

2497, 6 - 18:

I have large difficulties with this part of the analysis for two reasons: - Unless the rest of the paper this paragraph relies heavily on the accurate representation of the small scale ozone variability inside the polar vortex. The generation of the small scale ozone structure well within the vortex is a complicated interplay of differential subsidence, small scale intra vortex mixing, and synoptic scale features of the wind field. From these processes only the last point is represented physically in the model. Differential subsidence is not taken into account and small scale mixing is represented by a mixing parametrization. This parametrization is based on the degree of shear in the flow and it has been tuned by comparing filament structures in the model with observations. The filament structures are always related to a high shear situation. So the mixing parametrization is well tuned and tested for the high shear situation at the vortex edge and in the vicinity of filaments. It is much less clear how well the small scale mixing is represented in CLAMS for the quite flow well inside the vortex. Aircraft observations

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(e.g. ER-2 during AASE and SOLVE) suggest that the small scale fluctuations of ozone well inside the vortex are quite small. If any significant and consistent differences between the scatter of deltaO3 from Match and the "virtual Match" would be found, we could probably conclude that the mixing parametrization for the low shear situation well within the vortex is too weak in the model (How could the scatter in the Match analysis be systematically off ??). But from comparing the scatter for just one point and given the further limitations as described below, I do not think we can learn much from the comparison.

- The filter parameters (a), (b), and (c) as described above sort out matches that are in areas where the ozone field is highly structured. Since these parameters are ignored in the "virtual Match" it is not surprising that a larger statistical scatter is found. The comparison is in fact a good measure for the effectiveness of the filter procedure in Match, with the caveats mentioned above.

2497, 2:

The mixing bias should first be compared to the Match result itself and put into some perspective, i.e. it is less than 20 %, which is in the order of the stated 1 sigma statistical uncertainty.

2497, 20-27:

The conclusions need to be rewritten, based on the above comments. In my mind the main conclusion is, that an estimate of upper limits for the impact of mixing results in a relatively minor bias for the Match results - in the order of the one sigma uncertainty - even for the time period of strong mixing in January 1992. It must be clearly mentioned that this estimate probably overestimates the true impact of mixing. Hence, this study shows that mixing is not a major concern for Match.

Interactive comment on Atmos. Chem. Phys. Discuss., 2, 2489, 2002.

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