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Atmospheric Chemistry and Physics Discussions

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Interactive Comment

Interactive comment on "The impact of mixing across the polar vortex edge on Match ozone loss estimates" *by* J.-U. Grooßet al.

J.-U. Grooßet al.

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Reviewer #2 raises many fundamental issues about the CLaMS model and methods of determination of chemical ozone loss. Owing to this criticism the reviewer does not discuss the main points of the paper that is the comparison of ozone loss estimates by CLaMS and Match (point 2.2.0.8.).

However, we think that most of the criticism is caused by mis-understanding and the reviewers derived interpretation of some model details that probably could be described better in the paper. The reviewer characterizes himself/herself as working in a neighbored discipline. We therefore try to clarify the main points raised at this time and postpone a detailed answer to the reviewers arguments to a later time.

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1 Ozone budget

The aim of this paper is not to derive the ozone budget. We would understand the term ozone budget as a quantitative comparison of chemical production and loss processes of ozone. In the polar winter stratosphere, there are no major ozone sources and sinks besides chemical ozone loss. The quantity of interest to many studies (including this one) is the chemical ozone loss integrated over the winter. This represents the amount of ozone that is missing due to chemical destruction by the end of the winter. This quantity "chemical ozone loss" can be evaluated for a specific location, but is typically averaged over a given area; often the polar vortex is chosen as such an area. Note that the area of the polar vortex will change with season, so that the averaging is often not performed over a fixed size "control volume".

Due to variability of ozone mixing ratios caused by "dynamical processes", i.e. advection and mixing, this quantity is not easy to diagnose and therefore different sophisticated methods have been developed, one of which being the Match method (Harris et al., 2002; WMO, 2003).

2 Methods to determine ozone loss

In simulations, the use of two ozone tracers, O_3^{pass} and O_3^{chem}, is a rather common method to diagnose chemical ozone loss (Lef‘evre et al., 1994; Hansen et al., 1997; Chipperfield and Pyle, 1998; Goutail et al., 1999; 2005; Grooß et al., 2002; Konopka et al., 2007). At a reference time (i.e. beginning of the winter) O_3^{pass} and O_3^{chem} are initialized identically over the whole model domain (not only within a control volume). Both tracers undergo the same advection and mixing procedures, and only O_3^{chem} is changed by chemical reactions. Therefore, the difference O_3^{chem}–O_3^{pass} always contains the simulated chemical ozone loss by definition. This quantity can then be averaged

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and vertically integrated over a “control volume” to achieve a quantity that is comparable to the quantity derived from observations. For this rationale, no fluxes across the “control volume boundary” need to be considered.

One of the main reasons for this study is the discrepancy of ozone column loss determined by the CLaMS model and the Match technique. The results labeled “CLaMS method 2” by the reviewer are an attempt to mimic the Match time integration of vortex average ozone loss rates over the winter. We agree with the reviewer that this neglect of flux through the vortex edge (and potentially non-uniform descent) is problematic when deriving column ozone loss. However, this approach is used by the Match method. So we have to follow exactly the procedures of Match (Rex et al., 1997, 1998, 1999; Streibel et al., 2006). We show in our paper that this is the cause for part of the considered discrepancy.

3 Questions to the CLaMS Model setup

The reviewer raises questions about spacial and time resolution of CLaMS. The model CLaMS has been documented carefully in the scientific literature (McKenna et al., 2002a,b; Konopka et al., 2004; Grooß et al., 2005; Becker et al., 2000), where the issue of the vertical and horizontal resolution, the impact of the chosen time-step on the mixing intensity in CLaMS and further model issues are reported and discussed in detail. Results of CLaMS with similar resolution have been extensively compared with observations. It was shown that the model is especially able to reproduce small scale structures with the size of down to about 100 km (Konopka et al., 2004; 2005). Regarding mixing, the mixing scheme of CLaMS that is non-isotropic in space and time and that is driven by flow deformation has been shown to generate results that compare well with observations (McKenna et al., 2002a; Konopka et al., 2004). Figures 1 and 2 are also examples of this ability of the model to successfully reproduce the distribu-

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tion of chemical tracers in the stratosphere which suggest a successful simulation of advection and mixing.

Gravity waves are of importance for transferring momentum from the troposphere to the mesosphere. As long as the waves are not breaking, they should not significantly change the mean advection of an air parcel. There is no doubt that breaking gravity waves may cause mixing in the real atmosphere. But of course, single breaking gravity waves cannot be represented in todays atmospheric models. The mean effect of breaking gravity waves on the flow is implicitly represented through the ECMWF wind fields.

Thus, based on the published studies we conclude that CLaMS simulations using 6-hourly meteorological analyses as input have an adequate accuracy assessing the problems mentioned in this study.

4 Mixing through the vortex edge

The reviewer is right in the point that we have used the phrase "mixing through the vortex edge" where we should have rather used "transport through the vortex edge". Often the polar vortex is viewed as well isolated volume without significant flux of air through its edge. The transport through the vortex edge is illustrated by the shown quantity "vortex tracer", that is defined as the fraction of air in a given air parcel (or volume) that originated from inside the vortex at the begin of the simulation. One major point we want to make with this study is that a neglect of transport (or flux) through the vortex edge has important consequences on the derived chemical ozone loss estimate.

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