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Interactive Comment

Interactive comment on "The impact of tropical recirculation on polar composition" *by* S. E. Strahan et al.

Anonymous Referee #1

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General Remarks

This paper uses observationally derived mean age and modal age as diagnostics for model evaluation of tropical stratospheric transport characteristics and their influence on chemical composition of the stratospheric polar region. The results of this paper are significant and highlight the great importance of multiple observationally derived diagnostic tools in order to improve the evaluation of modelled stratospheric transport. Otherwise compensating errors could mask deficiencies in model transport. I have a few issues with the details of the method and the interpretation of some of the results, which are discussed below. I recommend publication with consideration of the following comments.

Specific Remarks

CH_4 in the upper stratosphere ($<$3 hPa and $>$0.1 hPa) is controlled by transport, but also by chemistry. Both time scales are in the order of a few months. Therefore CH_4 is still a proxy for mean age but the distribution is also strongly affected by chemical processes there. That means your results depend on simulated methane photochemistry in the upper stratosphere or even the lower mesosphere (if you look at the polar vortex region). I absolutely agree with the authors that the too strong isolation of the tropical pipe (GMI-GCM) leading to enhanced methane in the upper tropical stratosphere and impacts the methane distribution in the upper polar vortex region, but it can not be seen independent from the photochemistry code of your model. The authors make a remark about this topic at the end of paragraph 3.2. However, it would be reasonable to make this statement at a more prominent place. Alternatively it would be even better if the authors could find a way to roughly assess the uncertainties in modelled upper stratospheric and mesospheric methane loss. (Maybe this could be done by increasing the reaction rates describing stratospheric methane destruction to the upper limits of reasonable values in a reference run.)

2. Observation, Analyses and Models

It would help to write a few sentences about the details of the meteorological fields here, e.g. instantaneous or averaged, 3d- or 4d-var assimilation, 3-hourly or 6-hourly … Especially for stratospheric simulation the choice of the meteorological fields could have an impact on mean age of air and therefore also on the CH_4 distribution. A short comment on this topic should be done here.

p-7, l-1ff Why you are using different time series of meteorological fields and therefore different source gas boundary conditions also? This leads to an inconsistency in the comparison of both simulations with the HALOE observations (1993-2001). 1) For the time period 1994 – 1998 tropospheric CH_4 was still increasing whereas the trend has reached a constant level during 2004 – 2006 which is about 40 ppb

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higher than 1996 (see e.g. NOAA/ESRL CH4 time series Mauna Loa and American Samoa). These different CH4 boundary conditions would lead to slightly different CH4 levels in the stratosphere also. 2) Enhanced tropical upwelling after 2001 results in colder temperatures, lower water vapour and lower ozone near the tropical tropopause (Randel et al., 2006). This step-wise feature of changing tropical upwelling is most likely not present in CTM simulations with GEOS4-GCM winds but it should be present in simulations with “real” meteorological fields, i.e. from GEOS4-DAS. That means, that if you choose the same period (from 1994 – 1998) for the GMI-DAS as for the GMI-GCM simulation, you might get a different result (older modal and/or mean age for the GMI-DAS?).

3. Stratospheric circulation and the tropical pipe

p-9, l-10 To my point of view, the vertical velocities are only in good agreement between 21 and 26 km. At the level of 20 km GMI-GCM values are half of the vertical velocities derived from the tape recorder and there are significantly outside the 2-sigma error bars.

p-9, l-17ff Could you give a comment on the representativity of the mean age of air profiles derived from CO2 and SF6 OMS balloon measurements? In Andrews et al. (2001) there are only three balloon borne profiles - all from 1997.

p-10, l-4 I think that the correlation between mean age and methane already weakens in the upper stratosphere (see general remark also). This can be explained by the shorter lifetime of CH4 at higher altitudes, which leads to decorrelation, as shown by Plumb and Ko [1992].

p-13, l-2ff The formulation here is a bit misleading. The empirical derived modal age represents a lower limit on the transit time and therefore an upper limit (not a lower limit) for the ascent rate.

p-13, l-11f What is the (main) reason for the smaller CH4 photochemical loss rates in

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the tropical upper stratosphere in the GMI-DAS simulation?

p-13, l-15ff For the discussion of the high latitude CH4 distribution derived from the GMI-DAS (Figure 7) it would be helpful to add the midlatitude most probable profile from HALOE in the same way as it has been done for the GMI-GCM (Figure 4). Furthermore, I do not really agree to your statement here that vortex isolation of GMI-DAS above 50 hPa is good, especially if you look at the PDFs itself. The CH4 distribution is smeared out in the vortex. There is no pronounced CH4 mixing ratio in the vortex as it is prominent for the HALOE observation as well as for the GMI-GCM simulation (see small yellow, orange and red coloured band in Figure 4 which is missing in Figure 7).

4. Discussion and Summary

You point out that age spectra of the GMI-DAS simulation show the characteristic of a leaky polar vortex – as it is also demonstrated by the CH4 profiles (see comment above). To my opinion you should move Figure 8 and its interpretation to section 3.4 because the interpretation of the CH4 profiles are closely related to the age spectra. Alternatively you could add an extra section, e.g. 3.5 Mean age in the polar region.

Figures 2c The colour bar is missing. The colour coded age spectrum in Figure 2c does not really provide an additional information for the interpretation here. To my opinion, the main message of Figure 2c - the too weak recirculation diagnosed from the difference between mean and modal age - is even diluted by this additional displayed age spectra.

Figures 4, 7 The colour bars are missing.

Plumb, R.A. & M.K.W. Ko (1992), Interrelations between mixing ratios of long-lived stratospheric constituents, J. Geophys. Res., 97, 10145-10156.

Randel, W. J., F. Wu, H. Vömel, G. E. Nedoluha, and P. Forster (2006), Decreases in stratospheric water vapor after 2001: Links to changes in the tropical tropopause and the Brewer-Dobson circulation, J. Geophys. Res., 111, D12312,

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Interactive Discussion

Discussion Paper

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