

***Interactive comment on* “Simulation of stratospheric water vapor trends: impact on stratospheric ozone chemistry” by A. Stenke and V. Grewe**

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General comments

The referee made some general comments on the model’s ability to reproduce the basic atmospheric processes crucial for the present study which show that it has to be put more effort on describing the model performance.

Water vapour bias

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The referee stated that simulated stratospheric water vapour amounts are 50% higher than observed (Figure 1), even though the water vapour climatology of the model published in Hein et al. (2001) looks reasonable. A comparison between the modeled water vapour climatology and HALOE satellite observations as shown in Hein et al. (2001) (Figures 13 and 14) reveals that stratospheric H₂O mixing ratios are systematically higher than in the HALOE observations. In the region 40°N and 20 hPa the HALOE mixing ratios range between 4.5 and 5 ppmv throughout the year, whereas the modeled mixing ratios range between 6 and 7 ppmv. Thus the difference between the mixing ratios in the transient model run and the Boulder time-series (Figure 1) is of the same order of magnitude as the difference between the climatology in Hein et al. and HALOE observations. The overestimation of H₂O mixing ratios is no specific feature of the new transient model simulation. Generally, the water vapour distribution in the transient model run is as reasonable as the climatology in Hein et al. (2001).

Methane and upper boundary

The referee is right that methane is only reduced by 1/3 up to the model top in terms of mixing ratios. However, before we show that this feature is reproduced by the model, let us first comment this point. Looking at the methane mass which is reduced, the picture is somehow different. 1/3 in mixing ratios means approximately 0.5 ppmv, but in 99% of the atmosphere (1000 hPa to 10 hPa). The rest of the CH₄ decomposition of 1.2 ppmv occurs in 1% of the atmosphere. In terms of mass this is then only 2.5%, which is missed in the model.

A model bias concerning the methane oxidation as the referee supposed seems not to be responsible for the enhanced H₂O mixing ratios. In the tropics the modeled methane amounts decrease from about 1.6 ppmv near the tropopause to about 1.2 ppmv near the model top, which is in good agreement with the HALOE data. In

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high latitudes the modeled methane amounts near the upper boundary are higher than observed which can be taken as an indication for an upper boundary effect as mentioned in Hein et al. (2001). Nevertheless the quantity $\text{H}_2\text{O}+2\text{CH}_4$ does not show a substantial increase towards the upper boundary. Thus the authors expect that the upper boundary has only little impact on the simulation of stratospheric water vapour. Other quantities like the tropopause temperature or the advection scheme are rather supposed to affect the water vapour distribution. A comparison between the modeled temperature distribution and ECMWF reanalyses shows a temperature bias near the model's tropopause which is apparent in most general circulation models. The modeled tropopause is slightly raised and slightly to warm. This temperature bias results in enhanced entry level mixing ratios. Modeled entry level mixing ratios amount approximately 5.9 ppmv (annual mean), whereas observed entry level mixing ratios range between 3.6 and 4.1 ppmv (SPARC Report No. 2).

Water vapour increase in the transient model run

The transient model run shows a water vapour increase which is mainly associated with temperature changes at the tropical tropopause and to some extent with the methane increase. Several publications indicate that stratospheric water vapour increases or has been increasing (Rosenlof et al., 2001, Oltmans et al., 2000). Indeed, recent measurements show a (unexplained) decrease of stratospheric water vapour since the year 2000 which seems to be linked to temperature variations at the tropical tropopause (Randel et al., 2004). Taking into account the overall uncertainties in the discussion on stratospheric water vapour trends the model behaviour is reasonable and the magnitude of the simulated water vapour increase is comparable with observations.

As the referee has suggested we will include a short section to the paper explaining the above mentioned points concerning the modeled water vapour distribution.

Polar ozone chemistry

A detailed model validation of the stratospheric ozone layer by Hein et al. (2001) showed that the model is able to reproduce the temporal occurrence of the antarctic ozone hole in late September/early October as well as minimum total ozone values below 125 DU inside the polar vortex. Furthermore the modeled stratospheric polar vortex dynamics in the northern hemisphere show good agreement with observations, in terms of climatological mean states as well as interannual variability. However, as reported in Hein et al. (2001), there are some model deficiencies which appear to be linked to the cold bias in the southern polar stratosphere during antarctic winter and spring. The cold bias is a well-know feature of GCMs and also present in a number of middle atmosphere GCMs (e.g. Pawson et al., 2000). Current studies indicate that the cold bias in our model is related to the water vapour bias in the extratropical lowermost stratosphere. Nevertheless, the results of Hein et al. (2001) and Schnadt et al. (2002) show that CCMs with a model top centred at 10 hPa and an adequate vertical resolution in the tropopause region are appropriate to investigate chemistry-climate interactions in the lower stratosphere. A recent comparison between different chemistry-climate models by Austin et al. (2003) has shown that low top models can reproduce the observed geographical distribution of total ozone as well as high top models. Over the southern hemisphere in October the two models with the lowest upper boundary (one of them was our model) have even shown the best agreement with observations.

In the current model set up some updates have been carried out, but the general model climatology is the same as in Hein et al. (2001). The ozone distribution in the transient model run will be presented in a separate paper by Dameris et al. which is in preparation.

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The referee wondered how the simulated water vapour increase could increase the ozone loss in a region with virtual complete ozone loss. The simulated water vapour perturbations mainly affect the altitude region between 30 and 50 hPa which is below region of maximum ozone depletion in the unperturbed case (≈ 20 hPa). Furthermore, the main effect of the additional water vapour on total ozone occurs at the end of October and in November that means the ozone-hole duration is extended. In order to provide detailed insights in the perturbed polar calculations we will add the respective figures (e.g. change of chlorine compounds, PSCs) and discuss these results in respect of the unperturbed polar ozone chemistry.

Specific recommendations

Thanks a lot to the referee for his effort to improve our manuscript! There are a lot of very useful suggestions of the referee which we will include in the text. For example, to clarify the structure of our manuscript the summary of atmospheric chemistry will be removed. Instead the relevant reactions will be listed in the appendix. The referee's comments show that there are some points which are ambiguous and have to be better explained in the text. We will revise our manuscript seriously to meet the referee's comments.

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