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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Implications of Lagrangian transport for coupled chemistry-climate simulations" *by* A. Stenke et al.

A. Stenke et al.

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We thank the reviewer for their comments. We believe that these comments have helped to improve our manuscript. In the following we provide our response to the specific comments of the reviewer, listed according to their sequence.

General Comments:

- *"I invite the authors to discuss what the E39C-A with its known proficiencies and deficiencies is best suited."*

  As in the past, the model E39C-A is and will be used for studies concerning dynamics, chemistry and transport processes in the upper troposphere/lowermost stratosphere. Within this atmospheric region the model has a much higher vertical resolution than other CCMs, especially than middle atmosphere models. We are aware of the limitations given by the low model top. However, our study has shown that applying realistic boundary conditions E39C-A is also able to capture changes in stratospheric ozone. We have added a short paragraph on the fields of application of E39C-A in the conclusions.

- *"... it would be nice to see a short summary (perhaps in the conclusions?) describing the ways in which improved transport affects model dynamics."*

  We have revised the whole paper thoroughly in order to explain the cause and effect relationships between changes in tracer transport and model dynamics in more detail. In particular we extended the respective discussion (second paragraph) in the conclusions.

Minor Comments and Questions:

- p. 18733, l. 18: We agree that the mean age of air with ATTILA as presented in Reithmeier et al., 2008, is still younger than observed, but in the MM2 model intercomparison ATTILA lies at the upper bound of the model range.

  In E39C-A dynamical feedbacks lead to a further increase in the simulated mean age of air. To demonstrate this improvement we have included an additional figure showing the mean age spectrum for both model versions.

- p. 18736, l. 6-7: CO_2 is not prescribed as a 3D field, but as an atmospheric mean volume mixing ratio. For example, a CO_2 concentration of 353 ppmv is used to represent the year 1990. The respective sentence has been re-written.

- p. 18738, l. 15-17: The most important diagnostic for the analysis of the strength and the direction of wave propagation and eddy dissipation are the EP fluxes and divergence fields. These quantaties are usually compared to EP fluxes and

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divergence fields derived from observations, i.e. re-analyses (e.g. Hitchman and Huesmann, 2007). The term “The transfer of wave energy from one latitude and height to another is correctly simulated . . . ” means that the direction and the norm of the EP vectors are comparable to re-analyses.

- p. 18738, l. 27-29: As a first approximation we assume that the tropospheric wave activity is similar in both model versions. Due to the changes in the transport in radiatively active species and the resulting temperature changes, the simulated wind fields and, therefore, the conditions for wave propagation and dissipation change. Of course the changes in model dynamics can also impact, e.g., convective wave activity. As mentioned above (general comments) we revised our manuscript thoroughly discussing the mechanisms leading to improved model dynamics in more detail.
- p. 18739, l. 20-22: As shown in Stenke et al. (2008) the changes in water vapour transport and the associated reduction of the wet bias in the extratropical lowermost stratosphere lead to less radiative cooling and a reduction of the simulated cold bias. Of course in E39C-A other radiatively active species like ozone also contribute to temperature changes, but the changes in water vapour transport are the key driver. A short explanation of this mechanism has been introduced at the beginning of Section 3.1.
- p. 18739, last paragraph: The advanced numerics of the Lagrangian advection scheme lead to improved tracer distributions. Changes in the simulated distributions of radiatively active species like H_2O or O_3 feed back to modelled temperatures and circulation. In turn, the improved model dynamics have an impact on the tracer transport. The presented results include all coupling and feedback processes. The paragraph has been re-written in order to clarify this point.
- p. 18740, last lines: We agree with the reviewer that vertical diffusion also plays a role here. A short note has been added.

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Fig. 4: The HALOE contours have been added on the E39C and E39C-A figure.

- p. 18742, l. 1-21: Paragraph has been re-written as suggested by the reviewer.
- p. 18743, l. 17-19: We checked the CCMVal evaluation table. The suggested tests depend either on CH_4 or N_2O. As in the case of CH_4 the stratospheric N_2O sink is unrepresented in our model and, therefore, the polar N_2O values are overestimated.

  Struthers et al., ACPD, 2008, analyzed the position and strength of the mixing barrier at the Antarctic vortex edge in different CCMs including E39C and E39C-A. Their diagnostic indicates that the strength of the mixing barrier is underestimated in both model versions E39C and E39C-A.
- p. 18744: Yes, both model simulations use the same Cly upper boundary conditions. The Cly upper boundary values are taken from the 2D middel atmosphere model by Br184;hl and Crutzen (1993) in which the CFC emissions at the surface are prescribed. Therefore, the Cly upper boundary is consistent with the assumed total Cl of the emissions.

  We have included a figure showing a midlatitude Cly comparison between both model versions. Like in polar regions E39C-A shows enhanced stratospheric Cly values and a very good agreement with the measurements shown in Waugh & Eyring, ACP, 2008.
- p. 18745, l. 25-27: The improved representation of the ozonopause results from both, the change in the location of the tropopause and the improved tracer transport. From Fig. 9 it is obvious that the change in the ozonopause height (approx. 100 hPa in the extratropics) is larger than the change in the tropopause height (approx. 25 hPa in the extratropics), i.e. the reduced diffusion of the advection scheme also plays an important role.

- p. 18746: The height of the ozonopause in E39C-A agrees very well with observations. The reason for the overestimation of total ozone in E39C-A is that the ozone concentrations at the ozone maximum are too high, despite higher Cly values and cold enough temperatures. According to our opinion this indicates a problem in the modelled ozone chemistry. We agree that the upward shifted ozonopause in E39C compensated, at least in part, the larger stratospheric ozone concentrations. But that means that in E39C the total ozone was better due to the wrong reasons.
- p. 18748, l. 19-24: Paragraph has been re-written as suggested by the reviewer.
- Figure 7 and 8: Legend has been added.
- Figure 8 and 9: Differences and anomalies derived from observations have been included.

Language/Technical corrections:

- We have revised the text as suggested by the reviewer. We thank the reviewer for their time and efforts.

Interactive comment on Atmos. Chem. Phys. Discuss., 8, 18727, 2008.

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