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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Impact of Lagrangian Transport on Lower-Stratospheric Transport Time Scales in a Climate Model" *by* Edward J. Charlesworth et al.

Anonymous Referee #3

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Representation of air mass transport processes in the atmosphere, including in the upper troposphere and lower stratosphere (UTLS), is a long-standing question in the research community, as it is critically important to determine the global composition distribution and following climate projection. The choice of the transport scheme in climate models would induce the differences in efficiency of air mass transport and the tracer distribution. In this sense, a good representation of air mass transport in the numerical models is important for climate model simulations.

This study investigates the differences in the lower stratospheric transport between two transport schemes (EMAC-FFSL and EMAC-CLaMS) using the age spectrum, mean

age, and idealized tracers as diagnostics. The calculations are straightforward and the results appear reasonable, showing that a fully Lagrangian transport scheme results in significantly less numerical diffusion, stronger stratospheric transport barriers, and clearer structures in trace gas distributions. These results are noteworthy, and would definitely deepen our knowledge on the representation of air mass transport in UTLS and benefit the modeling community. The authors also discussed the underlying mechanisms and potential consequences from the choice of the transport scheme on simulations. In general, this work is interesting. The manuscript is well structured and written, and figures are nicely generated. I recommend publication after the following minor revisions.

Major points:

1) Abstract: I suggest the author to enhance the presentation here. They stated that they would assess the impact of the choice of trace gas transport scheme, however, what are the two schemes are not pointed out clearly (the Lagrangian scheme of EMAC-CLaMS and Eulerian scheme EMAC-FFSL?). Some statements here, for instance "In the lowermost stratosphere, air is much younger in EMAC (Line 11 – 12, Page 1)", introduced a little bit of confusion. What do you mean the "large-scale" and "smaller-scale" in Line 5-6? If my understanding is well, I would prefer to change "smaller-scale" to "regional-scale". What does the CCM mean? 2) Methods: In order to ensure the repeatability of the work, I would like to see the more details on the model and methods. For instance, what are the meteorological dynamical fields to force EMAC climate model? Could you provide the uppermost and lowest level of the 90 vertical layer of EMAC model configuration in this study? As to the Lagrangian modelling with EMAC-CLaMS, how the 300 million air parcels are initialized at the beginning of simulations? Are the air parcels are distributed uniformly in the atmosphere? 3) Section 3 Differences in the Zonal Mean State: Global Perspective: The authors diagnosed and compared many diagnostics here between two schemes, such as the mean age of air, chemical composition, inter-annual variability, and age spec-

trum shape. I am slightly confused as to these diagnostics. In my opinion, the paper might be more readable if the authors could add more explanations on the exact mean of these diagnostics. For example, what does the hotpot of inter-annual variability of mean age mean? Does its magnitude relate to the strength of air mass transport? What are the significance of the differences in this diagnostic between two transport schemes? Among those diagnostics, which one is of great importance to characterize the transport time scales? 4) Section 4 Differences in the representation of transport processes: One can notice that the variability in the age spectra with the transport time scale. There are multiple peak values or maxima occurred even within a period of 1-2 year. Could you provide more information on this issue? I would like to see the comparison of transport time spectra among three sub-regions as well (the tropical and mid-latitude stratosphere, the polar vortexes, and the lowermost stratosphere). For instance, why the shape of age spectra of three sub-regions are significantly different? One can see that the variabilities with transport time (year) is obvious in Figure 8 and 9, however, this feature is almost absent in Figure 10. Why? 5) Section 5 Discussion: The authors argued that reduced/enhanced numerical diffusive transportis responsible for the difference between the two transport schemes. The author might extend their discussion by providing explanations and emphasis the influence of this issue. For instance, as mentioned in the paper, the vertical velocity of EMAC-CLaMS is the diabatic heating rate, whereas EMAC-FFSL uses a kinematic vertical velocity, which could introduce, even in the UTLS region, larger difference in air mass transport (e.g., Hoppe, et al., 2016). Thus, I suggest the authors to discuss this point at end of Sect.5. 6) Conclusion: If possible, the paper could include simple comparisons to previous publications, for example, the study of Hoppe et al. (2014).

Minor points:

1) Line 15, P1: What does the acronyms CCM exactly mean? 2) Line 28, P2: A period is absent before "To our . . .". And Line 29, P2: A period could be deleted. 3) Line 13 P3: In section 2.1->In section 2. 4) Line 3 P7: Does the sentence"The Lagrangian

approach results in older air throughout most regions of the stratosphere"mean that more air mass could be transported to the stratosphere in the Lagrangian modelling? This is likely in agreement with previous studies. 5) Line 12, P5: It could be better to add some references here. 6) Line 30, P15: Figure 8 (a)->Figure 8 (b). 7) Line 21, P17: Figure 9 -> Figure 9 (b). 8) Line 4 P 18: Figure 9-> Figure 9 (a). 9) Line 5-6, P18: How did you conclude that "maxima in the spectra correspond to January-emitted tracers while minima correspond to July-emitted tracers"? Judging from the Figure 9 or other information?

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