Responses

Adrienne Jeske and Holger Tost

July 18, 2025

Thank you for your replies. We will address the comments in the following. The remarks from the editor and the referees' comments are *italicized* and blue. Our answers are displayed in an upright font and in black.

1 Answers to the editor's remarks

I have read the two reviews of your revised manuscript. Given the significant differences of opinion between the two reviewers, I went through the manuscript in more detail myself. I mostly agree with reviewer #1 that a more proper validation of the new CVTRANS module is necessary. As currently written, the impression is that it is tuned to not change the general outcome, or at least that there are (mostly undescribed) parameters in the scheme with a more dramatic effect. The latter is not a strong argument for validation, as nearly every scheme has tuning parameters that can drastically alter the behavior of the scheme. And if the new version is designed to be close to the old version, why not use the old version?

In many ways, the manuscript suffers from having multiple goals. First the validation of the convection module, and then the application thereof on the scalar transport. I will certainly be interested in considering a revised manuscript that is tight and properly addresses both goals, but I do advise you to consider writing a short validation paper, which could be a technical note in ACP or our sister journal GMD, depending on the details. The main ACP paper can then focus on the scalar transport. Given the open nature of the EGU journals, the review process can proceed near-concurrently.

Dear Thijs Heus,

Thank you for bringing to our notice that the goal of our study is not as clear as we thought. The goal is to evaluate the changes in convective transport over roughly the past four decades, applying the convective exchange matrix. We agree that the technical discussions might be misleading. We removed the minor technical changes from the manuscript. The details are included in the supplement.

The amount of turbulence can be considered as a tuning parameter. The statements for the evaluated period remain (largely) unaffected by the addition of a small amount of turbulence. Therefore, for this study, it is not relevant whether a small amount of turbulence is included (tuned towards the version without mixing to fit with the observations) or not. Strong turbulent mixing might quantitatively influence the mean values, but the time trends over 40 years should qualitatively behave similarly.

As turbulence influences the amount of material that reaches the upper troposphere and can affect the transport of single convective events, we agree that a further evaluation is interesting. However, this investigation is independent from the current study, and the here presented results are valid on their own. For this reason, we removed all discussions concerning the treatment of turbulence to keep the focus on the effects of climate change on the convective transport, as you suggested. The impact of the turbulent entrainment will potentially be investigated in an independent upcoming study, which requires a series of new simulations with tracers to analyse the effects in detail.

2 Answers to the comments by referee 1

One thing that strikes me when reading the revised manuscript is, that CVTRANSturb first gets mentioned in line 170, but it is not described in detail how this is different from CVTRANSnew other than that it has 'enhanced turbulence'. From your review replies, I got the impression, that correcting the physics of CVTRANSold actually *leads to CVTRANSturb, and that you then apply some sort of 'damping' to make it CVTRANSnew = a model that does not diverge 'too much' from the original version. "We avoid large changes in the simulation results by using CVTRANS 3.0 with relatively small turbulent mixing and not using the version CVTRANSturb" Thus, you actively tune the model to not diverge much from the old version? Thus, the 'correct physics' (you were aiming at correcting the physics?) would be in CVTRANSturb? So this is where I feel that some validation should be in place, more than "in comparison to the old version", plus explanation of what exactly the 'enhanced turbulence' is, or whether it is rather 'dampened turbulence' in CVTRANSnew. When CVTRANSturb is the version with 'correct physics', I would like to see a discussion of why the mixing then is too strong (if it is too strong, this would need to be shown in a validation). If you did not want to change the results of CVTRANS in the first place, it becomes unclear, what the meaning of changing it then is?*

Dear Wiebke Frey,

If we strictly use the formulations of Tiedtke (1989), that would indeed lead to CVTRANSturb. However, we would significantly reduce the amount of material which is transported to the upper troposphere with CVTRANSturb, but CVTRANS should be able to reproduce typical profiles of trace species as shown in Tost et al. (2010). In addition, the calculation of turbulent entrainment and detrainment used in the Tiedtke-Nordeng scheme depends on old measurements of cloud radii and the grid box size. As far as we know, there is no reason from a physical perspective why the turbulence should depend on the size of the grid box (especially if the size of the convective system is similar). This is why we "tuned" (to use our editor's wording) the turbulent mixing to fit with observations. We investigated how convective transport had changed over the 41-years. Therefore, the small changes in the turbulent mixing are not relevant. We agree with you that we could have used a version without turbulent mixing for the purpose of this study (the results are not affected), but addressing different questions, the turbulence might be more relevant (especially looking at the transport from the mid-troposphere to the upper troposphere by a single event).

As mentioned above, we agree with you that the discussion about turbulence in the manuscript might be confusing. We removed this discussion from the manuscript as the minimal turbulence versus no turbulence does not influence the results.

Additionally, maybe the colour scales are misleading, but for instance looking at Fig. 3a) and 3b) I can see significant differences. Fig. 4 on the other side, fails to show these differences, e.g. below the diagonal, also almost nothing for the change in upper right corner above diagonal in 4a) – isn't the transport here even mentioned in the abstract? I would expect a discussion about the differences here then, and to actually see them in the Figure.

We agree that the colour code not optimal in Fig. 4 especially compared to Fig. 3. These Figures are no longer included in the manuscript.

No reference is made in the abstract to Fig. 4. but to Fig 6 (now Fig. 4). In Fig. 6 (now 4) the increase at 130 hPa and above is indicated by the red colours (upper part of Fig. 6, i.e. model level 7 and smaller numbers at the vertical axes and nearly all model levels at the horizontal axes).

In conclusion, I think that a more convincing discussion around the different model versions and their validity is needed (including CVTRANSturb), and I hope that my issues with the current description became more clear now.

We decided not to include any (further) discussion about the different versions as this might distract from the original goal of this study to investigate the influence of global warming on convective transport.

We hope that we could increase the clarity of the manuscript and address you issue with our answer properly.

3 Answers to referee # 2

We thank you for your support.

References

M. Tiedtke. A comprehensive mass flux scheme for cumulus parameterization in large-scale models. *Monthly Weather Review*, 117(8):1779 – 1800, 1989. doi: 10.1175/1520-0493(1989)117⟨1779:ACMFSF⟩2.0.CO;2. URL `https://journals.ametsoc.org/view/journals/mwre/117/8/1520-0493_1989_117_1779_acmfsf_2_0_co_2.xml`.

H. Tost, M. G. Lawrence, C. Brühl, P. Jöckel, and The GABRIEL Team and The SCOUT-O3-DARWIN/ACTIVE Team. Uncertainties in atmospheric chemistry modelling due to convection parameterisations and subsequent scavenging. *Atmospheric Chemistry and Physics*, 10(4):1931–1951, 2010. doi: 10.5194/acp-10-1931-2010. URL `https://acp.copernicus.org/articles/10/1931/2010/`.