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Interactive Comment

Interactive comment on "Modelling tracer transport by a cumulus ensemble: lateral boundary conditions and large-scale ascent" *by* M. Salzmann et al.

M. Salzmann et al.

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Reply to Comments by Anonymous Referee #1:

- (1) The discussion of the domain size dependence in Sect. 3, page 3390 was omitted, but some notes have been kept elsewhere.
- (2) Instead of putting forward an overly simplistic discussion of the cold bias, the reader is now referred to a more detailed discussion in the literature. The origin of the different results for the water vapour is now addressed in the text.
- (3) Information for readers not used to Hovmöller diagrams was added, which will help to interpret these diagrams. For the 3D case, the Hovmöller diagrams

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could in principle be replaced by either animated contour plots or a longer sequence of x-y contour plots. An inspection of these plots shows single clouds and mesoscale convective systems (MCS) including linear structures. While this article focuses on the effects of lateral boundary conditions and of including VL-SAT, it of great interest to determine how much organized convection contributes to convective transport compared to individual clouds. Such an assessment is currently planned for a future study, in which the results of this study will be compared to the results from a single column model using a cumulus ensemble parameterization approach. For the 3D case, however, in order to obtain better statistical information about the MCS, a larger domain size would be beneficial. The time series of total precipitation (Fig. 3) can be considered a proxy for convective activity. From this Fig. it seems like no large temporal shifts in convective activity occur between the different runs.

- (4) Figs. 6 and 7c were corrected.
- (5) The finding that relatively little of a mid-tropospheric tracer (tracer B) is entrained into convective cells compared to a LT tracer (tracer A) can be sustained by comparing Fig. 8a to Fig. 6a. The text was changed from:
  "Further analysis (see also Fig. 9) yields that often updrafts push aside the the air containing the high tracer mixing ratios without entraining much of it. This finding does not conform with the 'convective ladder' effect postulated by Mari et al. (2000). Consequently the mixing ratio of tracer B in the UT increases much less rapidly than in the case of tracer A."
  to:
  "The amount of tracer B in the UT increases much less rapidly than that of Tracer A (compare Fig. 6a to Fig. 8a), because tracer B is less efficiently entrained into deep convective cells than tracer A. The findings that tracer B is entrained less efficiently than tracer A and that tracer A is predominantly detrained in the UT provides a different perspective than the 'convective ladder' effect postulated by

Mari et al. (2000).”

The reference to Fig. 9 in the original text was made in order to illustrate the fact that tracer mass is often “pushed aside” by convective updrafts instead of entrained. This can be seen much more clearly in animations than in Fig. 9. Since the main point here was not to describe the process of “pushing aside” tracer mass, but the less efficient entrainment of tracer B compared to tracer A, it was chosen to alter the argumentation in order to keep it short and sustain the main point. A 2D sensititivity run with 400m horizontal and 200m vertical grid resolution, which we chose not to include into the publication, yielded very similar results for the tracer transport. Whether using a much higher grid resolution would change the results significantly can only be speculated based on these results. Finally, in order to investigate the differences in entrainment between 2D and 3D runs, an additional 3D run with PLBC would be necessary (for the reasons indicated in the end of Sect. 4.4.).

- (6) Interpretation of the results in Fig 12: Unfortunately, the quantification of the horizontal tracer transport across the lateral boundaries for the 3D model run requested by the referee is hampered by practical reasons. The sentences “Detailed analysis of the 3-D results yields similar importance of the mesoscale subsidence in the 3-D and the 2-D run. In the 3-D run meridional tracer transport in the layers below the initial tracer mass location plays an important role in advecting tracer mass out of the domain.” were changed to “In the 3-D run meridional tracer transport in the layers below the initial tracer mass location acts to advect tracer mass out of the domain”. The detailed analysis was mainly based on inspection of animated series of horizontal and vertical tracer contour plots. In order to better quantify this finding, an analysis of the tracer budgets would be necessary. While preparing the original manuscript, a 2D run with SLBC and VLSAT was performed, in which complete tracer budgets were calculated (total change: horizontal advection, vertical advection and turbulent mixing). The

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results from these budget calculations lent support to a number of points which were discussed in the article. With some code modifications (memory usage, parallelization), it would be possible to perform similar calculations for the 3D case. However, we are currently running the model on a small Linux cluster and these calculations would consume a very large amount of available computing time. For the 2D cases, the results from the budget calculations supported the interpretations gained from inspecting the horizontally averaged wind and tracer fields. We believe the same to be probably true for the 3D simulations, although the differences in dynamics between 2D and 3D likely also have an impact as stated in the article, which would be difficult to quantify without performing additional 3D simulations. The finding that below 5km tracer mass was transported out of the domain due to the influence of meridonal wind component is very strongly supported by animated series of horizontal tracer contour plots (not included in the article).

- (7) The statement about the effect of using PLBC and VLSAT was deleted since it is not considered central to the discussion and the plots sustaining this statement were not shown in the paper.

- (8) It is meant to compare these results to single column versions of large scale 3D models. In many cases, the parameterizations used in these models were designed to describe the effect of a cumulus ensemble rather than that of a single cloud. To understand possible consequences of representing an ensemble as a single bulk updraft will be one of the goals of this comparison. One of the authors has submitted a paper on the treatment of this subject (Lawrence, M.G. and Rasch, P.J.: Tracer transport in deep convective updrafts: Plume ensemble versus bulk formulations, J. Atmos. Sci., submitted, 2004.)

Interactive comment on Atmos. Chem. Phys. Discuss., 4, 3381, 2004.