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Atmospheric Chemistry and Physics
Discussions

Interactive comment on "Parameterizations for convective transport in various cloud-topped boundary layers" *by* M. Sikma and H. G. Ouwersloot

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We thank Referee #1 for his/her comments on the manuscript that will improve the paper and are glad that he/she agrees that the results are of interest to the community. We will respond to his/her comments point by point. The reviewer's comments are shown in italic.

General comments:

1. the 'old' school (and the Reviewer belongs to this) believes it is much more accurate and physically consistent to estimate the mass flux directly, e.g. as function of the surface buoyancy flux), instead of estimating it as a product of two fitted quantities. This requires further analysis

The reviewer is right that it could be debated which method is more suitable to represent the convective transport of moisture. We therefore do not advocate that all models should use this procedure to calculate moisture transport this way. However, we do want to mention the possibility.
On the other hand, the convective transport of atmospheric tracers other than moisture, has to be calculated as a product of different functions. This is treated by, e.g. Ouwersloot et al. (2015). This clarification will be processed in the introduction of the revised manuscript.

2. the manuscript is a bit 'thin' in novelty and the authors should make clear what is actually new

To calculate the transport of atmospheric reactants, it is essential that the kinematic mass flux and chemical concentrations of the transported air are known. For the first time, we investigate the parameterization for the latter for 24 chemical species, over a wide range of conditions. To our knowledge, such a study has not been conducted before. Furthermore, the kinematic mass flux could be calculated directly by a convection routine, but this approach does not always have to be used. For example, in mixed-layer modelling the kinematic mass flux is calculated as described in the manuscript (see e.g., Neggers et al., 2006; van Stratum et al., 2014). Essential for these calculations, the current parameterization for active cloud area fraction is shown to be lacking and a novel, improved representation is introduced. Moreover, as the effectiveness of

convective transport of atmospheric tracers is affected by the area of venting (Ouwersloot et al., 2015), this updated parameterization for active cloud area fraction is even important for tracer transport if mass fluxes are directly calculated by a convection routine.
We will emphasize the novelty of the study by highlighting the applications of and advancements in the parameterizations in the conclusions chapter.

3. the discussion of the parametrization needs and status in large-scale models is in parts a bit superficial also it is not clear how useful and for whom is in practice the relation for the core fraction of the species: eg in forecasting using a mass flux scheme these values are estimated from lifting parcels from near the surface with a certain excess values applying some strong entrainment

We answered this questions already partly in the question above, but the presented parameterizations are essential to deal with the transport of atmospheric compounds, other than water. As such, it is very relevant for models that take into account chemical transport. For instance, such a parameterization has recently been applied to the atmospheric chemistry - climate model EMAC (Ouwersloot et al., 2015) to accurately simulate transport of atmospheric compounds. We will update the manuscript to clarify the usefulness of the parameterization.

Specific comments:

-page 3, line 12 :('50-200 km)' NWP and GCMs run nowadays at 10-200 km globally and 1-2 km regionally

This is fixed in the revised manuscript.

-page 3, lines 15-25: revise. Adjustment schemes do not transport mass as such, but adjust (relax) the thermodynamic profiles toward a moist adiabat. Please revise references herein as this is all quite inaccurate and obsolete including what you say about diffusive transport. You might have a look in the document below which summarizes also how mass flux schemes work in NWP and how tracer transport is done and also what are adjustment schemes and useful references http://old.ecmwf.int/newsevents/training/lecture_notes/LN_PA.html ("Atmospheric moist convection")

The reviewer raises a valid point. We re-checked the references and changed the paragraph into: *"The impact of convective transport on atmospheric state variables (e.g., moisture and temperature), can be parameterized in large-scale models by using a convective adjustment scheme (e.g. Betts, 1986), an eddy-diffusion scheme (e.g. Soares et al., 2004), or the mass flux approach (e.g., Bechtold et al., 2001; Bretherton et al. 2003). In this study, we mainly focus on the latter, which also allows for convective transport of chemical compounds."*

-page 4, line 15;'In contradiction' there is no contradiction, use different wording

The sentence is changed into: *"By not applying the simplifications present in previous literature (e.g. Neggers et al., 2006), we developed a general formulation..."*

-page 6, Eq (2): A mass flux should always include the factor rho (density) and have units kg/(m2 s)

We agree that for the general mass flux this is the case. However, since we are focusing on the kinematic mass flux, no factor rho is present in the formulas. We acknowledge that at some places the word "kinematic" was omitted, which is rectified in the revised manuscript.

-page 13, lines 5-8 and page 16 lines 6-7: you give references and say 'global models that use the parametrization of ... overestimate the mass transport'. None of these models computes mass transport using cloud fraction but directly estimates the mass flux! wrong references/literature for that problem

The reviewer is right. To our regret, we made a mistake here. The cloud area fraction parameterization of Cuijpers and Bechtold (1995) was not used for the computation of the mass flux in these models. We will change and clarify this in the revised manuscript.

-page 14, eq (12): This formulation can produce negative values in principle, robust?

That is right. When the mass flux is that strong that $\pm$85% (1/1.18) of a grid cell is drained, even negative concentrations would result. In the application of convective tracer transport, one should take this in consideration. To prevent the unrealistically low concentrations, numerical solutions need to be applied. A first, simple solution would be to limit the total transport to never yield negative concentrations. More fitting solutions would be to e.g., introduce intermediate time steps for the convective tracer transport calculations or to account for the concentration evolution during a time step, as is applied by Ouwersloot et al. (2015).

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