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Interactive comment on "Tropospheric mixing and parametrization of unresolved convection as implemented into the Chemical Lagrangian Model of the Stratosphere (CLaMS)" *by* Paul Konopka et al.

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Our intention for parameterization of convection is the simplest possible approach to study the global impact of this effect on tracer distributions, especially on the upward propagation of the CO_2 annual cycle. We thank Ingo Wohltmann for his comment and agree, that in the current version, this parameterization is not mass-conserving, however there are few arguments (listed below) which support our simple method:

1. The total mass transported through every potential temperature surface should

vanish at least in the annual mean. The residuum of the total mass transported through hybrid potential temperature surfaces extending between the Earth's surface and 400 K pot. temperature level was calculated for every 6-hours time step of the ERA-Interim data (exemplary for 2005) and is shown below (in contrast to pot. temperature, the hybrid potential temperature surfaces do not cross the Earth).

   Thus, the total budget shows a deficit (blue values) roughly in the region between 700 and 200 hPa. Our explanation for this deficit is that the horizontal resolution of this data (roughly 80 km) does not sufficiently resolves the convective towers (which are of the order 1 km) but does better resolve the large-scale convective downdrafts which, mainly due to radiatively active water vapor, are better reproduced in the ERA-Interim vertical velocities (i.e. mainly in their diabatic part). Thus, our parameterization aims to close this in-balance by including some additional convective updrafts. The results show that qualitatively our simple approach closes (or slightly reverses) such a deficit. That means, that we mainly include the convective updrafts to minimize such a deficit rather than to formulate a mass-conserving parameterization of convection. We will discuss this point in the revised version more clearly.

2. Our convective updrafts from the lowest model layer (approximating the PBL) are "in principle" balanced by the reverse downdraft transporting a CLaMS air parcel from the position where the convective updraft "ends" back to the PBL. However, because we overwrite all the mixing ratios in the PBL by a prescribed boundary condition, this downdraft does not have any influence on the tracer distributions in the here presented CLaMS version (so this is the reason for the wording "in principle"). Here, we follow much simpler Lagrangian ideas like in Ueyama et al., JGR, 2018 to include the effect of convection only on the upward transport of tracers.

3. Finally, CLaMS is using diabatic vertical velocities following procedure described

in Mahowald et al., JGR, 2002, which are *per se* not mass-conserving. Whereas above $p_r = 300$ hPa pure diabatic velocities are used, below p_r a hybrid vertical velocity is applied combining the kinematic (mass-conserving) with the diabatic (non mass-conserving) velocity. Also the CLaMS mixing scheme itself is not mass-conserving in a strict mathematical sense. However, it should be not an excuse to use a better mass-conserving convection scheme in the future.

We conclude that we certainly have to improve the explanation of our procedure in the revised version of our paper. Following the spirit of the published schemes proposed in the comment, we plan in the future to include such a better, mass-conserving scheme. Nevertheless, the presented approach significantly improves the performance of CLaMS in the troposphere and gives some first insights on the importance on convection, so we still believe that such a simplified approach has its justification.

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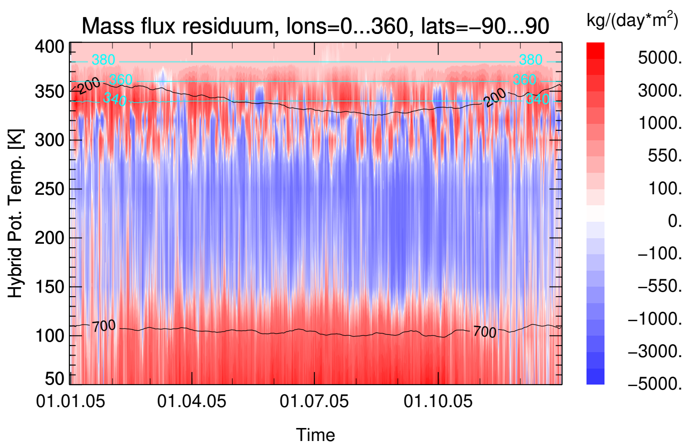

Fig. 1. Residuum of the total mass flux calculated at every hybrid potential temperature level surface extending between the Earth's surface on the 400 K pot. temperature level (ERA-Interim, 2005)