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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Deep-convective vertical transport: what is mass flux?" *by* J.-I. Yano

Anonymous Referee #1

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This paper is an extension of a number of papers examining the impact of deep moist convection on tropospheric trace species. The results of these studies have been inconsistent. It is tempting to answer this question by simply turning off convective transport in chemical transport models for model tracers. However, as suggested in Hess (2005) and Lawrence and Salzman (2008) this methodology has its limitations: the large scale grid resolved vertical velocity in general circulation models is upward in the tropics forming the upward branch of the Hadley circulation (the net mass flux due to parameterized deep convection is specified to be exactly zero within any grid cell). This large scale resolved velocity provides a robust, although slow transport pathway from the surface to the upper tropical troposphere even in the absence of convective transport. In the real atmosphere, of course, the upward transport in the Hadley cell is through deep convection. So what does it really mean to examine the impact due to deep convection on trace species?

One answer, although unrealistic, to pose a thought experiment in which tracer transport by real atmospheric deep convection does not occur. In that case there is probably no robust transport pathway from the surface to the upper troposphere in the tropics. The upward transport in the Hadley circulation occurs within convective elements. However even this approach begs a numbers of questions. In this thought experiment should we still maintain environmental tropical subsidence as a transport velocity? Is it acceptable to essentially zero-out the upward branch of the Hadley cell when we know this cell, in fact, does not depend on deep convection to drive it.

Another answer might be to simply turn off convective tracer transport in a numerical model. This is perhaps a more tractable question: what is the effect of parameterized deep convection within the model world. The implications of this approach are rather different than that of magically turning off convective transport in the atmosphere. Transport by the large-scale resolved Hadley circulation still exists in the model, providing a robust path for the transport of long-lived trace species to the upper troposphere. One might argue that even without deep moist convection the Hadley circulation exists so that the GCM solution may be relevant.

It does not seem like there is a unique solution to this quandary. The paper by J Yano argues otherwise, but is not convincing. Specific reasons are given below.

General Comments: J. Yano presents two schemes for turning off the convective mass flux. Neither of which strike me as well enough justified or explored to justify publication. Moreover, the results of the two proposals are different. This difference is not justified.

The first scheme, if I understand it, is to zero-out the explicit cumulus updraft and downdraft velocities, but to maintain the residual mass flux Me* (equal to Me minus the mean grid cell velocity W) as a transporting velocity. Since the grid mean vertical velocity is W, the net advection [W+Me* = W+(Me-W)] would be Me. This would be equivalent to the thought experiment in the introduction: turning off the transport due to deep moist convection in the atmosphere (and thus the vertical transport due

ACPD
9, S1066–S1069, 2009

to the Hadley circulation) on transported constituents, but leaving the compensating subsidence intact. This is one interpretation of turning off convective transport and might be defendable philosophically, but to my knowledge has not been tried. As J. Yano points out it does have technical difficulties associated with implementing it in a numerical model (and the non-conservation of mass is a big deal in practice!).

At any rate for the paper to be publishable this first scheme needs to be implemented in a model and carefully evaluated. Since this has not been done, the justification for publishing relies on the proposed second scheme. In my opinion an adequate justification for the 2nd scheme is not presented. In this 2nd scheme J. Yano simply would simply turn off the convective transport. This is the usual practice. Has the paper added significantly to the justification of this procedure? In my opinion the answer is no. The justification presented is rather cursory for its importance in the paper. It is based on the statement that the importance of convective transport is because the transport occurs in a convective tube, not because it is fast. One can raise a number of objections to this (e.g., the precipitation rate), but most notable, the speed of transport is extremely important when it comes to short lived chemical constituents (e.g. radon). Thus I do not really see how this point clarifies the discussion.

Specific:

1) I appreciate the quote by St Augustine. However, it is not immediately clear what is the confusion about convective mass flux. Thus the problem that J. Yano is setting out to solve is not clearly delineated.

2) I also appreciate viewing the problem from a historical context. It seems that the essential point the author is trying to make the point that the pipe aspect of the transport versus the speed is the important aspect. While I am not a tropical dynamicist, is it really correct to support this historical perspective using moist entropy as the example? For example Mapes (QJRMS, 2001) shows the observed and moist adiabatic lapse rates are very similar between the boundary layer and 12 km in the tropics resulting in

ACPD
9, S1066–S1069, 2009

a profile very different from Figure 1 in J. Yano

3) Page 3540, Lines 11-14. This argument does not follow. It seems the important quantity here is area times vertical velocity. Just showing the area to be small, does not necessarily imply area times vertical velocity is small.

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