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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Clarification on the generation of absolute and potential vorticity in mesoscale convective vortices" *by* R. J. Conzemius and M. T. Montgomery

Anonymous Referee #3

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Review of "Clarification on the generation of absolute and potential vorticity in mesoscale convective vortices", by R.J. Conzemius and M.T. Montgomery.

Summary:

This paper examines the origin and evolution of vorticity in high resolution numerical simulations of an idealised mesoscale convective vortex (MCV). The analysis is comprised of two main calculations. First, the relative contribution from horizontal flux convergence versus tilting of absolute vertical vorticity to the system-total absolute circulation is examined. Second, the relative contribution from stratiform versus convective precipitation regions to the total diabatic heating and generation of circulation

is examined. The main conclusions drawn from the analysis are that 1) the spin-up of system-total absolute circulation is dominated by the horizontal flux convergence of absolute vorticity, and that 2) the total diabatic heating, and hence potential vorticity (PV) generation, is dominated by the convective regions of the system. As promised by the article's title, these conclusions provide a useful clarification of the mechanisms that lead to the system-scale circulation of an MCV. The analysis has been designed to overcome the complicated, messy, and multiscale nature of an MCV-producing MCS in order to emphasize the bulk properties of the vorticity budget. It is this clear, simple, and unambiguous presentation of the bulk properties of the MCV that is the primary strength of the paper. This investigation leaves open several important issues concerning the multiscale evolution of PV from the storm scale up to the MCV scale. I would encourage the authors to perform an analysis focussed on these finer details as part of a future investigation complimentary to the present one.

General Comments:

One aspect of the analysis that could be elaborated concerns the origin of positive PV anomaly in the stratiform region, as shown in Figure 4 and discussed in section 4.3. Three positive PV centers of large magnitude that originate within the line of convection are identified and tracked as they move rearward into the stratiform region. Although the authors do not explain how these centers were tracked, their analysis suggests that the positive PV of the stratiform region is sourced from the line of convection. This is an important point that deserves a more detailed examination, perhaps as part of a future investigation. The following are a few additional questions that might have been considered during this analysis. What proportion of the total PV in the stratiform region was generated locally in the stratiform region itself, and what proportion was generated in the line of convection and then transported rearward? Do the fluid particles moving through line undergo significant ascent/descent en route to the stratiform region? What happens to the negative PV centers that are formed in the line of convection as part of the storm-scale horizontal dipoles? Do they also arrive in the stratiform region as weaker positive anomalies?

I note that it is stated in the introduction that some of the issues mentioned in the preceding paragraph would be treated by way of a “cursory investigation”, which is an accurate characterization of what was presented via Figure 4. Furthermore, in the last three sentences of the conclusions section the authors concede that these issues deserve further consideration, and that the BAMEX dataset could be useful. I would also encourage the authors to perform additional calculations in their simulations. For example, I recommend performing a trajectory analysis in which the PV histories of fluid particles moving through the line of convection as well as those originating in the stratiform region itself are examined. Figure 4 does not offer a full 3-d picture, nor does it make it absolutely clear that most of the positive anomaly is generated as particles move through the line of convection. If most of the positive anomaly is indeed sourced from the line of convection, then the accurate simulation of the PV structure in the stratiform region would rely upon the accurate simulation of the transport of mass in, around, and through the line of convection. Do we really require such detail to accurately simulate the system-scale MCV?

Specific comments

- It would be helpful if the authors could comment on how representative the two MCVs examined in this paper are for the range of MCVs encountered in nature. Related to this point, the authors should probably reference Kirk’s (2007, MWR) paper in which a phase-plot technique is used to visualize the different possible evolutionary paths of MCVs. The MCV examined in the present investigation would appear to be of the type characterized by Kirk’s method as being led by heating. Kirk also identifies an alternative evolutionary path that is dominated by tilting.

ref: Kirk, J.R., 2007: A Phase-Plot Method for Diagnosing Vorticity Concentration Mechanisms in Mesoscale Convective Vortices. Mon. Wea. Rev., 135, 801–820.

- On page 7535, lines 1-3, it is stated that “When titling occurs in conjunction with a

convective updraft, the vertical gradients of diabatic heating produce a concentration of PV substance”. I don’t think this statement is accurate. PV is generated when a heating occurs that has a gradient in the direction of the background absolute vorticity vector. On the mesoscale, heating has a vertical gradient directed against the background planetary vorticity, and hence vertical dipoles are generated. On the storm scale, diabatic heating has a large horizontal gradient in the direction of the background horizontal (shear) vorticity. This is why the PV accompanying the convective storms has a horizontal dipole structure. The horizontal PV dipole is not a consequence of tilting. The subsequent generation of relative vorticity within this horizontal PV dipole is the consequence of tilting.

- The MCS is initiated by inserting a warm-core, low-level vortex, with zero PV onto the background state. To what extent does this influence the evolution of vorticity later in the simulation? Although this structure has zero PV, you’ve effectively increased the background vertical vorticity against which diabatic heating generates anomalous PV.

- How was diabatic heating computed in the simulations? Is it a trivial calculation? In my experience, it is not always so trivial.

- All of the analysis presented in the paper is performed on the finest grid. If data is also available in the outer coarser domains, then it would be interesting to see if the budget calculations are similar to those in the convection-permitting domain. I’d be interested in knowing to what extent the results of the present investigation are influenced by the parameterization of convection. Such an analysis might also clarify which storm scale processes are most influential to the evolution of system-scale vorticity. If we need to accurately simulate the horizontal transport of mass in the storm environment, then would simulations relying upon a convective parameterization behave very differently from those that explicitly permit convection?

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