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Atmospheric Chemistry and Physics Discussions

Interactive comment on "A new paradigm for intensity modification of tropical cyclones: thermodynamic impact of vertical wind shear on the inflow layer" *by* M. Riemer et al.

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This is an outstanding paper that deserves careful reading of every aspect. Using idealized numerical simulations, Riemer et al. provide a detailed discussion of the dynamics and thermodynamics of tropical cyclones experiencing vertical wind shear. I am especially impressed with their ability to present an integrated explanation of multiple phenomena and processes: the role of vortex tilt in the core and outside the core, cold downdrafts driven by evaporation and precipitation loading, azimuthal wavenumber one asymmetries, vortex Rossby wave dynamics, and Ekman pumping, and to tie these into Willoughby's stationary band complex, Reasor's dry dynamics, and Emanuel's Carnot theory.

The paper provides a convincing description of the influence on intensity change of ambient shear-induced, asymmetric downward flux of low entropy air into the boundary layer. Many insights into aspects of sheared tropical cyclones are present throughout the manuscript. At first I resisted the idea that this was a "new paradigm". Mark Powell has discussed the role of downdrafts in boundary layer cooling, and the effect of insufficient recovery of this boundary layer air producing an opening in the eyewall when it reaches the core. But Riemer et al. provide such an integrated view of this process and how it acts in sheared tropical cyclones that I believe the title is appropriate.

Riemer et al. promise future papers that will describe further details of asymmetric dynamics, the role of vertical shear in the protected core as it is reduced from the imposed ambient shear by complex core dynamics, and the development and maintenance of the stationary band complex. I look forward to these manuscripts.

The authors deliberately chose "a simple set of physical parameterizations" that capture the "essence of TC-shear interaction". The comments and discussion below are not intended to be critical of that decision, but rather to address the role of factors not considered in this work.

1. A grid spacing of 5 km means that the smallest resolvable disturbance is at least 10 km. As a result, (i) individual cells, including vortical hot towers, cannot be fully resolved; and (ii) a vortex tilt of 5-10 km between the 1 and 10 km levels is right at the limit of the model (yet such a tilt is frequently present). An open question is what new insights might be gained by higher resolution, or alternatively, what might be missing at the current resolution?

2. The role of ice remains uncertain. Melting is a powerful process that tends to occur entirely within a 500 m layer, producing an intense upward increase of diabatic heating near the melting level. Unlike evaporation, it continues to occur when the air is saturated. In addition, the "central dense overcast" (CDO) of tropical cyclones results

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in part from advection of ice particles outward from the eyewall. Growth and fallout of particles in the CDO and subsequent melting and evaporation create broad cooling outside the core. This likely plays a role in preserving the radial temperature gradient in the free atmosphere required to maintain the tropical cyclone, in part by suppressing outer convection. The question: how might the mechanisms introduced by ice physics (on a sufficiently high resolution grid) impact the role of vertical wind shear in tropical cyclones?

3. In a broader sense, remarkably little is known in our field about the details of how downdrafts are initiated and how they evolve. The actual process might require knowledge of mixing of updraft and environment air that would have to be parameterized, even with a 1-km grid resolution. I raise the following general questions for future consideration: are downdrafts likely to be stronger when ice processes are included, or weaker as the authors suggest in section 7.2? What is the role of midlevel relative humidity in the initiation and evolution of these downdrafts? In tropical cyclones, at what level are downdrafts initiated, and how often do they reach the surface?

4. As the authors note, the role of ck/cd not equal to unity must be investigated.

The remaining comments below address secondary influences that are nonetheless of interest in the future.

5. Storms in these experiments move faster as shear increases. This introduces differing impacts of asymmetric friction that potentially confound comparisons among experiments. One could impose a shear with zero mean flow in the vertical as a way to address this issue.

6. A beta plane introduces asymmetries between easterly and westerly shear. This second-order effect might nevertheless influence the structure and evolution of convective asymmetries and the stationary band complex.

7. The shear is introduced in the model at a time of rapid intensification. I am curious

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whether the impact would be the same if it were introduced at, for instance, hour 30 or hour 66, when the storm intensity was quasi-steady.

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