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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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The study by Riemer et al. investigates a thermodynamic pathway by which vertical wind shear affects the intensity of a tropical cyclone (TC) in a 3D numerical model. Downdrafts associated with convective asymmetries, the manifestation of a TC's forced response to vertical wind shear, flush the boundary layer with low entropy (or θ_e) air limiting the tropical cyclone heat engine's effectiveness in generating mechanical energy.

1 Choice of Experiments and Model Setup

Wind shear is switched on while the vortex is still intensifying up to its maximum intensity. Some suggestions for future experiments are to assess the sensitivity of the intensity evolution to the time when wind shear is applied. The two limiting cases are to switch on the wind shear once the TC reaches a quasi-steady state (i.e. its maximum intensity) and to switch on the wind shear right at the onset of the experiment. These follow up experiments would assess whether the weakening and subsequent strengthening observed in all of the current experiments is a robust feature.

Although radiation likely doesn't play a strong role in the mechanism detailed in this study as the time scales of the phenomena at play are short (e.g. advection of a downdraft parcel to the radius of maximum winds), a simple radiation scheme in form of a slow relaxation to the initial state may prove useful in another regard in that it would help maintain the environmental shear in the near storm environment. The authors note that the shear evaluated in a 120km radius in the 20m/s shear case decreases considerably after 12 hours. One wonders if the tropical cyclone is in effect buffering the shear or that the shear over a larger region is being obliterated as the near field temperature gradient is diminished without any compensating forcing to restore the synoptic scale gradient.

2 Wavenumber One Pattern and Tilt of TC

In figure 17, the authors show a prominent wavenumber one pattern in the vertical velocities extending out to approximately 120km. Associated with this is a wavenumber one pattern in the relative vorticity of the same sign (as implied by Ekman pumping). However if this wavenumber one standing vortex Rossby wave pattern is forced by the tilt of the TC and the tilt direction is generally toward the south (figure 14) at this time, why is the positive anomaly in the NW semi-circle of the storm? Heuristically, if one has a two layer model with separate PV anomalies in each layer in which the upper layer PV anomaly is displaced to the south, the projection of that anomaly on the lower layer should result in a positive anomaly that is likewise in the southern semicircle. If so, is convective coupling playing a dominant role making causality hard to attribute?

The lowest 4km of the inner core is tilted much more strongly than the remainder of the vortex above in figure 16. One might suspect this strong tilting of the inner core to be associated with a strong baroclinic generation of eddy kinetic energy (Wang, 2001). For future work, it would be interesting to investigate thoroughly what processes are responsible for the excitation of vortex Rossby waves in a sheared TC.

3 θ_e Diagnostics

The areal extent to which the boundary layer θ_e is perturbed seems to be quite an important factor in separating weakening from intensifying storms in the shear experiments. A broad, but overwhelming injection of low θ_e air into the boundary layer versus localized, but nevertheless, intense downdrafts of low θ_e air have entirely different effects. The former appears to primarily affect the low frequency variability reducing the storm intensity on time scales of greater than several hours, whereas the latter seems to play a role in the high frequency variability.

In the Hovmoller diagrams presented in figure 13, the contrast in areal coverage the downward flux of θ_e is quite distinguishable during the first 30 hours of each experiment with the 20m/s shear experiment having a more sustained area of downward fluxes between radii of 50-150km. It would be interesting to see a time series of the area integrated downdraft θ_e flux through the top of the boundary layer in a disk within 150km of the center to assess whether there is indeed a large difference between each experiment.

Also in figure 13, there are often transient upward spikes in intensity that very nearly coincide with the downdrafts. Although only strictly valid in axisymmetric, slantwise neutral TC theory, the radial gradient of θ_e is proportional to the tangential wind speed. The downdrafts could be locally increasing this gradient resulting in these spikes in intensity. An alternative dynamic view is that the downdrafts are locally increasing the inflow resulting in a larger Coriolis torque and a corresponding increase in the tangential wind speed.

In figure 18, there is a rather large vertical θ_e gradient in the lowest 1km coincident with the strong downdrafts on the south side of the storm. The downdrafts are obviously not only modifying the temperature and moisture of the boundary layer, but also of the boundary layer height and near surface stability. How are the authors defining the top of the boundary layer since it varies with space and time?

4 Relationship with Prior Studies and Observations

The effect of wind shear on TCs was also a subject of a paper by Frank and Ritchie (2001) in which they hypothesize that wind shear acts to weaken the storm in a "top-down" fashion. Asymmetries are hypothesized to dilute potential vorticity and entropy at upper levels first and then descend with time. The hypothesis presented in the current paper is clearly a different one, whereby the entropy sink is due to convective fluxes into the boundary layer. It would be interesting for the authors to compare and contrast their results with those of Frank and Ritchie.

The authors point to ancillary evidence of the same downdraft mechanism occurring in two recent hurricanes: Omar in 2008 and Erin in 2001. Was there evidence in either reconnaissance, best track record, or other objective/subjective estimates of intensity of subsequent weakening after these arc clouds or bands of strong divergence were noted?

5 References

Frank, W.M., and E.A. Ritchie, 2001: Effects of Vertical Wind Shear on the Intensity and Structure of Numerically Simulated Hurricanes. Mon. Wea. Rev., 129, 2249-2269.

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