Atmos. Chem. Phys. Discuss., 10, C13975–C13979, 2011
www.atmos-chem-phys-discuss.net/10/C13975/2011/

Atmospheric Chemistry and Physics Discussions

Interactive comment on "Simple kinematic models for the environmental interaction of tropical cyclones in vertical wind shear" *by* M. Riemer and M. T. Montgomery

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Received and published: 22 February 2011

The authors investigate the flow topology of a numerical simulation of a sheared tropical cyclone and a simple kinematic model of a point vortex with a mass sink. Under the assumption steady, horizontal flow, the flow topology indicates sectors in which the environmental air can intrude in to the vortex. Weak tropical cyclones in sufficiently strong environmental relative flow (vertical wind shear) can suffer significant incursions of environmental air in to the core of the circulation. On the other hand, strong tropical cyclones are quite resistant to environmental intrusions of dry air, with the exception of the outer rainbands.

The scientific significance and quality along with the presentation quality of the work is already good. There are a few areas in the manuscript that can benefit from further explanation and clarification.

Assumption of Steady Flow

One of the main results of this paper is that strong tropical cyclones (major hurricanes) require tremendous amounts of vertical wind shear in order for the separatrix structure to allow environmental air to reach the eyewall. The author's briefly mention in section one that the assumption of steadiness breaks down in the vicinity of the eyewall, where one observes a stew of asymmetric, transient motions. However, this point can easily be lost, and it would be nice to reemphasize in the concluding section that transient motions can and probably do play an important role in bridging the environment and storm inner-core. There is indirect evidence of this in Fig. 5 where one still sees large downdrafts inside the limit cycle. Dry air is still getting in to some extent, but not by the steady (time-averaged), horizontal flow.

Vertical Motions

In section 2.1.2, it is stated there is a high degree of congruence between the flow topology and the distribution of θ_e. Since the framework presented here doesn't include vertical motions, how important are they in determining the distribution of θ_e? The vertical wind shear induces mesoscale ascent and subsidence on the downshear and upshear side, respectively. Moreover, convection itself strongly affects the distribution of θ_e, as evidenced by the stationary band complex. Additionally, at low levels, one has Ekman effects that also introduce wavenumber one asymmetries in θ_e. Hence, although the analysis suggests the separatrices do not permit significant mixing between the environment and inner core, important vertical or slantwise motions may not be captured here.

Source Region of Environmental Air

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In section 2.3, the authors state that "the source region of the environmental air that feeds the downdraft area exhibits a pronounced asymmetric, azimuthal wave number one structure." Does one see this in the Cram et al. (2007) back trajectory analysis of their numerical simulation of Hurricane Bonnie (1998)?

Limit Cycle

The limit cycle seems like a very important feature. Would it be possible to analytically solve for the radius of the limit cycle using the idealized point vortex/divergence model? Since the value of the streamfunction at the stagnation point can be solved for, it seems one could then determine the radius of the streamfunction at $\phi = 2\pi n$, where n is an integer. By taking the limit as $n \to \infty$ on the complex manifold, one could possibly determine the radius of the limit cycle, but I have not worked this out myself. This way, one can achieve an inner and outer radial bound on the possible penetration of environmental air by the steady, horizontal flow. Also, upon making some assumption about the divergence, D, a plot similar to Fig. 9 could be made.

Downdrafts as a Mass Sink at Midlevels

Another possible mass sink at midlevels is the formation of a large area of downdrafts, especially as shown in RMN. How might an organized, banded downdraft might affect the flow topology in such a way as to create a feedback that allows even more environmental air to be ingested in toward the center of the tropical cyclone?

Operational Implications

There are some operational implications regarding sampling of storms that I think would be useful to place in the concluding section if the authors so desire. Namely, is it important to get the the environmental flow and structure of the cyclone correct so that the flow topology can be correctly deduced. Additionally, the thermodynamic properties of the source region within the dividing streamline are important to sample correctly.

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Tropical Cyclone Size

Although the intensity is primarily addressed here, the size of a tropical cyclone also seems to be an important parameter in this framework (through the circulation, Γ). Since tropical cyclones of similar intensities can have vastly different sizes, how would the flow topology of a small storm compare with a larger one? It seems the authors may be able to use their results to explain why smaller tropical cyclones, which can be quite intense, seem to be much more susceptible to vertical wind shear and environmental intrusions of dry air.

Other Minor Points

Fig. 2. The wind profile of the Cat1 point vortex is actually not flat between 0-50 km. I recommend eliminating this portion of the curve inside 50 km.

Section 2.1.1, second paragraph. It's a bit tough to visualize the environmental storm-relative flow from the in-text description. Adding vectors of the storm-relative flow to Fig. 3 at each level would aid the reader in assessing how the geometry of the flow topology changes with the direction and magnitude of the environmental flow.

Section order. I would consider rearranging the article so that sections 3 and 4 come before section 2. The point vortex model serves are a nice didactic example to the more complex simulation. Additionally, some terms, like the "stagnation point" are clearly defined in section 3, but used before in section 2, which leads to some confusion initially.

Inner and outer separatrix. I'm confused by this terminology on pg. 28080. Perhaps labeling Fig. 7 or defining it better in the text would help. Also, why is the width of the opening of the separatrices, d, important? Does larger d guarantee a more direct path of environmental air to the inner-core?

Technical Corrections

Pg. 28080, Line 17. Comma missing between "dividing streamline" and "the presence."

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Pg. 28089, Line 6. “Extend” should be “extends.”

Interactive comment on Atmos. Chem. Phys. Discuss., 10, 28057, 2010.

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