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Interactive comment on "Impact of vertical wind shear on roll structure in idealized hurricane boundary layers" *by* Shouping Wang and Qingfang Jiang

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Title: Impact of vertical wind shear on roll structure in idealized hurricane boundary layers

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Recommend: Minor revisions

Synopsis: This paper describes a numerical model that can be used to investigate how the hurricane boundary layer mean flow affects the resulting organized roll vortices. Observations suggest that rolls are a fundamental aspect of the hurricane boundary layer. Yet, no numerical model PBL parameterizations include their effects. In large

part this is because quantitative information on how they affect the fluxes is lacking in observations. So, there have been attempts to capture their effects in LES-like numerical models. Given a simulation of rolls, their effects can be examined in isolation. The key question is whether or not the simulation properly represents the hurricane boundary layer.

Discussion: The method in this paper uses a relaxation methodology to impose a mean flow. It is clear that rolls are generated by a combination of shear and convective instabilities (dominated by the shear instability). The shape of the mean inflow profile (radial flow) controls the shear instability. However, the basic mean flow profiles are established by both the rolls and non-roll fluxes, which leaves a chicken-or-the-egg theoretical problem. Theory shows that the mean flow modifications due to rolls (roll-flux divergence effects) is somewhat subtle, so it makes sense to start with a reasonable non-roll flux (i.e. down-gradient, local fluxes), idealized PBL and examine the finite perturbations. This is the approach used in theoretical studies and it is essentially what has been done in this paper.

However, there is no clear way to select the down-gradient model and, as has been demonstrated elsewhere, the resulting mean flow profiles can vary wildly, as will the associated rolls. The value of this paper is that the relaxation methodology "generalizes" the LES technique toward the freedom allowed in theoretical studies to explore the parameter space associated with the selection of mean flow profiles. However, care must be taken to ensure that the target mean flow profiles are in fact realizable. There must be a consistent effective eddy-viscosity profiles that would produce the target mean flow profiles. This latent eddy viscosity associated with the target mean flow profile and the non-roll fluxes should be part of this paper.

Interesting questions arise. In some sense, current remote sensing capabilities are making it much easier to measure basic roll characteristics and mean surface winds than many other aspects of the turbulent hurricane boundary, especially turbulent fluxes (much less being able to separate the fluxes into roll and non-roll contributions).

Can tools such as the model presented here (and theoretical models) combined with observations be used to find constraints on the various local "gradient-flux" methodologies used in numerical models?

How can the non-local roll fluxes be parameterized? The mass flux-like method proposed by Zhu has a fundamental limitation. Convective boundary layers are comparatively much simpler than mixed shear/convective boundary layers. The former is highly skewed and the nonlocal fluxes are largely vertical over the locally warmer perturbations. The roll PBL is much less skewed, the roll characteristics depend on the entire mean flow profile, and, the updrafts are not vertical and co-located with the warmer temperature perturbations. (Zhu's lateral momentum entrainment parameter is an order of magnitude larger than that used for heat in mass flux models; this result has been replicated in theoretical models.) It might be simpler to attempt to modify the simple Mellor-Yamada-based parameterizations to include roll effects. However, the basic closure assumptions used in these models all assume near isotropy in the turbulence, so there may be fundamental inconsistencies.

In any case, the model that was developed for this paper stakes out an interesting middle path for exploring hurricane boundary layer rolls. In combination with the other tools and remote sensing capabilities that have been developed recently, we may be on the cusp of developing hurricane boundary parameterizations that correctly capture both the local and nonlocal contributions to the turbulent fluxes. As shown in this paper and elsewhere, the nonlocal fluxes are not a small contribution to the total. And they are inconsistent with standard down-gradient parameterization.

Specific suggestions:

1) Review the paper for English grammar. It is generally quite well written, but a few minor errors are present.

2) On page 10, line15-16 (and other places): I think you mean the "vertical shear of the radial wind".

3) Page 11 line 3: Might be clearer to use "r, t" subscripts instead of "x, y".

4) I think you need to provide effective eddy viscosity profiles for the choices of the target mean flow profiles, especially the "mixed" ones. As a further benefit, this would allow direct comparisons with theoretical roll models.

5) The roll effects are studied in detail and it took me a long time to puzzle through all of the figures. That isn't a criticism, there is a lot of information to digest. I wonder if some sort of "cartoon" drawing could help with the visualization and putting the results in context?

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