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Radial and Azimuthal Variations in Convective Burst Structure in Tropical Cyclones from Airborne Doppler Observations

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1. Motivation

Studies using observations from the NOAA P-3 aircraft have shown that the dynamical structure of a TC plays a crucial role in its future intensity (i.e. Jorgensen 1984; Kossin and Eastin 2001; Rogers et al. 2013). Riemer et al. (2010) further noted that the eyewall tilt is an important focal point for intensification forecasts as it determines how efficiently the storm is utilizing heat and moisture that is advected into the eyewall at the low levels.

The eyewall region is where the strongest updrafts are present which acts to drive a storm's circulation. Characteristics of convective events in the eyewall of TCs have been examined (e.g., Jorgensen et al. 1985;Black et al. 1996) and show that the frequency and azimuthal distribution of upper level convection in the eyewall region are directly related to intensity change. Black et al. (1996) found that updrafts in the eyewall are generally sloped radially outward, and that the strongest updrafts (exceeding 5 m s^{-1}) are located at heights around 8 km. A complete Doppler-derived wind field of Hurricane Alicia (1983) suggested that maximum updrafts at higher altitudes were the result of latent heat release above the melting layer, while downdrafts below the melting level were associated with latent heat release from melting (Marks et al. 1987).

The initiation of intense vertical motion within the eyewall region is related to the distribution of radial flow. Reasor et al. (2013) found that the radial wind profile of a TC can be substantially modified by the vertical shear the storm is experiencing. In storms experiencing moderate or stronger vertical shear, lower-tropospheric inflow is maximized in the downshear right quadrant, while outflow is maximized aloft. In the upshear-left quadrant, the opposite occurs: outflow predominates at the low levels and inflow is seen aloft. In the other two quadrants, there is not a clear signal. DeHart et al. (2014) expanded on this analysis and found that the strongest updrafts are in the downshear-right quadrant. These features are due to regions of convergence from the radial wind in their respective quadrants. Understanding the radial wind profile is thus crucial to predicting areas of intense vertical motion and a storm's overall intensity change.

In a composite study using airborne Doppler radar, Rogers et al. (2013) found that convective bursts (CBs; defined as the top one percent of all observed updrafts), were associated with intensifying (IN) TCs when they were found primarily within the radius of maximum winds (RMW). This is thought to be primarily due to the favorable positioning of diabatic heating from the CBs in a region of high inertial stability and subsequent tangential wind spin-up. CBs located outside of the RMW tended to be found in steady-state (SS) storms. What was

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not explored in this study, however, was the structure of the CBs themselves and how they varied for IN and SS storms.

This project will examine the structure of CBs as a function of shear-relative azimuthal location and RMW-relative radial location. These structures will be compared for IN and SS cases to determine if there are structural differences in the CBs that are related to TC intensity change.

2. Convective Burst Identification

For the entire Doppler dataset, the top one percent of updrafts was 5.5 m s^{-1}. All columns in each pass that had an updraft greater than 5.5 m s^{-1} were identified. Adjacent grid points that met the criteria were grouped using a depth first search in order to flag independent convective bursts. An example of the identification of CB's is shown in Figure 1. The center of the CB was found using a velocity weighted center and each CB was stratified by shear-relative quadrant (DSR-down shear right, DSL-down shear left, USL-up shear left, USR-up shear right), where shear values were obtained from SHIPS (DeMaria and Kaplan 1994).

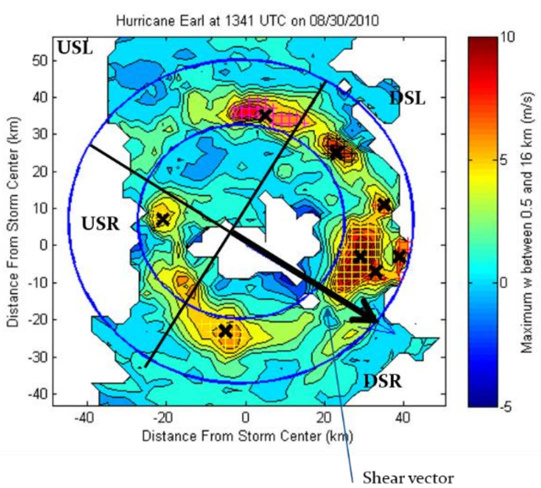

Figure 1. The maximum updraft (shaded) speed derived from the airborne Doppler analysis for Hurricane Earl at 1341 UTC. The '+' indicate all points whose maximum updraft is greater than 5.5 m s^{-1} and the 'x' denotes the CB center.

Radial cross sections of the CBs were taken about the burst center to get the general structure of the features. To account for missing data, each radial band was averaged ±4 km in the azimuthal direction. Perturbation values of each field were found by subtracting off the azimuthal mean of the field from the merged analysis (an average of all the passes from a single flight).

3. Results

The structure of the average CB (regardless of storm intensity change) in each shear-relative quadrant is shown in Figure 2.

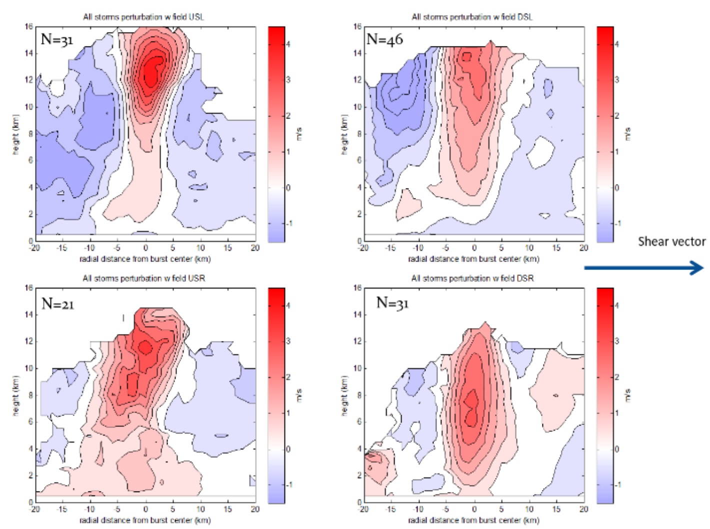

Figure 2. A shear-relative quadrant comparison of perturbation vertical velocities due to CBs.

The DSR quadrant has CBs at the lowest altitude and weakest updrafts. This is consistent with the DSR quadrant being the initiation quadrant due to convergence of the low-level radial wind. The CBs are larger in size and have a maximum updraft aloft in the DSL and USL quadrants. The largely unfavorable conditions in the USR quadrant

(Reasor et al. 2013; DeHart et al. 2014) weaken the structure of the updrafts by the time they reach there.

Each quadrant was stratified by IN and SS storms and the structures of the CBs were compared. When looking at the USL quadrant, significant differences arose in both the structure and strength of the updrafts (Figure 3). The CBs in IN storms have an updraft centered above 12 km altitude, while the CBs in SS storms are centered below 10 km. The differences in height of maximum updraft, updraft strength, and heights of the 12, 15 and 20 dBZ echo tops are significantly different between IN and SS storms at a greater than 95 percent confidence level. Although the sample size for the SS storms is six, there is a strong signal of the CB structural characteristics in this quadrant. To further advance this study, an attempt is being made to increase the number of swaths added to the dataset.

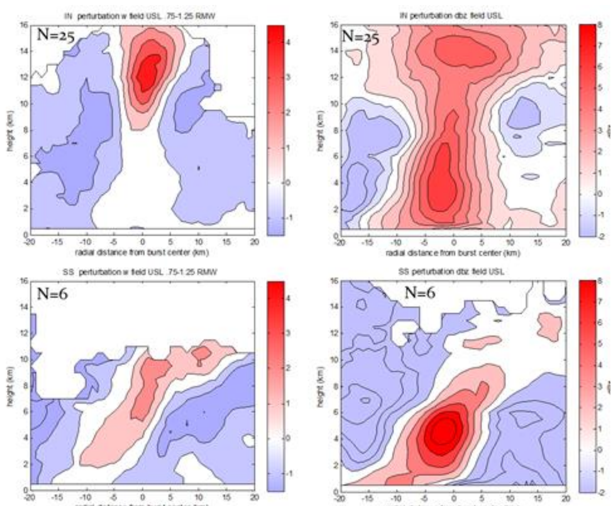

Figure 3. A comparison of perturbation vertical velocity and reflectivity between RI and SS storms.

4. Discussion

The results indicate that during an operationally tasked NOAA W3-PD aircraft mission, the data can be analyzed in near real-time to determine the structure of intense updrafts within the storm. The significant differences in CB structure are generally confined to the USL quadrant and can be used to forecast whether a storm will intensify.

4. References

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