12A.6 DEVELOPMENT AND EVOLUTION OF CONVECTIVE BURSTS IN WRF SIMULATIONS OF TCs DEAN (2007) AND BILL (2009)

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1. INTRODUCTION

Convection in tropical cyclones (TCs) has been studied extensively. The concept of narrow updraft cores known as “hot towers” or “convective bursts” (CBs) was introduced as far back as Malkus and Riehl (1960). Continued research has sought to understand eyewall convective structure (e.g. Braun and Wu 2007), as well as the TC intensity response to CB development (e.g. Rogers et al. 2013). However, the details of the processes that lead to extreme updraft formation remain unclear, and the nature and timing of the TC intensity change due to CBs are also a subject of ongoing investigation. This study investigates this problem using high-resolution simulations of Hurricanes Dean (2007) and Bill (2009).

2. DATA/METHODOLOGY

2.1 *Model Configuration and TCs Chosen*

The study used the Weather Research and Forecasting Model (WRF) Version 3.6. The GFS 0.5-degree analyses were used for boundary conditions. The model configuration included a fixed nest with 18-km grid spacing, and inner nests of 6-km and 2-km grid spacing that moved with the TC. The model contained 55 vertical levels, following Chen and Zhang (2012). The Dean simulation was run for 144 hours, and the Bill simulation for 126. The data was output every 15 minutes. The analysis begins at hour 12 for Dean and 36 for Bill, after spinup of each TC.

2.2 *Convective Burst Identification*

CBs were identified based on the 99th percentile of mean eyewall vertical velocity in the layer from z = 6-12 km: 8.4 ms^{-1} for Dean and 5.4 ms^{-1} for Bill. This is relatively similar to the methodology of Rogers et al. (2013), but uses a layer mean rather than W at a single height. Figure 1 shows an example of convective bursts, and Figure 2 shows the distribution of CBs in a shear-relative coordinate system. The coordinate system is also normalized by the radius of maximum winds (RMW), to allow for compositing. These figures show that the highest concentration of CBs is found downshear-left, consistent with Black et al. (2002) and Rogers et al. (2013). The Bill simulation had a higher degree of asymmetry than the Dean simulation, likely due to the higher shear over that TC.

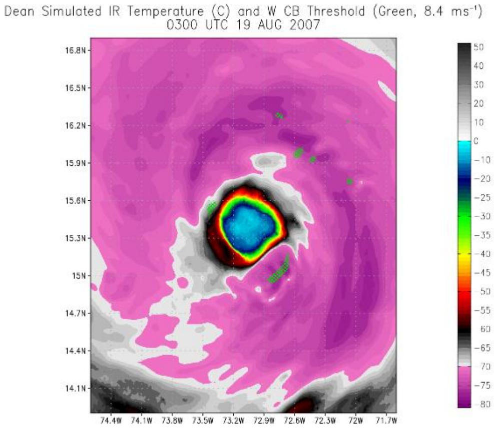

Figure 1: Simulated IR satellite and 6-12 km mean W greater than 8.4 ms^{-1} (green hatching) at hour 99.0 of the Dean simulation.

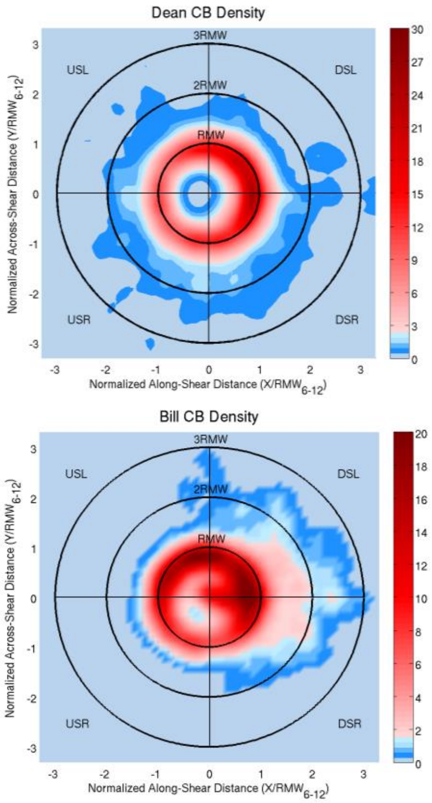

Figure 2: Density of CBs for all times in each WRF simulation (Dean top, Bill bottom) in a shear-relative coordinate system (for example DSL is downshear left), normalized by the RMW. The colorbars are scaled for comparison based on sample size.

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3. RESULTS PART I: CB DEVELOPMENT

3.1 *CBs and Mesovortices/Convergence*

One of the key factors controlling CB development in the simulations was found to be the location and strength of radial convergence due to mesovortices and rainbands, especially in the lowest 1-4 km of the TC. This is consistent with a hypothesis for CB development in Earl (2010) by Rogers et al. (2015), and indicates that convergence plays a key role in governing radial location of CBs. Correlations between radial convergence and CB counts in radial bands (not shown) reveal that the relationship is strongest near the eyewall and well outside the eyewall (> 2*RMW).

3.2 *Structure of Growing/Decaying CBs*

One aspect of CB development and structure that has not been well-documented is the difference between growing and weakening CBs. In this study, we track 4 strong individual CBs (two for each TC) for an hour prior to and after their peak. Figure 3 shows r-z composites of the radial flow for the hour prior to the peak (growing CBs) and hour after the peak (decaying CBs). The results show that the growing CBs had stronger PBL inflow, as well as stronger outflow from the eye to the eyewall, which was found to be a source of eyewall buoyancy, consistent with Braun et al. (2002). The decaying CBs had weaker PBL inflow, and also did not have recirculation into the eye.

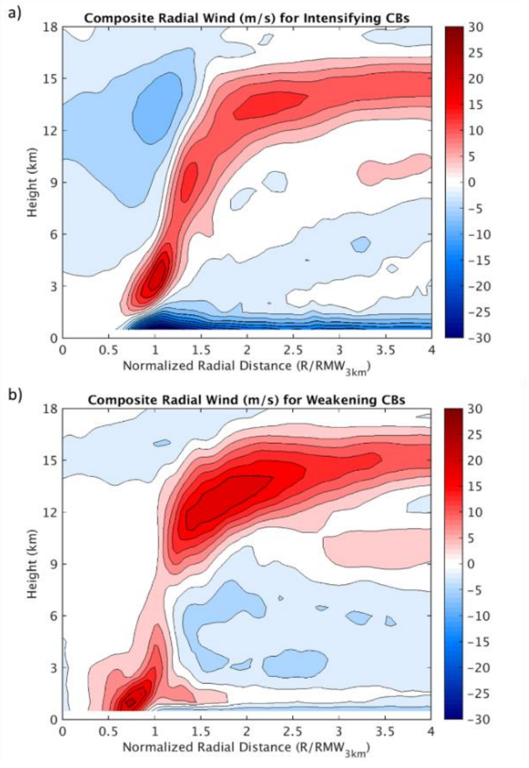

Figure 3: Composite radial velocity for a) The hour prior to the peak and b) The hour after the peak of the 4 individual CBs analyzed.

3.3 *3-Dimensional Trajectories*

3-dimensional trajectories were calculated into and out of several CBs using the HYSPLIT trajectory model (Draxler and Hess 1998). The x-y, r-z, and 3-dimensional paths of 27 parcels into and out of one of the CBs are shown in Figure 4. The parcels are pulled inward into the eye at low levels, then rapidly accelerated outward into the eyewall, where they quickly ascend in the CBs before moving outward in the outflow aloft. Some of these parcels are associated with CAPE as high as 524 Jkg^{-1} as they move into the eyewall (not shown). This source of buoyancy is consistent with Eastin et al. (2005). This finding indicates that eye-eyewall exchange may be one of the key forcing mechanisms for the most extreme updrafts within the inner-core region of the TC.

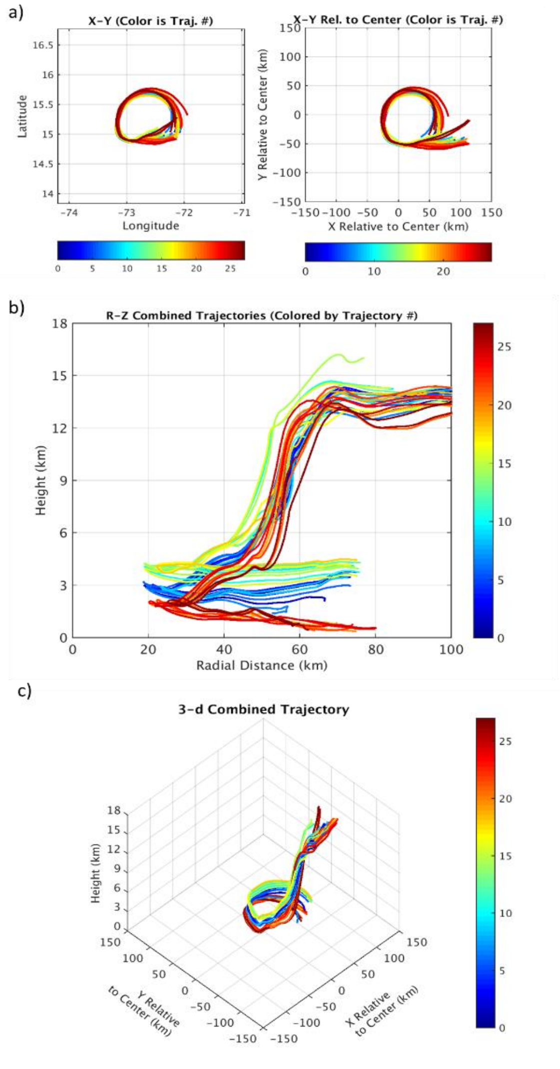

Figure 4: Paths of the 27 trajectories into and out of a CB at hour 98.50 of the Dean WRF simulation in a) X-Y space, both earth-relative and storm-relative b) R-Z space c) 3-D storm relative space. Each color represents a different trajectory initiated at a slightly different location at 3 heights: 2 km, 3 km, and 4 km.

4. INTENSITY RESPONSE TO CBs

One of the key questions surrounding CBs is how the TC intensity changes as a result of CB development. Figure 5 shows the percentage of CBs in each radial band for intensifying and weakening times for Bill (Dean was very similar). Consistent with Rogers et al. (2013), the intensifying times had a higher percentage of CBs inside the RMW, while the weakening times had a higher percentage outside the RMW. Lag correlations (not shown) showed that the typical lag between CB development and intensity change was approximately 0-3 hours. This indicates that CBs can sometimes be predictive of intensity change, but also may be indicative of continued intensification, as suggested by Zagrodnik and Jiang (2014).

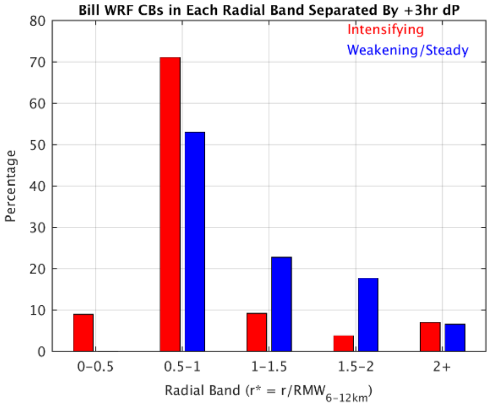

Figure 5: Percentage of CBs in different radial bands for Bill intensifying and weakening/steady times.

5. CONCLUSIONS

The results indicate that convective burst locations in the simulations are consistent with observed distributions. The high-resolution simulations show that locally-enhanced vorticity is a key forcing for CBs, through enhanced low-level inflow and convergence, as well as buoyancy through exchange of air between the eye and eyewall. CBs inside the RMW are found to be a predictor of future intensity change in both simulations, especially when the storm was already intensifying. These findings indicate that CBs are a key dynamic feature of the TC inner-core region and can play a large role through their connection to storm structure and intensity.

6. ACKNOWLEDGEMENTS

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