8A.6 WSR-88D OBSERVATIONS OF BOUNDARY LAYER ROLLS DURING HURRICANE LANDFALL

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1. INTRODUCTION

This study uses WSR-88D radar data to explore the structure of the hurricane boundary layer (BL) during landfall. Specifically, we will examine BL roll-like structures that appear in the Doppler residual velocity display. Wurman and Winslow (1998) analyzed Doppler on Wheels (DOW) data gathered during Hurricane Fran (1996). They showed the wind field in the lowest 200 m included features that resemble boundary layer rolls aligned along the mean wind vector. These features were small (<10 km long), narrow (<300 m wide) regions of enhanced flow flanked by large horizontal gradients (10^{-1} s^{-1}). Viewing the success of identifying BL rolls with the DOW, an attempt was made to locate the BL rolls with operational WSR-88D radar.

The WSR-88D in precipitation-mode completes a volume scan, composed of 360 scans at 14 elevation angles from 0.5° -19.5°, in 6 minutes. The mean radial velocity of each scan is a sine function of azimuth angle. The amplitude and phase of this sine curve are measures of the wind speed and direction at the scan elevation. Also, with a Fourier analysis of the Velocity-Azimuthal Display (VAD) one can estimate divergence (0-th harmonic), wind speed and direction (1st harmonic), and deformation (2nd harmonic) (Browning and Wexler 1968). Subtracting the mean radial velocity from the actual Doppler velocity, gives the 'residual' velocity. Given the location and elevation of the radar site, and using beam angles only between .5° and 5.5°, the wavelength, length, depth, magnitude, and motion of the BL rolls can be calculated from the residual velocity display.

2. PRELIMINARY RESULTS

To date, three storms have been examined: Fran (1996), Bonnie (1998), and Georges (1998) using the WSR-88D's from Wilmington, N.C.; Morehead City, N.C.; and Key West, FL, respectively. The analysis focuses on the time period between the first identified BL roll and hurricane landfall. Fran was a category 3 hurricane while approaching North Carolina and dropped to a category 2 at landfall. Fran passed within 28 km of Wilmington and the first BL rolls were identified 105 km from the eye. Bonnie was a category 1 to 2 during the sampling period and passed within 30 km from Morehead City. The first BL rolls were identified when Bonnie passed within 120 km of Morehead City. Georges passed 25 km from Key West as a category 2 storm and BL rolls were identified out to 80 km from the eye.

The cumulative distribution diagrams for Fran are shown (Fig. 1). The number of BL rolls tracked in Bonnie, Fran, and Georges was 44, 56, and 24, respectively. The Georges rolls were less frequent and weaker in intensity than those in Fran and Bonnie. The average low-level (800 m - 50 m) shear in Georges was substantially less than in the other storms, this likely contributed to the fewer number of rolls identified and the lower intensity of the rolls.

The wavelength parameter is shown as a 'half' wavelength since the measurement is made from the highest positive to the lowest negative residual velocity. Georges had the largest half wavelength (~700 m) with Fran next (~660 m) and then Bonnie (~600 m).

The length and depth measurements are dependent on beam angle. A higher beam angle detects a signal more along the vertical than along the length of the BL roll. By using the lower beam angles (see above) we have tried to alleviate this problem. The length and depth measurements are similar for Fran (~1610 m, ~290 m) and Bonnie (~1640 m, ~270 m) while Georges' BL rolls are smaller in both categories (~1320 m, ~235 m).

A schematic diagram of a BL roll was created using average mean values from the three storms (Fig. 2). The diagrams include the average median values of half wavelength, length, depth, magnitude, and horizontal motion. The mean height above the surface was ~300 m. The BL rolls contain strong positive residual velocities alongside strong negative residual velocities. This results in a horizontal wind shear of ~14 m s^{-1} over 660 m, corresponding to a vertical shear component of vorticity equaling 0.020 s^{-1}.

3. DISCUSSION

Hurricane BL rolls were tracked and documented using the WSR-88D Doppler radar, and some of the gross characteristics have been revealed. The low-level shear seems to play a significant role in the frequency and intensity of the BL rolls.

Broadly speaking, the BL rolls could play an important part in the mixing processes of heat, moisture, and momentum in the hurricane boundary layer.

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Future work includes modeling the BL rolls using a large eddy simulation model.

4. REFERENCES

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Wurman, J., and J. Winslow, 1998: Intense Sub-Kilometer Boundary Layer Rolls in Hurricane Fran. Science, 280(5363), 555-557.

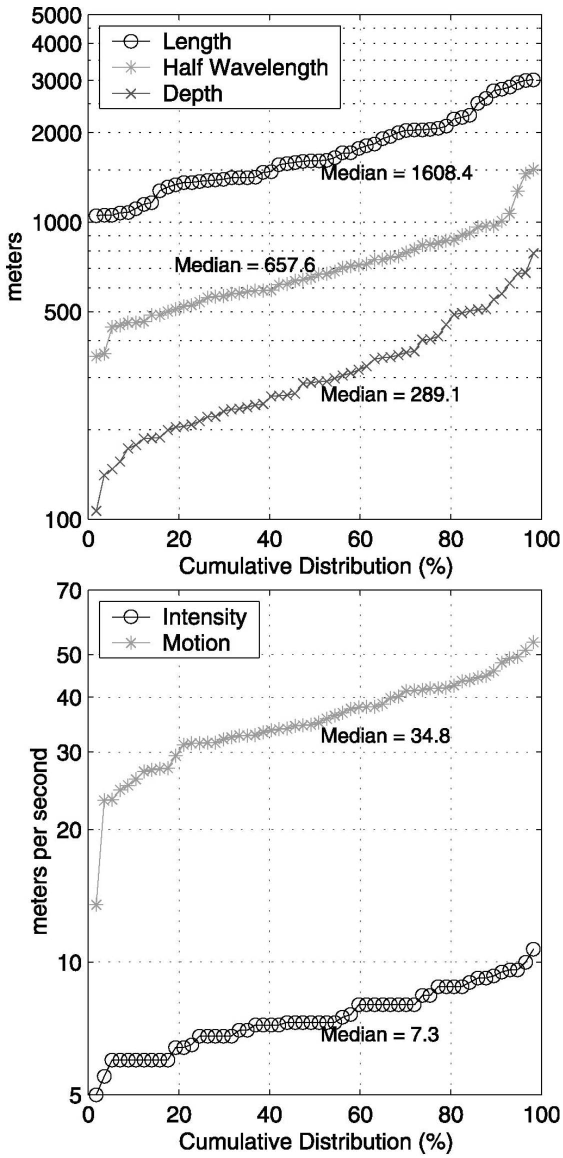

Figure 1. Cumulative distribution curves of boundary layer roll properties in hurricane Fran.

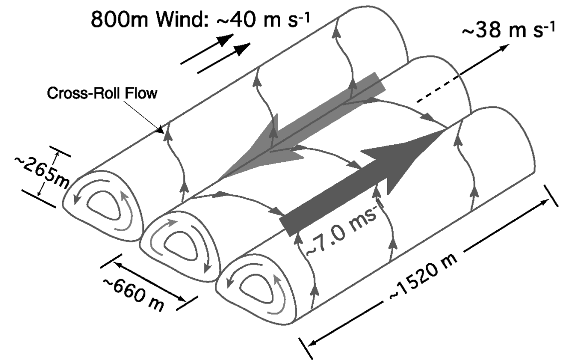

Figure 2: BL roll schematic for the average median values of Fran, Bonnie, and Georges. Small arrows indicate high (low) momentum air being transported downward (upward). Large arrows indicate the positive (negative) residual velocity captured by the WSR-88D. The 38 m s^{-1} value equals the motion of the BL roll and the arrow indicates the direction of motion. The wind speed and direction in the boundary layer at 800 m is indicated at the top of the figure. The mean height above the surface is ~300 m.