4A.2 THE STRUCTURE AND EVOLUTION OF A HURRICANE IN VERTICAL WIND SHEAR: HURRICANE ELENA (1985)

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1. INTRODUCTION

Recent theoretical and numerical modeling studies have documented the existence and important role of vortex Rossby waves (VRWs) in tropical cyclone structure and intensity change (see references in Wang and Wu 2004). However, very few observational studies (Kuo et al. 1999; Reasor et al. 2000) have investigated the nature of VRWs in real tropical cyclones due the difficulties in observing tropical cyclones over the open ocean.

One of the most complete data sets of a single tropical cyclone was recorded in Hurricane Elena (1985), as it was a slow moving, intensifying, convectively active tropical cyclone in the Gulf of Mexico. Elena was in an environment with a nearly constant direction, but changing magnitude of vertical wind shear for over 36 hours, during which 1,142 ground-based radar scans, 86 radial flight legs and 47 vertical incidence scans were collected.

It is the goal of the current study to use the high-resolution data set from Elena to do a detailed analysis of the properties of VRWs in a sheared tropical cyclone. By synthesizing all available data sources, the aim is to provide a clearer picture of the way a tropical cyclone evolves in and responds to environmental wind shear, and in doing so, bridge the knowledge gap between numerical models and observations of tropical cyclones.

2. DATA AND METHODOLODY

Continuous radar scans of Hurricane Elena's eyewall and rainbands were captured from the WSR-57 radar at Apalachicola, Florida (AQQ) from 22 UTC 31 August through 07 UTC 2 September. Michael Black of the Hurricane Research Division (HRD) of NOAA translated the reflectivity data from latitude-longitude coordinates to a storm-relative coordinate system with a domain of 300 x 300 km and a horizontal resolution of .75 km. The radar made 1,142 scans of Elena, with as little as 23 s between complete radar scans. In order to have a uniform time step between radar images, the scans were linearly interpolated to five-minute intervals. Only the closest two scans to the time in question were weighted and used to compute the interpolated scan. If there were no scans within five minutes of either side of the prospective interpolated time, no scan was calculated and a gap appears in the data.

Isobaric height, temperature, dew point, liquid water content, wind speed and direction are measured by the instrumentation on the NOAA WP-3D reconnaissance aircraft (Jorgensen 1984). The data were transformed by HRD personnel into storm relative coordinates through construction of the cyclone track by the method of Willoughby and Chelmow (1982), and interpolation of the data to a .5 km radial grid that moves with the vortex. The result is a 100-150 km long radial profile of the vortex structure at flight level (~850 hPa for Elena (1985)).

3. RESULTS

Figure 1 shows the interpolated AQQ radar images of Elena from 1825, 1925, and 2025 UTC 1 September in panels a) – c), respectively. The vertical wind shear was from the northwest at 7 m s^{-1} during this time and the reflectivity pattern shows an increasingly asymmetric wavenumber one pattern with almost all deep convection to the left of the vertical wind shear vector. The rainband pattern in Elena exhibits many of the features of Willoughby et al.'s (1984) stationary band complex (SBC): the deepest eyewall convection upshear left of the center; weakly convective connecting bands left of shear; and the principal rainband curving out from and around the storm from downshear to downshear right of the center. Also indicated in the SBC schematic are the so-called secondary bands that lie radially between the eyewall and principal rainband. It is one of these features that is tracked in figures 1a) – c).

At 1825 UTC, the center of the band is located ~45 km west of Elena (indicated by the black arrow in figure 1a)). Animations of the radar (available on-line at http://www.atmos.albany.edu/student/kristen/elena.html) show that the band originates as part of the convection in the eyewall that peels away from the main stationary feature (similar to the bands in black breaking off the northern eyewall in 1b)). The band continues to propagate radially outward and cyclonically around the center with time so that by 1925 UTC (1b)), the band has separated from the eyewall and lies ~70 km southwest of the center. Finally, at 2025 UTC (1c)), the band is south-southeast of the center at the 90 km radius, still maintaining a clear convective signature.

Radius-time and azimuth-time Hovmollers of the reflectivity field yield propagation speeds for the band of 6.5 m s^{-1} radially outward and 27 m s^{-1} cyclonically around the center. This azimuthal phase speed is ~60% of the local tangential wind. These values are consistent with VRW theory and the observational results of Reasor et al. (2000) and Black et al. (2002).

Figure 2 shows the vertical velocity (solid line) along the flight path of the radial leg indicated by the white line in figure 1b). Also shown is the radar

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reflectivity (dashed lines) for each five-minute period closest to when the plane flew over that radius. One updraft exists on the inner edge of the eyewall, while a second, stronger updraft is located just radially inward of the band peeling off the eyewall to the west (see figure 1b)). The band discussed above clearly shows up as a >35 dBZ peak in the reflectivity at the 70 km radius. The band is associated with a 10 km wide updraft located ~5km radially inward of its maximum reflectivity. A 20 km wide region of variable strength downdrafts dominates the center to rear portion of the band.

Further examination of this and other propagating bands and their associated thermodynamic and kinematic properties will be shown in the presentation, alongside radar animations of Elena.

4. ACKNOWLEDGEMENTS

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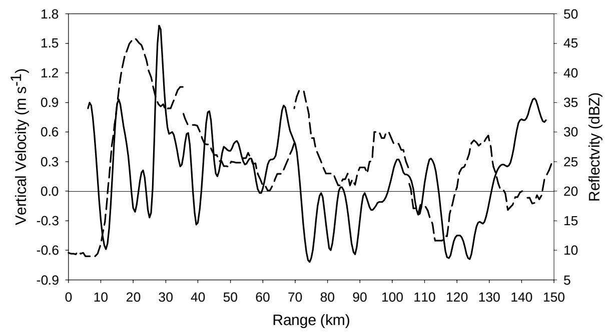

Figure 2. Vertical velocity (solid line, left axis) along the path of the radial flight leg indicated in figure 1b). Also shown is the radar reflectivity (dashed lines, right axis) for each five-minute period closest to when the plane flew over that radius.

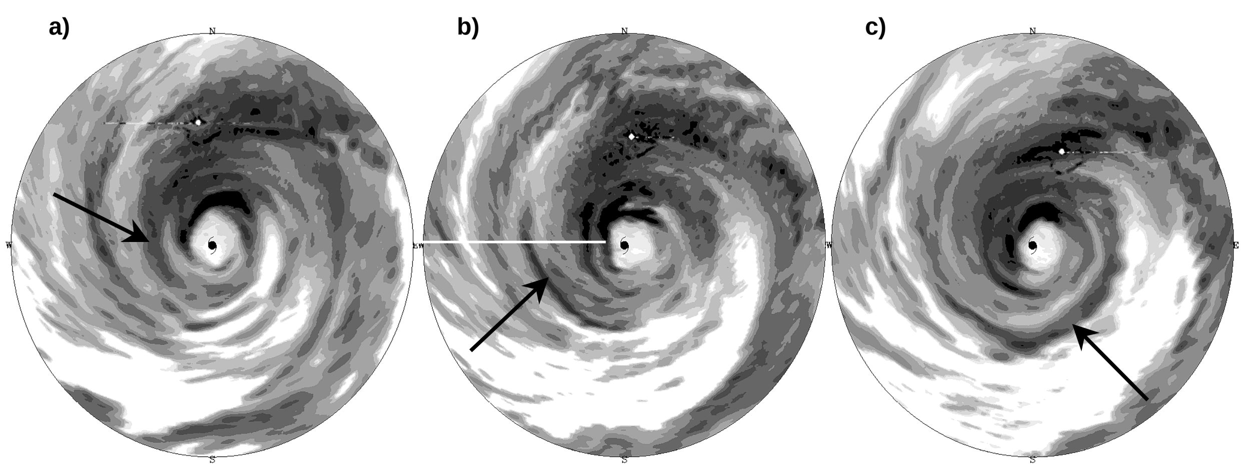

Figure 1. AQQ radar images of Elena from 1825, 1925, and 2025 UTC 1 September. Shading is every 4 dBZ beginning at 8 dBZ, with > 40 dBZ shaded black. The images are storm centered out to 150 km from the center (marked with a hurricane symbol). The position of the AQQ radar is noted by the white circle north and northeast of the storm center. Black arrows point to the band discussed in the text and the white line in b) shows the path of the radial flight leg shown in figure 2.