13B.6 GENESIS AND DECAY OF A TROPICAL STORM IN STRONG VERTICAL SHEAR

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1. INTRODUCTION

Forecasters have long been aware of the pulsing nature of convection in tropical cyclones. Often bursts of deep convection form close to the storm's center, only to move away from the center in the downshear direction. One day the low level center may be exposed, and the next it may be embedded in the central dense overcast (Dvorak 1975). This can have a large impact on a storm's intensity. While this behavior is well known, its causes are not well understood.

Tropical Storm Edouard formed off the East Coast of Florida in September 2002. Though the storm was constantly under shear in excess of 13 ms^{-1}, it was able to maintain tropical storm strength for nearly 72 hours. Edouard underwent a series of convective pulses in which lightning increased and convection formed over the center, then shifted 100 km or more outward. The purpose of this study is to understand what causes these pulses of convection, and why they alternate between the storm center and outer regions.

2. DATA AND METHODOLOGY

This study makes use of aircraft reconnaissance data from the U.S. Air Force, infrared satellite imagery from the Space Science Engineering Center (SSEC) at the University of Wisconsin-Madison, and cloud-to-ground lightning locations from the National Lightning Detection Network (NLDN). From the temperature and dewpoint measurements collected by the reconnaissance flights, the equivalent potential temperature (θ_e) was calculated, following Bolton (1980). Six-hourly Best Track (BT) center positions produced by the National Hurricane Center (NHC) were linearly interpolated to generate a continuous storm track. Shear was calculated using 1.125 degree gridded analyses from the European Centre for Medium-Range Weather Forecasts (ECMWF).

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3. RESULTS

Figure 1 shows the number of lightning flashes observed within a 100 km radius of the BT center, wind barbs indicating 850-200 hPa environmental vertical wind shear, and BT central pressure. Three major convective events are noticeable on September 3, 4, and 5. Also notable is the strong vertical wind shear affecting the storm: 12.5 ms^{-1} on September 2, increasing to 25 ms^{-1} on September 5. Figure 1 also shows that convective maxima produce small decreases in pressure, whereas increasing vertical shear produces increasing central pressure.

Figure 2 shows a series of infrared satellite images, theta-e values, and flight level winds, centered on the convective pulse indicated by the red line in figure 1. Theta-e values are shown by the colored dots at the end of the wind barbs, specified as in the caption. At 0715 UTC (Fig. 2a) on September 3, Edouard was a minimal tropical storm with a maximum wind speed of 35 kt. The center of Edouard is barely visible as a low cloud swirl, with convection occurring only to the east. A reconnaissance flight through the storm found winds at the 850 hPa level no stronger than 25 kt. An 850 hPa theta-e maximum near the center of nearly 358 K is elevated approximately 15 K compared to values only 50 km away.

Figure 2b shows that the center has not moved much, but is now covered by cold cloud tops. The extensive high cloud region in Fig. 2b occurred at 1215 UTC, just after the lightning maximum indicated by the red line in Fig. 1. A dramatic increase in peak wind speed has occurred. Reconnaissance data at this time recorded winds in excess of 70 kt at the 350 m elevation northeast of the storm's center, but only 20 kt to the southeast, outside of the convection. Theta-e values, this time in the boundary layer, are still approaching 358 K near the center and are still 15 K lower only 50 km away. The best track surface wind maximum was raised to 55 kt.

Only 5 hours later, however, at 1715 UTC (Figure 2c), the convection has diminished and the coldest cloud tops have retreated well to the east of the storm's center, leaving it exposed once again. At this time, no winds higher than 45 kt could be found by the reconnaissance aircraft. Theta-e values, however, have increased further to 364 K in the center. Perhaps it is this high theta-e air that fuels the convective pulses that occur over subsequent days. The reasons for the storm's behavior will be addressed in the presentation.

4. ACKNOWLEDGEMENTS

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5. REFERENCES

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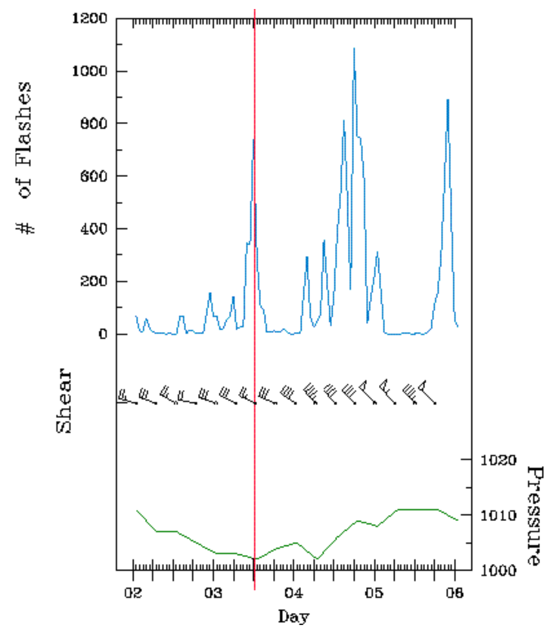

Figure 1: Number of hourly lightning flashes observed within a 100 km radius of the BT center (blue contour), environmental vertical wind shear (850-200 hPa; half barb, full barb, and flag denote 2.5, 5, and 25 ms^{-1} respectively), and minimum central pressure (hPa; green contour). The red line indicates the time of the event in Fig. 2b.

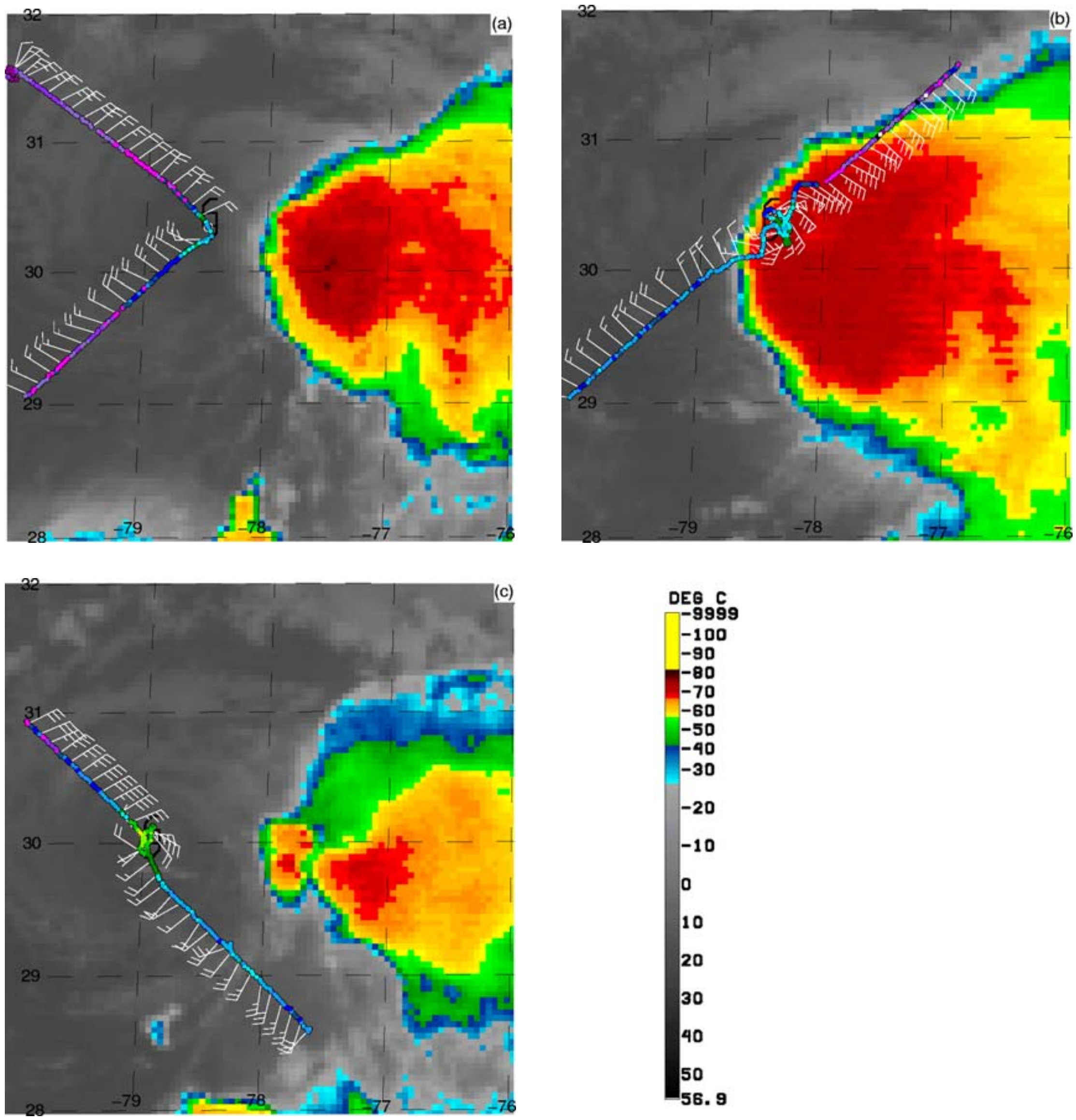

Figure 2: Infrared satellite images, with BT center shown by the tropical storm symbol. The color enhancement used to highlight cloud brightness temperatures is shown on the color bar to the lower right of this figure. Winds are indicated with white barbs, and theta-e values with color ranges (purples >335 K, blues > 345 K, greens > 355 K). (a) 0715 UTC 3 September 2002 at 850 hPa. (b) Same as (a), but for 1215 UTC at 250-500m. (c) Same as (b) but for 1715 UTC at 300-400m.