# WSR-88D Characteristics of Tornado Producing Convective Cells Associated With Tropical Cyclones

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## 1. Introduction and Methodology

This paper documents tornadic radar signatures associated with Tropical Cyclones (TCs) Josephine (1996), Opal (1995), Erin (1995) and Gordon (1994). Each of the TCs had winds of 17 m/s or greater when the tornadoes developed. Reflectivity and radial velocity data from National Weather Service WSR-88D radars were used to analyze characteristics which occurred at, or very close to, times of tornado occurrence. Specifically, storm relative velocity map (SRM) data were analyzed to find the intensity, diameter and depth of each mesocyclone, based upon manual recognition techniques. Likewise, base and composite reflectivity data were analyzed to document the size, strength and depth of each parent cell. General comparisons between the TC tornadic cells and the more classic tornadic supercells of the US Southern Plains will then be discussed.

The times of tornado occurrence were acquired from the publication STORM DATA. Although STORM DATA indicated that greater than 20 tornadoes occurred in association with the 4 TC's, this study was limited to 20 Florida touchdowns due to incomplete data sets.

Of the 20 TC tornado cases examined, 16 occurred within outer rain bands, with the remaining 4 confined to the eyewall portion of the TCs. Most of the tornadoes were weak (F0) and were short-lived (0.15 km damage path), however 2 of the tornadoes were strong, producing F2 damage. One of these F2 tornadoes remained on the ground for more than 16-km and produced a 400 m wide damage swath. Sections 2 and 3 of this paper will specifically address the radar signatures of the outer rain band tornadoes while section 4 will detail the eyewall tornadoes. Section 5 will conclude by discussing some of the most important findings.

## 2. Velocity Data of Outer Rain Band Tornadoes

Mesocyclonic characteristics were found by first manually identifying a maximum inbound/outbound velocity couplet at each elevation angle and then calculating the rotational velocity, diameter and subsequent shear for that couplet. The depth of the mesocyclone was found by repeating this process for each elevation until a circulation could no longer be identified.

Using the above criteria, it was found that each of the mesocyclones showed the strongest rotation (rotational velocity) in the low levels and weakened with height. The average rotational velocity at the lowest elevation angle (0.5 deg ) was 15.5 m/s. The average shear at 0.5 deg was .015 /s. Overall the low level mesocyclone core diameters were small, averaging 3.2 km, and gradually broadening with height. The average depth of the tornadic mesocyclones was 3-km, with no mesocyclone exceeding 4.4 km. As a comparison, mesocyclones associated with supercells in the US Southern Plains typically range between 9 and 11 km in depth, with average low-level diameters of 7-km (Burgess and Lemon 1990). Except for two cases, the tornadoes were associated with small convective cells (or "mini" supercells; Grant and Prentice 1996). The mesocyclones were typically located within the rear quadrant (relative to storm motion) of the convective cells. Regarding the two cases which were not associated with mini-supercells, one was tropical bow- echo type while the other consisted of a line/bow echo. The tornado associated with the bow echo was positioned near the center of the cell, while the line/bow echo tornado was located in the line portion of the cell.

**3. Reflectivity Data of Outer Rain Band Tornadoes**

One of the more interesting aspects of this study involved the horizontal size and magnitude of radar reflectivity associated with the tornadic cells. Using a definition of the 50 dBZ composite reflectivity contour to define the convective cell, nearly all the cells were quite small, typically oval in shape, with diameters of 8 to 11 km. Although all of the tornadic cells had reflectivity values greater than 50 dBZ, none of the cells had values above 60. The average vertical extent of the 50 dBZ contour was only 4-km, with no cells having a 50 dBZ value above 6-km. The average height where the tornadic cell was no longer identifiable as a single entity was 7.1 km. All of the cells were strongly tilted as maximum dBZ values associated with each cell were displaced downstream with increasing height.

Comparing TC tornadic reflectivity characteristics with those associated with supercells of the United States Southern Plains, no well defined "classic" reflectivity signatures, such as Bounded Weak Echo Regions (BWERs), maximum dBZ aloft, or "hooks", were found in this TC tornado data set. However, Sharp et al. (1997) did fine more classic signatures in mesocyclones associated with TC Opal. In this study, a few of the cells during the time of tornadogenesis did show sharp reflectivity inflow gradients and pendant features.

**4. Eyewall Tornadoes**

TCs Erin and Opal produced 1 and 3 eyewall tornadoes, respectively. Unlike the tornadic mesocyclones in the outer rain bands, manual analysis of the SRM velocity data did not indicate any well defined shear couplets with the eyewall tornadoes. However, strong cyclonic shear was evident along the interface between maximum winds in the eyewall and the center of the TC. Time lapses of the reflectivity data show that the 4 tornadoes occurred with convective elements in the eyewall which appeared to be sub-vortices (which showed sharply curved reflectivity signatures) within the overall eyewall circulation. All 4 tornadoes developed in the northeast quadrant of the eyewall.

## 5. Discussion

Relative to the TC scale radar reflectivity pattern, outer rain band tornadic cells were typically discrete, persistent, and possessed large dBZ values. No cells in this data set below 50 dBZ produced tornadoes. Also, no tornadoes occurred within the stratiform rain areas. Rotational characteristics of the outer rain band tornadic mesocyclones showed them to often be quite small both in width and depth, and significantly less than their counterparts in the US Southern Plains.

Eyewall tornadoes were much harder to identify, as individual shear couplets were not easily discernable within the given data set. However reflectivity signatures did provide clues to possible tornadic development, as these tornadoes developed in areas of enhanced reflectivity which showed local areas of curvature.

Radar operators who are responsible for warnings during TC situations should closely monitor all cells which show persistent high values of reflectivity. Due to the shallow nature and small rotational diameter of the tornadic cells, echoes at increasing distances from the radar site will be ill sampled, and therefore cells possessing even (persistent) weak rotation should be considered suspect. As sampling efficiency decreases, high values of spectrum width may also assist in tracking suspect cells and adding confidence to the warning decision process (Spratt et al. 1997). Based upon the current data set, cells which show persistent rotation, no matter how weak should be warned for. In fact, Spratt et al. (1997) suggested using a rotational velocity shear threshold of .010 /s, to issue tornado warnings during such situations. Since average shear values of .015 s-1 were observed near the time of tornado occurrence in the current study, the 010 /s shear value of shows considerable promise as a lead-time warning threshold.

## 6. References

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