8B.2 WSR-88D RADAR CHARACTERISTICS OF QUASI-LINEAR CONVECTIVE SYSTEM TORNADOES USING THE NSSL SEVERE STORM ANALYSIS PROGRAM

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1. INTRODUCTION AND MOTIVATION

An estimated 18% of tornadoes that occur yearly in the continental United States are spawned by Quasi-Linear Convective Systems (QLCS) (Trapp et al. 2004). Despite the significant contribution of QLCS tornadoes to the annual total, they are only recently being studied in depth. This paper will compare radar characteristics of QLCS tornadoes to their more common supercellular counterparts using the National Weather Service's Weather Surveillance Radar - 88 Doppler (WSR-88D) (Crum and Alberty, 1993).

These comparisons will be made using the National Severe Storms Laboratory's (NSSL) suite of radar algorithms known as the Severe Storm Analysis Program (SSAP), specifically the NSSL Mesocyclone Detection Algorithm (MDA) Stumpf, et al. 1998), and the Tornado Vortex Signature (TVS) Detection Algorithm (TDA) Mitchell, et al. 1998).

It is commonly believed that QLCS tornadoes are generally weaker than those spawned by supercells, however Tessendorf and Trapp (2000) show that QLCSs have produced occasional Fujita scale F4 tornadoes. Beyond this capacity to produce violent tornadoes, the distribution of QLCS tornado intensity reflects that of all tornadoes, namely that the majority are weak (F0 or F1).

The mechanism for QLCS tornado formation, and more aspects of their climatology, will be explored in additional papers. This paper attempts to quantify the radar characteristics of QLCS tornadoes and their parent circulation, and the possible differences between them and supercell tornadoes.

2. DATA AND METHODOLOGY

Building on the work of Tessendorf and Trapp (2000), the authors have compiled a set of ground truth data specific to tornadoes associated with QLCSs. This set, known as Q1, is comprised of information on the location and time of tornado occurrences from the National Climatic Data Center's *Storm Data* publication. The ground truth data set spans 2 years (1998-1999) and is for the entire continental United States. Archive II radar data were then obtained and processed. Most of the data was retrieved by using NCDC's new Hierarchical Data Storage System - Access System (HAS). The radar base data (base reflectivity and radial velocity) were combined with near storm environmental data and processed through the SSAP. The output from the SSAP contains up to 245 "attributes" or computed quantities, including output found in the MDA and TDA. These data can be then displayed using the National Severe Storms Laboratory's (NSSL) Weather Decision Support System - Integrated Information (WDSS-II) (Lakshmanan 2002).

At this point, we correlated the QLCS ground truth data to the MDA and TDA detections displayed by WDSS-II. This new data set, called Q2, contains the UTC date and time as well as the TDA and MDA detections' ID numbers. To show trends leading to tornadogenesis, the Q2 data were then sub-divided into time, relative to the volume scan in which the tornado occurred. These sub-divisions range from the tornadic volume scan (TOR) to four volume scans prior to the tornadic volume scan. I.e., TOR- 4, TOR-3, TOR-2, TOR-1, and TOR.

This setup mimics that of the NSSL's Tornado Warning Guidance (TWG) data sets, which therefore allows us to compare the QLCS tornadoes to the more extensive TWG tornado database (WDTB 2002). For this purpose, however, the 1999 TWG data set has been filtered so that it contains *only* tornadic supercell data. The second data set contains only QLCS tornado data as described above. A breakdown of the QLCS and "supercell" datasets is shown in Table 1.

TABLE 1

Number of:	Supercell	QLCS
Tornadoes	432	69
TOR Vol. Scans	1385	114
TOR-1 Vol. Scans	331	65
TOR-2 Vol. Scans	299	53
TOR-3 Vol. Scans	283	43
TOR-4 Vol. Scans	244	32

Table 1. Breakdown of datasets

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The data were checked for radar-range dependency. In terms of distance from the respective radar, the MDA detections for each dataset were divided into “bins” of 25 km and plotted as a histogram (Figure 1). So, for QLCS MDA detections, there were 78 detections between the ranges of 51-75 km, and there were 307 detections for the same range from the TWG dataset. Since there are many more detections for the TWG (1709) dataset than for the QLCS (275) set, we normalized the data for each bin. Specifically, each bin’s population was divided by the total number of detections for the respective dataset. The result is a percentage of detections for each bin, which allows greater ease for comparison between datasets.

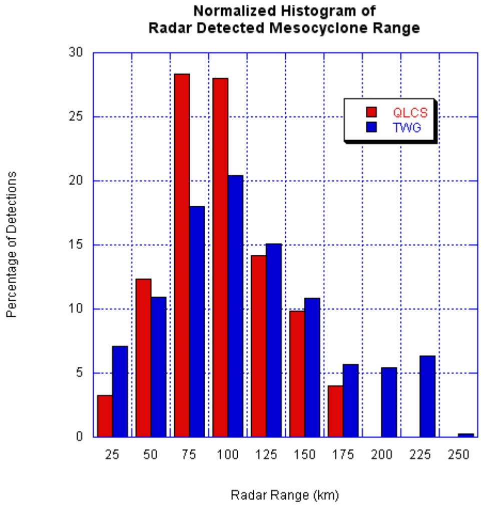

Figure 1. Normalized histogram of radar detected mesocyclone range (km). See text for explanation.

3. RESULTS

Thirty-five quantities from the SSAPprocessed datasets were deemed relevant for this analysis. The quantities fall into two categories: height (ARL), and rotational properties. Circulations associated with QLCS tornadoes were generally closer to the Earth's surface than the circulations associated with supercell tornadoes.

All eight quantities measuring the height of particular features, such as mesocyclone base and height of TVS maximum shear, resulted in values closer to the ground for those in the QLCS data set. Nearly all of the QLCS "height parameters" were 0.5 to 1.0 km lower than those for the respective TWG features. Also, supporting the observations of Trapp, et al. (1999), all but two of the height attributes exhibited non-descending behavior. Figure 2 shows the height of the TVS base for TWG tornadoes (cross-hatched) and QLCS tornadoes (open).

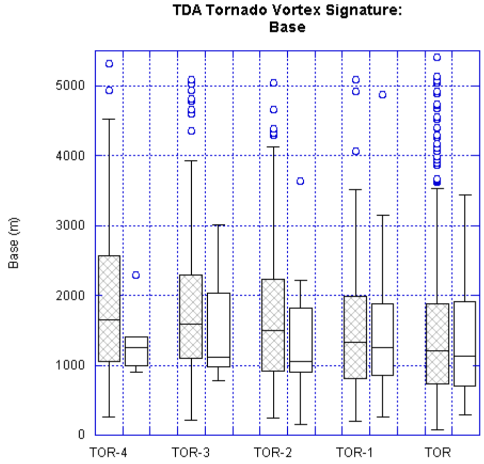

Figure 2. Box-and-whisker plot of TDA TVS Base (m ARL). X-axis is volume scans prior to tornadic volume scan, cross-hatched area is supercell data.

It should be noted that the supercell circulations (TVS and mesocyclones) were 0.5 to 1.0 km deeper than those of QLCS storms. Figure 3 displays the depth of supercell (cross-hatched) and QLCS (open) mesocyclones.

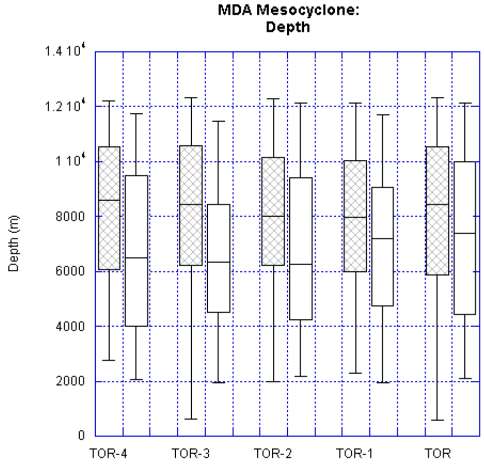

Figure 3. Same as in Figure 2, but for MDA mesocyclone depth.

In terms of rotational characteristics, most of the quantities showed less than a 3 m/s difference in the mean between the two datasets. Those quantities that did show a difference of greater than 4 m/s were maxima, i.e., maximum rotational velocity, maximum gate-to-gate velocity difference, etc., with supercell values being more intense. But even these differences were no greater than 10 m/s. In one exception, we did observe (Fig. 4) that QLCS TVSs exhibited greater gate-to-gate velocity differences preceding the onset of tornadoes. All other measures of rotation resulted in greater values for supercell storms.

One notable quantity that does not fall into the height or rotation categories is convergence. Here we find the mean mesocyclone low-level convergence preceding tornadogenesis is also larger in QLCSs than in supercells (Fig. 5). Midlevel convergence displayed a similar trend (QLCS greater than supercell), however the difference between the two parent storm types was not as great

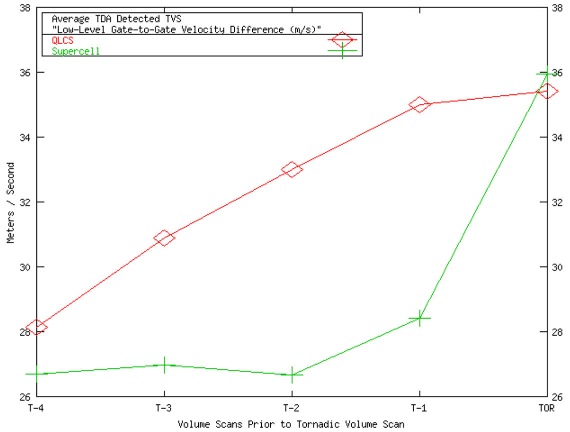

Figure 4. Mean TVS low-level gate-to-gate velocity difference. X-axis is the same as Fig. 2. Crosses are supercell data, diamonds are QLCS.

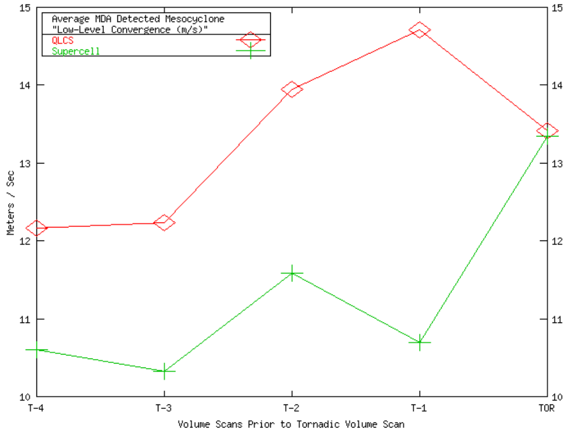

Figure 5. Same as in Figure 4, but for mean mesocyclone low-level convergence.

Finally, we examined the number of volume scans between the first MDA detection and the volume scan in which the tornado occurred. Since all the data were obtain using Volume Coverage Pattern 11 or 21, each volume scan, on average, takes approximately 5 to 6 minutes to complete. The QLCS data and a subset of the TWG data were compared to investigate the possible difference in lead time. The QLCS data set consists of MDA detections that were analyzed from the formation of the circulation to its demise. A subset of the TWG data were analyzed in the same way in order to accurately compare it to the QLCS dataset. The results show that TWG cases had, on average, 6.5 volume scans between the first MDA detection and the tornadic volume scan. This translates to approximately 33 minutes of lead time. With QLCS tornadoes, there was an average of 3.15 volume scans from the first MDA detection to the tornadic volume scan, resulting in slightly over 15 minutes of lead time.

4. CONCLUSIONS

We have quantified the radar characteristics of 69 QLCS-spawned tornadoes. In comparison to supercell-spawned tornadoes, tornadic QLCS circulations (TVSs and mesocyclones) tended to be shallower and lower to the ground prior to tornadogenesis. Low-level convergence within the diagnosed mesocyclones tended to be larger in QLCSs preceding tornadogenesis than in supercells. Finally, the rotational characteristics of tornadic QLCS circulations were generally the same as those of tornadic supercell circulations, with the exception of gate-to-gate velocity difference, which was larger in QLCS TVSs prior to tornadogenesis. Finally, MDA mesocyclones associated with QLCS tornadoes provide less lead time than those associated with the TWG dataset.

5. ACKNOWLEDGEMENTS

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