11B.6 A COMPARISON OF WARM AND COOL SEASON TORNADIC QUASI-LINEAR CONVECTIVE SYSTEMS IN NORTH ALABAMA

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1. INTRODUCTION

Quasi-Linear Convective Systems (QLCS) provide a particularly difficult warning and decision making challenge to National Weather Service (NWS) forecasters as tornadoes can evolve rapidly from within these features. In one of the earliest papers on the QLCS phenomenon, Fujita (1978) depicts an evolution of a bow echo with anticyclonic and cyclonic comma head features. Trapp et al. (2005) indicated that 18% of tornadoes in their study were produced by a QLCS. However, one of the most striking studies from Knupp et al. (1996) noted that within northern Alabama 90% of tornadic storms are associated with convective lines. Knupp (2000) also documented several cases of narrow straight-line wind damage which appeared to be tornadic in character. In light of these studies, along with active tornado years across NWS Huntsville's forecast area in 2008 and 2009, further study is needed to heighten understanding of QLCS tornadoes in hopes of improving NWS tornado warnings.

In an effort toward this goal, two case studies will be presented where QLCS tornadoes impacted north Alabama. A warm and cool season case will be investigated with warm season defined as occurring during the spring, and the cool season during the fall. The first case happened on 8 May 2008 (warm season) where a total of seven tornadoes tracked over the NWS Huntsville forecast area. One of the tornadoes, a small EF-2 was caught on security camera video near Leighton, Alabama. The second case occurred on 10 December 2008 (cool season) where an EF-2 tornado of a much shorter duration and track developed near Scottsboro, Alabama.

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An analysis of the synoptic and mesoscale environments will be discussed in section 2. Section 3 includes an examination of radar data from the dual-polarized Advanced Radar for Meteorological and Operational Research (ARMOR) (Petersen et al. 2005) and Weather Surveillance Radar 88 Doppler (WSR-88D) KHTX/KGWX radars. Section 4 contains conclusions and recommendations.

2. SYNOPTIC AND MESOSCALE ENVIRONMENT

QLCS nocturnal tornadoes have been documented to occur in environments with high shear and low surface based instability (Kis 2009). In addition, Godfrey et al. (2004) noted the importance of high Mixed-Layer Convective Available Potential Energy (MLCAPE), 0-1 km bulk shear, 0-3 km bulk shear, and low values of Convective Inhibition (CIN) in determining whether an environment is conducive for QLCS tornadoes.

With this in mind, several different datasets were analyzed to assess the near-storm environmental conditions: 1) Upper-air soundings from Calera, Alabama (BMX); selected proximity soundings utilizing the 40 km Rapid Update Cycle (RUC) model (Benjamin et al. 2004) along with 1200 UTC soundings from Redstone Army Arsenal (RSA) located in Huntsville, Alabama (Figure 1, Table 1). To gain a large scale perspective of the environment, surface analysis along with analysis of the mandatory pressure levels was also conducted.

2.1 8 May 2008

On this particular day, an almost closed short wave trough depicted at 850 hPa tracked across the middle Mississippi river valley with a strong low-level jet (LLJ) of 45 knots across much of the Tennessee Valley (Figure 2). Surface cyclo-genesis resulted in a deepening low pressure center over far northern

Mississippi. With the jet streak orientation, surface low location, and strong LLJ, dewpoints across the region rose into the lower to middle 60s(℉).

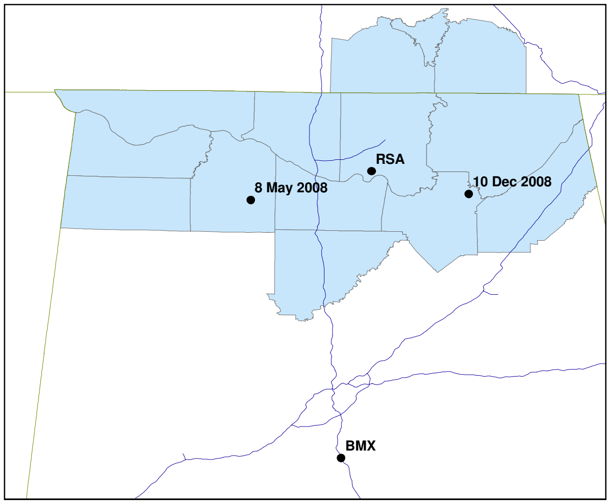

Figure 1: Calera, Alabama and Redstone Arsenal radiosonde locations along with selected RUC sounding locations. RUC inflow proximity soundings for 8 May 2008 and 10 Dec 2008 are labeled respectively. Blue shaded area depicts the NWS Huntsville forecast area.

A morning sounding (1200 UTC) from RSA indicated 0-1 km storm-relative environmental helicity (SRH; Davis-Jones, et al. 1990) of 205 $m^2 s^{-2}$ with strong warm air advection and surface-based convective available potential energy (SBCAPE) of 92 J kg^{-1} (Figure 3, Table 1). Another 1200 UTC sounding (not shown) from NWS Birmingham showed a SBCAPE of 187 J kg^{-1} with 0-1 km SRH of 197 $m^2 s^{-2}$ (Table 1).

2.2 10 December 2008

A QLCS formed during the late evening hours of the 9th and persisted through the early morning hours of the 10th. At 0000 UTC, a positively tilted 500 hPa trough was centered near the Wyoming/Utah border. Meanwhile, a positively tilted 850 hPa trough axis stretched from northeast to southwest from the Great Lakes to the northwest Gulf of Mexico coastline.

Looking at the 0000 UTC surface analysis, a surface cold front was positioned across much of the Mississippi River valley (Figure 4). A secondary low was developing over Louisiana and southern Arkansas with a warm front lifting northward over northern Alabama. In the warm sector, dewpoint temperatures were around 60℉. It is believed that the proximity of the 850 hPa trough enhanced the LLJ (40 kts.) and moisture

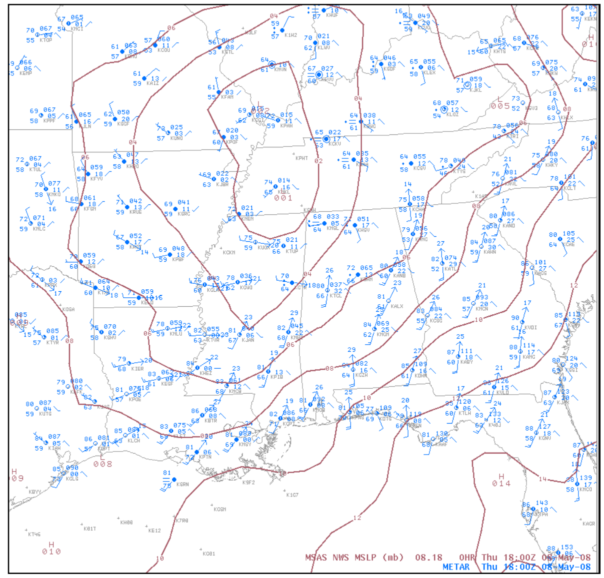

Figure 2: The 1800 UTC surface analysis with surface observations. The Mesoscale Analysis and Prediction System (MAPS) Surface Assimilation System (MSAS) isobars are also shown on the map (Miller and Barth 2003).

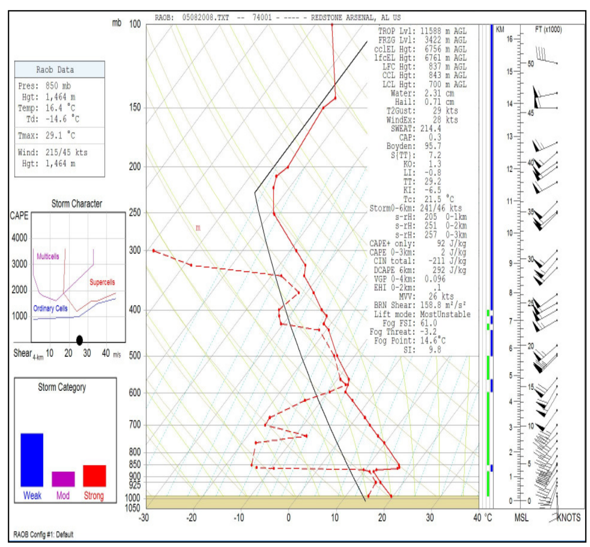

Figure 3: RSA 1200 UTC sounding on 8 May 2008.

	05/08/08 RSA 1200 UTC	05/08/08 BMX 1200 UTC	05/08/08 BMX 1700 UTC	05/08/08 RUC 1700 UTC	12/10/08 BMX 0000 UTC	12/10/08 RUC 0600 UTC
SBCAPE (J kg^{-1})	0	187	741	827	0	380
MLCAPE (J kg^{-1})	0	16	317	110	191	145
0-1 km SRH ($m^2 s^{-2}$)	205	197	187	208	317	386
0-1 km shear (kts)	32	35	50.5	31.1	40.8	48.6
Surface T (°F)	68	66	75	72	66	64
Surface T_D (°F)	59	63	63	63	57	63

Table 1: Severe weather parameters and individual tornado statistics for both QLCS cases. RSA is the Redstone Arsenal sounding, BMX is the Calera, Alabama sounding, and RUC is the Rapid Update Cycle model proximity sounding taken close to the inflow of both QLCSs.

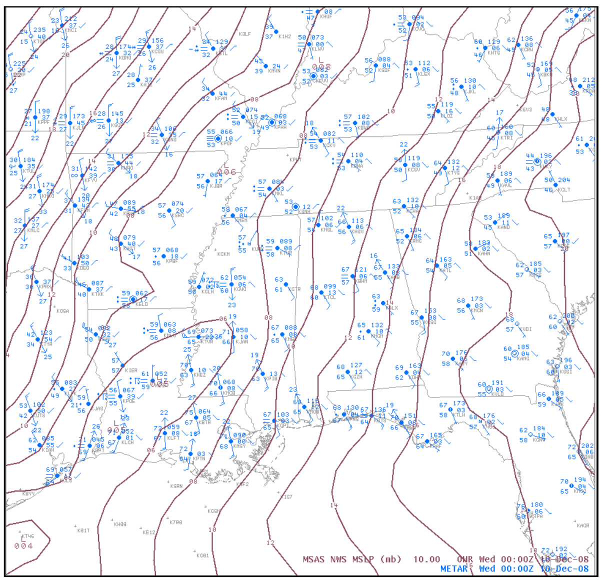

Figure 4: The 0000 UTC surface analysis with surface observation and MSAS analyzed isobars.

availability across the Tennessee Valley region (not shown). The RSA sounding during the mornings of the 9th and 10th were deemed unrepresentative of the near-storm environment, and were not used for this study. Instead, RUC point soundings and the BMX sounding were utilized (Table 1). Local RUC and observed BMX soundings indicated similar findings as the 8 May 2008 case with high shear and low or negligible instability. In fact, the 0000 UTC BMX sounding indicated 0-1 km SRH values over 317 m^2 s^{-2} and surface-based instability (SBCAPE) of 0 J kg^{-1}. The RUC hodograph showed a 0-2 km SRH value around 683 m^2 s^{-2} (Figure 5), while the sounding showed a similar instability value of 0 J kg^{-1}.

3. RADAR ANALYSIS

For the two cases in question, radar signatures and overall event evolution were examined. Specifically, storm attributes and trends were correlated with surveyed tornado tracks utilizing GR2 Analyst (Gibson Ridge Software 2009) (Table 2). Base reflectivity and velocity moments (along with the derived storm relative motion products) were utilized to document the meso-vortices involved in tornado-genesis. The Normalized Rotation (NROT) algorithm trends (within GR2Analyst) were also used to determine this product's utility.

The strongest tornado along the QLCS on 8 May 2008 occurred over northeast Colbert and southern Lauderdale Counties in northwest Alabama. ARMOR was particularly useful in detecting the development, evolution, and storm structure of the QLCS given its closer proximity to the approaching line. For the 10 December 2008 case, the KHTX WSR-88D radar was utilized specifically due to the tornado's close proximity to that radar.

3.1 8 May 2008

As mentioned previously, due to its geographic location relative to the approaching line, ARMOR had a superior depiction on the QLCS (Figure 6). As seen in the figure, a hybrid or "other mesovortices"; (Agee and Jones' proposed taxonomy, 2009) QLCS storm formed

	5/8/2008	12/10/2008
Tornado length (km)	15.5	5.95
Tornado width (m)	228.6	274.3
EF-rating	2	2
Injuries	0	0
Fatalaties	0	0

Table 2: Selected tornado characteristics for both QLCS cases.

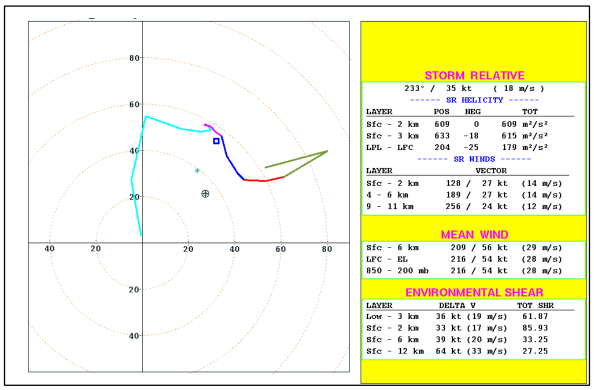

Figure 5. RUC 10 December 2008 0600 UTC hodograph from Meridianville, Alabama.

over northern Colbert County. As the tornado progressed across the Tennessee River, ARMOR indicated a RIJ (Rear-Inflow Jet) and S-shaped reflectivity structure. It is difficult to classify this particular tornado as defined by Agee and Jones (2009) given the RIJ and almost single cell characteristics (i.e. the reason for classifying it as hybrid). The tornado formed on the northeast quadrant of the bowing segment which formed a well-defined line-break. The couplet depicted on ARMOR first developed near the town of Leighton, Alabama at 1732 UTC. The ensuing tornado then tracked northeast for 15.5 km, crossing the Tennessee River and dissipating just northwest of Rogersville, Alabama. The KGWX radar detected the strengthening meso-vortex/meso-cyclone as the tornado developed (Table 2).

Along its path, the EF-2 tornado struck an equipment shop tossing cars, causing widespread tree damage, and moving a house off its foundation.

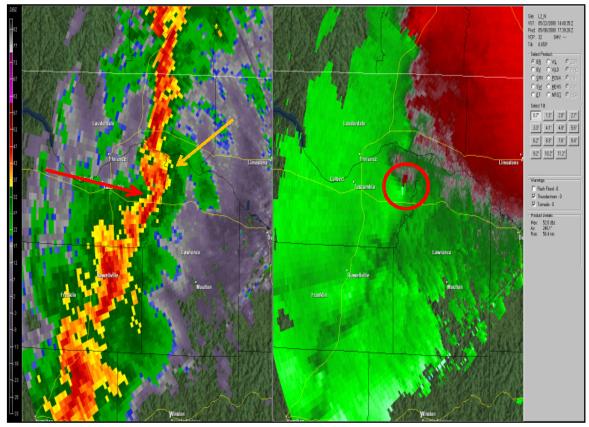

Figure 6: ARMOR 0.7° elevation reflectivity (left) and velocity (right) image from 1739 UTC 8 May 2008 depicting tornadic couplet (red circle), RIJ (red arrow), and S-shaped reflectivity structure (orange arrow) east of Tuscumbia, Alabama.

3.2 10 December 2008

A QLCS tracked across the lower Mississippi and Tennessee River valleys. As it crossed into northeast Alabama, a circulation formed just southwest of Pikeville, Alabama on KHTX radar at approximately 0702 UTC (Figure 7). Looking at the radar picture, a RIJ is present along with a bookend vortex (BEV). Using the proposed classification from Agee and Jones (2009), this tornado would more likely fit into the BEV type. As the tornado progressed northeast, a couple of small vortices appeared. Afterwards, the storm quickly lost its rotational couplet by 0710 UTC at which time the tornado dissipated. During the same time period, ARMOR depicted a weak broad couplet due to its distance from the tornado and beam spreading.

As the EF-2 tornado continued moving northeast, it remained on the ground for approximately 6 km (Table 2). Several high voltage electrical trusses were toppled, mobile homes were destroyed, several houses received varying degrees of damage, and trees were uprooted or snapped.

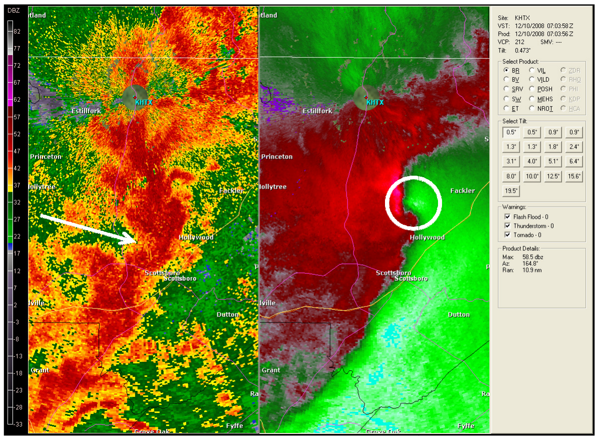

Figure 7: KHTX 0.5° elevation reflectivity (left) and velocity (right) image from 0703 UTC 10 December 2008 depicting tornadic couplet (white circle) and RIJ (white arrow) north of Scottsboro, Alabama.

4.0 RECOMMENDATIONS

Based on this brief study, and in accordance with previous similar studies, a few recommendations can be made regarding the environmental conditions that may increase the potential for QLCS related tornadoes:

a) high SRH values (greater than 100 $m^2 s^{-2}$) especially in the 0-1 km level,
b) low amounts of SBCAPE do not necessarily inhibit tornadic potential, and
c) a large scale LLJ can enhance moisture advection but also low level wind shear.

The authors also provide some recommendations for forecasters that may be analyzing radar data for the potential evolution of QLCS related tornadoes. Specifically, forecasters should be vigilant for any of the following:

a) the development of strong RIJs behind the line,
b) developing line breaks within the QLCS, or
c) near S-shaped reflecting/velocity signatures.

More research is still needed on QLCS tornadoes, especially over northern Alabama where a greater number of these type of tornadoes occur (Knupp 1996). Future work may involve including more cases in an expanded regional study.

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