Storm Interrogation

AWOC Severe Track

IC3-III-G

Quasi-Linear Convective System tornadoes

Contributions from Ron Przybylinski

Welcome to the AWOC Severe Track

IC3-III-G

Quasi-Linear Convective System tornadoes

This lesson is 15 slides long and should take 15 minutes to complete.

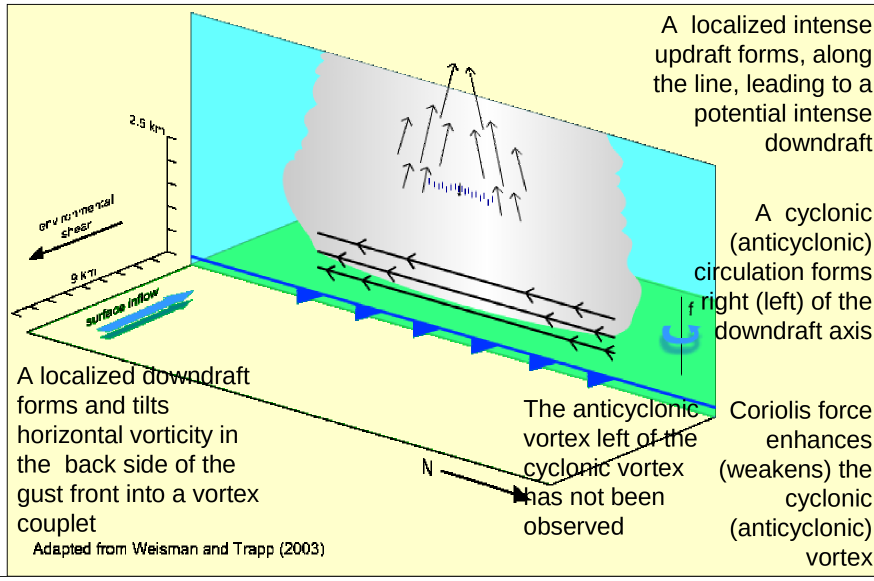
Much of this material has been adapted from Ron Przybylinski, the SOO at NWS, St. Louis, MO

Quasi Linear Squall Line (QLCS) tornadoes

- Objectives
  1. Recognize reflectivity/velocity precursor signatures to QLCS tornadoes
  2. Understand the importance of QLCS intersections with boundaries in regards to locating and timing the greatest tornado potential
  3. Understand the time-height evolution of a typical QLCS vortex
  4. What is the strength of of low-level rotation between tornadic and nontornadic vortices
  5. Familiarization with the theory of low-level QLCS vortex production by Trapp and Weisman (2003)

There are five objectives in this lesson. First, recognize the precursor signature in reflectivity and velocity most commonly observed with QLCS tornadoes. Second, learn how important QLCS intersections with boundaries are with regards to locating the greatest tornado threat. Third, learn the differences of the time-height evolution of a typical QLCS vortex and that of an isolated storm. Finally, this lesson will familiarize yourself with a theory of QLCS low-level vortex formation proposed by Trapp and Weisman (2003).

Theory for QLCS low-level vortices



According to Trapp and Weisman (2003),

1. A localized intense updraft forms, along the line, leading to a potential intense downdraft
2. A localized downdraft forms and tilts horizontal vorticity in the immediate back side of the gust front into a vortex couplet
3. A cyclonic (anticyclonic) circulation forms right (left) of the downdraft axis, when facing in the direction of QLCS motion
4. The Coriolis force enhances (weakens) the cyclonic (anticyclonic) vortex

This theory is based on numerical modeling results and a careful circulation budget analysis where the contributing terms to the vorticity equation were analyzed around the perimeter of both the anticyclonic and cyclonic vortices. To date, no one has observed a vortex couplet with an anticyclonic component to the left of the cyclonic component following QLCS motion. Therefore, it is likely some revision may need to be done to this theory.

This mechanism for vortex formation is not the same as that for the larger midlevel vortex commonly called Mesoscale Convective Vortex (MCV).

Low-level Boundaries

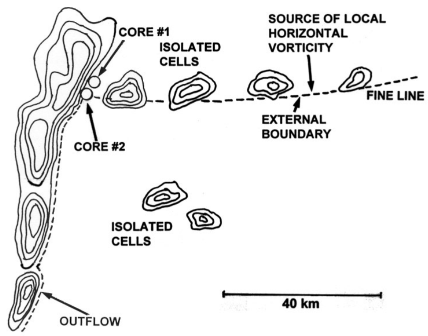
- A common occurrence with QLCS tornado events:
  - a ***low-level boundary*** from earlier convection or
  - an ***old quasi-stationary frontal boundary***
- Boundaries found to be ***orthogonal*** to the approaching convective line.
- **16** of the **21** MCSs we studied appeared to be directly influenced by either a low-level or elevated boundary

Research both at WFO DVN (Ray Wolf), and WFO LSX (Ron Przybylinski) found a majority of QLCS tornado events to be associated with some external boundary. Most of these boundaries were oriented mostly orthogonal to the QLCS axis. Of the 21 MCS (also QLCS) events that Pryzbylinski studied, 16 of them were influenced by a low-level, or elevated boundary.

These results are very similar to those of project VORTEX concerning more isolated convection.

(QLCS) tornado favored regions

- QLCS vortices are favored near and just on the cool side of boundary intersections.
  - Similar results to project VORTEX concerning isolated tornadic cells
  - This is the region of enhanced 0-1 km shear
  - Enhanced lifting occurs at the intersection point
  - This occurs prior to any bowing of the line



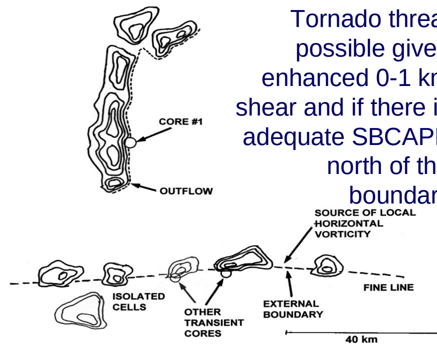
QLCS vortices appear to form near the intersection and just on the cool side of an external boundary. As with more isolated supercells, the enhanced low-level shear on the cool side of the boundary appears to enhance the probabilities of low-level vortex formation. However, it is not known if the same processes that generate low-level mesocyclones operate here. Another mechanism could be related to enhanced updraft and lifting promoting more intense cells near the boundary intersection with the QLCS.

Remember that you typically see vortex formation preceding the bowing of the QLCS segment near the boundary.

(QLCS) tornado favored regions

- QLCS vortices can occur well poleward of an external boundary if:
  - There is sufficient SBCAPE
  - Low SBCIN
  - Be careful about situations where severe winds can occur under the frontal inversion

Tornado threat possible given enhanced 0-1 km shear and if there is adequate SBCAPE north of the boundary



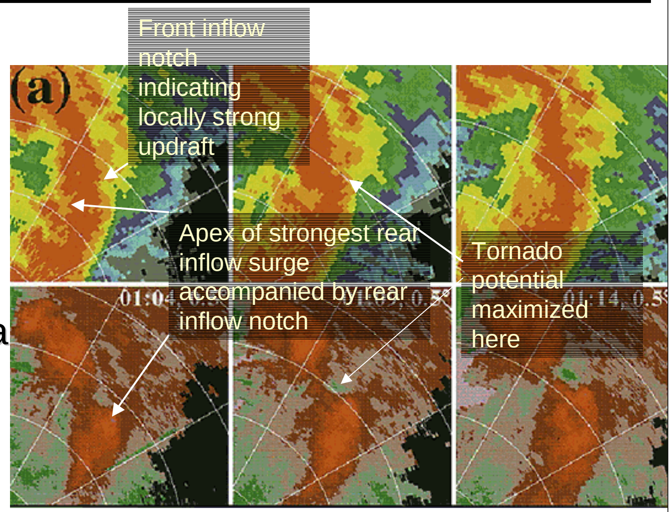
If the airmass north of a stationary front or outflow boundary is characterized by adequate SBCAPE and low SBCIN, QLCS vortices can form well poleward of the boundary.

Often the boundary may be difficult to detect after dark once solar heating diminishes. The only indication of the boundary may be from convective cells forming along a line, from METAR data, and vertical wind profiles. Some of these boundaries may be elevated. Either way, the fact that convective cells can develop along the boundary ahead of the QLCS should give you an indication that enhanced updraft is likely at the point where the QLCS intersects the boundary.

In some cases, the downdrafts and vortices may form in deceptively deep stable layers. Be aware of that fact.

Vertical vorticity signature along gust front of a squall line

- Low-level vortex formation behind leading edge, at or north of the apex
- A local maxima in vertical vorticity phases with strong updraft signature

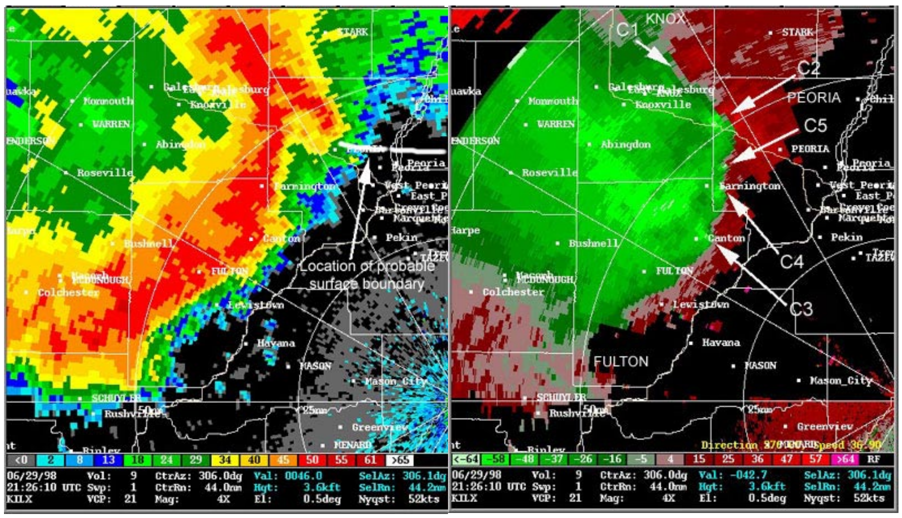


Provided that the updraft can keep up with the outflow surge (often needing strong deep layer shear), the left side and apex of the surge will contain a strong likelihood of tornado formation.

Vortex formation usually begins at low-levels and then builds up with time.

It is not known where the contributions to low-level vertical vorticity originate.

Vertical vorticity along a large bow echo: 29 June 1998



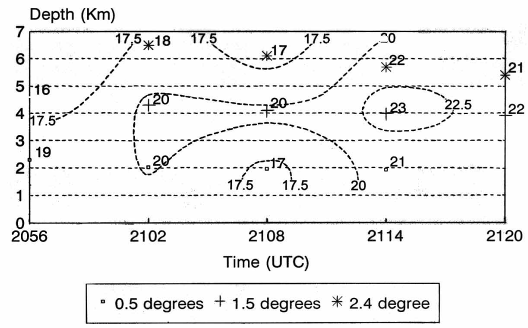
Adapted from Pryzbylinski (2002)

2103 UTC 29 June 1998 reflectivity (0.5°)(left); storm-relative velocity (right) from Lincoln IL (KILX). Convective towers extending southeast from the northern end of the large line reflects the location of an old outflow boundary. Circulation cores #1 and #2 formed at this intersection.

2126 UTC 29 June 1998 reflectivity (0.5°) slice (left); storm-relative velocity right). Circ #2 intensified rapidly since 2103 UTC and became tornadic (F1 damage). Core #3 became tornadic only during the very early stages of its lifetime. Core #4 became tornadic after 2135 UTC.

Time height comparisons

- Core #1 V_r reaches 20 m/s (40 kts)
- Note this core descends (the other 20%)
- No tornado reported



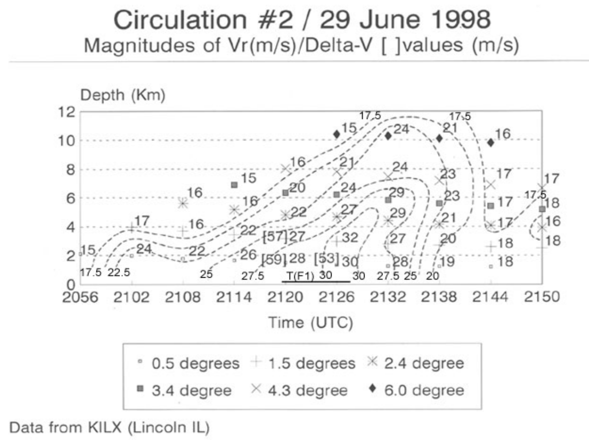
Data from KILX (Lincoln IL)

Core #1 Exhibited weaker rotation and lower overall depth compared to Core #2 that will be shown next. Maximum Vr reached 40 kts.

Note that this core descends with time, which is in the minority of observed QLCS vortex time height tendencies. Pryzbylinski (personal communication), has noted that many first cores descend over time, with none so far observed being tornadic.

Time height comparisons

- Core #2 was more intense V_r=30 m/s (60 kts)
- Nondescending V_r with time indicates low-level vorticity becoming stretched upward

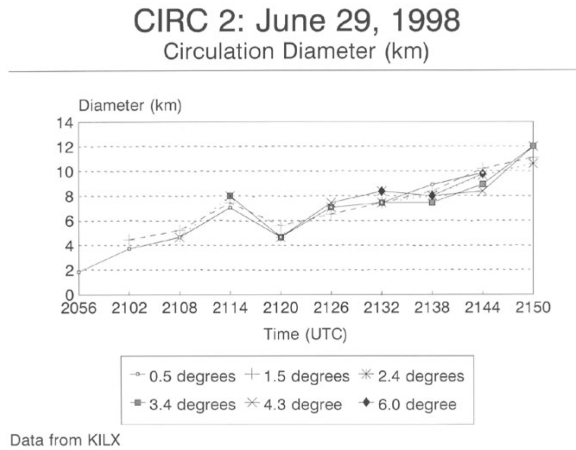


Core #2 Exhibits upscale growth non-descending characteristics) with strongest rotation detected within the lowest 3 km.
Vr reaches 60 kts as a peak intensity.

A Tornado produced **F1** damage between 2120 and 2126 UTC just before Core #2 reached its greatest depth.

Time height comparisons

- Core #2 showed collapse in diameter during tornadogenesis at 2120 UTC



A time plot of the core diameter of Core #2 shows a collapsing phase at tornadogenesis time at 2120 UTC. Collapsing core diameters of circulations have been found to frequently occur with tornadic supercells and other QLCS tornado events.

Mesocyclone strength: isolated vs linear convection

- Comparison of circulation characteristics between Przyblynski et al. 2001 data set and Burgess et al. (1982) data set.
- Larger mesocyclone diameters in linear systems than with isolated cell mesocyclones
- Weaker V_r with linear systems

	Rot Vel (m/s)	Diameter (km)	Height (km)
Squall Line (Low)	19.0	7.2	
Trad Super-cell (Low)	23.0	5.4	
Squall Line	18.8	7.4	7.6
Trad Supercell	25.0	6.0	9.2

L = surface to 8200 ft.

A comparison between QLCS and isolated supercell vortex characteristics show that QLCS vortices tend to have stronger maximum Vr values. However QLCS vortices tended to be wider. The top two rows in the table refer to the low-level values of Vr and core diameter while the highest values of each are labeled in the lowest two rows.

Summary

- QLCS tornadoes favored
  - In regions with strong 0-1km shear, 0-3 km (≥ 15 m/s), 0-5 km (≥ 18 m/s) shear, similar to supercell tornado parameter space
  - At or left of intersections with
    - quasi-stationary fronts
    - outflow boundaries
- QLCS vortices may develop from the tilting of horizontal vortex lines within the cold pool and then enhanced by the coriolis force

QLCS tornadoes are favored in regions of strong 0-1 km shear and 0-6 km shear, a very similar setup to that of more isolated mesocyclonic tornadoes. As with isolated mesocyclonic tornadoes, QLCS tornadoes tend to be favored at and just north of a boundary external to the QLCS event.

QLCS vortices may develop from the downward tilting of horizontal vortex lines within the cold pool and then enhanced by the coriolis force. The coriolis force seems to act fairly quickly, within an hour, to enhance the cyclonic vortex and weaken the anticyclonic vortex to its north. Again, this theory has yet to have observational support since there has been no anticyclonic vortex observed immediately left of the cyclonic one.

Summary (contd)

- QLCS tornado signatures
  - Near front inflow notch
  - In region of strong vertical vorticity along boundary
    - especially a low-level vortex
  - At or north of the initial bowing apex
- QLCS vortex time trends
  - mostly nondescending
  - typically larger and shallower than supercell mesocyclones
  - weaker rotational velocities than supercell mesos

QLCS tornadoes appear to be associated with a front inflow reflectivity notch in a region of strong low-level vertical vorticity just left of a region of a convex bow in the gust front. Look for a rear inflow notch to the right of the front inflow notch and behind the convex curve of the gust front as another indication that tornadogenesis probabilities increase.

QLCS vortices tend to be nondescending in nature. They are larger in diameter than traditional supercell mesocyclones but have weaker rotational velocities.

Resources in QLCS systems

- http://www.crh.noaa.gov/lsx/science.php