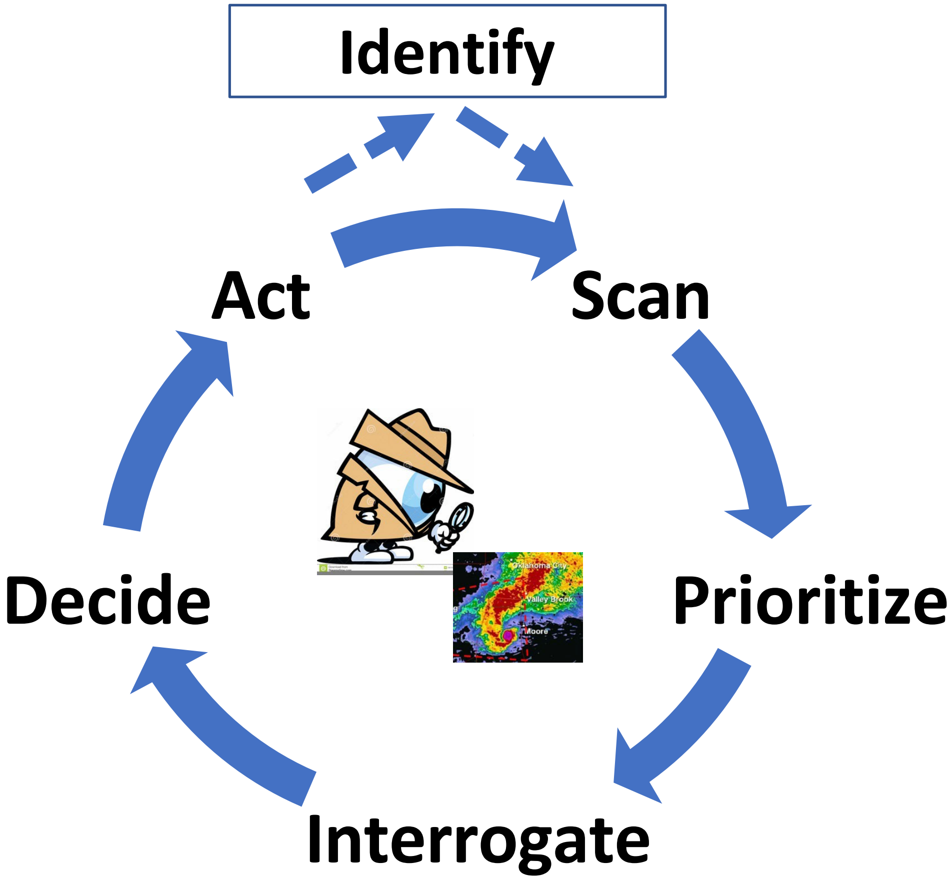
The I-SPIDA Warning Workflow



Identify potential hazards based on mesoscale and near-storm environment.

Scan for storms in your sector that need attention.

Prioritize storms and pick the one that needs to be addressed first.

Interrogate the highest priority storm.

Decide whether to issue a warning/statement or intentionally not issue, and if so, what product to issue.

Act on the warning decision you've made, following the 10 Steps process.

Tornado

Use the environmental tables below to identify the tornado hazard. NOTE: Exceeding “Preferred Values” indicates favorable conditions; not meeting “Necessary Value” indicates unfavorable conditions.

Mesocyclonic Parameters	Necessary Value	Preferred Value
0-1 km shear	≥15 kts	≥20 kts
Significant Tornado Parameter	**>0**	**>1**
• 100 mb mixed layer CAPE (MLCAPE)	>0 J/kg	>1500 J/kg
• 100 mb mixed layer CIN (MLCIN)	>-200 J/kg	>-50 J/kg
• 100 mb LCL height (MLLCL)	<2000 m	<1000 m
• Effective storm relative helicity (ESRH)	>0 m2/s2	>150 m2/s2
• Effective bulk wind difference (EBWD)	≥25 kts	≥40 kts

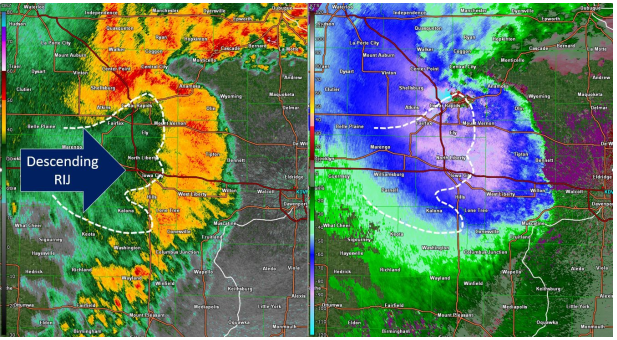
Non-Mesocyclonic Parameters	Necessary Value	Preferred Value
Non-Supercell Tornado Parameter		**>1**
• 0-3 km mixed layer CAPE	>0 J/kg	>100 J/kg
• 100 mb mixed layer CIN (MLCIN)	>-225 J/kg	>-25 J/kg
• 0-1 km lapse rate		>9˚ C/km
• Surface relative vorticity		$>8x10^{-5}\ s^{-1}$
• 0-6 km bulk wind difference	≤35 kts	≤25 kts

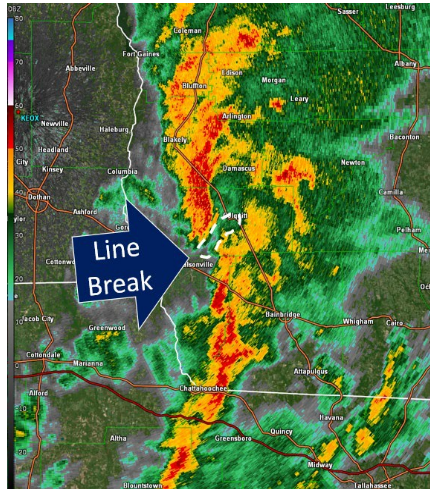
QLCS Parameters (Three Ingredients Method)	Necessary Value	Preferred Value
0-3 km line normal bulk shear		≥30 kt
Rear inflow jet or outflow caused surge in line (Y/N)		Yes
0-3 km mixed layer CAPE		≥40 J/kg

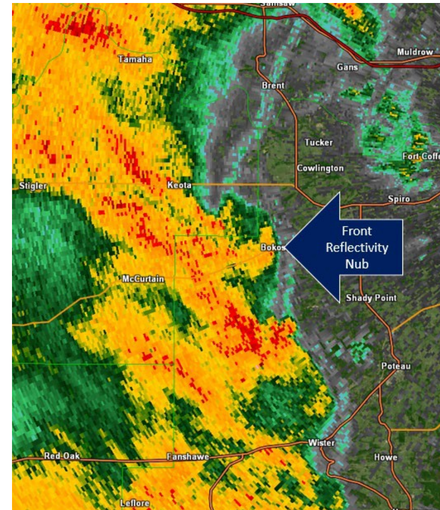
Use the radar signatures table below to identify the tornado hazard.

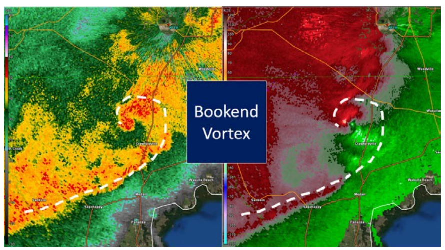
Radar Signatures	Mesocyclonic	Non-Mesocyclonic	QLCS
Storm Type			
Discrete, surface-based supercell (Y/N)	Yes		
Reflectivity (Z) core aloft (~0 ˚C) co-located w/misoscale vortex along the boundary (Y/N)		Yes	
Quasi-linear convective system (QLCS) (Y/N)			Yes
General Features			
Acceleration & convergence into a strong, low-level mesocyclone prior to tornadogenesis (Y/N)	Yes		
Formation of cold pool (Y/N)		No	
Descending rear inflow jet (RIJ) (Y/N)			Yes
Enhanced surge (Y/N)			Yes
Line break (Y/N)			Yes
Updraft deep convergence zone (UDCZ) entry/inflection point (Y/N)			Yes
Paired front/real inflow notch (Y/N)			Yes
Boundary ingestions (Y/N)			Yes
Front reflectivity nub (Y/N)			Yes
Mesocyclone/Tornado Features			
Tornado vortex signature (TVS)/ tornado signature (TS) (Y/N)	Yes	Yes	Yes
Contracting bookend vortex (Y/N)			Yes
Tight/strong mesovortex (Y/N)			Yes
Max V_{rot} at 0.5˚	≥30 kts	≥20 kts	≥25 kts
Tornado debris signature (Y/N)	Yes	Yes	Yes

Quasi-Linear Convective System (QLCS)

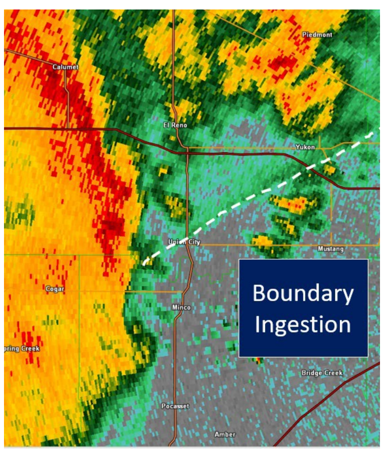


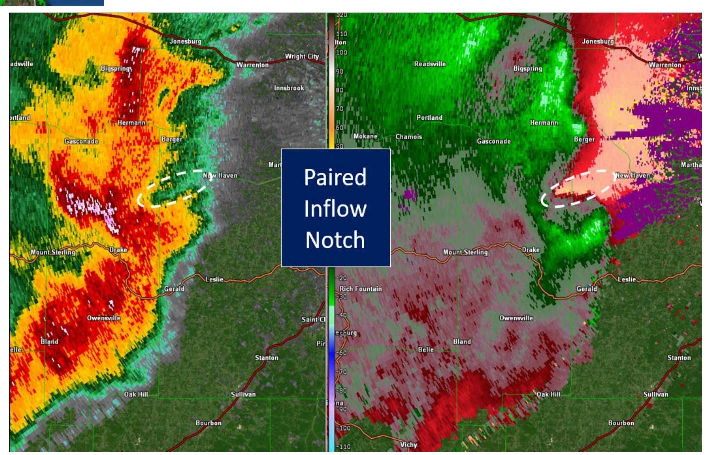


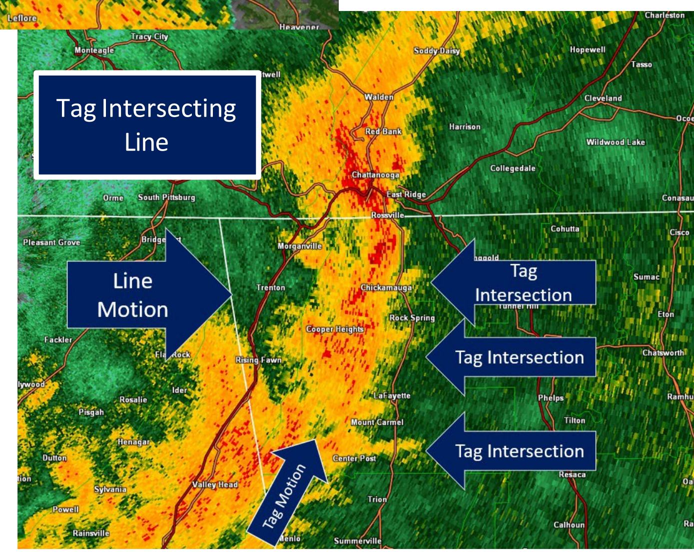




Linear Tornado Indicators (LTI)
aka “Nudgers/Confidence Builders”







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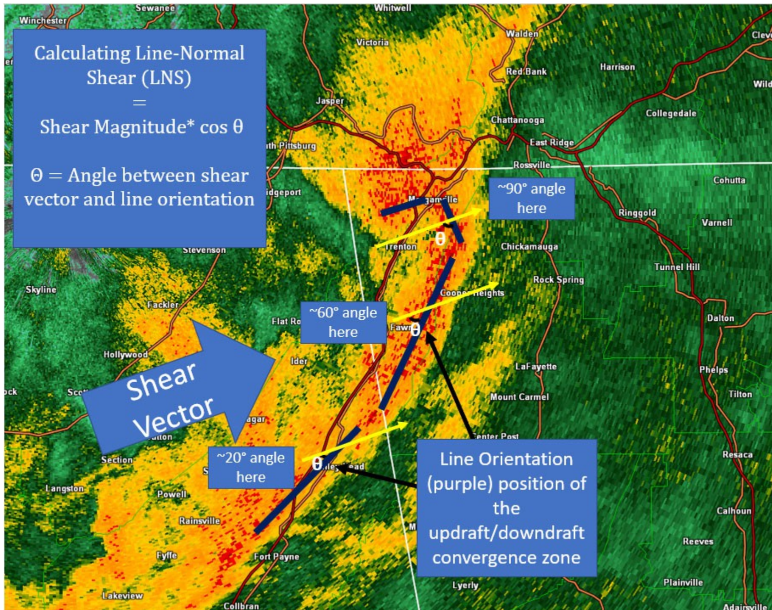
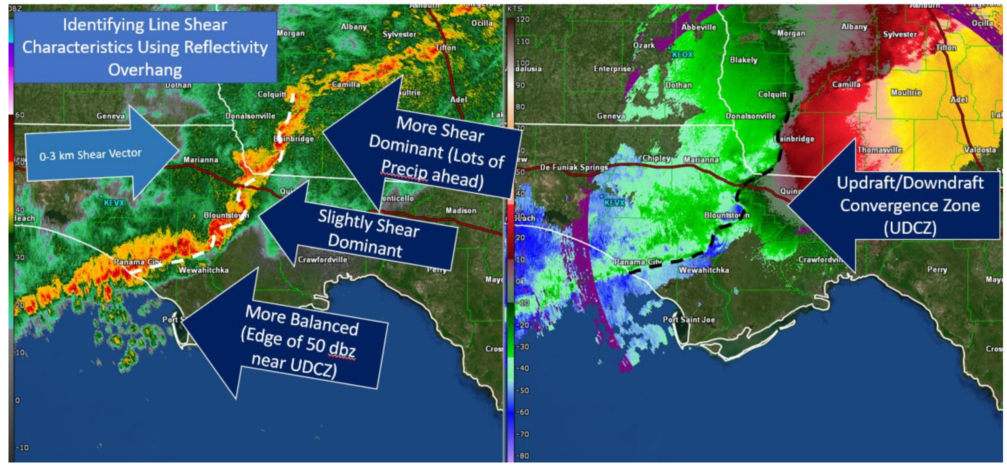
Quasi-Linear Convective System (QLCS): Warning Techniques





Be quicker to warn in favorable environments/history of tornadoes

Overall more shear, more rotation = more threat

QLCS Tornado Warning Techniques

Three-Ingredients Method

1. 0-3 km LN Shear ≥ 30 kt
2. Established Rear Inflow Jet
3. Balanced/Near Balanced portion of line

Warning Threshold is all 3 ingredients + 5 Indicator/Nudgers

Multiply Line Normal Shear by # of Indicators Method

0-1 km LNS * number of LTIs = 150
0-3 km LNS * number of LTIs = 300

Any 20 kt V_{rot} Meso in > 25 kt 0-1 km Shear

MCV and Supercell-like Structures = Much Higher Tornado Threat

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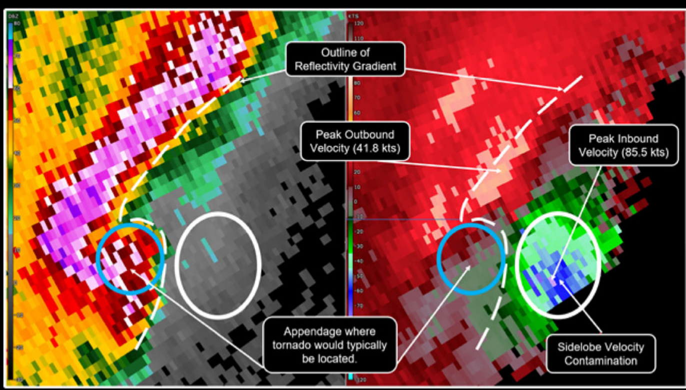
Identifying A Sidelobe Imposter Circulation

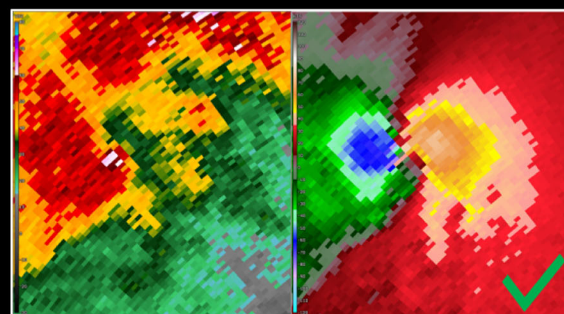
1. Location



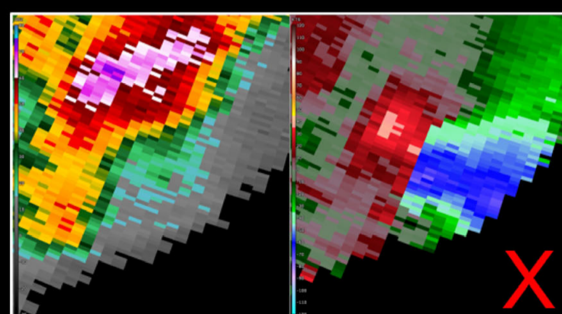
Valid: Located near the RFD with reflectivity >20 dBZ

Imposter: Often located near FFD/inflow with all or some portion reflectivity <20 dBZ

2. Texture

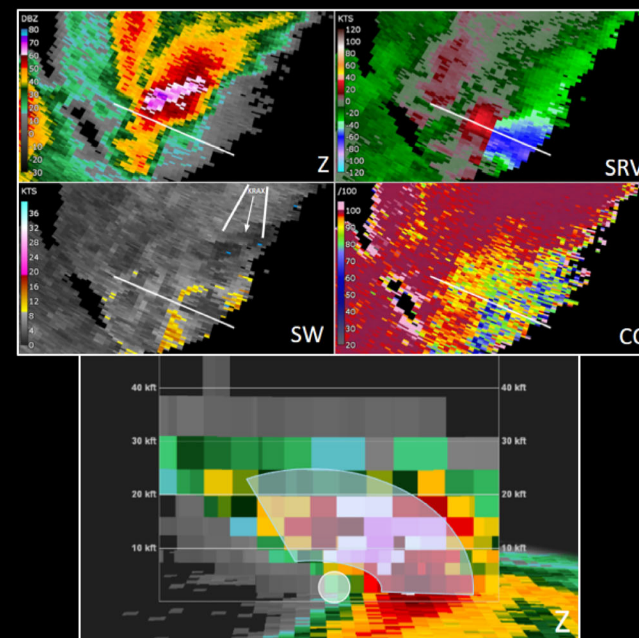


Valid: Smooth increase in velocities as they approach circulation center



Imposter: "Blocky," No clear gradient in velocities

3. Cross-Section/3D



Extent of highly reflective targets aloft for sidelobes to strike

Increase confidence in imposter

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Impact-Based Tornado Warning Guidance

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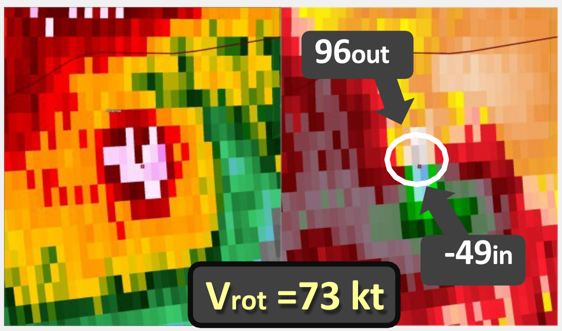
30 kt V_{rot}	40* kt V_{rot}	50* kt V_{rot}	70* kt V_{rot}
If STP >0 – Tornado Warning Likely Needed	Considerable Tag With Report or TDS, STP >1	Considerable Tag Without Report/TDS, STP >1	Catastrophic Tag With Report or TDS, STP >6

Put this into context with other available information and your professional judgement/experience

Measuring V_{rot}

$$V_{rot} = \left| \frac{V_{r[max]} - V_{r[min]}}{2} \right|$$



Important To Remember…

- V_{rot} relationships weaken at ranges > 70 nmi
- Is the velocity in area of > 20 dBZ?

Nowcasting Significant Tornadoes

* Median EF-2 cases begin at this V_{rot} and STP >3. STP 1-3 cases have a slightly higher FAR but may still be sufficient for considerable tag. QLCS cases may require slightly lower thresholds and examination of shear variables rather than STP.

TDS Height Threshold

EF2+: 8,000-10,000 ft.

Upgrade to Catastrophic Tag "Tornado Emergency" if:

(Must meet BOTH)

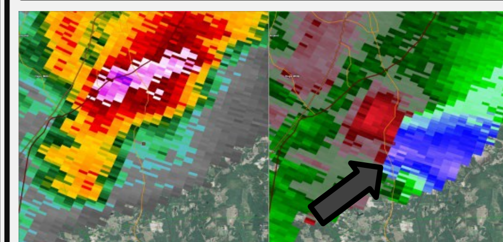
1. Tornado 100% confirmed via TDS or credible source
2. Destructive tornado/catastrophic damage potential

V_{rot} ≥ 70 kt, STP ≥ 6.0

Evaluate/update with SVS frequently!

Potential Pitfalls

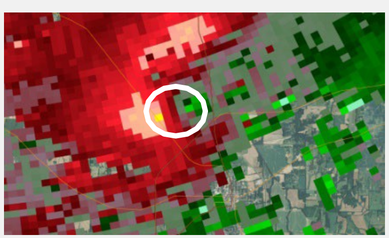
CAUTION: Low CC in inflow area can APPEAR to be TDS
Make sure the dBZ is ≥20



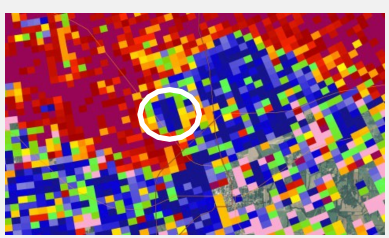
Vertical Side Lobe Contamination
Strong velocity in Weak Z below strong meso aloft, may not be valid signal

Tornado Debris Signature (TDS) Identification

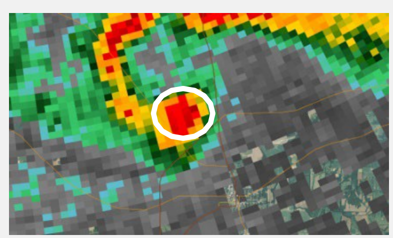
Criteria for a "Radar Confirmed Tornado"



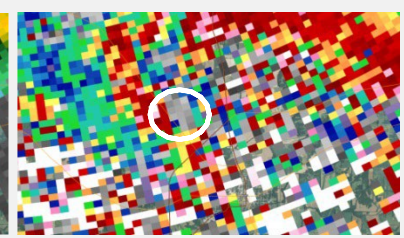
First, Identify a valid velocity circulation at the lowest elevation tilt



Is the CC below 0.90?



Collocated with Z above 30 dBZ?



ZDR near zero? – Not necessary but adds confidence

Time continuity
+
Height continuity

ADDS CONFIDENCE!!

Significant Tornado Parameter

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0 1 3+

Chances for significant tornadoes with higher V_{rot} increase as STP increases

But BE AWARE of how STP is put together and calculated

$$STP = \frac{MLCAPE}{1500} * \frac{2000-MLLCL}{1000} * \frac{ESRH}{150} * \frac{EBWD}{20} * \frac{200+MLCIN}{150}$$

The mlLCL term is set to 1.0 when mlLCL < 1000 m, and set to 0.0 when mlLCL > 2000 m;

the mlCIN term is set to 1.0 when mlCIN > -50 J kg-1, and set to 0.0 when mlCIN < -200;

the EBWD term is capped at a value of 1.5 for EBWD > 30 m s-1, and set to 0.0 when EBWD < 12.5 m s-1.

Lastly, the entire index is set to 0.0 when the effective inflow base is above the ground.

If the boundary layer is mis-analyzed (too stable) the STP can go to zero erroneously

SPC Mesoanalysis is a 40km resolution analysis - finer scale details can and will impact overall tornado potential

Tornado Warning Points of Emphasis*

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* To be used in the full context and after completion of all NWS Warning Ops Training

Supercell Warning Confidence Thresholds

Significant Tornado Parameter (STP)

Includes these ingredients:

- Surface-based CAPE
- Surface-based LCL height
- SRH
- 0-6 km BWD

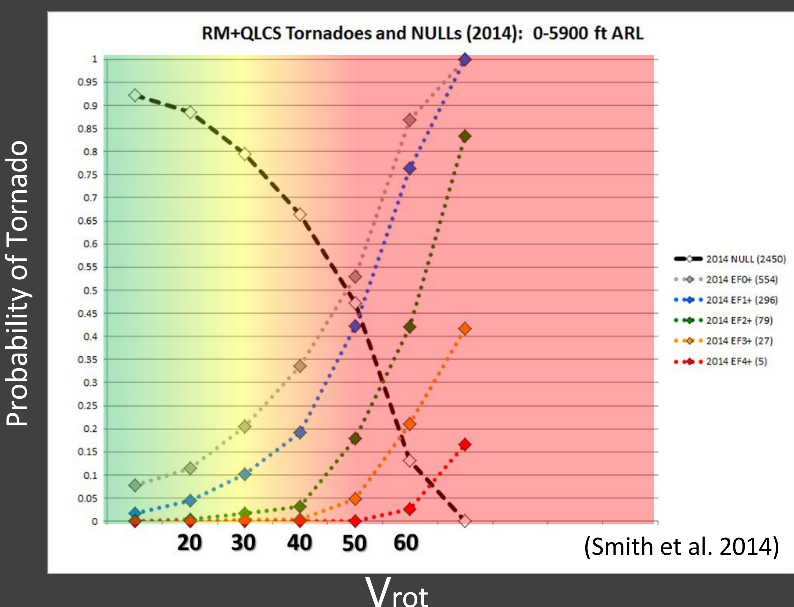
When using STP, be sure to also examine these ingredients individually during any severe weather mesoanalysis!

Is the Environment Favorable?

Given a 30 kt Vrot Signature:

Warning may be unnecessary	Environment favorable enough to be cautious	TOR WARN
0	1	3

STP Values



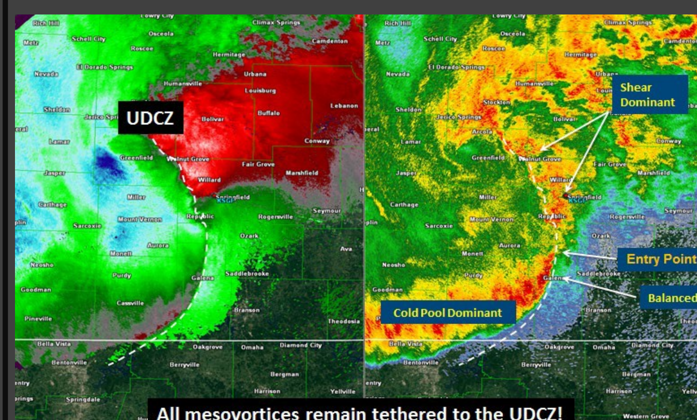
Keep in Mind...

- Presence of a hook indicates a supercell, not NECESSARILY a tornado, evaluate velocity data
- Evaluate the storm/velocity at all elevation angles!
- Warn downstream with sufficient lead time
- Vrot methods/Pitfalls/TDS Identification (see reverse side)
- Attempt to limit false alarm area
- Collaborate on the CWA borders as much as possible
- Avoid "blanket" warnings in QLCS when possible

QLCS Three Ingredients Method

Key features to look for when assessing QLCS tornado potential:

1. Slightly shear dominant portion of line
2. 0-3km shear >30 kts
3. Surges/Bows in line



Other features to watch for:

- UDCZ entry/inflection point
- Descending RIJ or reflectivity drop
- Line break
- Paired front/rear inflow notch
- Front reflectivity nub
- Contracting bookend vortex (Vr > 25 kts)
- Tightening mesovortex (Vr > 25 kts)

Remember: Rotational Velocity will assess CURRENT intensity, but likely not provide much lead time on QLCS tornadoes. Stronger environments may require more proactive warnings.

Hail

Use the environmental parameters table below to identify the severe hail hazard.

Parameters	Base Severe (≥1”)	Significant (≥2”)	Giant (≥4”)
Large Hail Parameter (LHP)	**≥4**	**≥5**	**≥8**
• Most Unstable CAPE (MUCAPE)	≥1600 J/kg	≥1850 J/kg	≥3000 J/kg
• Effective bulk wind difference (EBWD)	≥30 kt	≥1850 J/kg	≥3000 J/kg
• 700-500 mb lapse rate		≥6.5 °C/km	≥7.0 °C/km
• Surface to equilibrium level bulk shear [$Shear_{EL}$/LCL-EL(Cloud Layer)]		≥46 kt	≥60 kt
Significant Hail Parameter (SHIP)		**>1**	

Use the dual-pol radar table below to identify the severe hail hazard.

Hydrometeors	Z	ZDR	CC	KDP
Severe rain/hail mix	>55 dBZ	>1 dB	0.93-0.96	>0.5 °C/km
Severe, dry hail	>55 dBZ	<1 dB	0.95-0.97	<1 °/km
Significant (≥2”) hail	>55 dBZ	~0 dB or lower	<0.9	No Data

Common hail sizes:

1” Quarter

1.25” Half-dollar

1.5” Walnut

1.5” Ping-pong ball

1.75” Golf ball

2” Lime

2.5” Tennis ball

2.75” Baseball

3” Large apple

4” Softball

4.5” Grapefruit

Use the radar signatures table below to interrogate the severe hail hazard. NOTE: Signatures may not agree with each other (or exist at all).

Radar Signatures	Base Severe (≥1”)	Significant (≥2”)	Giant (≥4”)
Thunderstorm type	Discrete thunderstorm	Discrete supercell	Discrete supercell*
** Mini-supercells (~24-32 kft top) virtually never produce giant (≥4”) hail*			
Reflectivity Height			
50 dBZ thickness above melting level	Use cursor readout *(refer to 50 dBZ chart)*		
60 dBZ height (°C)		Above -20 °C	
65 dBZ height (°C)			Above -30 °C
Storm-Top Divergence ΔV Values Based on Environmental Freezing Level			
Freezing level ≈ 10.5-11.5 kft	74-115 kts	126-148 kts	
Freezing level ≈ 11.5-12.5 kft	80-120 kts	135-155 kts	
Freezing level ≈ 12.5-13.5 kft	110-143 kts	152-170 kts	233-267 kts**
Freezing level ≈ 13.5-14.5 kft	115-147 kts	160-180 kts	
Freezing level ≈ 14.5+ kft	135-178 kts	188-209 kts	
*** Specific values not available for giant hail (Boustead, 2008; Blair and co-authors, 2011)*			
Other Features for Hail			
Three Body Scatter Spike (TBSS)	Likely		
Max hail size from HDA algorithm or MRMS	≥1”	≥2”	
Bounded weak echo region (BWER) (Y/N)		Yes	
Updraft persists		≥30 min	
Highest V_{rot} at any elevation		≥28 kts	≥40 kts
ZDR column height (if detectable)	> 7.5 km > 8.5 km		
ZDR column intensifying (Y/N)	Yes		
ZDR value at top of ZDR column	> 4.5 dB		
KDP value	<0.5 °/km (dry) 0.5-1.5 °/km (mix) >3-4 °/km (some melt possible)		
CC co-located w/highest Z		<0.85	

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Severe (1") Hail Warning Criteria:

50-dBZ Echo Height Above the Melting Level

Melting Level	50 dBZ height 25th Percentile
6500	22000
7000	23000
7500	24000
8000	24900
8500	25900
9000	26900
9500	27900
10000	28800
10500	29800
11000	31900
11500	32900
12000	33900
12500	34900
13000	35800
13500	36800
14000	37800
14500	38800

Source: Cavanaugh and Schultz, 2012

Wind

Use the tables below to identify the environmental wind hazard.

Wet Microburst Parameters	Necessary Value	Preferred Value
0-3 km maximum theta-e difference (Theta E Diff)		>25 K
Microburst Composite (MBCP)	**5-8**	**≥9**
• Surface-based CAPE (SBCAPE)	≥3100 J/kg	≥4000 J/kg
• 0-3 km lapse rate	>8.4 ˚C/km	
• Downdraft CAPE (DCAPE)	≥900 J/kg	≥1100 J/kg
• Precipitable water	≥1.5”	

Dry Microburst Parameters	Necessary Value	Preferred Value
Inverted-V sounding (Y/N)		Yes
Most unstable CAPE (MUCAPE)	1-500 J/kg	
100-mb mean parcel LCL height	>3 km AGL	Above Melting Layer
0-3 km lapse rate	≥Dry adiabatic	
Effective bulk wind difference (EBWD)		<30 kts

	QLCS		Derecho*	
Parameter	Necessary	Preferred	Necessary	Preferred
MLCAPE	≥500 J/kg	≥2300 J/kg	≥1500 J/kg	≥3000 J/kg
MLLCL	≤1500 m	≤1000 m	≤1000 m	≤500 m
PWAT	≥1.00-inch	≥1.5-inch	≥1.00-inch	≥1.5-inch
DCAPE	≥500 J/kg	≥1000 J/kg	≥500 J/kg	≥1000 J/kg
MeanW (Mn mixing ratio)	≥10 g/kg	≥12 g/kg	≥12 g/kg	≥15 g/kg
0-3 km lapse rate	≥6.0˚C/km	≥7.5˚C/km	≥6.0˚C/km	≥8.0˚C/km
700-500 mb lapse rate	≥7.0 ˚C/km	≥8.0 ˚C/km	≥7.0˚C/km	≥9.0˚C/km
0-1 km line-relative wind	≥5 kts	≥10 kts	≥10 kts	≥20 kts
LCL-EL mean wind	≥15 kts	≥25 kts	≥20 kts	≥30 kts
EBWD	≥10 kts	≥15 kts	≥20 kts	≥30 kts
Unidirectional wind in 700-500 mb layer?	≤30˚ variation	≤10˚ variation	≤30˚ variation	≤10˚ variation

**A derecho swath of wind damage occurs in a progressive sequence, is at least 250 miles long, and has wind gusts of at least 50 kts with several well-separated 65 kt gusts. Also, the wind swath originates from an MCS that moves faster than the mean wind (i.e., is primarily wind-driven) and contains radar-observed storm features such as bow echoes and rear-inflow jets. Also, this table is not valid for strongly-forced and/or low dewpoint derechos.*

Use the radar signatures table below to interrogate the severe wind hazard.

Radar Signatures	Supercell	Microburst	QLCS/ Derecho
General Thunderstorm Signatures			
Rear-flank downdraft (Y/N)	Yes		
Rapid formation of strong reflectivity or VII core at -10 ˚C (Y/N)		Yes	
Descending core bottom (Y/N)		Yes	
Mid-altitude radial convergence (MARC) ∆V		>15 kts	>50 kts
Low-level velocity (<1500 ft AGL)	>50 kts	>30 kts	>50 kts
Fast (≥40 kt) storm motion (Y/N)	Maybe		Yes
Wet/Melting Hail Signature			
Three-body scatter spike (TBSS) (Y/N)		Yes	
Correlation coefficient (CC)		0.93-0.96	
Specific differential phase (KDP)		>3 ˚C/km	
QLCS/Derecho/Cold-Pool Driven Signatures			
Strong leading reflectivity gradient (Y/N)			Yes
Bow echo (Y/N)			Yes
Rear inflow jet (RIJ) (Y/N)			Yes
Deep convergence zone			>10 kft
Gust front hugs close to reflectivity gradient (Y/N)			Yes
Linear weak echo region (WER) along leading edge (Y/N)			Yes

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