Severe Weather Warning Techniques

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Severe Hail
Severe Hail Indicators

- Donavon Technique
- MRMS Products:
  - MESH
  - Reflectivity at -20 °C (60 dBZ)
- TBSS
- Dual-Pol Products
- Storm-Top Divergence
- WER/BWER
- Lemon Technique
Donavon Technique

• A proxy for updraft strength and 1”+ hail development.

• Relationship between the Melting Level (ML) and the height of the 50 dBZ echo.

• The Higher the ML, the Higher the 50 dBZ echo height needs to be.
Donavon 2010 (Updated for 1” hail)
Previous research in 2007 focused on ¾” hail
## Donavon (2010) Hail Criteria

<table>
<thead>
<tr>
<th>MDepth(AGL)</th>
<th>0.75” in Criterion</th>
<th>1 in Criterion</th>
<th>1.75” in Criterion</th>
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</thead>
<tbody>
<tr>
<td>6000 ft</td>
<td>15176 ft</td>
<td>17116 ft</td>
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<tr>
<td>6500 ft</td>
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<td>22580 ft</td>
<td>23969 ft</td>
<td>29465 ft</td>
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<td>10000 ft</td>
<td>23798 ft</td>
<td>25274 ft</td>
<td>30976 ft</td>
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<td>32511 ft</td>
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<td>34070 ft</td>
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<td>39000 ft</td>
<td>40695 ft</td>
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<tr>
<td>15000 ft</td>
<td>40998 ft</td>
<td>42819 ft</td>
<td>47413 ft</td>
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Heights generally higher than the Donavon study.

<table>
<thead>
<tr>
<th>Melting Level</th>
<th>50 dBZ height</th>
<th>25th Percentile</th>
<th>10th Percentile</th>
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<tr>
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<tr>
<td>14500</td>
<td>40695</td>
<td>38800</td>
<td>35900</td>
</tr>
</tbody>
</table>

Donavon values

Max dBZ at -20°C
Mean dBZ: 63
25th Percentile: 60
10th Percentile: 56
Height needed for a 50 dBZ echo to reach in order to produce 1” hail
One step further...

- Calculate the difference between the actual 50 dBZ echo height and the 50 dBZ echo height needed to produce 1” hail.

- Use MRMS 50 dBZ echo height for the actual height.

- MRMS 50 dBZ echo height – Donavon 50 dBZ echo height =
  - Positive values indicate 1”+ hail likely.
  - Negative values indicate the Donavon criteria not met.
2 AWIPS Fields Required to Perform this Subtraction

- **MRMS 50-dBZ Echo Tops for Donavon**
  - Baseline is 0.00 kft.
  - Original MRMS 50 dBZ echo height Baseline is “No Data”.

- **50 dBZ Hgt for 1 in. Svr Hail for MRMS**
  - Units are in kft.
  - Original 50 dBZ Hgt for 1 in. Svr Hail is in feet.
MRMS 50-dBZ Echo Tops for Donavon
1 inch Hail occurred 8 miles north of Uvalde

MRMS 50-dBZ Echo Tops for Donavon – RAP13 Layer 50 dBZ Hgt for 1in. Svr Hail for MRMS

MRMS 50-dBZ Echo Tops for Donavon – LAPS Layer 50 dBZ Hgt for 1in. Svr Hail for MRMS
May 31, 2016 Baseball Size Hail in Ricardo: Hail Parameters will not always line up perfectly.
Maximum Estimated Size of Hail (MESH)
MESH

• Largest hailstone possible.

• Underestimate with:
  – Highly-tilted storms
  – Left-moving Supercells
  – Large BWER (shows up as a MESH hole)
  – Low density, dry hailstones
MESH Tracks

• Assess storm intensity trends.

• Assess storm motion.
  – Deviant motion
60 dBZ Reflectivity at the -20 °C level

• Favored Hail Growth Zone (-10°C to -30°C).

• Great indicator of 1”+ hail.
  – Usually Golfball or larger.

• $Z \geq 60$ dBZ at any level or 50 dBZ at -20°C suggests hail of any size.
Three-Body Scatter Spike (TBSS)

- Mie Scattering produces TBSS.

- $Z < 25 \text{ dBZ}; \text{ CC } < 0.5; \text{ ZDR extreme positive transitioning to lower positive or negative.}$

- Presence of Severe Hail is likely.

- If $Z \geq 5 \text{ dBZ}$, then Golfball size or larger hail is present.  
  - “Pronounced TBSS”
Correlation Coefficient (CC)

- A measure of uniformity among horizontal and vertical pulses.
- Most consistent indicator of hail near the surface.
- $0.70 \geq CC \leq 0.97$ for hail.
  - $CC < 0.85-0.90$ equates to larger than golfball size.
Beware of Non-Uniform Beam Filling!
Differential Reflectivity (ZDR)

- Difference between horizontal and vertical reflectivity factors ($Z_{DR} = Z_H - Z_V$).

- Table:

<table>
<thead>
<tr>
<th>Major Axis Diameter (mm)</th>
<th>Image</th>
<th>ZDR (dB)</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 0.3 mm</td>
<td>~ 0.0 dB</td>
<td></td>
</tr>
<tr>
<td>1.35 mm</td>
<td>~ 1.3 dB</td>
<td></td>
</tr>
<tr>
<td>1.75 mm</td>
<td>~1.9 dB</td>
<td></td>
</tr>
<tr>
<td>2.65 mm</td>
<td>~2.8 dB</td>
<td></td>
</tr>
<tr>
<td>2.90 mm</td>
<td>~3.3 dB</td>
<td></td>
</tr>
<tr>
<td>3.68 mm</td>
<td>~4.1 dB</td>
<td></td>
</tr>
<tr>
<td>4.00 mm</td>
<td>~4.5 dB</td>
<td></td>
</tr>
</tbody>
</table>
Differential Reflectivity (ZDR)

- ZDR -0.5 to 1.5 dB due to tumbling motion of hail.
- ZDR ~ 0 dB along with high Z means hail is occurring.
- ZDR ≤ 0 dB along with high Z and CC < 0.85-0.9 means > 2” hail.
Specific Differential Phase (KDP)

- Change in Differential Phase Shift ($\Phi_{DP}$).
  - $\Phi_{DP}$ is the difference between horizontal and vertical 2-way propagation phase shifts.

$$\Phi_{DP} = \Phi_H - \Phi_V$$
Specific Differential Phase (KDP)

- Can vary significantly.
  - Dry Hail, KDP < 1 °/km
  - Hail mixed with Rain, KDP > 0.5 °/km
  - Melting Hail, KDP > 1.5-3 °/km

- KDP not computed when CC < 0.90.
  - Good indicator of golfball or larger hail.
“Classic” Hail (1-1.75”) Mixed with Rain Dual-Pol Signature

- $Z > 55$ dBZ
- $ZDR \sim 1-2$ dB
  - Lower with pure hail.
- $CC \sim 0.93 – 0.97$
  - Higher with pure hail.
- $KDP > 0.5 ^\circ/km$
  - Can be lower with pure hail.
Significant (≥ 2”) Hail Dual-Pol Signature

- $Z > 55$ dBZ
- $ZDR \sim 0$ dB or lower
- $CC < 0.90$
- KDP not computed
Storm-Top Divergence:
\[ | V_{\text{inbound}} | + | V_{\text{outbound}} | \text{ at storm summit} \]

**Witt and Nelson 1991 Study**
- \( \Delta V = 100 \text{ kts} \): 50% chance of \( \frac{1}{4}'' \) hail
- \( \Delta V = 130 \text{ kts} \): 50% chance of golfball hail
- \( \Delta V = 200 \text{ kts} \): 50% chance of baseball hail

**Blair et al. 2011 Study**
- \( \Delta V \ 80-121 \text{ kts} \): \( \sim \) Golfball size hail
- \( \Delta V \ 117-171 \text{ kts} \): 4” size hail
## WDTD Recommended Storm-Top Divergence Severe Hail Warning Criteria

<table>
<thead>
<tr>
<th>Storm-Top Divergence</th>
<th>Max Hail Size (in.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peak $\Delta V$ (kts)</td>
<td></td>
</tr>
<tr>
<td>70-102</td>
<td>Quarter (1”)</td>
</tr>
<tr>
<td>103-134</td>
<td>Ping Pong (1 ½”)</td>
</tr>
<tr>
<td>115-147</td>
<td>Golf ball (1 ¾”)</td>
</tr>
<tr>
<td>130-162</td>
<td>Hen Egg/Lime (2”)</td>
</tr>
<tr>
<td>159-192</td>
<td>Tennis Ball (2 ½”)</td>
</tr>
<tr>
<td>174-207</td>
<td>Baseball (2 ¾”)</td>
</tr>
<tr>
<td>233-267</td>
<td>Grapefruit (4”)</td>
</tr>
</tbody>
</table>
WER/BWER

- Region above WER/BWER is an area of rapid hail growth.

- Wide persistent WER/BWER enhances hailstone growth.

- If BWER present, then high likelihood of ≥ 2” hail.
• Strong, persistent mesocyclone can be an indicator of severe hail.

• Supercells produce a high percentage of ≥ 2” hail.

• Supercells produce most ≥ 4” hail.
Left-movers can be prolific hail producers.
Lemon Technique for SVR Issuance

1. 50+ dBZ echo at 27+ kft AGL.

In the absence of #1, then ALL must occur:

- $Z \geq 46$ dBZ 16-39 kft AGL.

- WER extending $\geq 3.2$ nm beyond the outer-edge of the low-level $Z$ echo.

- Highest echo top located on the storm flank possessing the overhang AND be above the low-level $Z$ gradient between the echo core and echo edge or lie above the overhang itself.
Severe Wind
Severe Wind Indicators

- Bowing segment/line
  - Rear Inflow Notch (RIN)
  - Bookend Vortices

- WER/BWER

- “MARC” signature

- Descending core

- Diverging winds near the surface
Multicell/Linear (Squall Line) Conceptual Model

Houze et al. 1989
Quasi-Linear Convective System (QLCS) Structure
Balanced Cold Pool and Shear

• “Slab-like” lifting.
  – Deepest convection

• Damaging winds will be the strongest.

• Mesovortices very possible.

• Maintains itself longer.
Other aspects of a severe bow echo

• Strong Z gradient along leading edge.
  – Location A

• Gust front speed matches system speed.
  – Location A

• Stronger winds at Location A.

• Cold pool and shear are in balance at Location A.
Shear-dominant

• More discreet cells possible.
  – Possible supercells

• Damaging winds possible.

• Mesovortices possible.
Cold-pool dominant

• More broken convection.

• Gust front outruns convection.

• Damaging wind possible but not as intense.

• Mesovortices much less likely.
Bowing Segment or Line (Bow Echo, LEWP)

June 2, 2010 Double Squall Lines – 80-90 mph winds across Corpus Christi
Severe Bow Echo
(Top 5 Severe Wind Event for Corpus Christi Int’l Airport)

Bow Echo March 18-19, 2016

Rear-Inflow Notch (Widespread 55-70kts)

Rear-Inflow Jet
Rear Inflow Notch & Bookend Vortices

• RIN indicates the location of the RIJ.
  – “Evaporatively cooled” from dry air aloft.
  – Increased negative buoyancy.
  – Multiple RINs possible with larger systems.
  – Greater potential for strong winds.

• Presence of Bookend Vortices can enhance the RIJ.
  – Potential for stronger winds.
WER/BWER

• Can sometimes occur with mature systems when deep shear is present.

• Enhanced potential for damaging winds.

• Usually a tight low level Z gradient present.
WER just north of Bow Echo Apex – March 19, 2016
Effective Bulk Shear 40-50 kts
Mid-Altitude Radial Convergence (MARC) Signature

• Precursor to descent of Rear Inflow Jet.

• Persistent convergence > 50 kts at 3-7 km AGL.
MARC Signature from March 18, 2016 Bow Echo
Descending Core – Single Cell

• Negative buoyancy due to:
  – Precipitation loading
  – Evaporative cooling
    • 0-3km layer $\Delta \theta_e > 25 \, ^\circ$C
    • Maximum $\Delta \theta_e > 20 – 30 \, ^\circ$K
  – Melting/Sublimation
Evolution of the 65 dBZ isosurface associated with the severe downburst. The red line shows the maximum height (MSL) of the 65 dBZ isosurface, while the blue line shows the minimum height. X marks the initial sampling time of the near surface divergent signature, while the O marks the sampling time of the maximum base velocity (0002 UTC). Kuster et al. (2014)
Diverging Near-Surface Winds

- Downburst/Microburst spreading out as it encounters the surface.
- Little to no lead time.

70+ mph east of Petronila – 4/22/15
Rear Flank Downdraft from a Supercell

67 mph wind gust at KCRP on 3/6/08
“Wake Low” Severe Winds

- Two main theories:
  - Adiabatic Warming/Drying due to Subsidence.
  - Gravity Wave Formation.

- Maximized on trailing edge of stratiform pcpn.

- Falling pressures produce the strong winds.
  - Usually 35-50 mph winds.
  - Can reach severe levels.
Coastal Bend “Wake Low” High Wind Event – April 24, 2015

61 mph wind gust at KCRP

KCRP Z at 505 AM showing rapid drying

KCRP V at 446 AM showing 60-70 mph winds just above the surface

90 mph winds several hundred feet above the surface at the peak of this event!

Pressure falls 5-7 mbs.
Tornado
Tornado Indicators

- TVS/TS
- TDS
- Hook Echo/BWER
- QLCS Mesovortices
- Bookend Vortices
- Tropical Cyclone Tornadoes

Corpus Christi EF-2 Tornado on October 24, 2002
Low Level Rotational Velocity (LLRV)

\[ V_{\text{rot}} = \left( |V_{\text{in max}}| + |V_{\text{out max}}| \right) / 2 \]

To determine rotational velocity, add the absolute value of the highest inbound and outbound velocity values in the couplet, and then divide by 2.
Mesocyclone Criteria

• Core diameter typically < 5 nm.

• LLRV exceeds minimal mesocyclone strength.

• Persistence > 10 min.
Mesocyclone Evolution

Cyclic Mesocyclones
Mesocyclone Lifecycle

- Starts in mid levels.

- At Mature Stage:
  - Low-level convergence
  - Mid-level pure rotation
  - Upper-level divergence
Tornadic Vortex Signature (TVS)
Tornado Signature (TS)
MRMS Rotation Tracks (0-2km, 3-6km AGL)

- Azimuthal Shear
- Intensity and Coverage Trends
- Great for detecting supercells.
- Detect smaller-scale circulations such as mesovortices.
- Great for damage surveys.
Tornado Impact-Based Warnings (IBW)
Peak 0.5° LLRV vs. EF-Scale
for ≤ 10k ft within 101 mile radius

Smith et. al. 2015
Impact Based Warnings Guidance

30 KT $V_{rot}$
Initial Supercell Tornado Warning Threshold

40 KT $V_{rot}$
Considerable Tag Threshold With TDS

50 KT $V_{rot}$
Considerable Tag Threshold Without TDS

* These are guideline thresholds. Should be used in contact with other IDW resources found at: http://training.weather.gov/twwt/courses/lwv2/areas/c2.php

Measuring $V_{rot}$

$$V_{rot} = \frac{|V_{in(max)}| + |V_{out(max)}|}{2}$$

Nowcasting Significant Tornadoes

TDS Height Threshold
EF2+: 8,000-10,000 ft.

Other EF-2+ Indicators:
- 8,000 ft. or deeper mesocyclone with $V_{rot} \geq 30$ kt persisted for 2 volume scans
- Peak $V_{in} \geq 50$ kt on any elevation angle in last 3 scans
- 0.5 Near Gate-to-Gate $\geq 70$ kt on any of the last 3 scans
- Near Storm Environment (NSE)
- Past History of Storms

Upgrade to Catastrophic Tag
“Tornado Emergency” if:
(Must meet ALL)
1. Tornado Confirmed (TDS or credible source)
2. Expected to impact populated area
3. Believed to be strong/violent (EF-2+)

Potential Pitfalls

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

Vertical Side Lobe Contamination
Strong velocity in Weak Z (may be a weak mesocyclone);
may not be valid signal

Tornado Debris Signature (TDS) Identification
Criteria for a “Radar Confirmed Tornado”

First, identify a valid velocity circulation
Is the CC below 0.90?
Collocated Z above 20 dBZ?
ZDR near zero? – Not necessary but adds confidence
Tornadic Debris Signature (TDS)

- Identify a valid velocity circulation.
- CC < 0.90 collocated with the circulation.
- Sufficient reflectivity > 35 dbZ collocated.
- ZDR near 0 or below.

Entremont et. al.
TDS Height vs. Tornado Intensity

Percentiles - EF Scale vs TDS Height

Max TDS Height (Kft)

~10K ft or greater

Entremont et al.
Lemon Technique for Tornado Warning: BWER and Hook Echo
QLCS Mesovortex Tornadoes and the 3 Ingredients Method
1.) Locate the Balanced or Slightly Shear Dominant section of the QLCS.

- Define the Updraft Downdraft Convergence Zone (UDCZ)
  - Coincident with gust front.
2.) Find Line-Normal 0-3 km Bulk Shear ≥ 30 kts

- Important in the creation of horizontal shear vorticity.

Schaumann and Przybylinski 2012
NSEA Digital Cursor Readouts Tool

- Volume
- Obs
- NCEP/Hydro
- Local
- Upper Air
- Satellite
- Kcp
- Radar
- MMRS
- SCAN
- Maps
- GIS

Bundles
- Elevated CAPE Environment
- Hall Environment
- Heavy Rainfall Environment
- Pulse Severe Environment
- OLCS Tornado/Wind Environment
- Supercell Tornado Environment
- Composite Indices and Parameters
- Critical Heights and Levels
- Heavy Rainfall/Moisture Parameters
- Shear Parameters
- Storm Motion
- Surface Analysis
- Thermodynamic Parameters
- Upper Air Analysis

- 0-3 km Line Normal Bulk Shear Arrows (Mag >= 30 kts)
- 0-3 km Bulk Shear Magnitude
- 0-3 km Bulk Shear Vectors
- 0-2 km Bulk Shear Magnitude
- 0-2 km Bulk Shear Vectors
- 0-1 km Bulk Shear Magnitude
- 0-1 km Bulk Shear Vectors
- 0-500 m Bulk Shear Magnitude
- 0-500 m Bulk Shear Vectors
- 0-500 m Helicity
- Critical Angle
- Critical Angle (CAPE/CIN Filtered)
EF-0 Mesovortex Tornado at Holiday Beach
EF-0 Mesovortex Tornado at Holiday Beach
NO DATA
Microburst Composite = 0.60
50 dBZ Hail Hgt AGL = 48563.52 ft
0-3 km ThetaE Diff = -35.21 K
DCAPE = 196.20 J/kg
-99.00 dBZ
GMZ275
77 10
NSEA Local AWIPS App (RAP/LAPS)
3.) Look for Surges or Bows in the Line

- A RIJ or enhanced outflow are likely candidates to cause a surge or bowing.

- Use both SRM and V.

- When all 3 items are co-located, there is an increased likelihood of tornado-producing mesovortices.

Schaumann and Przybylinski 2012
Any one of the 8 scenarios met with the three ingredients is often worthy of a *Tornado Warning*. Multiple scenarios present should further increase confidence in a TOR.

Nudgers are secondary, and should add confidence in issuing a TOR when one of the scenarios and the three ingredients are present.

*Three ingredients not necessary to issue a TOR with a contracting bookend vortex (#6) or TDS (#8).*
Jan 9, 2011 EF-1 Mesovortex Tornado: First ever Torndao recorded in January!
May 15, 2015 Multiple EF-0 Tornadoes: Gregory and Flour Bluff

1805Z

1810Z
May 24, 2015 Brief EF-1 Tornado: Downtown Corpus Christi
May 10, 2012 Multiple Tornadoes
(Not all pictured)
Waterspout over Aransas Bay:
Feb 14, 2017 ~800 AM
March 29, 2018 Seadrift EF-1 Tornado
March 29, 2018 Woodsboro EF-0 Tornado
EF-0 Mesovortex Tornado: Twiggs County, Georgia on 1/21/17
EF-1 Mesovortex Tornado:
Bleckley County, Georgia on 1/21/17
Mesovortex Tornado:
Fort Bend County TX 2/14/17
Fort Bend County Tornadic Mesovortex

SRM at 1419Z  V at 1421Z
“Broken-S” Signature

- QLCS Mesovortex
- Mostly Cool Season
- High shear/Low Cape
- Mainly Southeast U.S.
Broken “S” Mesovortex Tornado: Monroe County, Georgia on 1/21/17 ~Noon
Bookend Vortex Tornado
Bookend Vortex Tornado: Natchez MS, 5/8/1995
Tropical Cyclone Tornado Techniques
Tropical Cyclone Center-Relative Plots of Tornadoes

A) All Tropical Cyclones
B) Hurricanes
C) Tropical Storms
D) Tropical Depressions, Remnant Lows, and TC remnants.

Events plotted with respect to north-relative azimuth. Reference frame is with respect to north.

Source: Roger Edwards, EJSSM 2012
Radar Recommendations

• VCPs 12 or 212.

• Look at both V and SRM.

• Modify default storm motion given the varying motions around the center of the storm.

• Comparison of KDP and ZDR.
  – “Sorting”
Tropical Cyclone Tornado Guidance (WDTB, 2014)

<table>
<thead>
<tr>
<th>Range from Radar</th>
<th>LL $V_{rot}$</th>
<th>LL Shear</th>
<th>Circulation Contracting</th>
<th>Inflow Notch or Hook</th>
<th>ZDR/KDP Displacement</th>
<th>Mesocyclogenesis VES</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-39 nm</td>
<td>20+ kts</td>
<td>≥ 0.01 s$^{-1}$</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>40-70 nm</td>
<td>15+ kts</td>
<td>x</td>
<td>✓</td>
<td>x</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>&gt;70 nm</td>
<td>12+ kts</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
</tbody>
</table>

"Velocity Enhancement Signature" - enhanced radial velocities of 30+ knots between 7,000 and 14,000 feet AGL on the right flank of a mesocyclone

- Occurs when storm motion deviates from mean flow, leading to an asymmetric mesocyclone velocity pattern.
- Located above low-level inflow and vertically co-located with the low-level mesocyclone and hook signature.
- WDTB analysis showed about 85% of tornadic events had this signature while about 42% of non-tornadic events did.
- Max values generally 1-4 volume scans before the tornado.

Identifying Mesocyclonic VES

Horizontal Displacement of ZDR/KDP

- Implies size sorting of hydrometeors from increased directional shear within the storm due to strong mesocyclone development.
- Maximum KDP values displaced left of the maximum ZDR values relative to the mean storm motion.
- Can be detected in storms greater than 40 nm from radar.
- WDTB analysis: 70% of tornadic events had this signature while about 58% of non-tornadic events did.

INGREDIENTS

- Mid-level RH should not be too dry, limiting convection
- 0-1km SRH generally above 170 m$^2$s$^{-3}$ (supercell tors)
- 25th and 75th %-ile MLCAPE is 520 and 870 m (supercell)

Produced by Alex Lamers, NWS TLH
Tropical Storm Debby – June 25, 2012 0004Z
EF-2 Tornado in Polk County east of Tampa Bay

Hook Echo and LLRV ~ 35 kts velocity enhancement signature ~ 54 kts Max KDP displaced left of Max ZDR
Hurricane Emily’s 13 Tornadoes – July 20, 2005

EF-0 Premont Tornado
2 of Hurricane Emily’s Tornadoes

**EF-1:** 8 miles N of Alice – 1621Z
LLRV ~ 40 kts

**EF-0:** 3 miles SW of Anna Rose – 1542Z
LLRV ~ 22 kts
Side Lobe Contamination
Side Lobe

• Side lobes are small amounts of radiation that emanate from the radar.

• This weak signal is often masked by the returned energy from the main lobe.

• However, there are times when the energy returned from the side lobe can be larger than the main lobe.

• This is called "side lobe contamination".
Side Lobe

- In tilted storms:
  - Side lobe can interact with the higher core aloft.
  - Main lobe can interact with the reflectivity-free area beneath the overhang.

- If the difference exceeds 54 dB, then velocity data from side lobe gets incorrectly mapped to the lower elevation of the main lobe.
Side Lobe

- False low level couplet, displaced by several miles to the SE of the low level reflectivity.

- Spectrum width values $\geq 16$ kts can be helpful in diagnosing.

- Low CC values and inconsistent ZDR values may also be helpful.
All Hazards Decision Chart

Radar and Forecast Aids Sections: SOO webpage

All Hazards Decision Chart

Using Radar to Estimate Hail Size
The End