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# Uses of Dual-Pol Radar for Tornadoes: More Than Just Debris

Dual-Pol Refresher and Previous Research

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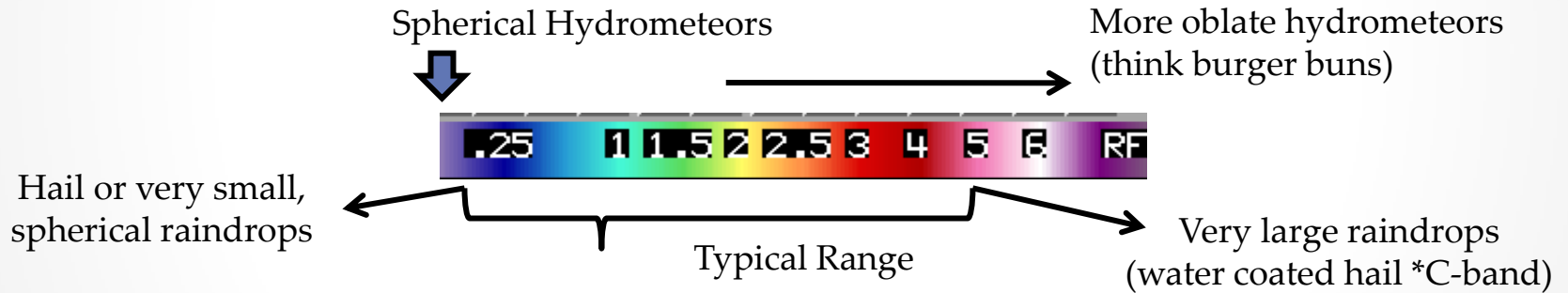
# Dual-Pol Variable Refresher: What do they mean?

## Horizontal Reflectivity: $Z_H$



- higher values → heavier rainfall or hail
- (alone cannot be used to differentiate between the two)

## Differential Reflectivity: $Z_{DR}$



- ratio of reflectivity returned in the horizontal and vertical polarizations
- gives information about drop size (typical range is 1 to 6 dB)

## Specific Differential Phase: $K_{DP}$



- Related to drop size and liquid water content
- Used with  $Z_{DR}$  to get better rainfall rate estimates

# Dual-Pol Variables:

## $Z_{DR}$ arc, Dynamics & Thermodynamics

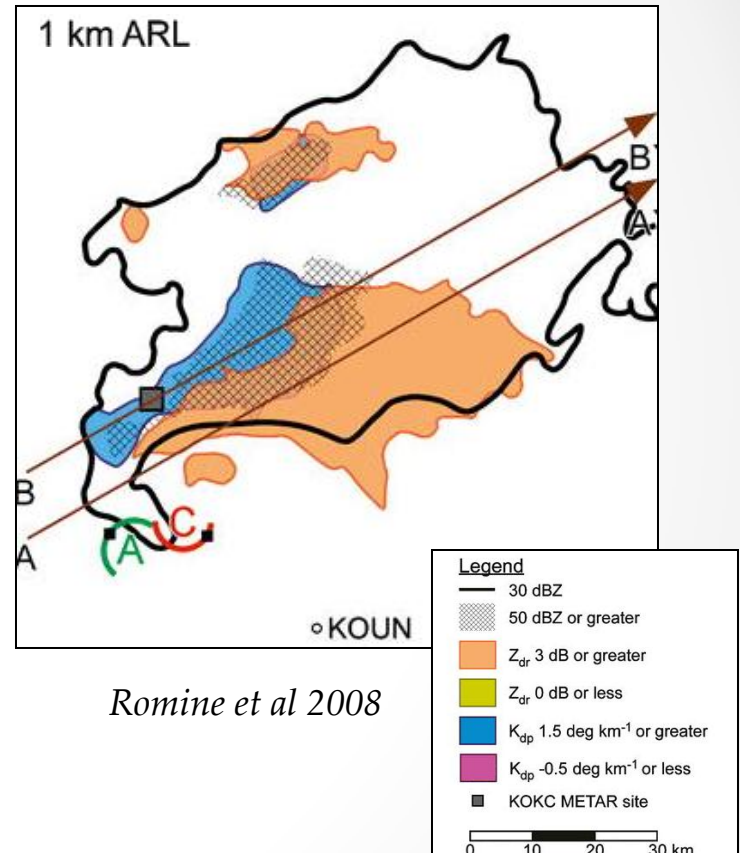
- $Z_{DR}$  arc

(e.g. Romine et al 2008, Kumjian & Ryzhkov 2008)

- In tornadic and non-tornadic storms
- Lowest 1-2km of storm
- right side of cell, along  $Z_H$  gradient
- values often  $>5$  dB (tornadic  $>6$  dB)
- sign of locations of weaker vertical velocities just outside of core
- Landfalling TC Outbreak case – had arcs, values  $> 6$  dB, and spatial separation of dual-pol fields (Crowe et al 2010)

*Evidence of size sorting, microphysics, and thermodynamics of RFD (evaporation)*

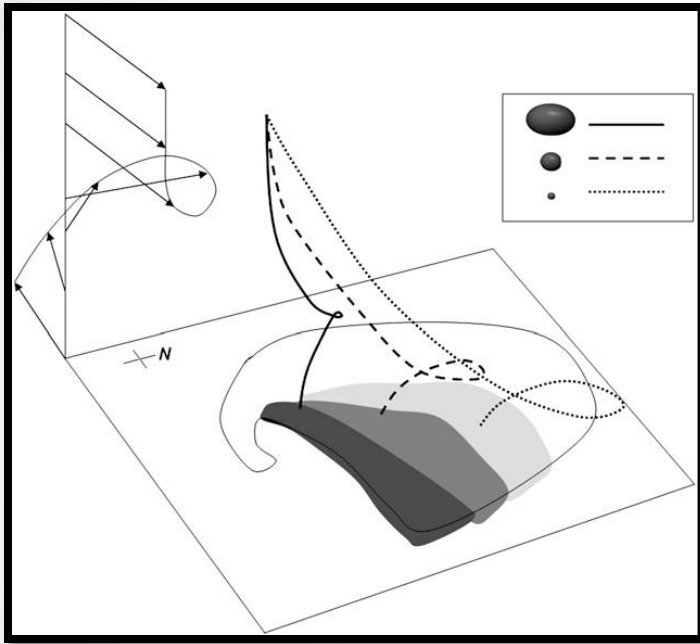
**Total size sorting results in →  
enhanced  $Z_{DR}$  along right flank &  
increased  $K_{DP}$  in forward flank (left of  $Z_{DR}$ )**



*Larger  $K_{DP}$ , Smaller  $Z_{DR}$  = smaller raindrops, larger liquid water content  
Smaller  $K_{DP}$ , Larger  $Z_{DR}$  = larger raindrops, smaller liquid water content*

# Dual-Pol Variables:

## SRH estimation & Radar Type Caveats



- **$Z_{DR}$  arc and SRH:**

*(Kumjian & Ryzhkov 2009 modeling study)*

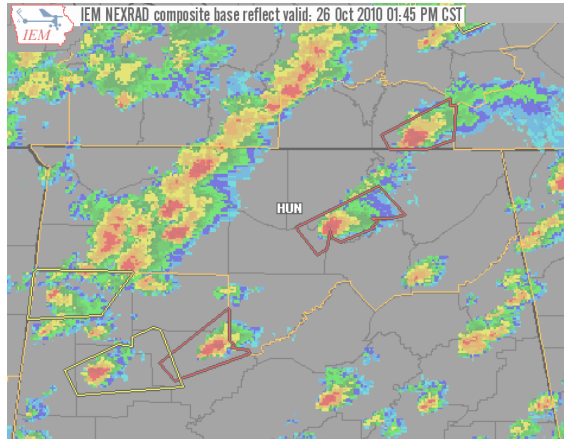
- Inc. directional shear  $\Leftrightarrow$  more substantial arc
  - Stronger wind shear = greater size sorting = increased mag of  $Z_{DR}$
- Localized Low Level SRH estimated combining
  - Surface Wind Vector
  - Storm Motion Vector
  - Estimated SR winds in layer immediately above the arc (perpendicular to major axis of arc)

### Notes for C- (research to follow) vs. S-band:

- $K_{DP} \sim 1 / \text{radar wavelength}$  (C-band = 2x higher values than S-band)
- $Z_{DR}$  depends on differential resonance response at different wavelengths
  - No significant differences at lower values ( $\sim 3\text{dB}$ )
  - Higher values ( $>6\text{dB}$ ) more rare at S-band
  - Hail signature of  $Z_{DR} \sim 0 \text{ dB}$  more apparent in S-band (water coated hail = Mie issues at C-band  $\rightarrow$  large  $Z_{DR}$  values)

# Our Events

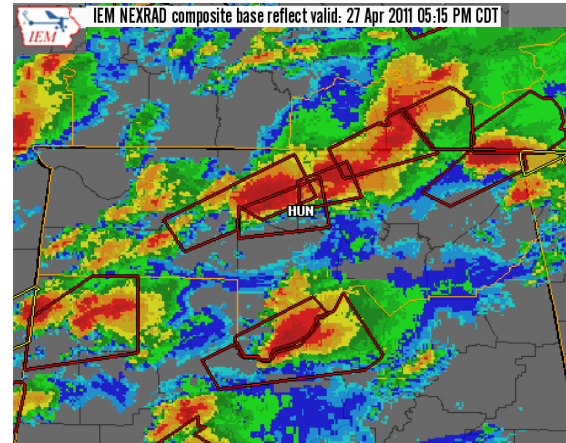
October 26, 2010



Warnings: 39  
Tornadoes: 4 (EF1-0)

Widespread Supercells  
POD: 100% FAR: 88% LEAD: 14

April 27, 2011



Warnings: 92  
Tornadoes: 40 (EF0-5)

All Modes  
POD: 92% FAR: 49% LEAD: 17

Data from: ARMOR Dual-Polarimetric Radar (C-band)

**9 Storms In Range**

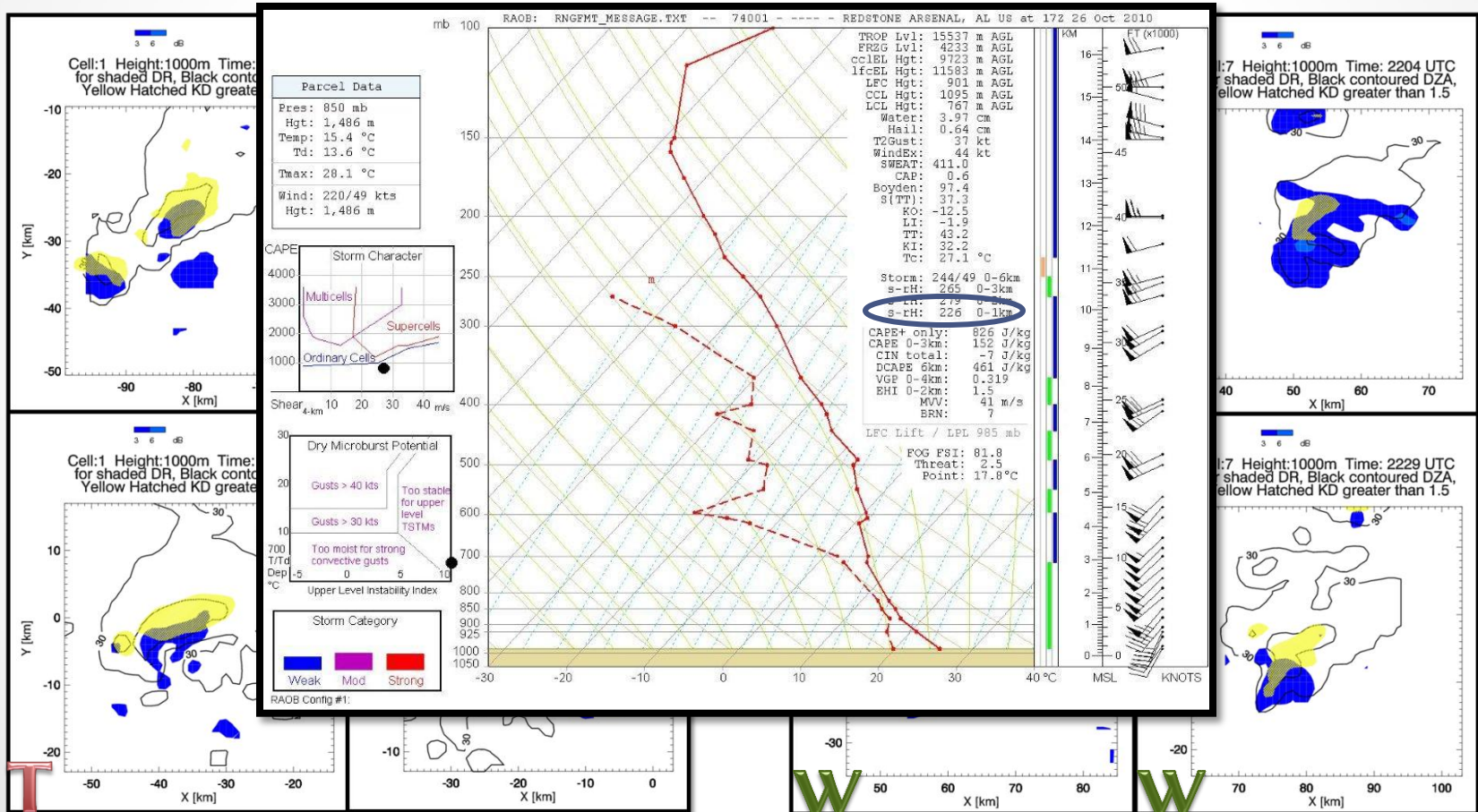
**8 Storms In Range**

# Results - October 26



## Tornadic Cell

## Non-Tornadic Cell

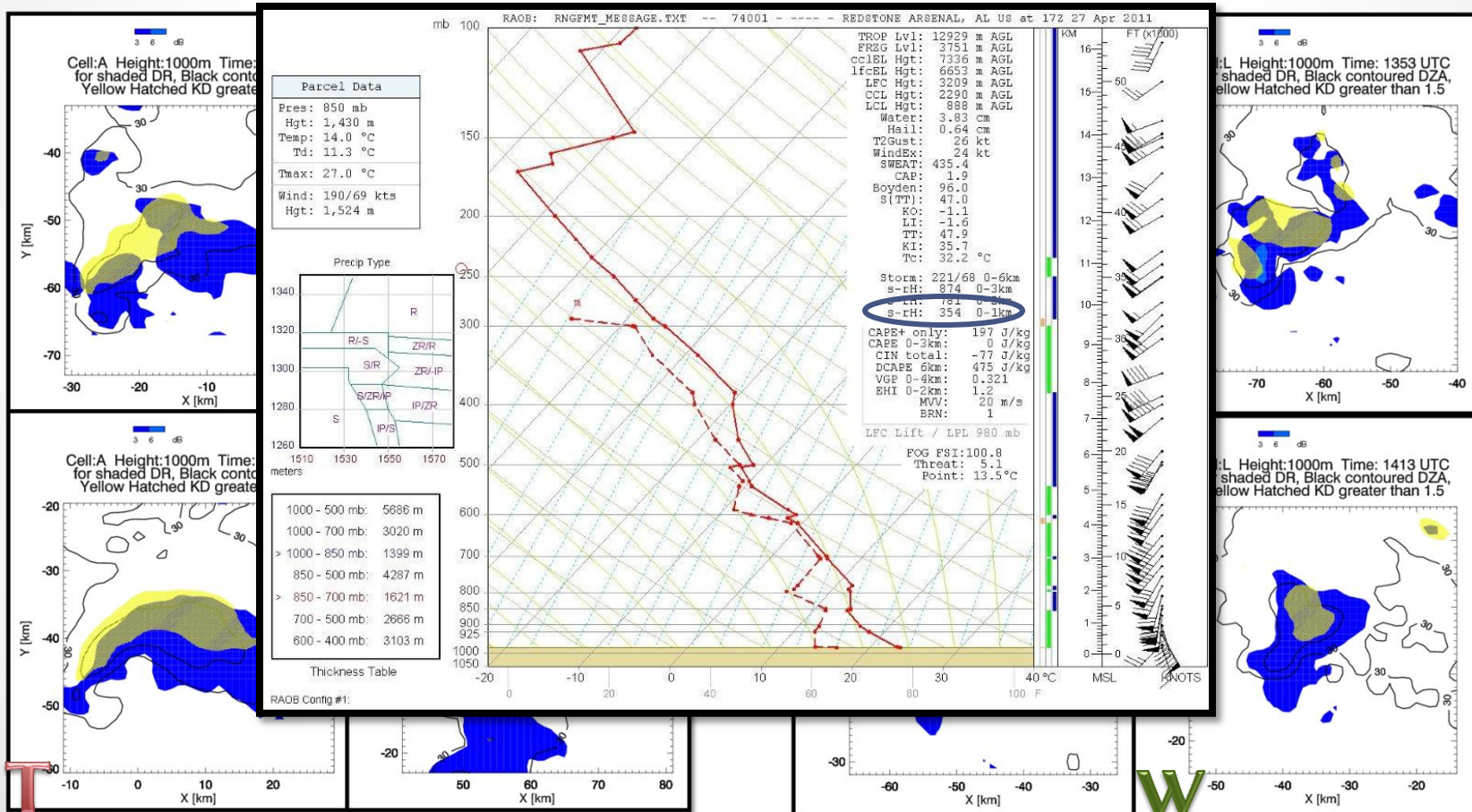


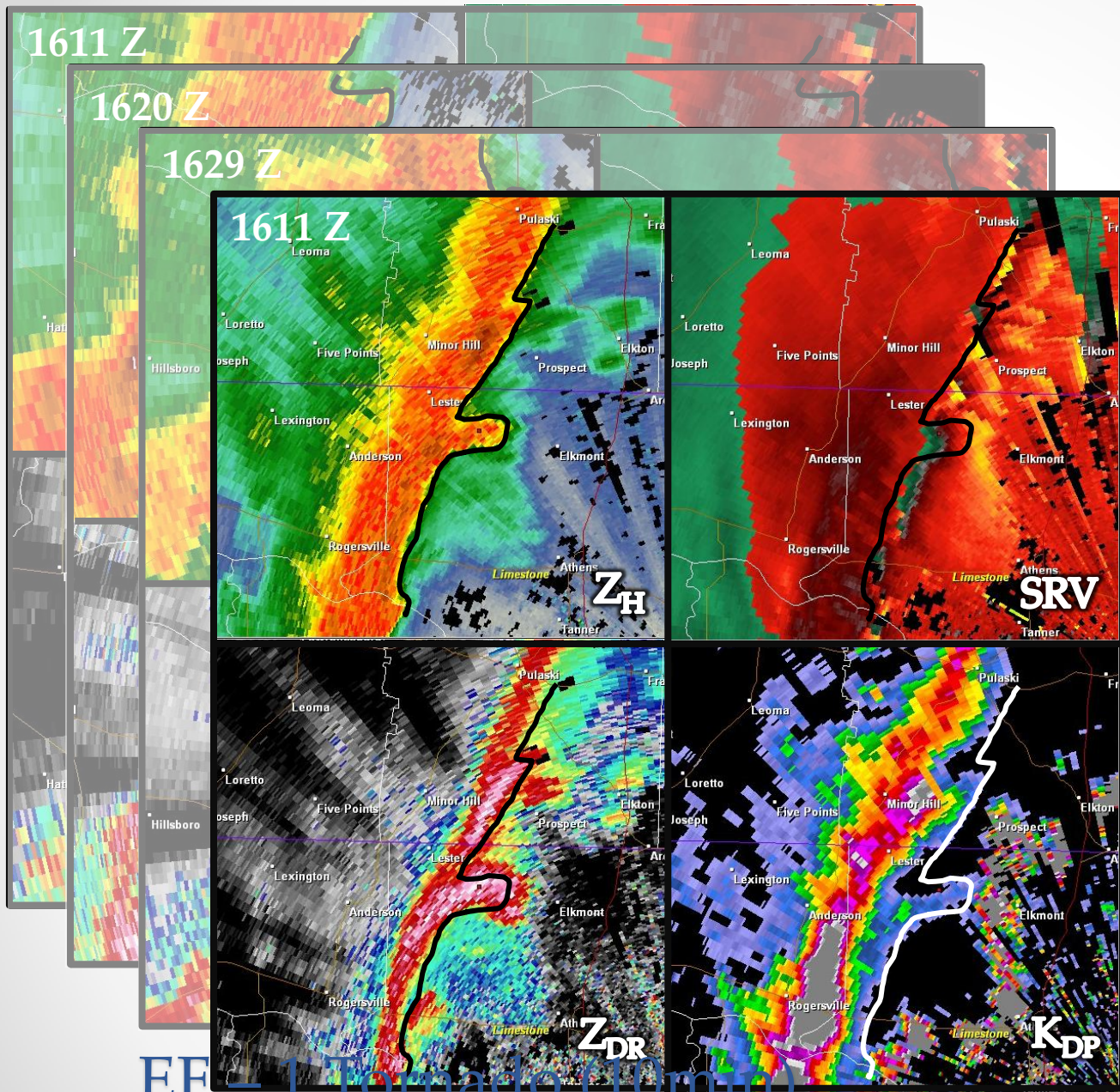
# Results - April 27



## Tornadic Cell

## Non-Tornadic Cell





## What about QLCS?

Z<sub>H</sub>

- 35dBZ = yellow
- 45 dBZ = red

Z<sub>DR</sub>

- 3dB = red
- 6dB = white

K<sub>DP</sub>

- 1.0° km<sup>-1</sup> = blue/grey
- 2.0° km<sup>-1</sup> = blue
- 3.0 °km<sup>-1</sup> = green

EF-1 Tornado (10min)

Other non-tornadic section



# What have we learned?

- **Dual-pol fields show different behavior in tornadic vs. non-tornadic storms**
- **Indicate different dynamics & thermodynamics of the near-storm environment**
  - Near storm SRH increases = enhanced  $Z_{DR}$  arc
  - Enhanced size sorting leads to separation of dual pol fields
  - Microphysics – RFD thermodynamics and ‘Goldilocks syndrome’
- ★ **KDP vs. ZDR separation most useful**
  - Non-tornadic periods had higher  $Z_{DR}$  values back into the ‘hook’
  - Non-tornadic periods had greater overlap of fields
  - Tornadic periods had better spatial separation of fields and more apparent  $Z_{DR}$  arcs (more substantial arcs on April 27<sup>th</sup>)
  - QLCS cases also show some separation of fields
- **Threshold of 6dB in arc does not work in all cases**
  - Worked better in higher shear case days
  - S-band also reacts differently than C-band (need for addtl. research)
  - Use ‘normalized’  $Z_{DR}$  for threshold in different env./storm types? (Kumjian 2010)
- **Potential utilization in QLCS cases**

# Thank You

- Crowe, C.C., W.A. Petersen, L.D. Carey, and D.J. Cecil, 2010: A dual-polarization investigation of tornado-warned cells associated with Hurricane Rita (2005). *Electronic J. Operational Meteor.*, EJ4. (<http://www.nwas.org/ej/pdf/2010-EJ4.pdf>)
- Crowe, C.C., C.J. Schultz, M. Kumjian, L.D. Carey, and W.A. Petersen, 2012: Use of dual-polarization signatures in diagnosing tornadic potential. *Electronic J. Operational Meteor.*, EJ5. (<http://www.nwas.org/ej/pdf/2012-EJ5.pdf>)

*Check the references sections of these papers for other great dual-pol resources!*

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Questions? Feel free to contact me at  
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