Zdr/Kdp Behavior in Potentially Tornadic Storms

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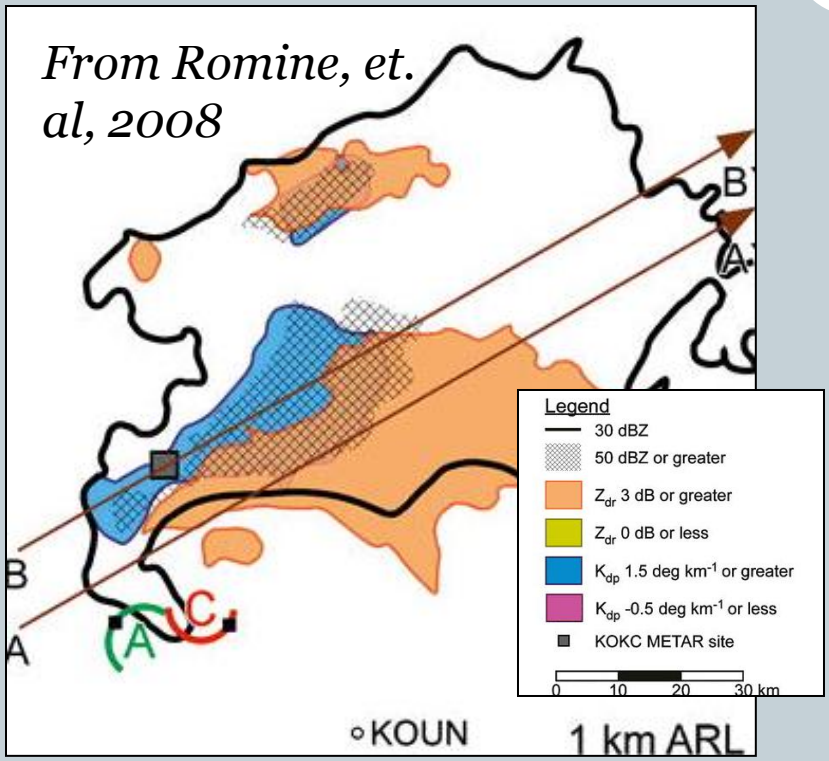
Outline

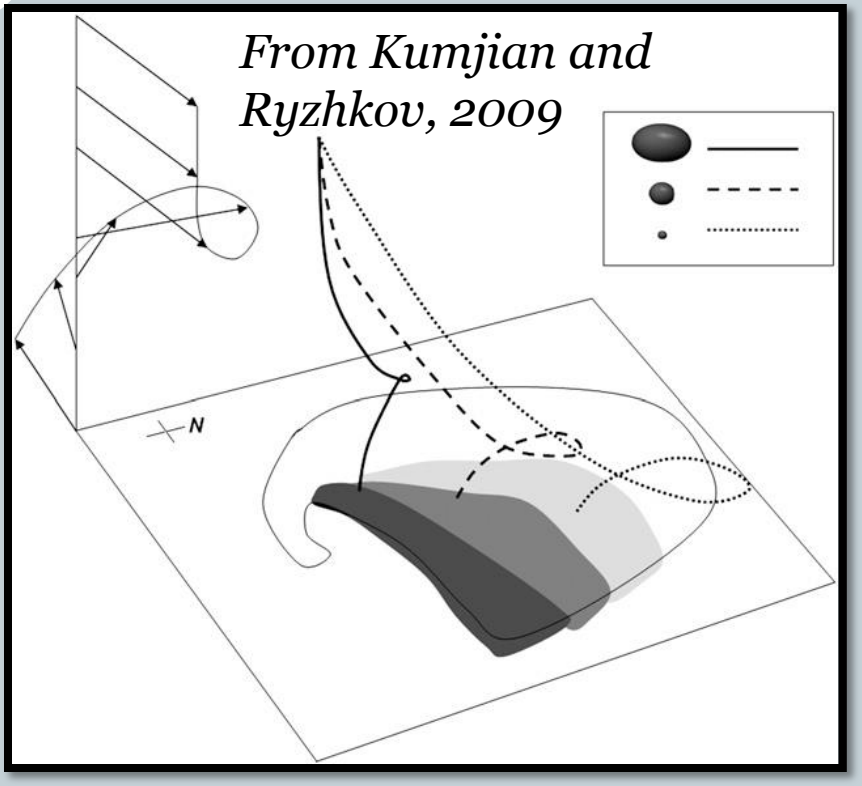
- Previous Research
- Study Results
- Recent Supercell Example
- Preliminary Conclusions / Future Work

Previous Research

Drop Size Sorting / Zdr Arc



* Enhanced Kdp (blue) gets displaced left of enhanced Zdr (orange) via preferential size sorting



* Conceptual schematic of differing hydrometeor descents and Zdr arcing

Conceptual Model (Kumjian, et al. 2011)

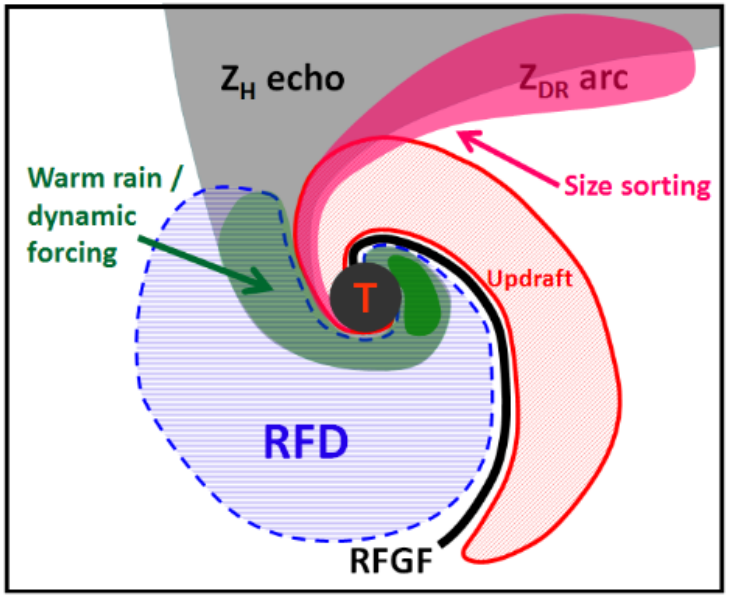
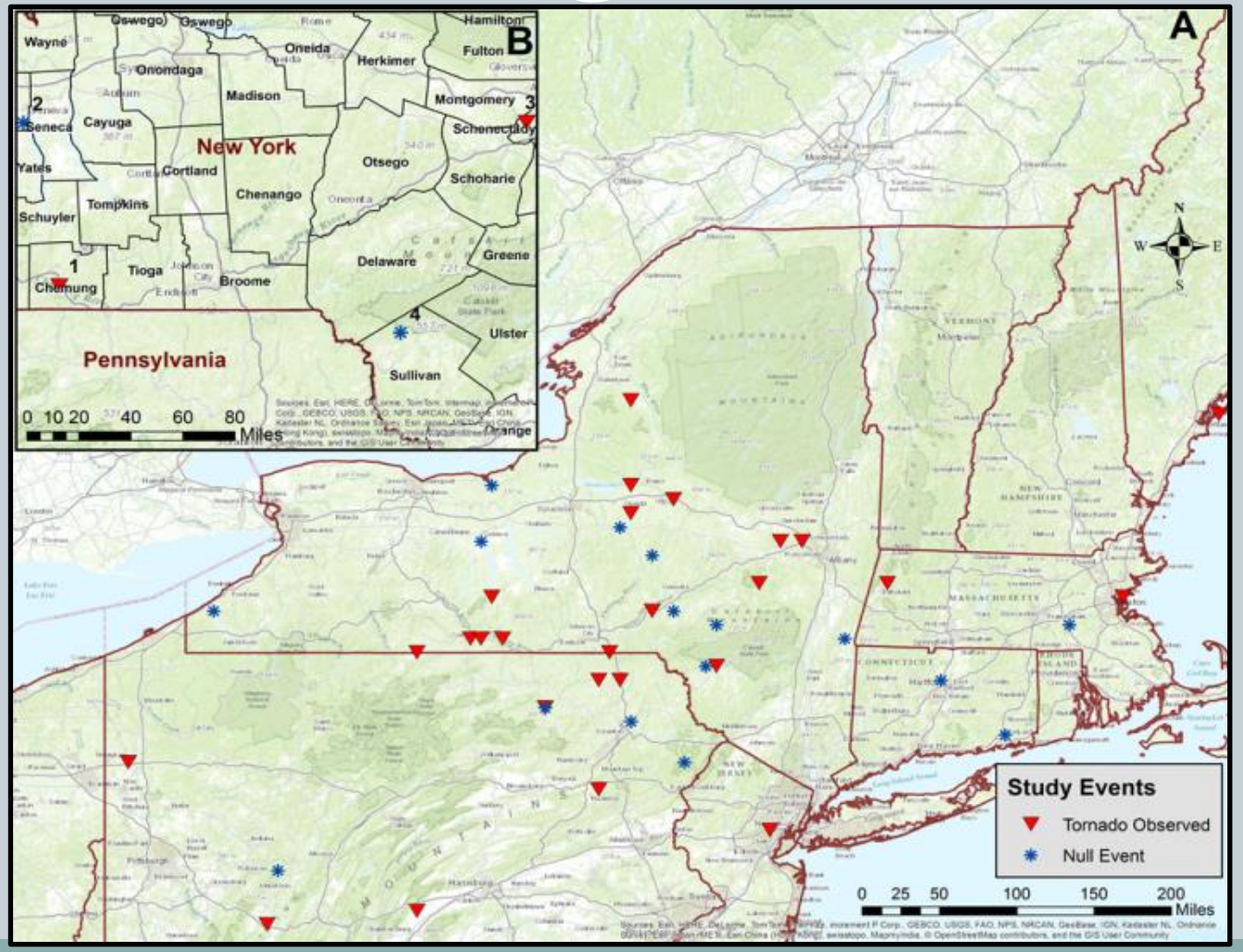


Figure 10: Conceptual model of the precipitation characteristics of supercell hook echoes overlaid with the locations of updraft (red), RFD (blue), and the primary rear-flank gust front (black line, RFGF). The region shaded in pink indicates large-drop zones with high Z_{DR} (including the Z_{DR} arc). The green shading represents regions of lower Z_{DR} and smaller drop sizes. The dark green region represents an enhancement in tiny drops transported by the occlusion downdraft. The location of the tornado is indicated by the black circle with a red "T".

Results of Northeastern U.S. Study

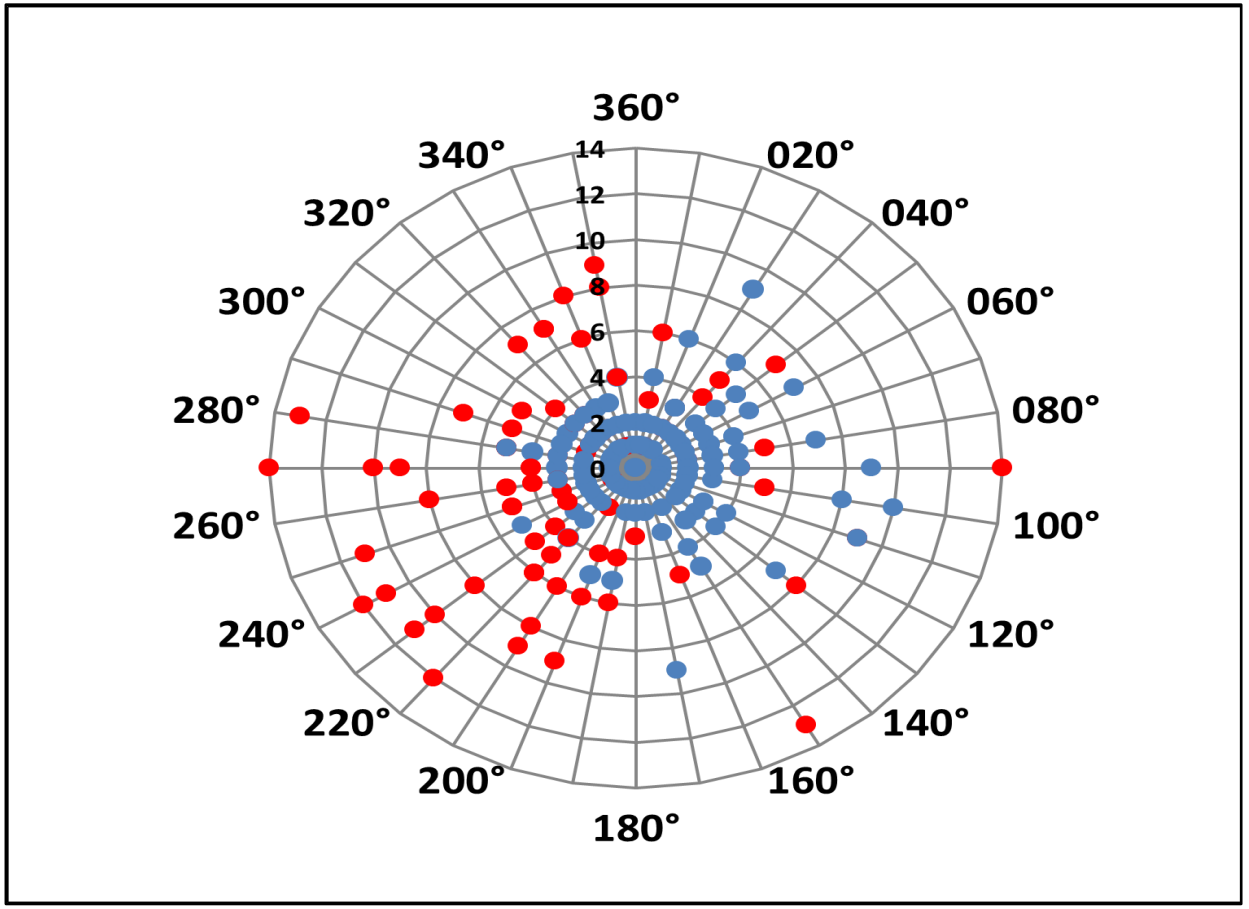
Event Cases: 42 total
26 Tornadic and 16 non-tornadic



* All 42 storms in the database represented

* Note the typically much larger horizontal separation for tornadic storms (red)

* For the non-tornadic storms (blue), little separation was typically seen (data points tightly clustered around the center of the plot)



Polar Plot of Kdp maxima (red for tornadic storms and blue for non-tornadic storms) versus Zdr maxima (center point)

* Looking at +/- 3 volume scans from T=0

* T=0 is either the time of initial tornado touchdown or tornado warning issuance (null events)

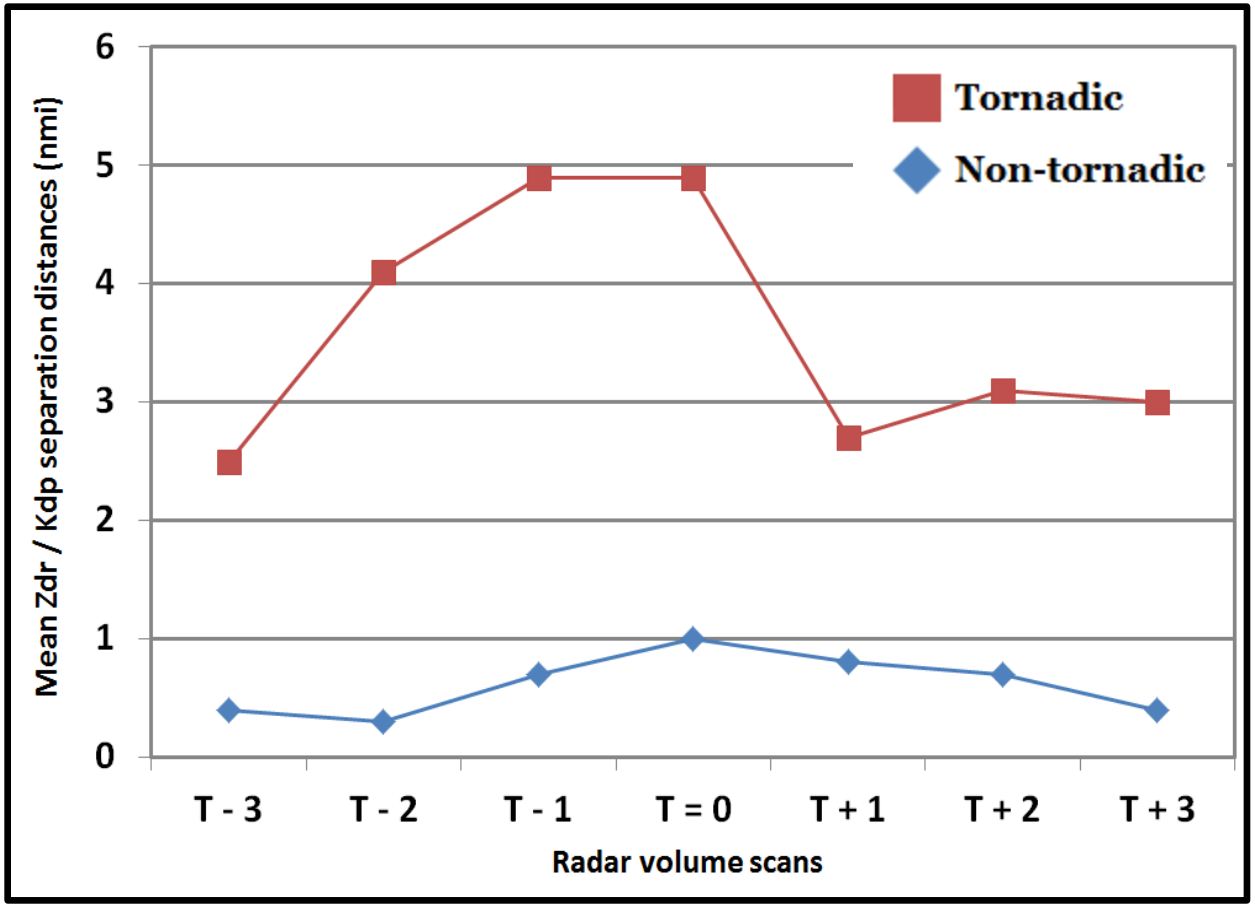
* Note the large differences in separation magnitude between T-2 and T=0

* Separation distances for tornado events:

2.5 - 5 nmi (4-8 km)

* Separation distances for non-tornado events:

0.5 - 1 nmi (1-2 km)



Horizontal Separations (nmi, y-axis) of Zdr and Kdp maxima over time

* Once again, looking at +/- 3 volume scans from T=0

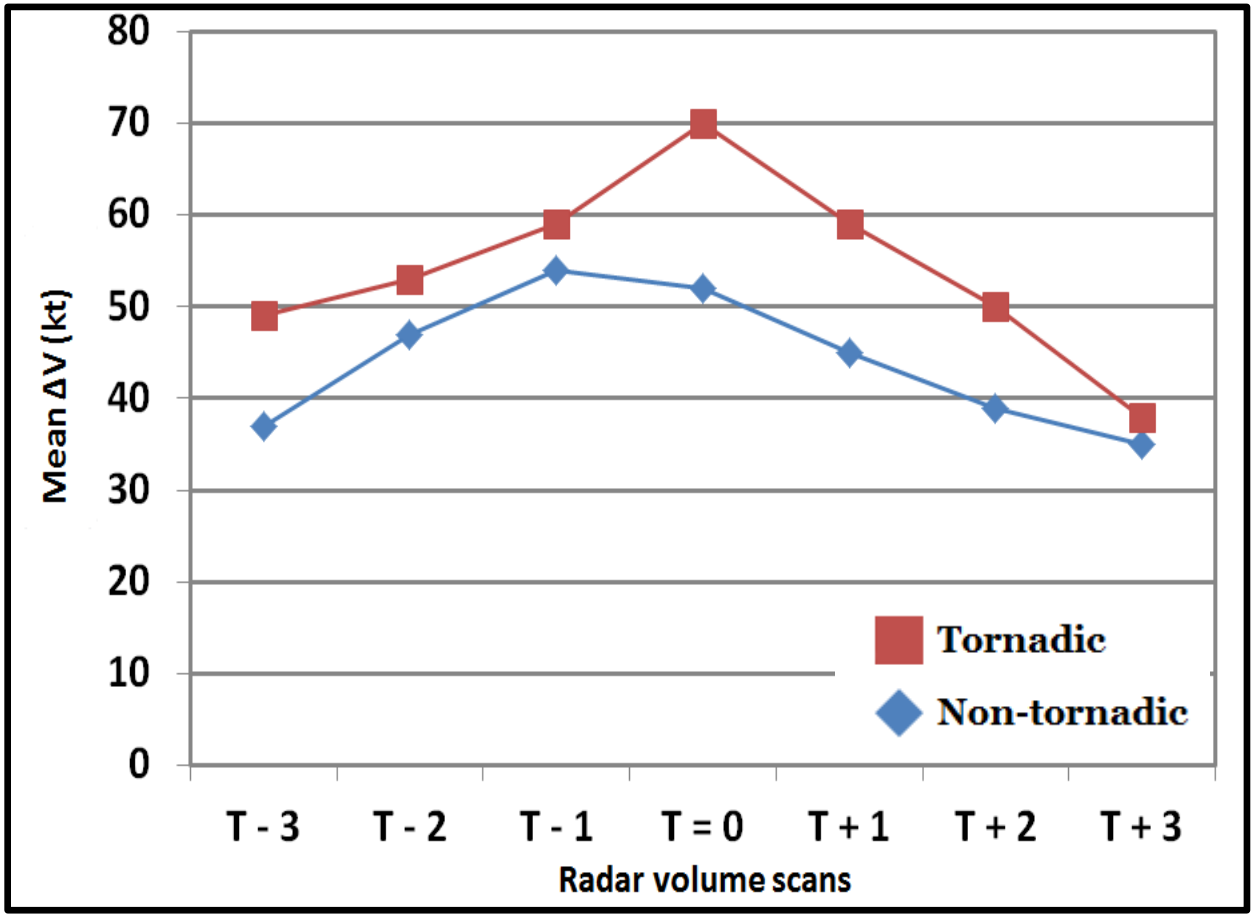
* T=0 is either the time of initial tornado touchdown or tornado warning issuance (null events)

* Rotational velocity couplet seems to spike in intensity near T=0 for tornadic storms and T-1 for non-tornadic storms

* Tornado events: mean ΔV: 70 kts

* Non-tornado events: mean ΔV: 54 kts

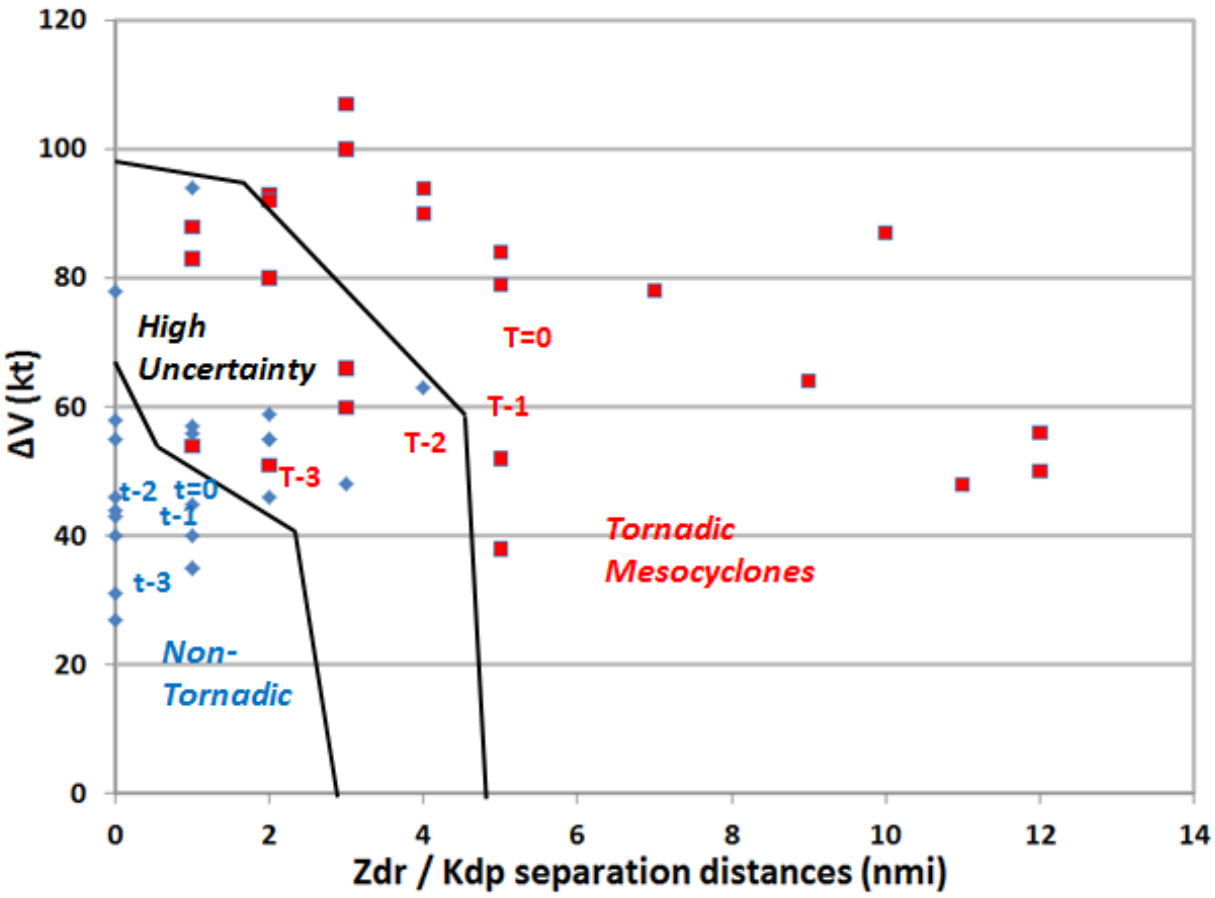
Note: $\Delta V = |\max_{inbound}| + |\max_{outbound}|$



Trends of Maximum Gate-Gate Shear (kt, y-axis (Storm Relative Motion)) over time

* Lower-tropospheric ΔV vs. Zdr/Kdp horizontal separation distances

* Improved ability to discriminate between tornadic and non-tornadic storms, when newer dual-polarization and more traditional velocity techniques are both considered

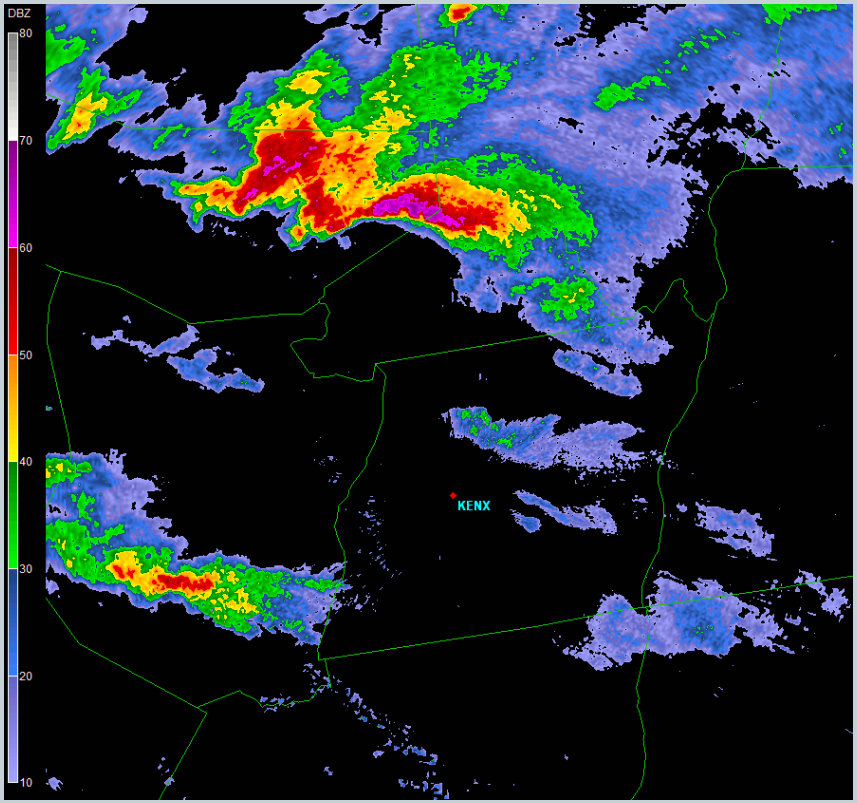


Updated nomogram based on 42 events in present study

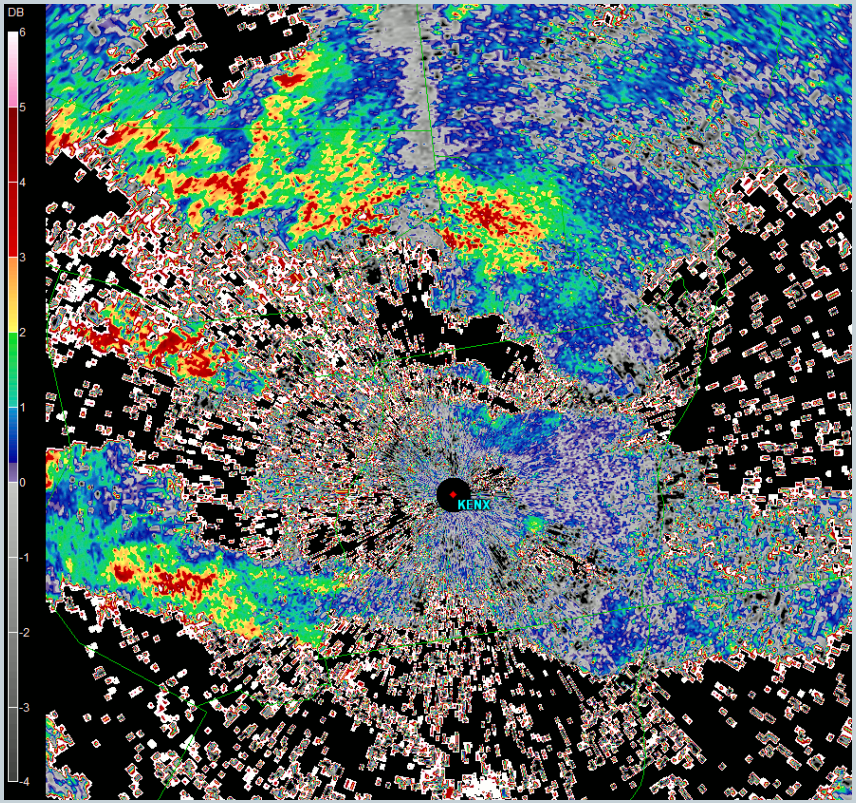
Supercell Example (22 May 2014 near Albany, NY)

Zdr Arc Development (Slide 1)

Z at 1923z (t-3)

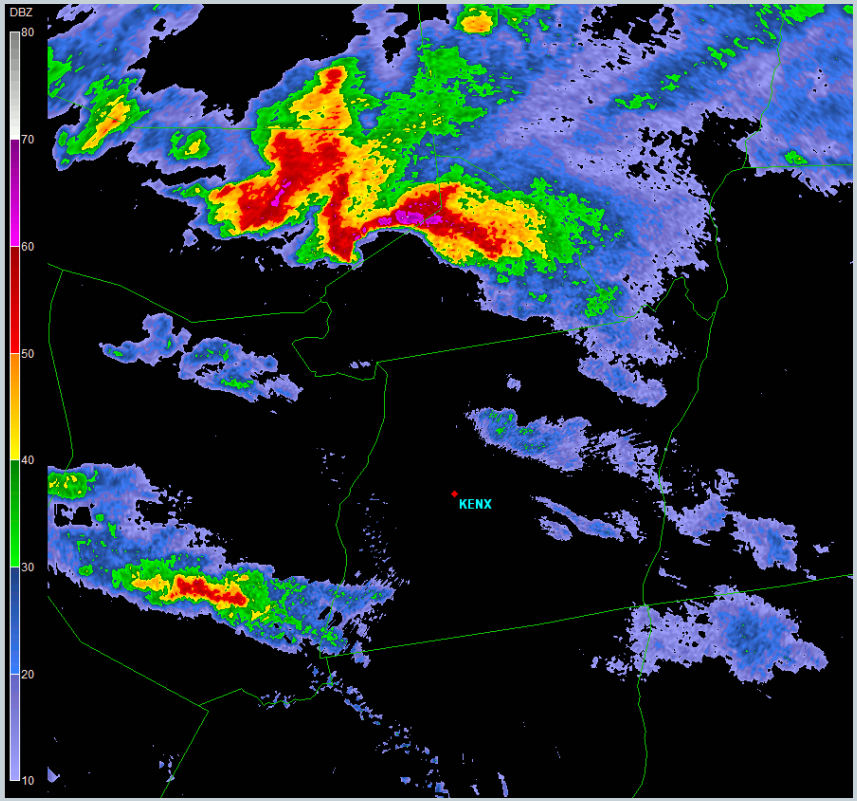


Zdr at 1923z (t-3)

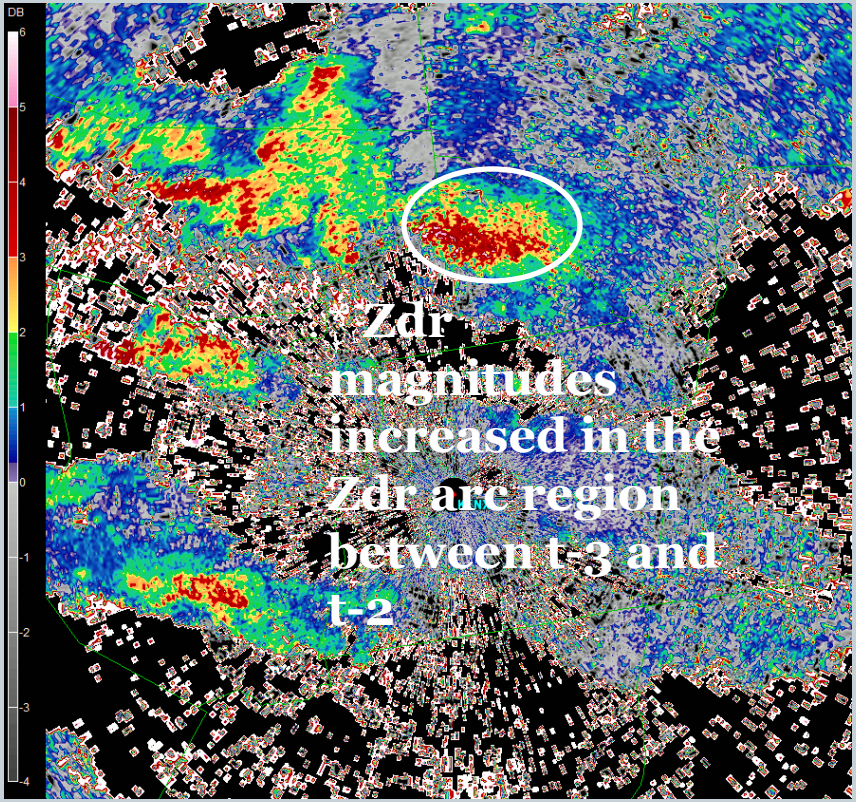


Zdr Arc Development (Slide 2)

Z at 1928z (t-2)

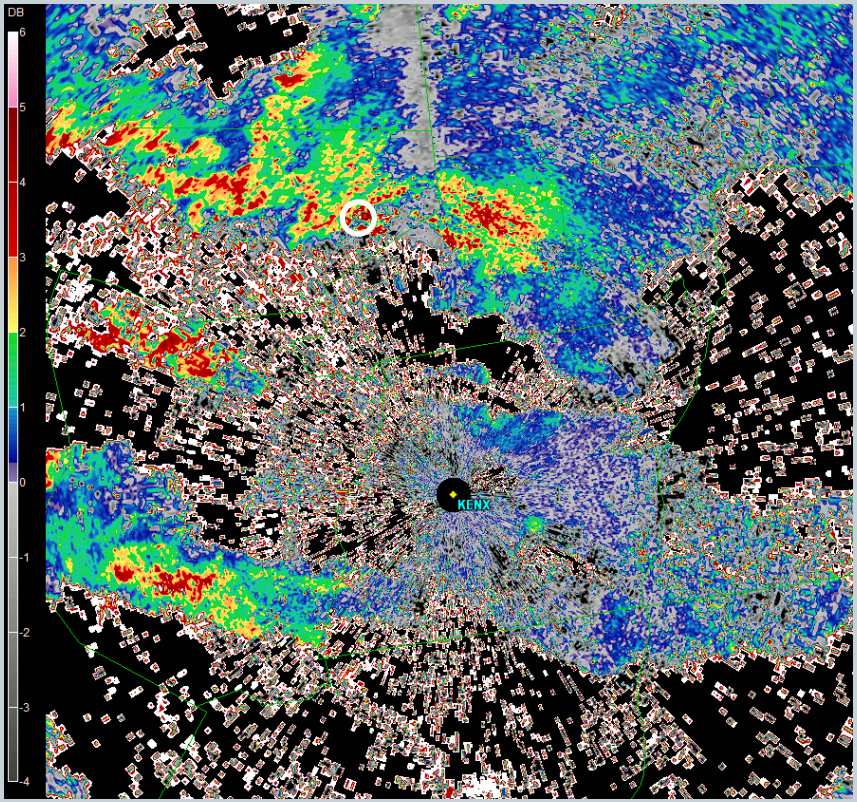


Zdr at 1928z (t-2)

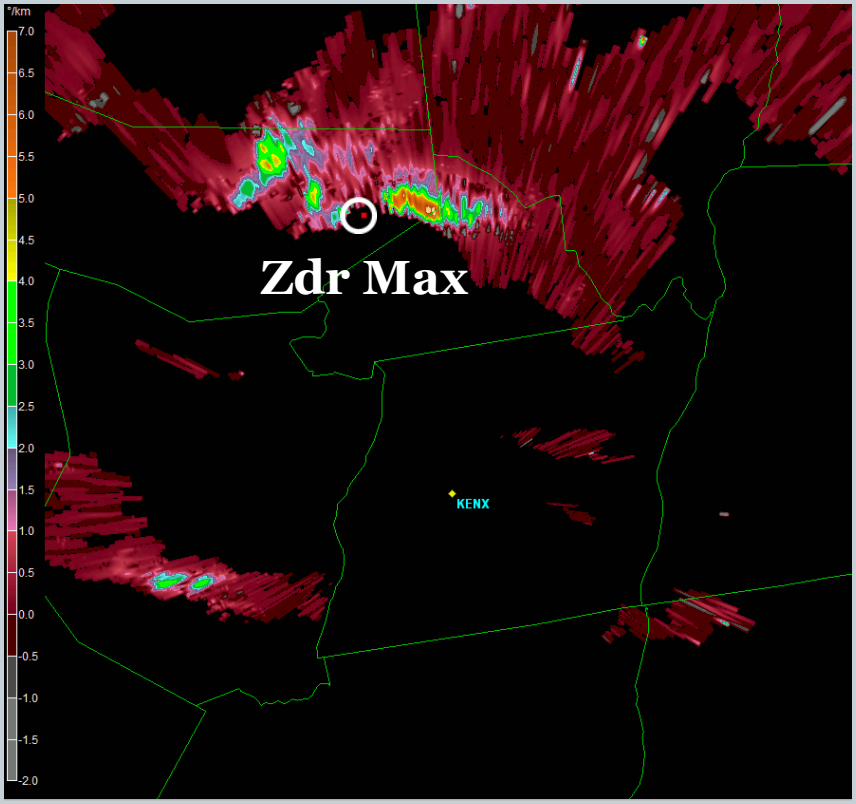


Zdr/Kdp Separation (Slide 1)

Zdr at 1923z (t-3)

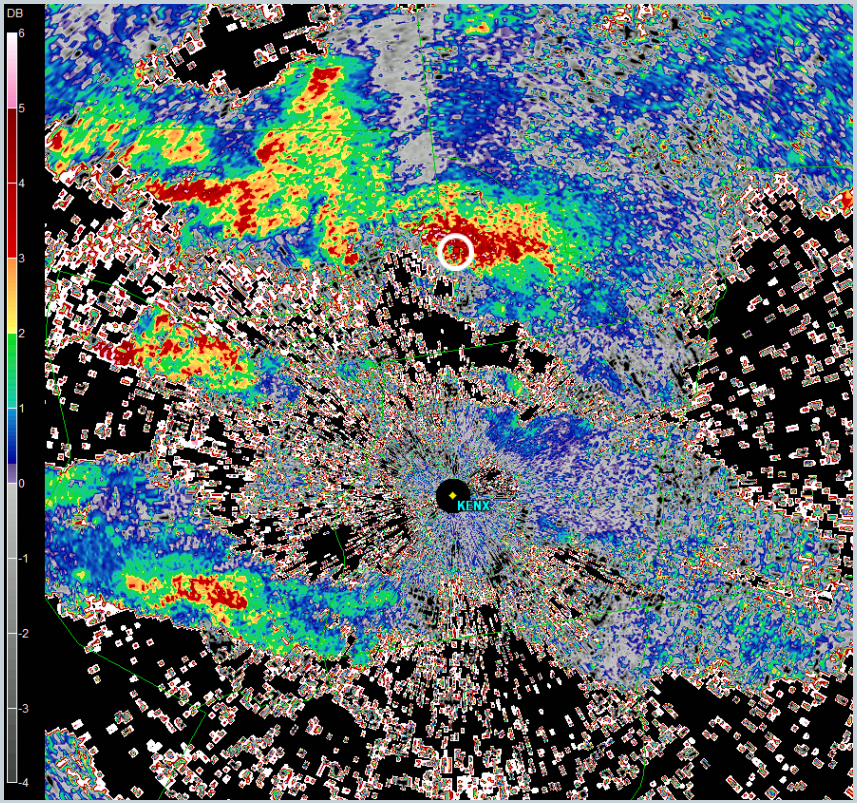


Kdp at 1923z (t-3)

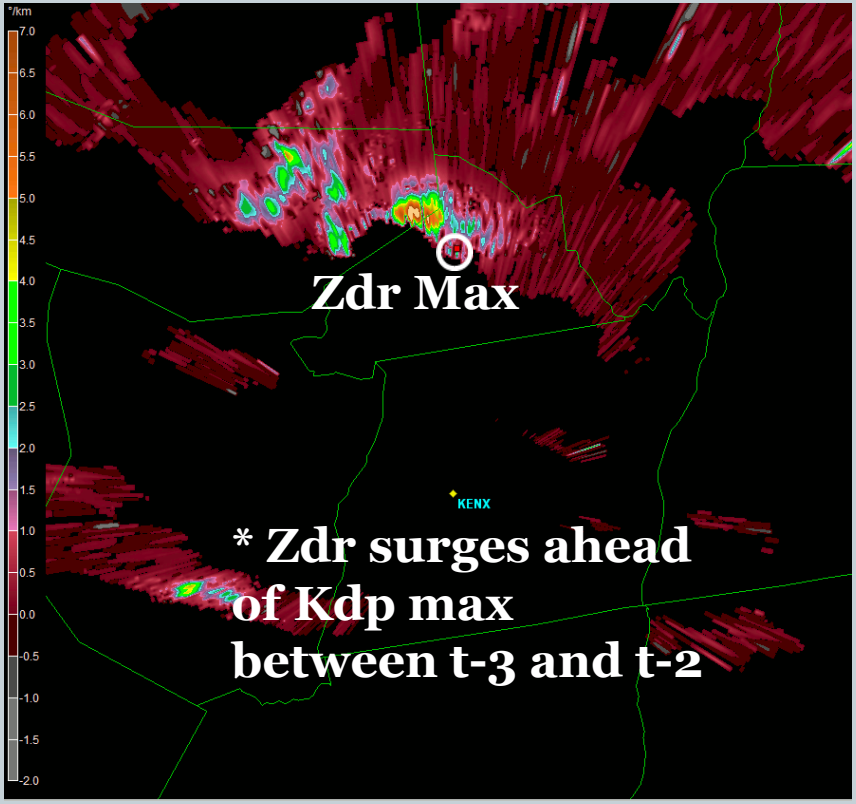


Zdr/Kdp Separation (Slide 2)

Zdr at 1928z (t-2)

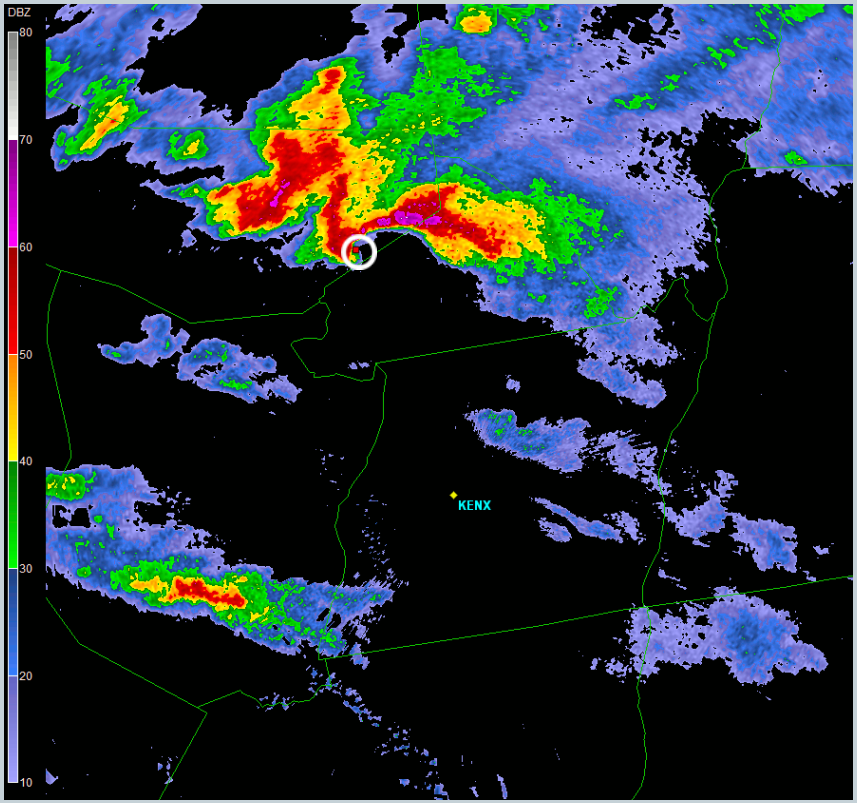


Kdp at 1928z (t-2)

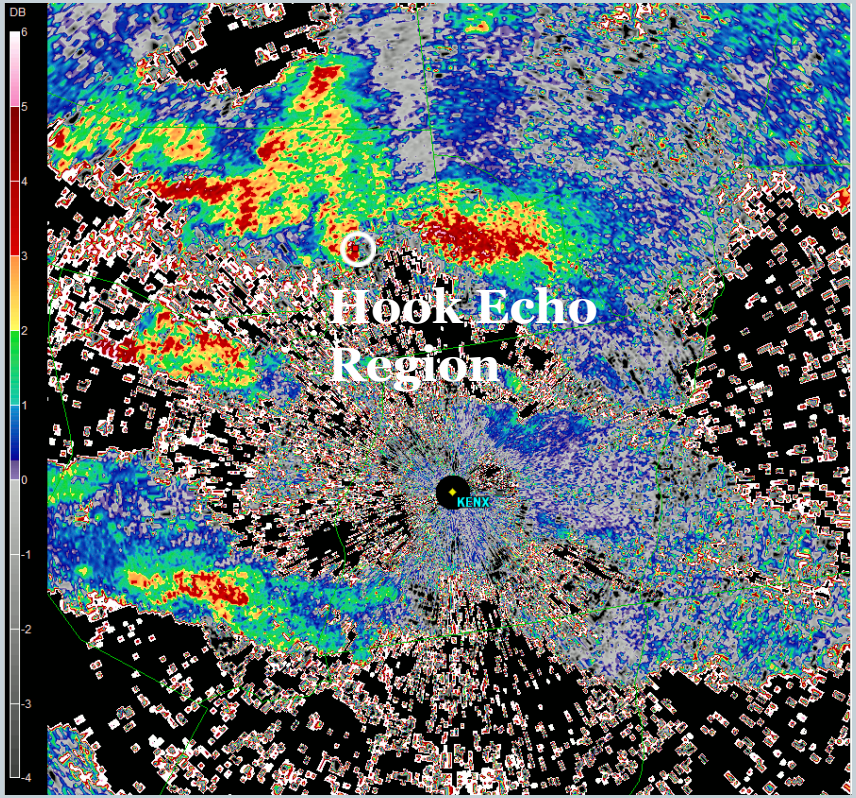


RFD/Hook Echo (Slide 1)

Z at 1928z (t-2)

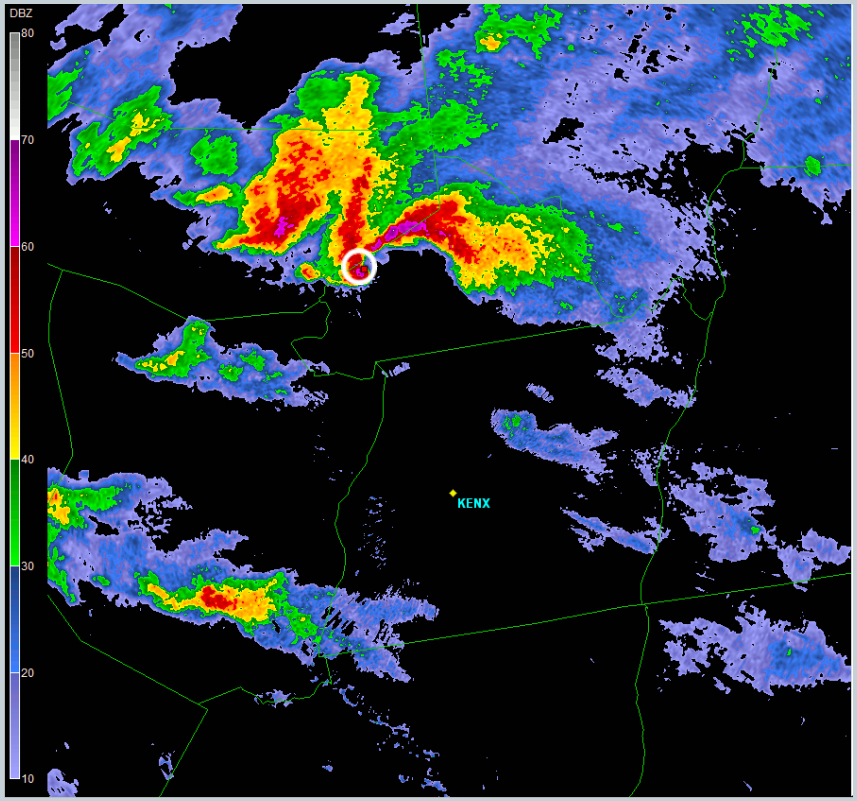


Zdr at 1928z (t-2)

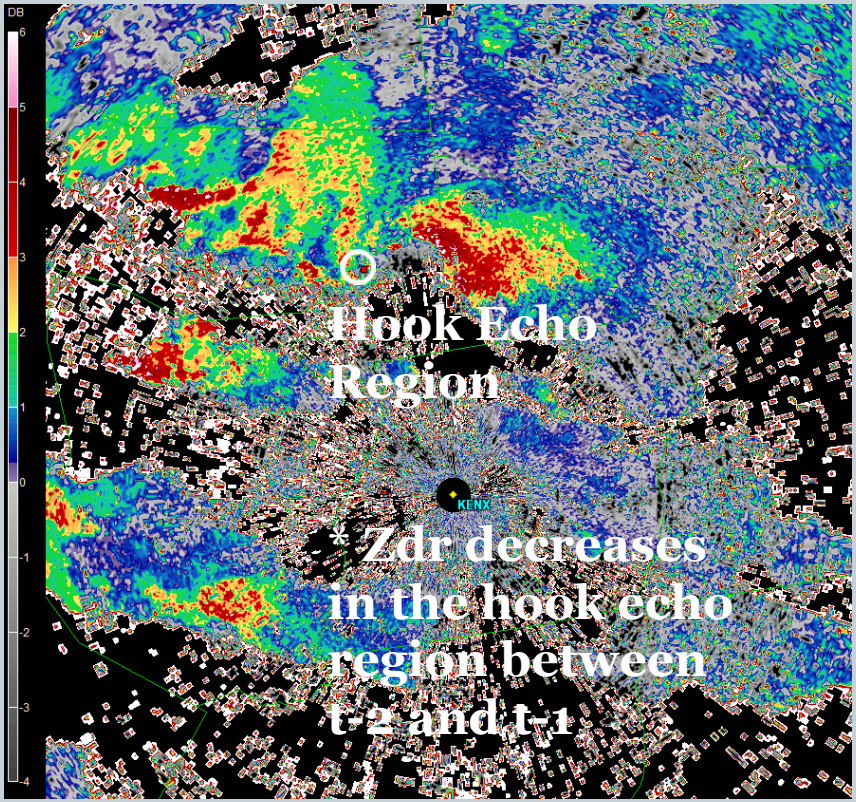


RFD/Hook Echo (Slide 2)

Z at 1933z (t-1)

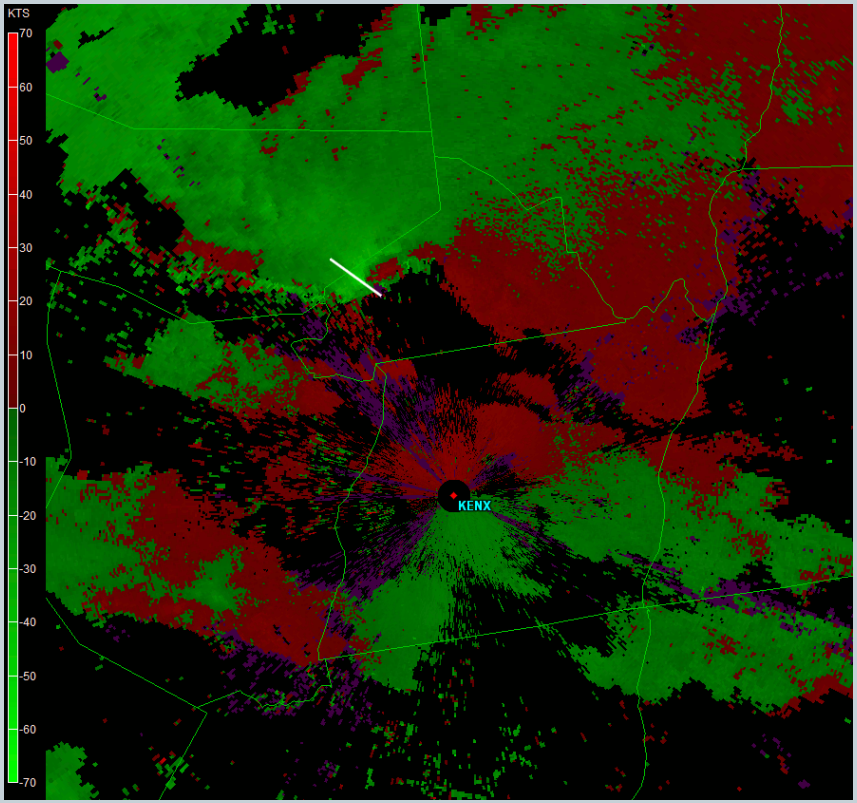


Zdr at 1933z (t-1)

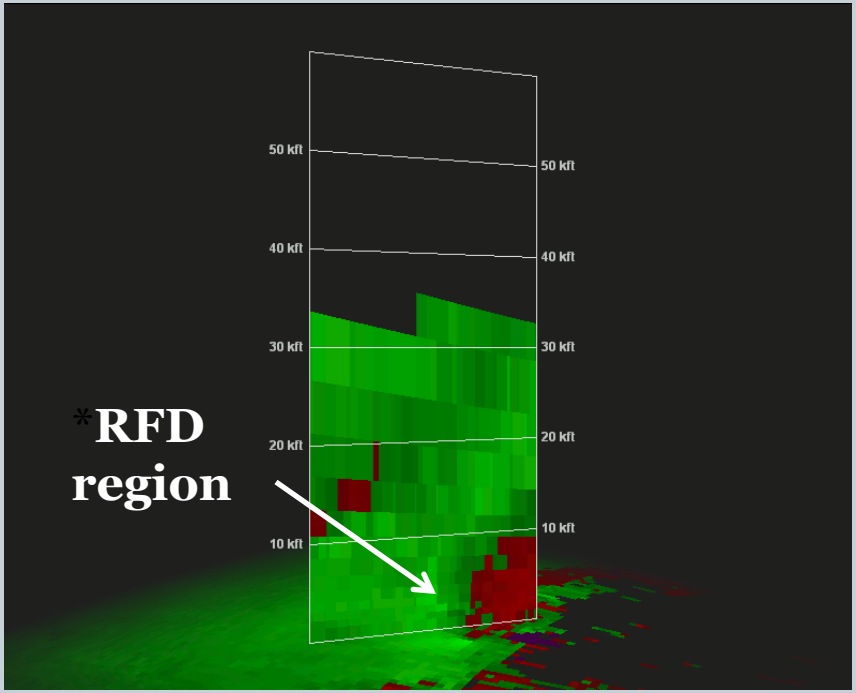


RFD/Hook Echo (Slide 3)

Cross-section axis

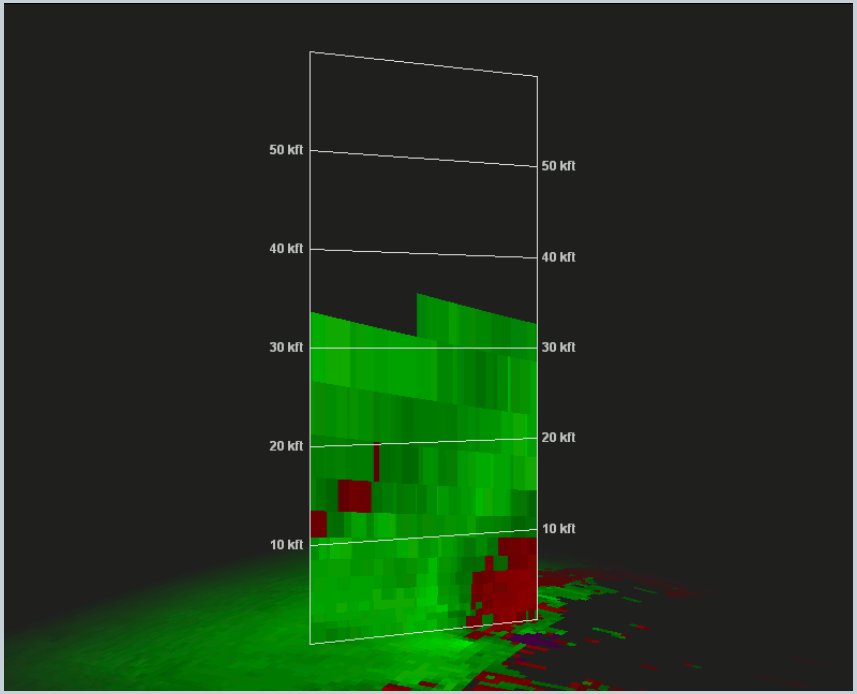


V x-s at 1933z (t-1)

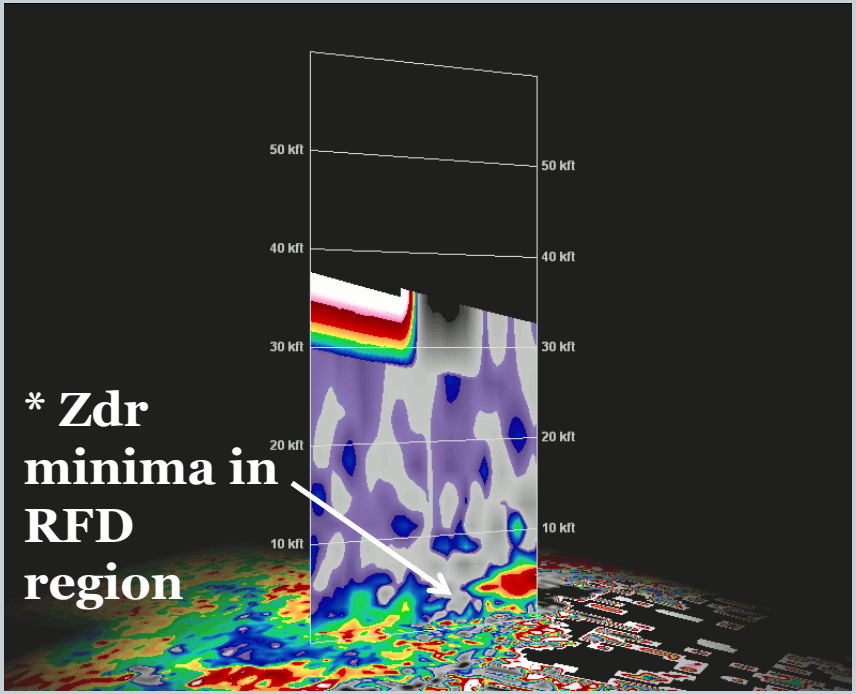


RFD/Hook Echo (Slide 4)

V x-s at 1933z (t-1)

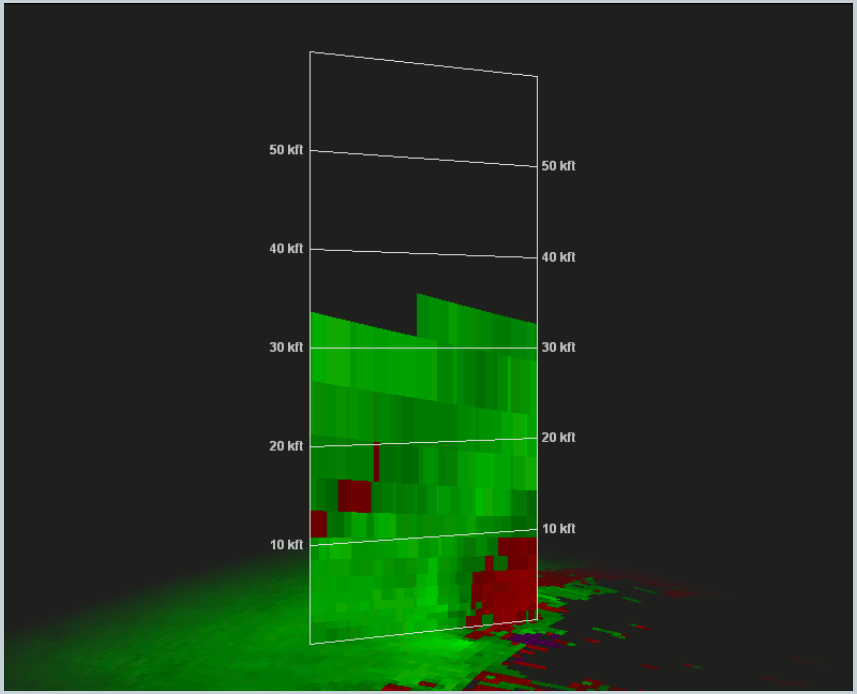


Zdr x-s at 1933z (t-1)

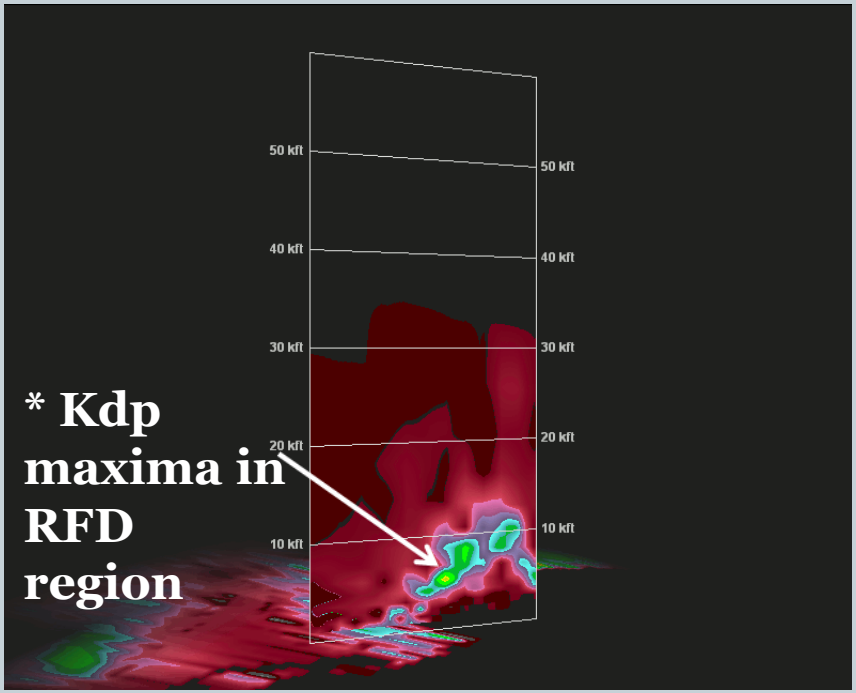


RFD/Hook Echo (Slide 5)

V x-s at 1933z (t-1)



Kdp x-s at 1933z (t-1)



Conclusions/Future Work

Main Take Home Points

- Reliable indicators just prior to tornadogenesis, especially for supercells (typically t-3 to t-1, and often before you see “bright and tight” couplet):
  - Zdr maxima surges ahead of Kdp maxima, with increasing horizontal separations (Kdp lags back to the west)
  - Zdr flare up in the arc/inflow region
  - Zdr decrease in the hook echo region
  - Higher Kdp gates becoming more prevalent in the RFD region (downward transport ?)
    - Warmer more buoyant RFD’s ?
- Cursory evidence suggests tornadic QLCS development could be somewhat different
  - Higher Zdr gates noted S-SE of tornadic vortex
    - Cooler drier RFD’s still sufficient for tornadogenesis ?
  - Zdr arc development seems less important
- Reliable indicators just prior to tornado dissipation, or for non-tornadic storms:
  - Relatively low Zdr and/or decreasing Zdr in the inflow/arc region
  - Zdr becoming more spread out/homogeneous across the storm cell
    - Tornado undercutting ?
  - Less Zdr/Kdp maxima separation over time

Future Work

- Publish results
  - Near-future submission to W&F
- Develop methods to make Zdr/Kdp signatures easier to recognize in real-time
  - Better visualization needed in operational setting
    - Better color curves for Zdr (4-5+ db) and Kdp (2-3+ deg/km)
  - Future WDTB/academia collaboration likely
- Continue to evaluate these processes in coming convective seasons

Questions ?