Identification of Dual-Polarization C-band Radar Signatures to Improve Convective Wind Nowcasting at Cape Canaveral Air Force Station and NASA Kennedy Space Center

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Purpose

- U.S. Air Force's 45[th] Weather Squadron (45WS) supplies weather support to Cape Canaveral Air Force Station and NASA Kennedy Space Center (CCAFS/KSC)
- 45WS desires 30 min. lead time for 35+ knot downbursts
- **Goal**: decrease false alarms and increase lead times for 35+ knot downbursts while maintaining high skill scores

Background

- Liquid hydrometeors lofted above 0 °C level by updraft appear as "column" of positive differential reflectivity (Z_{dr}) (Illingworth et al. 1987); indicates updraft magnitude (Kumjian et al. 2014)
- Produces precipitation ice (Tuttle et al. 1989), with 30+ dBZ radar reflectivity (Z_h) and near-0 dB Z_{dr} (Deierling et al. 2008)
- Peak Z_h develops, descends to surface; indicates time of downburst (Wakimoto and Bringi 1988); peak Z_h value may indicate downburst strength – hydrometeor loading (Loconto 2006)
- Precip. ice melts below 0 °C level; Z_{dr} increases to 3+ dB (White 2015); melting over shallow layer (Atlas et al. 2004) with high relative humidity (Srivastava 1987) intensifies downburst
- Gust front forms; new cells may develop (Browning et al. 1976)

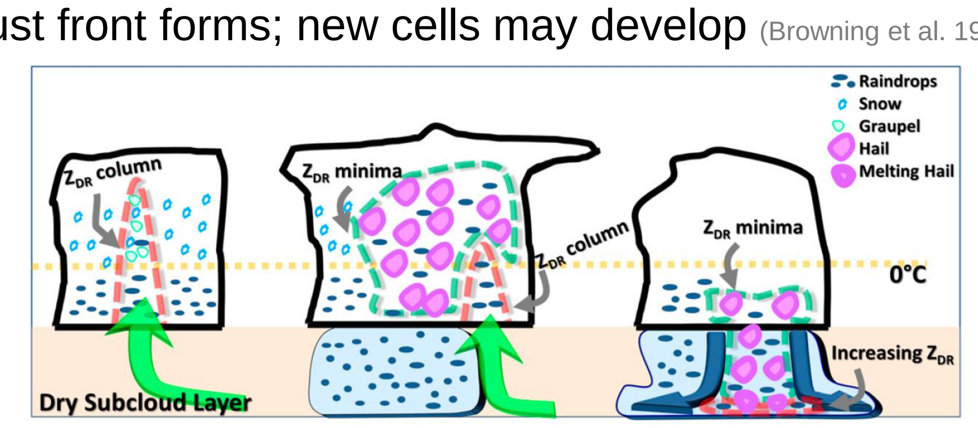
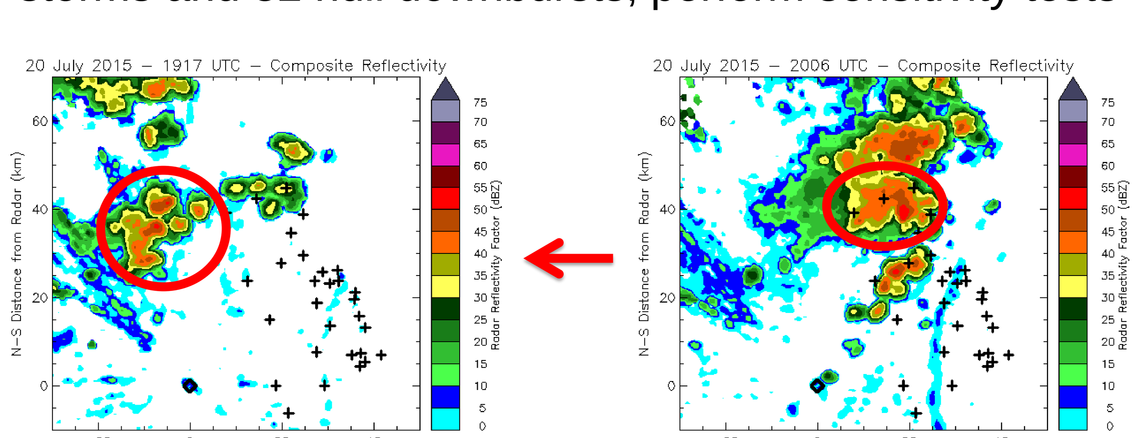


Image source: Mahale et al. (2016)

Data & Methodology

- Wind Data: Cape WINDS – weather observation towers
- Radar Data: C-band dual-polarization radar operated by the 45WS (termed 45WS-WSR in this study)
- Grid 45WS-WSR data with Py-ART (Helmus and Collis 2016); 500 m res., 1 km const. ROI, Cressman (1959) weighting
- Use Cape WINDS and 45WS-WSR composite Z_h to identify cell responsible for threshold-level winds
- Manually track cell back in time (example below); use vertical cross sections of Z_h, Z_{dr}, and correlation coefficient (ρ_{hv}) to analyze physical processes
- Identify signatures in 32 threshold-level downburst storms and 32 null downbursts; perform sensitivity tests

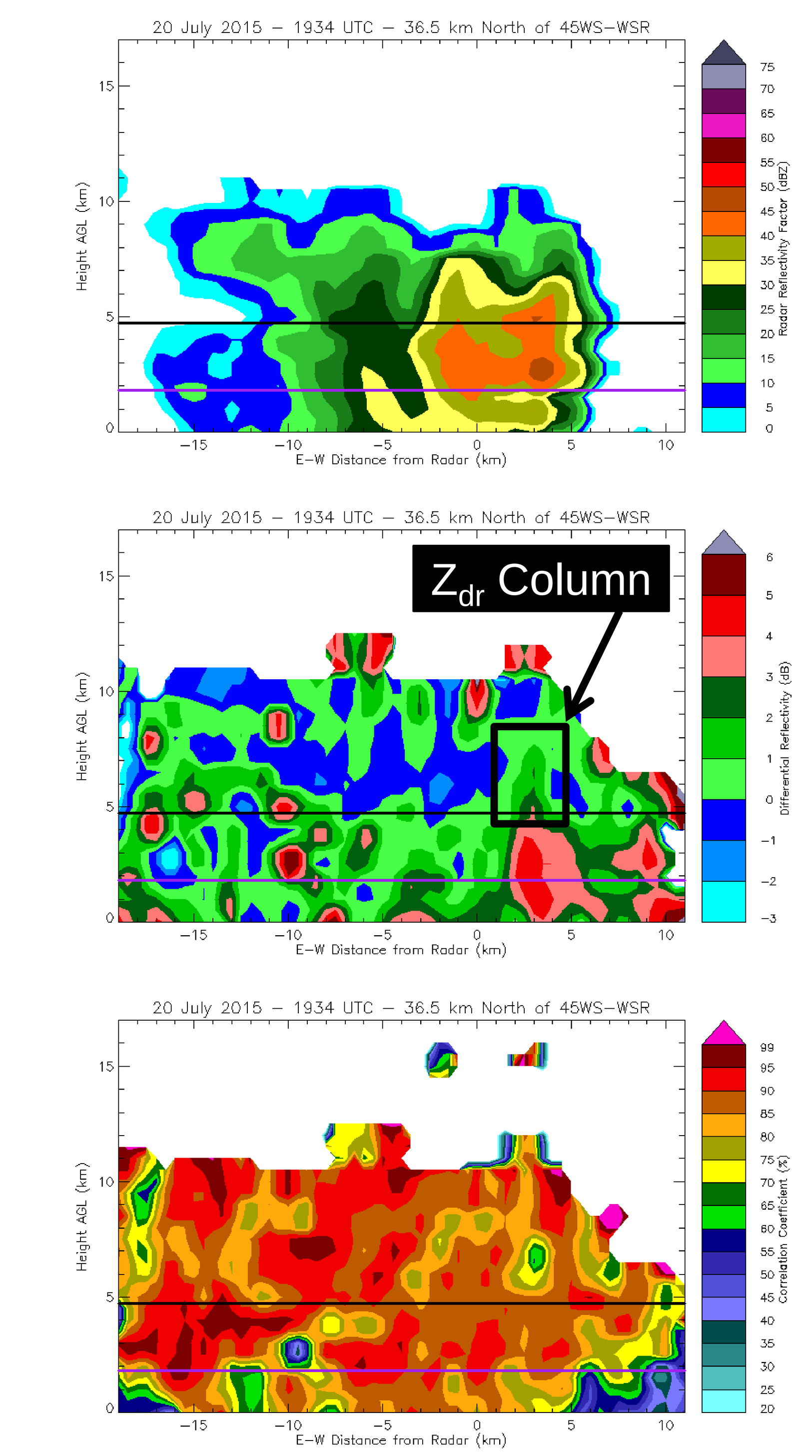


Dual-Polarization Radar Signatures

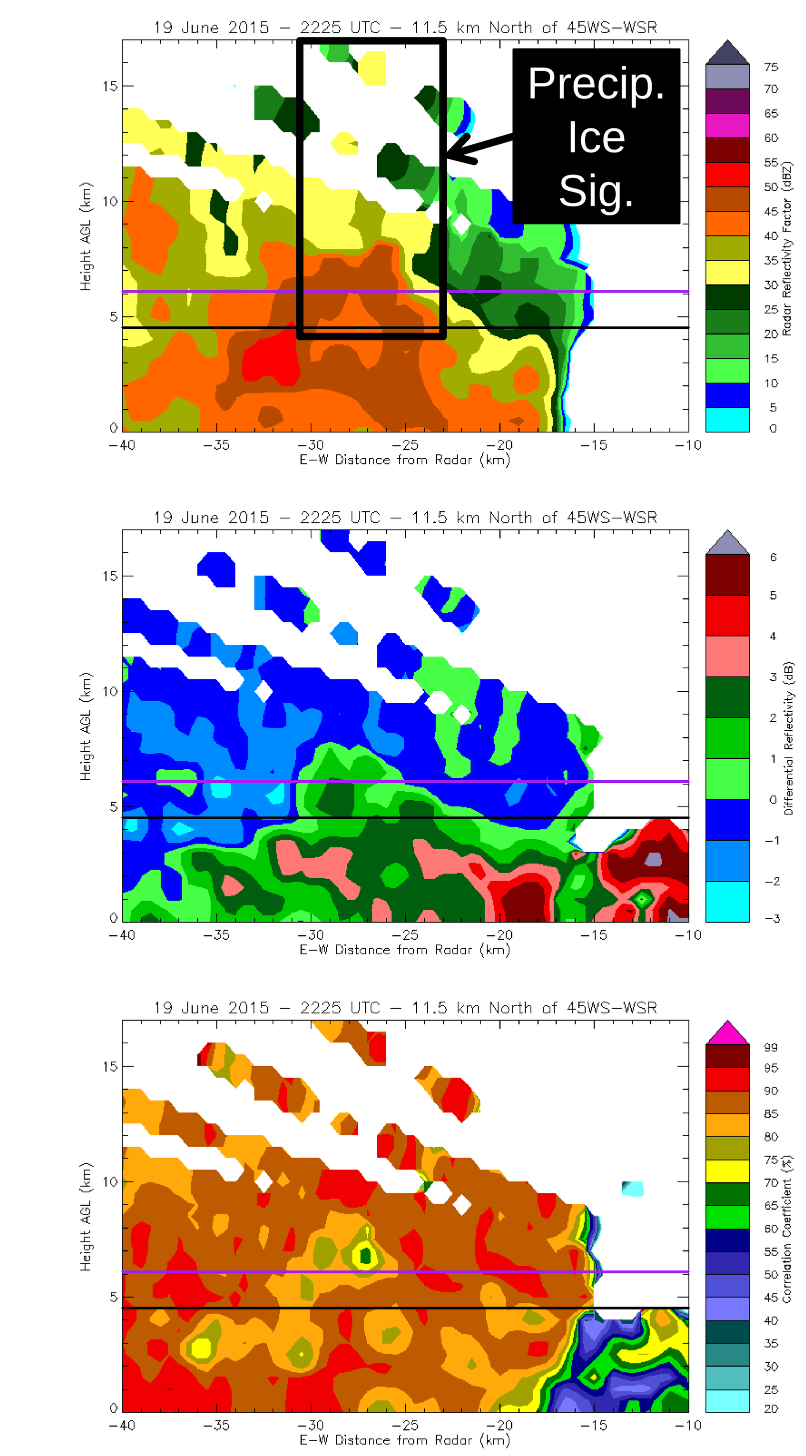
- **Signatures #1 – #5**:

1) Peak height above 0 °C level of 1 dB contour within Z_{dr} Column
2) Peak height above 0 °C level of co-located 30+ dBZ Z_h and near-0 dB Z_{dr} (i.e., "precipitation ice signature")
3) Peak Z_h value in storm cell
4) Height below 0 °C level where Z_{dr} increases to 3 dB in descending reflectivity core (DRC)
5) Vertical Z_{dr} gradient over ±500 m around 1 dB contour in DRC

- Vertical cross sections of Z_h (top), Z_{dr} (middle), and ρ_{hv} (bottom); black horizontal line denotes 0 °C level
- Indicate precipitation ice importance
- Often observed in earlier cells within threshold-level multicell storms
- Signatures **directly** related to peak wind velocity in their collapsing cell
- Strong gust front intensifies updrafts in new cells, enhances downbursts; signatures also **indirectly** related to peak wind velocity in later cells

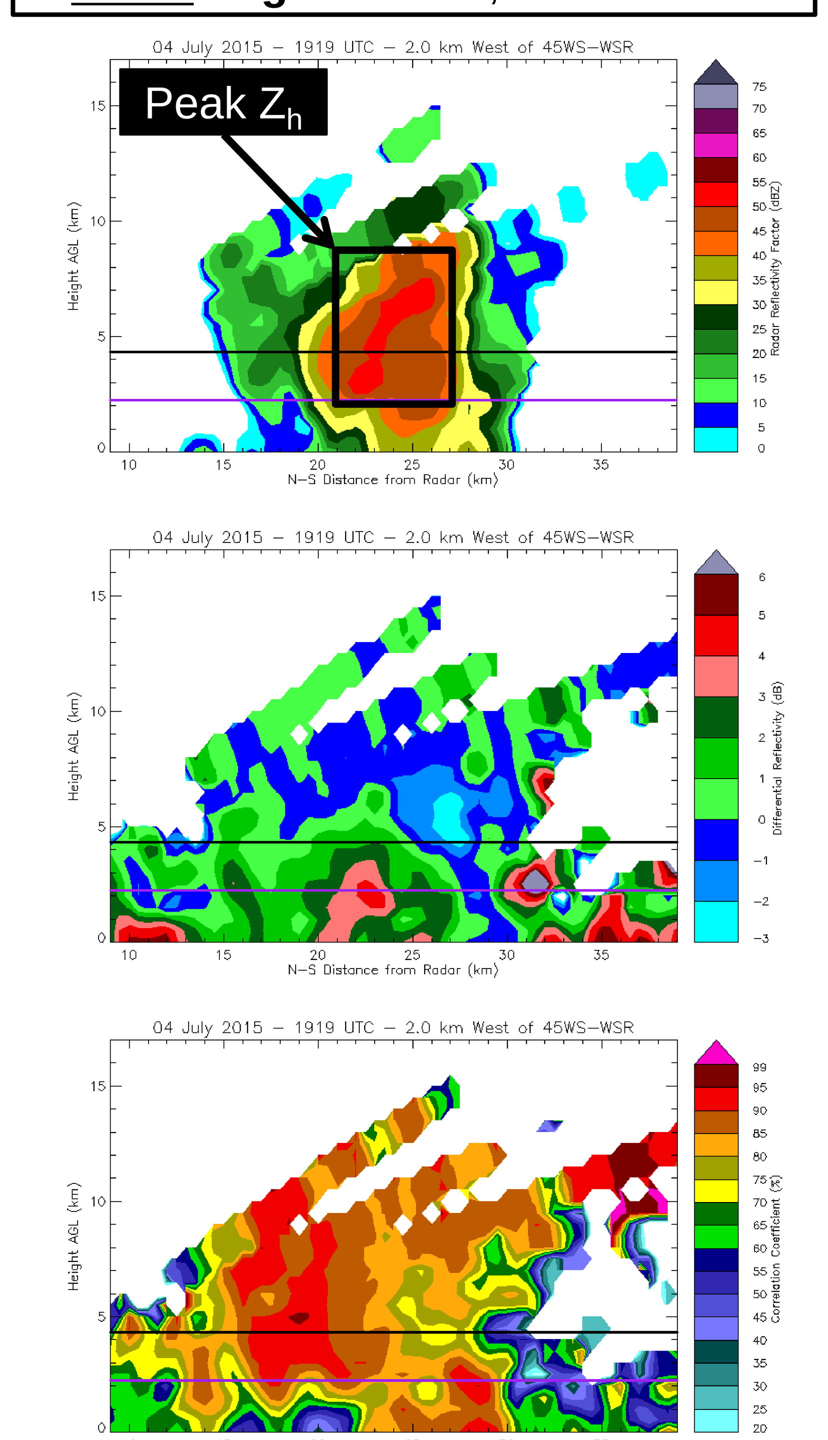


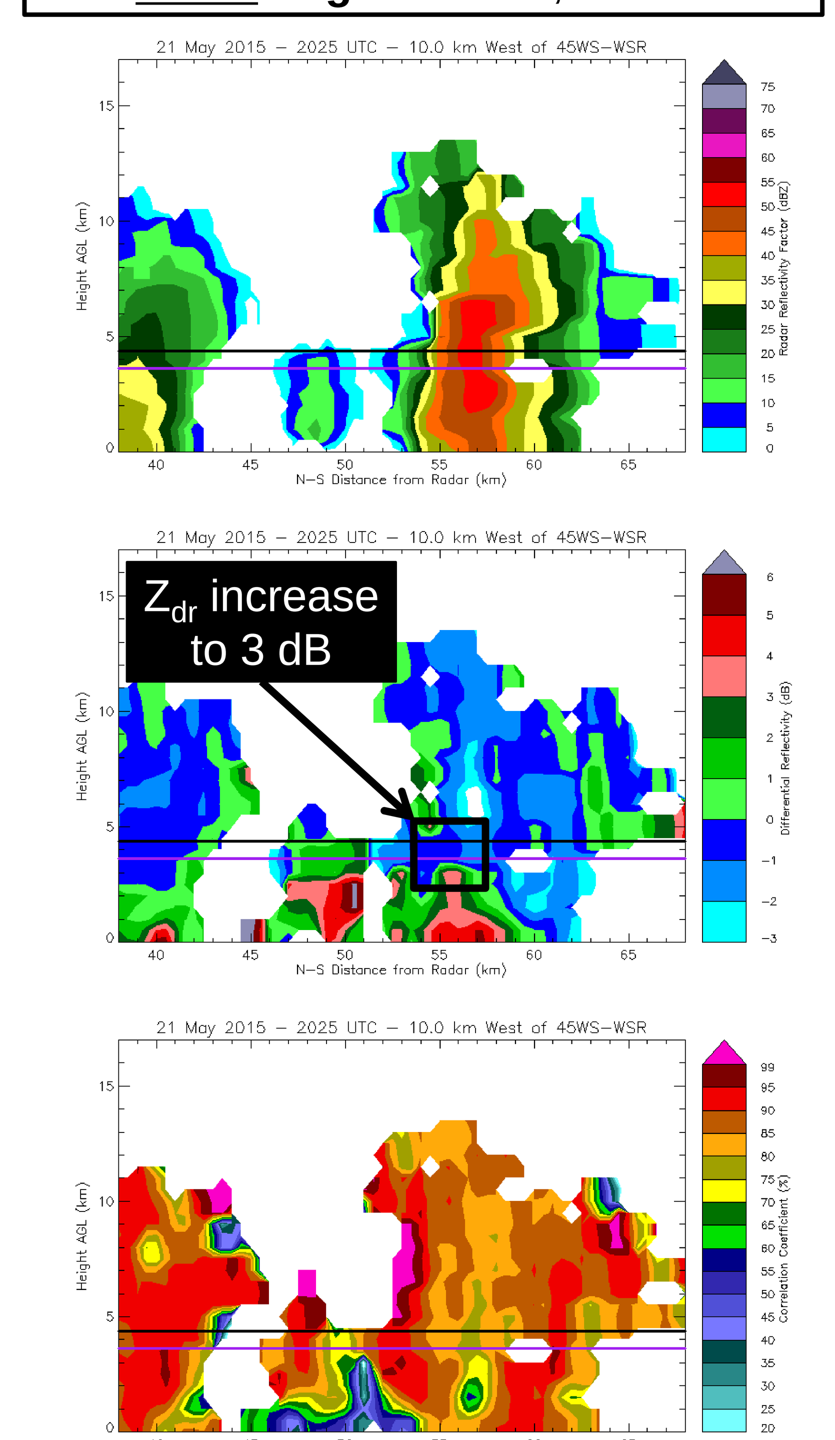
Above: **Signature #1**, 3 km
Below: **Signature #4**, 1.2 km

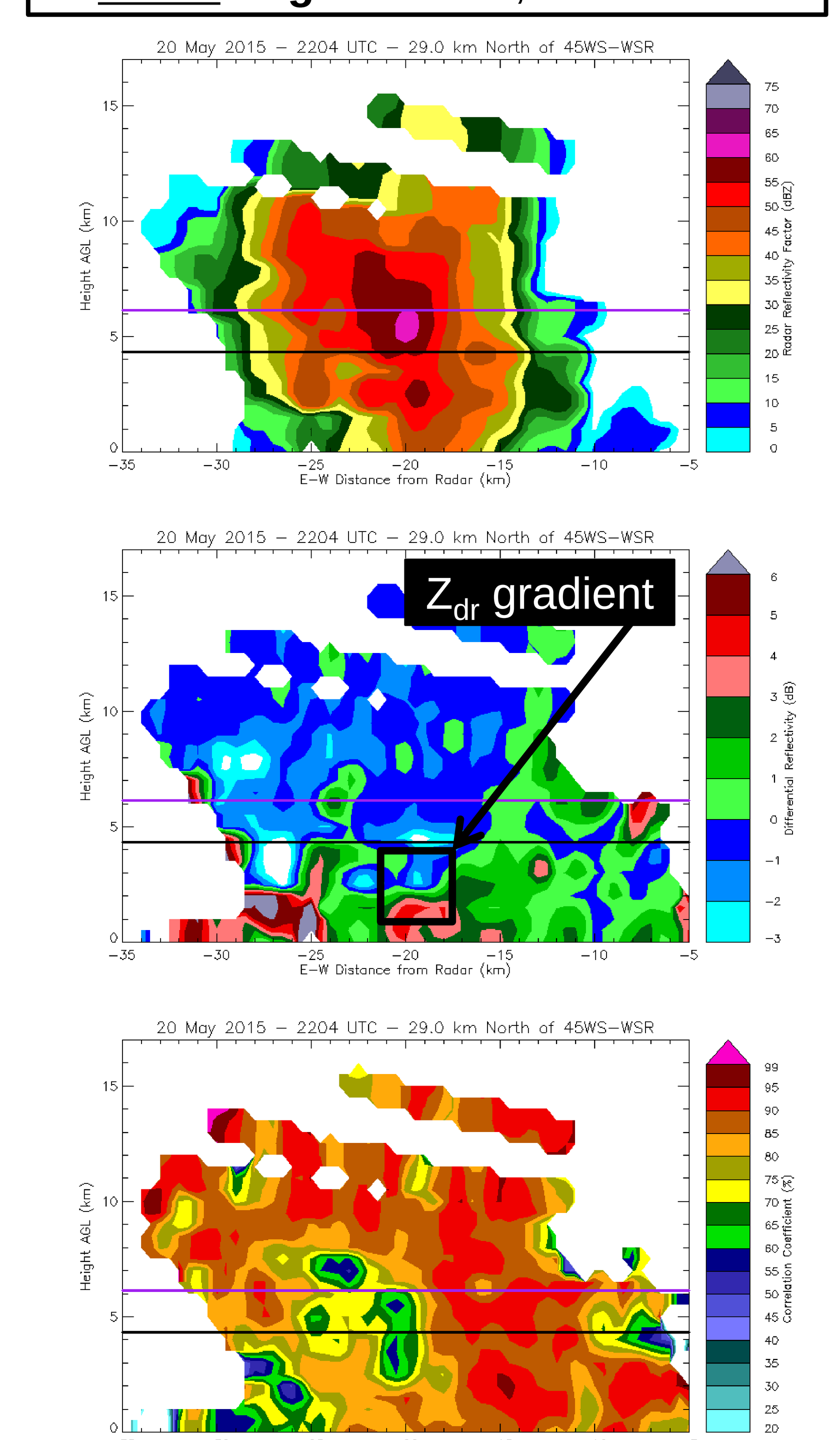


Above: **Signature #2**, 12 km
Below: **Signature #5**, >6 dB km^{-1}

Below: **Signature #3**, 50 – 55 dBZ







Sensitivity Test Results

Statistical Parameter	Signature #1	Signature #2	Signature #3	Signature #4	Signature #5
	2.0 km above 0 °C level	4.5 km above 0 °C level	50 dBZ	2.5 km below 0 °C level	>3 dB km^{-1}
POD	0.84	0.81	0.91	1.00	0.84
POFA	0.21	0.10	0.34	0.40	0.31
TSS	0.63	0.72	0.44	0.34	0.47
CSI	0.69	0.74	0.62	0.60	0.61
Mean LT (min)	47.3	47.2	51.5	46.2	46.5

- POD = Probability of Detection
- POFA = Probability of False Alarm (or False Alarm Ratio)
- TSS = True Skill Statistic (-1 = worst; 1 = best)
- CSI = Critical Success Index (0 = worst; 1 = best)
- LT = Lead Time (downburst time - end of volume scan)
- Best-performing threshold value shown for all signatures
- Increasing threshold often yielded lower POD, POFA, and lead time, along with higher skill scores
- Long lead times from analyzing earlier cells in multicell storms; location-relative; shorter in single-cell storms
- **Signature #4**: 2.5 km threshold had POD of 100%
- **Signature #2**: 4.5 km threshold was strongest standalone signature tested

Conclusions & Future Work

- Five C-band dual-polarization radar signatures identified; all related to formation and melting of precipitation ice
- Different thresholds yielded different statistics; users can select optimal parameter(s) based on trade-offs
- Potential to analyze signatures in earlier cells in multicell storms to predict downburst intensity in later cells (signatures directly and indirectly related to peak wind)
- Utility of analyzing earlier cells in multicell storms should be investigated further (e.g., using larger sample sizes, considering range of initial cell from CCAFS/KSC)
- Improve definition of null downburst, combine radar and environmental signatures (e.g., Medina et al. 2017, poster 148 at this conference), check interaction among signatures, improve 45WS 50+ knot wind warning

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