Variations in Hail and Small Drop Distributions in Classic Supercells and their Relationship to Environmental Variables

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Introduction

Background

Hydrometeor types can be classified using values of different polarimetric radar variables including reflectivity factor (Z_{HH}), differential reflectivity (Z_{DR}), and correlation coefficient (ρ_{hv}). The polarimetric hail signature includes Z_{HH} >45 dBZ, Z_{DR} ~0 dB, and ρ_{hv} <0.95; the polarimetric small drop signature includes Z_{HH} <30 dBZ, Z_{DR} ~0-1 dB, and ρ_{hv} >0.97 (Straka et al. 2000). In this study, polarimetric signatures of three classic supercells were examined at the lowest elevation angle, and the relationship of the areal extent of hail and small drops to environmental variables was explored.

Objectives

- Compare *signature areal extent* for both hail and small drops through the temporal duration of each supercell event
- Relate the hail and small-drop areal extents to environmental variables (such as relative humidity and wind shear) obtained from soundings that are representative of the storm environment

Methods

- Tornadic events and nontornadic supercell events were identified using the NCDC Storm Events Database. These three cases were chosen out of a larger database of supercell events, based on the following criteria:
  - Events had to be within ~93 km (~50 nmi) of a WSR-88D
  - Rotation was present in the updraft region (either at base level or midlevel scans)
- The nearest polarimetric WSR-88D radar dataset was identified and gathered for each event
- Environmental data for each event was gathered from RUC/RAP soundings that were representative of the storm environment (e.g., on the same side of a boundary) using Bufkit. Values of numerous environmental parameters were collected, including different measures of moisture, instability, and shear.
- Areal extent (km²) of the hail and small-drop drop size distributions were estimated for each event at the 0.5° elevation angle

Results

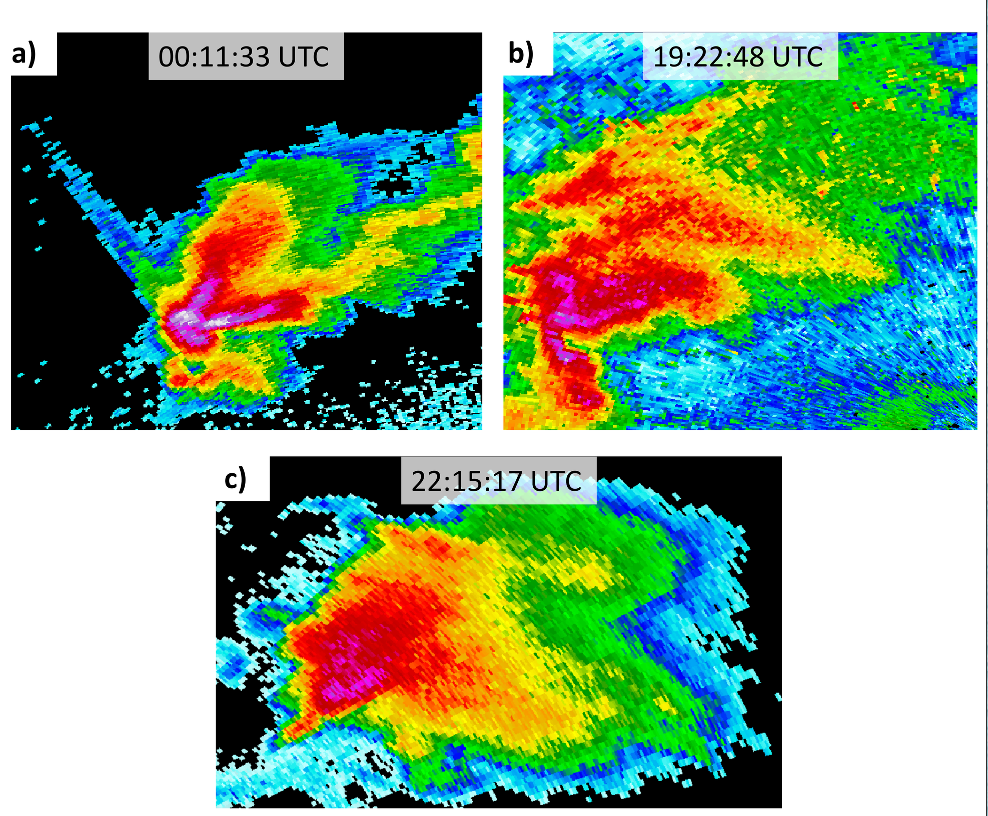

Fig. 1: Z_{HH} images from storms in the domain of a) Dyess Air Force Base, Texas WSR-88D (KDYX) on 24 April 2014, b) Dodge City, Kansas WSR-88D (KDDC) on 30 April 2012, and c) Lubbock, Texas WSR-88D (KLBB) on 23 May 2013. All scans are from the 0.5° elevation angle.

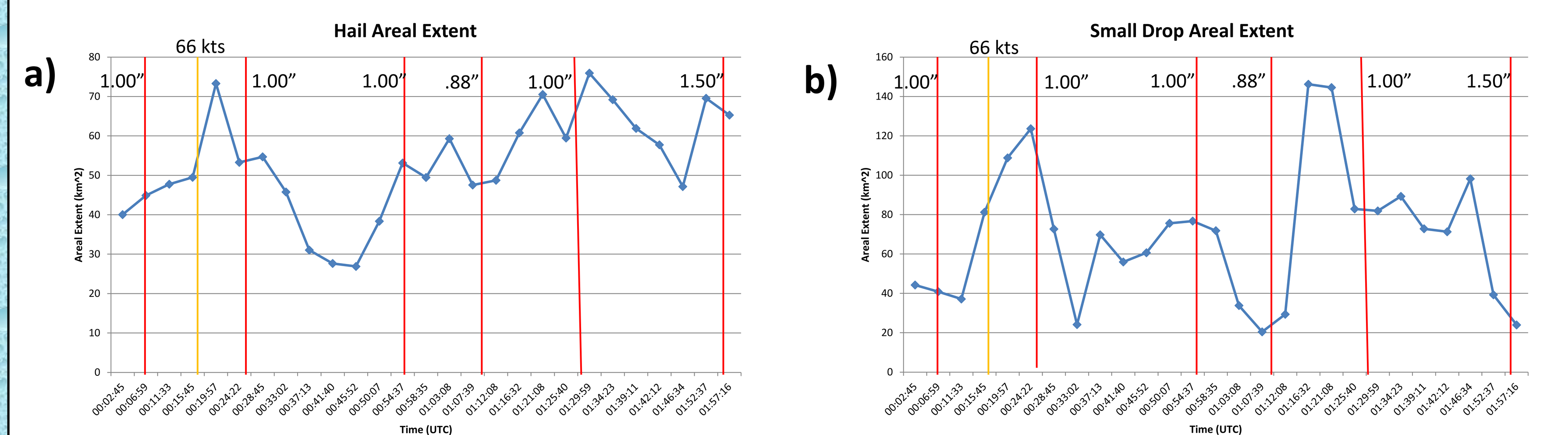

Fig. 2: A time series of the areal extent for a) hail and b) small drop DSDs at the lowest elevation angle (≈ 0.5°) from the storm in the domain of KDYX. Storm reports from NCDC are included as the vertical lines: hail reports in red and wind reports in yellow. Hail size and gust speed are noted near the lines.

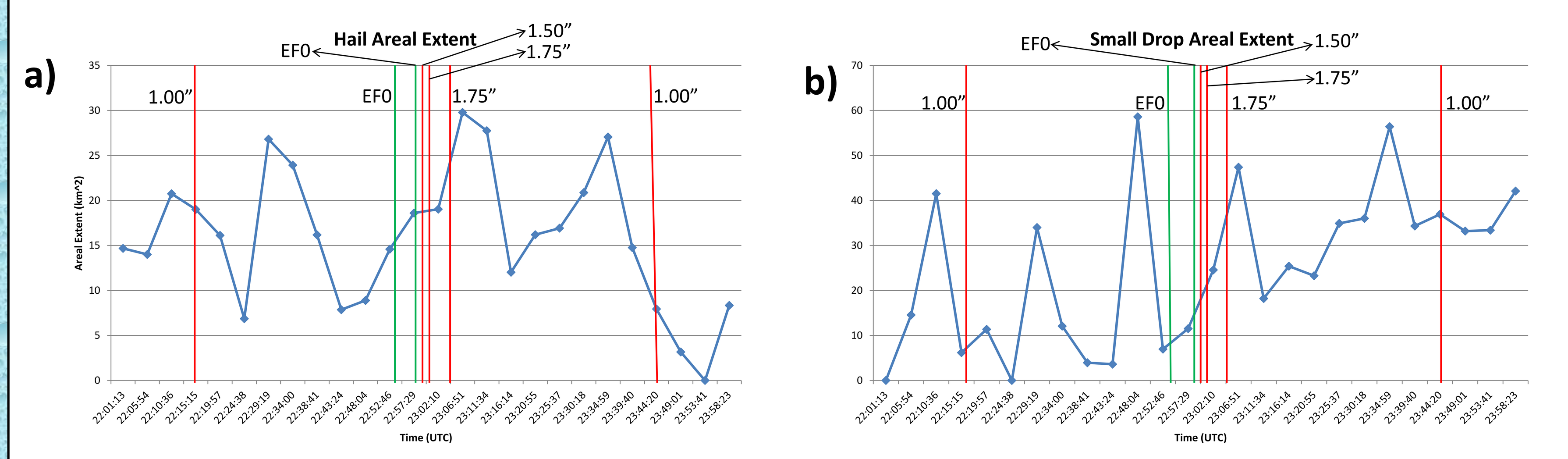

Fig. 3: As in Fig. 2 except for the storm in the domain of KDDC. Tornado reports are also included as the green vertical lines, with tornado strength noted near the lines.

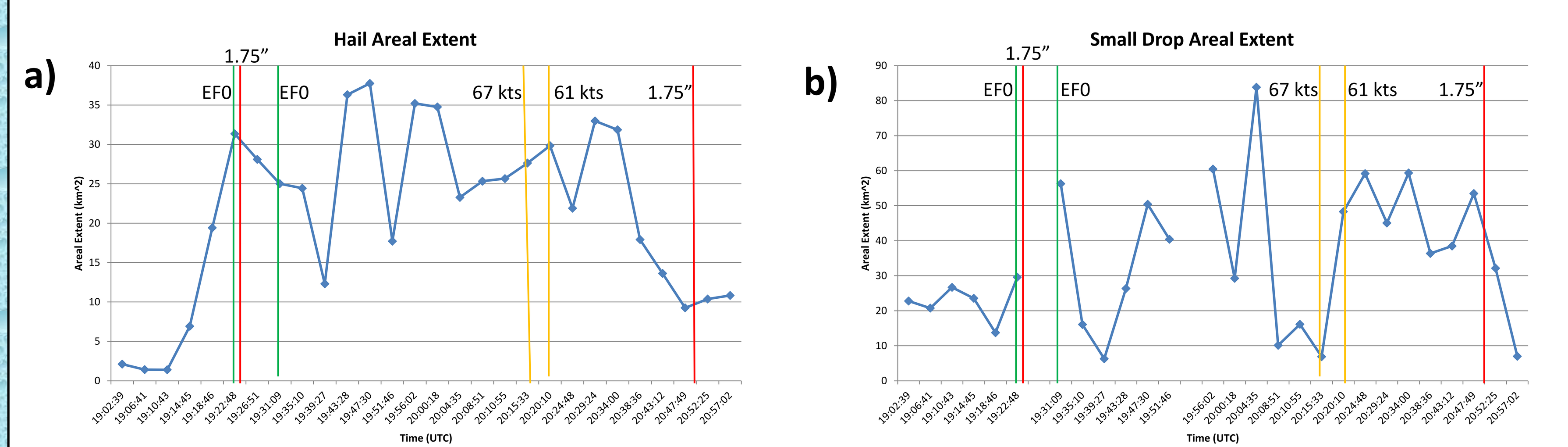

Fig. 4: As in Fig. 3 except for the storm in the domain of KLBB. This supercell was interacting with a boundary throughout its lifetime.

Hodograph Shape

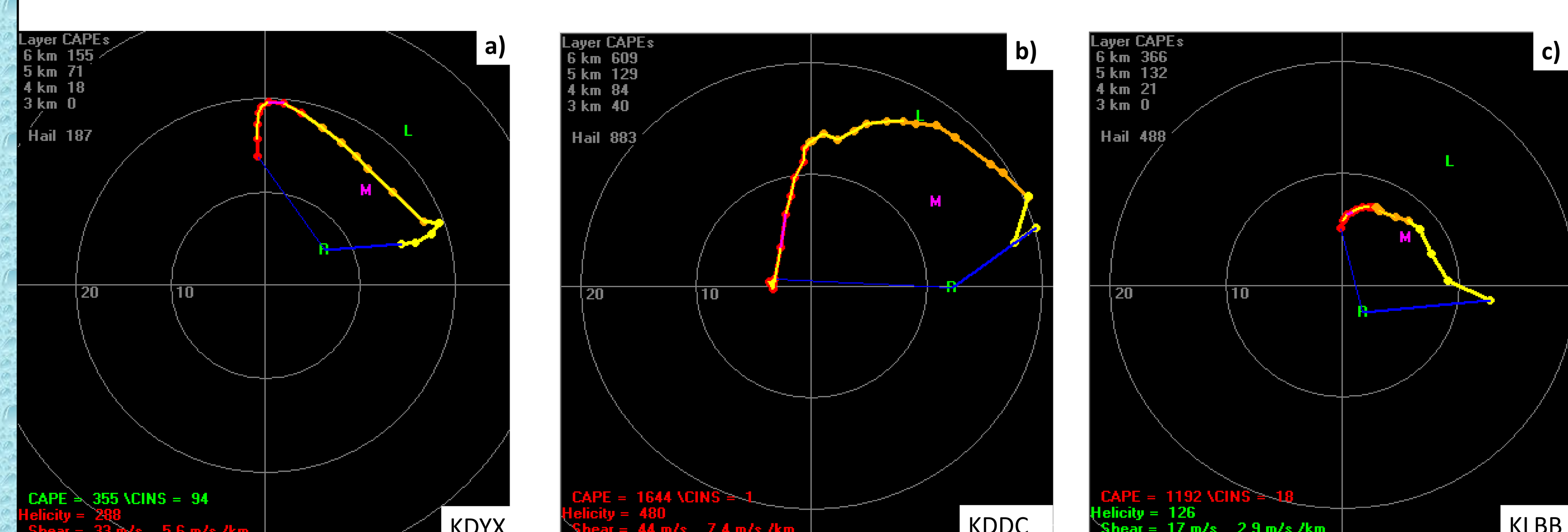

Fig. 4: Hodograph shapes from 0-6 km for the three cases: a) KDYX, b) KDDC, and c) KLBB.

Comparison with Environmental Variables

Average Areal Extent (km²)

	Hail	Small Drops
KDYX	52.9	69.5
KDDC	15.9	26.7
KLBB	21.2	34.0

Table 1: Comparison of average areal extent (in km²) for both hail and small drops for each of the three cases.

	KDYX (24 April 2014)	KDDC (30 April 2012)	KLBB (23 May 2013)
Tornadic or non-tornadic	Non-tornadic	Tornadic	Tornadic – interacting with a boundary
0°C Level (m)	3,300	3,200	3,300
Lifting Condensation Level (LCL) height (m)	2,002	347	535
3-6 km mean RH	50.02%	91.51%	71.36%
6-9 km mean RH	42.78%	91.77%	55.74%
3-9 km mean RH	75.06%	93.28%	47.58%
0-1 km shear ($m\ s^{-1}$)	10	15	4
0-3 km shear ($m\ s^{-1}$)	22	34	6
0-6 km shear ($m\ s^{-1}$)	33	44	17
Period of hail cyclicality	~ 1 hour	~20-30 minutes	N/A*
Period of small drop cyclicality	~ 30 minutes (increases in throughout time series)	~ 20 minutes (for first half of time series)	~ 30-45 minutes

Table 2: Comparison of environmental variables for the different cases. The RH values are layer-average values, rather than values at specific levels. *It is worth noting that the period of hail cyclicality is different with this storm (KLBB; being less cyclic) than with the other cases. This may be because the storm was interacting with a boundary.

Conclusions and Future Work

Conclusions

- Areal extent of both hailfall and small drop distributions was cyclic throughout the lifetime of the storm at the lowest elevation angle, with the period of hailfall cyclicity generally remaining consistent throughout the time series (showing bursts of hailfall) and the period of small drop cyclicality increasing throughout the time series similar to results in Van Den Broeke et al. 2008.
- KDYX had a higher average areal extent for both hail and small drops. This case had a higher LCL height as well as the least difference between the LCL height and the 0°C level.
- There was greater average areal extent (in both hailfall and small drops) when the hodograph was less curved similar to findings in Van Den Broeke et al. 2010.
- Higher shear values, at all three levels, produced lower average areal extent values for both hail and small drops which contrasted with findings in Van Den Broeke et al. 2010 and Gilmore et al. 2004.
- Higher RH values and lower LCL heights did not have higher average areal extents for small drops in this small sample of storms as suggested in French et al. 2015.

Future Work

- Time series comparison of signatures throughout lifetime of storms for a large dataset of storms
- Signature comparison to more environmental variables for a large dataset of storms

Acknowledgements

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