Spatiotemporal Variability of Z_{DR} Column Areal and Altitudinal Extent in Tornadic and Nontornadic Supercells

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Background

- Assessment of microphysical distributions provides insight into processes that govern supercell updrafts
- How distributions vary through space and time is well-researched (e.g., Grant and Van Den Heever 2014; Van Den Broeke 2014), however, full-understanding not yet gained
- Polarimetric radar observations allow for inference of these distributions

Background

Z_{DR} Columns

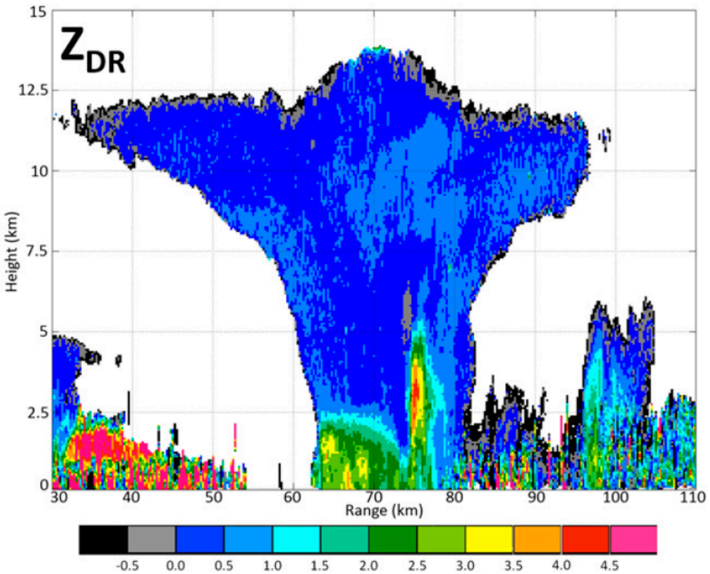
- Hall et al. (1984) first to document narrow region of high Z_{HH} collocated with high Z_{DR} approximately 1.5 km above the environmental 0˚C level

- Regions of enhanced values that extend above the environmental 0˚C level and are co-located with the updraft (Kumjian and Ryzhkov 2008)

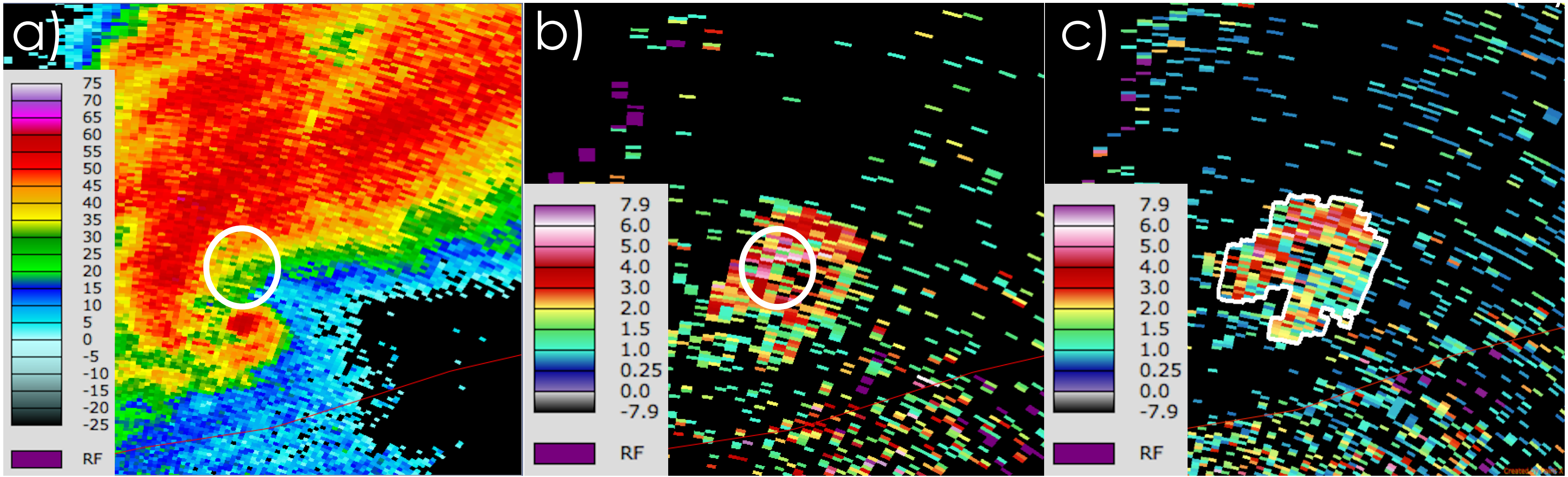
Background

- Results from the lofting of liquid drops above this level via strong vertical motion
- Are associated with strong updrafts (.e.g, Kumjian and Ryzhkov 2010; Johnson et al. 2016)
- Column height and areal extent increase as updraft intensifies (Kumjian et al. 2010; Kumjian 2013)
- Snyder et al. (2015) presented an algorithm to detect Z_{DR} columns

Kumjian et al. 2014



Radar from KTLX (Twin Lakes, Oklahoma) of a supercell at 2153 UTC on 19 May 2013. (a) Reflectivity (dBZ) at base-scan. (b) 1-dB Z_{DR} at 4.03˚. (c) 0.5-dB Z_{DR} at 5.12˚. White circle in (b) denotes a Z_{DR} column with the associated storm-relative location outlined in (a). White annotation in (c) denotes a 0.5-db Z_{DR} column aloft.



Research Question and Objective

- *How do Z_{DR} columns vary as a function of environment and supercell type (tornadic or nontornadic)?*

Objectives:

- Assess the degrees to which Z_{DR} column:
  1. maximum altitudinal extent above the 0˚C level, and
  2. areal extent at approx. 1 km above the 0˚C level

  vary <u>through time in updrafts</u> and <u>across environments</u>

Methodology

- Supercells identified following criteria of Thompson et al. (2003); all cases within 113 km of WSR-88D

- Cyclonic azimuthal shear met the mesocyclone threshold of Stumpf et al. (1998) in the two lowest elevation angles

Methodology

- 1-dB Z_{DR} column maximum altitudinal extent determined for each supercell sample volume associated with analysis times (consistent with Snyder et al. 2015)

- Representative environmental 0˚C level from the nearest RUC/RAP was subtracted from the column extent for each sample volume

- 0.5-dB column areal extent evaluated at elevation angle nearest 1 km above 0˚C level
- Mean column altitudinal and areal extent calculated for cases with ≥ 3 analysis times
- Statistical relationships between mean column altitudinal/areal extent and environmental conditions in each subset were then explored

Cases

Date	Hours (UTC)	Radar	#Alt Extent Vols	#Areal Extent Vols	Type	Tornado?
26 Feb. 2012	0200-0300	KBMX	11	6	tornadic	yes
14 Apr. 2012	1600-1700	KDDC	5	3	tornadic	yes
1 May 2012	0000-0100	KAMA	9	7	tornadic	no
1 June 2012	2300	KAMA	7	6	nontornadic	
24-25 Aug. 2012	2300-0000	KBIS	15	12	nontornadic	
4-5 Sept. 2012	2300-0000	KARX	13	11	tornadic	no
10 Mar. 2013	0200	KEWX	11	7	nontornadic	
18 Mar. 2013	2100-2200	KFFC	17	11	tornadic	yes
17-18 Apr. 2013	2300-0000	KFDR	21	9	tornadic	yes
17-18 May 2013	2300-0000	KDYX	18	12	tornadic	yes
20 May 2013	2100-2200	KEAX	18	7	tornadic	yes
21 May 2013	0100	KDMX	6	5	nontornadic	
30 May 2013	1800-1900	KTLX	10	7	nontornadic	
9-10 July 2013	2300-0000	KABR	15	14	nontornadic	
10 Aug. 2013	1800	KAKQ	7	5	nontornadic	
7 July 2014	0200-0300	KBIS	13	13	nontornadic	
7 July 2014	2000-2100	KBOX	19	11	nontornadic	

Results

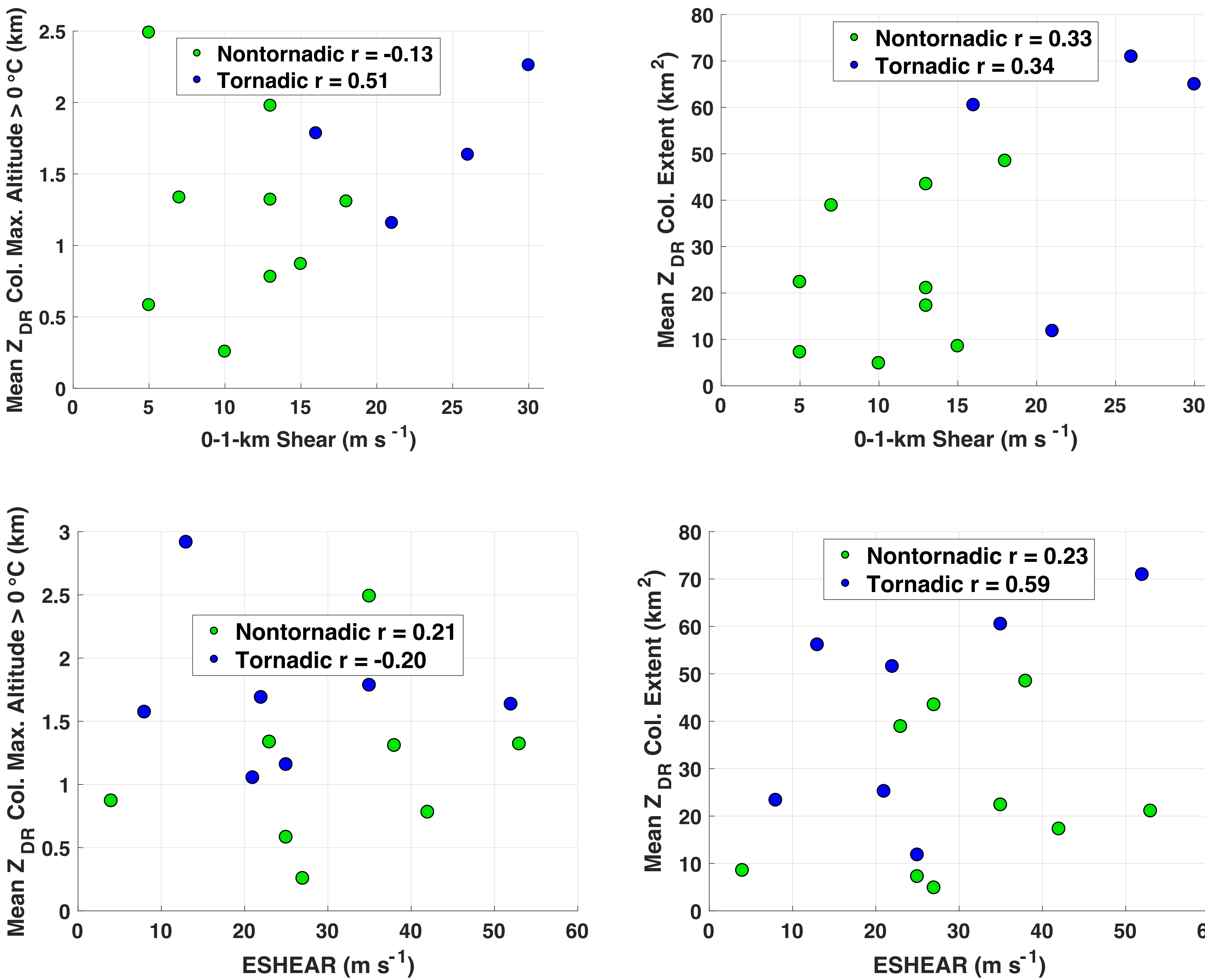
Correlation Coefficient (*r*) for Z_{DR} Mean Altitudinal Extent Above the Environmental 0˚C Level and Environmental Parameters. Bold numbers denote those with *r* ≥ ±0.50.

Environmental Parameter	Nontornadic *r*	Tornadic *r*
LCL Height (m)	-0.04	**0.53**
LCL Temp (˚C)	-0.26	**-0.70**
CCL Temp (˚C)	**0.58**	**-0.63**
CIN (J kg^{-1})	**-0.67**	-0.10
9-km RH (%)	**-0.58**	-0.31
3-6-km RH (%)	-0.41	**0.62**
3-9-km RH (%)	**-0.61**	0.30
6-9-km RH (%)	**-0.61**	0.02
0-1-km Shear (m s^{-1})	-0.13	**0.51**
0-6-km Shear (m s^{-1})	0.27	**0.50**
0-1-km SRH (m^2 s^{-2})	-0.23	**0.91**
0-3-km SRH (m^2 s^{-2})	-0.01	**0.71**
0-3-km VGP	0.23	**-0.51**

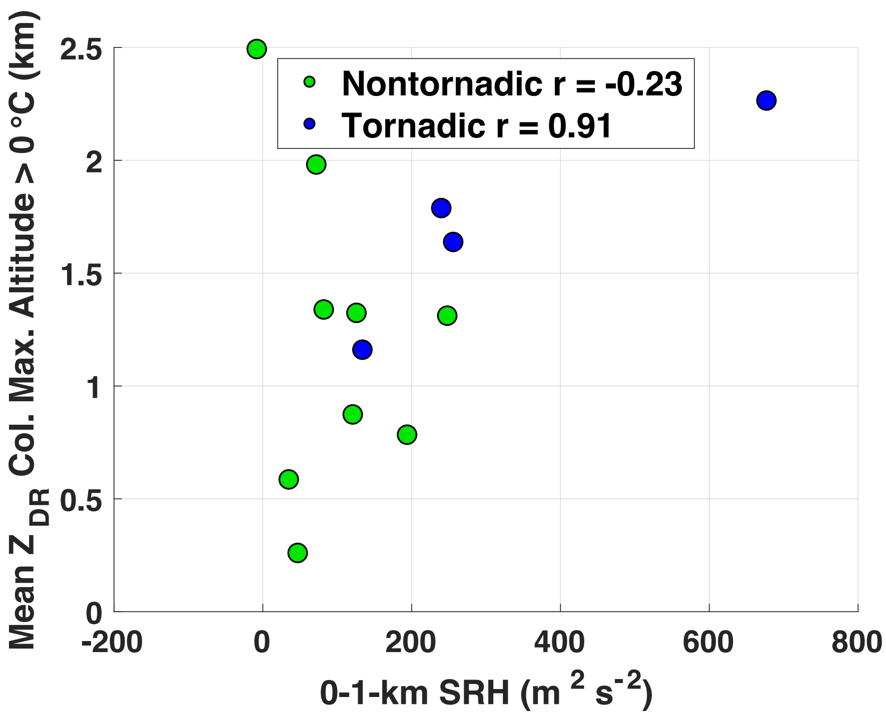
Results

Correlation Coefficient (*r*) for Z_{DR} Mean Areal Extent Above the Environmental 0˚C Level and Environmental Parameters. Bold numbers denote those with *r* ≥ ±0.50.

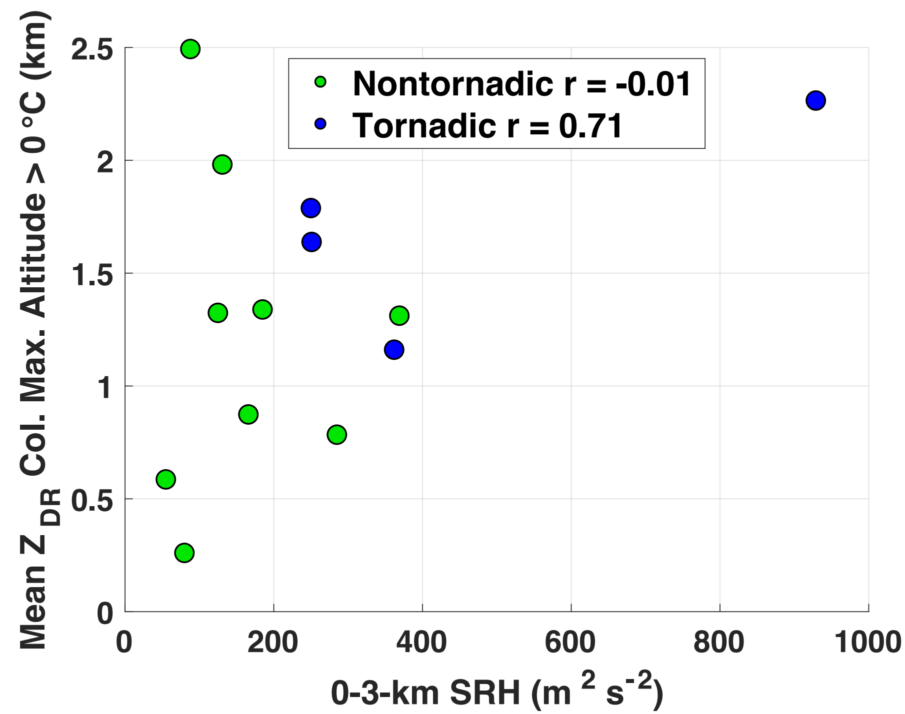
Environmental Parameter	Nontornadic *r*	Tornadic *r*
CCL Temp (˚C)	**0.75**	-0.25
CIN ($J\ kg^{-1}$)	-0.32	**-0.75**
0-3-km Shear ($m\ s^{-1}$)	**0.51**	-0.33
ESHEAR ($m\ s^{-1}$)	0.23	**0.59**
0-1-km SRH ($m^2\ s^{-2}$)	0.39	**0.52**
0-3-km SRH ($m^2\ s^{-2}$)	**0.56**	0.16
SCP	-0.39	**0.55**
STP	-0.06	**0.73**



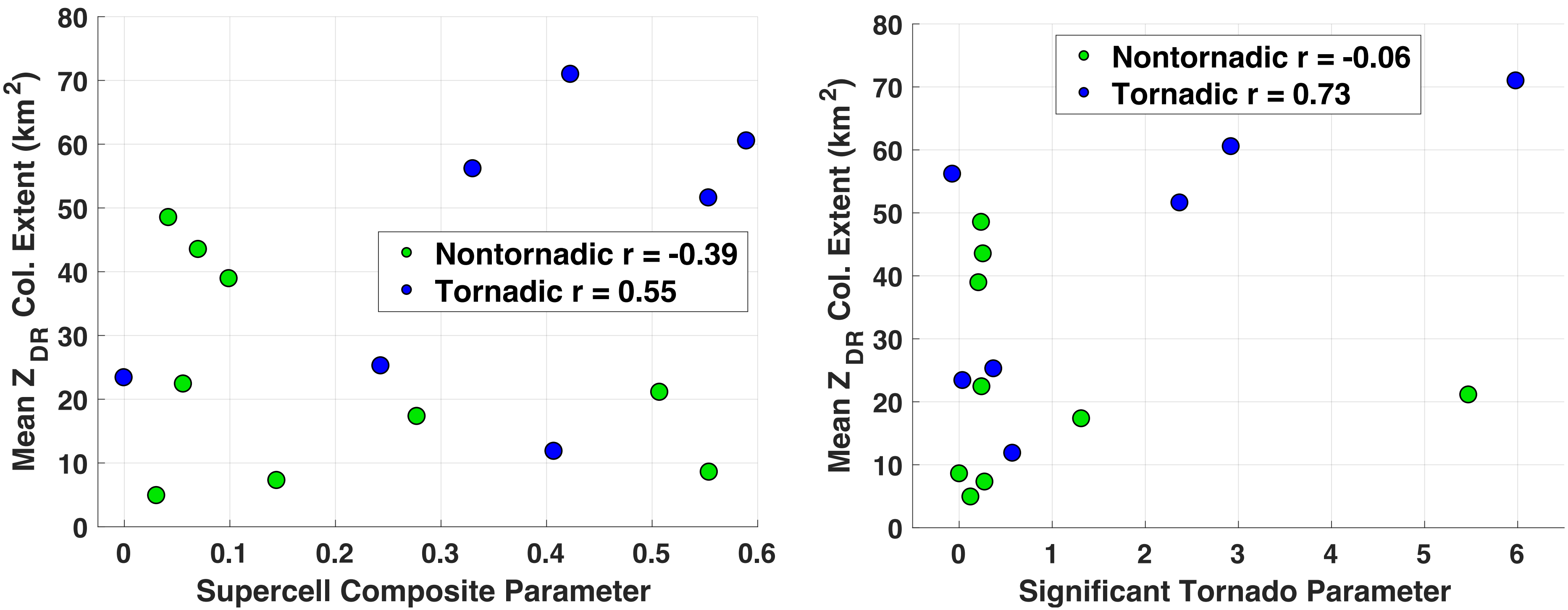
Nontornadic r = -0.13
Tornadic r = 0.51
Mean Z_{DR} Col. Max. Altitude > 0 °C (km)
0-1-km Shear (m s^{-1})
Nontornadic r = 0.33
Tornadic r = 0.34
Mean Z_{DR} Col. Extent (km^2)
0-1-km Shear (m s^{-1})
Nontornadic r = 0.21
Tornadic r = -0.20
Mean Z_{DR} Col. Max. Altitude > 0 °C (km)
ESHEAR (m s^{-1})
Nontornadic r = 0.23
Tornadic r = 0.59
Mean Z_{DR} Col. Extent (km^2)
ESHEAR (m s^{-1})



Mean Z_{DR} Col. Max. Altitude > 0 °C (km)
Nontornadic r = -0.23
Tornadic r = 0.91
0-1-km SRH ($m^2 s^{-2}$)
2.5
2
1.5
1
0.5
0
-200
0
200
400
600
800



Mean Z_{DR} Col. Max. Altitude > 0 °C (km)
Nontornadic r = -0.01
Tornadic r = 0.71
0-3-km SRH ($m^2 s^{-2}$)
2.5
2
1.5
1
0.5
0
0
200
400
600
800
1000


Mean Z_{DR} Col. Extent (km^2)
Supercell Composite Parameter
Nontornadic r = -0.39
Tornadic r = 0.55
Significant Tornado Parameter
Nontornadic r = -0.06
Tornadic r = 0.73

Conclusions

- In general, environmental variables not as strongly predictive of Z_{DR} column areal extent as for altitudinal extent (consistent with Van Den Broeke 2016)
- Increased Z_{DR} column altitudinal and areal extent increase with instability (e.g., Van Den Broeke 2016)
- Areal extent more dependent upon kinematic parameters than thermodynamic parameters? (Gilmore et al. 2004; Van Den Broeke 2016)

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