Differences between Severe and Nonsevere Warm-Season, **Nocturnal Bow Echo Environments**

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OUTLINE

1. Introduction

2. Data & Methodology

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4. Summary & Conclusions



INTRODUCTION **BOW ECHOES & DERECHOS**



- - (Fujita and Wakimoto 1981; Davis et al. 2004; Ashley and Mote 2005; Atkins et al. 2005; Wheatley et al. 2006; Wakimoto et al. 2006)
- - (Johns and Hirt 1987: Przybylinski 1995: Davis et al. 2004: Ashley and Mote 2005)





- (NWS)
- namely, severe, long-lived bow echoes (Corfidi et al. 2016)



high CAPE and strong vertical wind shear over the lowest 5 km above ground level (AGL) (Weisman 1993)

low-level moisture and relatively dry conditions at

midlevels (James et al. 2006; Guastini and Bosart 2016)

a subset of mesoscale convective systems (MCSs), frequently generate damaging straight-line surface winds

the majority of casualties and damage resulting from convective nontornadic winds in the United States

a widespread, long-lived wind storm that is associated with a band of rapidly moving showers or thunderstorms



low instability and weak deep-layer shear (James et al. 2006; Guastini and Bosart 2016)

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INTRODUCTION FORECAST THE DERECHOS

Hard to Forecast Derechos

low-level (0–2.5 km) shear **not** skillful in forecasting long-lived bow echoes. (Coniglio et al. 2004)

high **variation** in the ambient shear and instability, suggesting that they are **not** sufficient to differentiate derecho environments from those associated with nonsevere MCSs. (Evans and Doswell 2001)

Nonsevere MCSs

Severe MCSs

Severe derecho-

producing MCSs

deep layer shear

low- to upper-level wind speeds

median 0–1-km system-relative wind speeds

midlevel environmental lapse rates

vertical difference in θ_e and CAPE

(Cohen et al. 2007)



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INTRODUCTION NOCTURNAL BOW ECHO & OBJECTIVE

Bow echoes and intense derechos often occur at **night**. (Johns and Hirt 1987; Bentley and Mote 1998; Bernardet and Cotton 1998; Davis et al. 2004; Wakimoto et al. 2006; Wheatley et al. 2006; Adams-Selin and Johnson 2010; Coniglio et al. 2012; Adams-Selin and Johnson 2013; Guastini and Bosart 2016)

These nocturnal bow echoes are more **poorly forecast** compared to daytime convective systems. (Davis et al. 2003, Wilson and Roberts 2006; Clark et al. 2007; Weisman et al. 2008; Hitchcock et al. 2019; Weckwerth et al. 2019)

Nocturnal bow echo environments are often characterized by a stable boundary layer (SBL) and a LLJ, which provide an elevated source of moist and unstable air and creates a favorable environment for MCSs. (Corfidi et al. 2008; Schumacher and Johnson 2009; French and Parker 2010; Blake et al. 2017)

Out of 13 MCSs sampled by the Plains Elevated Convection at Night (PECAN), almost every post-convective nocturnal sounding observed a surface cold pool. (Geerts et al. 2017)



examine the differences in near-storm parameters between warm-season, nocturnal bow echoes that produce severe winds and those that do not.



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Criteria for Nocturnal Bow Echoes

A bowing convective line

2 present between 0200 and 1100 UTC

132 warm-season, nocturnal bow echo events occurring during the April–August period each year from 2010 to 2018.



no measured severe winds or wind damage reports for at least six hours before and after the time of maximum bow echo development

Low-intensity Severe cases (LS)

41 all wind reports were in the range of 50–55 knots

High-intensity Severe cases (HS)

47 at least one severe wind report with a magnitude greater than 70 knots occurred



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Criteria for Nocturnal Bow Echoes



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Present between 0200 and 1100 UTC

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132 warm-season, nocturnal bow echo events occurring during the April–August period each year from 2010 to 2018.

NonSevere cases (NS)

no measured severe winds or wind damage reports for at least six hours before and after the time of maximum bow echo development

Low-intensity Severe cases (LS)

41 all wind reports were in the range of 50–55 knots

High-intensity Severe cases (HS)

at least one severe wind report with a magnitude greater than 70 knots occurred





General Meteorology Package (GEMPAK)

to obtain a set of **43** sounding-derived parameters from the 40-km horizontal grid spacing SPC mesoanalysis system

Selected Parameters

vertical wind shear, wind speed, multiple thermodynamic properties and also four composite indices

Name	Description	
	Kinematic parameters	
S1MG (kt)	0–1-km shear magnitude	
SRH1 $(m^2 s^{-2})$	0–1-km storm relative helicity	
SRH3 $(m^2 s^{-2})$	0–3-km storm relative helicity	
U3SV (kt)	0–3-km U shear component	
V3SV (kt)	0–3-km V shear component	
UPMW (kt)	0-6-km pressure-weighted U component	
VPMW (kt)	0-6-km pressure-weighted V component	
S6MG (kt)	0–6-km shear magnitude	
U6SV (kt)	0-6-km U shear component	
V6SV (kt)	0–6-km V shear component	
U8SV (kt)	0-8-km pressure-weighted U component wind	
V8SV (kt)	0-8-km pressure-weighted V component wind	
VKLC $(\mu b s^{-1})$	Average kinematic vertical velocity (MUPL-LCL)	
UWND (kt)	Surface U wind component	
VWND (kt)	Surface V wind component	
UEIL (kt)	U component top of effective inflow laver	
UMXP (kt)	U wind component at best CAPE level	
VEIL (kt)	V component top of effective inflow laver	
VMXP (kt)	V wind component at best CAPE level	
, mili (m)	Thermodynamic parameters	
$M1CP(Ik\sigma^{-1})$	100-hPa mean mixed CAPE	
$M1CN(Jkg^{-1})$	100-hPa mean mixed CIN	
3KRH (%)	3-km average relative humidity	
BHC5 (%)	Average relative humidity from LCL to 500 hPa	
BHIC(%)	Average relative humidity from LCL to LEC	
ASRH (%)	Average subcloud humidity	
$DNCP(Ikg^{-1})$	Downdraft CAPE	
$LR75 (°C km^{-1})$	Lapse rate from 700 to 500 hPa	
LR85 (°C km ⁻¹)	Lapse rate from 850 to 500 hPa	
$LLLR (°C km^{-1})$	Lower-level lapse rate from surface to 3 km AGL	
TE3K (K)	Max theta-e difference in lowest 3 km	
$MXMX (\sigma k \sigma^{-1})$	Maximum mixing ratio	The proven
$MUCP(Ikg^{-1})$	Most unstable CAPE	
$\frac{MUCN}{(Ikg^{-1})}$	Most unstable CIN	
BH70 (%)	Relative humidity 700 hPa	
RH80 (%)	Relative humidity 800 hPa	6.0
SI CH (m)	Surface-based I CL beight	
STHE (°C)	Surface equivalent potential temperature	
$SBCP(Ikg^{-1})$	Surface-based CAPE	
$SBCN(1kg^{-1})$	Surface-based CIN	
SDOR (JAg)	Composite parameters	
XTRN $(\alpha kt k \alpha^{-1})$	MXMX × (wind speed at MIIPI)	
DCP (numeric)	Derecho composite parameter	
STP (numeric)	Significant tornado parameter_fixed laver	
SCP (numeric)	Supercell composite parameter_effective laver	
Ser (numeric)	Supercent composite parameter—effective layer	



DATA & METHODS

STATISTICAL METHODS



$$PC = \frac{a+d}{a+b+c+d} = \frac{a+d}{n}.$$
 (2)

The perfect value for PC is the unity and the reference value is the chance agreement:

$$E = p\{(x = 1 \text{ and } \hat{x} = 1) \text{ or } (x = 0 \text{ and } \hat{x} = 0)\}$$

$$= p(x=1)p(\hat{x}=1) + p(x=0) p(\hat{x}=0), \qquad (4)$$

where x is the observation and \hat{x} is the forecast. Its maximum-likelihood estimate is

$$E = \left(\frac{a+c}{n}\right) \left(\frac{a+b}{n}\right) + \left(\frac{b+d}{n}\right) \left(\frac{c+d}{n}\right).$$
(5)

Then, HSS is

$$HSS = \frac{PC - E}{1 - E} = \frac{2(ad - bc)}{(a + b)(b + d) + (a + c)(c + d)}.$$
 (6)



(3)



Shear discriminates well between NS and severe ev

ni:	Name	Description	NS	LS
60.5		Kinematic parameters		
	S1MG (kt)	0–1-km shear magnitude	16.0	25.4
	SRH1 $(m^2 s^{-2})$	0–1-km storm relative helicity	102	215
	SRH3 $(m^2 s^{-2})$	0–3-km storm relative helicity	163	307
	U3SV (kt)	0–3-km U shear component	15.19	23.71
	V3SV (kt)	0–3-km V shear component	3.08	7.70
50.0	UPMW (kt)	0-6-km pressure-weighted U component	8.73	14.2
and the second second	VPMW (kt)	0-6-km pressure-weighted V component	5.90	13.6
	S6MG (kt)	0-6-km shear magnitude	27.4	36.9
	U6SV (kt)	0-6-km U shear component	22.4	31.6
	V6SV (kt)	0-6-km V shear component	2.90	5.99
	U8SV (kt)	0-8-km pressure-weighted U component wind	26.4	35.0
	V8SV (kt)	0-8-km pressure-weighted V component wind	4.94	5.32
	VKLC ($\mu b s^{-1}$)	Average kinematic vertical velocity (MUPL-LCL)	-0.00253	-0.00490
	UWND (kt)	Surface U wind component	-0.933	-1.42
	VWND (kt)	Surface V wind component	0.139	1.38
- 25.0 9	UEIL (kt)	U component top of effective inflow laver	8.04	15.1
	UMXP (kt)	U wind component at best CAPE level	5.77	8.07
Oberti.	VEIL (kt)	V component top of effective inflow laver	5.76	13.6
	VMXP (kt)	V wind component at best CAPE level	9.74	20.4
	vinitia (kt)	Thermodynamic parameters	2.14	20.4
12.5	$M1CP(Ika^{-1})$	100-bPa mean mixed CAPE	712	040
	$M1CN (Ika^{-1})$	100-hPa mean mixed CIN	-150	-140
	avpu (%)	2 km avaraga relativa humiditu	-150	71.1
	SKKH (70) BHC5 (%)	Average relative humidity from LCL to 500 hBs	74.0	(1.1
and here as a dise	RHCS(%)	Average relative humidity from LCL to 500 hPa	07.0	00.2
- 0.0	KHLC (%)	Average relative number of the LCL to LFC	77.4	73.4
	ASKH(%)	Average subcioud numidity	75.0	/4.9
	$DNCP(J kg^{-1})$	Downdraft CAPE	/46	8/8
	LR/5 (°C km ⁻¹)	Lapse rate from 700 to 500 hPa	6.57	6.89
	LR85 (*Ckm ⁻¹)	Lapse rate from 850 to 500 hPa	6.21	6.47
-12.5	LLLR (°C km ⁻¹)	Lower-level lapse rate from surface to 3 km AGL	5.06	5.29
Î.	TE3K (K)	Max theta-e difference in lowest 3 km	11.7	14,4
20 0	MXMX (gkg^{-1})	Maximum mixing ratio	12.1	12.7
	$MUCP (J kg^{-1})$	Most unstable CAPE	1261	1564
	$MUCN (J kg^{-1})$	Most unstable CIN	-68.1	-71.4
	RH70 (%)	Relative humidity 700 hPa	71.7	68.0
	RH80 (%)	Relative humidity 800 hPa	75.9	76.6
vents.	SLCH (m)	Surface-based LCL height	488	532
	STHE (°C)	Surface equivalent potential temperature	338	340
	SBCP $(J kg^{-1})$	Surface-based CAPE	652	872
	SBCN $(J kg^{-1})$	Surface-based CIN	-235	-244
		Composite parameters		
	XTRN (g kt kg $^{-1}$)	$MXMX \times (wind speed at MUPL)$	196	330
	DCP (numeric)	Derecho composite parameter	0.676	1.57
	STP (numeric)	Significant tornado parameter—fixed laver	0.159	0.467





CAPE is not a good discriminator between NS and LS envir Increased values of CAPE and DNCP are found to be a d trait of HS bow echoes.

CIN is among the worst discriminators overall.

wirest 1	Name	Description	NS	LS
NS		Kinematic parameters		
LS	S1MG (kt)	0–1-km shear magnitude	16.0	25.4
HS	SRH1 $(m^2 s^{-2})$	0–1-km storm relative helicity	102	215
vě z	SRH3 $(m^2 s^{-2})$	0–3-km storm relative helicity	163	307
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5	VWND (kt)	Surface V wind component	0.139	1.38
2	UEIL (kt)	U component top of effective inflow laver	8.04	15.1
-250.0	UMXP (kt)	U wind component at best CAPE level	5.77	8.07
	VEIL (kt)	V component top of effective inflow laver	5.76	13.6
	VMXP (kt)	V wind component at best CAPE level	9.74	20.4
	, min (m)	Thermodynamic parameters	211.1	
	M1CP $(I k \sigma^{-1})$	100-hPa mean mixed CAPE	712	949
	$M1CN(Ikg^{-1})$	100-hPa mean mixed CIN	-150	-140
	3KRH (%)	3-km average relative humidity	74.0	71.1
	BHC5 (%)	Average relative humidity from LCL to 500 hPa	67.0	65.2
	RHIC(%)	Average relative humidity from LCL to LEC	77.4	75.4
2	ASRH (%)	Average subcloud humidity	75.6	74.9
	$DNCP(Ikg^{-1})$	Downdraft CAPE	746	878
	$LR75 (°C km^{-1})$	Lapse rate from 700 to 500 hPa	6 57	6.89
2 * 5 · · · · · · · · · · · · · · · · · ·	$I R85 (°C km^{-1})$	Lapse rate from 850 to 500 hPa	6.21	6.47
0.0	$LLR(^{\circ}Ckm^{-1})$	Lapse rate from surface to 3 km AGI	5.06	5 20
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ronments	PH70 (%)	Polativo humidity 700 hPo	71 7	68.0
	R11/0 (%)	Relative humidity 800 hPa	75.0	76.6
	SI CH (m)	Surface based I CL beight	13.9	520
dictinctivo	SLCH (III)	Surface-based LCL height	400	352
uistilictive	SIRE(C)	Surface based CAPE	220 452	540 970
	SBCP(J kg)	Surface-based CAPE	052	012
	SBCN (J Kg -)	Surface-based CIN	-255	-244
	VTDN (a beha-l)	MYMY × (wind aread at MUDL)	104	220
	DCD (mm sic)	Dereche composite recomposite	190	220
	STD (numeric)	Significant tornada parameter	0.070	1.57
	STP (numeric)	Significant tornado parameter—fixed layer	0.159	0.407
	SCP (numeric)	supercen composite parameter—effective layer	1.37	3.32





RH70 discriminates only between HS and LS/NS RH80 discriminates between HS and LS. RHC5 discriminates between HS and NS.

LR75 performs well when comparing HS and LS.

verity NS		Name	Description	NS	LS					
	A		Kinematic parameters							
в нз 🕂 9	9.0	S1MG (kt)	0–1-km shear magnitude	16.0	25.4					
		SRH1 $(m^2 s^{-2})$	0–1-km storm relative helicity	102	215					
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1000	<u>e</u>	UWND (kt)	Surface U wind component	-0.933	-1.42					
	Ō	VWND (kt)	Surface V wind component	0.139	1.38					
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	ê	UMXP (kt)	U wind component at best CAPE level	5.77	8.07					
	ě	VEIL (kt)	V component top of effective inflow laver	5.76	13.6					
Sec. 1	<u>e</u>	VMXP (kt)	V wind component at best CAPE level	9.74	20.4					
		Thermodynamic parameters								
- 5	5.0	M1CP $(I k \sigma^{-1})$	100-hPa mean mixed CAPE	712	949					
1911 1912		$M1CN(Jkg^{-1})$	100-hPa mean mixed CIN	-150	-140					
		3KRH (%)	3-km average relative humidity	74.0	71.1					
		BHC5 (%)	Average relative humidity from LCL to 500 hPa	67.0	65.2					
		RHLC(%)	Average relative humidity from LCL to LEC	77.4	75.4					
- 4	4.0	ASRH (%)	Average subcloud humidity	75.6	74.9					
	2010 - 10 - 10 - 10 - 10 - 10 - 10 - 10	DNCP $(I k \sigma^{-1})$	Downdraft CAPE	746	878					
		LR75 (°C km ⁻¹)	Lapse rate from 700 to 500 hPa	6.57	6.89					
		$LR85 (°C km^{-1})$	Lapse rate from 850 to 500 hPa	6.21	6.47					
		$\mathbf{LILR} (^{\circ}\mathbf{C} \mathbf{km}^{-1})$	Lower-level lapse rate from surface to 3 km AGL	5.06	5.29					
		TE3K (K)	Max theta-e difference in lowest 3 km	11.7	14.4					
		$MXMX (\sigma k \sigma^{-1})$	Maximum mixing ratio	12.1	12.7					
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tvpe	es.	RH70 (%)	Relative humidity 700 hPa	71.7	68.0					
-)		RH80 (%)	Relative humidity 800 hPa	75.9	76.6					
		SI CH (m)	Surface-based I CL beight	488	532					
		STHE (°C)	Surface equivalent potential temperature	338	340					
		SBCP (Ikg^{-1})	Surface-based CAPE	652	872					
		SBCI $(J kg^{-1})$	Surface based CIN	_235	-244					
		SDCN (JKg)	Composite parameters	-235	-244					
		YTPN (aktha-1)	MYMY × (wind speed at MUDL)	106	220					
		DCP (numeric)	Derecho composite parameter	0.676	1 57					
		STP (numeric)	Significant tornado parameter fixed lavor	0.070	0.467					
		SCP (numeric)	Supercell composite parameter affactive layer	1 27	5 22					
		SCF (numeric)	supercen composite parameter—enective rayer	1.37	3.32					





All parameters differentiate significantly among all severity types.

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	Name	Description	NS	LS				
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-38.0	UWND (kt)	Surface U wind component	-0.933	-1.42				
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	UEIL (kt)	U component top of effective inflow layer	8.04	15.1				
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2.3	Thermodynamic parameters							
C. C. Starter	M1CP $(J kg^{-1})$	100-hPa mean mixed CAPE	712	949				
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	3KRH (%)	3-km average relative humidity	74.0	71.1				
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	SCP (numeric)	Supercell composite parameter_effective laver	1 37	5 32				
	oer (numerie)	Supercent composite parameter effective layer	4.01	2.24				



RESULTS SHORT SUMMARY 1



DNCP, LR75, SCP, STP, and DCP are the parameters among the 43 examined that discriminate significantly among all three severity types.

Only severe composite indices and some thermodynamic variables can help differentiate environments likely to produce bow echoes with high intensity severe wind from ones that will only produce marginally severe wind.



To ensure that typical nocturnal trends in parameters are not the primary cause of differences between the severity levels, the sample was divided into two groups of similar size:

- before 0500 UTC (late evening): 65 cases
- after 0500 UTC (early morning): 67 cases •



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$M1CP (J kg^{-1})$
M1CN $(J kg^{-1})$
3KRH (%)
RHC5 (%)
RHLC (%)
ASRH (%)
DNCP $(J kg^{-1})$
LR75 ($^{\circ}C \text{ km}^{-1}$)
LR85 ($^{\circ}C \text{ km}^{-1}$)
LLLR ($^{\circ}C \text{ km}^{-1}$)
TE3K (K)
MXMX $(g kg^{-1})$
MUCP $(J kg^{-1})$
MUCN (J kg ⁻¹)
RH70(%)
RH80(%)
SLCH (m)
STHE (°C)
SBCP $(J kg^{-1})$
SBCN $(J kg^{-1})$

100-hPa mean mixed CAPE 100-hPa mean mixed CIN 3-km average relative humidity Average relative humidity from LCL to 500 hPa Average relative humidity from LCL to LFC Average subcloud humidity Downdraft CAPE Lapse rate from 700 to 500 hPa Lapse rate from 850 to 500 hPa Lower-level lapse rate from surface to 3 km AGL Max theta-e difference in lowest 3 km Maximum mixing ratio Most unstable CAPE Most unstable CIN Relative humidity 700 hPa Relative humidity 800 hPa Surface-based LCL height Surface equivalent potential temperature Surface-based CAPE Surface-based CIN

DNCP can discriminate between all types before 0500 UTC, and only between HS and NS after 0500 UTC.

Relatively good separation between HS and the other two types can be seen.







RESULTS

NOCTURNAL DISTRIBUTION ANALYSIS





RESULTS

SINGLE-PARAMETER FORECAST SKILL

Name	Description	Severity	Parameter	Threshold range	HSS	
6114(0, (1, 4)	Kinematic parameters					
SIMG (kt) SRH1 ($m^2 s^{-2}$)	0-1-km shear magnitude	NS	STP (numeric)	< 0.039	0.6	
SRH3 $(m^2 s^{-2})$	0–3-km storm relative helicity		SCP (numeric)	<1.77	0.59	
U3SV (kt)	0-3-km U shear component		DCP (numeric)	< 0.64	0.59	
V3SV (kt)	0–3-km V shear component		XTRN (σ kt k σ^{-1})	<260.18	0.51	
UPMW (kt)	0-6-km pressure-weighted U component		SDU2 $(m^2 c^{-2})$	<167.00	0.01	
S6MG (kt)	0-6-km shear magnitude		SRH3 (III S)	<107.09	0.46	
U6SV (kt)	0–6-km U shear component		S6MG (kt)	<33.21	0.44	
V6SV (kt)	0-6-km V shear component		S1MG (kt)	<14.77	0.43	
U8SV (kt)	0-8-km pressure-weighted U component wind		SRH1 $(m^2 s^{-2})$	<148.75	0.42	
V8SV (kt) VKLC (ubs^{-1})	0-8-km pressure-weighted V component wind		LIGSV (kt)	<24.36	0.42	
UWND (kt)	Surface U wind component		VMVD(1+)	<12.90	0.12	
VWND (kt)	Surface V wind component		VMAP (KL)	<12.82	0.39	
UEIL (kt)	U component top of effective inflow layer	LS	VMXP (kt)	12.82-27.39	0.38	
UMXP (kt)	U wind component at best CAPE level	Lb	STD (numoria)	0.157 0.005	0.35	
VEIL (kt) VMXP (kt)	V component top of effective inflow layer		STP (numeric)	0.137-0.903	0.35	τι c ·
VMAR (Kt)	Thermodynamic parameters		SCP (numeric)	1.77-8.0	0.35	The four composite parameters
M1CP $(J kg^{-1})$	100-hPa mean mixed CAPE		XTRN (g kt kg ^{-1})	242.67-382.77	0.33	
M1CN $(J kg^{-1})$	100-hPa mean mixed CIN		U3SV (kt)	22.50-35.33	0.32	SCP, STP, and DCP, are among t
3KRH (%)	3-km average relative humidity		DCP (numeric)	0.64-3.18	0.31	
RHUC(%)	Average relative humidity from LCL to LEC		VPMW (kt)	0 30 25 30	0.3	highly skilled for all severity types.
ASRH (%)	Average subcloud humidity		$\sqrt{1}$	9.59-25.50	0.3	
DNCP $(J kg^{-1})$	Downdraft CAPE		SRH1 $(m^2 s^2)$	148.75-495.23	0.29	
LR75 (°C km ^{-1})	Lapse rate from 700 to 500 hPa		STHE (°C)	324.43-335.79	0.28	
LR85 ($^{\circ}Ckm^{-1}$)	Lapse rate from 850 to 500 hPa		M1CP $(J kg^{-1})$	122.98-614.88	0.27	
$\frac{LLLR(CKm^{-1})}{TE3K(K)}$	Max theta-e difference in lowest 3 km					
$MXMX (g kg^{-1})$	Maximum mixing ratio	HS	STP (numeric)	>0.59	0.45	
MUCP (J kg ⁻¹)	Most unstable CAPE		MUCP $(J kg^{-1})$	>1949.4	0.44	
MUCN $(J kg^{-1})$	Most unstable CIN		DCP (numeric)	>1.78	0.42	
RH70 (%)	Relative humidity 700 hPa		SCP (numeric)	>2.64	0.12	
KH80 (%) SI CH (m)	Surface-based I CL beight		SCF (numeric)	-3.04	0.42	
STHE (°C)	Surface equivalent potential temperature		$M1CP (J kg^{-1})$	>1147.8	0.42	
SBCP $(J kg^{-1})$	Surface-based CAPE		SBCP $(J kg^{-1})$	>657.35	0.39	
SBCN $(J kg^{-1})$	Surface-based CIN		TE3K (K)	>22.85	0.37	
VTDN (a ktha-1)	Composite parameters		XTRN (σ kt k σ^{-1})	>289 37	0.36	
DCP (numeric)	Derecho composite parameter		LIGN (1+)	>25.14	0.25	
STP (numeric)	Significant tornado parameter—fixed layer		OOSV(KI)	>55.14	0.55	
SCP (numeric)	Supercell composite parameter—effective layer		DNCP $(J kg^{-1})$	>1162.6	0.33	

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RESULTS TWO-PARAMETER FORECAST SKILL

Name	Description	- Severity	Combination	x _{opt 1} range	x _{opt 2} range	F
	Kinematic parameters		Comoniumon	Nopt,1 Tunge	Wopt,2 runge	
SIMG (kt) SPL1 $(m^2 e^{-2})$	0-1 km sterm relative belieity	NS	DCP + SRH3	<1.27	$<244 (m^2 s^{-2})$	0
SRH1 (m s) SRH3 ($m^2 s^{-2}$)	0-3-km storm relative helicity		DCP + U3SV	< 0.892	< 21.9 (kt)	0
U3SV (kt)	0-3-km U shear component			<0.852	(21.) (Kt)	0
V3SV (kt)	0-3-km V shear component		SCP + XTRN	<1.//	$< 289 (g \text{ kt kg}^{-1})$	0
UPMW (kt)	0-6-km pressure-weighted U component		DCP + S6MG	< 0.892	<35.7 (kt)	0
VPMW (kt)	0-6-km pressure-weighted V component		STP + SCP	<0.157	<177	0
S6MG (kt)	0–6-km shear magnitude		511 + 501	<0.157	~1.77	0
U6SV (kt)	0–6-km U shear component	15	DCP + VMXP	0.671_3.35	115_{275} (kt)	0
V6SV (kt)	0-6-km V shear component	LS		0.071-5.55	11.5-27.5 (Kt)	0
U8SV (kt)	0-8 km pressure weighted V component wind		SCP + VMXP	1.54–11.4	11.5–27.5 (kt)	0
$VKLC (ubs^{-1})$	Average kinematic vertical velocity (MUPL-I CL)		XTRN + SCP	$252-467 (g kt kg^{-1})$	1.54-8.10	0
UWND (kt)	Surface U wind component		$M1CD \perp VMVD$	216 2273 $(1 k a^{-1})$	11.5.27.5(1+t)	0
VWND (kt)	Surface V wind component			210-2373 (J Kg)	11.3-27.3 (Rt)	0
UEIL (kt)	U component top of effective inflow layer		SCP + DCP	1.54–11.4	0.671–3.35	0
UMXP (kt)	U wind component at best CAPE level					
VEIL (kt)	V component top of effective inflow layer	HS	SBCP + U6SV	$>657 (J kg^{-1})$	>29.8 (kt)	0
VMXP (kt)	V wind component at best CAPE level		SBCP + S6MG	$>657 (J kg^{-1})$	>25.6 (kt)	0
	100 LD Thermodynamic parameters		MICD SCMC	>729 (11 r_{2} ⁻¹)	> 24.4 (1-4)	0
$M1CP (J Kg^{-1})$ $M1CN (J kg^{-1})$	100-hPa mean mixed CAPE		MICP + SOMG	>738 (J Kg)	>24.4 (Kt)	0
3KRH (%)	3-km average relative humidity		MUCP + S6MG	$>1401 (J kg^{-1})$	>24.4 (kt)	0
RHC5 (%)	Average relative humidity from LCL to 500 hPa		STHE + U6SV	>336 (°C)	>29.8 (kt)	0
RHLC (%)	Average relative humidity from LCL to LFC		STILL + COST	- 550 (0)	> 29.0 (Rt)	
ASRH (%)	Average subcloud humidity					
DNCP $(J kg^{-1})$	Downdraft CAPE					
LR75 (°C km ^{-1})	Lapse rate from 700 to 500 hPa					
LR85 ($^{\circ}$ C km ⁻¹)	Lapse rate from 850 to 500 hPa					
LLLR (°C km ⁻¹)	Lower-level lapse rate from surface to 3 km AGL					
TE3K (K)	Max theta-e difference in lowest 3 km					
MICP (Ika^{-1})	Most unstable CAPE					
$\frac{MUCN}{(Jkg^{-1})}$	Most unstable CIN	A multi-n	arameter forecasting	method produced imr	proved forecast skill c	omnar
RH70 (%)	Relative humidity 700 hPa	A mana p	arameter forecasting	method produced mp	noved forecast skill e	ompai
RH80 (%)	Relative humidity 800 hPa	with singl	a parameter chill			
SLCH (m)	Surface-based LCL height	with singi	e-parameter skill.			
STHE (°C)	Surface equivalent potential temperature					
SBCP $(J kg^{-1})$	Surface-based CAPE					
SBCN $(J kg^{-1})$	Surface-based CIN					
VTDN (~1-(11)	Composite parameters					
DCP (numeric)	$MAMA \times (Wind speed at MUPL)$					
STP (numeric)	Significant tornado parameter_fived laver					
SCP (numeric)	Supercell composite parameter—effective laver					



SUMMARY & CONCLUSIONS 1

Parameters able to discriminate between LS and NS events tend to be kinematic based (shear, SRH) and severe composite parameters.

Parameters that differentiate between HS and LS include some that are **thermodynamic** based, mostly CAPE, and severe composite.

DNCP is a good discriminator for all severity types only for **late evening** environments, but it does discriminate between severe and nonsevere in the other time periods.

CIN variables are among the worst discriminators.

When separated into two nocturnal time periods, **midlevel relative humidity** parameters are poor discriminators for both time periods.

Midlevel lapse rates were good discriminators for bow echo severity for the full sample of nocturnal events, but when examining subperiods, they were not good discriminators for the early morning period.

Severe composite parameters, especially DCP and STP, were shown to be among the most skillful discriminators between all severity types.

A multi-parameter forecasting method produced improved forecast skill compared with single-parameter skill.





Thanks for listening!

