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

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Speaker: Jo-Yu Wu

OUTLINE

INTRODUCTION

BOW ECHOES & DERECHOS

Bow echoes

- a subset of mesoscale convective systems (MCSs), frequently generate damaging straight-line surface winds (Fujita and Wakimoto 1981; Davis et al. 2004; Ashley and Mote 2005; Atkins et al. 2005; Wheatley et al. 2006; Wakimoto et al. 2006)
- the majority of casualties and damage resulting from convective nontornadic winds in the United States (Johns and Hirt 1987; Przybylinski 1995; Davis et al. 2004; Ashley and Mote 2005)

Derechos

- a widespread, **long-lived** wind storm that is associated with a band of rapidly moving showers or thunderstorms (NWS)
- namely, severe, long-lived bow echoes (Corfidi et al. 2016)

DOs

- 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)

DON'Ts

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

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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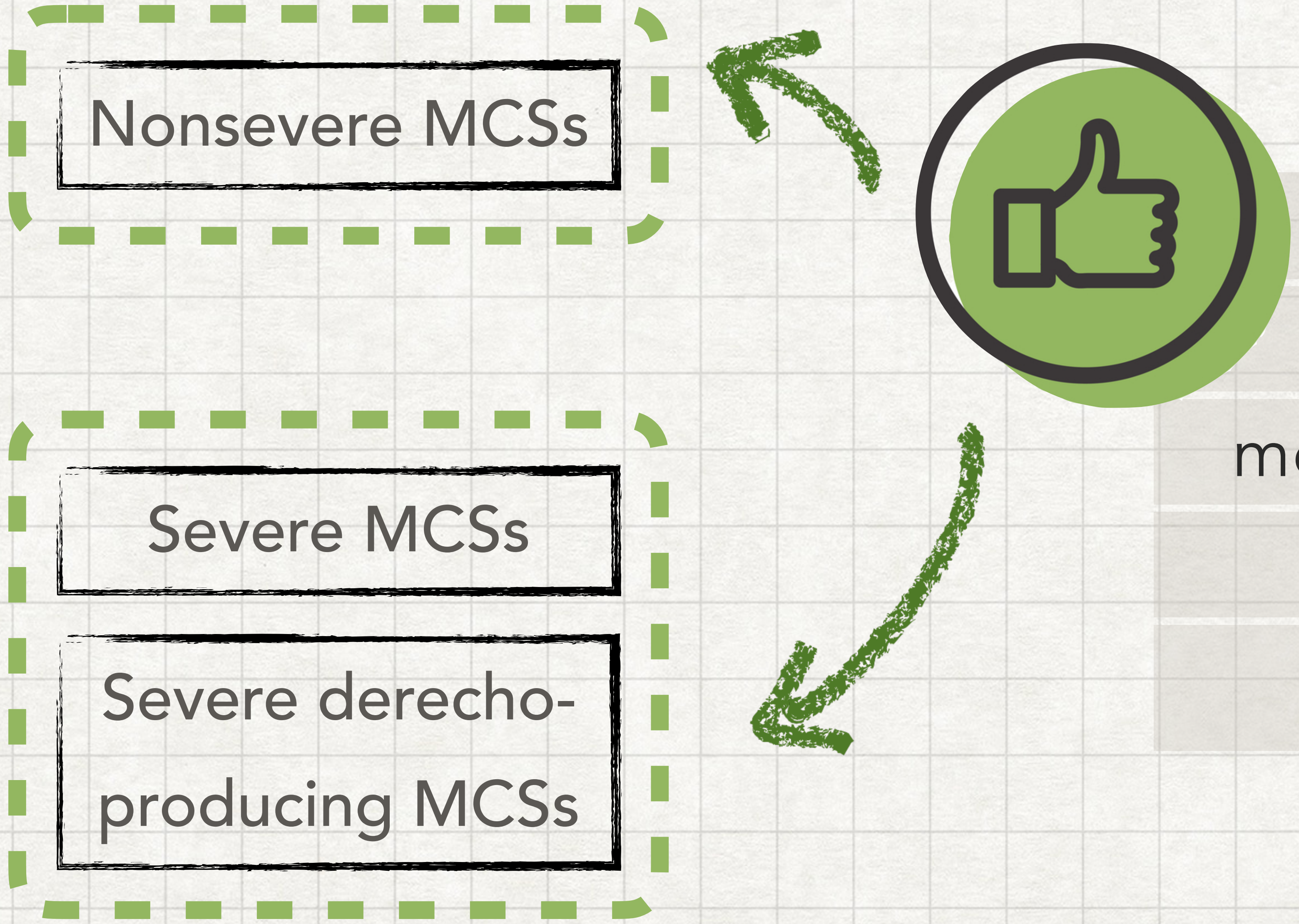

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INTRODUCTION

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)

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

DATA & METHODS

DATA COLLECTION AND CLASSIFICATION

Criteria for Nocturnal Bow Echoes	
1	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.

NonSevere cases (NS)	
44	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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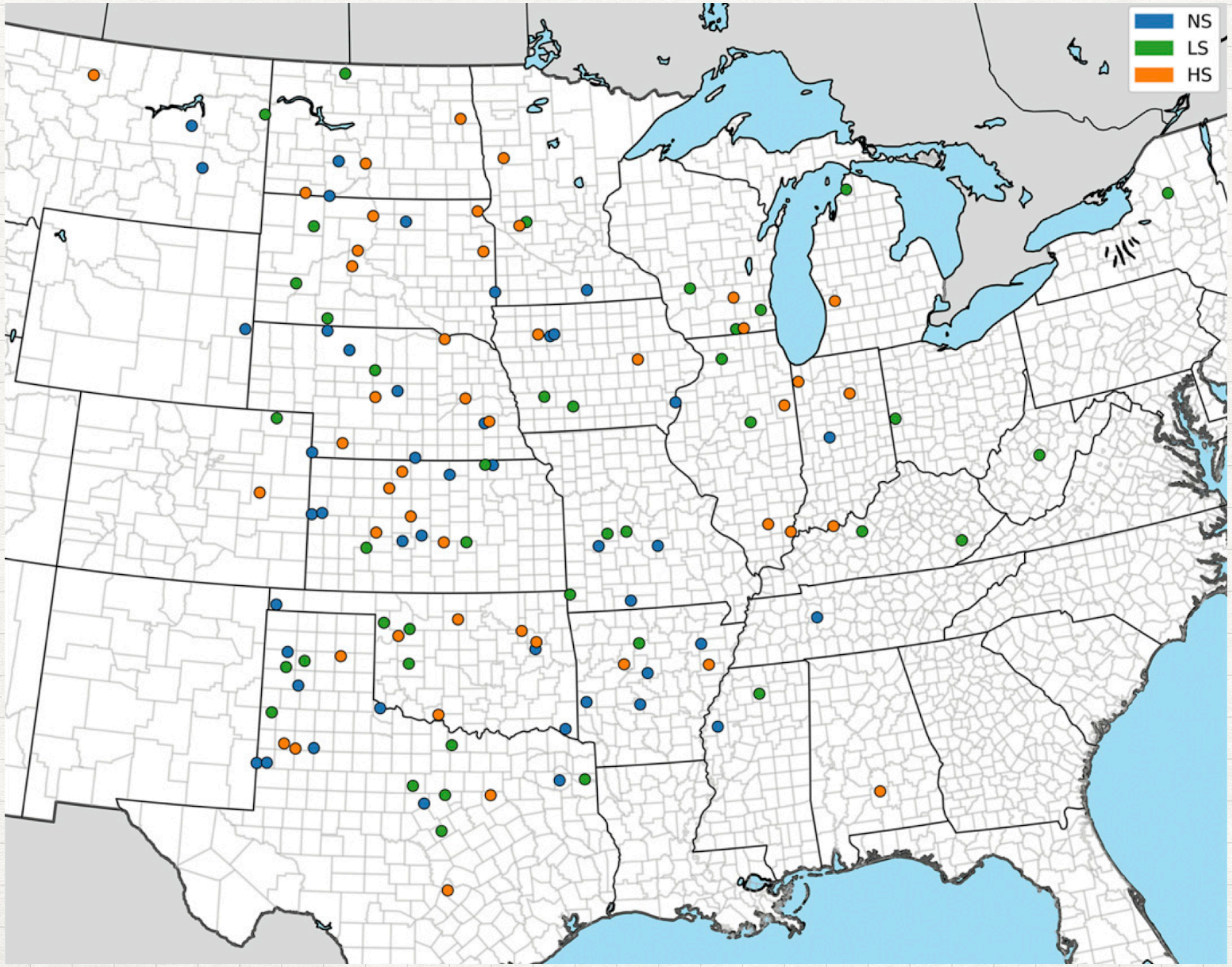

DATA & METHODS

DATA COLLECTION AND CLASSIFICATION

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 layer
UMXP (kt)	*U* wind component at best CAPE level
VEIL (kt)	*V* component top of effective inflow layer
VMXP (kt)	*V* wind component at best CAPE level
	Thermodynamic parameters
M1CP ($J\, kg^{-1}$)	100-hPa mean mixed CAPE
M1CN ($J\, kg^{-1}$)	100-hPa mean mixed CIN
3KRH (%)	3-km average relative humidity
RHC5 (%)	Average relative humidity from LCL to 500 hPa
RHLC (%)	Average relative humidity from LCL to LFC
ASRH (%)	Average subcloud humidity
DNCP ($J\, kg^{-1}$)	Downdraft CAPE
LR75 ($^{\circ}C\, km^{-1}$)	Lapse rate from 700 to 500 hPa
LR85 ($^{\circ}C\, km^{-1}$)	Lapse rate from 850 to 500 hPa
LLLR ($^{\circ}C\, km^{-1}$)	Lower-level lapse rate from surface to 3 km AGL
TE3K (K)	Max theta-e difference in lowest 3 km
MXMX ($g\, kg^{-1}$)	Maximum mixing ratio
MUCP ($J\, kg^{-1}$)	Most unstable CAPE
MUCN ($J\, kg^{-1}$)	Most unstable CIN
RH70 (%)	Relative humidity 700 hPa
RH80 (%)	Relative humidity 800 hPa
SLCH (m)	Surface-based LCL height
STHE (°C)	Surface equivalent potential temperature
SBCP ($J\, kg^{-1}$)	Surface-based CAPE
SBCN ($J\, kg^{-1}$)	Surface-based CIN
	Composite parameters
XTRN ($g\, kt\, kg^{-1}$)	MXMX × (wind speed at MUPL)
DCP (numeric)	Derecho composite parameter
STP (numeric)	Significant tornado parameter—fixed layer
SCP (numeric)	Supercell composite parameter—effective layer

DATA & METHODS

STATISTICAL METHODS

HEIDKE SKILL SCORE (HSS)

(Heidke 1926)

$$HSS = 2\frac{ad - bc}{(a+c)(c+d) + (a+b)(b+d)}$$

Forecast $\hat{x}$	Observation x: 1	Observation x: 0
1	a (hit)	b (false alarm)
0	c (miss)	d (correct rejection)

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

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

$$E = p\{(x=1 \quad \text{and} \quad \hat{x}=1) \quad \text{or} \quad (x=0 \quad \text{and} \quad \hat{x}=0)\} \quad (3)$$

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

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

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

Then, HSS is

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

RESULTS

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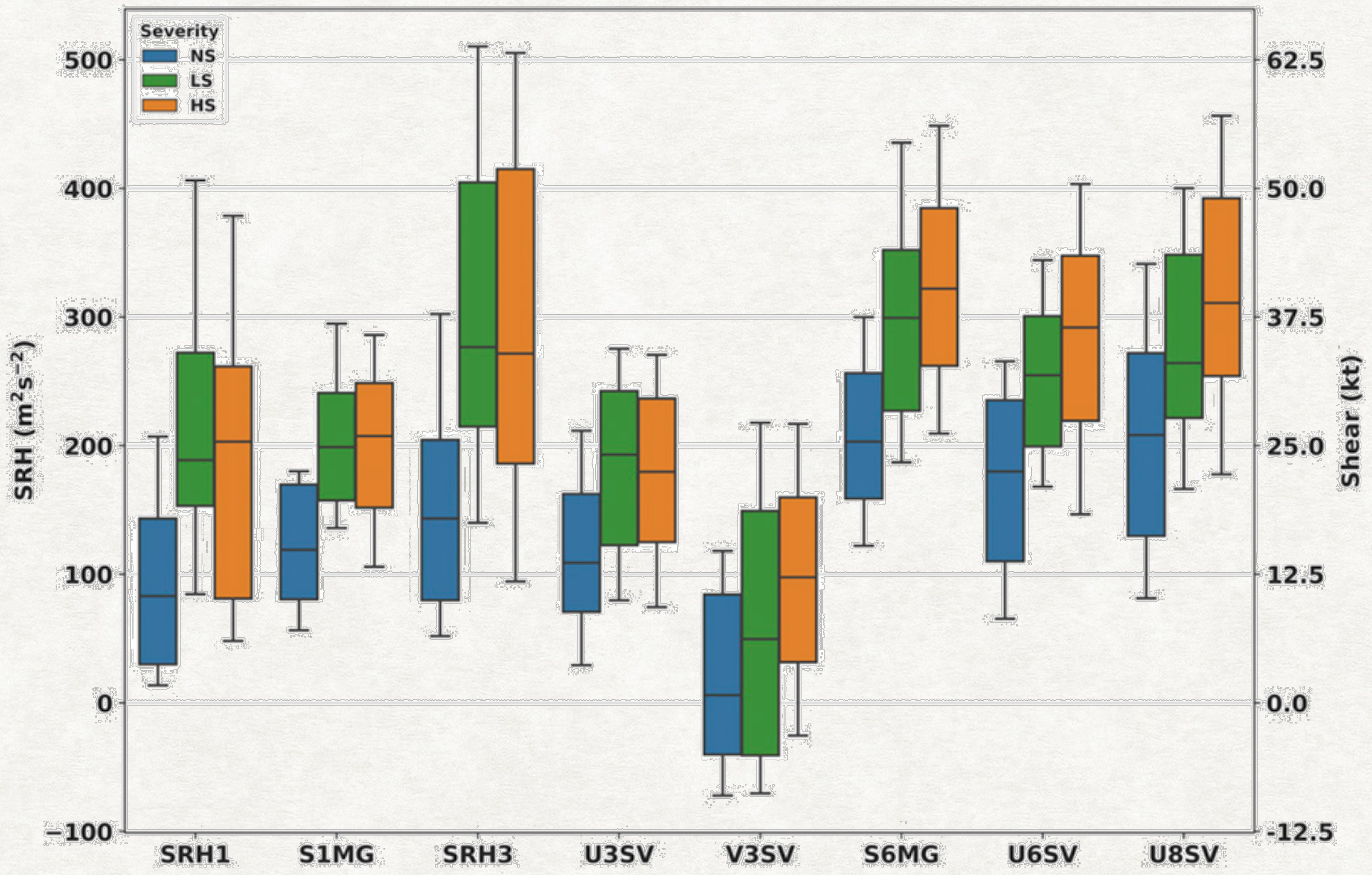

Shear discriminates well between NS and severe events.

Name	Description	NS	LS	HS
	Kinematic parameters			
S1MG (kt)	0–1-km shear magnitude	16.0	**25.4**	25.3
SRH1 ($m^2 s^{-2}$)	0–1-km storm relative helicity	102	**215**	206
SRH3 ($m^2 s^{-2}$)	0–3-km storm relative helicity	163	**307**	295
U3SV (kt)	0–3-km *U* shear component	15.19	**23.71**	21.94
V3SV (kt)	0–3-km *V* shear component	3.08	7.70	**12.6**
UPMW (kt)	0–6-km pressure-weighted *U* component	8.73	**14.2**	12.4
VPMW (kt)	0–6-km pressure-weighted *V* component	5.90	13.6	**14.4**
S6MG (kt)	0–6-km shear magnitude	27.4	36.9	**41.1**
U6SV (kt)	0–6-km *U* shear component	22.4	31.6	**36.2**
V6SV (kt)	0–6-km *V* shear component	2.90	5.99	**8.91**
U8SV (kt)	0–8-km pressure-weighted *U* component wind	26.4	35.0	**39.8**
V8SV (kt)	0–8-km pressure-weighted *V* component wind	4.94	5.32	**5.33**
VKLC ($\mu b\, s^{-1}$)	Average kinematic vertical velocity (MUPL–LCL)	−0.00 253	−0.004 90	**−0.006 74**
UWND (kt)	Surface *U* wind component	−0.933	−1.42	**−1.67**
VWND (kt)	Surface *V* wind component	0.139	**1.38**	0.902
UEIL (kt)	*U* component top of effective inflow layer	8.04	**15.1**	12.5
UMXP (kt)	*U* wind component at best CAPE level	5.77	**8.07**	3.74
VEIL (kt)	*V* component top of effective inflow layer	5.76	13.6	**14.1**
VMXP (kt)	*V* wind component at best CAPE level	9.74	**20.4**	17.6
	Thermodynamic parameters			
M1CP ($J\, kg^{-1}$)	100-hPa mean mixed CAPE	712	949	**1605**
M1CN ($J\, kg^{-1}$)	100-hPa mean mixed CIN	**−150**	−140	−141
3KRH (%)	3-km average relative humidity	**74.0**	71.1	68.7
RHC5 (%)	Average relative humidity from LCL to 500 hPa	**67.0**	65.2	59.5
RHLC (%)	Average relative humidity from LCL to LFC	**77.4**	75.4	73.3
ASRH (%)	Average subcloud humidity	**75.6**	74.9	75.4
DNCP ($J\, kg^{-1}$)	Downdraft CAPE	746	878	**1025**
LR75 ($°C\, km^{-1}$)	Lapse rate from 700 to 500 hPa	6.57	6.89	**7.27**
LR85 ($°C\, km^{-1}$)	Lapse rate from 850 to 500 hPa	6.21	6.47	**6.62**
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RH70 (%)	Relative humidity 700 hPa	**71.7**	68.0	61.1
RH80 (%)	Relative humidity 800 hPa	75.9	**76.6**	72.2
SLCH (m)	Surface-based LCL height	488	532	**608**
STHE (°C)	Surface equivalent potential temperature	338	340	**345**
SBCP ($J\, kg^{-1}$)	Surface-based CAPE	652	872	**1518**
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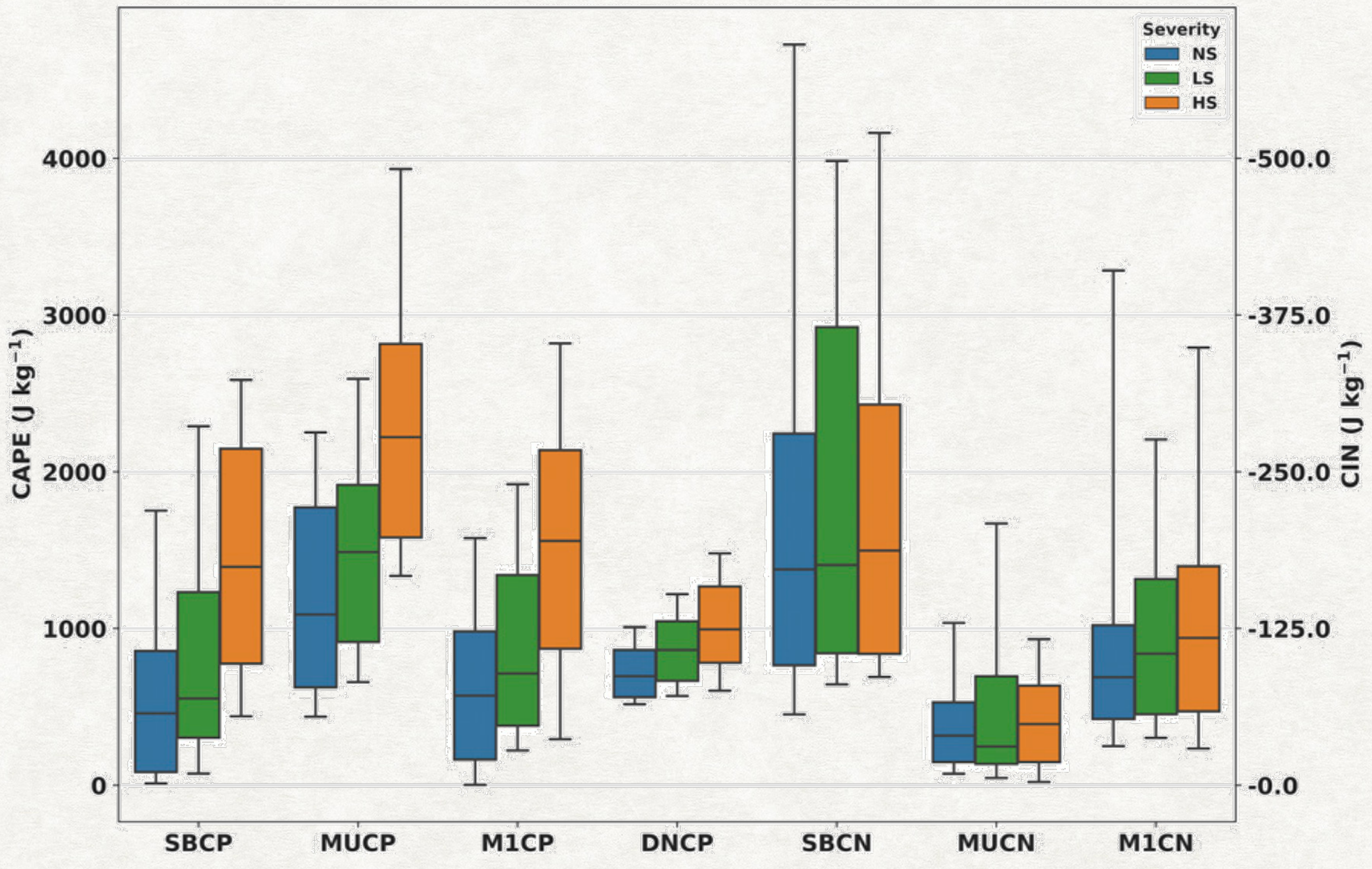

CAPE is not a good discriminator between NS and LS environments.

Increased values of CAPE and DNCP are found to be a distinctive trait of HS bow echoes.

CIN is among the worst discriminators overall.

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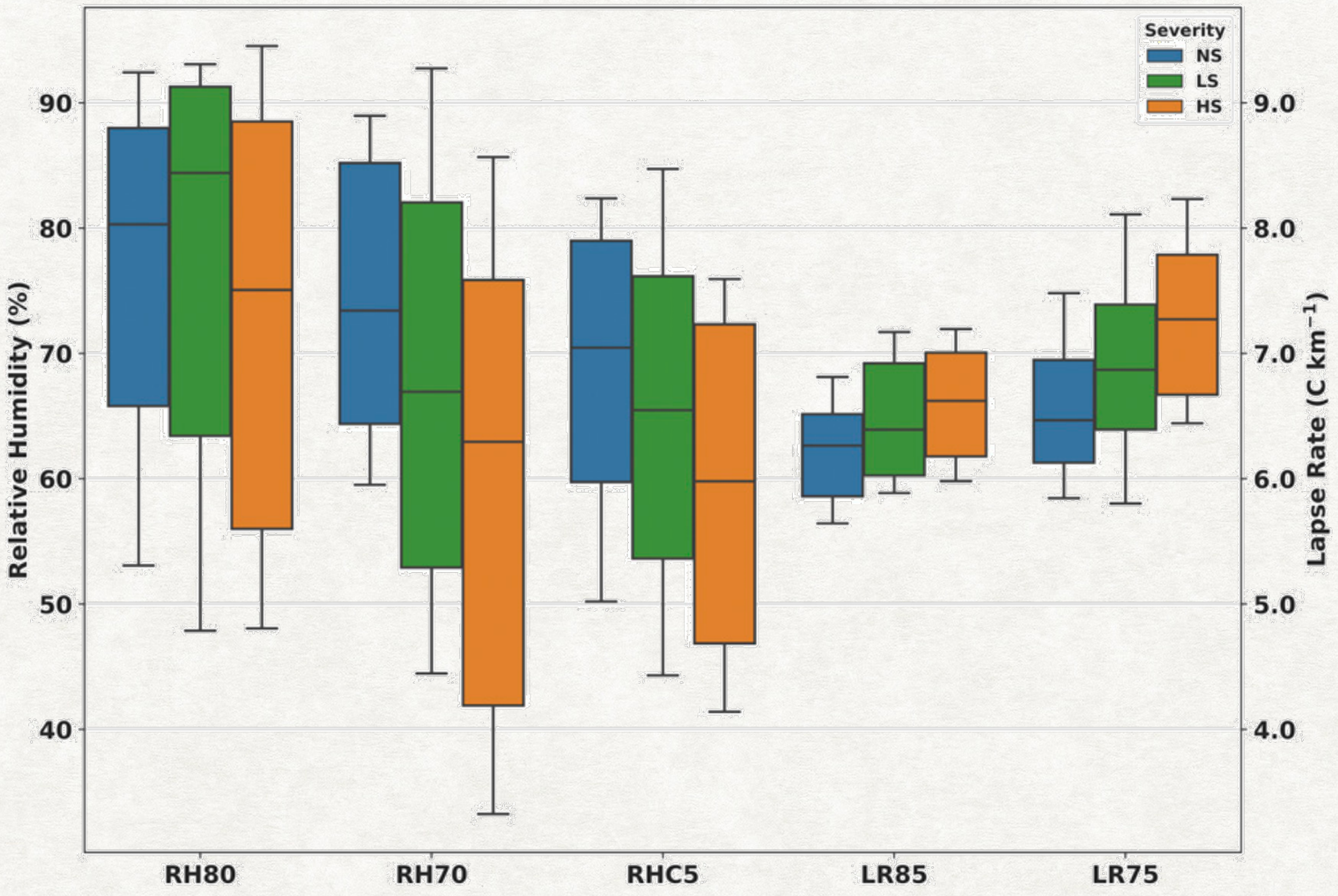

RH70 discriminates only between HS and LS/NS types.
RH80 discriminates between HS and LS.
RHC5 discriminates between HS and NS.

LR75 performs well when comparing HS and LS.

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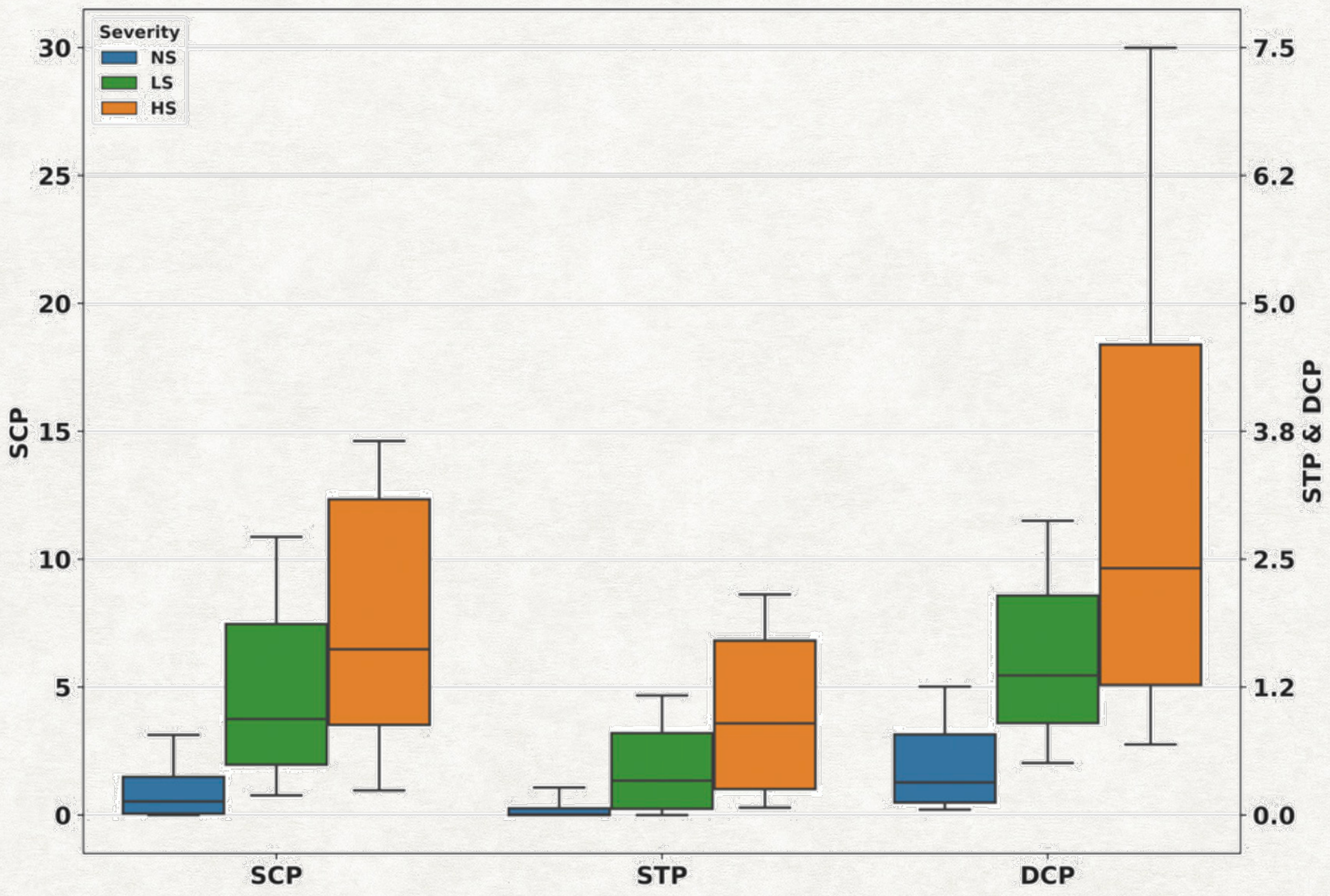

All parameters differentiate significantly among all three severity types.

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VKLC ($\mu b\, s^{-1}$)	Average kinematic vertical velocity (MUPL–LCL)	−0.00 253	−0.004 90	**−0.006 74**
UWND (kt)	Surface *U* wind component	−0.933	−1.42	**−1.67**
VWND (kt)	Surface *V* wind component	0.139	**1.38**	0.902
UEIL (kt)	*U* component top of effective inflow layer	8.04	**15.1**	12.5
UMXP (kt)	*U* wind component at best CAPE level	5.77	**8.07**	3.74
VEIL (kt)	*V* component top of effective inflow layer	5.76	13.6	**14.1**
VMXP (kt)	*V* wind component at best CAPE level	9.74	**20.4**	17.6
	Thermodynamic parameters			
M1CP ($J\, kg^{-1}$)	100-hPa mean mixed CAPE	712	949	**1605**
M1CN ($J\, kg^{-1}$)	100-hPa mean mixed CIN	**−150**	−140	−141
3KRH (%)	3-km average relative humidity	**74.0**	71.1	68.7
RHC5 (%)	Average relative humidity from LCL to 500 hPa	**67.0**	65.2	59.5
RHLC (%)	Average relative humidity from LCL to LFC	**77.4**	75.4	73.3
ASRH (%)	Average subcloud humidity	**75.6**	74.9	75.4
DNCP ($J\, kg^{-1}$)	Downdraft CAPE	746	878	**1025**
LR75 (°C km^{-1})	Lapse rate from 700 to 500 hPa	6.57	6.89	**7.27**
LR85 (°C km^{-1})	Lapse rate from 850 to 500 hPa	6.21	6.47	**6.62**
LLLR (°C km^{-1})	Lower-level lapse rate from surface to 3 km AGL	5.06	5.29	**5.33**
TE3K (K)	Max theta-e difference in lowest 3 km	11.7	14.4	**19.3**
MXMX ($g\, kg^{-1}$)	Maximum mixing ratio	12.1	12.7	**13.9**
MUCP ($J\, kg^{-1}$)	Most unstable CAPE	1261	1564	**2363**
MUCN ($J\, kg^{-1}$)	Most unstable CIN	−68.1	**−71.4**	−54.8
RH70 (%)	Relative humidity 700 hPa	**71.7**	68.0	61.1
RH80 (%)	Relative humidity 800 hPa	75.9	**76.6**	72.2
SLCH (m)	Surface-based LCL height	488	532	**608**
STHE (°C)	Surface equivalent potential temperature	338	340	**345**
SBCP ($J\, kg^{-1}$)	Surface-based CAPE	652	872	**1518**
SBCN ($J\, kg^{-1}$)	Surface-based CIN	−235	**−244**	−232
	Composite parameters			
XTRN ($g\, kt\, kg^{-1}$)	MXMX × (wind speed at MUPL)	196	330	**358**
DCP (numeric)	Derecho composite parameter	0.676	1.57	**3.48**
STP (numeric)	Significant tornado parameter—fixed layer	0.159	0.467	**1.11**
SCP (numeric)	Supercell composite parameter—effective layer	1.37	5.32	**8.55**

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.

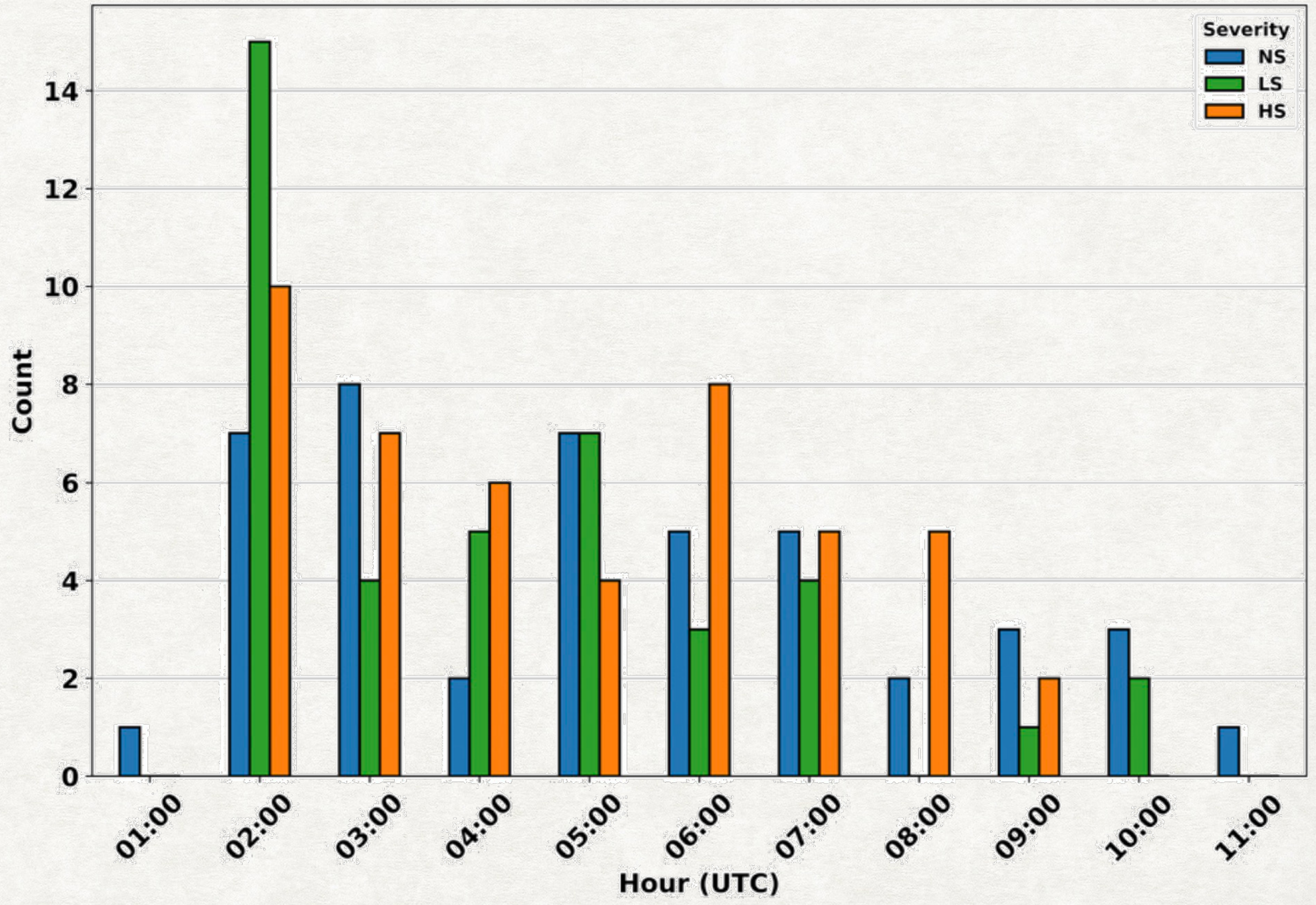
Only severe composite indices and some thermodynamic variables can help differentiate environments likely to produce bow echoes with high intensity severe wind from ones that will only produce marginally severe wind.

RESULTS

NOCTURNAL DISTRIBUTION ANALYSIS

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



RESULTS

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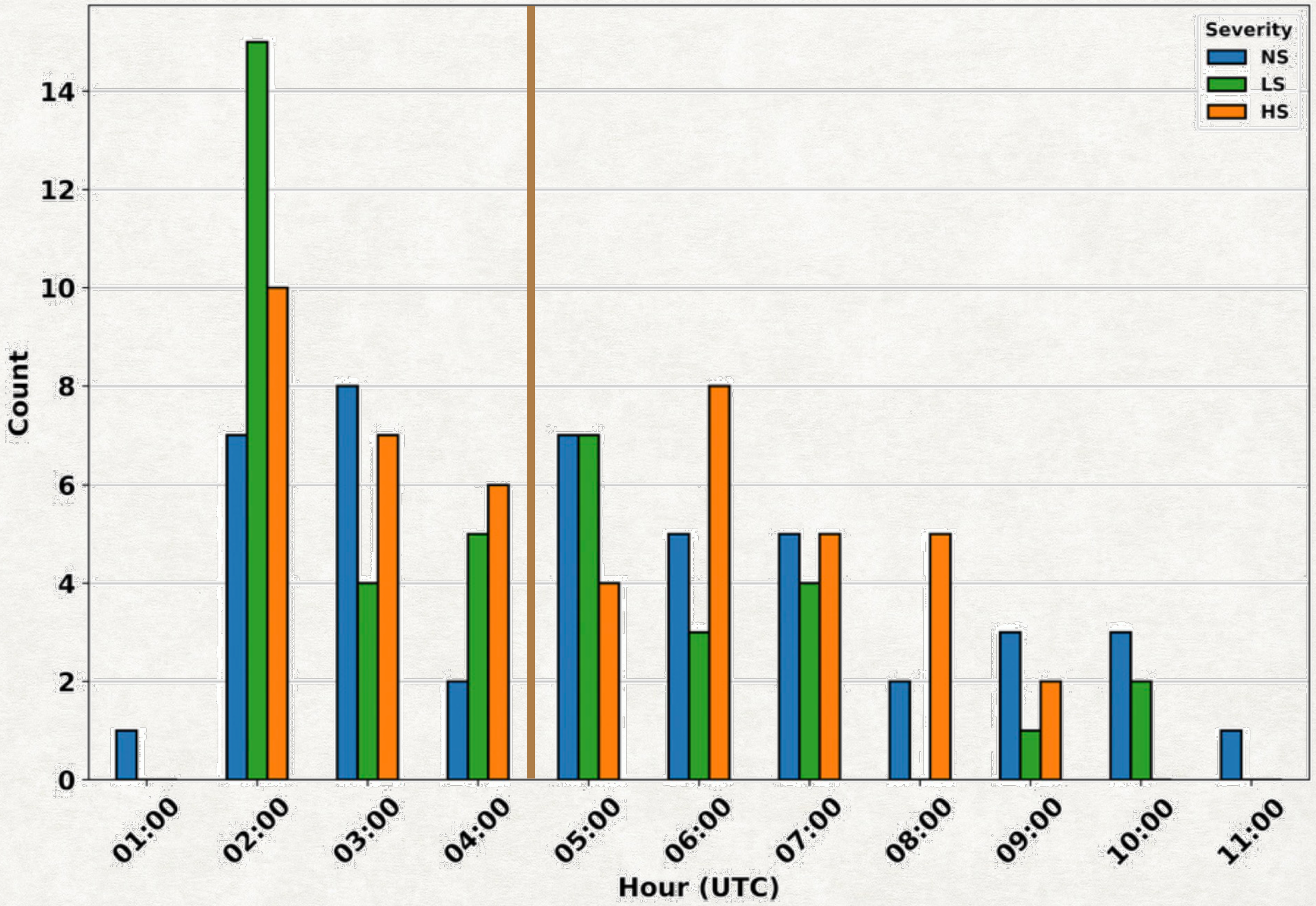
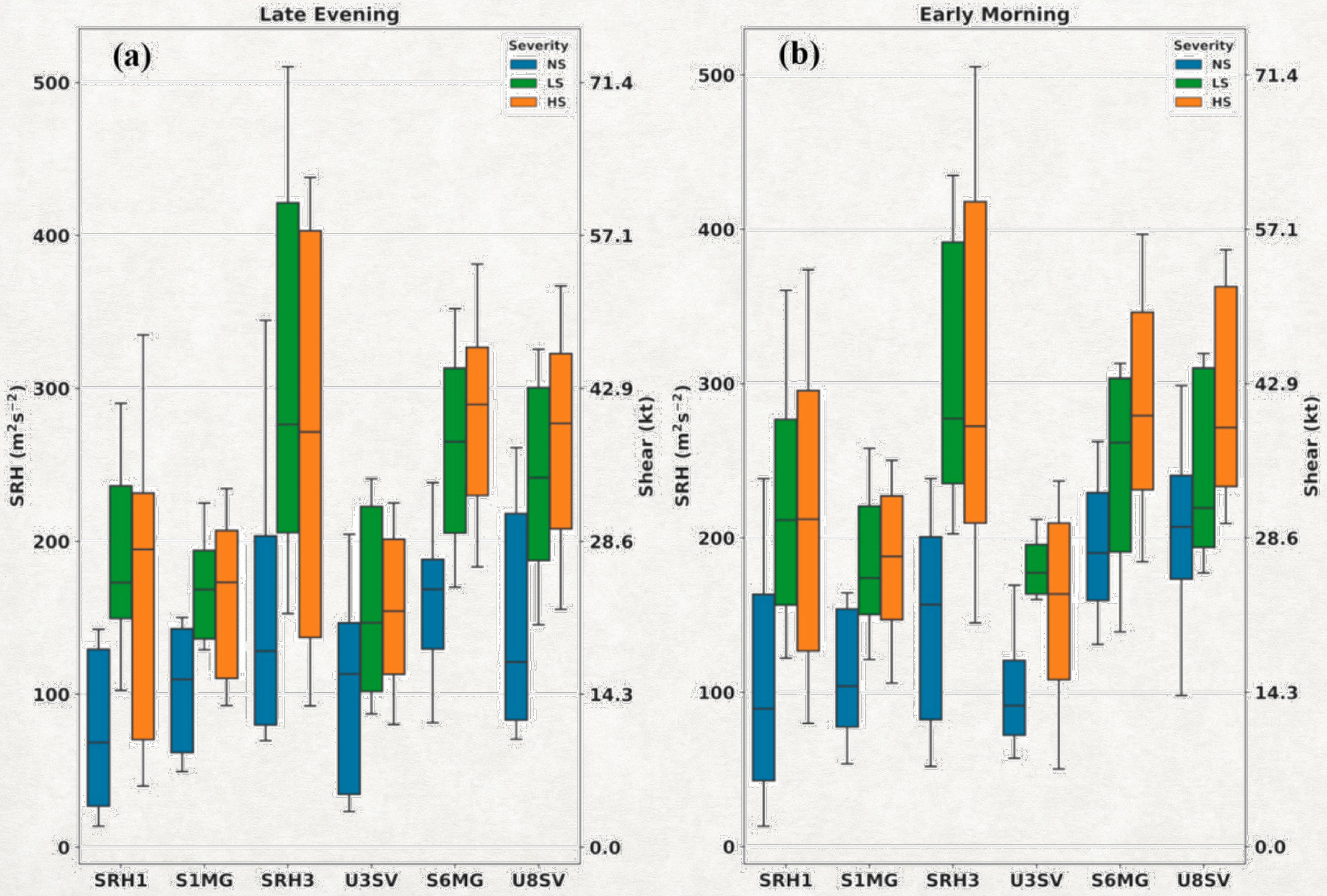


RESULTS

NOCTURNAL DISTRIBUTION ANALYSIS

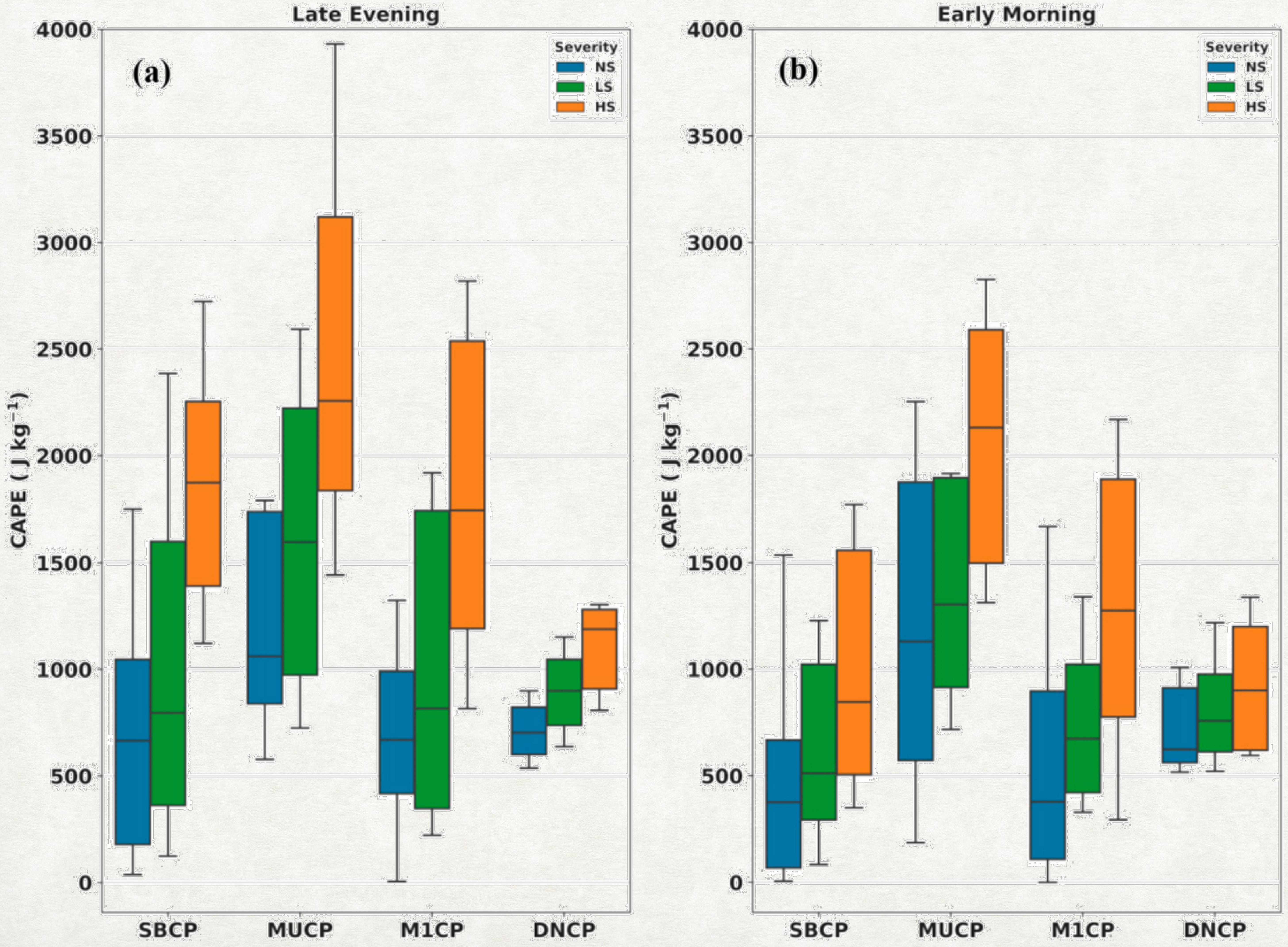


Name	Description
	Kinematic parameters
S1MG (kt)	0–1-km shear magnitude
SRH1 ($m^2 s^{-2}$)	0–1-km storm relative helicity
SRH3 ($m^2 s^{-2}$)	0–3-km storm relative helicity
U3SV (kt)	0–3-km *U* shear component
V3SV (kt)	0–3-km *V* shear component
UPMW (kt)	0–6-km pressure-weighted *U* component
VPMW (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

Shear still discriminates well between NS and severe events.

RESULTS

NOCTURNAL DISTRIBUTION ANALYSIS



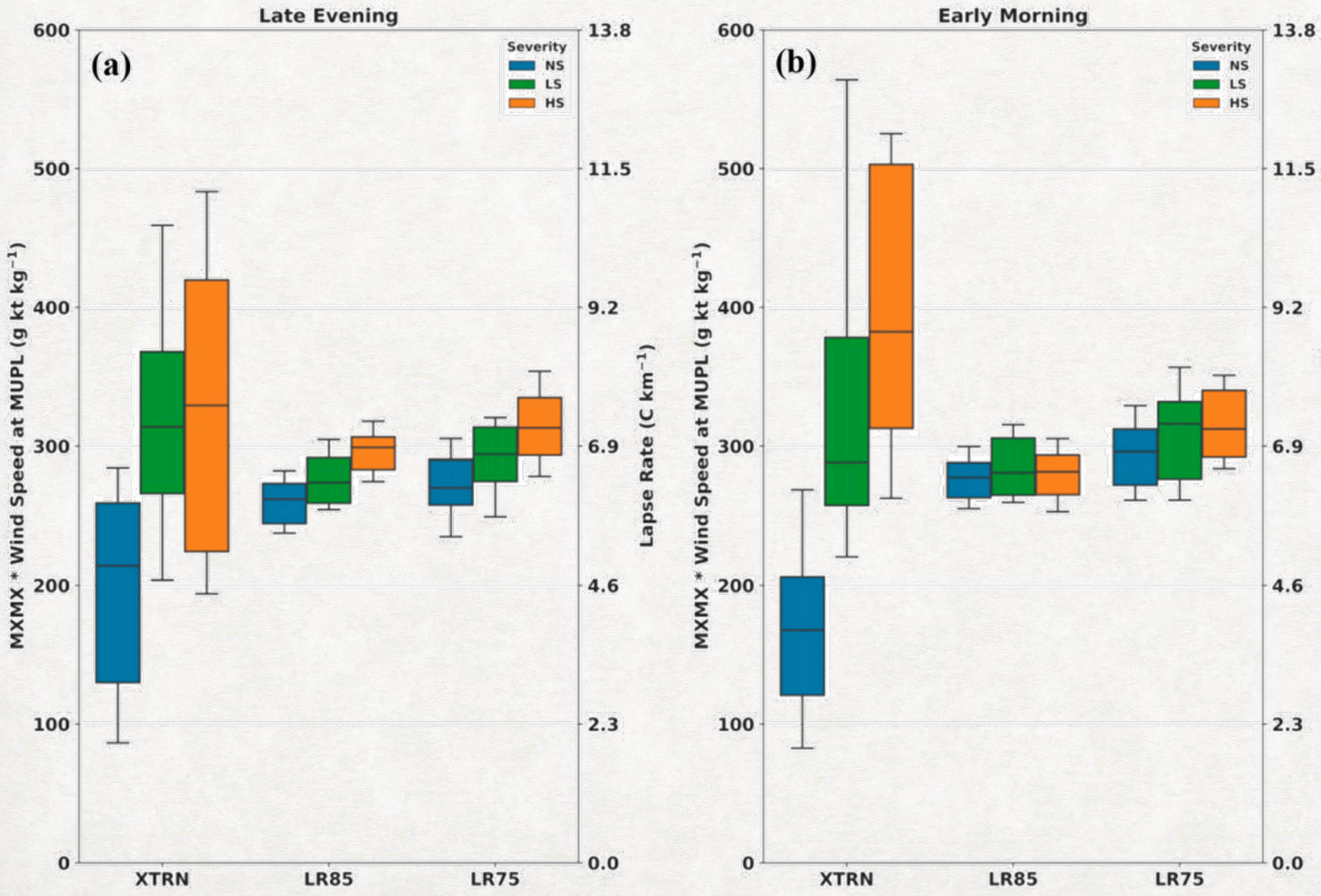
M1CP (J kg^{-1})	100-hPa mean mixed CAPE
M1CN (J kg^{-1})	100-hPa mean mixed CIN
3KRH (%)	3-km average relative humidity
RHC5 (%)	Average relative humidity from LCL to 500 hPa
RHLC (%)	Average relative humidity from LCL to LFC
ASRH (%)	Average subcloud humidity
DNCP (J kg^{-1})	Downdraft CAPE
LR75 (°C 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 (g kg^{-1})	Maximum mixing ratio
MUCP (J kg^{-1})	Most unstable CAPE
MUCN (J kg^{-1})	Most unstable CIN
RH70 (%)	Relative humidity 700 hPa
RH80 (%)	Relative humidity 800 hPa
SLCH (m)	Surface-based LCL height
STHE (°C)	Surface equivalent potential temperature
SBCP (J kg^{-1})	Surface-based CAPE
SBCN (J kg^{-1})	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



M1CP (J kg^{-1})	100-hPa mean mixed CAPE
M1CN (J kg^{-1})	100-hPa mean mixed CIN
3KRH (%)	3-km average relative humidity
RHC5 (%)	Average relative humidity from LCL to 500 hPa
RHLC (%)	Average relative humidity from LCL to LFC
ASRH (%)	Average subcloud humidity
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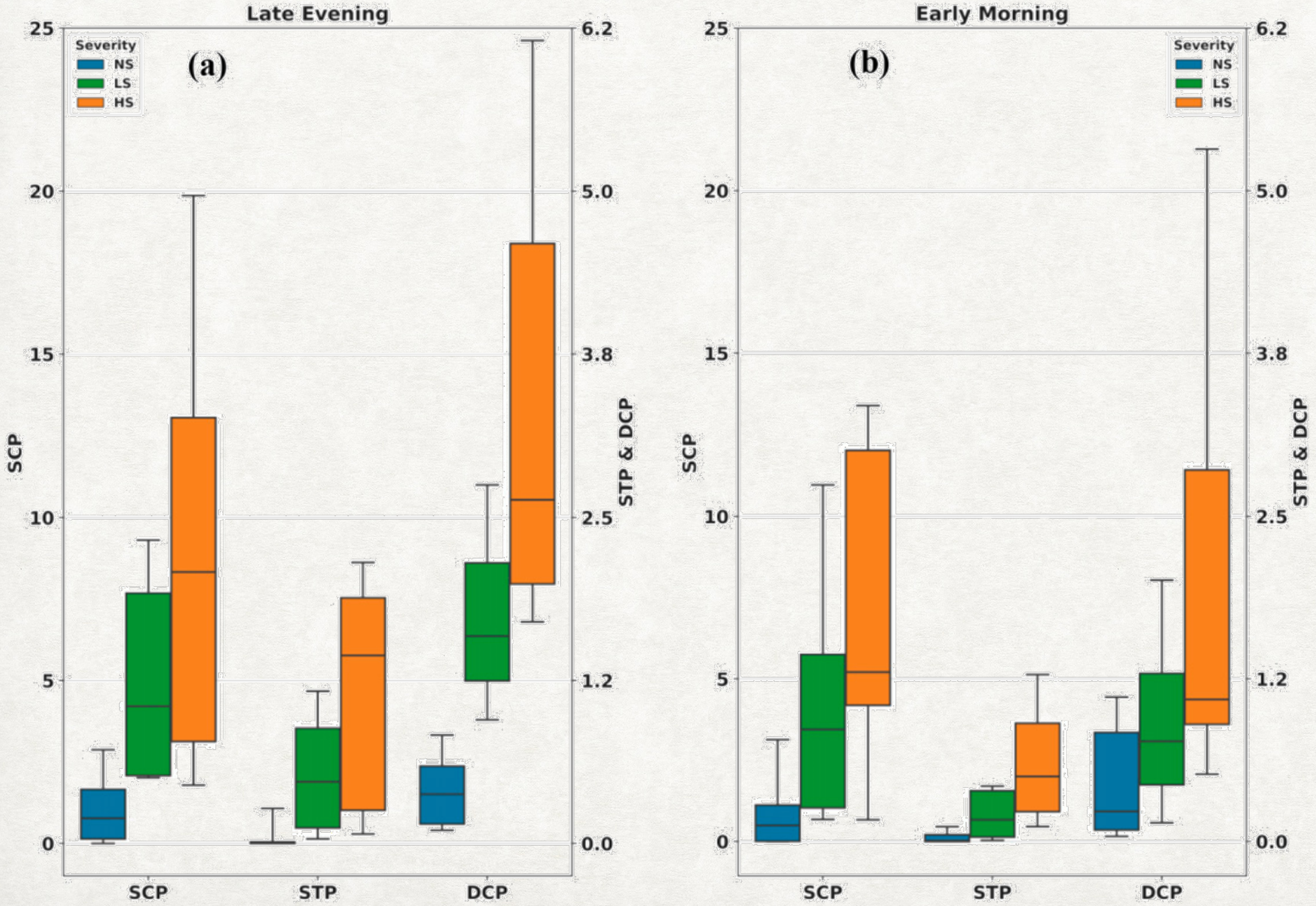
MUCP (J kg^{-1})	Most unstable CAPE
MUCN (J kg^{-1})	Most unstable CIN
RH70 (%)	Relative humidity 700 hPa
RH80 (%)	Relative humidity 800 hPa
SLCH (m)	Surface-based LCL height
STHE (°C)	Surface equivalent potential temperature
SBCP (J kg^{-1})	Surface-based CAPE
SBCN (J kg^{-1})	Surface-based CIN
	Composite parameters
XTRN (g kt kg^{-1})	MXMX × (wind speed at MUPL)

Both lapse rate parameters differentiate among all severity types only **during late evening**.

XTRN only discriminates between severe and nonsevere as well.

RESULTS

NOCTURNAL DISTRIBUTION ANALYSIS



DCP (numeric)	Derecho composite parameter
STP (numeric)	Significant tornado parameter—fixed layer
SCP (numeric)	Supercell composite parameter—effective layer

All parameters differentiate significantly among all three severity types.

RESULTS

SINGLE-PARAMETER FORECAST SKILL

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 layer
UMXP (kt)	*U* wind component at best CAPE level
VEIL (kt)	*V* component top of effective inflow layer
VMXP (kt)	*V* wind component at best CAPE level
	Thermodynamic parameters
M1CP ($J kg^{-1}$)	100-hPa mean mixed CAPE
M1CN ($J kg^{-1}$)	100-hPa mean mixed CIN
3KRH (%)	3-km average relative humidity
RHC5 (%)	Average relative humidity from LCL to 500 hPa
RHLC (%)	Average relative humidity from LCL to LFC
ASRH (%)	Average subcloud humidity
DNCP ($J kg^{-1}$)	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 ($g kg^{-1}$)	Maximum mixing ratio
MUCP ($J kg^{-1}$)	Most unstable CAPE
MUCN ($J kg^{-1}$)	Most unstable CIN
RH70 (%)	Relative humidity 700 hPa
RH80 (%)	Relative humidity 800 hPa
SLCH (m)	Surface-based LCL height
STHE (°C)	Surface equivalent potential temperature
SBCP ($J kg^{-1}$)	Surface-based CAPE
SBCN ($J kg^{-1}$)	Surface-based CIN
	Composite parameters
XTRN ($g kt kg^{-1}$)	MXMX × (wind speed at MUPL)
DCP (numeric)	Derecho composite parameter
STP (numeric)	Significant tornado parameter—fixed layer
SCP (numeric)	Supercell composite parameter—effective layer

Severity	Parameter	Threshold range	HSS
NS	STP (numeric)	<0.039	0.6
	SCP (numeric)	<1.77	0.59
	DCP (numeric)	<0.64	0.59
	XTRN ($g kt kg^{-1}$)	<260.18	0.51
	SRH3 ($m^2 s^{-2}$)	<167.09	0.48
	S6MG (kt)	<33.21	0.44
	S1MG (kt)	<14.77	0.43
	SRH1 ($m^2 s^{-2}$)	<148.75	0.42
	U6SV (kt)	<24.36	0.42
	VMXP (kt)	<12.82	0.39
LS	VMXP (kt)	12.82–27.39	0.38
	STP (numeric)	0.157–0.905	0.35
	SCP (numeric)	1.77–8.0	0.35
	XTRN ($g kt kg^{-1}$)	242.67–382.77	0.33
	U3SV (kt)	22.50–35.33	0.32
	DCP (numeric)	0.64–3.18	0.31
	VPMW (kt)	9.39–25.30	0.3
	SRH1 ($m^2 s^{-2}$)	148.75–495.23	0.29
	STHE (°C)	324.43–335.79	0.28
	M1CP ($J kg^{-1}$)	122.98–614.88	0.27
HS	STP (numeric)	>0.59	0.45
	MUCP ($J kg^{-1}$)	>1949.4	0.44
	DCP (numeric)	>1.78	0.42
	SCP (numeric)	>3.64	0.42
	M1CP ($J kg^{-1}$)	>1147.8	0.42
	SBCP ($J kg^{-1}$)	>657.35	0.39
	TE3K (K)	>22.85	0.37
	XTRN ($g kt kg^{-1}$)	>289.37	0.36
	U6SV (kt)	>35.14	0.35
	DNCP ($J kg^{-1}$)	>1162.6	0.33

The four composite parameters, XTRN, SCP, STP, and DCP, are among the most highly skilled for all severity types.

RESULTS

TWO-PARAMETER FORECAST SKILL

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
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UEIL (kt)	*U* component top of effective inflow layer
UMXP (kt)	*U* wind component at best CAPE level
VEIL (kt)	*V* component top of effective inflow layer
VMXP (kt)	*V* wind component at best CAPE level
	Thermodynamic parameters
M1CP ($J kg^{-1}$)	100-hPa mean mixed CAPE
M1CN ($J kg^{-1}$)	100-hPa mean mixed CIN
3KRH (%)	3-km average relative humidity
RHC5 (%)	Average relative humidity from LCL to 500 hPa
RHLC (%)	Average relative humidity from LCL to LFC
ASRH (%)	Average subcloud humidity
DNCP ($J kg^{-1}$)	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 ($g kg^{-1}$)	Maximum mixing ratio
MUCP ($J kg^{-1}$)	Most unstable CAPE
MUCN ($J kg^{-1}$)	Most unstable CIN
RH70 (%)	Relative humidity 700 hPa
RH80 (%)	Relative humidity 800 hPa
SLCH (m)	Surface-based LCL height
STHE (°C)	Surface equivalent potential temperature
SBCP ($J kg^{-1}$)	Surface-based CAPE
SBCN ($J kg^{-1}$)	Surface-based CIN
	Composite parameters
XTRN ($g kt kg^{-1}$)	MXMX × (wind speed at MUPL)
DCP (numeric)	Derecho composite parameter
STP (numeric)	Significant tornado parameter—fixed layer
SCP (numeric)	Supercell composite parameter—effective layer

Severity	Combination	$x_{opt,1}$ range	$x_{opt,2}$ range	HSS
NS	DCP + SRH3	<1.27	<244 ($m^2 s^{-2}$)	0.71
	DCP + U3SV	<0.892	<21.9 (kt)	0.68
	SCP + XTRN	<1.77	<289 ($g kt kg^{-1}$)	0.67
	DCP + S6MG	<0.892	<35.7 (kt)	0.67
	STP + SCP	<0.157	<1.77	0.67
LS	DCP + VMXP	0.671–3.35	11.5–27.5 (kt)	0.50
	SCP + VMXP	1.54–11.4	11.5–27.5 (kt)	0.46
	XTRN + SCP	252–467 ($g kt kg^{-1}$)	1.54–8.10	0.46
	M1CP + VMXP	216–2373 ($J kg^{-1}$)	11.5–27.5 (kt)	0.45
	SCP + DCP	1.54–11.4	0.671–3.35	0.45
HS	SBCP + U6SV	>657 ($J kg^{-1}$)	>29.8 (kt)	0.53
	SBCP + S6MG	>657 ($J kg^{-1}$)	>25.6 (kt)	0.53
	M1CP + S6MG	>738 ($J kg^{-1}$)	>24.4 (kt)	0.52
	MUCP + S6MG	>1401 ($J kg^{-1}$)	>24.4 (kt)	0.51
	STHE + U6SV	>336 (°C)	>29.8 (kt)	0.50

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

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!