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Prediction of Convective Morphology in Near-cloud Permitting WRF Model Simulations

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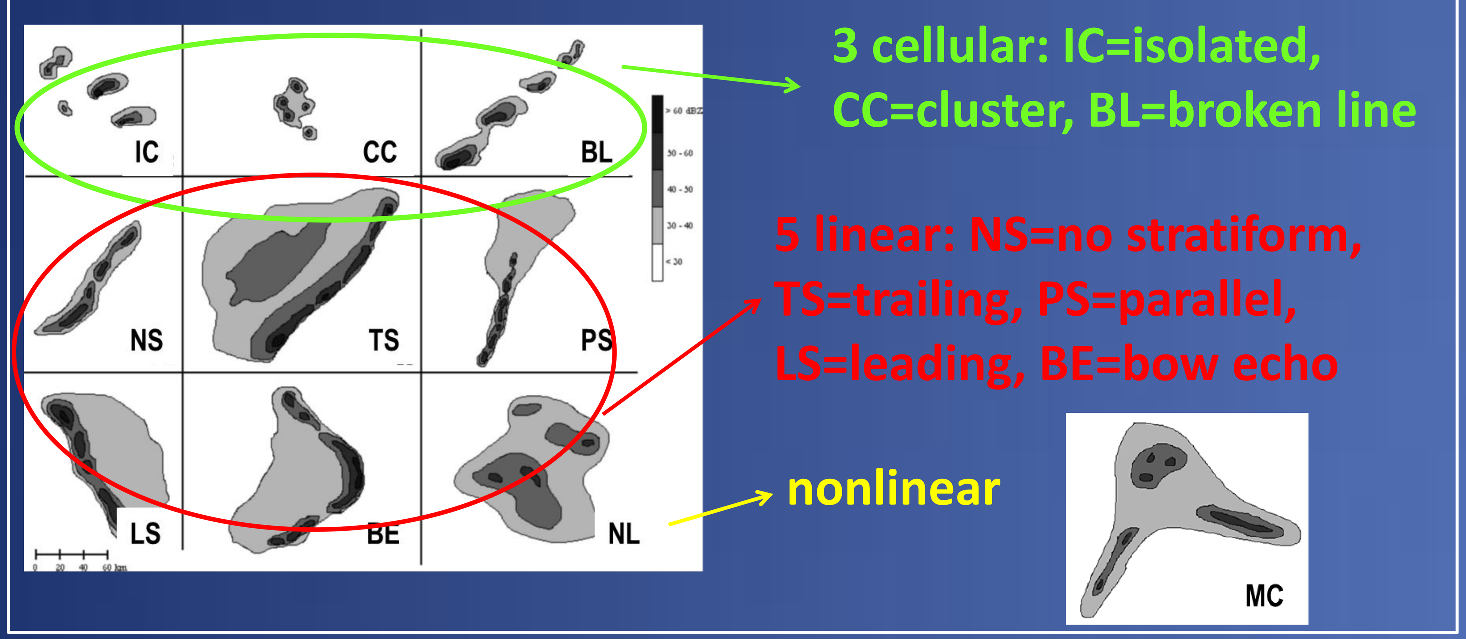
Introduction

- 37 warm season convective events from 2006-2010 were simulated using WRF3.1.1 (ARW) with 3 km grid spacing (Thompson microphysics, NAM IC/LBC) and integrated for 24h
- Simulated events were classified using 10 morphologies, and then compared to observed morphologies
- Larger scale environment documented at initiation using 20 km RUC analyses 1 hour prior to initiation
- Objective skill score based on degree of mode agreement and timing was developed and used to rate events

Modes used included 9 used by Gallus et al. (2008) plus one mixed-complex (MC) mode added.



For objective verification, normalized time scales used for both simulated and observed systems, then merged (example below).

Mode	Time (UTC)	Length (hours)	Normalized time	
BL	2054		0	Initiation
NS	0425	7.52	0.50	
BE	0724	10.50	0.70	
	1200	15.10	1	End of period

Observations

Mode	Time (UTC)	Length (hours)	Normalized time	
CC	2000		0	Initiation
NS	0330	7.5	0.47	
NL	0600	10	0.63	
TS	0930	13.5	0.84	
	1200	16	1	End of period

WRF model

T_1	T_2	ΔT	Obs.	WRF
0	0.47	0.47	BL	CC
0.47	0.50	0.03	BL	NS
0.50	0.63	0.13	NS	NS
0.63	0.70	0.07	NS	NL
0.70	0.84	0.14	BE	NL
0.84	1	0.16	BE	TS

Group match – modes in same general classification (linear, cellular) but not exact =1/2 point over time interval

Detailed match – exact modes = 1 point over time interval

- Final score for example case would be 0.5*.47+0.5*.16 +0.13 = **0.45**
- Note: penalty was introduced if simulated initiation or dissipation of system was more than 3 hours different from that observed
- **Average score for full sample was 0.49**

20km RUC hourly analyses used to obtain initial environment conditions (1 hr prior to initiation)

- Surface-based CAPE
- Mixed-layer CAPE
- 0-3 km bulk shear
- 0-6 km bulk shear
- Potential temperature at surface
- Potential temperature at level of maximum theta-E

General Results

- WRF forecasted more cellular modes and fewer linear modes than observed

	IC	CC	BL	BE	TS	NS	PS	LS	NL	MC	Total
Radar	6	7	24	21	19	17	1	0	17	3	115
Model	8	16	24	8	13	22	1	0	16	1	109
Difference	**2**	**9**	**0**	**-13**	**-6**	**5**	**0**	**0**	**-1**	**-2**	**-6**

- WRF usually simulated a cellular mode when a cellular mode was observed

Observed mode	Comparisons	Detailed matches		Group matches	
IC	7	3	43%	6	86%
CC	11	5	45%	9	82%
BL	34	17	50%	24	71%
Total	**52**	**25**	**48%**	**39**	**75%**

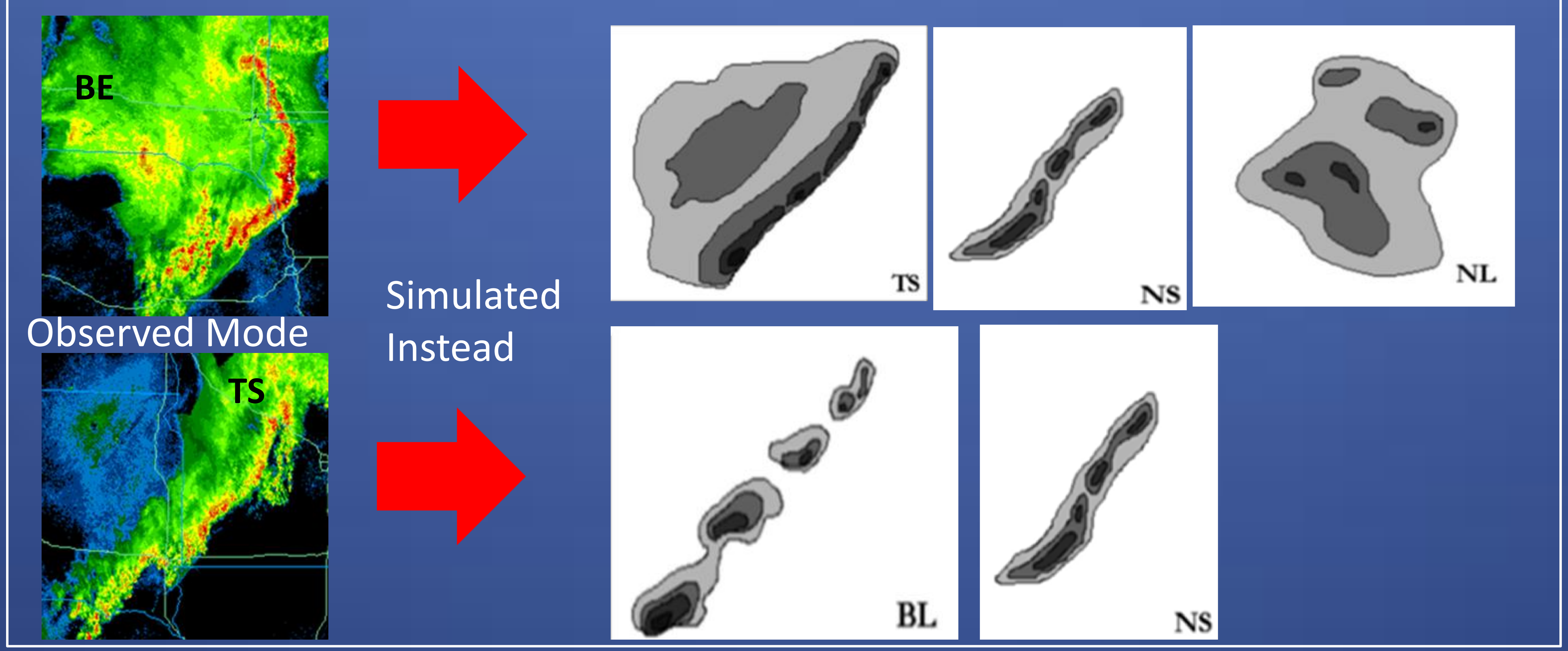
- WRF struggled more to predict linear modes

Observed mode	Comparisons	Detailed matches		Group matches	
BE	44	7	16%	26	59%
TS	29	7	24%	17	59%
PS	1	0	0%	1	100%
NS	24	8	33%	10	42%
LS	0				
Total	**98**	**22**	**22%**	**54**	**55%**

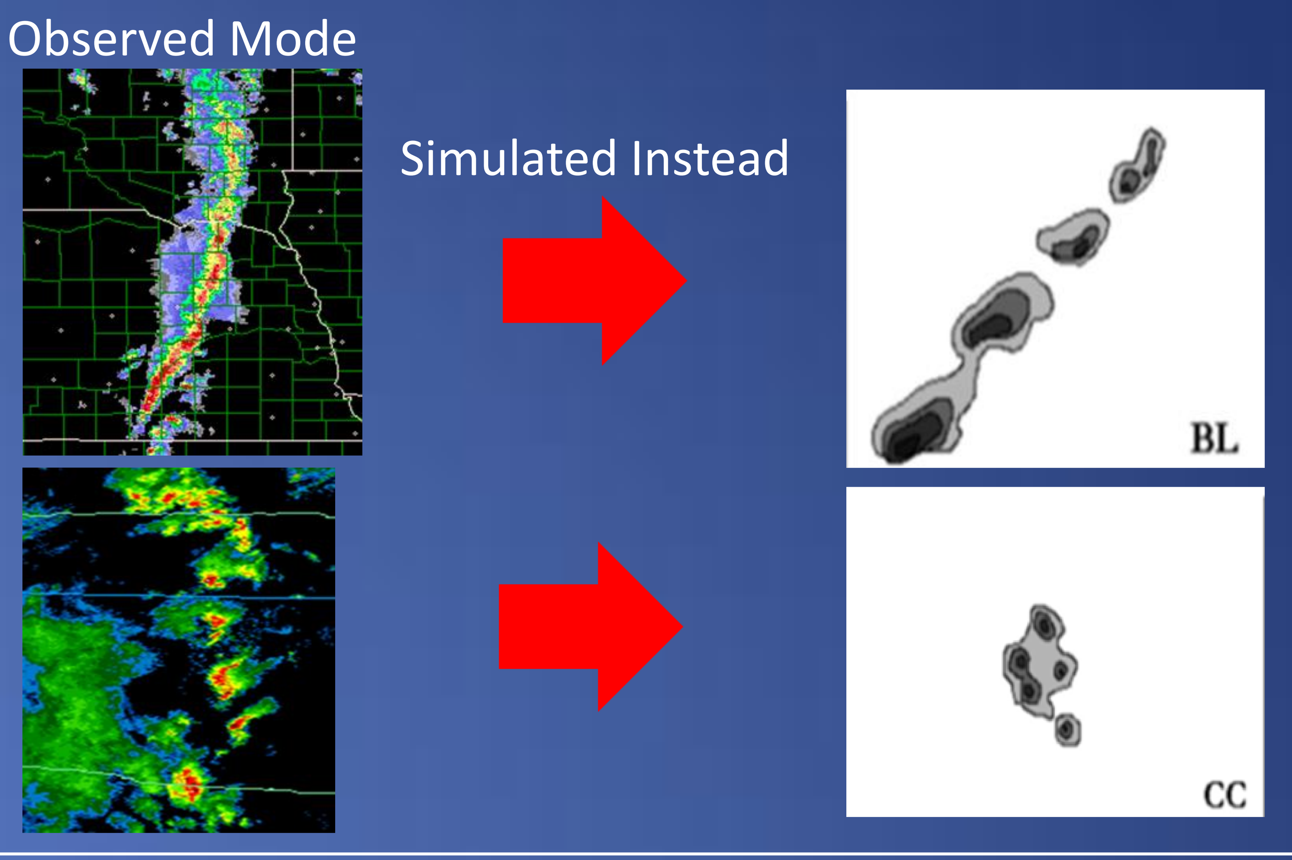
- WRF struggled to predict nonlinear and the mixed-complex modes

Observed mode	Comparisons	Detailed matches	
NL	29	10	33%
MC	6	1	17%
Total	**35**	**11**	**31%**

- Bow Echoes and Trailing Stratiform Squall Lines were most poorly predicted, with a failure to produce stratiform rain a common problem, along with problems organizing the convective line



- WRF often showed NS as cellular and BL missed at initiation



	All cases	Cases with score > 0.5	Cases with score < 0.5
SBCAPE (J kg^{-1})	1860	1936	1802
MLCAPE (J kg^{-1})	2422	2251	2553
CAPE diff. (J kg^{-1})	562	315	751
0-3 km shear (m s^{-1})	11.7	11.9	11.6
0-6 km shear (m s^{-1})	19.8	22.4	17.8
Theta sfc. (K)	303.5	302.6	304.2
Theta max. (K)	307.1	305.2	308.5
Theta diff. (K)	3.6	2.6	4.3
Lev. of max theta-E (hPa above sfc)	65	48	77
Theta lapse (K hPa^{-1})	5.8	5.7	5.8

Statistically significant at 90% confidence level

Skill at predicting mode seems to depend on strength of 0-6 km shear, and possibly also max theta value (CAP strength) or strength of low-level stable layer

Summary

- Model was more accurate at matching cellular modes than linear modes (especially TS, BE)
- Strong 0-6 km shear and cool potential temperatures at the level of maximum theta-E at initiation associated with better-scoring cases
- Weaker 0-6 km shear and stable conditions near the surface at initiation associated with timing issues
- Individual case studies (not shown) suggest problems in simulating near-storm shear may explain model failures at depicting mode

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