Identifying severe convection in convection-permitting weather forecasts: state of the science and applications to convection-permitting climate simulations

Ryan Sobash
NCAR / Mesoscale and Microscale Meteorology Laboratory
With contributions from: Glen Romine, Craig Schwartz, Morris Weisman, Jack Kain

Challenge: Devise objective method to identify severe convection* in convection-permitting models across different seasons, regions, environments, and convective modes.

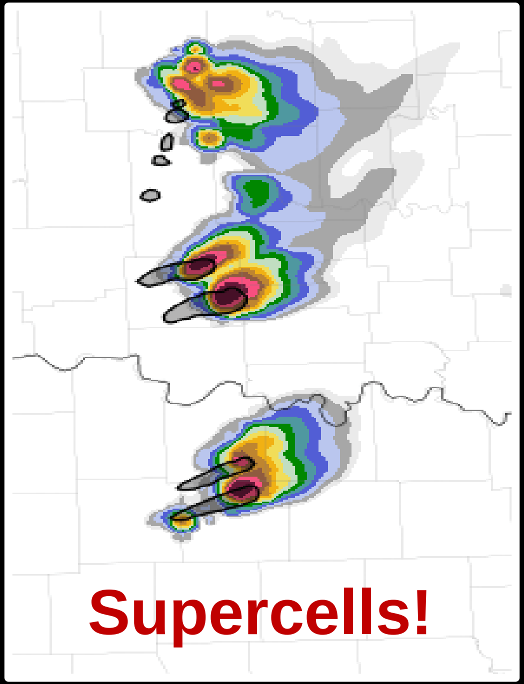
***severe convection**: occurrence of a convective wind gust > 50 knots, hail > 1 inch in diameter, tornado

Identifying severe convection in convection-permitting models

Event	Forecast Field	Observed Field
Heavy Precipitation	Accum. Precip > 1 in hr^{-1}	Obs. Precip > 1 in hr^{-1}
Severe Weather	Updraft Helicity > 100 m^2 s^{-2}	All Severe Reports
Hail	Vertically Integrated Graupel > 25 mm	Hail Reports
Tornado	Low-level vorticity > 0.01 s^{-1}	Tornado Reports

Since severe weather hazards are not directly resolved, use diagnostics as "surrogates" for the presence of severe weather hazards in CPMs.

Identifying severe convection in convection-permitting models



Composite Reflectivity &
2 km – 5 km UH > 50 $m^2\ s^{-2}$

Updraft helicity (UH) used to identify supercells and as a surrogate for severe weather hazards in CPMs (e.g. Kain et al 2008; Sobash et al 2011; Clark et al 2013).

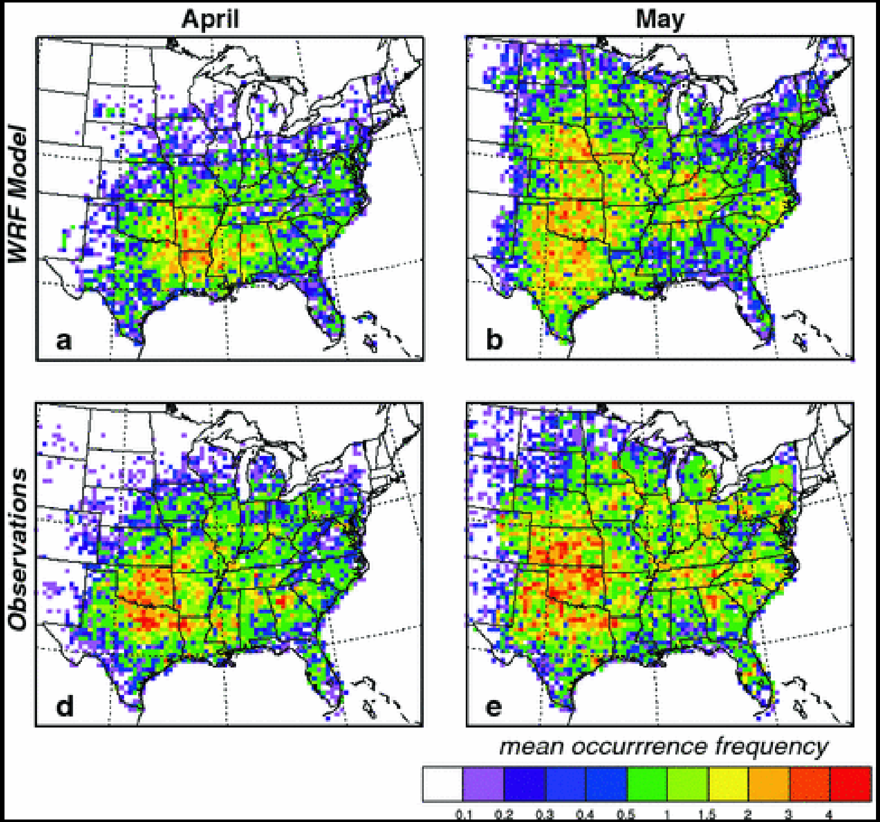
$$UH = \int_{z_b}^{z_t} w\zeta dz$$

In general, UH is superior to other diagnostics! No other diagnostic has proven to be as skillful at discriminating between non-severe and severe convection.

UH and other storm-scale diagnostics stored as hourly-maximum values to capture variability of storm-scale processes.

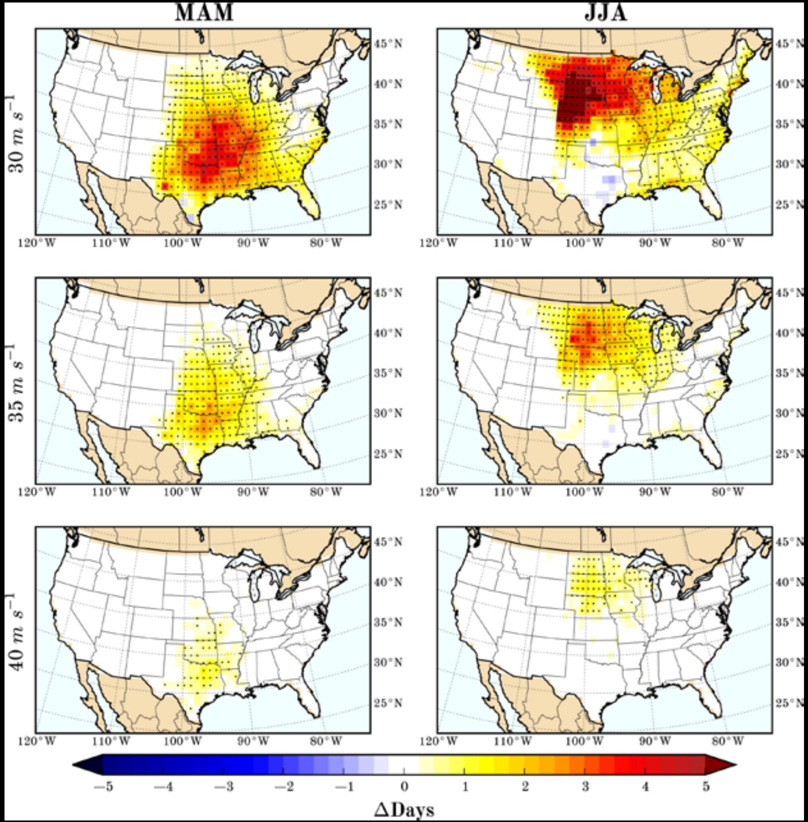
Previous work: Surrogate approach used with dynamical downscaling

UH/Z occurrence



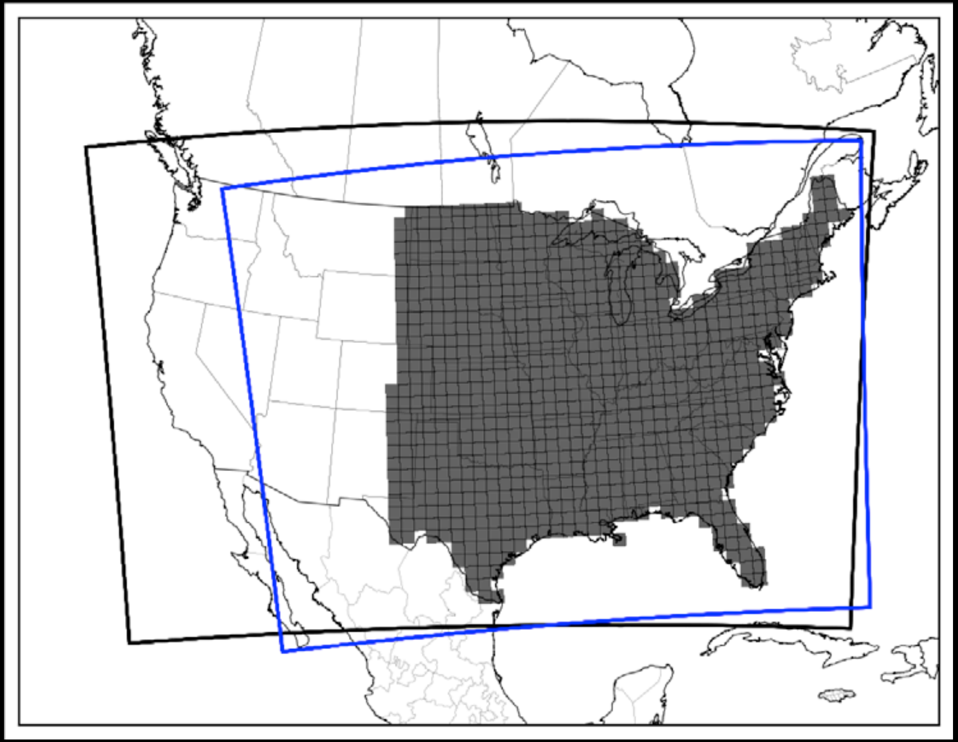
Trapp et al. (2011)

W occurrence



Hoogewind et al. (2017)

Use NSSL-WRF to examine variations in severe weather climatologies



- NSSL-WRF: experimental CPM run daily at NOAA/NSSL.
- Nearly fixed configuration since 2008.

- 30 Jan 2008 – 30 Jan 2016 (N=2,819)
- WRF V3.1.1
- 00 UTC > 36 hour forecasts
- IC/BC: 12-km NAM
- dx = 4 km
- YSU/WSM6 PBL/MP physics

Diagnostic Calibration

1) Count grid boxes where UH magnitude is exceeded (SSRs) w/in 24-hour period.

2) Count grid boxes where observed severe weather occurred (OSRs) w/in 24-hour period.

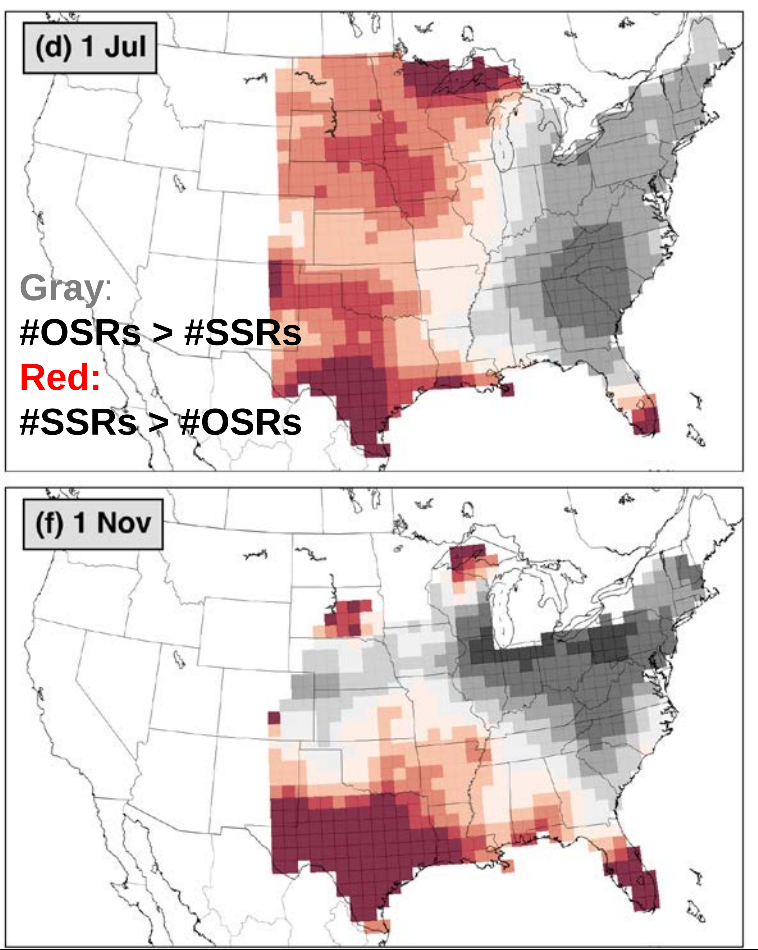
3) Sum over a large collection of forecasts.

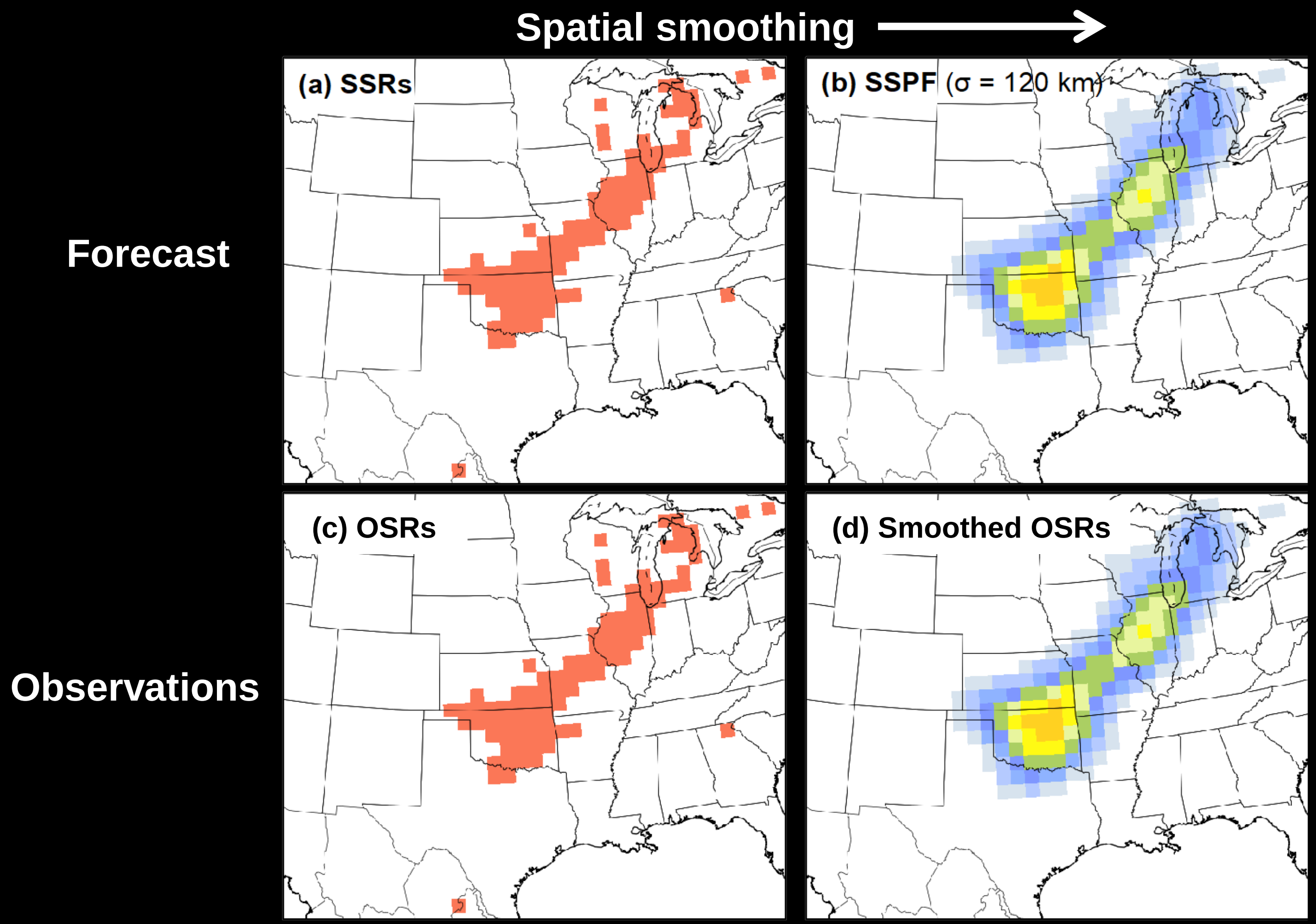
Three calibration strategies:

1) Domain-wide, all seasons

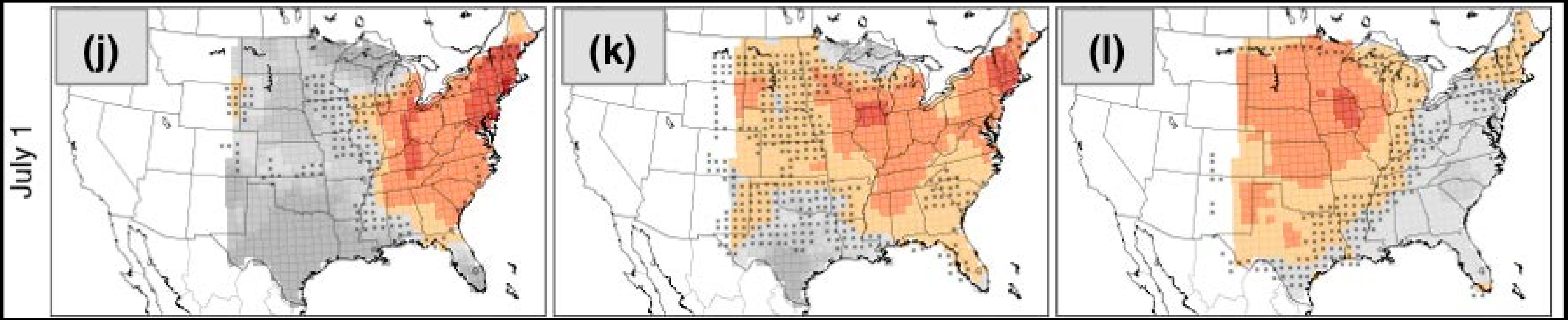
2) Domain-wide for each day

3) Per grid box per day




Spatial smoothing
Forecast
Observations
(a) SSRs
(b) SSPF (σ = 120 km)
(c) OSRs
(d) Smoothed OSRs

Brier Skill score for severe weather (reds positive; grays negative)



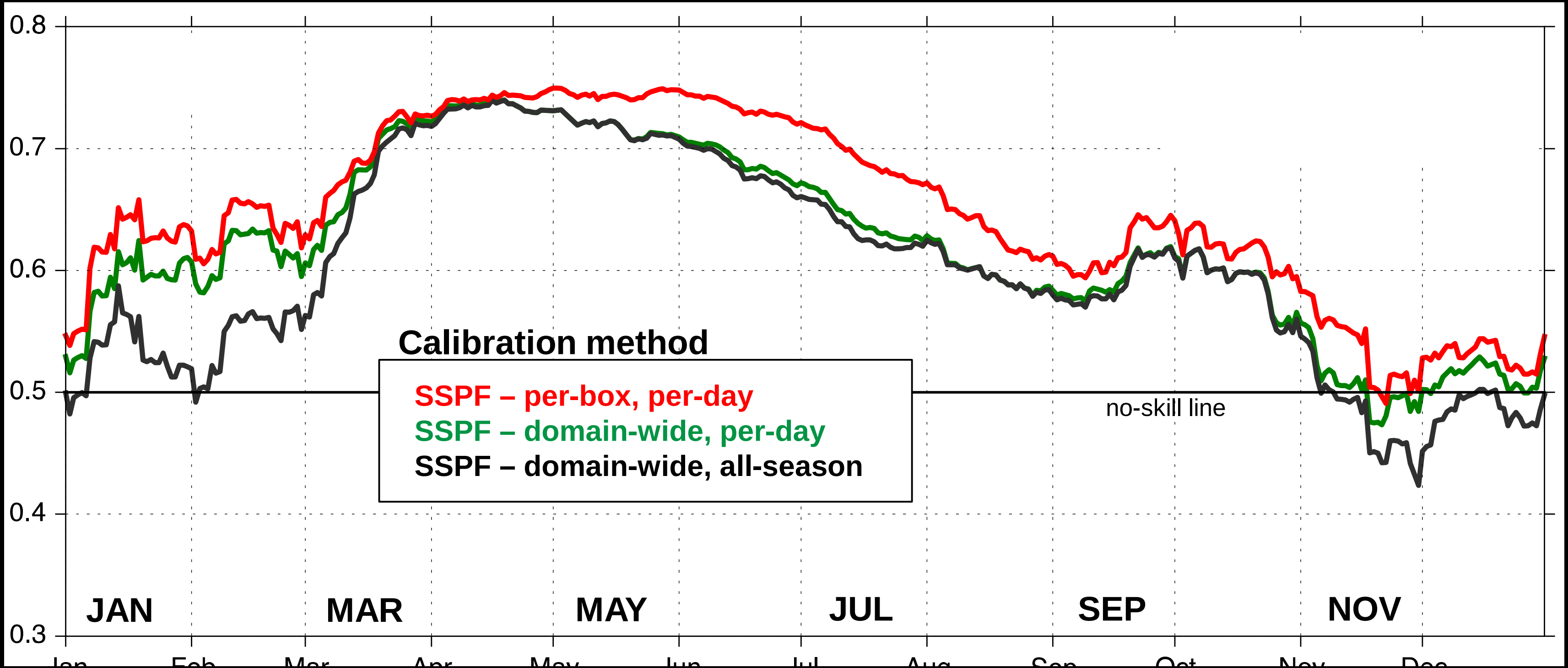
Low Threshold

High Threshold

Variations in skill exist depending on threshold used for UH diagnostic.

Suggests different types of convection responsible for severe weather.

Severe weather forecast skill using Fractions Skill Score

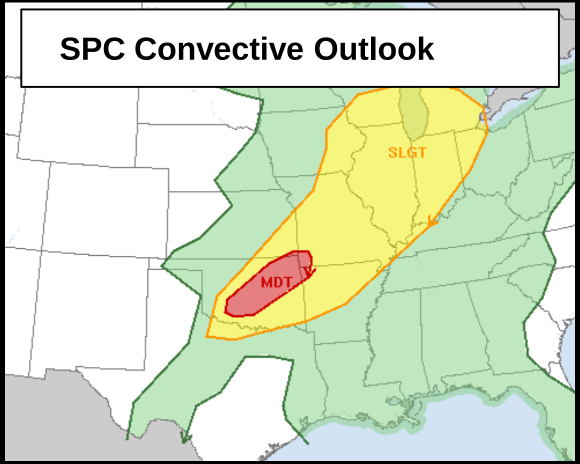


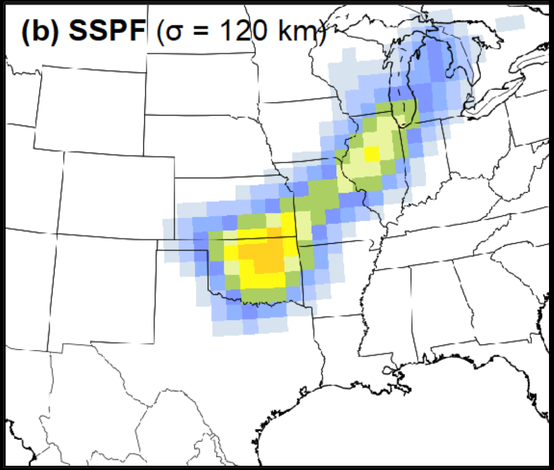
Sobash and Kain (2017)

Why are cool-season and summer severe weather forecasts less skillful?

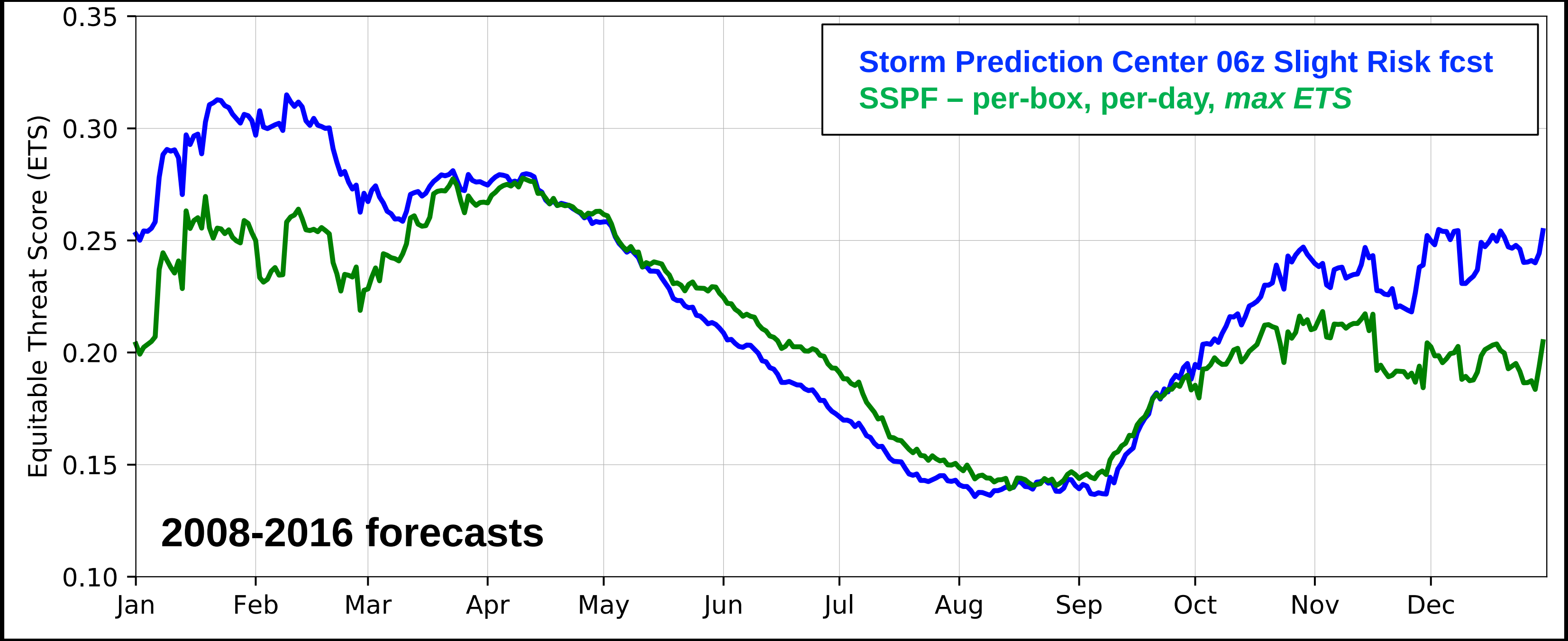
Attempt to untangle **lower practical predictability** and **poor detection with UH**.

Look to human forecasts of these events for insight…

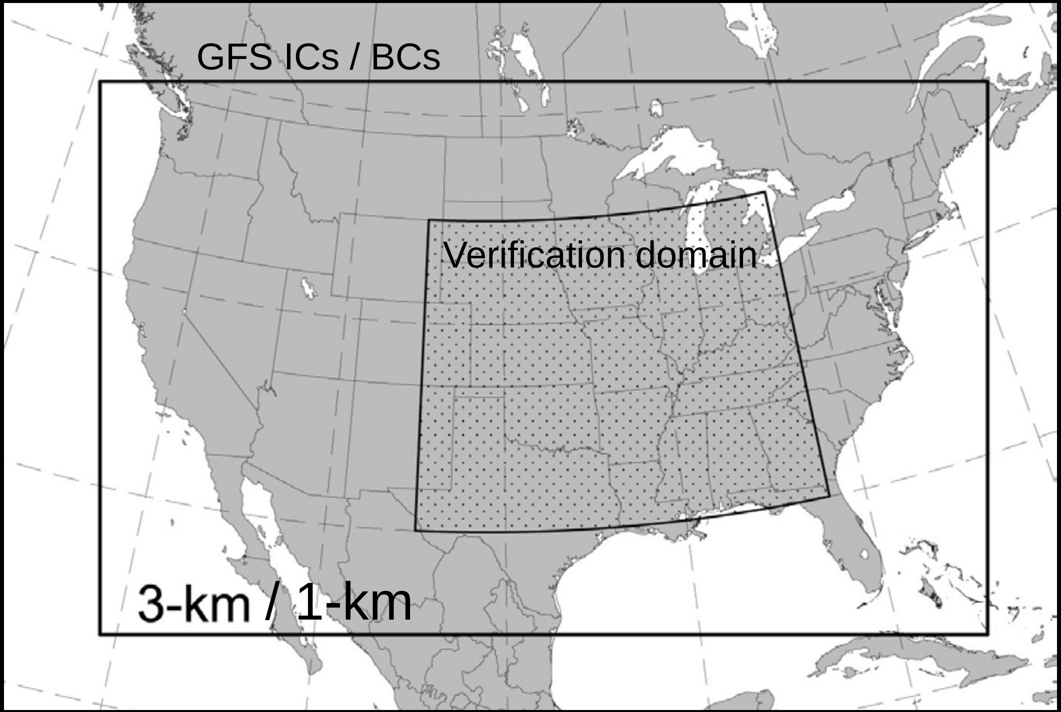




Human forecasts (SPC) vs. SSPF



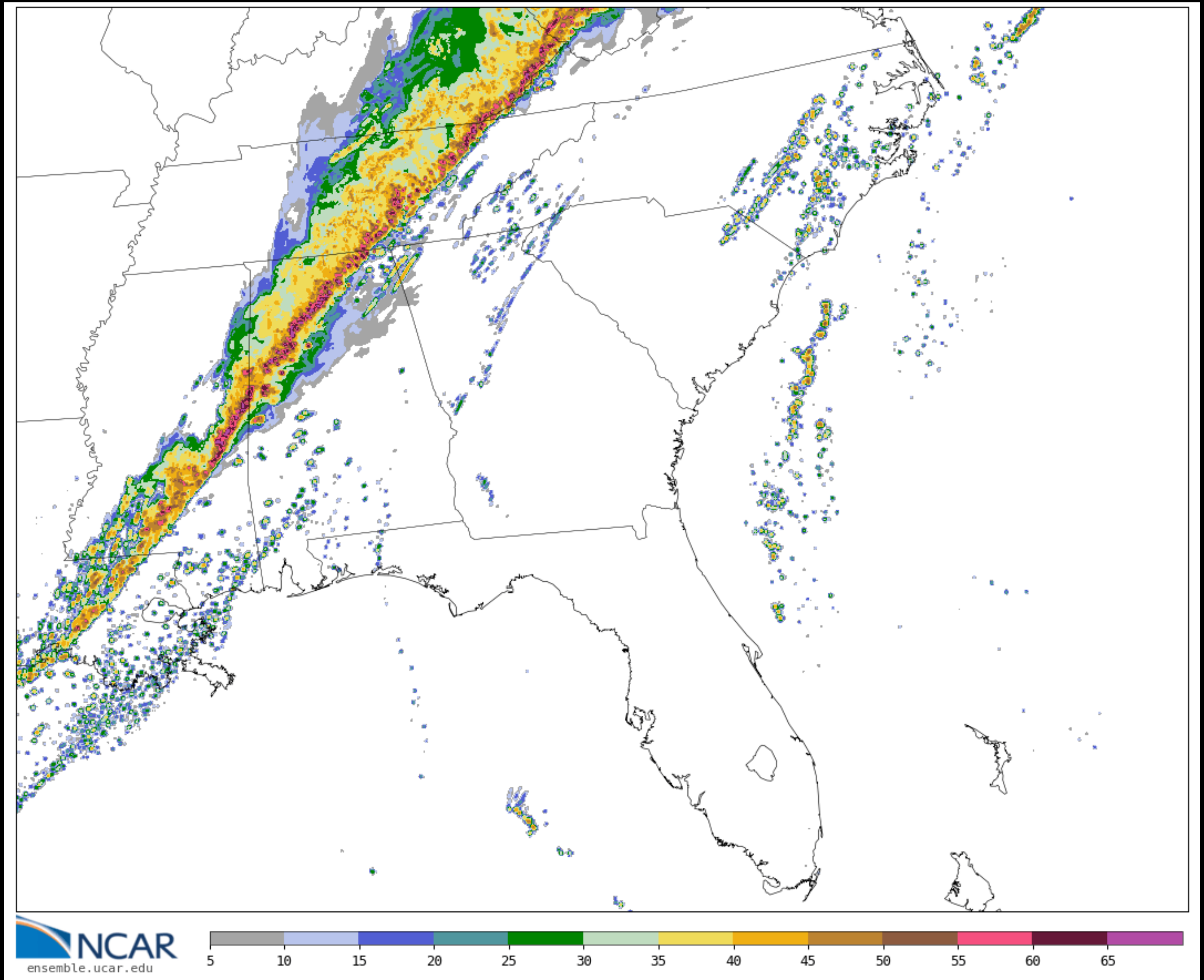
Deterministic full-CONUS forecasts with 3-km and 1-km horizontal grid spacing



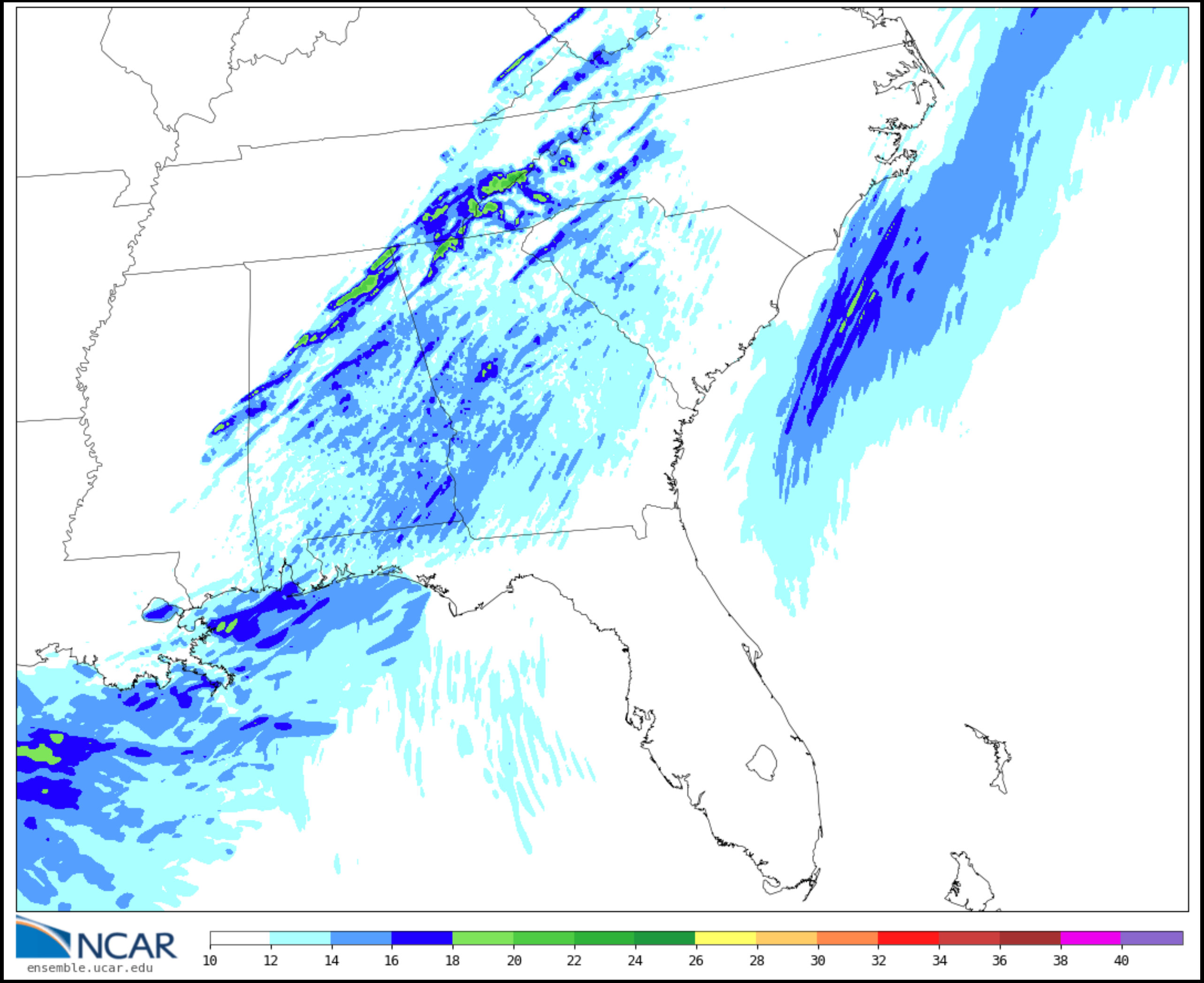
- ~ 500 cases over 7 years (2011-2017; SPC event archive)
- WRF V3.6.1 (no nest)
- 00 UTC > 36 hour forecasts
- ICs: GFS analyses
- BCs: GFS forecasts

A: 10-member, 3-km deterministic forecast (1580 x 985)

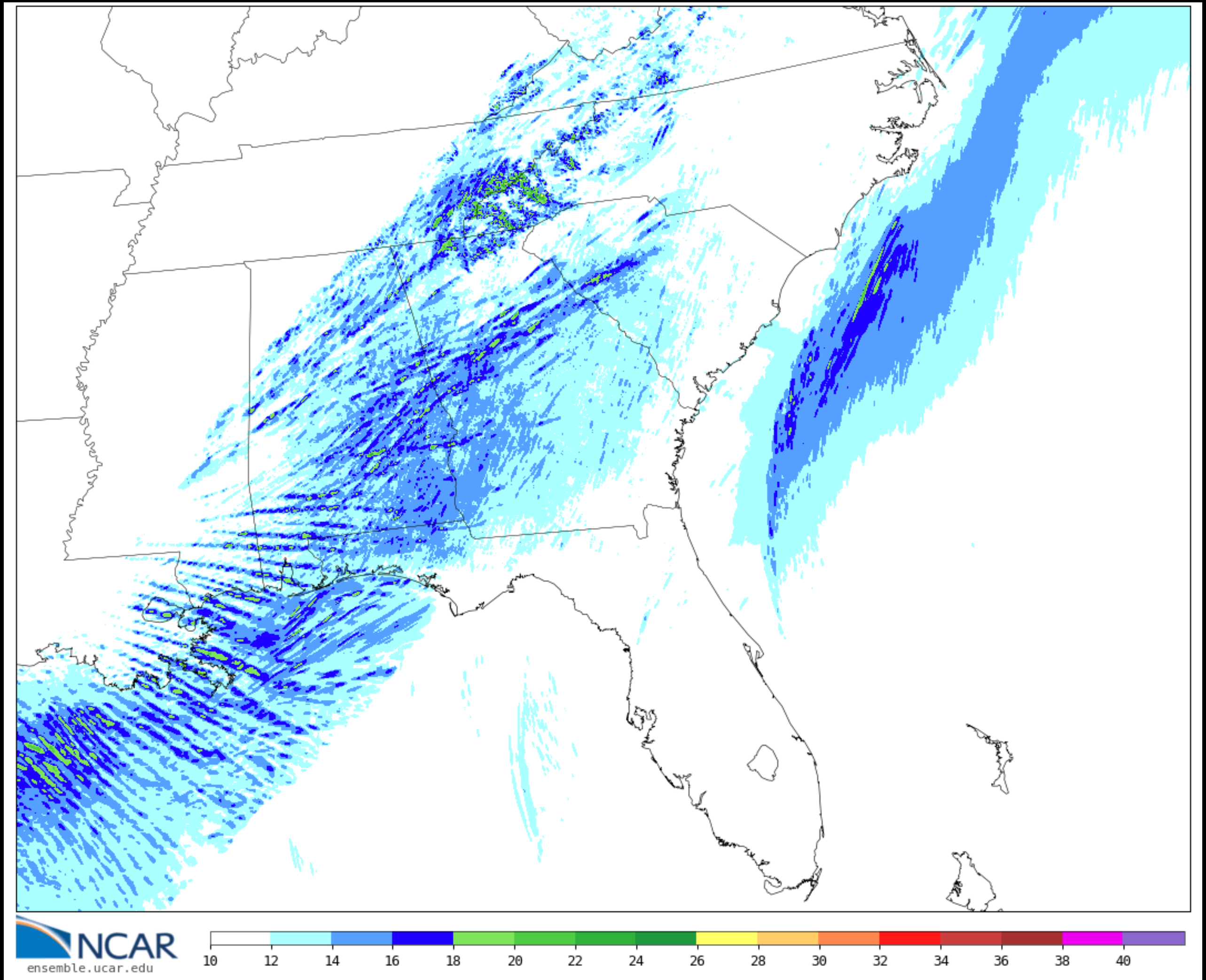
B: 10-member 1-km deterministic forecast (4740 x 2955)



5
10
15
20
25
30
35
40
45
50
55
60
65
NCAR
ensemble.ucar.edu

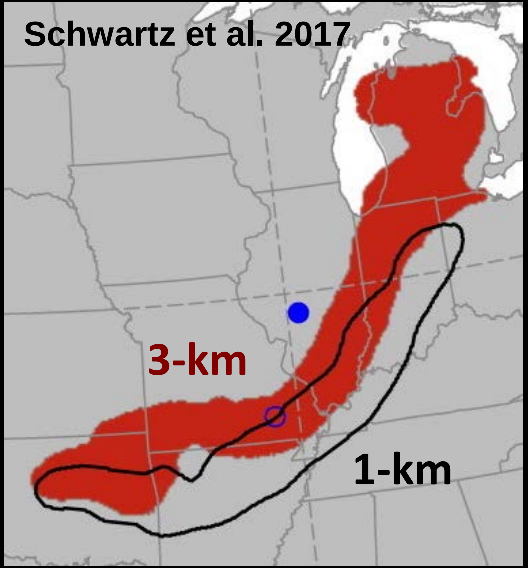


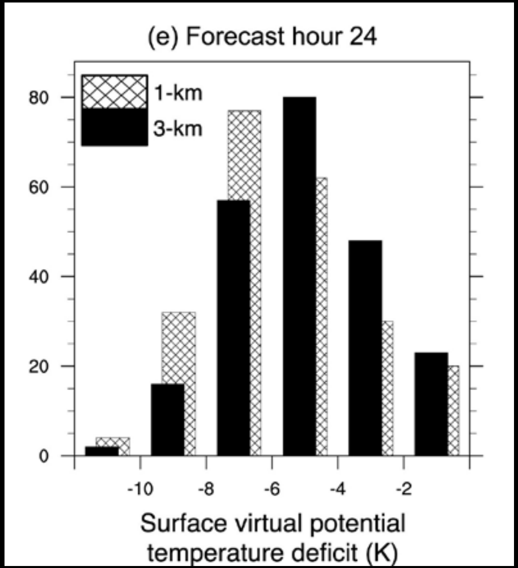
NCAR
ensemble.ucar.edu
10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40

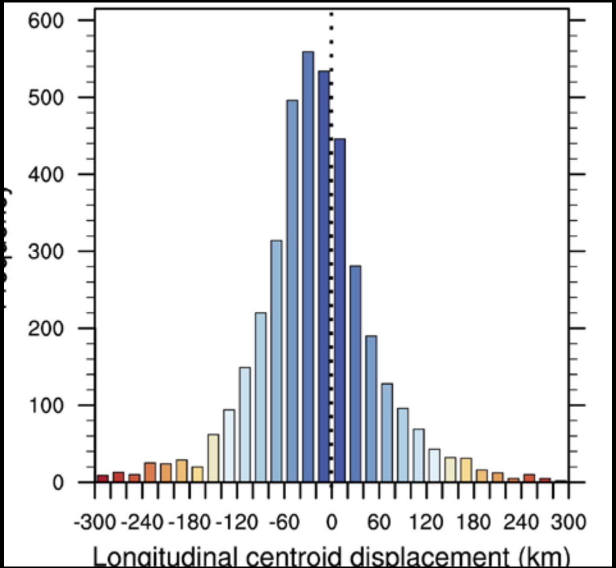

NCAR
ensemble.ucar.edu
10
12
14
16
18
20
22
24
26
28
30
32
34
36
38
40

Cold pool properties of MCSs: precipitation objects

(object area threshold of 10,000 km^2)







1-km MCSs possessed stronger cold pool theta-v deficits, resulting in MCSs that diverged from 3-km MCSs, ending up further to the SE.

1-km MCS locations in better agreement with observed MCSs.

Summary

Usage of UH as a surrogate severe diagnostic depends on convective mode and environment.

Other diagnostics needed to capture potential for severe weather hazards during the cool-season and other convective hazards (e.g. tornadoes).

Evidence exists that CPM forecasts using 1-km grid spacing are needed to improve forecasts of low-level rotation associated with supercells and MCSs.

Knowledge gained with usage of severe weather diagnostics can be applied to convection-permitting climate simulations.


Thanks!