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

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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

<table>
<thead>
<tr>
<th>Event</th>
<th>Forecast Field</th>
<th>Observed Field</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heavy Precipitation</td>
<td>Accum. Precip &gt; 1 in hr$^{-1}$</td>
<td>Obs. Precip &gt; 1 in hr$^{-1}$</td>
</tr>
<tr>
<td>Severe Weather</td>
<td>Updraft Helicity &gt; 100 m$^2$ s$^{-2}$</td>
<td>All Severe Reports</td>
</tr>
<tr>
<td>Hail</td>
<td>Vertically Integrated Graupel &gt; 25 mm</td>
<td>Hail Reports</td>
</tr>
<tr>
<td>Tornado</td>
<td>Low-level vorticity &gt; 0.01 s$^{-1}$</td>
<td>Tornado Reports</td>
</tr>
</tbody>
</table>

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

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.

\[ UH = \int_{z_b}^{z_t} w\zeta \, dz \]

Supercells!

Composite Reflectivity & 2 km – 5 km UH > 50 m² s⁻²
Previous work: Surrogate approach used with dynamical downscaling

UH/Z occurrence

April

May

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

(a) SSRs
(b) SSPF ($\sigma = 120$ km)
(c) OSRs
(d) Smoothed OSRs

Forecast
Observations
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)

SSPF – per-box, per-day
SSPF – domain-wide, per-day
SSPF – domain-wide, all-season

Calibration method
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…

SPC Convective Outlook
Human forecasts (SPC) vs. SSPF

2008-2016 forecasts
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)

Verification domain
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.
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.