Assessment of CFSv2 forecasts of parameters associated with U.S. monthly tornado activity

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Is it time to consider extended range, monthly or seasonal forecasts of tornado activity?
• Observations are bad
  – Tornado data is unreliable. Data quality and uncertainty will affect results. Should first work to improve the tornado dataset.

• Numerical models are bad
  – Model have biases in the Central US. Warm season precipitation is poorly represented. Varying bias patterns in tornado-prone regions.

• Forecasts are bad
  – Extending any results based on reanalysis and observations to forecasts is problematic. Forecast biases in the central US.
A hard problem to ignore

• April and May 2011
  – $22.5 billion total losses
  – 540 fatalities

• March 2012
  – First billion-dollar weather disaster of 2012

• “You go to war with the army you have, not the army you might want or wish to have at a later time.”
Outline

• Background
• A new monthly tornado activity index
• “Perfect prognosis”
• Monthly CFSv2
  – Climatology
  – Forecasts
Basic Questions

1. Can environmental parameters explain tornado activity?

Does the distribution of environmental parameters during a month determine tornado activity?

2. Is there information in monthly environmental parameters which is associated with monthly tornado activity?

3. Are they predictable?
Background
Typical environmental parameters associated with tornadoes

- Instability, updrafts, e.g. CAPE
- Shear, e.g., 0-6km shear, Storm Relative Helicity (SRH)
Probability of severe thunderstorms with F2 tornado, 5cm hail, or 120 km/h wind gusts

**Figure 8.4.** Probability in percent of environment producing severe thunderstorm with a tornado with at least F2 damage, 5 cm diameter hail, or 120 km/h wind gusts. Based on data described by Brooks and Craven (2002).

These two steps in discrimination (severe vs. non-severe, tornadic vs. non-tornadic) can form the basis of identifying environments that are favorable for various classes of weather events. Given the sparse coverage of upper-air observations, however, carrying the discrimination to other locations is challenging. To address this problem, Brooks et al. (2003b) attempted to use data from the National Center for Atmospheric Research/National Centers for Environmental Prediction global reanalysis dataset. The reanalysis was treated as a source of pseudo-proximity soundings and the analysis of Brooks and Craven (2002) was repeated (Lee 2002). Discrimination between the severe and non-severe environments was found to be almost identical to the observed dataset. Discrimination was not as good, but still used the same variables in the same qualitative sense. Problems with sharp vertical gradients and the boundary layer in the reanalysis are likely sources of the differences. Brooks et al. (2003b) counted the number of days per year with conditions that the reanalysis identified as favorable for significant severe thunderstorms and tornadoes from a seven-year period over the

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Significant severe parameter (Craven and Brooks, 2004)
CAPE x 0-6 km Shear > 10,000 m³ s⁻³
Figure from Brooks and Dotzek (2008)
3. Results

3.1. Identification of parameters for discrimination

Previous studies indicated that CAPE and shear over a deep level of the atmosphere are good parameters to use in combination to discriminate between significant severe thunderstorms and less severe events (Rasmussen and Blanchard, 1998; Craven et al., 2002a). The question of which parcel to use in calculating CAPE does not have an obvious answer. Based on Craven et al. (2002b), we have chosen a parcel with thermodynamic properties mixed over the lowest 100 hPa. For the shear, we have chosen to use the magnitude of the vector difference between the winds at the surface and 6 km above ground level. (Since the only time we will compare shear values of different soundings will be for shear over a constant depth of the atmosphere, we will occasionally refer to the wind difference as 'shear' for simplicity.) A scatterplot of the 0–6 km shear and CAPE for all soundings with non-zero CAPE associated with severe thunderstorms from the reanalysis in the United States for 1997 to 1999 illustrates the discrimination based on the reanalysis (Fig. 1). In general, significant severe thunderstorms are associated with high CAPE and high shear. (The non-severe soundings are not included in the figure, but would predominantly be found in the low CAPE region.)

Fig. 1. Magnitude of the vector wind difference between the surface and 6 km (m s\(^{-1}\)) and CAPE (J kg\(^{-1}\)) for all reanalysis soundings associated with severe thunderstorms in US for 1997 – 1999, segregated by weather type: non-significant severe weather (small gray dots), significant, non-tornadic severe weather (large black dots), and significant tornadoes (open squares). Solid black line is best discriminator between soundings associated with significant severe thunderstorms of any kind and other soundings. Note that non-severe soundings are not included in the figure.

(Brooks et al. 2003)
The poorer agreement is also likely to result from our poorer understanding of tornadic processes. It is almost certainly true that the relationship is not as simple as can be explained by a few environmental parameters. Also, those parameters that have been suggested as important for distinguishing significant tornadoes from non-significant ones.
A new monthly tornado activity index
A monthly index for the number of U.S. tornadoes

- Index = \( \exp(\text{constants} \times \text{environmental parameters}) \)
- Constants estimated by Poisson regression
- Potential parameters = CAPE, CIN, lifted index, lapse rate, mixing ratio, SRH, vertical shear, precipitation, convective precipitation and elevation
- Estimate constants from observed \textit{climatology}
  - Avoids issues with changing technology and reporting practice
  - Same constants at all (U.S.) locations, all months of year

Data
- NARR data 1x1 degree grid. 1979-2010.
- SPC Tornado, Hail, and Wind Database. 1979-2010.
- \textit{All} tornadoes (>F0). [F1 and greater gives smaller values, similar sensitivities]
A monthly index for the number of U.S. tornadoes

- Parameters = SRH and convective precipitation
- Estimate 3 constants from annual cycle data
  - No annually varying data used to select parameters or fit constants
  - No forecast data used. “Prefect prognosis”
- Index = Expected number of tornadoes/month
  - 1x1 degree grid
  - All tornadoes (>F0).
Perfect prognosis results with NARR environmental parameters
Interannual variability

Correlation between index and observed number CONUS

<table>
<thead>
<tr>
<th>Jan</th>
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<td>0.25</td>
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(a) Annual

(b) April
Interannual variability

What is the relative importance of the factors?

Correlation between index and observed number CONUS

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<td>0.15</td>
<td>0.28</td>
<td>0.53</td>
<td>0.74</td>
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Most months, cPrcp variability is more important
Monthly CFSv2 forecasts
CFSv2 hindcasts

• 1982-2010
• First month lead
• 16 ensemble members (9-24)
• Forecast June average = start from May 21, May 26, May 31 and June 5
• Same index constants (no MOS)
Climatology
Climatology

Annual cycle

Pattern correlation NARR/CFSv2
April indices
April parameters

Apr NARR cPrcp

Apr NARR SRH

Apr CFSv2 cPrcp

Apr CFSv2 SRH
May indices

NARR

CFSv2

Obs
May parameters

- May NARR
- May NARR SRH
- May CFSv2
- May CFSv2 SRH
June indices

NARR

CFSv2

Obs
June parameters
Monthly Forecasts
Correlation between index and observed number CONUS

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## Regional correlations

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Summary

• A new index associating environmental variables and US tornado activity
  – Explains aspects of annual cycle and interannual variability

• Systematic differences between NARR and CFSv2 convective precipitation.

• Monthly CFSv2 forecasts of index show some skill on continental and regional scales

• MOS could be beneficial