Simulations of the Supercell Outbreak of 18 March 1925

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Introduction

- 18 March 1925 outbreak spawned the Tri-State tornado
  - Deadliest and longest track tornado in U.S. history
    - Killed nearly 700 people
    - 215 mile long damage path
      - Missouri, Illinois, Indiana
Introduction

All times are local

Changnon and Semonin (1966)
Introduction

- Widespread severe weather outbreak
  - Numerous tornado and hail reports
- Comparable to other historical outbreaks
  - 3 April 1974 area shown for comparison

Maddox et al. (2011)
Motivation

• This is the most significant tornado in U. S. history
  – Need to understand why this tornado was so unique
• However, there is a lack of data from this event
  – No pictures of the tornado or storm
  – Radar network did not yet exist
  – No upper air data (no sounding network)
  – We do have surface observations
    • U.S. Weather Bureau maps
    • U. S. Weather Bureau 1014 and 1001 forms
      – Pressure, temperature, dew point, wind speed, wind direction
Event Overview

13 UTC 18 March 1925

18 UTC 18 March 1925

Subjective analysis created from sfc observations collected from U.S.W.B. 1011 and 1014 forms

• At 13 UTC, outflow from overnight convection is slowing northward progression of warm front
  • Tornado first reported ~18 UTC in southeast Missouri
    • Tornadic storm formed near the triple point

Maddox et al. (2011)
Purpose

• Better understand the storm environment that produced this historic event
  - Maddox et al. (2011) used the surface observations to investigate structure of the surface low pressure system
    • Tornado formed near location of triple point
  • By simulating this event, we can look at modern-day indices that have been shown to be good indicators of severe weather
    • CAPE, wind shear, storm relative environmental helicity
    • These indices all require knowledge of 3-D structure of the atmosphere
      - Not available in 1925
Methodology

• Data from 20th century reanalysis project
  – 56 ensemble members
• Use data collected from U.S. Weather Bureau forms (1011 & 1014) to determine the ‘best’ ensemble member
  – Correlation between observed sea level pressure and sea level pressure from ensemble member
• Model Evaluation Tools (MET)
Methodology

Member ‘B’ was chosen due to high correlation at all times

0 Z (18 March), 12 Z (18 March), 18 Z (18 March)
Methodology

- WRF-ARW V3.2
- 5 nests
  - 50 x 30 dx = 162 km
  - 94 x 58 dx = 54 km
  - 178 x 124 dx = 18 km
  - 304 x 202 dx = 6 km
  - 637 x 466 dx = 2 km

Nests 1, 2, & 3 initialized at 0 Z on 18 March 1925

Nests 4 & 5 initialized at 12 Z on 18 March 1925

Model run ends at 0 Z on 19 March 1925
Results

Comparison of Model Forecast to Observations

- Good agreement between position of low pressure center
- Modeled low pressure system is somewhat elongated
- Isotherms match well
- Model is too dry in the warm sector
Results

Comparison of Model Forecast to Observations

18 Z

- Moisture in the southeast now agrees well
- Temperatures match well in the region of interest
- Modeled low is accurately positioned, although somewhat distorted
- Modeled warm front too far north
Results

**Storm Environment**

Indicates a low CAPE – high shear environment. This setup has been shown to be common in ‘cool’ season tornadic events [e.g. Johns et al. (1993)]
Results

A quick note on ‘typical’ CAPE and shear values

For significantly tornadic events:
CAPE > 2000 J kg\(^{-1}\) is common
CAPE in our simulation is < 1000 J kg\(^{-1}\) across much of Tri-state track
0-6 km shear < 30 m s\(^{-1}\) but > 20 m s\(^{-1}\) is common
Shear in our simulation is > 30 m s\(^{-1}\) across portions of Tri-state track
Results

**Storm Environment**

- Large values of helicity near the track of the Tri-State tornado
- Shown to be associated with significantly tornadic events

Thompson et al. (2003)
Results

- ‘Dominant’ cell tracks across Missouri, Illinois and Indiana
- Track closely follows that of the actual Tri-state tornado damage path
Results

Modeled sounding and hodograph near Baker, MO at 19 Z

- CAPE = 667
- SREH = 297
- CIN = -55
- LCL = 929
- LFC = 646
- SHEAR = 58 (kts)
Discussion

• How do we be confident the modeled storm environment is representative of the actual event?
  – Results compare well with recent studies of weak CAPE tornadic events

Timing of weak CAPE tornadoes:
More likely to occur during cool season
More likely to occur during morning hours

Guyer and Dean (2010)
Summary

• Model output for ‘best’ ensemble member shows reasonable agreement with surface observations
  – Dew point too small in some locations at 13 Z
  – Warm front position is off by 18 Z
• Model results suggest the Tri-State tornado occurred in a low CAPE, high shear environment
  – Typical of cool season tornadic events
• Simulation produces a convective feature that approximately follows track of Tri-state tornado damage path
Ongoing Work

• Improve quantification of ‘best’ ensemble member
  – Look at correlation of temperature and dew point in addition to sea level pressure
• Test sensitivity to model parameterizations
  – e.g. microphysics
• Increase resolution
  – Add additional nests
• Increase accuracy of 20\textsuperscript{th} century reanalysis data
  – Assimilate pressure more frequently
Questions?
Extra Slides

• WPS configuration
  – Map projection
    • Lambert Conformal
  – Interpolation method:
    • 16 point overlapping parabolic interpolation
    • 4 point bilinear interpolation
Extra Slides

• MET configuration
  – Confidence interval: 0.05
  – Interpolation method: distance weighted mean
  – Interpolation region: 9 x 9