Simulations of the Supercell Outbreak of 18 March 1925

Jason Naylor
University of North Dakota

Melissa Becker, Matthew Gilmore, Justin Weber
University of North Dakota

Robert Maddox
Tucson, AZ

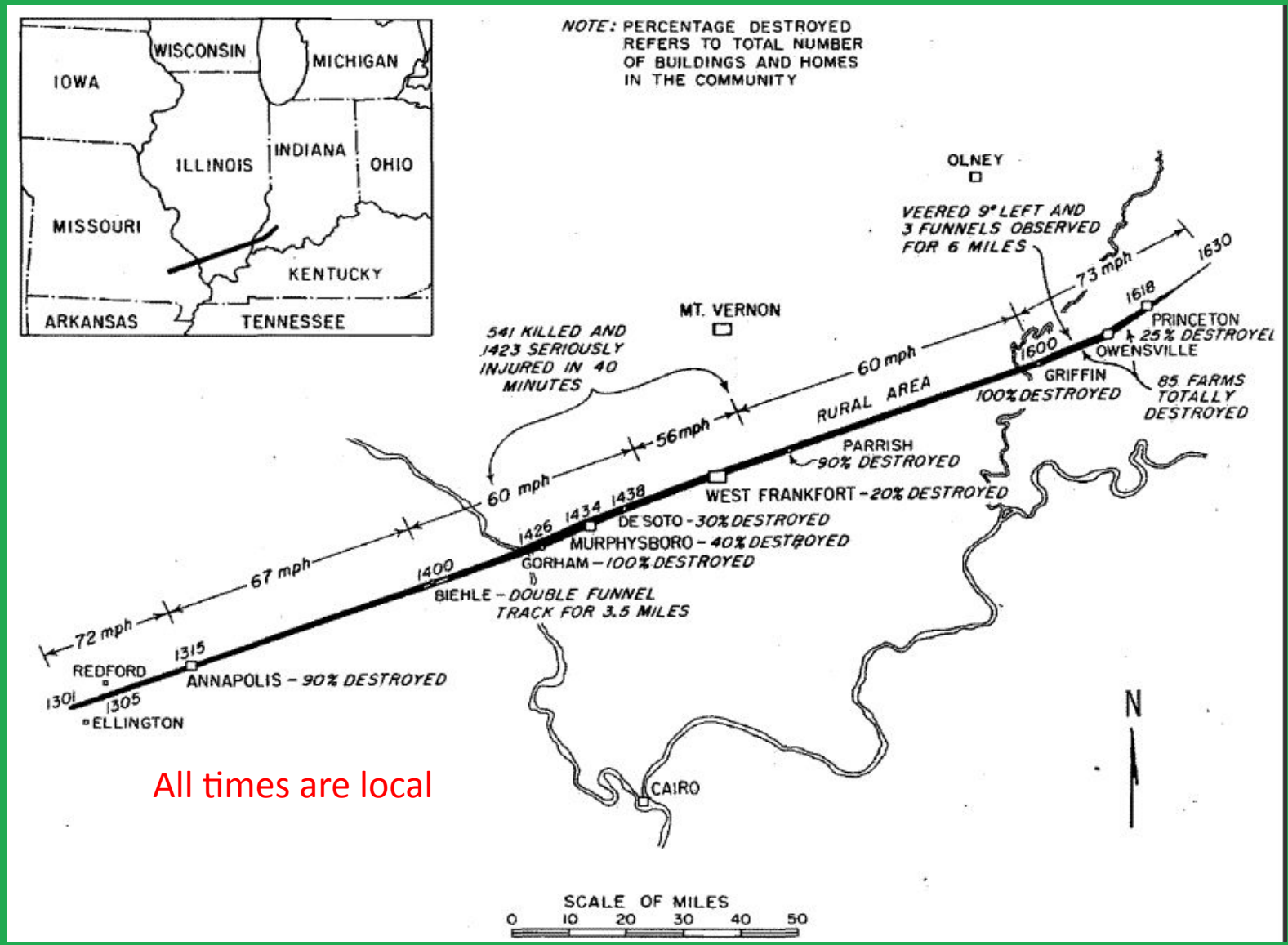
Gilbert Compo, Jeffrey Whitaker, Thomas Hamill
NOAA Earth System Research Laboratory

This research was supported by NSF grant AGS-0843269. Computational resources were provided through Teragrid allocation TG-ATM100039.

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

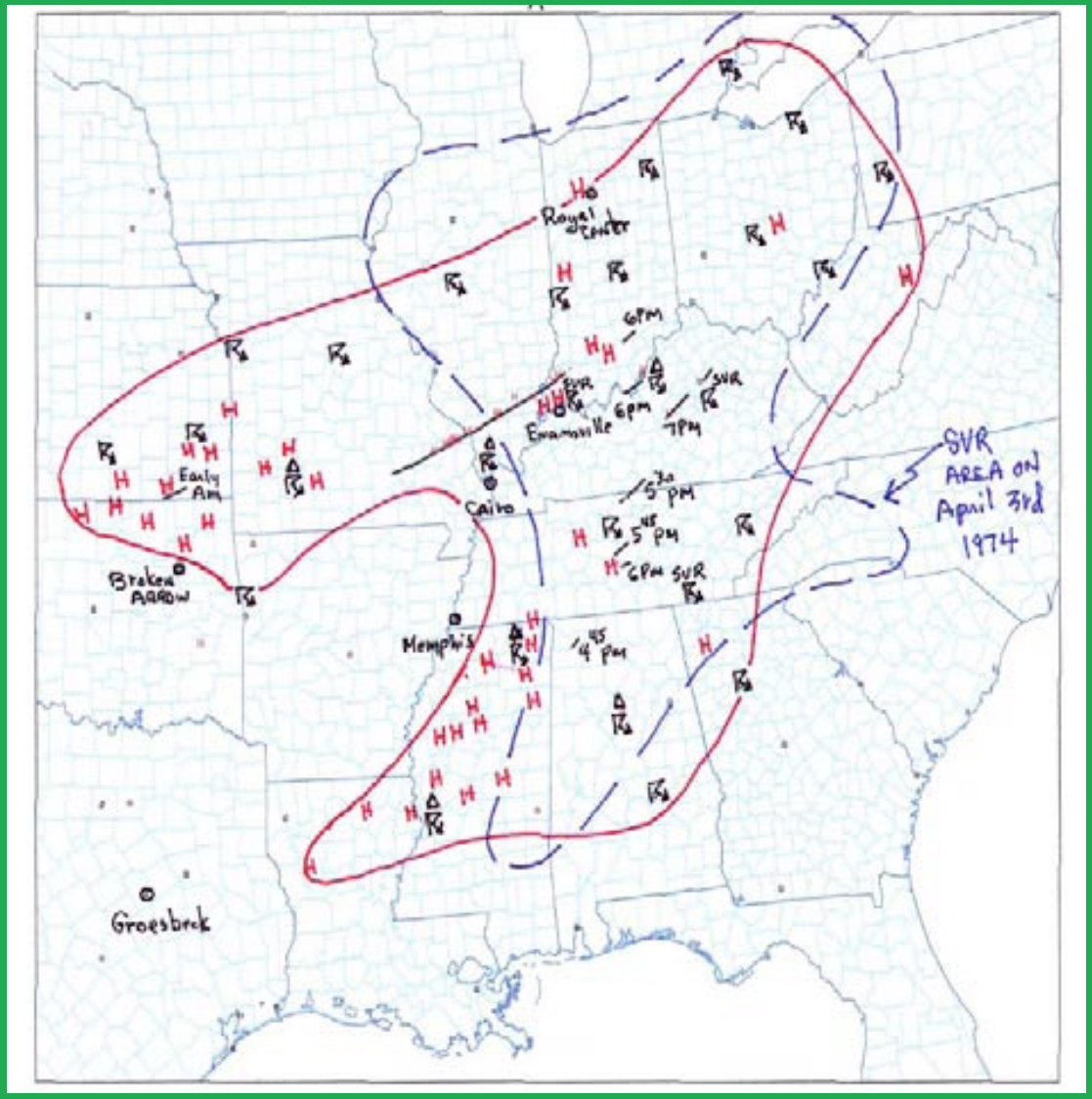
Introduction



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

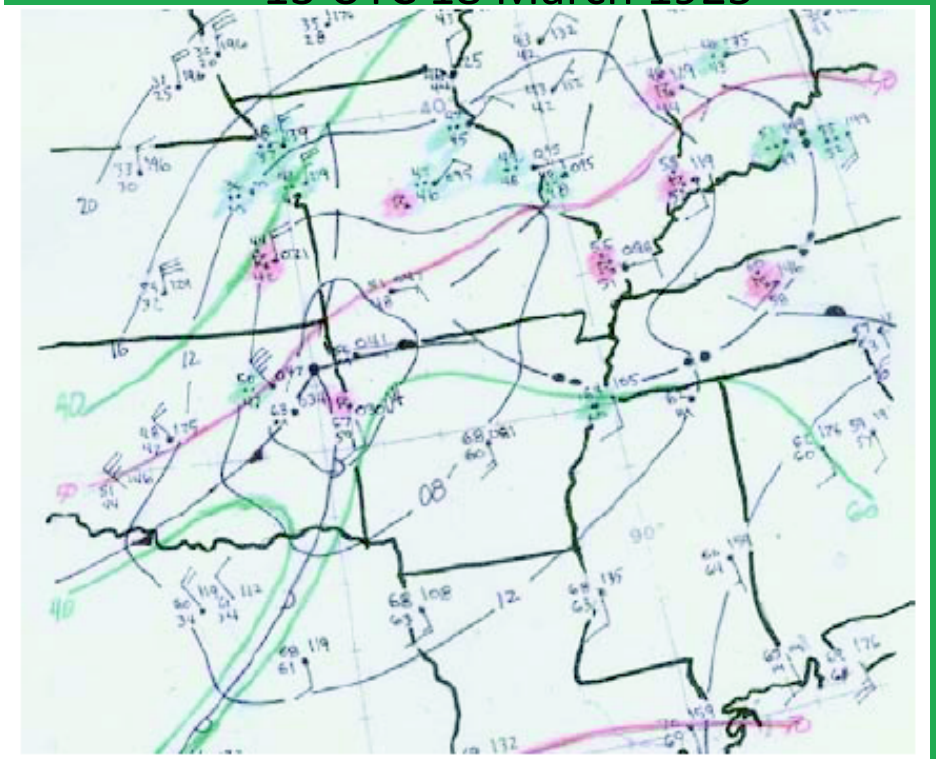
Maddox et al. (2011)

Motivation

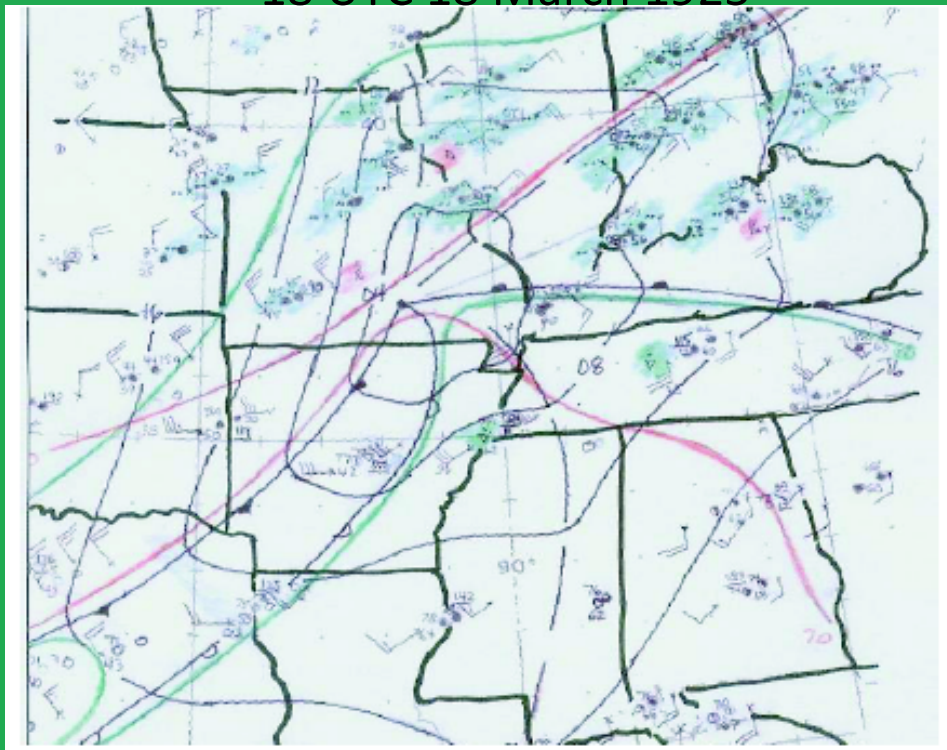
- **This is the most significant tornado in U. S. history**
  - Need to understand why this tornado was so unique
- However, there is a lack of data from this event
  - No pictures of the tornado or storm
  - Radar network did not yet exist
  - No upper air data (no sounding network)
  - We do have surface 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

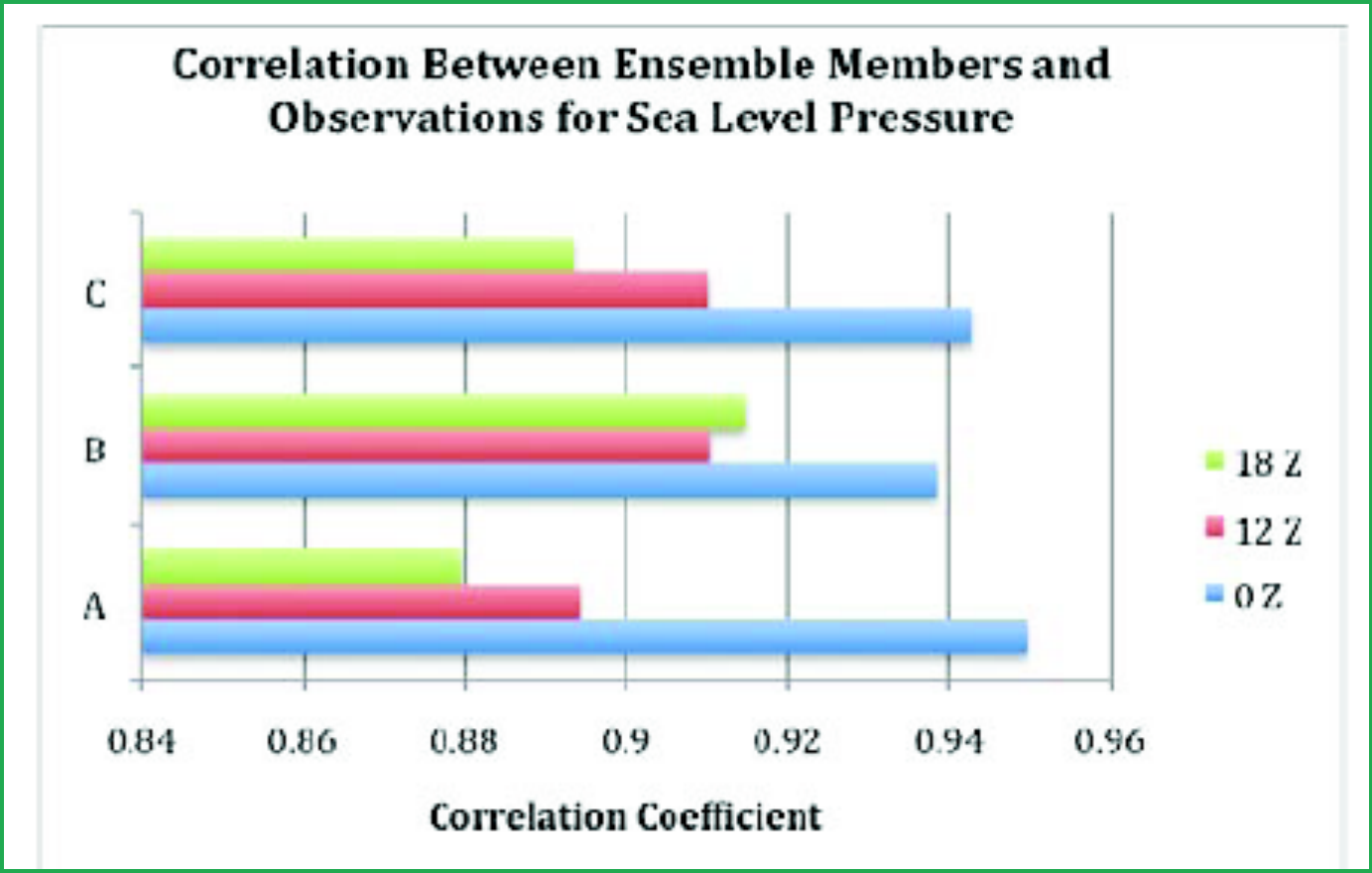
- Better understand the storm environment that produced this historic event
  - Maddox et al. (2011) used the surface observations to investigate structure of the surface low pressure system
    - Tornado formed near location of triple point
- By simulating this event, we can look at modern-day indices 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)

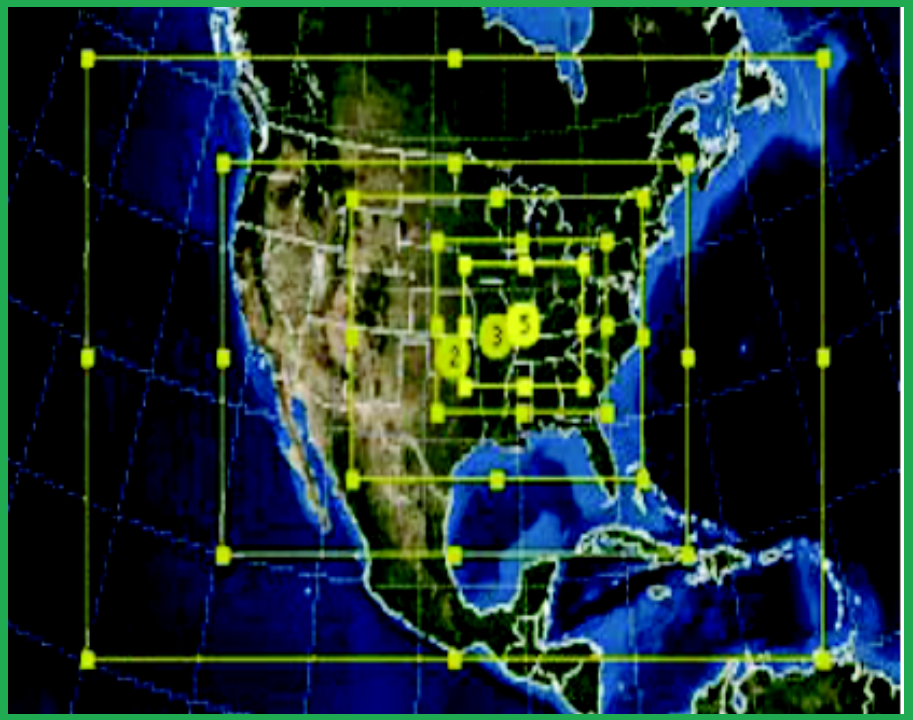
Methodology

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



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

Methodology



Microphysics	WDM-6
Boundary Layer	YSU
Surface layer	Noah land-surface
Convective	Kain-Fritsch
Radiation	Dudhia (sw) rrtm (lw)

- WRF-ARW V3.2
- 5 nest
  - 50 x 30 dx=162 km
  - 94 x 58 dx =54 km
  - 178 x 124 dx = 18 km
  - 304 x202 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

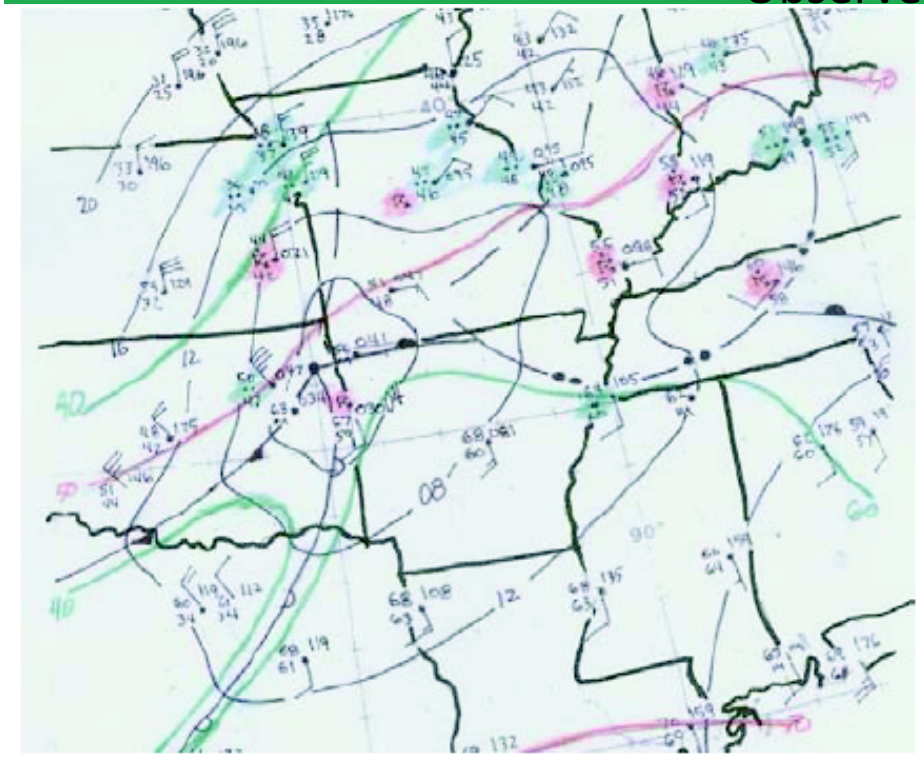
Model run ends at 0 Z on 19 March 1925

Results

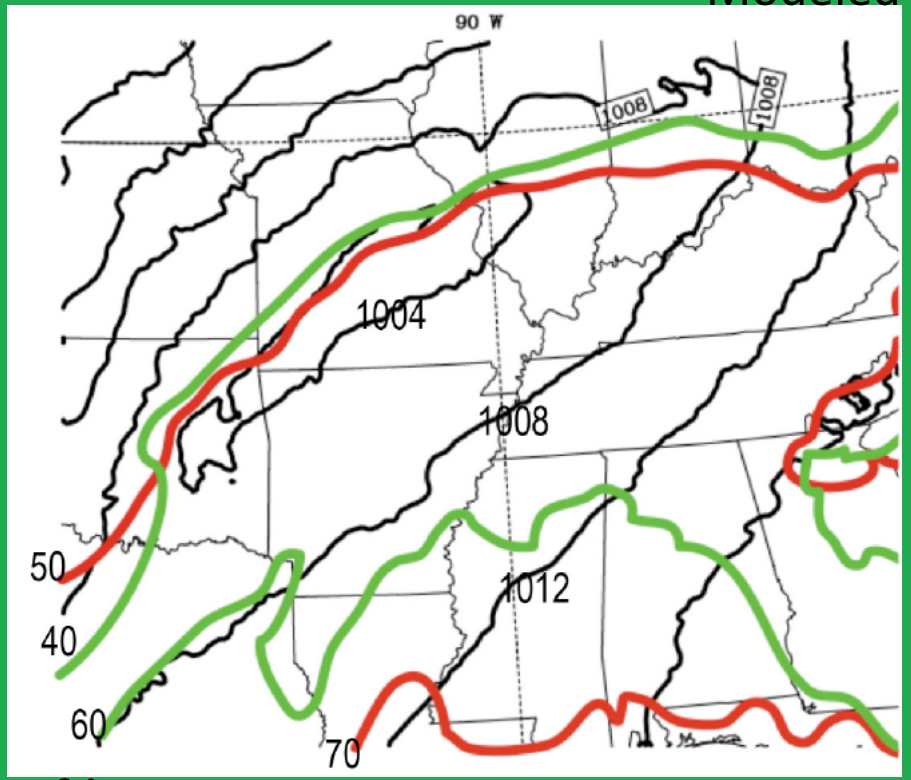
Comparison of Model Forecast to Observations

13 Z

Observed



Modeled



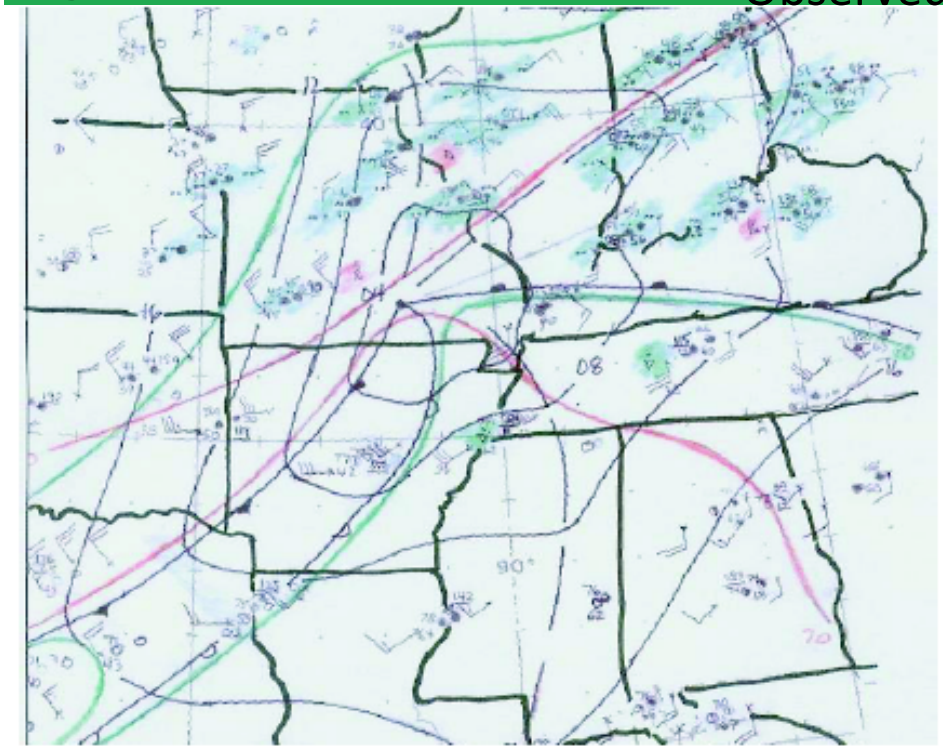
- Good agreement between position of low pressure center
- Modeled low pressure system is somewhat elongated
- Isotherms match well
- Model is too dry in the warm sector

Results

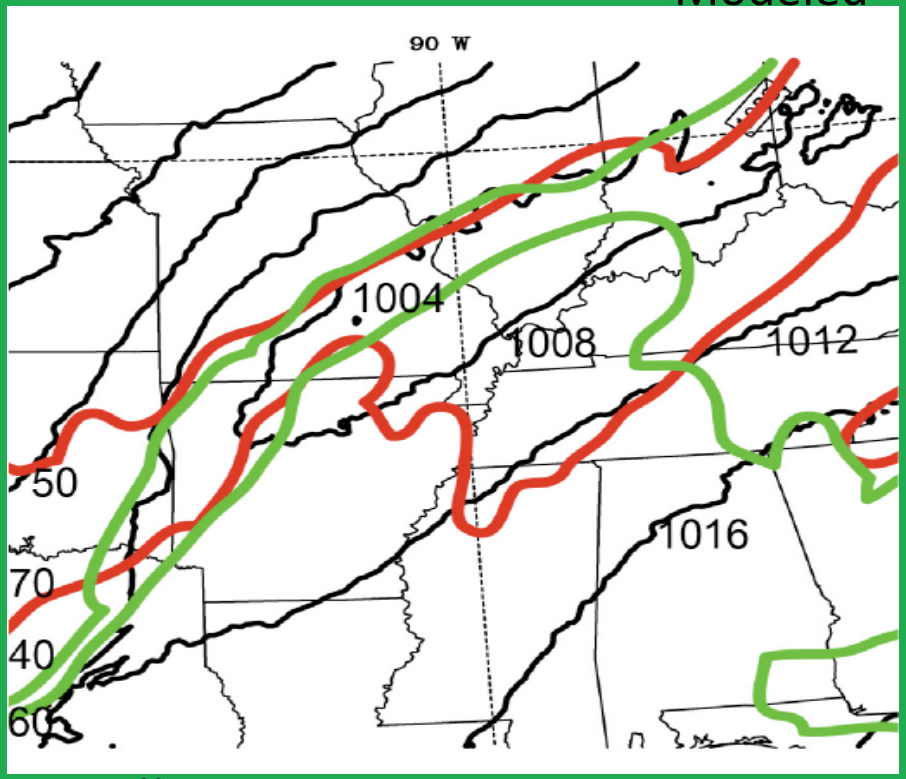
Comparison of Model Forecast to Observations

18 Z

Observed



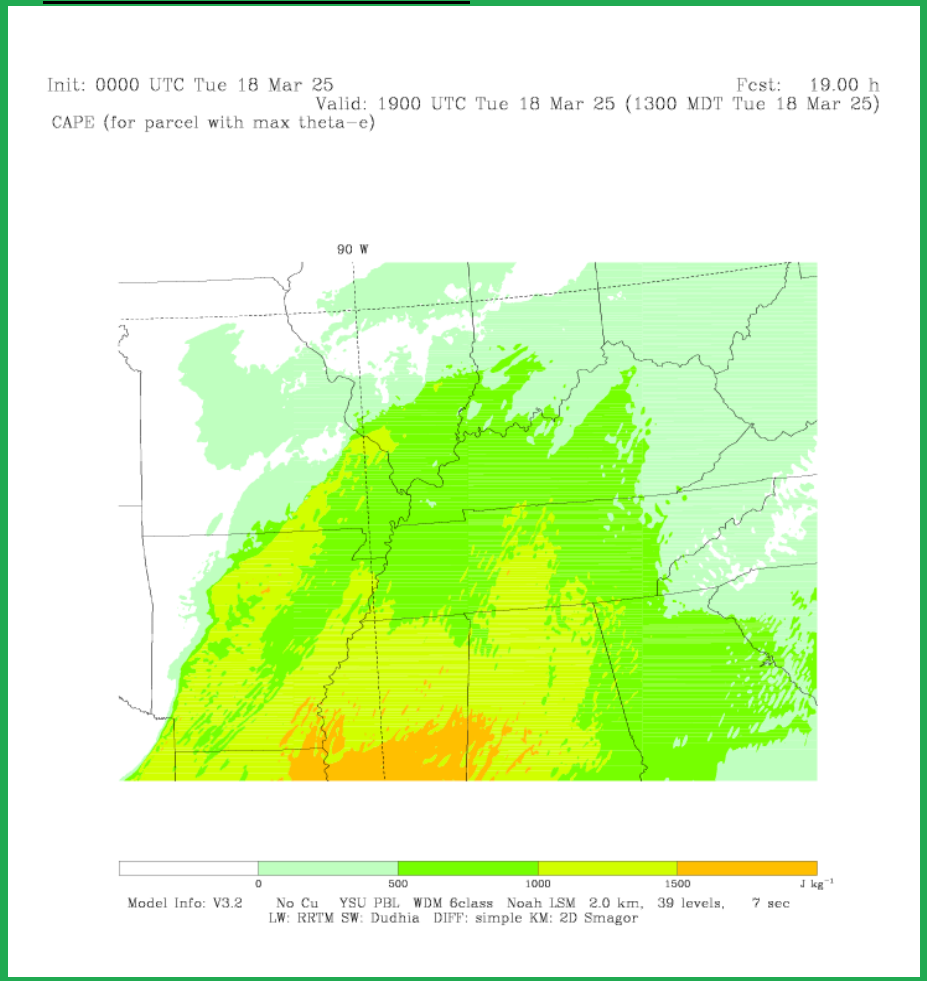
Modeled

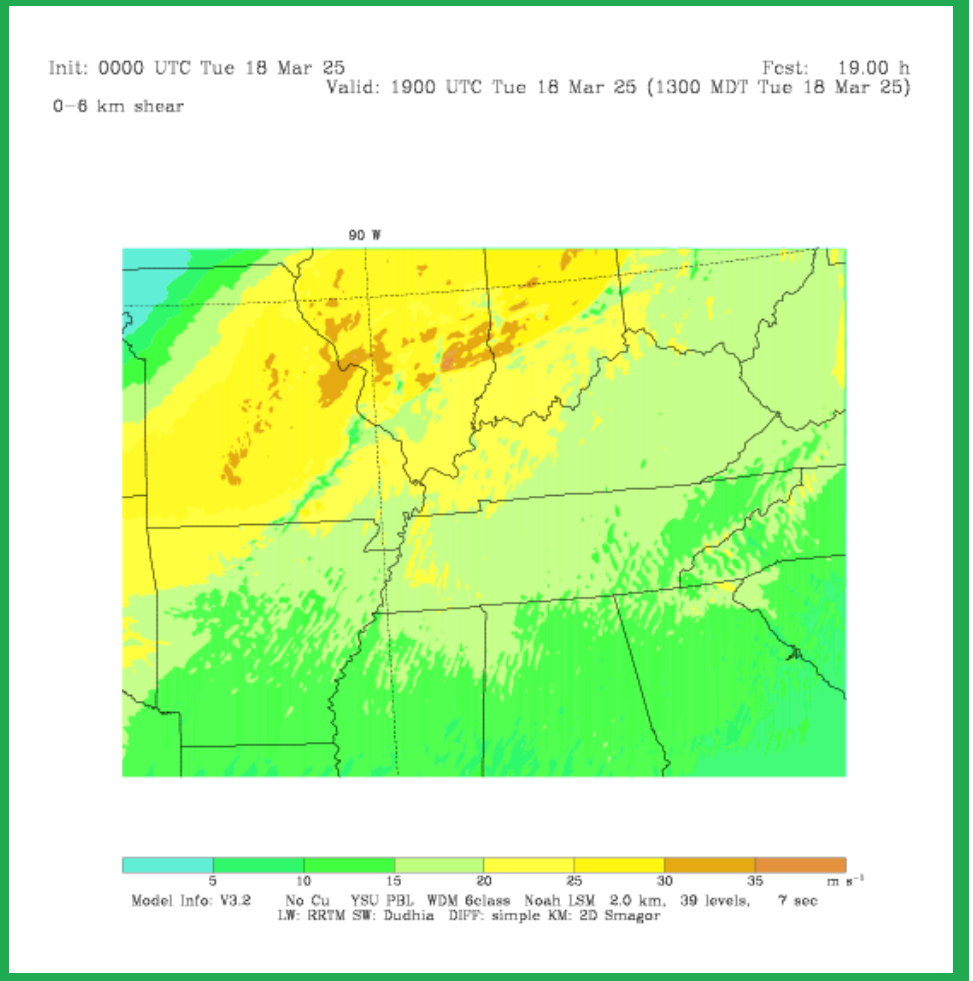


- Moisture in the southeast now agrees well
- Temperatures match well in the region of interest
- Modeled low is accurately positioned, although somewhat distorted
- Modeled warm front too far north

Results

Storm Environment



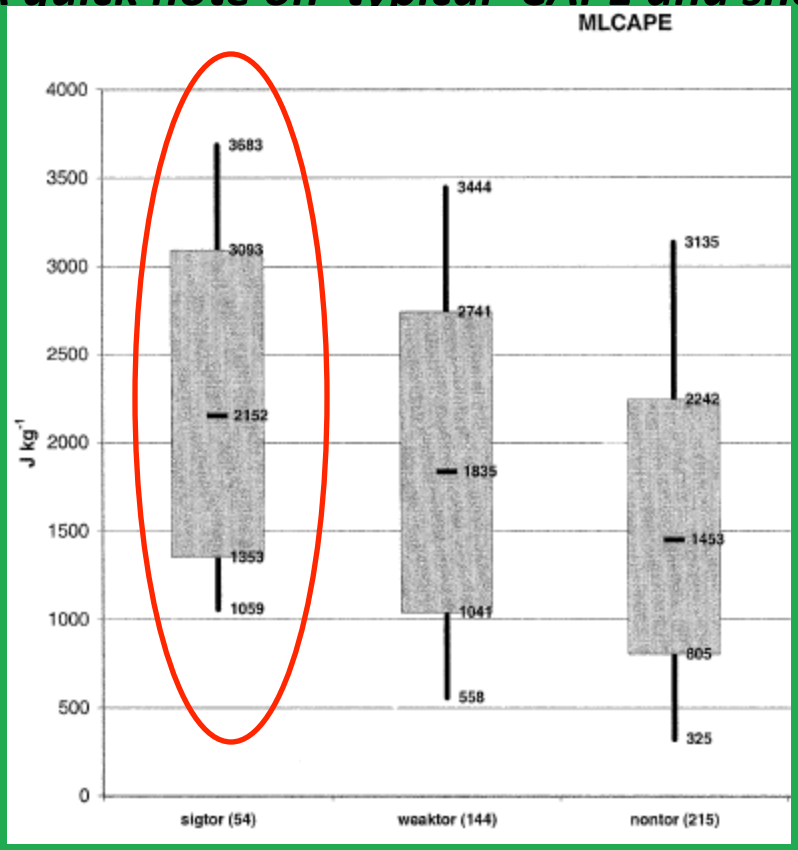


Indicates a low CAPE – high shear environment. This setup has been shown to be common in 'cool' season tornadic events [e.g. Johns et al. (1993)]

Thompson et al. (2003)

Results

A quick note on 'typical' CAPE and shear values



<u>For significantly tornadic events:</u>

CAPE > 2000 J kg-1 is common

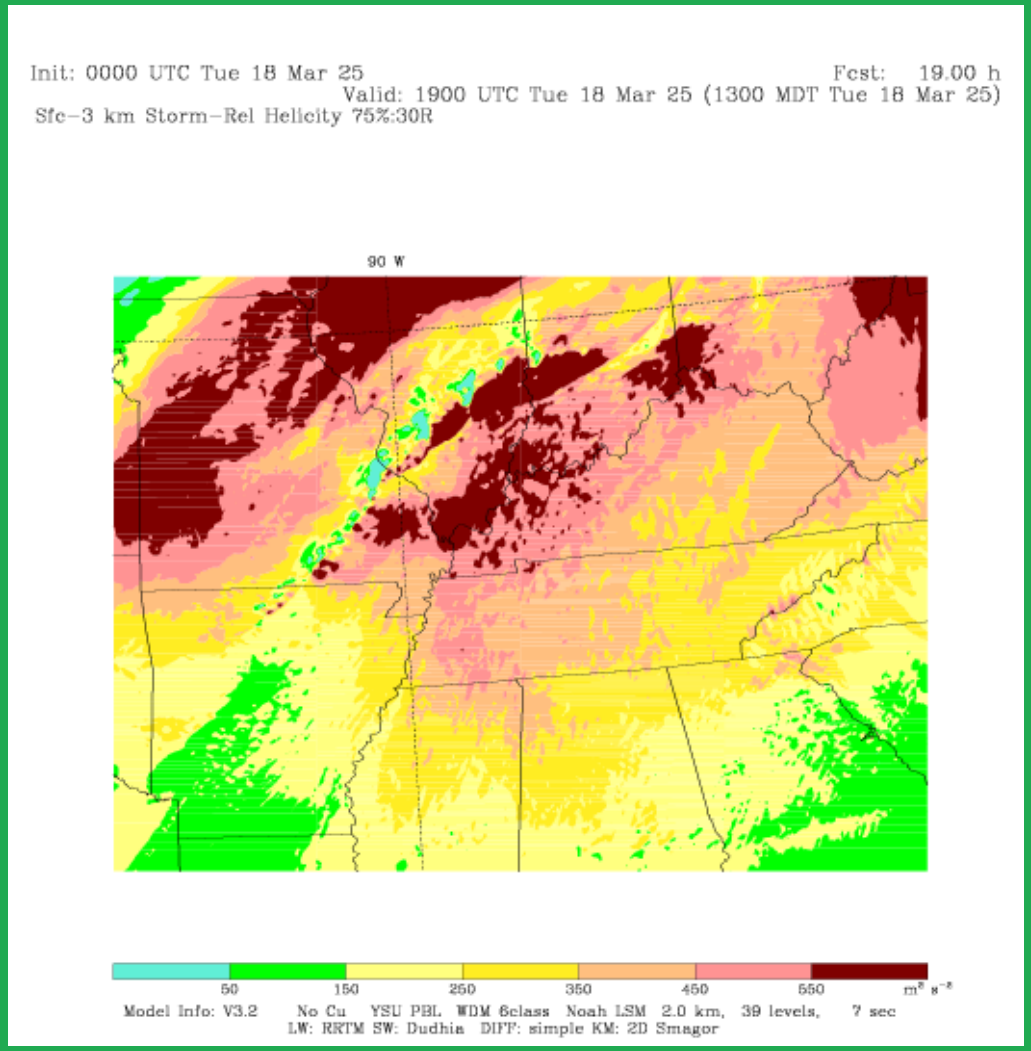
CAPE in our simulation is < 1000 J kg^{-1} across much of Tri-state track

0-6 km shear < 30 m s^{-1} but > 20 m s^{-1} is common

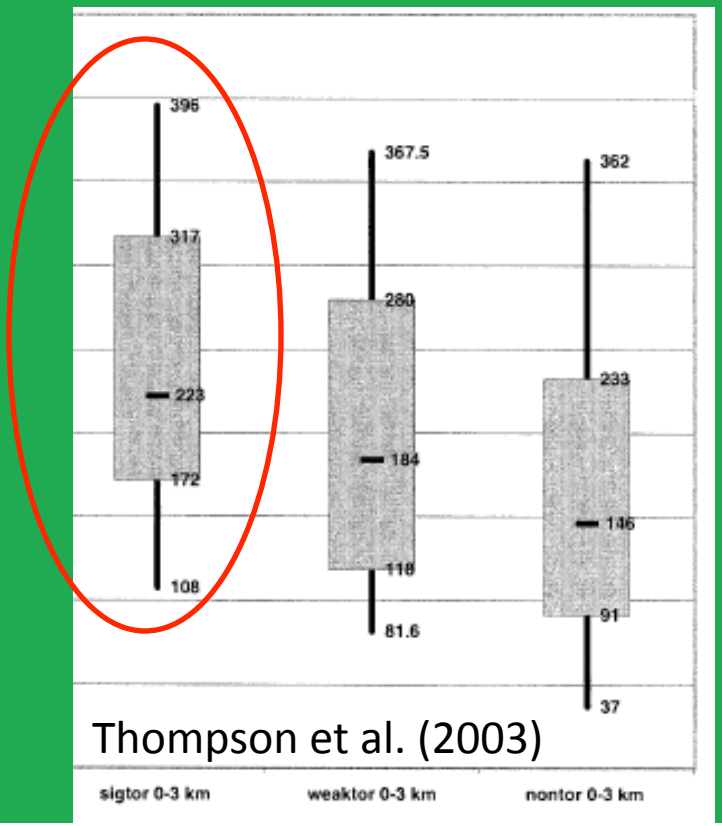
Shear in our simulation is > 30 m s^{-1} across portions of Tri-state track

Results

Storm Environment

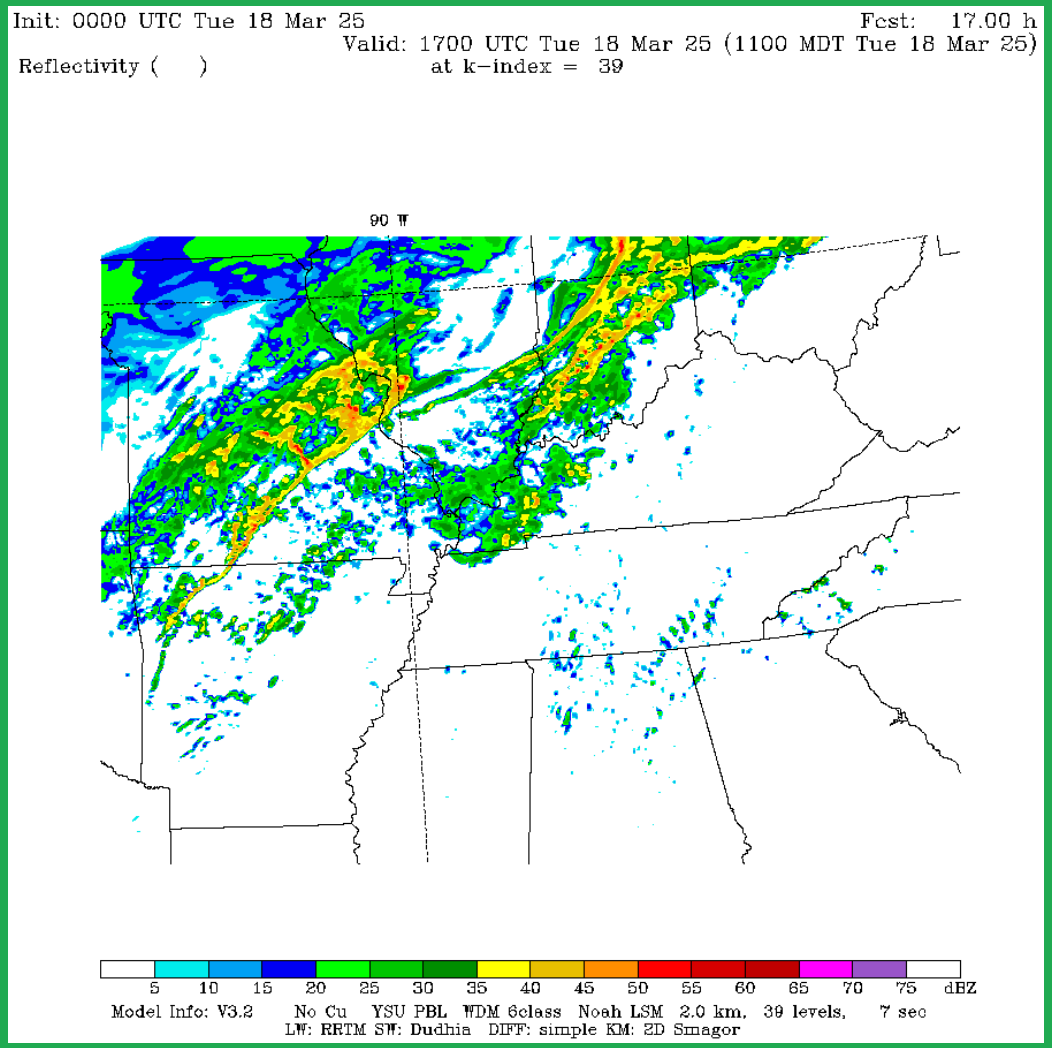


- Large values of helicity near the track of the Tri-State tornado
  - Shown to be associated with significantly tornadic events



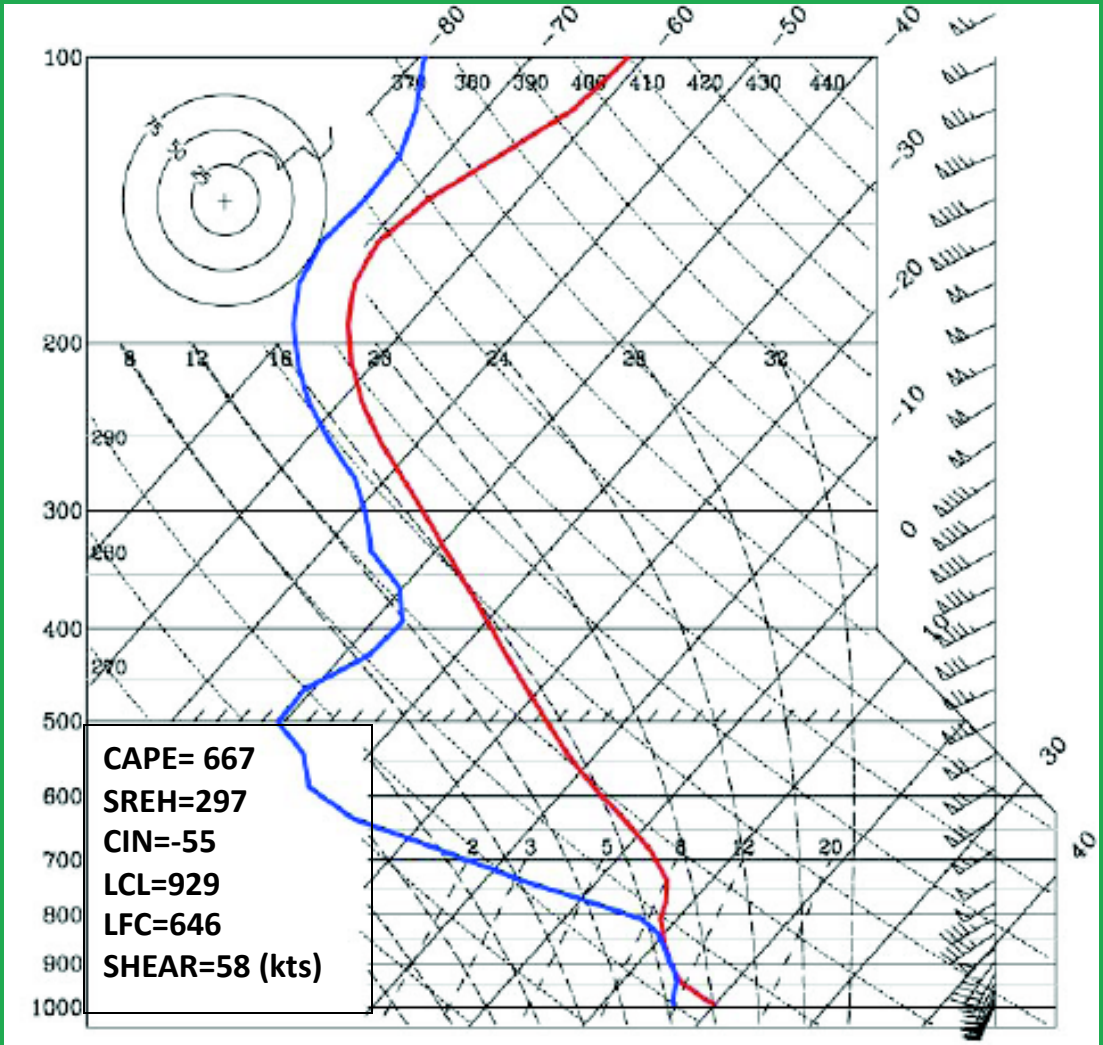
Thompson et al. (2003)

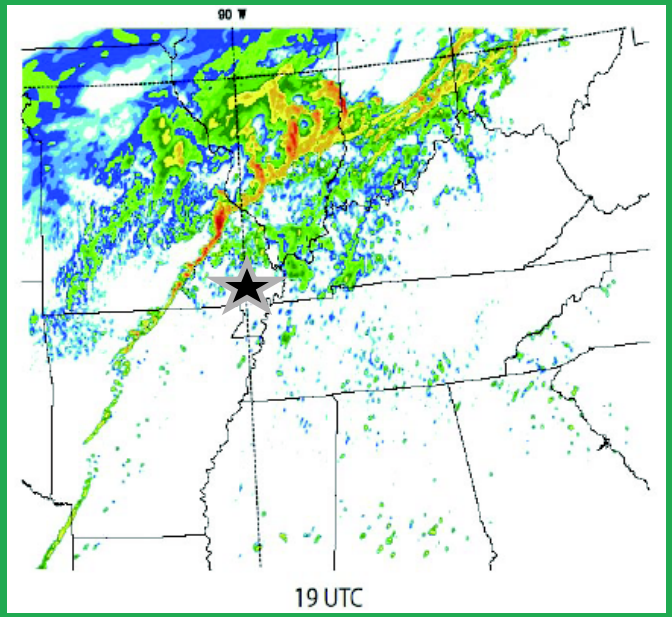
Results



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

Results

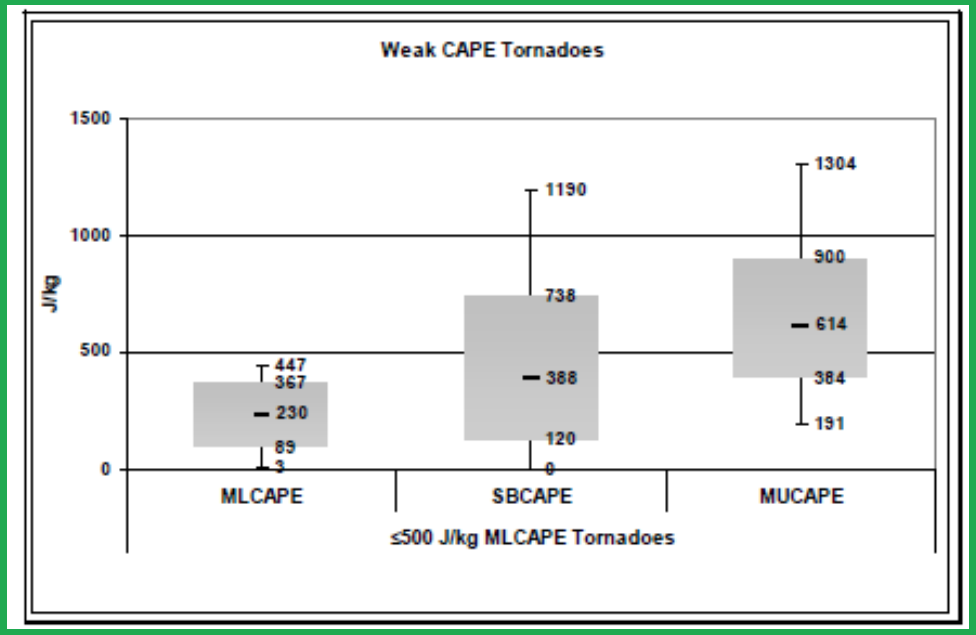


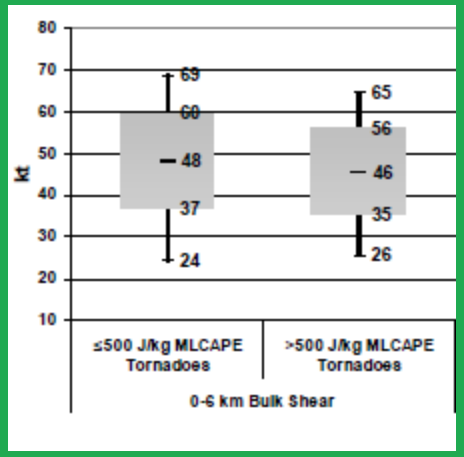


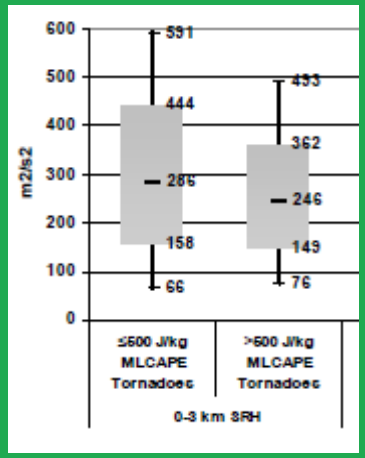
Modeled sounding and hodograph near Baker, MO at 19 Z

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







<u>Timing of weak CAPE tornadoes:</u>

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 20th 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