Synoptic Regulation of the 3 May 1999 Oklahoma Tornado Outbreak

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To appear: Weather and Forecasting (June 2002)
The Outbreak: Facts

- 66 tornadoes, produced by 10 long-lived and violent supercell thunderstorms
- Oklahoma City’s first F5 tornado
- Almost 2300 homes destroyed and 7400 homes damaged
- Over $1 billion in damage, the nation’s most expensive outbreak
- 45 fatalities, 645 injuries in Oklahoma
- About 500–700 expected fatalities in days before outlook/watch/warning system (Brooks)
Forecasts from the Storm Prediction Center were updated as forecaster confidence grew.

First tornado watch preceded the F5 tornado by 2.5 hours.

The Forecast Office in Norman, Oklahoma, issued 31 severe thunderstorm and 48 tornado warnings with 48 mins. of avg. lead time for F2 and greater tornadoes (18 mins. lead time for all tornadoes).

(NWS)
Despite the Successes, Considerable Uncertainty Existed Among Forecasters

- Jet streak/shortwave trough
  - (PV filament or southern PV anomaly)
  - initial and forecast strength of this feature
- Cirrus
  - Would the cirrus inhibit destabilization?
  - Associated with tropospheric-deep ascent?
- Dryline
  - diffuse, with weak surface convergence

pressure (hPa) on dynamic tropopause
(1.5-PVU surface)
CNTL simulation
Satellite Imagery

1745 UTC 3 May 1999

cirrus

Satellite Imagery

(Thompson and Edwards 2000)

1902 UTC 3 May 1999

(Thompson and Edwards 2000)
Objective

Through observations and numerical-modeling investigations, explore the impact of the three processes hypothesized by forecasters to be important in the outbreak: **dryline, cirrus, and PV filament**.

Modeling experiments: We’re not considering explicit prediction of the supercells, but investigating the environment in which they formed.
Model Characteristics

- MM5: cold start with initial and lateral conditions provided from the 0000 UTC 3 May forecast cycle of the AVN
- 4 domains: 54-km, 18-km, 6-km, 2-km
- 23 levels

- Reisner, Kain–Fritsch (outer two domains), Blackadar PBL, cloud radiation every 2 min, 5-layer soil model

Stage IV Radar/Gauge Precip. Analysis (Baldwin and Mitchell 1997)
CNTL

d4

pink:
1.5-km w
(> 0.5 m/s)

blue:
9-km
cloud-ice
mixing ratio
(>0.1 g/kg)

2300 UTC
0000 UTC
0100 UTC
0200 UTC

PBL Similarities: Observed and Model

• Convection initiated within relatively homogeneous air mass

• Diffuse/double dryline

• “Billow” clouds

2100 UTC 3 May:
surface dewpoint (every 2°C),
vertically integrated cloud water and cloud ice
Convective Initiation

- thin lines: 1800 UTC
- thick lines: 2240 UTC
(10 minutes prior to convective initiation)

- warm cap removed
- moist layer deepened

Convective Initiation in Cirrus Gaps

- 2210 UTC
- 2230 UTC
- 2250 UTC
- 2310 UTC

- 9-km cloud-ice mixing ratio
- maximum vertical motion in column
Modeled Storms as Supercells

- Identify updrafts (>5 m/s) correlated with vertically coherent relative vorticity for at least 60 minutes
- 22 supercells, 11 of which are on OK–TX border
- Can’t address tornadogenesis
Observed vs Modeled Supercells

<table>
<thead>
<tr>
<th></th>
<th>OBSERVED</th>
<th>MODELED</th>
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<tbody>
<tr>
<td>LIFETIMES (minutes)</td>
<td>120–450 minutes for 10 supercells</td>
<td>60–170 minutes for 11 supercells near OK–TX border</td>
</tr>
<tr>
<td>MEDIAN LIFESPAN (minutes)</td>
<td>203</td>
<td>90</td>
</tr>
<tr>
<td>SIMULTANEOUS STORMS</td>
<td>7</td>
<td>5</td>
</tr>
<tr>
<td>LONGEST TRACK (km)</td>
<td>250</td>
<td>160</td>
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Experiments

CNTL: control simulation

NOPV: PV filament removed from initial conds.

2XPV: PV filament doubled in initial conds.

NOCR: cloud-radiative effects turned off
PV-Surgery Methodology

- Compute mean and anomaly PV from 0000 UTC 3 May to 0300 UTC 4 May.
- Isolate PV filament from PV-anomaly field at 0000 UTC 3 May.
- Use PV inversion to calculate the induced flow (wind, temperature, and height) associated with the PV filament (Romero 2001; Davis and Emanuel 1991)
- Remove PV filament, restart MM5 without the filament in the initial conditions

Initial Conditions

- NOPV
- CNTL
NOPV

**NOPV vs 2XPV Precipitation**

Accumulated precipitation: 1800 UTC 3 May to 0300 UTC 4 May

1, 5, 10, 15, 25, 50, 100 mm
Quantifying importance of PV filament pressure on tropopause

2100 UTC 3 May

0300 UTC 4 May

Moore

2100 UTC 3 May

0300 UTC 4 May
Quantifying importance of PV filament pressure on tropopause

2XPV
2100 UTC
3 May

0300 UTC
4 May

NOCR
Summary

- 30-h forecast produced long-lived supercells, albeit with errors in timing and location, regardless of southern PV anomaly strength.
- Convective initiation was favored east of the dryline in weakened cap: lower-level moistening and synoptic-scale ascent due to PV anomaly.
- Breaks in cirrus were favored locations for convective initiation, but were neither necessary nor sufficient.
- Cirrus shield limited widespread convection and reduced competition between storms.