# 2024 Fall Scholarly and Creative Activities Poster Symposium

# Numerical Simulation of a Severe Convective Storm in Texas using the WRF Model

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## Abstract

This research study focuses on some of the most crucial atmospheric variables that fuel long-lived, dangerous tornado outbreaks. Understanding these variables with model simulations is essential for predicting severe storms hazards. This numerical study analyzed variables including CAPE (convective available potential energy), vorticity, updraft motion, and moisture in order to discover potential patterns in a devastating tornado outbreak, particularly the outbreak of April 29, 2017 in Texas.

## Motivation

- Gaining experience with WRF (Weather Research and Forecasting) model simulations.
- Discovering patterns in tornadic storms that lead to their formation.
- Acquiring the skill of predicting tornado outbreaks accurately.
- Hypothesis: High vorticity/updraft motion and high moisture/CAPE values have a synergistic effect in intensifying tornado outbreaks.

## Methodology

1) Set up the inner and outer domain in WPS (WRF Preprocessing System), with the inner domain being centered on Texas and the outer domain encompassing the United States.
2) Obtain the initial and boundary conditions of the WRF simulations from the ERA5 reanalysis data site (Hersbach et al. 2019).
3) Complete the WPS steps of geogrid, ungrib, and metgrid, and run the full WRF simulation.
4) Search for variables of interest using ncview.
5) Use python codes for post-processing, and a gif maker to make a continuous simulation out of all the WRF outputs.

## Study Domain Setup

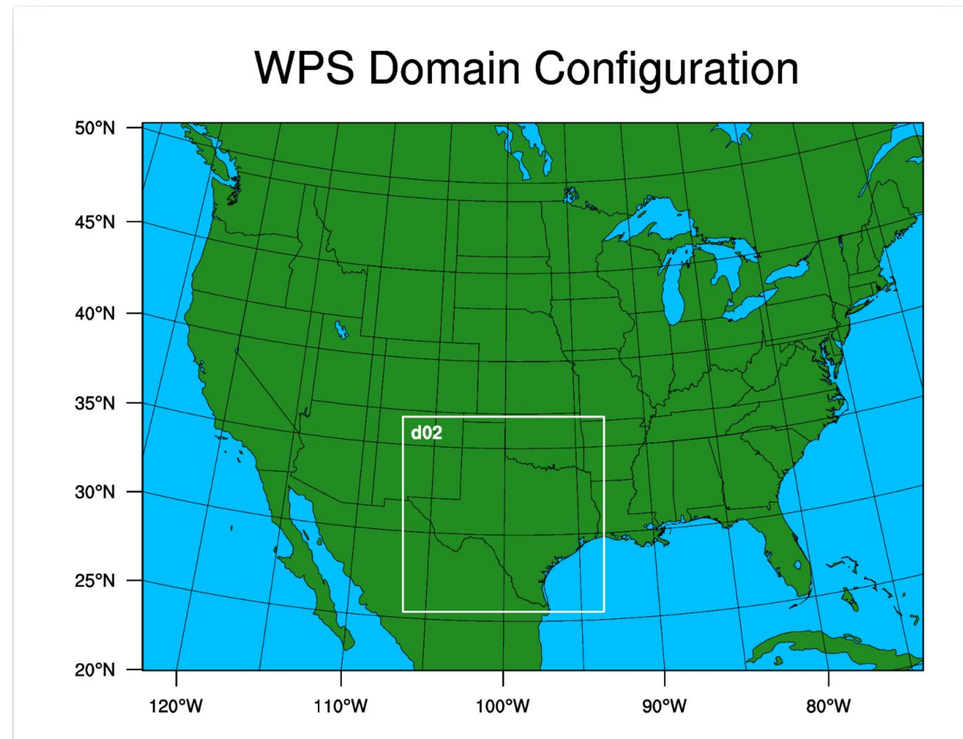


Fig. 1. Study Domain Configuration map.

- Map of the *outer* domain (d01) containing the contiguous United States, and the *inner* domain (d02) over the state of Texas, with a resolution of 21 km and 3 km respectively.

Table. 1. WRF Model Specifications.

| Model Specifications | d01 | d02 |
|---|---|---|
| Computational Domain | Refer to Fig. 1 | Refer to Fig.1 |
| Horizontal Resolution | 21 km | 3 km |
| Cumulus Parameterization | Kain-Fritsch | N/A |
| Planetary Boundary Layer | YSU | |
| Cloud Microphysics | Thompson | |

## Results

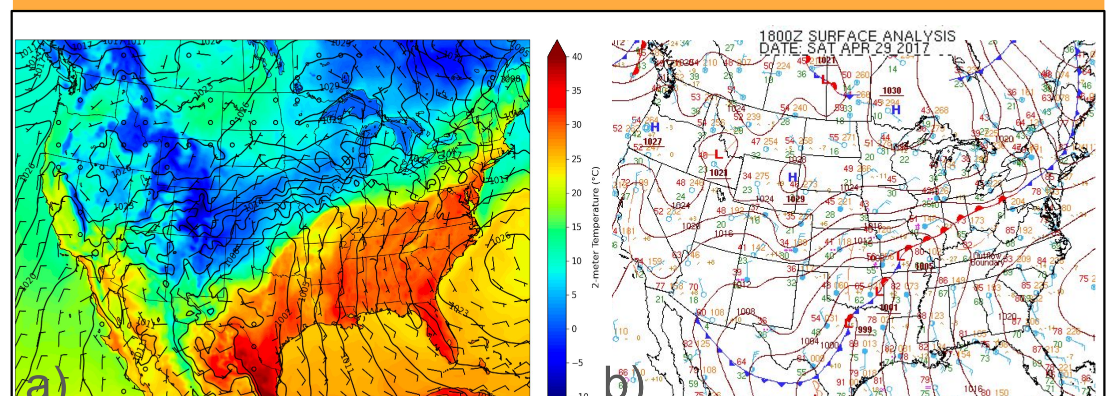

Fig. 2. (a) Simulation of Sea Level Pressure (SLP) at the surface, 2-m temperature, & 10-m wind barbs. b) Observed Conditions (NOAA) on 4/29 at 18 UTC.

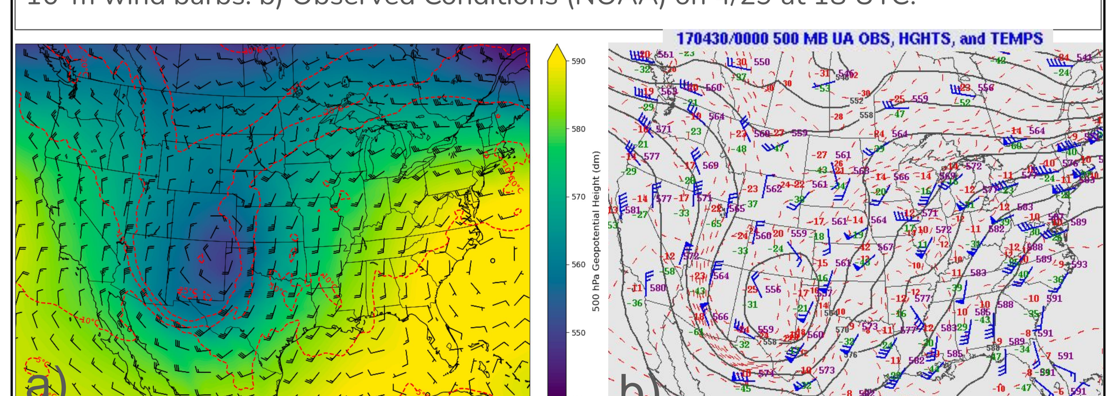

Fig. 3. (a) Simulation of 500-mb geopotential height, isotherms, & wind barbs. (b) Observed Conditions (NOAA) on 04/30 at 00 UTC.

### Synoptic Conditions

- The composite map (fig. 2a) demonstrates a low pressure system, an advancing cold front through texas, and light southern winds.
- The composite map (fig. 3a) illustrates a lower geopotential height in the region of cold temperature and low pressure, with strong upper level winds coming from the South.

## Results (cont.)

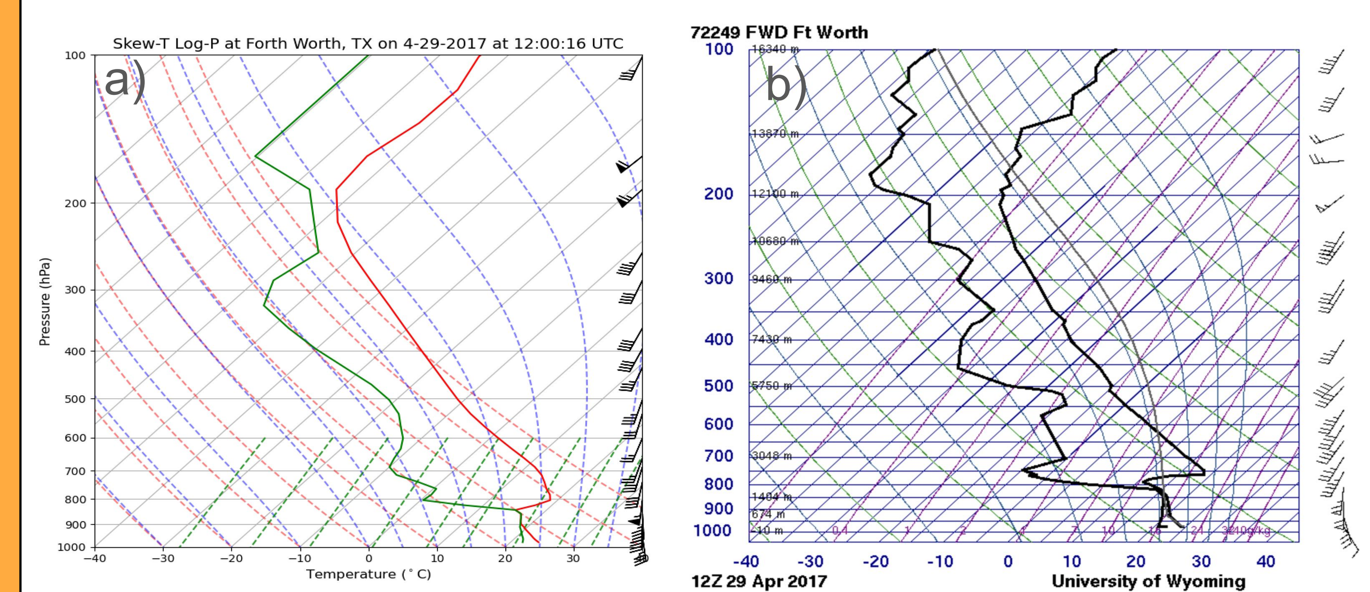

Fig. 4. (a) Simulated & (b) observed radiosonde (UWYO) at Fort Worth, TX on April 29th, 2017.

### Radiosonde: Simulations and Model Verification

- The simulated radiosonde (fig. 4a) accurately captures the saturation observed in the radiosonde (fig. 4b) between 850-900 hPa and the dryness between 500-800 hPa. However, it misplaces the observed dry layer at 480 hPa by approximately 150 hPa, aligning it around 320 hPa, and overestimates the level and depth of saturation between 350-200 hPa.
- Wind barbs are well-captured with a slight southern bias near the surface.
- The near-surface saturation suggests enhanced instability and a low-level LCL, conducive to convective storms.

### Radar Reflectivity: Simulations and Model Verification

- The simulated reflectivity in (fig. 5a) and (fig. 5c) appear to overestimate the precipitation in some areas, likely due to the lower resolution of the simulation in comparison to the fine detail of the observed measurements in (fig. 5b) and (fig. 5d). Despite this, the simulation tends to capture the general shape and areas of high precipitation quite well.
- Simulated reflectivity indicates high dBZ values of well over 60 dBZ, with the system taking on a "bow" shape, indicative of a line of strong convective thunderstorms.

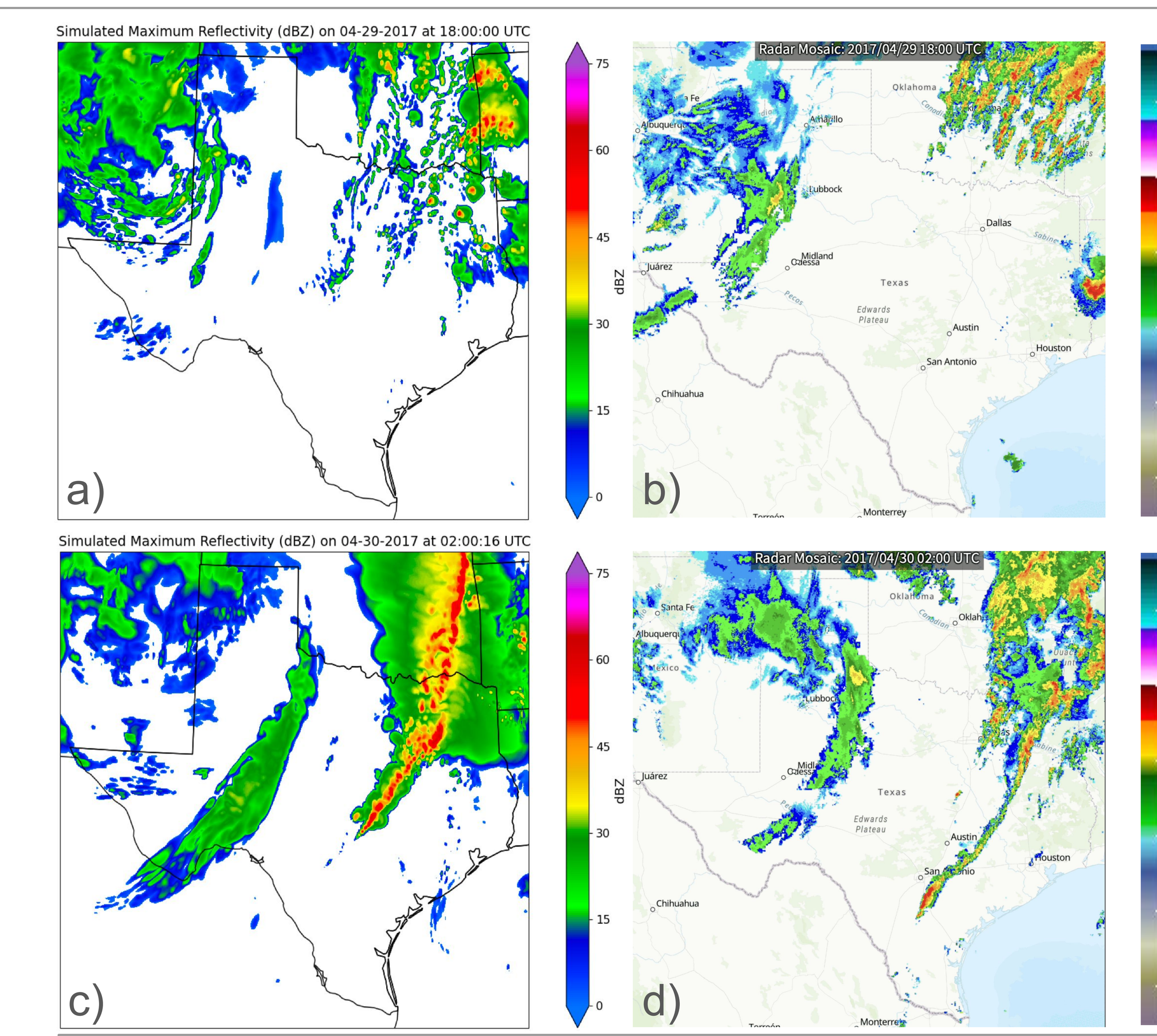

Fig. 5. Radar reflectivity over Texas on April 29-30, 2017: (a) Simulated maximum reflectivity (dBZ) at 18 UTC; (b) observed radar mosaic at 18 UTC; (c) simulated maximum reflectivity (dBZ) at 02 UTC; & (d) observed radar mosaic at 02 UTC.

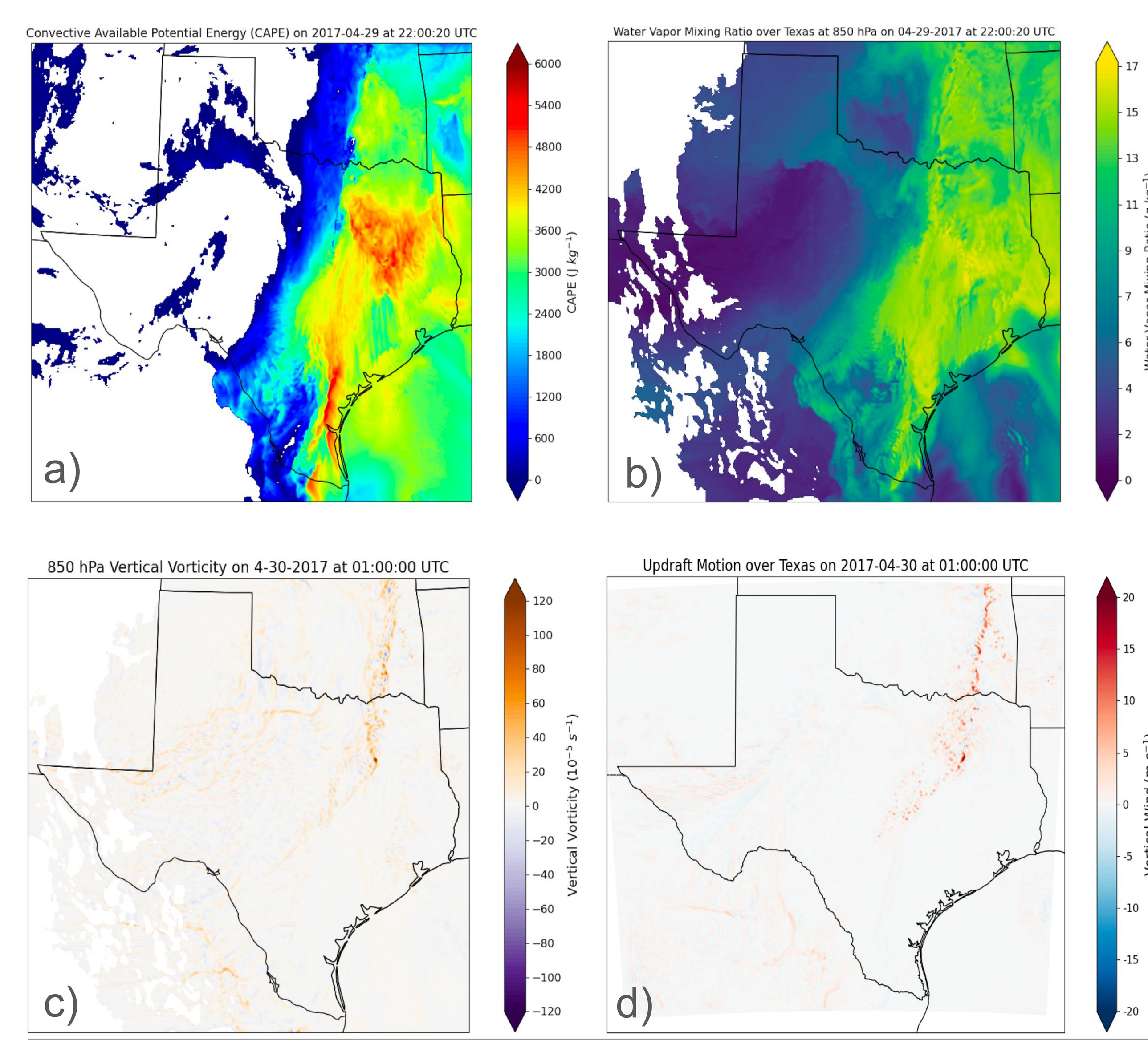

Fig. 6. Simulations of a) CAPE, b) Water Vapor Mixing Ratio, c) Vertical Vorticity, & d) Updraft Motion.

### Simulated Convective Variables

- The meteorological conditions over the Texas region on April 29th, 2017 are illustrated through (fig. 6a) extraordinarily high CAPE values, with a region of nearly 6000 J $kg^{-1}$, (fig. 6b) an abundance of moisture flowing in from the Gulf of Mexico with large areas of values approaching 17 g $kg^{-1}$, (fig. 6c) high vertical vorticity in the lower levels, with distinct eddies rotating at nearly 120 x $10^{-5}$ $s^{-1}$ present (likely mesocyclones or potential tornadoes), and (fig. 6d) powerful updraft velocities upwards of 20 m $s^{-1}$ near similar regions of high vorticity.

## Summary

- The study domain setup is configured at 21 km (outer) and 3 km (inner) resolutions.
- Synoptic conditions show southern surface winds, low 500 mb geopotential height, a low-pressure system, and a cold front at the surface.
- Simulated sounding slightly miscalculates dry level depth but accurately simulates low-level saturation, favorable for severe convection.
- Simulated reflectivity overestimates light precipitation but accurately represents high precipitation in a "bow" echo pattern.
- High CAPE, moisture, vorticity, and updraft motion precede the severe storm outbreak of April 29th, 2017.

## Acknowledgments & References

*Check out the WRF simulations & additional results!!! (references included)*

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