Improving the anticipation of potential tornado intensity across different time scales

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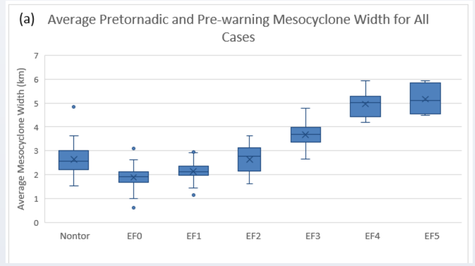
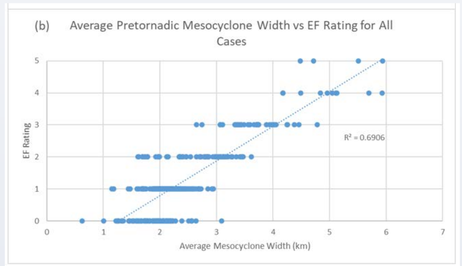
Overview

- Much of the recent research on tornadoes has focused on tornadogenesis or the diagnosis of the intensity of an ongoing tornado.
- Given that the majority of damage and fatalities are caused by strong to violent tornadoes, there is a need for robust operational tools that focus on anticipating tornado intensity rather than simply on tornadogenesis or ongoing tornadoes.
- The anticipation of tornado intensity is operationally relevant across different time scales including during the pre-tornadic period of ongoing thunderstorms as well as during the tornado watch time scale several hours before storms develop.
- In Sessa and Trapp (2023, *J. Operational Meteor.*), we demonstrated the robust relationship between the intensity of a tornado and its pre-tornadic mesocyclones characteristics as well as its near-storm environment with 300 tornadic events. We have also applied these relationships to explore tornado-intensity prediction approaches through machine learning applications to examine their skill in predicting significant or non-significant tornado intensity for a given storm.
  - Results demonstrate a skilled binary prediction of tornado intensity, conditioned upon tornadogenesis and demonstrate the potential for these machine learning applications to become a helpful resource in an operational setting.

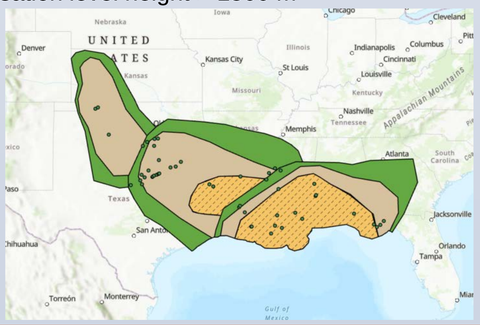




- ***The work herein focuses on the anticipation of tornado intensity on the tornado watch time scale before convection initiation using storm-scale diagnostics combined with other environmental parameters from convection-allowing models.***

HRRR Analysis

- Included non-tornadic events, non-significantly tornadic events (EF0-1), and significantly tornadic events (EF2-5)
- Sampled High-Resolution Rapid Refresh (HRRR) model forecasts of storm-scale diagnostics such as updraft helicity, vertical vorticity, and the Okubo-Weiss number as well as environmental parameters such as the significant tornado parameter (STP) prior to convection initiation
  - Utilized Storm Prediction Center tornado outlook regions (convective outlook regions when not available) as geographic and temporal sampling bounds to calculate the mean, median, and maximum values of the storm-scale diagnostic and environmental parameters as well as specific percentile values for individual forecast hours
    - 2% or marginal risk acts as outer bounds
    - Calculated statistics for comparison within each present outlook region
  - T-0 is the time of the first tornado within and during a valid tornado outlook
  - New tornado outlooks are used as they are issued during a severe thunderstorm event with a new T-0 and associated HRRR initialization
  - Aggregated forecast hours for events to calculate swatch statistics of storm-scale diagnostics such as length and area
  - Tornadoes are associated with the environment in the hour prior to the hour in which the tornado occurred
  - Storm-scale diagnostic fields are masked using the following environmental constraints in the hour preceding the tornado hour of focus: STP < 0.05, surface-based convective-available potential energy (CAPE) to most-unstable CAPE ratio < 0.75, and a lifted-condensation level height > 1500 m
    - Removes regions unfavorable to tornadoes and rotation signatures from elevated convection
  - Environmental fields are masked and sampled using the hour preceding the tornado hour of focus: STP < 0.05, composite reflectivity > 20 dBZ
    - Removes regions unrepresentative of the large-scale environment supportive of tornadoes
- Complete majority of analysis using GIS software



Tornado reports and outlook regions from 12/13/2022

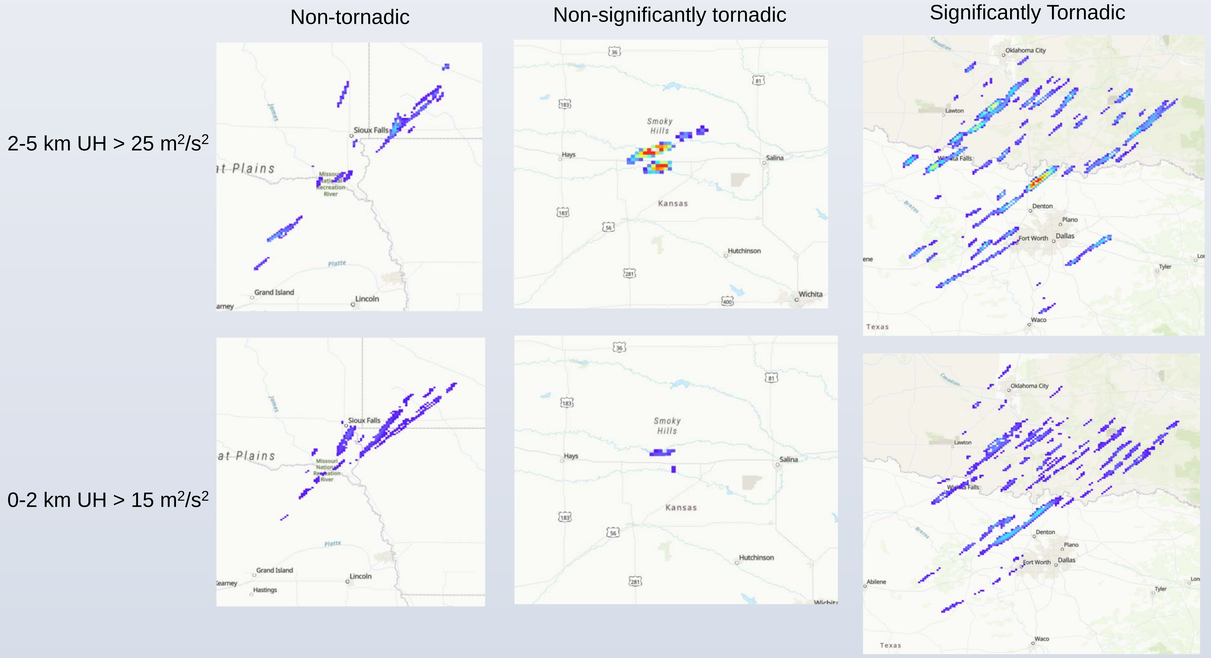
HRRR Analysis Results

- Shown here are the results from three case studies from the past year: a non-tornadic event (5 hours) from 10/23/22, a non-significantly tornadic event (4 hours) from 06/23/22, and a significantly tornadic event (5 hours) from 12/13/22.

Mean of the maximum value from each hour, within the masked outlook region:

	Non-tornadic Hours	Non-significantly Tornadic Hours	Significantly Tornadic Hours
Mixed-layer CAPE (J/kg)	1354	1450	1986
STP	0.4	2.6	5.9
Effective Storm Relative Helicity (m^2/s^2)	110	176	378
2-5 km Updraft Helicity (m^2/s^2, hour max)	42	109	115
0-2 km Updraft Helicity (m^2/s^2, hour max)	14	25	46
Upward Vertical Velocity (m/s, hour max)	21	26	37

Encouraging results thus far showing separation between non-tornadic, non-significantly tornadic, and significantly tornadic events



Future Work

- Develop large dataset of cases to evaluate the ability of the HRRR to anticipate potential tornado intensity during the tornado watch time scale
- Explore different (potentially machine-learning) methods of comparing the storm-scale diagnostics and environmental parameters sampled from non-tornadic, non-significantly tornadic, and significantly tornadic events

Concluding statement: The goal of this work is to provide new relationships and tools to improve the anticipation of tornado intensity during the tornado watch time scale and to understand the ability of HRRR model forecasts of storm-scale diagnostics and other environmental parameters in skillfully contributing to and achieving this predictive goal.