Using Polarimetric Radar Data to Identify Tornadoes in Near Real-time

Katie Ward, Bethany Fay, and Lauren McCarthy
kward@verisk.com

Motivation

Severe storms, including wind, hail, and **tornadoes**, are the most frequent billion-dollar events.

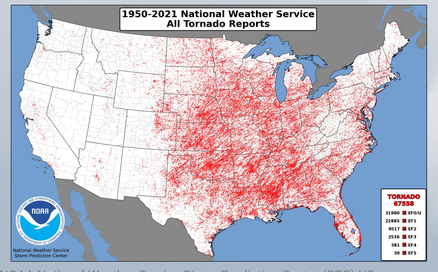
Billion-dollar events to affect the United States from 1980 to 2023[*](CPI-Adjusted)

Disaster Type	Events	Events/ Year	Percent Frequency	Total Costs	Percent of Total Costs	Cost/ Event	Cost/ Year	Deaths	Deaths/ Year
Drought	30	0.7	8.4%	$334.8B	13.0%	$11.2B	$7.6B	4,275[†]	97[†]
Flooding	41	0.9	11.5%	$190.2B	7.4%	$4.6B	$4.3B	723	16
Freeze	9	0.2	2.5%	$36.0B	1.4%	$4.0B	$0.8B	162	4
Severe Storm	174	4.0	48.7%	$417.1B	16.2%	$2.4B	$9.5B	2,070	47
Tropical Cyclone	60	1.4	16.8%	$1,359.0B	52.9%	$22.7B	$30.9B	6,890	157
Wildfire	21	0.5	5.9%	$135.5B	5.3%	$6.5B	$3.1B	435	10
Winter Storm	22	0.5	6.2%	$97.1B	3.8%	$4.4B	$2.2B	1,402	32
All Disasters	357	8.1	100.0%	$2,569.7B	100.0%	$7.2B	$58.4B	15,957	363

[*]Deaths associated with drought are the result of heat waves. (Not all droughts are accompanied by extreme heat waves.)
Flooding events (river basin or urban flooding from excessive rainfall) are separate from inland flood damage caused by tropical cyclone events.
The confidence interval (CI) probabilities (75%, 90% and 95%) represent the uncertainty associated with the disaster cost estimates. Monte Carlo simulations were used to produce upper and lower bounds at these confidence levels (Smith and Matthews, 2015).

NOAA National Centers for Environmental Information (NCEI) U.S. Billion-Dollar Weather and Climate Disasters (2023). https://www.ncei.noaa.gov/access/billions/, DOI: 10.25921/stkw-7w73

There is a need for accurate near real-time tornado data to help inform industries such as insurance of the most impacted areas.



NOAA National Weather Service Storm Prediction Center (SPC) US severe report database (updated: 25 April 2023). https://www.spc.noaa.gov/gis/svrgis/

The goal of Verisk's Respond Tornado Probability product is to provide **probability** of tornadoes based on real-time polarimetric radar data, *not* to provide tornado path/track or wind speed information as the latter is only available upon manual assessment.

Specs

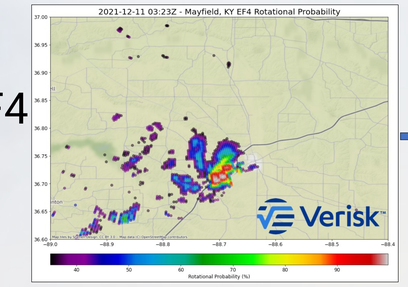
- Leveraging our existing real-time radar pipeline
- WSR-88D CONUS radar network
- Algorithm is run on every 5-minute volume scan
- Data are spatially and temporally combined into a 1-km^2, 5-minute standard grid to provide tornado probability information based on customer needs
- Tornado probability output is available in rolling increments throughout the day, leading to a 24-hour view. These output are available in as little as 15-minute delay from real-time
- Data are available in several formats (i.e., shapefile) via API or SFTP as well as within the web-based Respond Mapping and Analytics Platform (MAP)

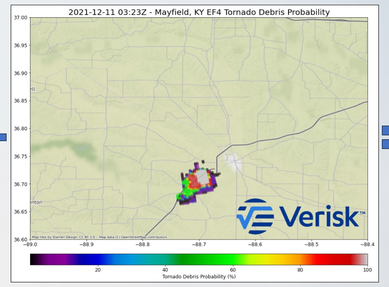
Rotational probability

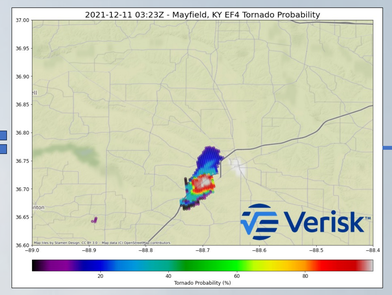
Tornado debris probability

Respond tornado probability

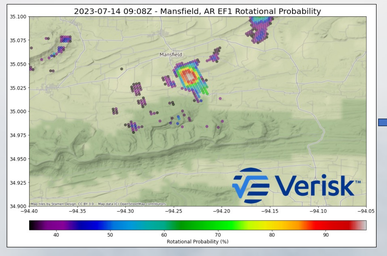
EF4

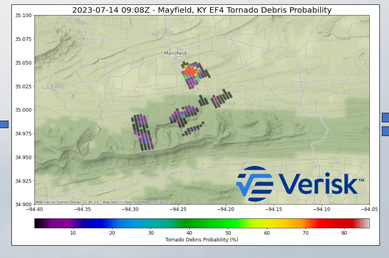


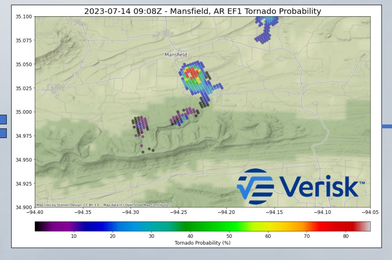




EF1



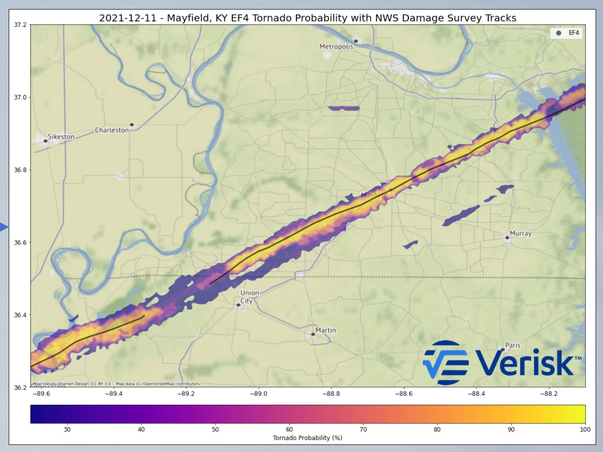




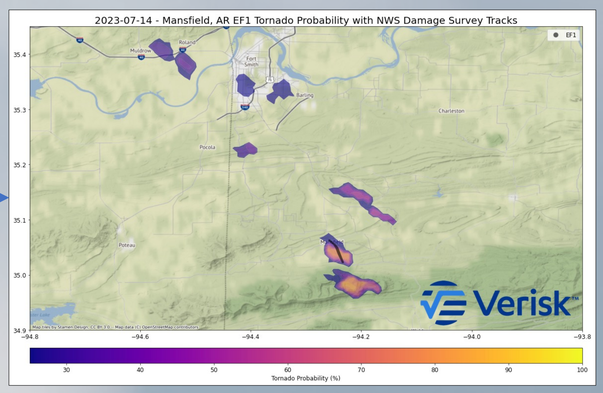
Many automated near real-time tornado detection methods rely on estimates of rotation computed from radial velocity to identify and represent tornadoes. While these methods often capture tornadoes, they have a high false-positive rate since not every rotation detected by radar is indicative of a tornado.

Conversely, identification of features such as debris signatures can be biased against weaker tornadoes or those that do little damage.

Using a combination of **rotational** and **tornado debris** probabilities yields accurate estimates of tornado probability. Vertical information is also used to add information about the depth of signatures and provide further confidence in the output.

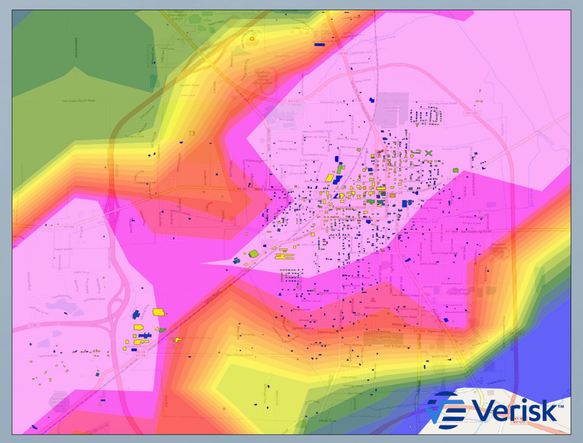


Combining the two key components results in a robust relationship between tornado probability and damage survey paths compared to either rotation tracks or debris signatures alone.



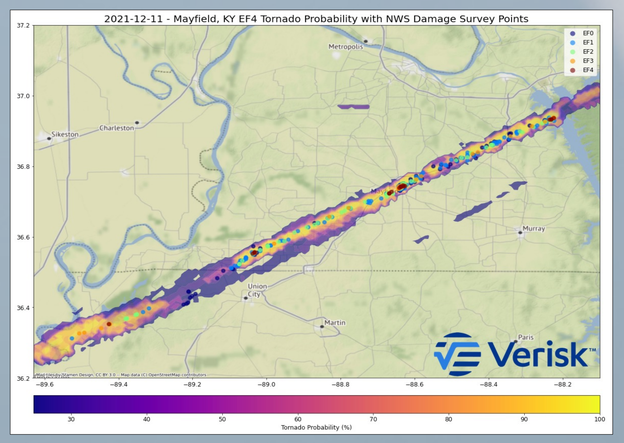
This algorithm can capture tornadoes across the intensity spectrum while reducing false positives, providing more accuracy in conveying the likelihood of tornado occurrence.

Ground validation



Tornado probability with building damage overlaid. Buildings are categorized by CATscore. CATscore is a machine-learned building damage score based on before and after aerial imagery.

Blue → Red



Respond tornado probability with NWS damage survey points overlaid.

Future work

- Additional noise and contamination reduction
- Integrate more temporal information for enhanced confidence
- Target improvements to handle wider range of storm morphologies and environments
- Refine algorithm to further reduce false positives
- Expand to include international radar networks

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