On Improving Tornado Detection in the Northeast US via a Radar and near Storm Environment Algorithm

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Background

*Verification statistics show a need to improve tornado detection at WFO Mount Holly; critical success index (CSI) of around 0.10 from 2010-2019

*Summer 2017 Hollings project developed objective radar and environment based scale ("Southern New England Tornado Detection Scale") at WFO Boston which has been integrated into operations at that office and has shown promise as a tool to improve tornado detection

*Summer 2019 research applied this scale to WFO Mount Holly CWA and modified it based on results – updated version of the scale was developed

Methodology

*26 tornadoes in WFO Mount Holly CWA from 2010-2019 were studied

*22 randomly selected false alarm tornado warnings over the same period were analyzed in identical manner to determine if each scale would have eliminated the false alarm

*26 random control cases were studied to determine if each scale would have triggered a false alarm. These were severe, non-tornadic thunderstorms which did not have tornado warnings issued

*Low level radar data for each storm was studied using GR2Analyst; this involved studying lengthy portions of the life cycle of each storm in order to assure times of maximum rotation were properly assessed

*Environmental parameters retrieved from the SPC Mesoanalysis archive

Results in Brief

*Only 4 of 26 tornadoes were detected before touchdown in real time. The SNE detection scale would have detected 12. The mid-Atlantic scale would have detected 15.

-In some cases with only 30-60 seconds of lead time, assumes warning issuance exactly at scan time which is impractical in operations

*Of 22 false alarm cases, SNE scale eliminated 12. The mid-Atlantic scale eliminated 10.

*Of the 26 control cases, both added just 1 false alarm

Southern New England Tornado Detection Scale

* Rotational velocity must be gate-to-gate
* Assess highest score under 10,000 feet
* Use with caution <10nm or >80nm from radar

Add the two scores

Rotational Velocity (kts)	Points	NROT	Points
15	1	0.4-0.5	1
20	2	0.6	2
25	4	0.7	3
30	6	0.8	4
35	10	0.9	6
		1.0-1.1	7
Vr = Max(in) + Max(out) / 2		1.2-1.3	8
		1.4+	9

Score	Interpretation
0-5	Tornado Unlikely
6-9	Tornado Possible
9-12	>50% tornado probability
>12	Tornado likely

Correction, if applicable	Points
0-1km SRH >= 150 m^2s^{-2}	+1
PWATs >= 2"	+1
LCL > 1000m	-1
Supercell storm structure	-2

Score	Warning Strategy
0-5	SVR (if applicable), no TOR tag
6-8	SVR with "tornado possible" tag
9+	TOR

Based upon Hollings research by Jonathan O'Brien (2017)

*An area of rotation is assigned two instantaneous point values based off a radar scan, with one value corresponding to rotational velocity and the other to GR2 Analyst normalized rotation ("NROT")

-Those two scores are added together

*Adjustments are then made from environmental parameters, which should be known and updated as an event unfolds

Mid-Atlantic Tornado Detection Scale

SRH (m^2s^{-2})	Points	PWAT (in.)	Points	LCL (m)	Points	Supercell?	Points
<50	-1	<1.5	-1	1000+	-1	Yes	1
<100	0	≤1.8	0	500+	1	No	0
≤200	1	≤2.2	1	≤500	2		
200+	2	2.2+	2				
Gate-to-Gate (kts)	**Points**	**NROT**	**Points**	**Spectrum Width (kts)**	**Points**	**NROT Adj. (-)**	**Points**
<10	-1	<0.4	0	<15	-1	≤0.05	-1
<15	0	<0.6	1	<18	0	<0.14	0
<18	1	<0.75	2	<20	1	<0.2	1
<23	2	<0.9	3	≤24	2	≤0.5	2
<30	4	<1.1	4	24+	3	0.5+	3
<35	5	<1.3	6				
35+	7	<1.5	7				
Vr=Max(in)+Max(out)		≤1.75	8				
2		1.75+	9				

Score	Interpretation
0-7	Tornado Unlikely
8-10	Tornado Possible
10-15	Tornado Probability > 50%
16+	Tornado Likely

Score	Warning Strategy
0-7	SVR (if applicable), no TOR tag
8-10	SVR with "Tornado Possible" tag
10+	TOR

*Mid-Atlantic scale introduces spectrum width as a variable for consideration

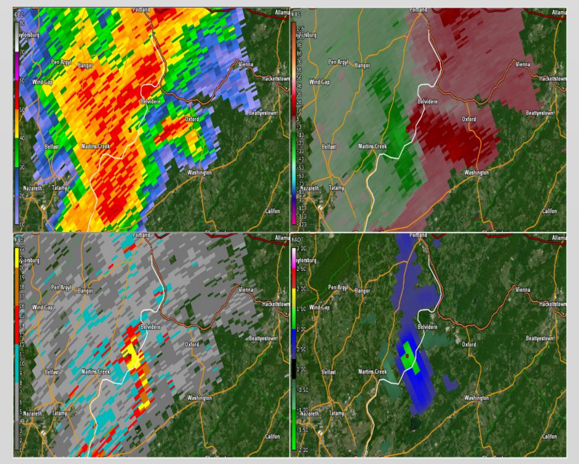
*Also introduces concept of "adjacent NROT" based on tendency of many tornadoes to have regions of opposite direction shear surrounding the tornadic circulation

*Environmentally, the mid-Atlantic scale is more robust in its quantification of parameters, with multiple thresholds for each

S. New England Scale Examples

Added Detection

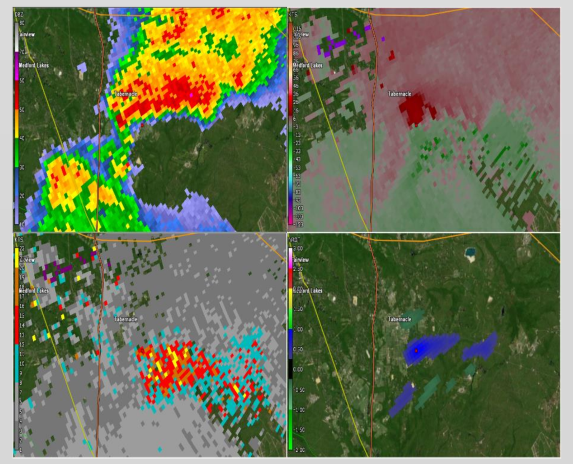
7/14/2016 (EF0)



Vr: 25 (4)
NROT: 1.25 (8)
Net ENV*: (-2)
Score: 10 → TOR

Removed False Alarm

9/25/2018

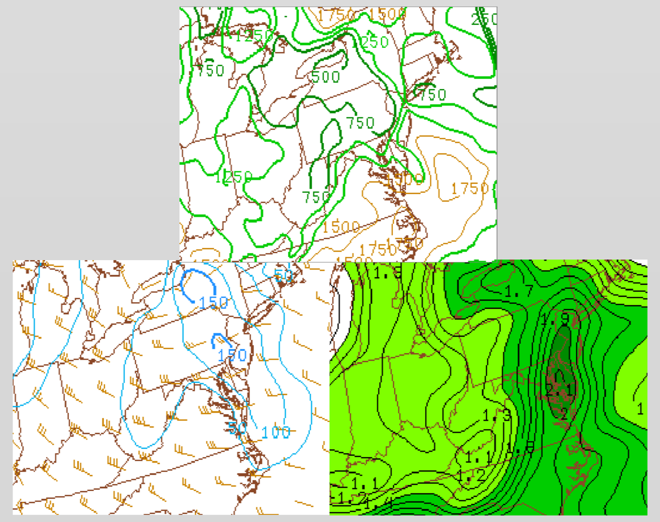


Vr: 15 (1)
NROT: 0.97 (6)
Net ENV: (-2)
Score: 5 → SVR

*Net ENV = sum of adjustments from environmental parameters

Mesoanalysis Example

8/9/2011



*Monmouth County, NJ tornado

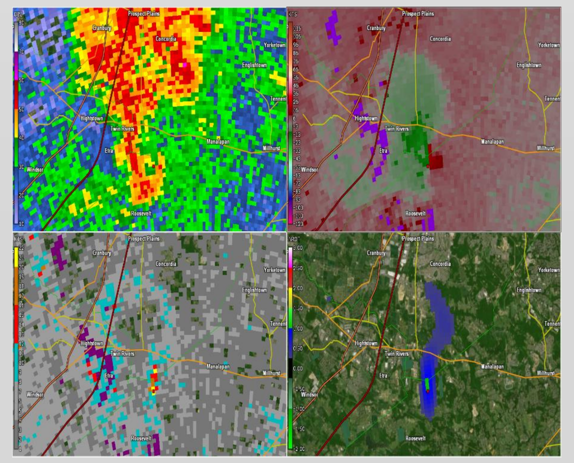
*Zoom into area of interest at the time of interest. Take the shown value; interpolation allowed for "in between" areas

*In this case, an LCL of 1000m, 0-1km SRH of 125 m^2s^{-2}, PWAT value of 2.0"

Mid-Atlantic Scale Examples

Added Detection

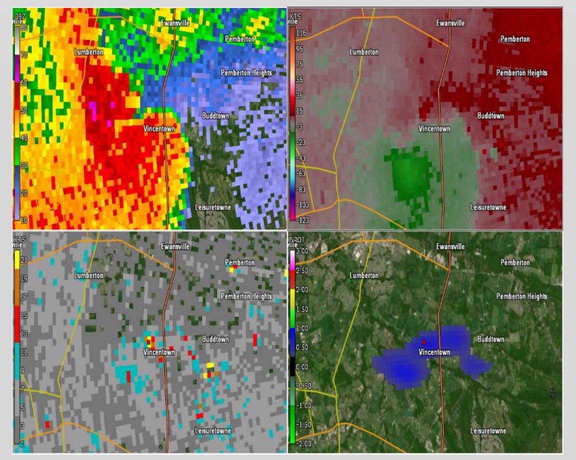
8/9/2011 (EF0)



Vr: 16 (1) -NROT: -0.30 (2)
NROT: 1.05 (4) Net ENV: (2)
SW: 28.2 (3)
Score: 12 → TOR

Removed False Alarm

7/15/2014



Vr: 15 (1) -NROT: -0.22 (2)
NROT: 0.73 (2) Net ENV: (1)
SW: 27.2 (3)
Score: 9 → SVR

NROT is a fairly complex derived product that tries to find areas of rotation in dealiased BV (BVD).
1) At each BVD bin, AE applies a 2d filter that simultaneously fits a second order surface to, and takes the azimuthal gradient of, the 5x5 surrounding bins. If not enough data is available, it tries with a 3x3 set of bins.
2) After step #1, AE has true ROT. Due to various physical factors, the significance of the value of true ROT varies with range. So, AE divides true ROT by the piecewise-linear curve given in the Algorithms->MDA Settings dialog box to remove this range-dependency.

Discussion Points

*While performance differences between the two are limited, the mid-Atlantic scale tends to run more sensitive than the Southern New England scale, detecting more tornadoes but at increased risk of false alarms

*Among false alarms, that were eliminated were not close to triggering TOR warning thresholds. In some cases, this was due to warnings being based off of funnel cloud or waterspout reports as opposed to radar

*Only 1 added false alarm out of 26 control cases in the Mount Holly CWA vs 4 out of 21 in the Boston CWA

-More thunderstorms occur in the mid-Atlantic; likely lower ratio of added false alarms vs. SNE, but makes it harder to find those cases

-Studying additional control cases would likely false alarms, but not enough for either scale to lose skill compared to actual verification

*What qualifies as a "scalable circulation" is difficult to determine. **Before** using either scale, **the forecaster** must decide if an area of rotation is of appropriate size and shape to be potentially tornadic

Conclusions and Future Work/Challenges

*Both methods in this study significantly improved detection statistics

*No one size fits all; human forecasters retain the most vital roles

*There remains a large amount of opportunity for developing similar objective analysis methods using different or modified parameters and scoring values; ultimate goal is "best fit" to the actual verification

*Must keep in mind operational constraints!

*Lead time remains a challenge! These scales are designed for very short term detection of developing tornadoes. While a worthy endeavor, such an approach will not aid in the goal of longer lead time warnings!

References

Cooper, D. and A. Vorst, 2016: Assessing the utility of normalized rotation in detecting tornado development in the Allegheny Front. *NROW XVII*, Albany, NY. https://www.weather.gov/media/rlx/NROTpresentation.pdf

O'Brien, J. and J. DelliCarpini, 2018: Improving tornado detection and lead time: the July/August 2018 tornadoes in southern New England. *NROW XIX,* Albany, NY. http://cstar.cestm.albany.edu/nrow/NROWX1X/Agenda.htm

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