BP-31 Updated Radar-Based Techniques for Tornado Warning Guidance in the Northeastern United States

Brian J. Frugis *and Thomas A. Wasula*
NOAA/National Weather Service, Albany, NY

Motivation

-Available tornado warning guidance is not always focused on Northeastern US tornadoes, which are commonly weak, short-lived and impacted by variable terrain.

-Previous studies (such as the COMET V-R Shear Study by LaPenta et al. from 2000) was only based on 4 bit radar data and an update to this was needed to account for 8 bit, super resolution radar data.

-New dual-pol products provide valuable insight during the warning process, which can be used by the warning meteorologist.

-Impact based warnings require knowledge of tornadic strength. Other ongoing studies regarding this topic (Entremont and Lamb 2015) have not examined tornadic events from the Northeastern US with this work.

CSTAR Grant #: NA01NWS4680002

Previous Study Work

V-R Shear Technique

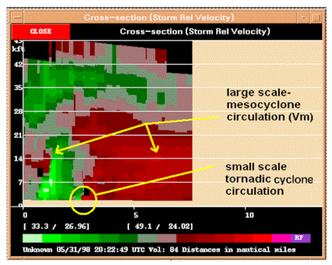
-Maximum observed gate-to-gate shear below 3 km was found to be useful in identifying tornadic storms (LaPenta et al. 2000)

$$S=V_r/(D*1800)$$

Shear (S) is measured in units of s^{-1}, rotational velocity (V_r) in knots and D is the diameter of which S is calculated in nm.

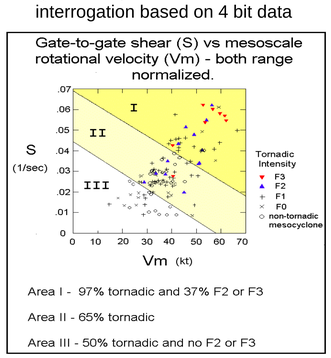
-In the LaPenta study, D was set to 0.5 nm for areas within 30 nm of radar and adjusted for areas further away due to beam spreading.

Calculation of Maximum Velocity of Mesocyclone using a Velocity Cross-Section



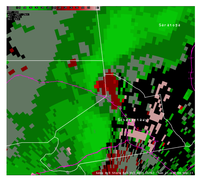
Mechanicville, NY F3 from 31 May 1998 2022 UTC

Nomogram for operational use during storm interrogation based on 4 bit data



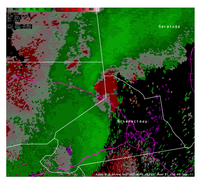
From local COMET research (LaPenta et al., 2000)

Legacy 4 bit vs. Super Resolution 8 bit



4 bit: 1 km (0.54 nm) x 1°

An example of 4 bit super resolution storm relative motion (SRM) from KENX at 2123 UTC 4 Sept 2011



8 bit: 0.25 km (0.13 nm) x 0.5°

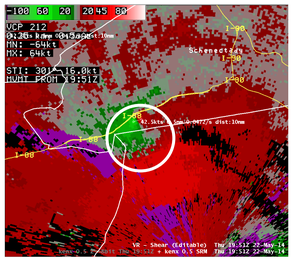
An example of 8 bit super resolution storm relative motion (SRM) from KENX at 2123 UTC 4 Sept 2011

Because of the higher resolution of SRM, D can be set to 0.5 nm for up to 60 nm from the radar when using 8-bit radar data when looking to measure shear of the actual gate-to-gate tornadic couplet.

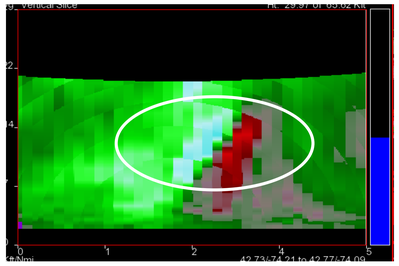
Updated V-R Shear Technique

76 tornadic events & 21 null events were examined in total from 2003-2015 from the Northeastern US. D was set to 0.5 nm for all tornadic events within 60 nm once super resolution radar data was available (2008). Null events were defined as strong mesocyclones that prompted tornado warnings, but did not produce a tornadic event.

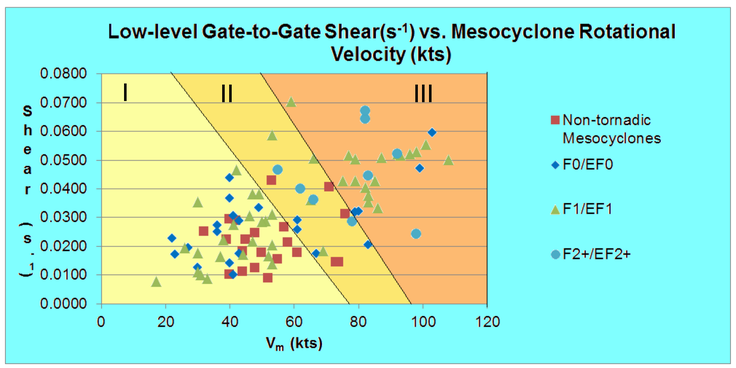
Duanesburg-Delanson, NY EF3 Tornado 22 May 2014
Images from 19:51Z during height of tornado



Rotational Velocity of tornadic couplet from 0.5° SRM measured over 0.5 nm width (about 10 nm from KENX radar located just south-southeast of tornadic couplet)
V_r=42.5 kts, S=0.0472 s^{-1}



Cross-Section of SRM over 3.5 nm width of Mesocyclone.
Max Strength: 89 kts
(V_m=Max inbound + Max Outbound of Meso)

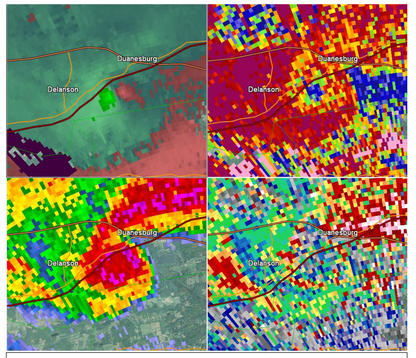


Group I: No Clear Signal Between Tornadic & Non-Tornadic Mesocyclones; no F2/EF2 or stronger
Group II: 71% Tornadic & Mainly Weak Tornadoes **Group III:** 100% tornadic; mainly F1+/EF1+

Height of Tornadic Debris Signature (TDS)

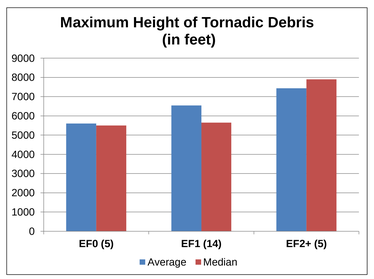
69 tornadic events from 2012-2015 from the Northeastern United States were examined for the presence of a Tornadic Debris Signature (TDS). Out of those 69 tornadoes, a TDS was present in 24 of them (35%). Of these 24, 12 tornadic events occurred within supercell thunderstorms and 12 were within Quasi-Linear Convective System (QLCS) thunderstorms. All EF2+ strength tornadoes occurring in the Northeastern US between 2012-2015 displayed a TDS.

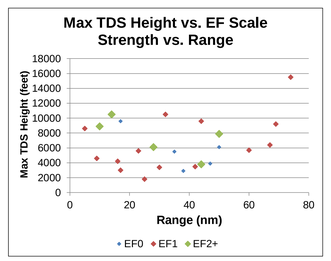
TDS Detection Methodology
Adapted from Entremont and Lamb 2015



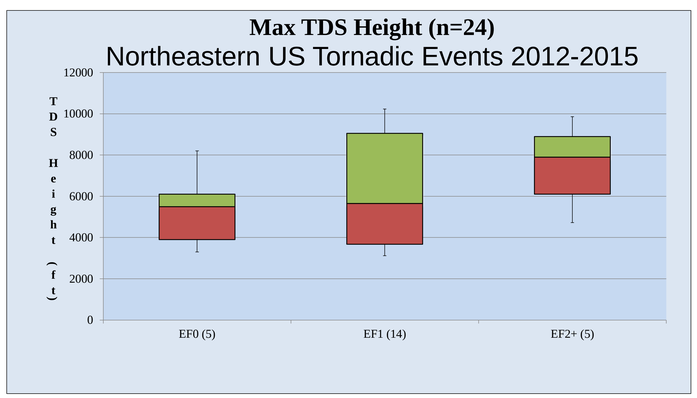
1951 UTC 22 May 2014 Duanesburg-Delanson, NY EF3 KENX Radar 0.5° Elevation Angle
Top-left: SRM (kts), **Top-right**: CC
Bottom-left: Z (dBZ), **Bottom-right**: ZDR (dB)

1) Find a tornadic couplet in SRM (kts)
2) Have Correlation Coefficient (CC) less than 0.90 co-located with the couplet
3) Have Reflectivity (Z) values 35 dBZ or greater co-located with the couplet
4) Have Differential Reflectivity (ZDR) values around zero co-located with the couplet
5) If all these criteria are met, check next radar elevation slice above and continue the process until they are not met anymore. The top slice where all criteria is met is the Max TDS Height.





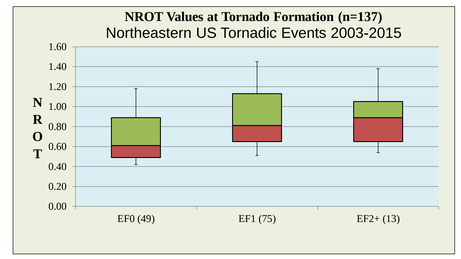
The number of events in the database is indicated next to each EF-category.

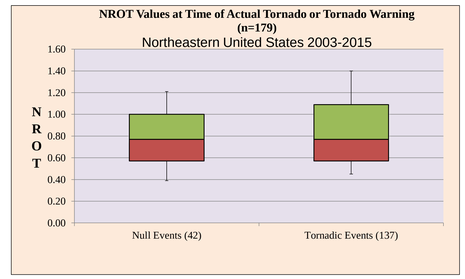


The number of events in the database is indicated next to each EF-category.

Normalized Rotation (NROT)

137 tornadic events from 2003-2015 from the Northeastern United States were examined using Gibson Ridge's software GR2Analyst. The value of Normalized Rotation (NROT) was recorded at the onset for each tornadic event. Only modest changes in NROT were noted with the increase in tornado strength, although the limited dataset of EF2+ storms may have impacted the dataset. In addition, 42 null events were examined as well. Null events showed enough rotation to warrant a tornado warning, but a tornado was not reported. There appears to only minor differences between the tornadic and non-tornadic events, showing only limited value in using NROT as a tornado warning indicator on its own.





Conclusions

-The updated V-R Shear technique shows similar results as the previous study done by LaPenta et al. in 2000, but now accounts for the improvements in radar resolution.

-Strong tornadoes for the Northeast (EF2+) show a strong correlation between increasing amounts of low-level shear and the increased strength within the mid-level mesocyclone.

-As also shown by Entremont and Lamb 2015, the higher Max TDS Heights are correlated with an increase in tornado strength.

-NROT is not always a clear discriminator on its own for tornadic vs. non-tornadic storms. There also isn't a strong signal seen in increasing tornadic strength with increasing NROT values either.