Examining Methods to Accurately Predict Significant Severe Thunderstorm Wind Damage across the Northeastern United States

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Motivation

-Determining severe vs. significant severe thunderstorms can be difficult for a warning meteorologist.

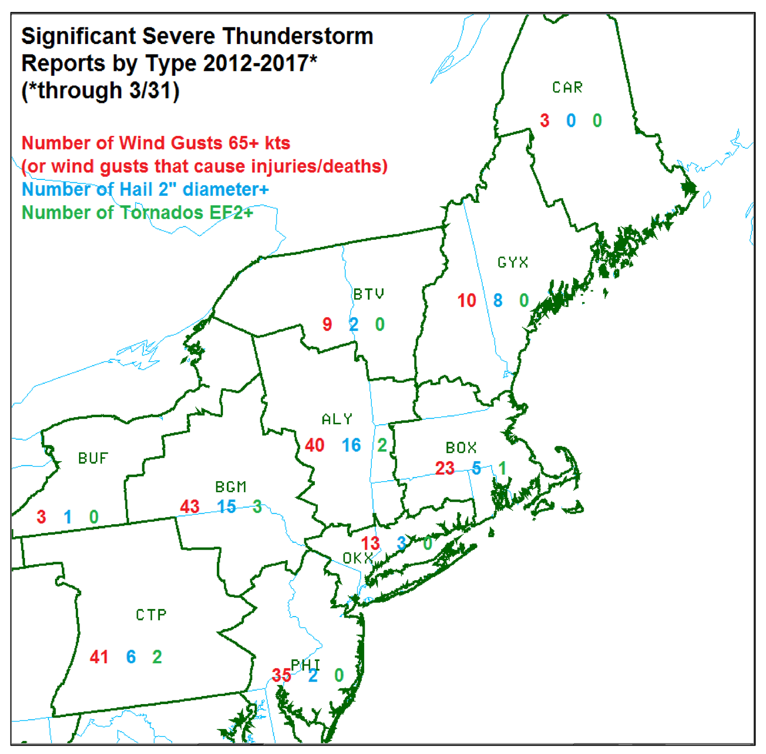
-This has been a challenge for NWS Albany (ALY) forecasters on several occasions during the summers of 2016 & 2017. Several significant thunderstorms were either missed or under warned.

-Impact-based warnings requires the warning forecaster to have specific knowledge of wind speeds & damage potential for warning text/graphics.

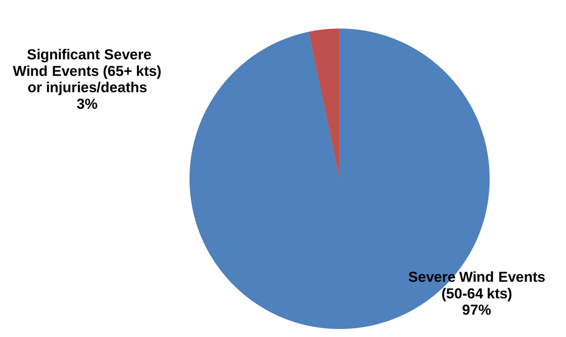
-New technology and warning techniques being investigated in research need to be implemented into operations.

What is a Significant Severe Thunderstorm?
According to the Storm Prediction Center (SPC), a significant severe thunderstorm is one that produces either wind gusts of 65+ kts, 2"+ diameter hail or EF2+ tornado. This study will also consider thunderstorms that produce any injuries or deaths as well.

Climatology of Significant Severe Thunderstorms in the Northeastern* United States by NWS County Warning Area

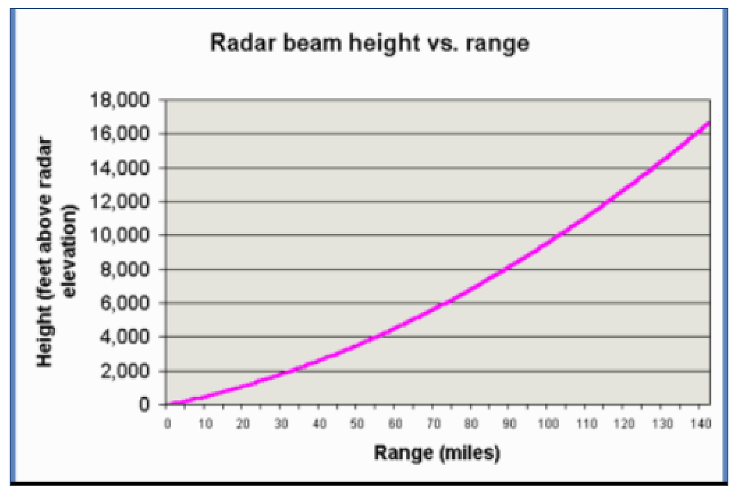


WFO Albany Severe Wind
Jan 1, 2012 through March 31, 2017



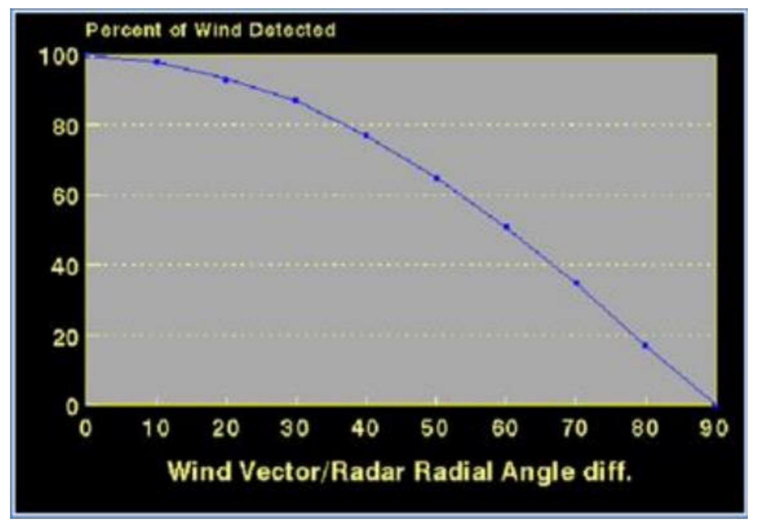
*This study's domain considers the Northeast to be New England, New York, New Jersey, Delaware, northeastern Maryland & central and eastern Pennsylvania

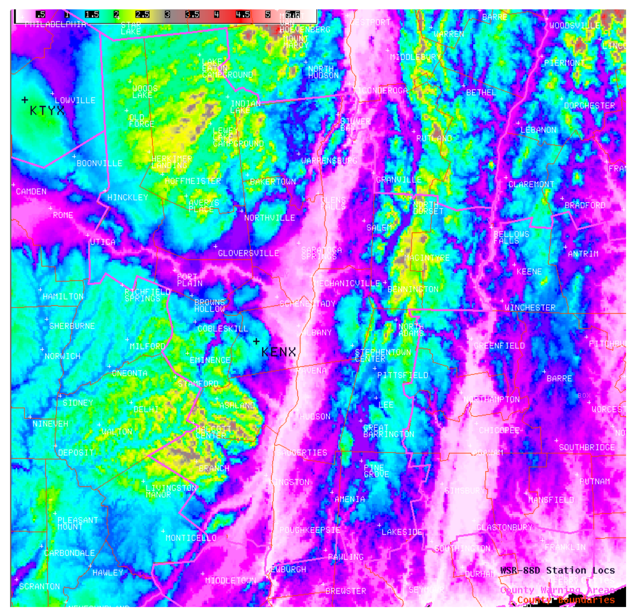
Radar Limitations & Considerations



Images from NOAA/NWS Warning Decision Training Division (WDTD)
Radar & Applications Course (RAC, formerly DLOC)

The warning meteorologist must always consider the storm's location and movement in relation to where the radar is located. Storms far away from the radar may not be sampled fully and radial velocity data may not always be showing the true strength of the storm's winds.





Elevation (in kft) surrounding the Albany KENX radar site.

Catskill Mountains south of KENX cause considerable beam blockage. This is an issue for storms that develop over the high terrain and then track eastward into the mid-Hudson Valley, as it may underestimate strength of storms headed towards populated areas around Kingston and Poughkeepsie.

Great Rule of Thumb from NOAA WDTD (RAC training):

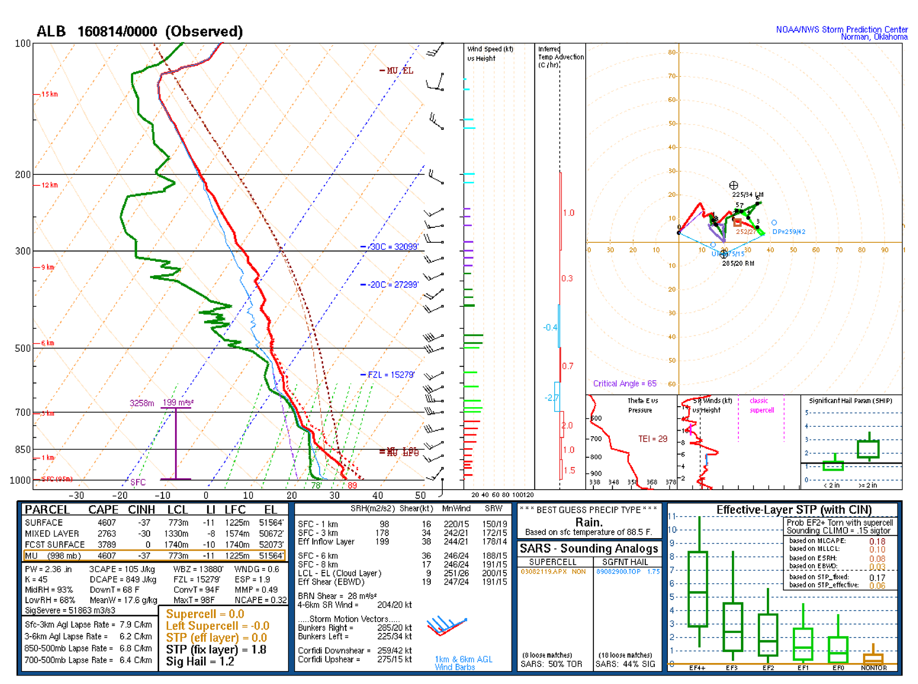
Note to self:
When you see something strong - it's probably strong.
When you see something weaker - it may be weaker, but then again, it may not be…

Craven-Brooks SigSevere Product

- From SPC & Craven and Brooks 2004: The simple product of 100mb MLCAPE and 0-6km magnitude of the vector difference (m/s; often referred to as "deep layer shear") accounts for the compensation between instability and shear magnitude. Using a database of about 60,000 soundings, the majority of significant severe events (2+ inch hail, 65+ knot winds, F2+ tornadoes) occur when the product exceeds 20,000 m^3/s^3.
- The index is formulated as follows:

  C = (MLCAPE J/kg) * (SHR6 m/s)

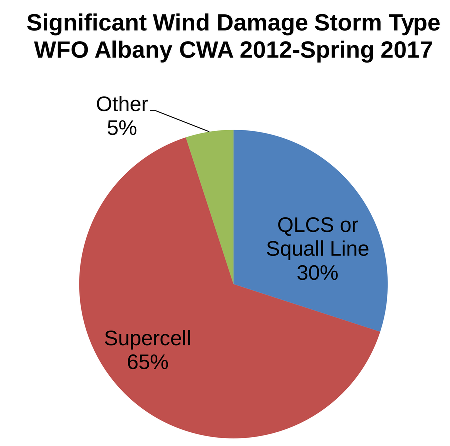
Forecasters at NWS Albany are now checking SigSevere values before and during events (via the SPC Mesoanalysis page) to assess the potential for significant severe thunderstorm events. 9 significant severe wind events since 2012 showed SigSevere values in excess of 20,000 from the nearest KALY observed sounding.

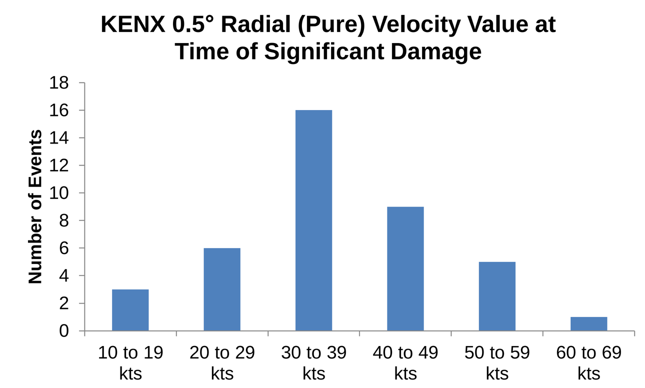


KALY observed upper air sounding from 00Z 14 August 2016. Widespread severe convection was ongoing around this time and a significant severe event occurred just shortly before the sounding was launched across Fulton County NY. The SigSevere Parameter exceeded 50,000 m^3/s^3.

Potential Methods To Increase Detection

Radar data from the Albany KENX WSR-88D was examined for the 40 thunderstorms that produced significant wind damage across the Albany WFO CWA from 2012 to Spring 2017. Several radar-based parameters, such as radial velocity and Specific Differential Phase (KDP), were collected at the time of and just prior to the time of the damage report via GR2Analyst software. The storm type was noted as well.



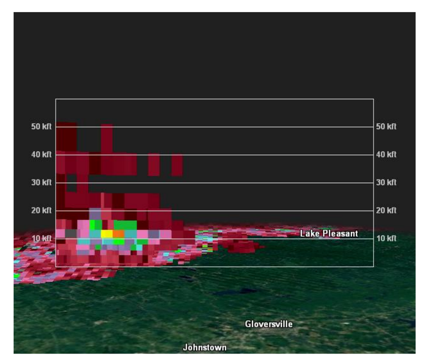


Significant wind damage not always associated with high radial (pure) velocity values due to mentioned radar limitations.

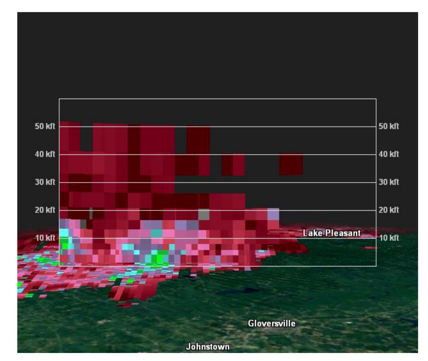
Collapsing KDP Columns due to Wet Microburst

Out of the 40 storms analyzed, 25 of them showed an elevated KDP column suspended aloft for several scans before the wind damage occurred. This KDP column collapsed towards the surface at the time of the wind damage report as a result of a wet microburst. Within the 25 times this was noted, 21 of those storms were associated with supercell thunderstorms.

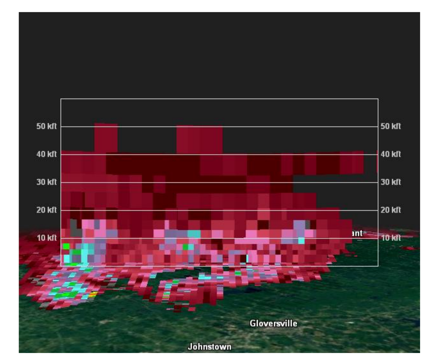
The highest KDP value within the suspended column aloft averaged to be 7.0 deg/km within these thunderstorms & the median value was 6.6 deg/km.



KENX KDP Cross-section
13 Aug 2016 20:14Z



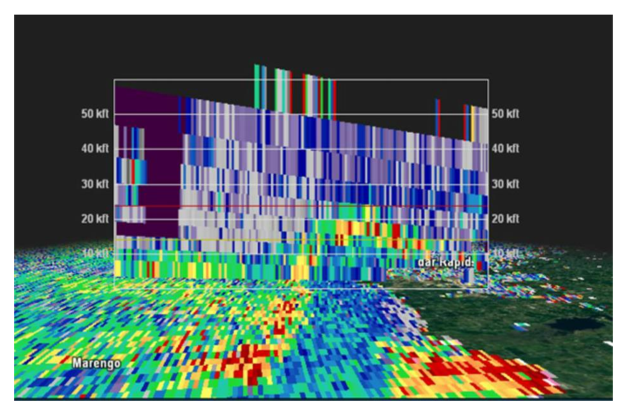
KENX KDP Cross-section
13 Aug 2016 20:20Z



KENX KDP Cross-section
13 Aug 2016 20:26Z

Cross-section of KDP from KENX show the elevated KDP column falling down to the surface on 13 August 2016 thanks to a strong microburst within a severe squall line. Significant damage occurred at 20:25Z at the Pine Lake Campground in the town of Caroga in Fulton County, New York. The max value of the KDP within the elevated column was around 5.5 deg/km.

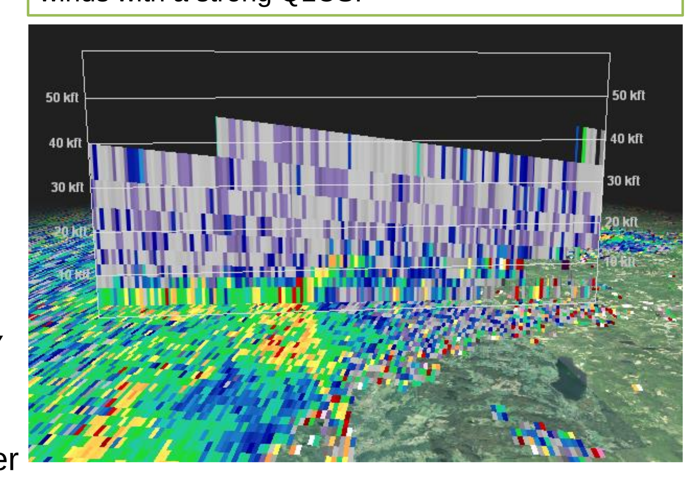
Z_{DR} Arch within QLCS



Example of a Z_{DR} Arch from 30 June 2014 at 1940Z from a severe thunderstorm produced by a strong QLCS over Iowa (Trogdon 2015).

Research done by Trogdon 2015 shows that size sorting of hydrometeors within a QLCS sometimes takes on arch shape within Z_{DR} when viewed in a cross-section. The backside of arch shows the interaction of the rear-inflow jet with the surface and could be used as a warning indicator for severe winds with a strong QLCS.

Out of the 40 cases examined since 2012, 12 were QLCS/Squall line. 4 of those *may* have shown a signal of a Z_{DR} arch, although the feature was subtle and would probably be difficult for a warning forecaster to pick out during a real-time event. More cases will need to be analyzed to see if this feature can be found more easily.



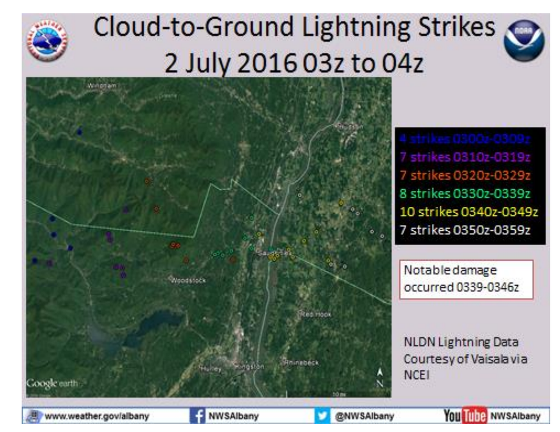
A possible example of a Z_{DR} arch from 18 May 2017 at 22:25Z across the Mohawk Valley of New York. A severe thunderstorm squall line produced widespread damage across southern Herkimer County.

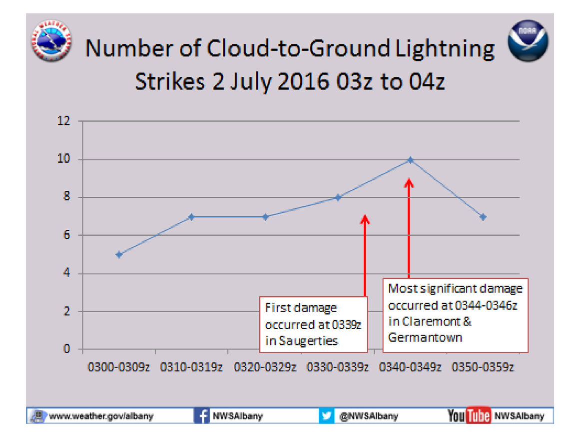
Utilizing Lightning Jumps

Warning Decision Training Division (WDTD) recommends utilizing Total Lightning Flash Rate when examining the potential for severe winds within a QLCS in their Warning Operations Course (WOC)

The confidence in the utility of this method in the Northeast will be enhanced by recently completed COMET/CSTAR V work (Eck 2017). That particular study (a collaborative project between the NWS and UAlbany) is incorporating lightning jumps along with upslope and radar-based parameters into a useful tool for predicting severe thunderstorms.

The implementation of the Global Lightning Mapper (GLM) on the GOES 16 satellite will also help greatly as well, as there will be better coverage of total lightning across North America.





Although only cloud-to-ground strikes were available to study for this particular event, an increase in lightning activity could have been a signal of a strengthening storm on 2 July 2016. This particular storm (which occurred during the late evening hours) developed within an area over the eastern Catskills that suffers from beam blockage from the KENX radar, so low level Z/V products were probably not sampled fully. This storm produced significant wind damage within parts of the mid-Hudson Valley from 0339Z to 0346Z.

Conclusions

- Significant severe thunderstorms do occur over the Northeastern United States, with significant wind damage being the highest threat.
- Determining if a severe thunderstorm will produce significant damage can be difficult at times for warning forecasters to pick out based on radial (pure) velocity alone. Knowing how strong a thunderstorm will be is valuable information for impact-based warnings.
- Radar limitations (beam blockage, larger angles, distance from RDA) can all have an impact on the quality of radar data and need to be kept in mind during warning decisions.
- Using the SigSevere product can help improve situational awareness of the possibility of significant severe thunderstorms.
- Watching for collapsing KDP columns may be helpful during the warning process, especially within supercells with elevated KDP values of greater than 6.5 to 7 deg/km.
- ZDR Archs may possibly be seen in some strong QLCS/Squall lines, but could be difficult to pick out in real-time.
- Lightning jumps (especially in conjunction with upslope and radar-based parameters) may be useful during the warning process. New COMET/CSTAR research and data from the GOES 16 GLM will be helpful in integrating this into operations.
- Additional cases, including null cases, will need to be examined over the next few years to fully learn the utility of these items.

This project is a non-funded collaborative project of CSTAR VI between the National Weather Service and the University at Albany.