Severe Weather Applications of Dual-Pol Radar

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ATM362: Forecasting & National Weather Service Operations
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Numerous Applications for Dual-Pol Radar With Severe Local Storms

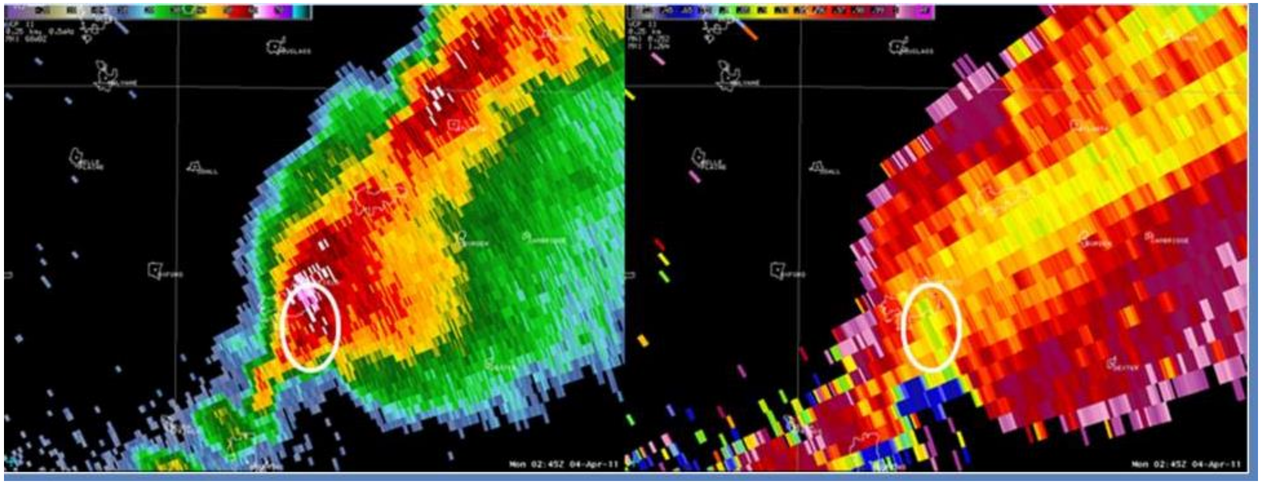
- Locating hail & differentiating between severe and non-severe hail

- Identifying tornadic debris

- Helping predict the possibility of significant severe wind gusts

Locating Hail & Differentiating Between Severe & Non-Severe Hail

- With cross-sections of reflectivity (Z), very high values (50+ dBZ) can be used to locate possible areas of hail
- Correlation Coefficient (CC) can be used to help determine hail or hail/rain mix compared to just rain



Use of Radar During the Warning Decision Process

- NWS Meteorologists must make decisions for warnings knowing the size of the hail

- But how we do we know how big the hail is?

Motivation for Local Hail Study

- The official National Weather Service criterion for severe hail was changed from 1.9 cm (0.75 in) to 2.5 cm (1.00 in) on 5 January 2010.

- Previous local severe hail warning guidance was based off the legacy criterion and other previous local studies have only focused on pulse thunderstorms, while the majority of hail producing storms in the Albany County Warning Area (CWA) are from multicells or supercells.

- Other national studies for hail have not focused on the Northeast, whose thunderstorms generally do not grow as tall as storms occurring across the Plains.

- Differentiating between severe and non severe hail in the Northeast can be difficult due to many storms only containing marginally strong updrafts. Also, radar coverage is compromised in areas of high terrain and verification can be difficult in rural and mountainous areas.

Data and Methodology

- 384 hail events from 2005-2010 from the Albany CWA were compiled in a database. Hail events were obtained from local storm reports entered into *StormData*. 177 of these events would be considered severe under the new criterion.

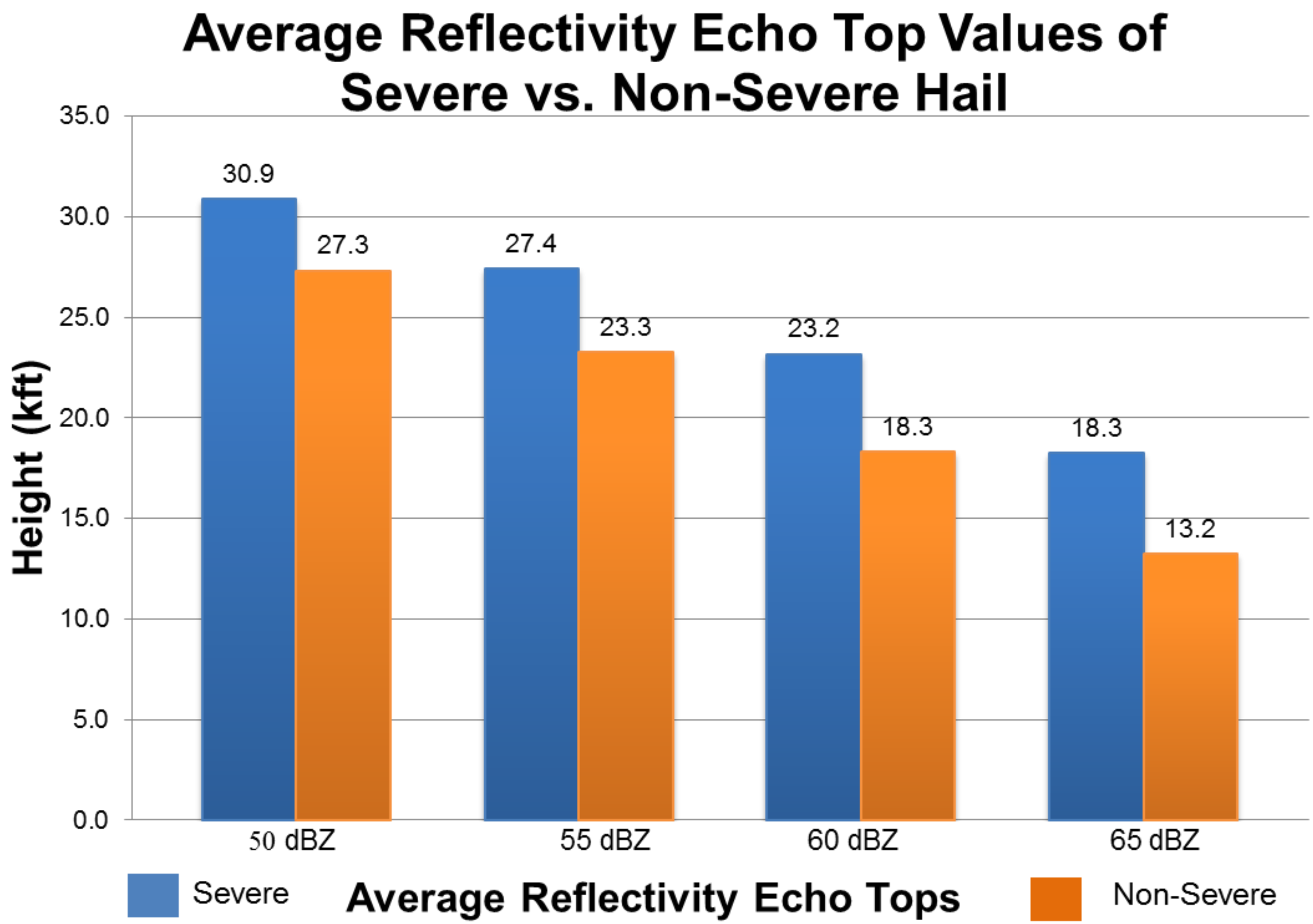
- Radar data (mainly from KENX) was examined for each hail event on the Weather Event Simulator (WES) using both the Four-Dimensional Storm Investigator (FSI) and plane view graphics from Display Two-Dimensions (D-2D).

- The height of the top of 50, 55, 60 and 65 dBZ echoes were recorded from the radar time closest to the hail report for the location in which it occurred. In addition, these values were also examined in relation to the 0°C and -20°C levels, as obtained from the most recent Albany, NY (KALY) upper air sounding.

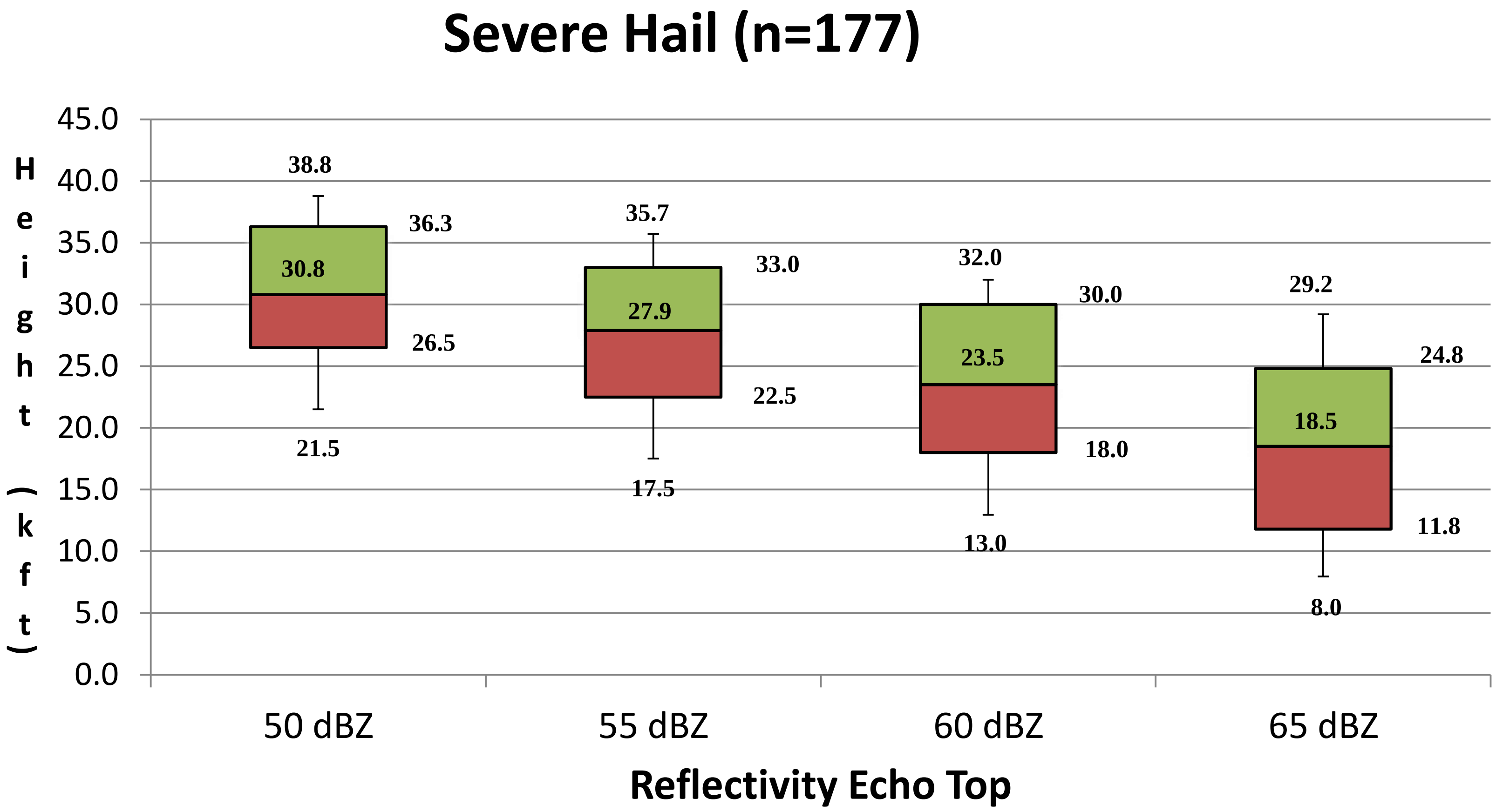
Charts for Operational Use:
Average Values

	SEVERE 1.00”+ (Quarter or Larger) Hail	NON-SEVERE 0.25”- 0.88” (Nickel or smaller) Hail	Difference
Average Height of 50 dBZ Echo Top	30.9 kft	27.3 kft	3.6 kft
Average Height of 55 dBZ Echo Top	27.4 kft	23.3 kft	4.1 kft
Average Height of 60 dBZ Echo Top	23.2 kft	18.3 kft	4.9 kft
Average Height of 65 dBZ Echo Top	18.3 kft	13.2 kft	5.1 kft
Average Height of 50 dBZ Echo Top above -20° C Isotherm	8.7 kft	5.5 kft	3.2 kft
Average GVIL (kg/m^2)	50 kg/m^2	44 kg/m^2	6 kg/m^2

Charts for Operational Use:
Average Values

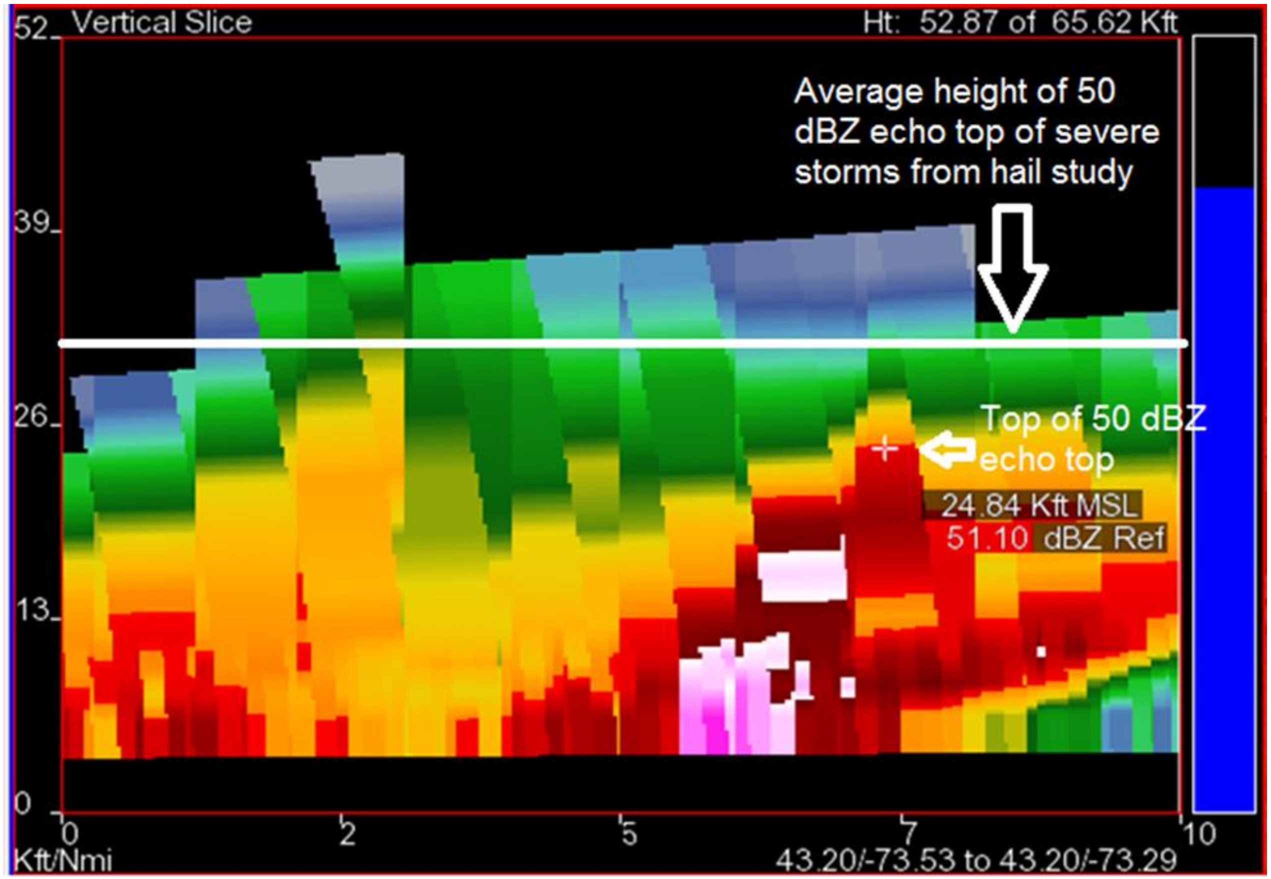


Charts for Operational Use:
Box and Whisker Plot

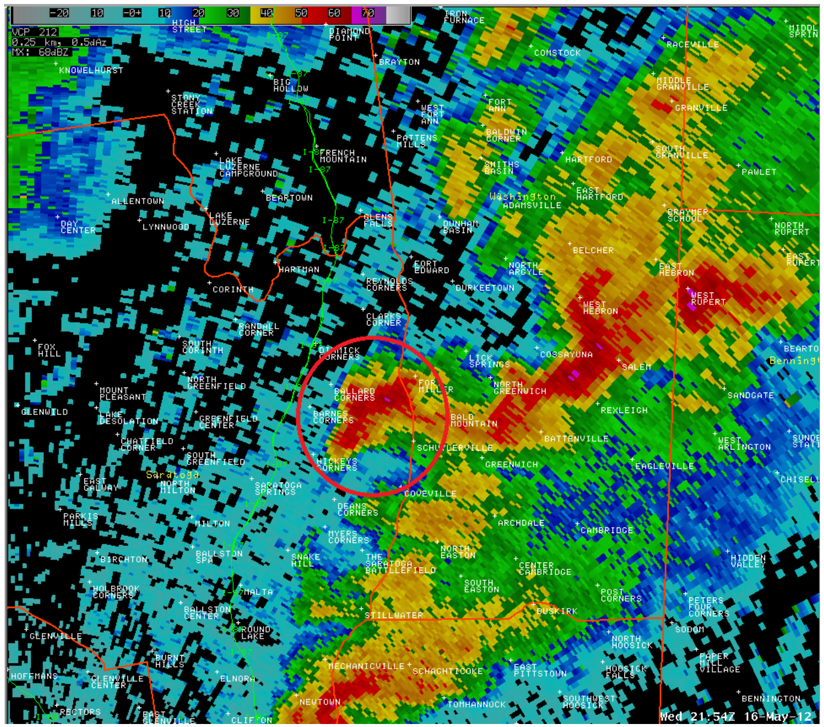


16 May 2012
Vertical Cross-Section Reflectivity (Z)

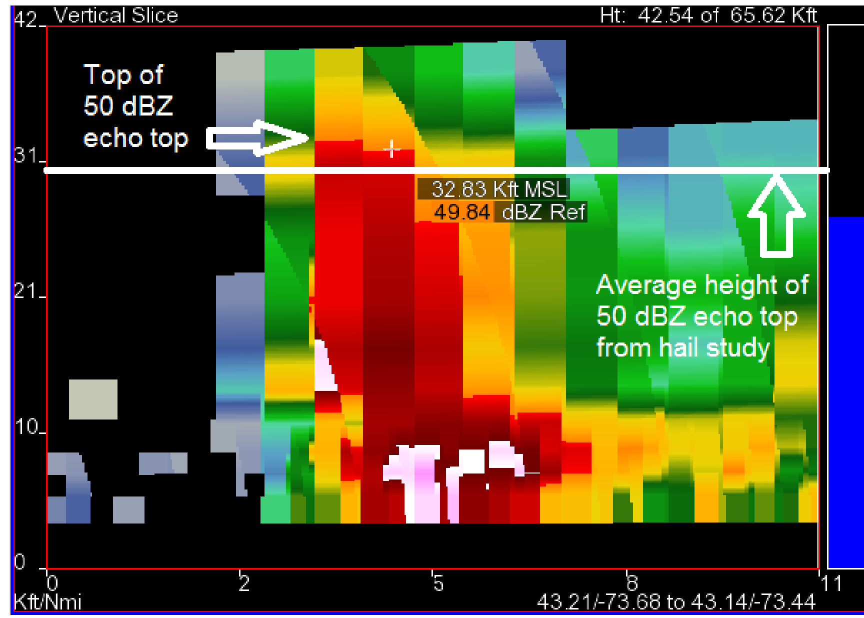
A vertical cross-section of a thunderstorm over Washington County, NY from 2135Z (5:35 pm EDT) on 16 May 2012. Using information from the ALY Hail Study would suggest that severe hail would occur when the 50 dBZ level reached 8.7 kft higher than the -20°C level (28.9 kft in this case). The 50 dBZ values only reached an echo top of around 24.8 kft. This level, also short of the hail study's average 50 dBZ height of 30.9 kft, would suggest severe hail is unlikely from this storm.



16 May 2012
Reflectivity (Z)

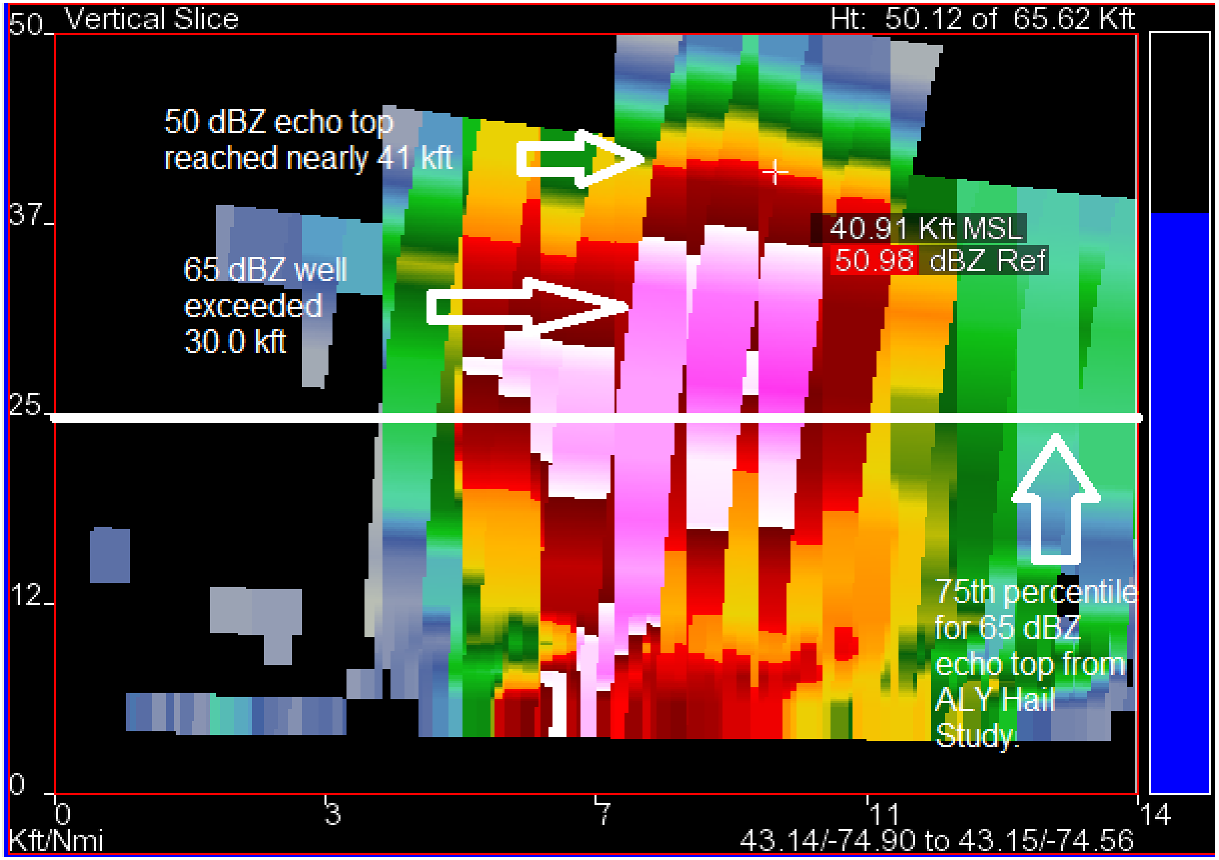


Base (0.5°) reflectivity of a thunderstorm over Saratoga County, NY from 2154Z (5:54 pm EDT) from 16 May 2012. This storm produced quarter (1.00”) to ping pong ball (1.50”) size hail near Flagler Corners at this time, which covered the ground.



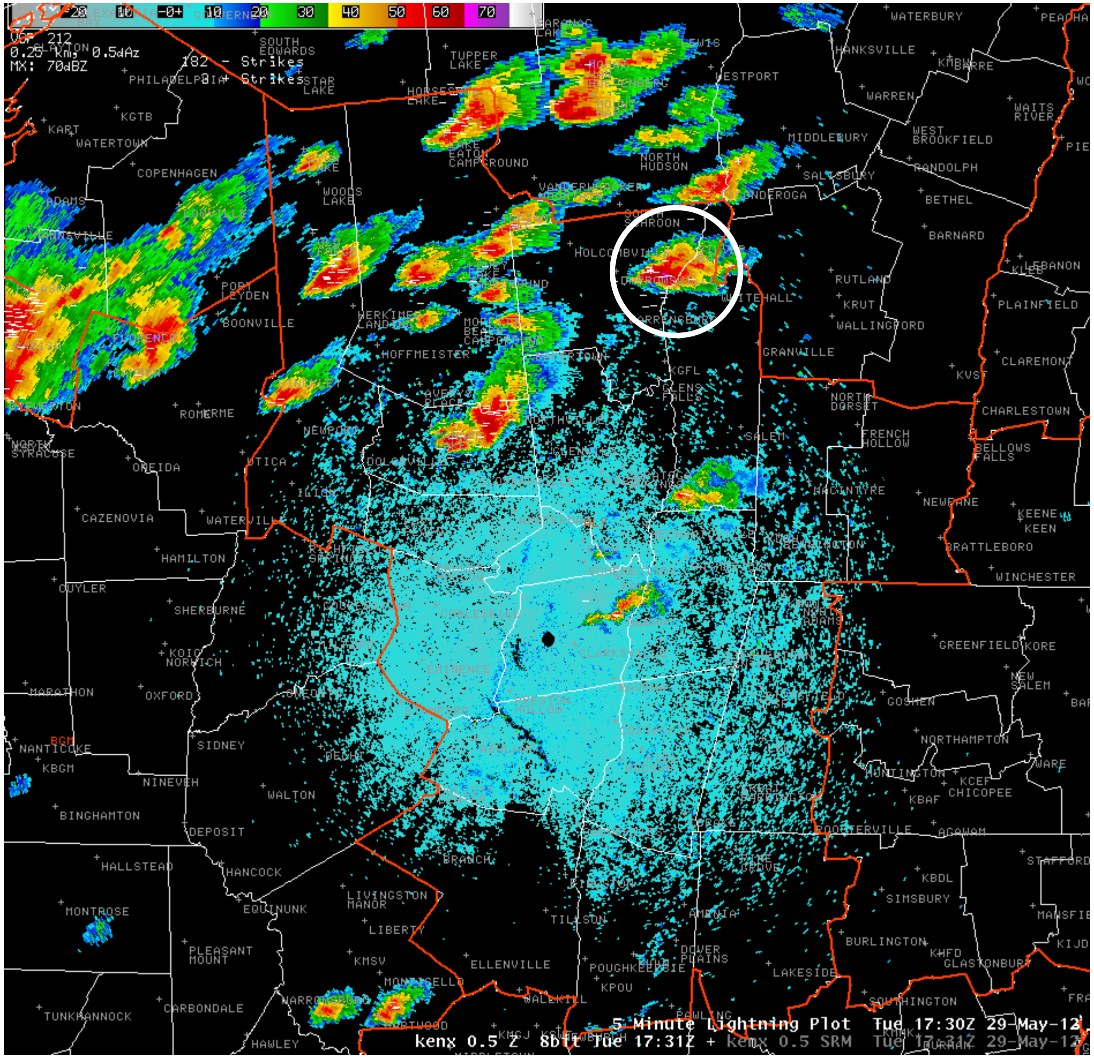
A vertical cross-section of a thunderstorm over Saratoga County, NY from 2154Z (5:54 pm EDT) on 16 May 2012. The 50 dBZ echo top exceeded the hail study’s average value by 1.9 kft, suggesting severe hail was possible. The storm produced 1.00”-1.50” hail near Flagler Corners.

29 May 2012
Vertical Cross-Section Reflectivity (Z)



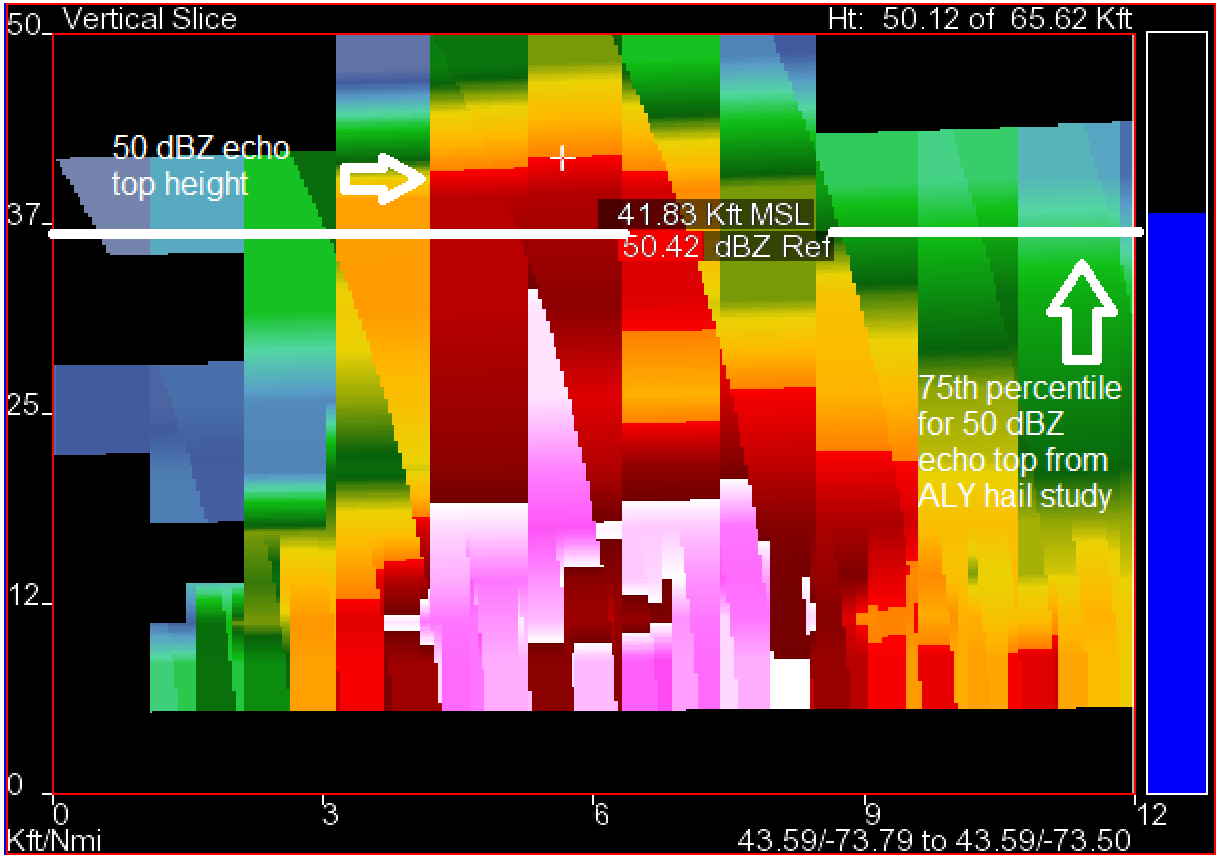
A vertical cross-section of a thunderstorm over Fulton County, New York from 1649z (12:49 pm edt). The 65 dBZ echo top exceeded the hail study's 75th percentile by about 10.0 kft, suggesting severe hail was extremely likely and potentially very large. Hail reached the size of a baseball, which is considered very rare for Upstate New York.

29 May 2012 1731 UTC
KENX 0.5° Reflectivity (Z)



29 May 2012 1731 UTC
Cross-section near Bolton, NY

Hail stones of at least golf-ball size (1.75" expected) !!!



-20°C height= 23.7 kft AGL
-30°C height= 27.9 kft AGL

Hail Size was increased based on FSI cross-section and application of research

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WWUS51 KALY 291733
SVSALY

SEVERE WEATHER STATEMENT
NATIONAL WEATHER SERVICE ALBANY NY
133 PM EDT TUE MAY 29 2012

NYC113-115-291815-
/O.CON.KALY.SV.W.0014.000000T0000Z-120529T1815Z/
WASHINGTON NY-WARREN NY-
133 PM EDT TUE MAY 29 2012

...A SEVERE THUNDERSTORM WARNING REMAINS IN EFFECT UNTIL 215 PM EDT
FOR NORTHEASTERN WARREN AND NORTHERN WASHINGTON COUNTIES...

AT 131 PM EDT...NATIONAL WEATHER SERVICE DOPPLER RADAR CONTINUED TO
INDICATE A SEVERE THUNDERSTORM CAPABLE OF PRODUCING GOLF BALL SIZE
HAIL...AND DAMAGING WINDS IN EXCESS OF 60 MPH.  THIS STORM WAS
LOCATED NEAR SHELVING ROCK...OR 10 MILES WEST OF WHITEHALL...MOVING
EAST AT 25 MPH.

THE SEVERE THUNDERSTORM WILL BE NEAR...
  HULETTS LANDING...SABBATH DAY POINT AND SILVER BAY BY 145 PM EDT...
  CLEMONS...SNODY DOCK...WHITEHALL AND LOCK TWELVE MARINA BY 150 PM
  EDT...
  OTTENBURGS RAMP BY 155 PM EDT...
  LOW HAMPTON AND 6 MILES SOUTH OF PUTNAM STATION BY 205 PM EDT...

PRECAUTIONARY/PREPAREDNESS ACTIONS...

A TORNADO WATCH REMAINS IN EFFECT FOR THE WARNED AREA. IF A TORNADO
IS SPOTTED... ACT QUICKLY AND MOVE TO A PLACE OF SAFETY IN A STURDY
STRUCTURE...SUCH AS A BASEMENT OR SMALL INTERIOR ROOM.

IN ADDITION TO LARGE HAIL AND DAMAGING WINDS...CONTINUOUS CLOUD TO
GROUND LIGHTNING IS OCCURRING WITH THIS STORM. MOVE INDOORS
IMMEDIATELY! LIGHTNING IS ONE OF NATURES NUMBER ONE KILLERS.
REMEMBER...IF YOU CAN HEAR THUNDER...YOU ARE CLOSE ENOUGH TO BE
STRUCK BY LIGHTNING.

IF ON OR NEAR LAKE GEORGE...GET OUT OF THE WATER AND MOVE INDOORS OR
INSIDE A VEHICLE. REMEMBER...LIGHTNING CAN STRIKE OUT TO 15 MILES
FROM THE PARENT THUNDERSTORM. IF YOU CAN HEAR THUNDER...YOU ARE
CLOSE ENOUGH TO BE STRUCK BY LIGHTNING. MOVE TO SAFE SHELTER NOW.
DON'T BE CAUGHT ON THE WATER IN A THUNDERSTORM!

PLEASE REPORT HAIL SIZE...DAMAGING WINDS AND REPORTS OF TREES DOWN TO
THE NATIONAL WEATHER SERVICE BY EMAIL AT ALB.STORMREPORT@NOAA.GOV OR
ON FACEBOOK AT WWW.FACEBOOK.COM/US.NATIONALWEATHERSERVICE.ALBANY.GOV.

A TORNADO WATCH REMAINS IN EFFECT UNTIL 900 PM EDT TUESDAY EVENING
FOR WESTERN MASSACHUSETTS AND EASTERN NEW YORK AND SOUTHERN VERMONT.

&&

LAT...LON 4377 7334 4369 7340 4359 7342 4358 7340
      4363 7337 4363 7332 4353 7323 4352 7324
      4350 7338 4349 7368 4366 7375 4374 7364
      4381 7348 4381 7338
TIME...MOT...LOC 1732Z 254DEG 22KT 4360 7359

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FRUGIS/WASULA
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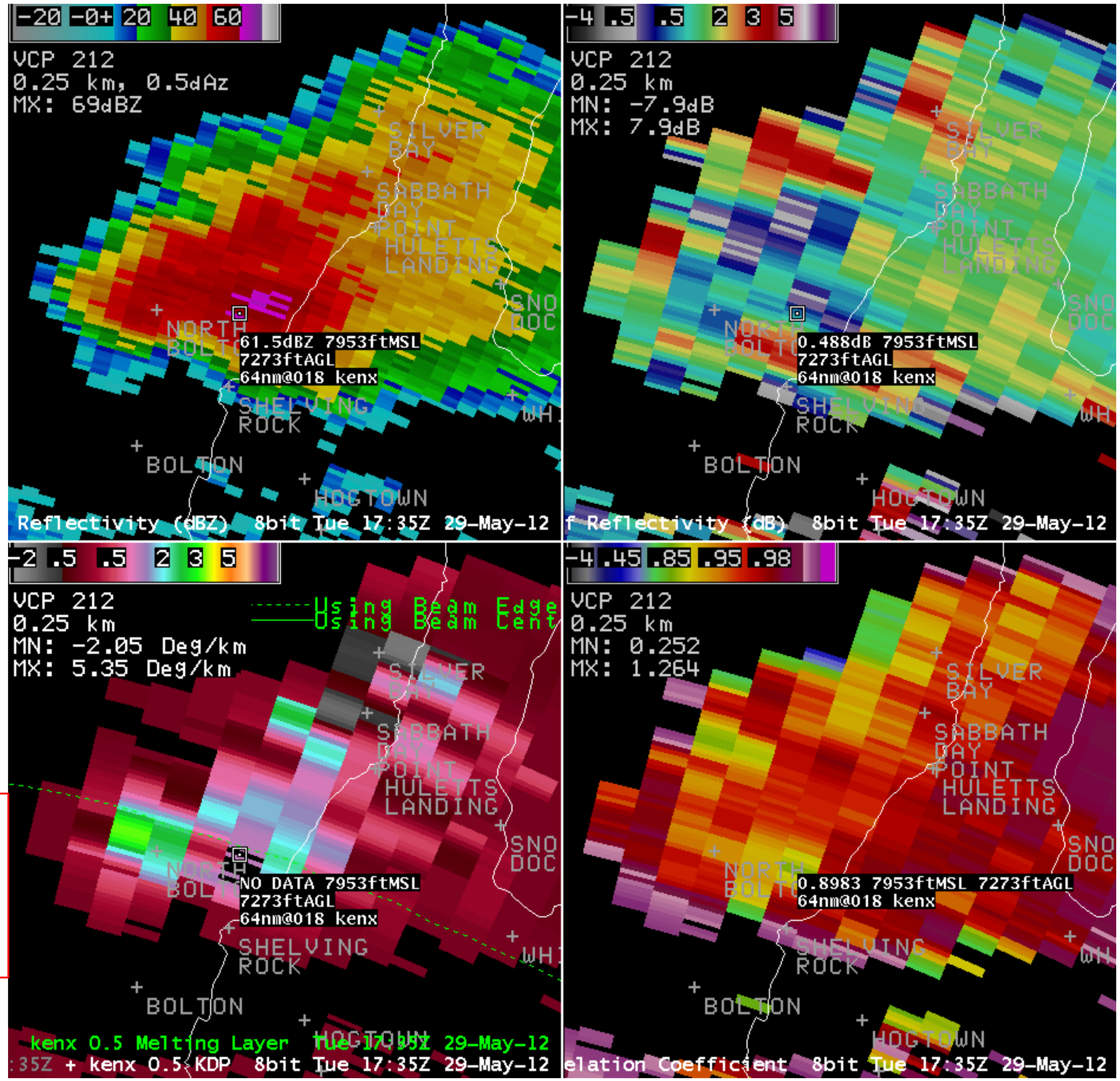
29 May 2012 1735 UTC
0.5° Z, ZDR,KDP,CC near Bolton, NY

0.5° Z

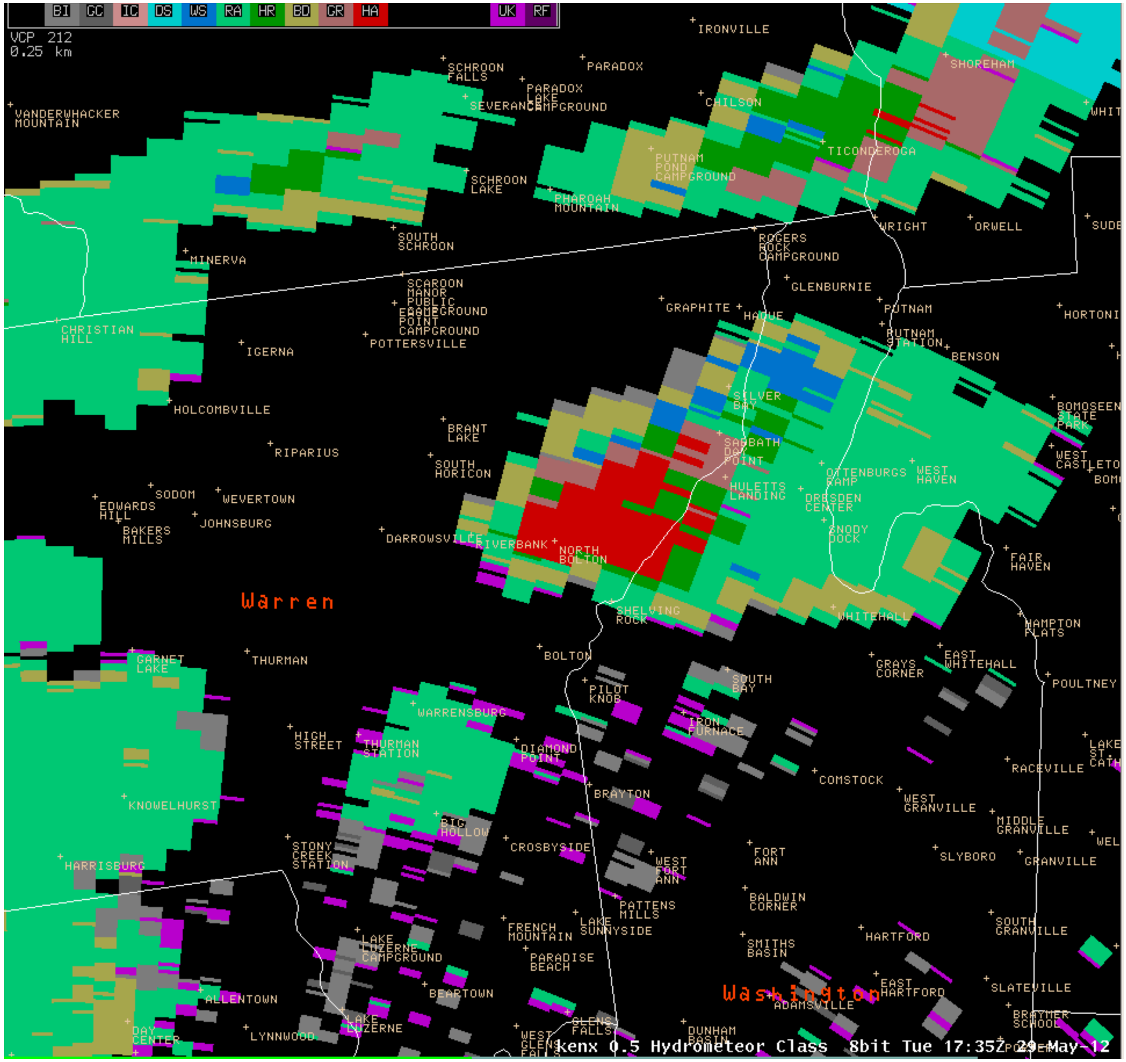
Differential Reflectivity (ZDR)



Specific Differential Phase (KDP)

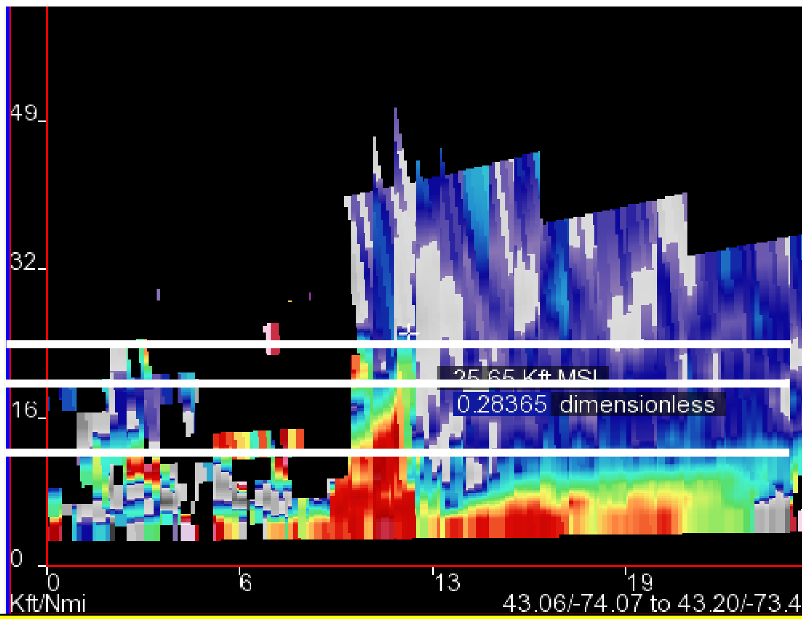
Correlation Coefficient (CC)

29 May 2012 1735 UTC
Hydrometeor Classification 0.5°

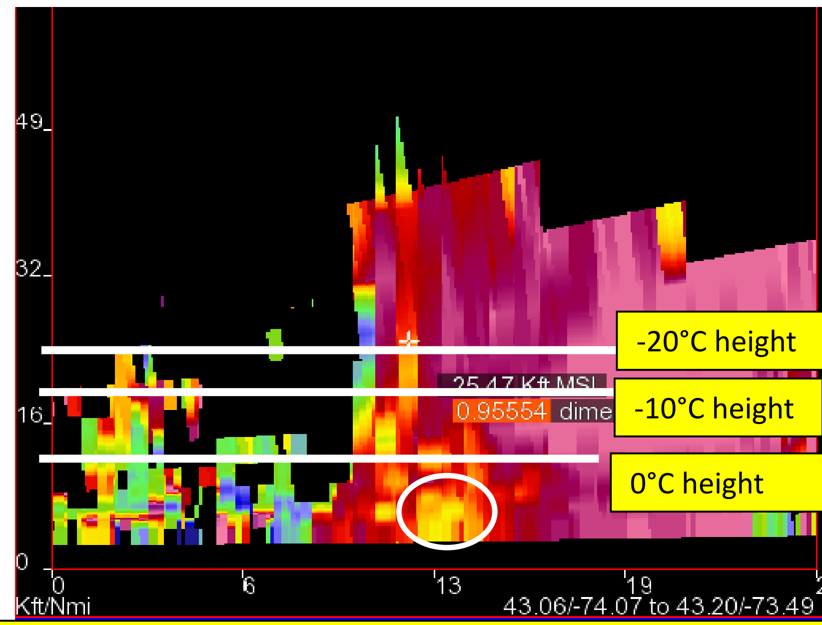


29 May 2012 1735 UTC
Differential Reflectivity (ZDR) & Correlation Coefficient Vertical Cross-sections

ZDR



Correlation Coefficient

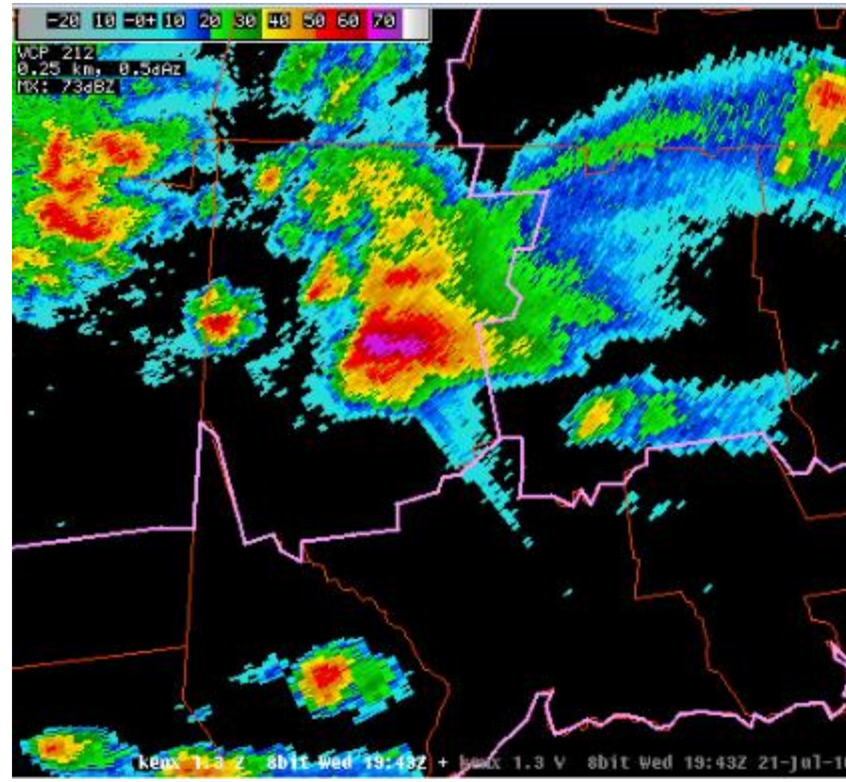


ZDR Column extends above -20°C height (23.7 kft), and CC values in the 0.90-0.95 range in the hail growth zone. Based on local research by Ian Lee, this indicates supercooled hydrometeors have transitioned to frozen hydrometeors (large hailstones). Hailstones fallen to ground (white circle area). The strength of the updraft is indicative by the ZDR column.

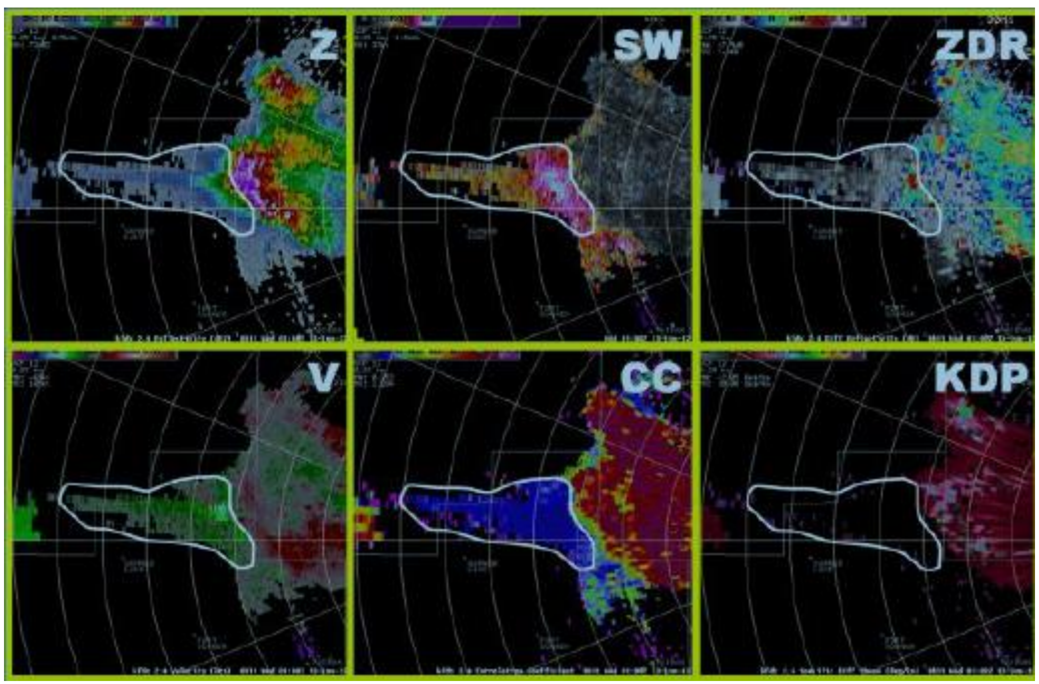
May 29, 2012: Bolton 3.5” hail stones in Lake George, Warren County

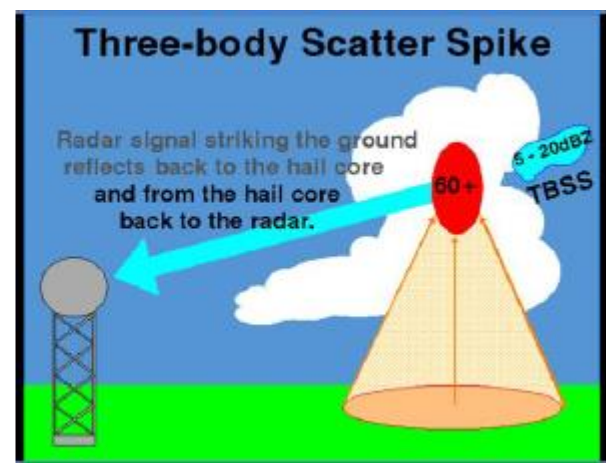
Three-Body Scatter Spike

Three-body Scatter Spikes (TBSS) are a radar artifact caused by the radar beam interacting with large hail within a thunderstorm. These can be a clue to the warning forecaster that large hail is present.



KENX 1.3° Z from 21 Jul 2010 19:43 UTC



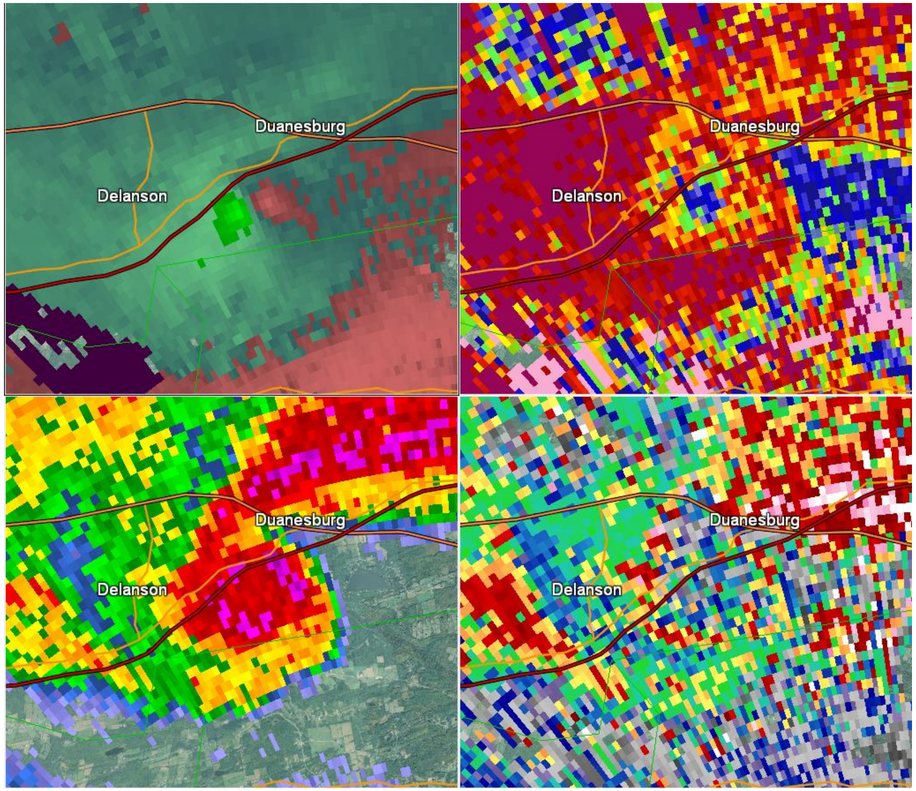


Identifying Tornadic Debris

- Dual-pol radar can be used to determine if debris is present within a thunderstorm
  - This would suggest a tornado is occurring or has recently occurred and has caused damage
- A Tornadic Debris Signature (TDS) helps confirm tornadoes and help suggest how strong they may be
  - Provides info for Tornadic Warning Update Statements
  - Does NOT help you initially warn on the tornado

Tornadic Debris Signature Detection (TDS) 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 with gate-to-gate rotation.

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.

Tornadic Debris Signature Statistics Northeastern US Events 2012-2015

EF-0	EF-1	EF-2	EF-3	EF-4	EF-5
5	**14**	**4**	**1**	**0**	**0**

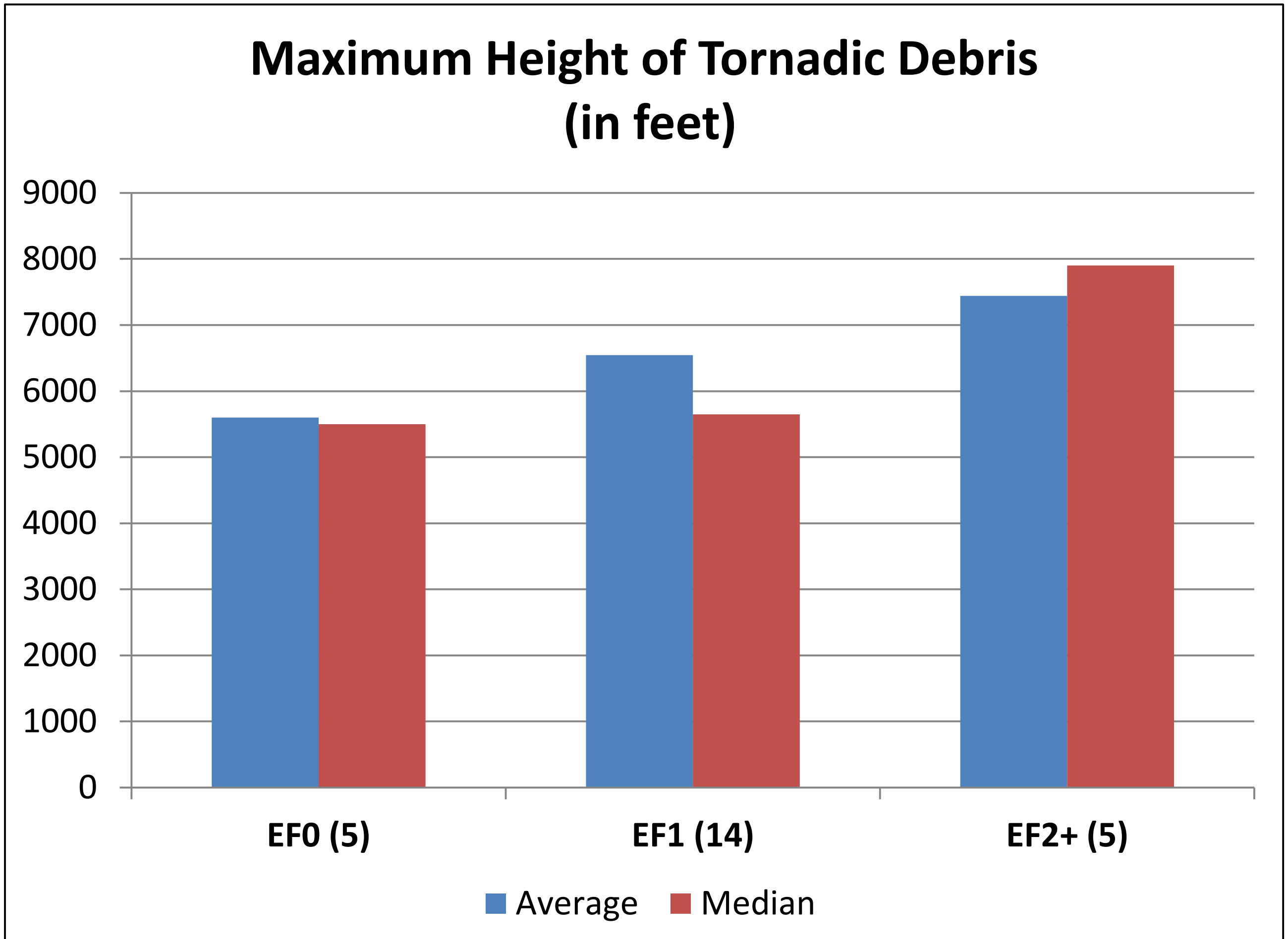
69 tornadic events from 2012-2015 from the Northeastern United States were examined for the presence of a Tornadic Debris Signature (TDS).

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.

Maximum Height of TDS Average & Median Values

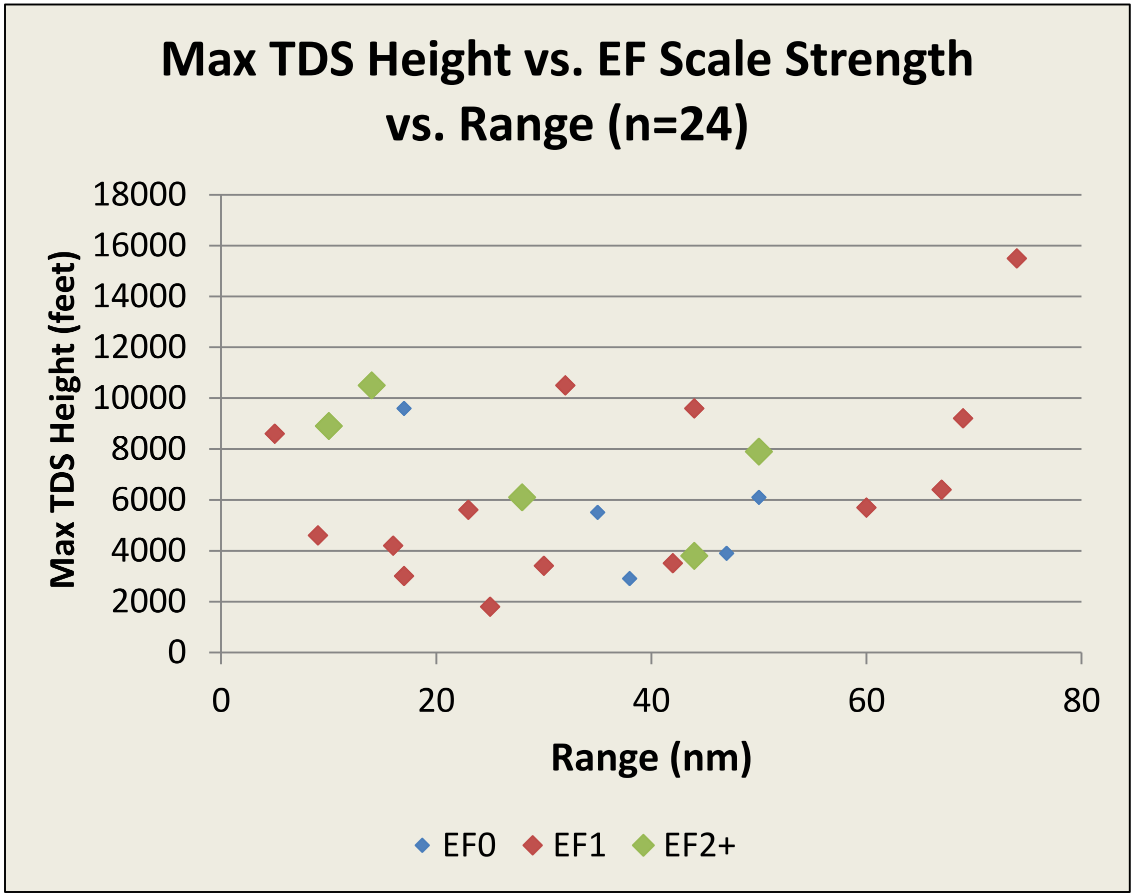


For the 24 events examined between 2012-2015, the average & median values increase with increasing tornadic strength, especially once reaching the EF2 level.

This is similar to results found by Entremont and Lamb (2015).

More storms will be examined in future years as the dataset expands to see if these trends continue.

Maximum Height of TDS vs. EF Scale Strength vs. Range

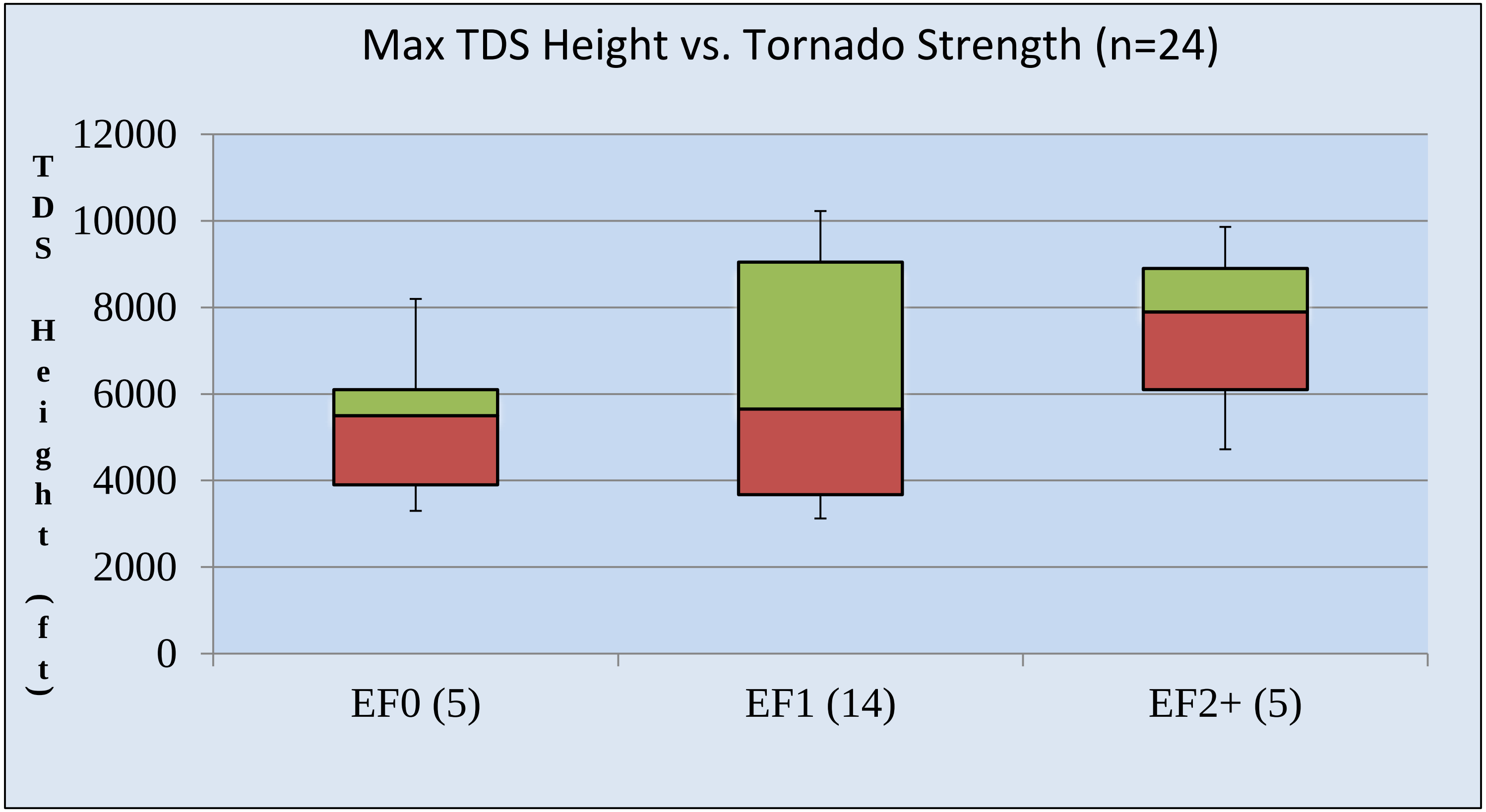


Weak tornadic events (EF0) were generally only see close to the radar, as debris generally didn't get very high and beam height rising over distance would prevent these further away storms from being seen.

Hard to seen much difference between EF0/EF1 storms with this plot.

Maximum Height of TDS

Northeastern US Tornados 2012-2015
Box and Whisker Plot



EF0/EF1 are similar, but jump up seen with EF2+ events. Entremont and Lamb (2015) also saw a similar signal in their data as well (which contained 181 events).

Determining Significant Severe Wind Gusts

- Typically, velocity (V) is used to help determine how strong thunderstorm wind gusts will be
- However, velocity doesn't always show the full potential of the wind due to some limitations
  - Beam blockage, too large of an angle, distance from radar site can all play a role in this
- Local research has determined that dual-pol product Specific Differential Phase (KDP) may be useful in helping predict significant severe wind gusts

Motivation for Research

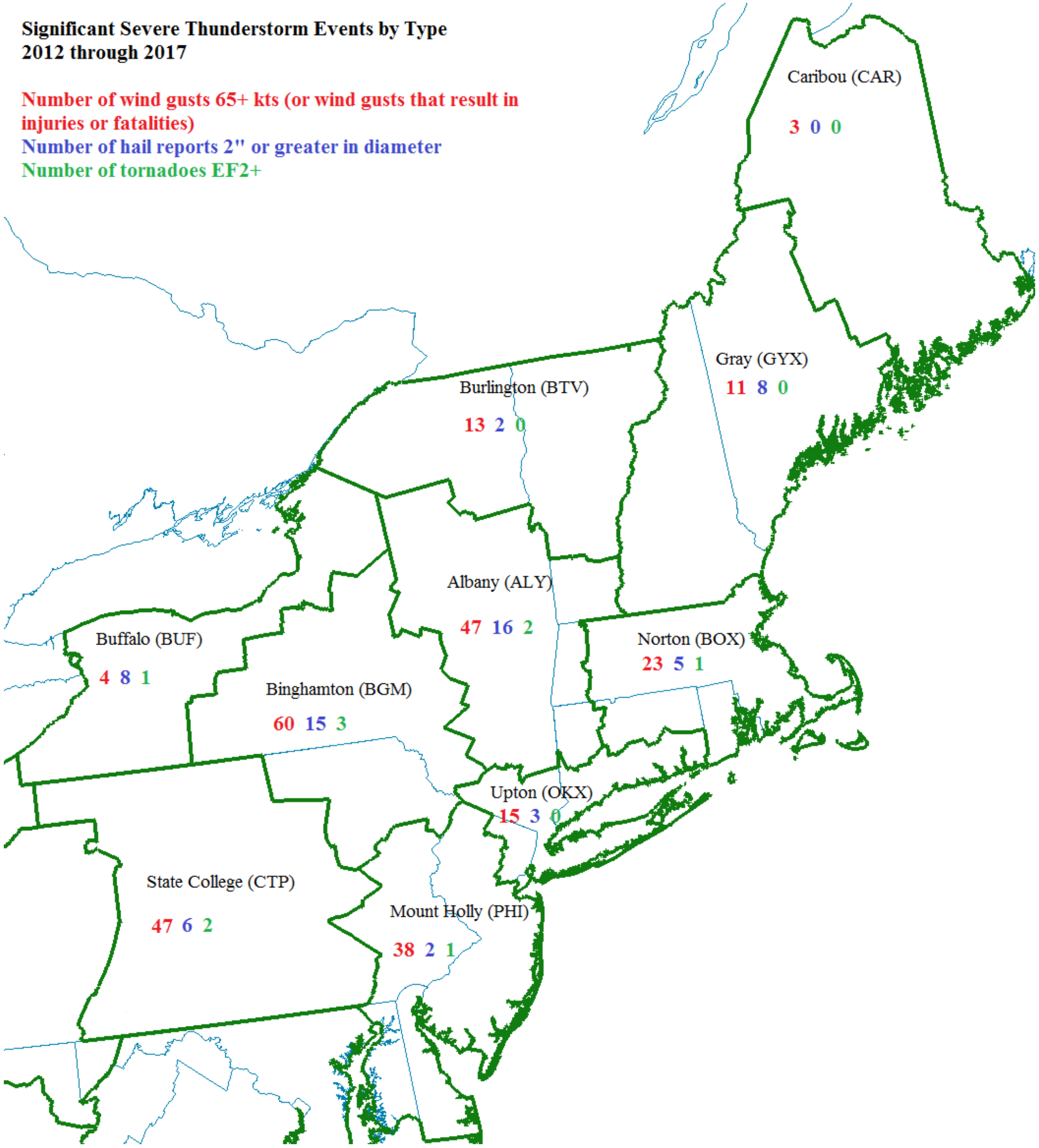
- Determining severe vs. significant severe thunderstorms can be difficult for a warning meteorologist.
- This has been a challenge for NWS Albany (ALY) forecasters on several occasions during the summers of 2016 & 2017. Several significant thunderstorms were either missed or under warned.
- Impact-based 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?

- SPC considers thunderstorms that produce wind gust of 65 kts (75 MPH), hail two inches in diameter or greater, and/or an EF2+ tornado to be significant

- For the purpose of this study, will also consider thunderstorms that produce injuries or deaths to be significant as well

Significant Severe Thunderstorm Climatology for Northeast*

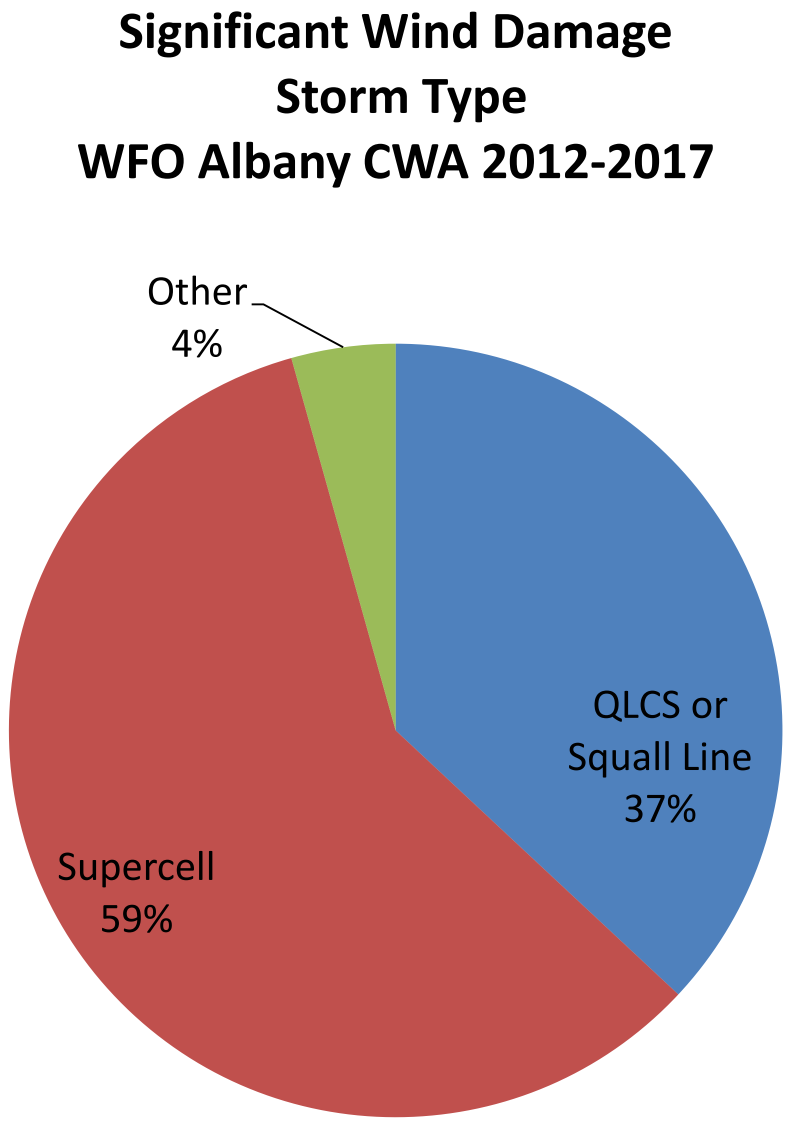


*For the purpose of this study, Northeast is considered New England, New York, New Jersey, Delaware, northeastern Maryland & Central and Eastern Pennsylvania

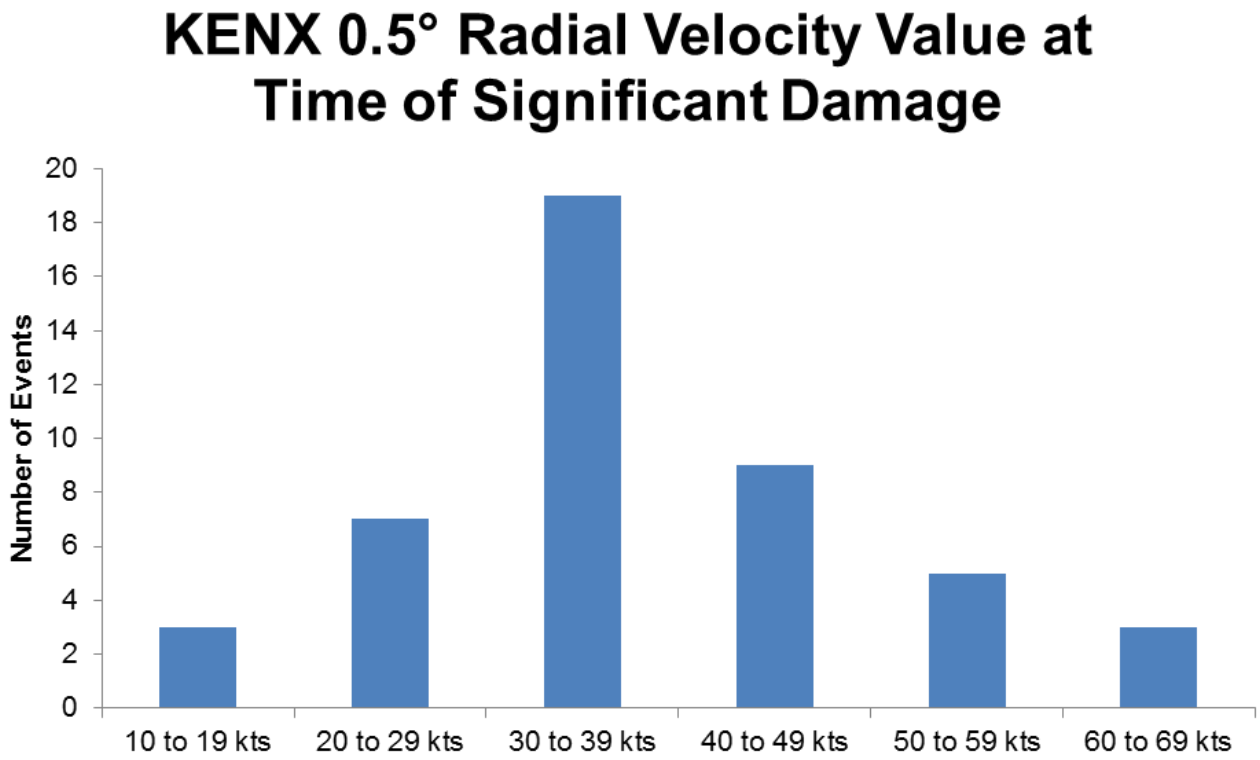
Radar Analysis of Significant Severe Thunderstorms

Radar data from the Albany KENX WSR-88D was examined for the **46** thunderstorms that produced significant wind damage across the Albany WFO CWA from 2012 to 2017.

Several radar-based parameters, such as storm type, radial velocity and Specific Differential Phase (K_{DP}), were collected at the time of and just prior to the time of the damage report via GR2Analyst software.



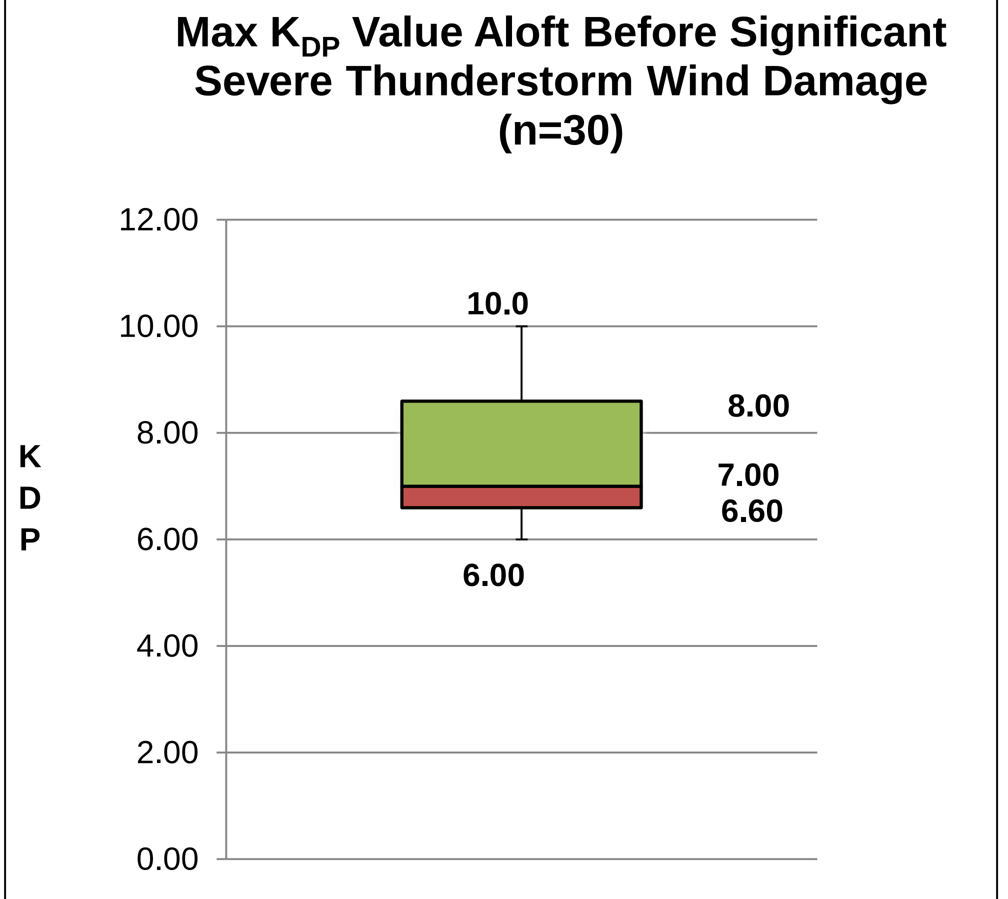
Radial Velocity Analysis



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

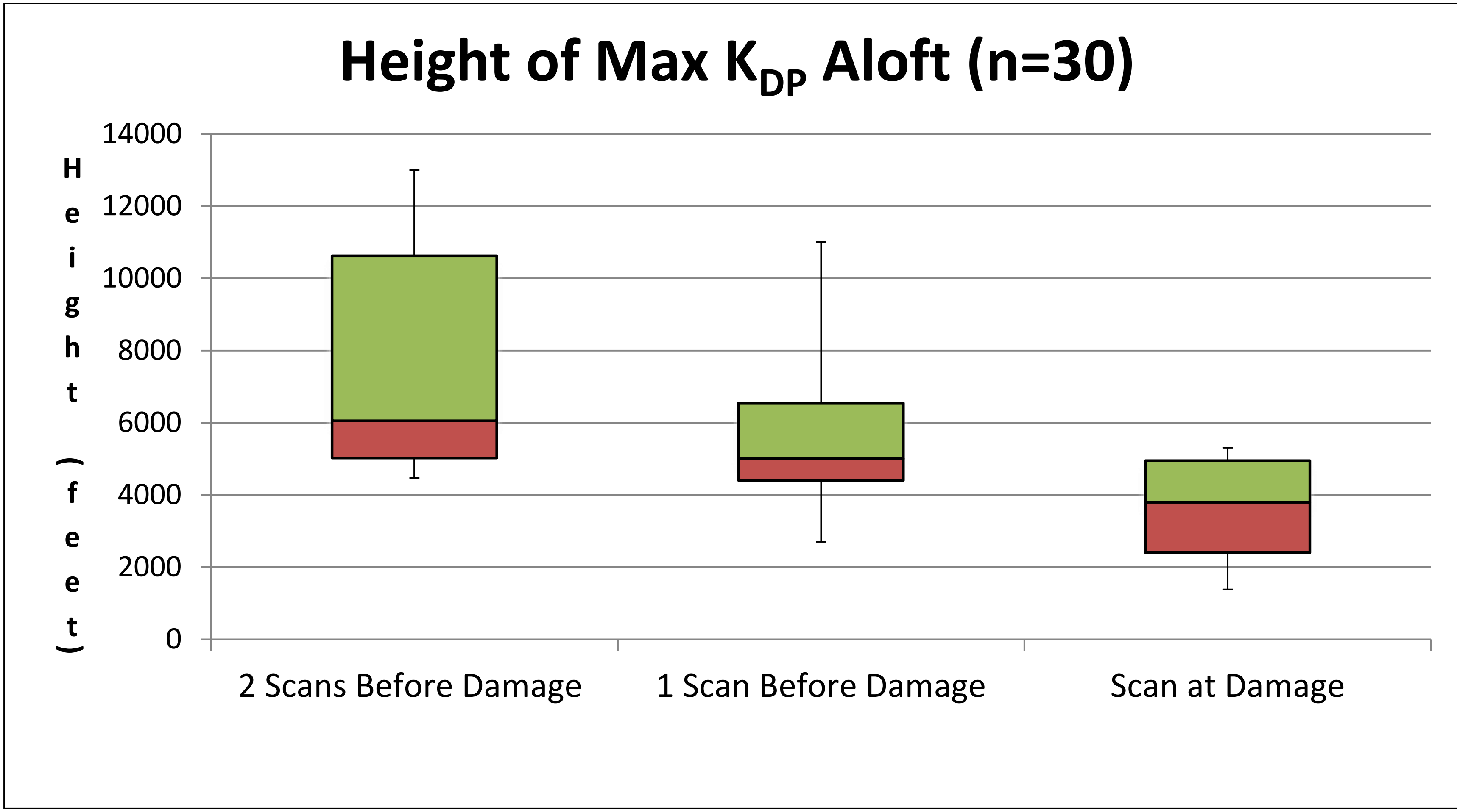
Specific Differential Phase (K_{DP})

- Out of the 46 storms analyzed, 30 of them showed an elevated K_{DP} column suspended aloft for several scans before the wind damage occurred.
- This K_{DP} column collapsed towards the surface at the time of the wind damage report as a result of a wet microburst.
- Within the 30 times this was noted, 22 of those events were associated with supercell thunderstorms.



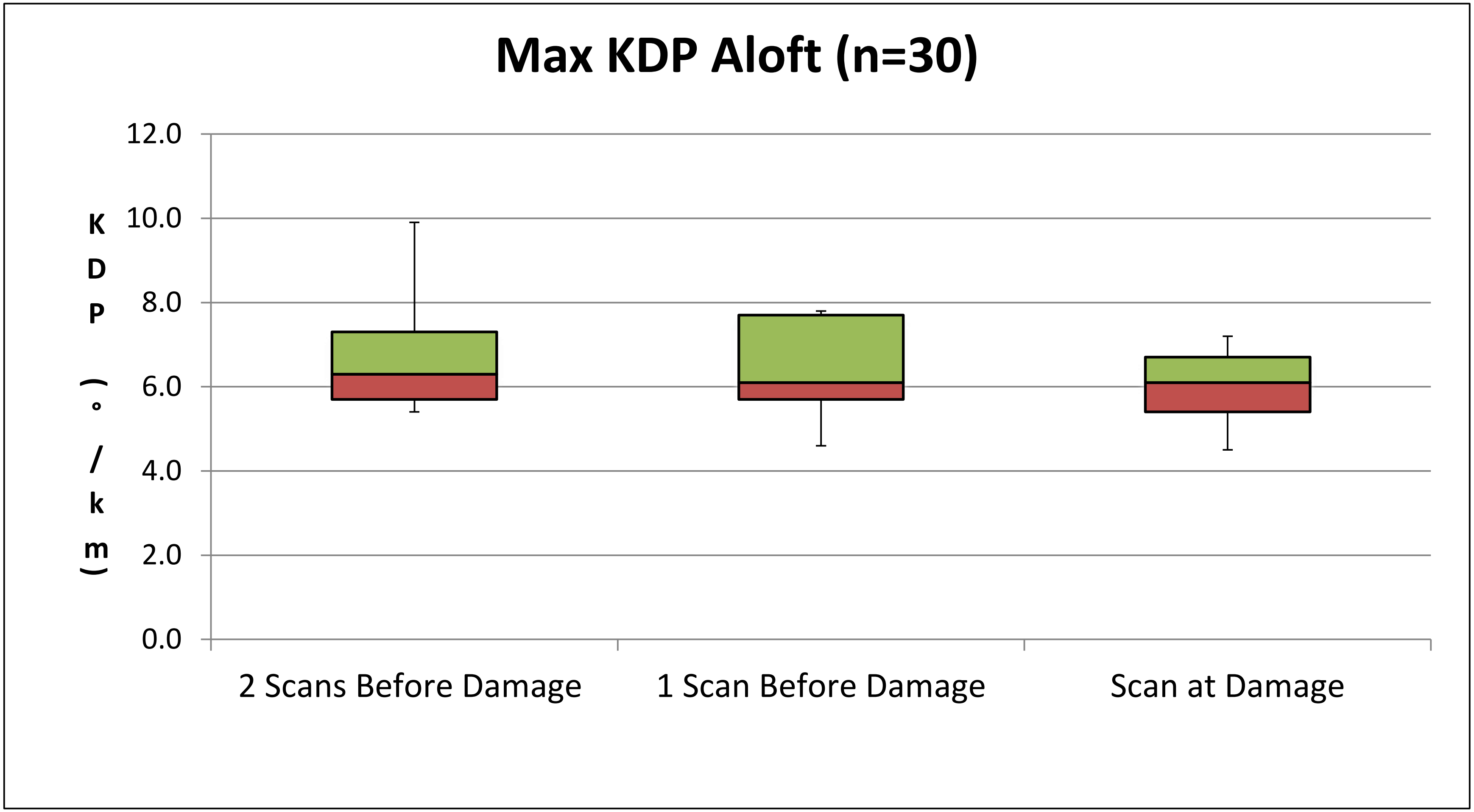
The highest K_{DP} value within the suspended column aloft averaged to be 7.6 deg/km within these thunderstorms & the median value was 7.0 deg/km.

Max K_{DP} Height Over Time



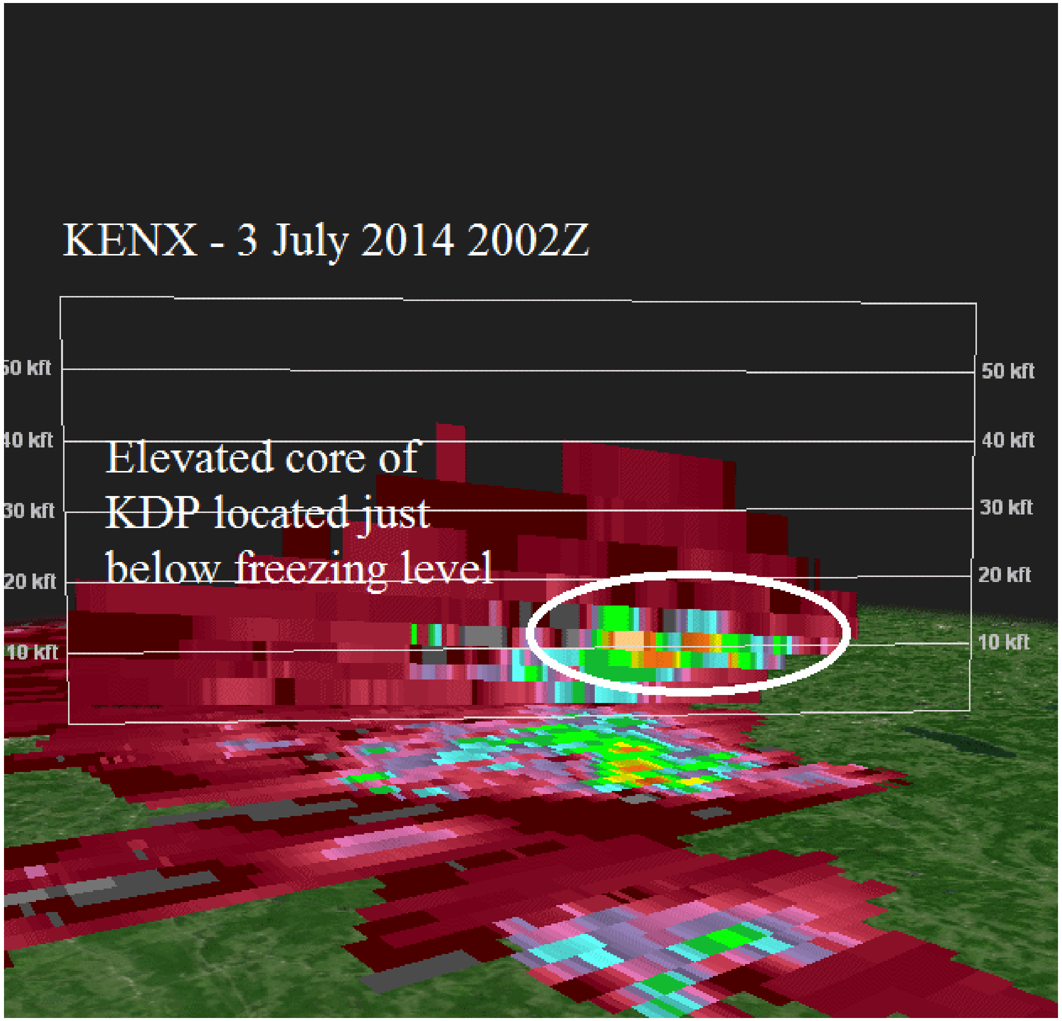
Typical Radar Volume Scan Lasts 4 to 6 minutes

Max K_{DP} Value Over Time



Typical Radar Volume Scan Lasts 4 to 6 minutes

Example of Lowering K_{DP} Core



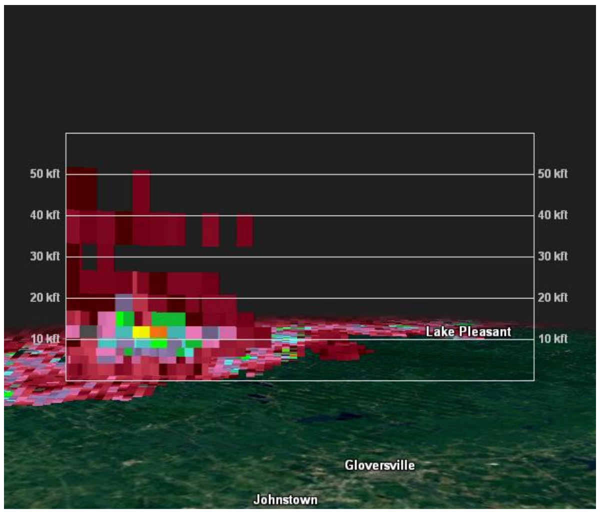
3 July 2014 over southern Herkimer County, New York

Type of storm: Supercell
Max KDP Value: 8.8 deg/km

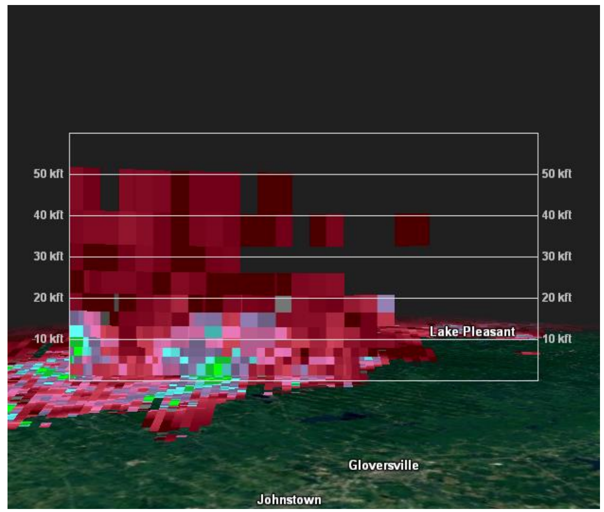
Significant damage occurred at 2014Z in hamlet of Jordanville.

Elevated KDP core was seen at least 12 minutes before significant damage occurred

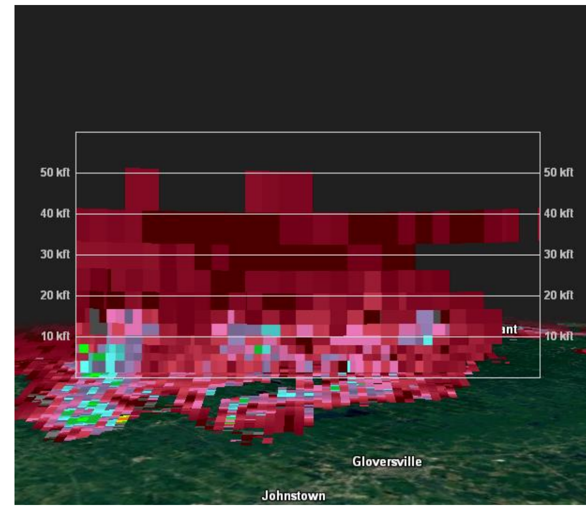
Descending K_{DP} Column During a Squall Line Event



KENX K_{DP} Cross-section
13 Aug 2016 2214Z



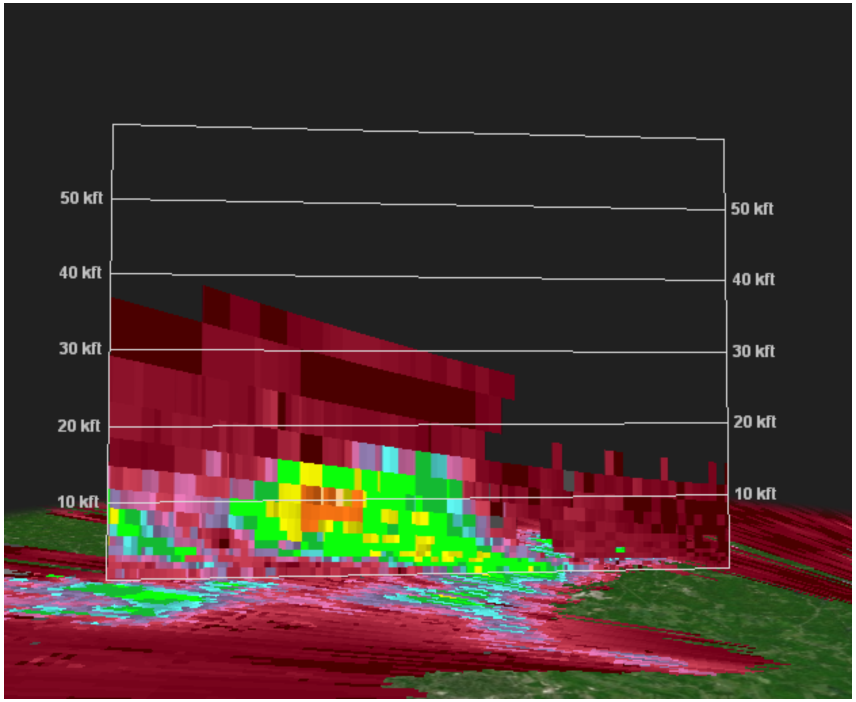
KENX K_{DP} Cross-section
13 Aug 2016 2220Z

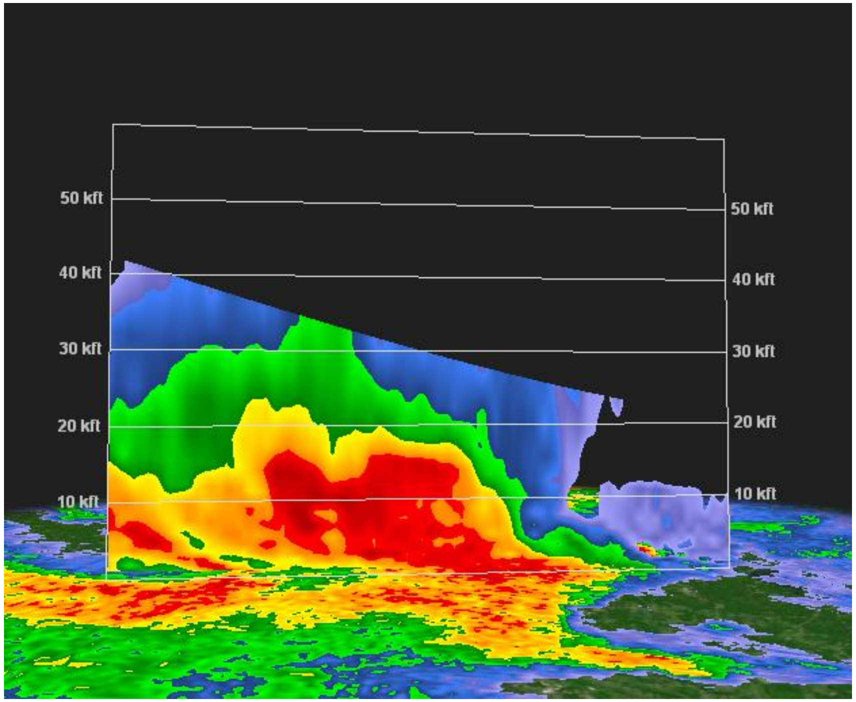


KENX K_{DP} Cross-section
13 Aug 2016 2226Z

Cross-section of K_{DP} from KENX show the elevated K_{DP} column falling down to the surface on 13 August 2016 thanks to a strong microburst within a severe squall line. Significant damage occurred at 2225Z at the Pine Lake Campground in the town of Caroga in Fulton County, New York. The max value of the K_{DP} within the elevated column was around 5.6 deg/km.

K_{DP} vs. Z





A comparison of vertical cross-sections of K_{DP} and Z from 30 June 2017 at 2016Z near Ravena, NY. This storm would go on to produce significant damage in South Schodack, NY at 2028Z. The elevated K_{DP} core was around 8 deg/km around 10,000 ft. The K_{DP} core aloft is easier to pick out for a warning forecaster compared to the broad area of 50+ dBZ within the Z cross-section.

Use During Warning Process

- While a warning forecaster is interrogating other base data products, they can look for building columns of K_{DP} within a thunderstorm.
- If values appear to remain elevated and reach critical values (around 6 deg/km based off this study), a warning decision forecaster can anticipate an increased chance for significant damage when this column collapses towards the surface.
- While base velocity can have its flaws based on beam angle and direction, K_{DP} columns can help alleviate this limitation.
- Still, inherent issues with beam width and terrain blockage will cause issues when evaluating K_{DP} as well.
- In addition, storms that contain large hail may not always show K_{DP} columns, as K_{DP} is not plotted when associated with low values of correlation coefficient (<0.90).

Thanks for listening!
Any questions?!

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