

A Multi-Scale Analysis of the 29 August 2020 Tornadic Event across Eastern New York

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NOAA/NWS Albany, NY
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My name is Thomas Wasula and I am a Lead Meteorologist at the NWS at Albany and this was a severe weather tornadic case study where 3 tornadoes impacted eastern NY on the 29 August 2020. I will be applying some of the recent local tornado research done with my colleague Meteorologist Brian Frugis to this event. This case study was first virtually shown at NROW XXI on November 4th 2020.

Motivation

- The Albany forecast area had an above normal year with tornado occurrences (13 through the end of AUG and OCT 7th would bring it to 14 with additional one)
- 29 August 2020 case study: two EF1 tornadoes and 1 EF0 (11 tornadoes overall in August) **Note: EF0 just added OCT 29th**
- **Key question:** What caused the tornadoes on August 29th and what was the convective environment?
- CSTAR VII (2019-2022) continues looking at severe weather in complex terrain and improving tornado warning guidance & using new advances with dual pol data



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The motivation for this presentation is to highlight how active the tornado season was in the NWS at Albany County Warning Area. A total of 13 tornadoes occurred between May 1st and August 31st across eastern NY and western New England. An additional one occurred on October 7, 2020 with the serial derecho. In the 29 August case study, 3 tornadoes occurred with 2 EF1's and a recently added EF0 as of October 29, 2020. This presentation will focus on the 2 EF1's. The main questions that will be addressed is what caused the tornadoes on August 29th and what was the convective environment. CSTAR VII continues looking at severe weather in complex terrain and attempting to improve tornado warning guidance and using new advances with dual polarization data.

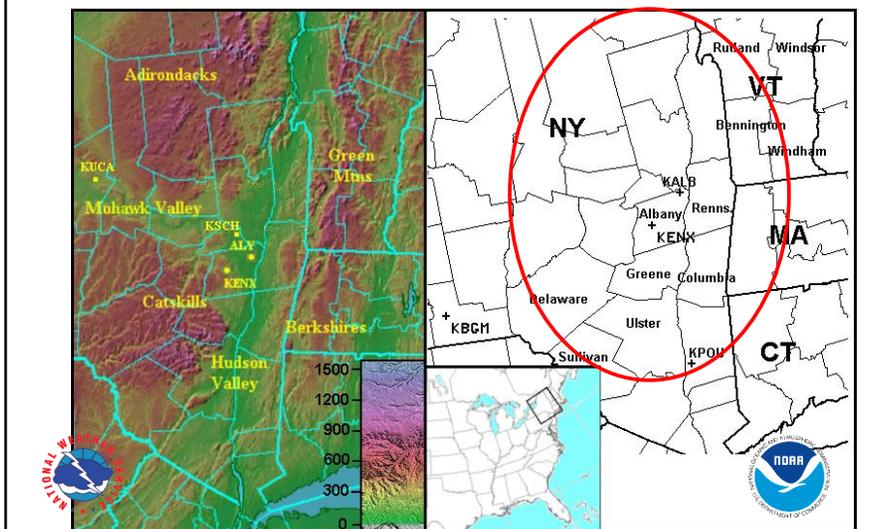
Outline

- Review WFO ALY Tornado Climatology
- Brief Synoptic Overview 29 AUG 2020 case
- Mesoscale Analysis (SPC Meso-analysis data (Rapid Refresh))
- Brief Review of WFO at ALY Tornado Study (V-R Shear and Normalized Rotation (NROT) Studies)
- Storm-Scale Analysis of the EF1 tornadic storms using GR2Analyst and V-R Shear tool in AWIPS



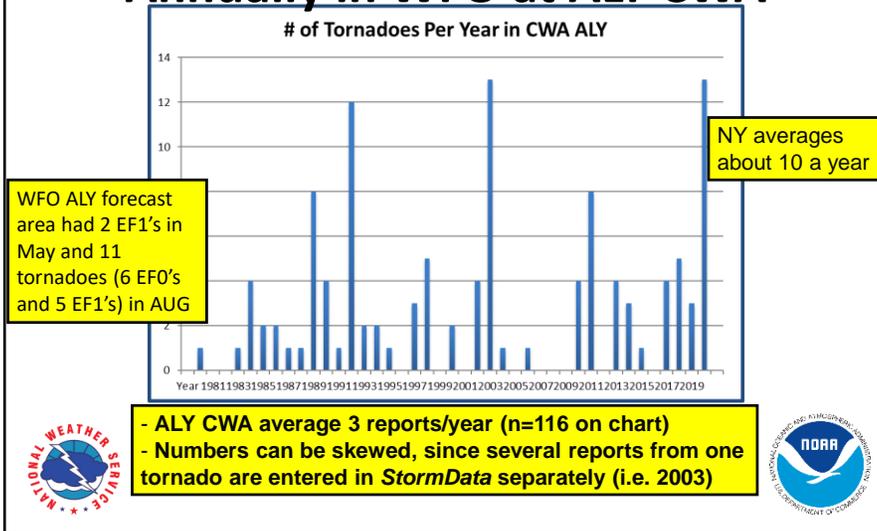
The outline for the presentation includes reviewing the WFO Albany tornado climatology since 1980. A brief synoptic-scale analysis and a mesoscale analysis using the SPC Rapid Refresh mesoscale data will be shown. A brief review of the WFO at ALY tornado (V-R Shear and Normalized Rotation) studies by Frugis and Wasula (2013, 2015) will briefly be reviewed. Finally, a detailed storm-scale analysis will review the EF1 tornadic storms using GR2analyst and the V-R Shear tool in AWIPS.

NWS at Albany Forecast Area



The WFO at ALY forecast area covers eastern NY and western New England. The topography consists of two major river valleys (Mohawk and Hudson) and several mountain ranges (southern Adirondacks, southern Green Mountains, Berkshires, Eastern Catskills and the Taconics). One third of the WFO ALY forecast area is 1500 ft or greater in elevation. The severe weather and tornadoes on August 29th were primarily across eastern NY and from the eastern Mohawk Valley and the Capital Region northward into the Upper Hudson Valley and the Lake George corridor.

1980 - AUG 2020 Tornadoes Annually in WFO at ALY CWA

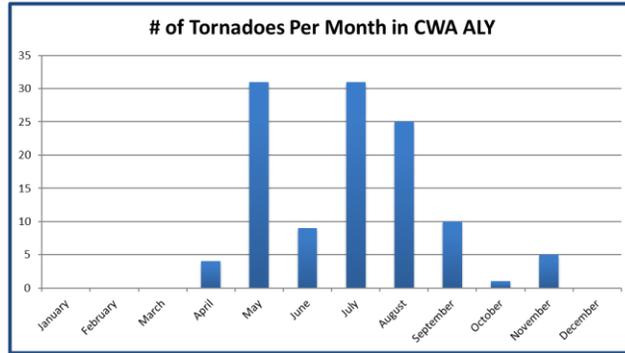


The 2020 tornado season for the ALY County Warning Area (CWA) was well above normal and record tying up to August 31st. The ALY CWA typically averages about 3 tornadoes a year. The state of NY averages about 10. Including the OCT 7th tornado, the ALY CWA will have a record breaking 14 events topping 2003. Note that some numbers can be skewed in past seasons as multiple reports can be from one tornado (i.e. July 21, 2003). The 2020 season is unique that numerous individual events occurred with 2 EF1's in May and 6 EF0's and 5 EF1's in August.

1980 - AUG 2020 ALY CWA

Tornadoes by Month

(N = 116 tornado events)



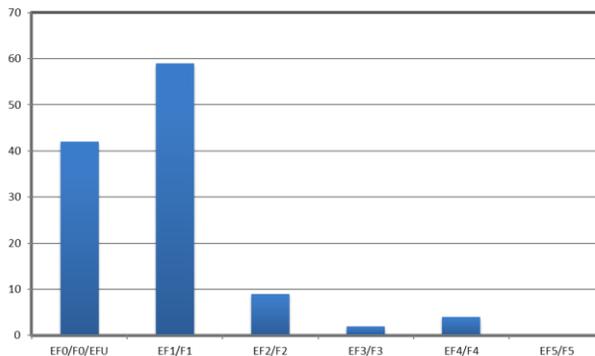
Peak in late Spring into Summer (May and July maxima's). A significant increase in AUG 2019 (3) and 2020 (11) with 14 tornadoes!



The ALY CWA typically has the most tornadoes in May and July since 1980. There is a peak in the late spring into the summer. A significant increase in tornadoes has occurred in August that past 2 years with 3 in 2019 and 11 in 2020. From 1980-2018 only 11 occurred in August!

1980 - AUG 2020 ALY Tornadoes by EF-scale Intensity/Strength

of Tornadoes By Intensity in CWA ALY



N=116 tornado events

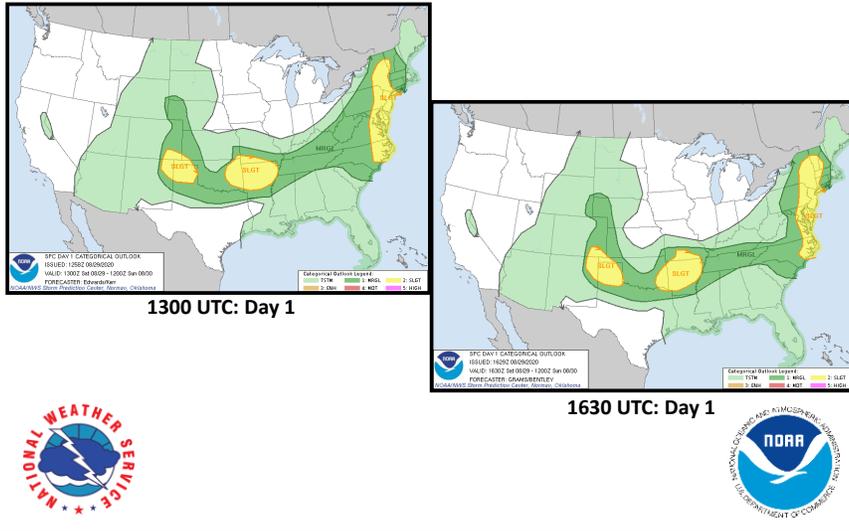
~87% are EF0/F0 and EF1/F1!!!

*** ~ 5% are EF3/F3 or greater



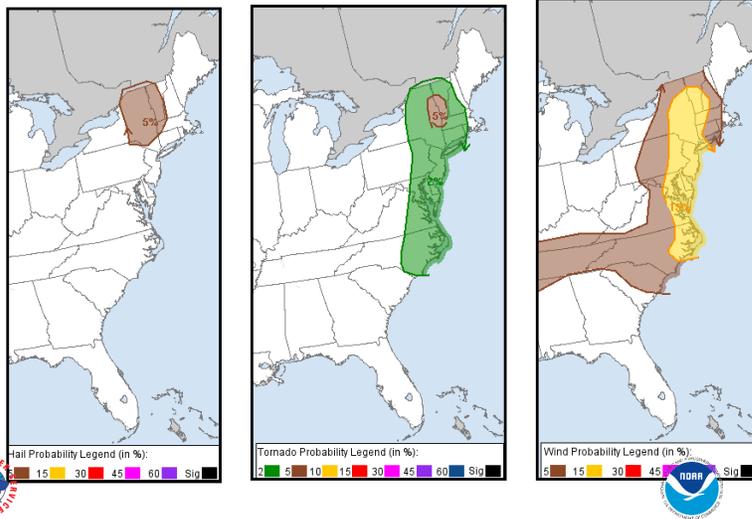
Most of the tornadoes in the ALY forecast area are EF0/F0 or EF1/F1 on the Enhanced-Fujita Scale. Since 1980, ~87% are EF0/F0 or EF1/F1. Out of 116 events, 58 of the tornadoes are EF1/F1. Only ~5% are EF3/F3 or greater.

SPC Day 1 Outlooks: 29 AUG 2020



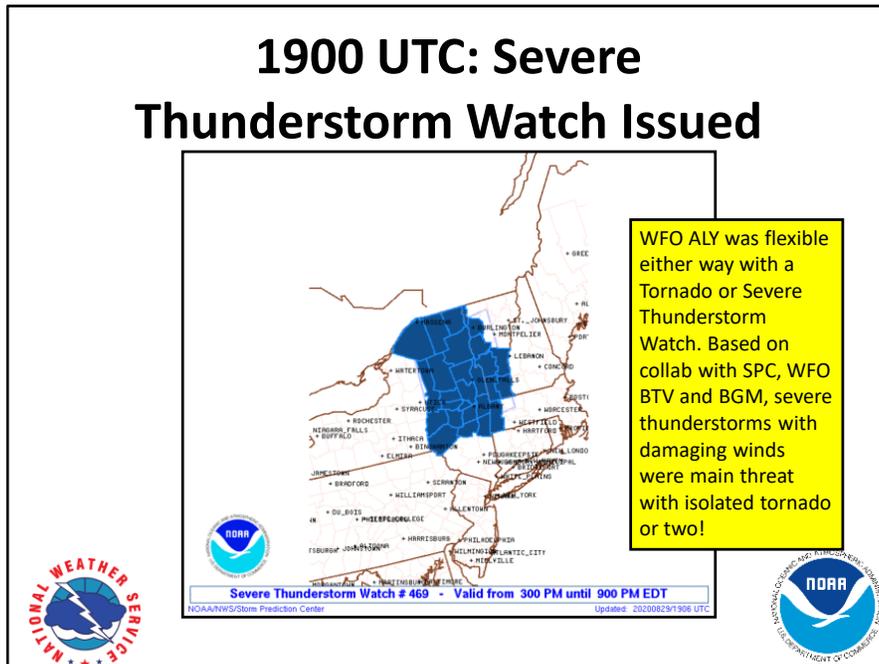
The SPC Day 1 outlook at 1300 UTC 29 AUG 2020 had a Slight Risk across most of eastern NY and small area of south-central VT that extended northward from the Mid Atlantic coastal region. The Slight Risk was expanded further into western New England with the 1630 UTC Day 1 Outlook.

SPC Day 1 Severe Probability Outlooks: 1630 UTC 29 AUG 2020



SPC's 1630 UTC Day 1 Severe weather probabilities favored damaging winds (15%), but the tornado probabilities increased to 5% in the Capital District, Upper Hudson Valley, south-central VT, and the northern Berkshires of western Massachusetts. Hail probabilities were fairly low at 5% or less.

1900 UTC: Severe Thunderstorm Watch Issued

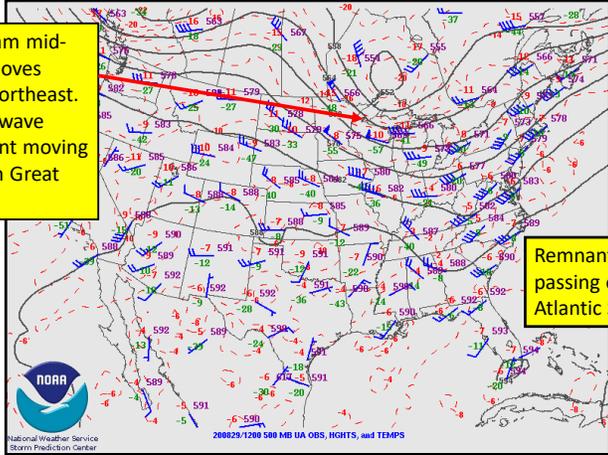


At 1900 UTC 29 AUG 2020, a Severe Thunderstorm Watch was issued over a large portion of eastern NY (mainly north of the southeast Catskills and the mid Hudson Valley) and western New England (north of Connecticut and west of the CT River Valley). WFO ALY was flexible to go with a Tornado Watch, but based on collaboration with WFO's BTV and BGM (they favored a Severe Thunderstorm Watch) with SPC it was agreed damaging winds would be the main threat with an isolated tornado or two. The Severe Thunderstorm Watch would go until 0100 UTC 30 AUG 2020.

1200 UTC 29 AUG 2020
500 hPa Heights, Isotachs, and Temps

Strong upstream mid-level trough moves towards the Northeast. Weaker short-wave with warm front moving east of eastern Great Lakes Region

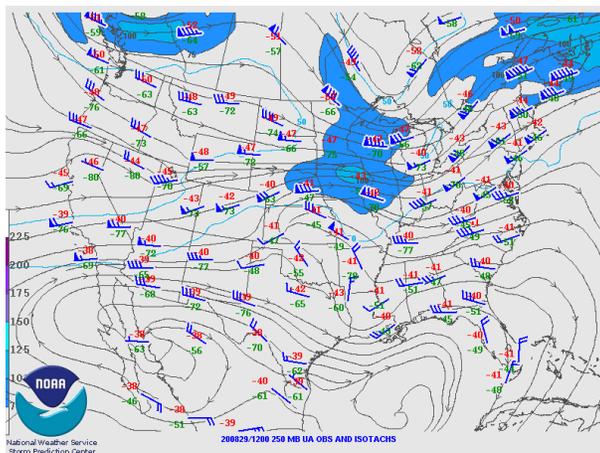
Remnants of Laura passing east of Mid Atlantic States



www.spc.noaa.gov

At 500 hPa, a strong upstream mid-level trough was moving towards the Northeast at 1200 UTC 29 AUG 2020. A weaker embedded short-wave associated with a surface warm front was moving east from the eastern Great Lakes Region in the morning across upstate NY. The remnants of tropical system Laura were passing east of the Mid Atlantic States. Some of the low-level moisture would be drawn northward in the southwest flow aloft across NY and New England.

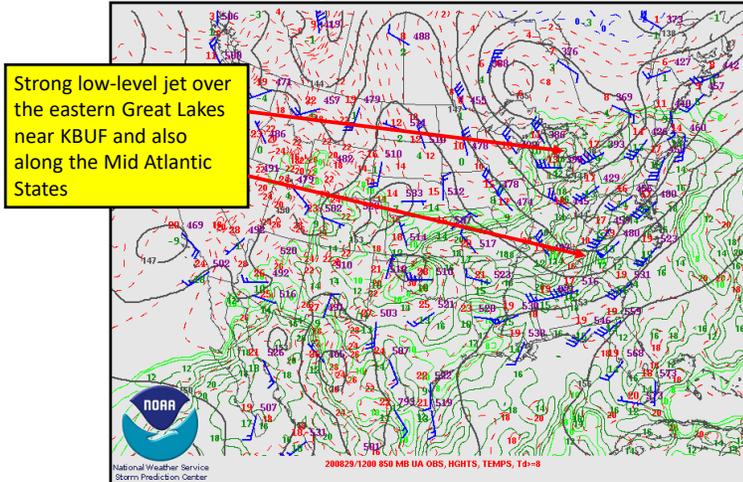
1200 UTC 29 AUG 2020
250 hPa Upper Observations, Streamlines & Isotachs



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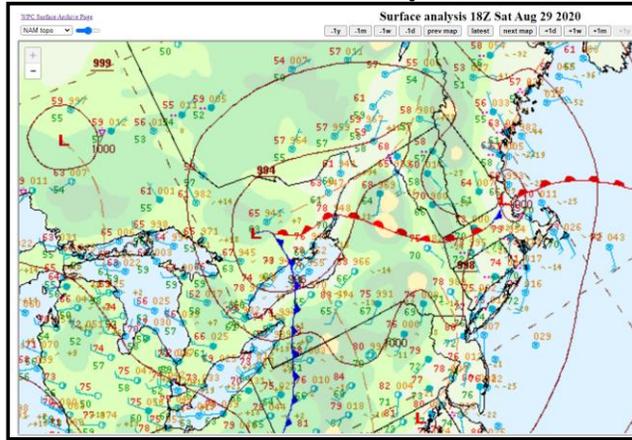
At 250 hPa, a strong upper level jet streak (~100 knots) was upstream over eastern IA moving into the Midwest and Great Lakes Region. A poleward jet streak was moving into the Canadian Maritimes. Southwest flow continued aloft with a strengthening upper level jet in 70-80 knot range. Cyclonically curved jets tend to favor potential severe weather episodes.

1200 UTC 29 AUG 2020
850 hPa Heights, Isotachs, Temps, & Td's



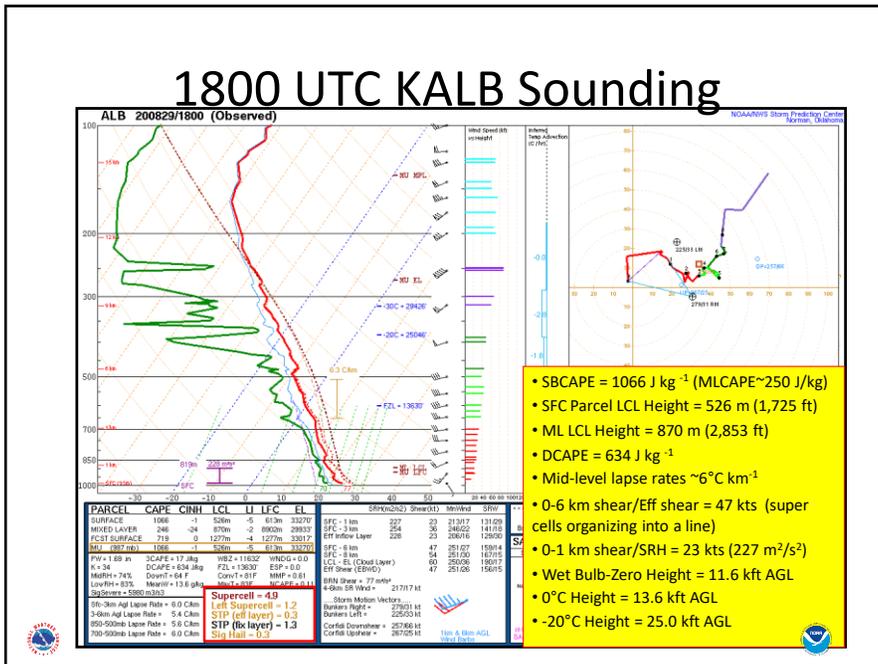
The 850 hPa flow was relatively strong at 1200 UTC 29 AUG 2020. A 40 knot low-level jet was over the eastern Great Lakes near KBUF. A strengthening 850 hPa jet of 40-50 knots was moving northeast from central NC and VA. Strong low-level jets can be a favorable ingredient for potential tornadoes with enough shear and instability.

1800 UTC 29 AUG 2020 Surface Map



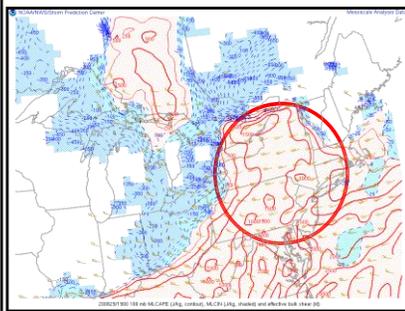
At 1800 UTC 29 AUG 2020 on the surface map, a warm front was moving north of the Mohawk Valley, Capital Region into central New England. Surface dewpoints on the south side of the boundary were in the upper 60s to lower 70s. The surface flow up the Hudson Valley was south to southeast. Low pressure was moving across southeast Ontario with a cold front making steady progress from western NY and PA.

1800 UTC KALB Sounding

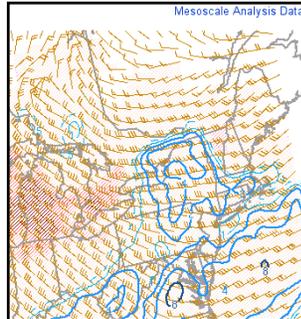


KALB did a special 1800 UTC sounding after some rainfall ahead of the warm front. The surface temperature and dewpoint were 77°F and 70°F. The surface based CAPE was 1066 J/kg and the MLCAPE was around 250 J/kg. The mixed layer LCL heights were low at 526 meters (2,853 ft). The DCAPE was not exceptionally high at 634 J/kg. The mid-level lapse rates were marginal around 6°C/km. The surface to 700 hPa wind profile exhibited veering. The 0-6 km bulk shear or effective shear was 47 knots. Some super cells were possible organizing into a potential line. The 0-1 km shear was 23 knots and the 0-1 km storm relative helicity was 227 m²/s². The Supercell parameter was 4.9. The wet bulb zero and freezing level heights were relatively high so severe hail look limited with low to moderate amounts of instability and weak lapse rates. The tornado threat was increasing due to the low LCL's, high shear and low to moderate CAPE environment.

1900 UTC 29 AUG 2020
RAP MLCAPE/MLCIN/Eff Shear & Supercell Comp. Parameter



Best MLCAPE 1000-1500 J/kg Hudson River Valley westward with 35-45 kts of effective shear



Supercell Composite parameter 2-4+ over eastern NY with Bunker Storm Motion vectors overlaid

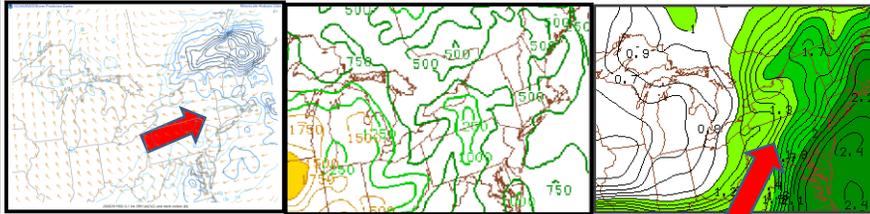


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The SPC RAP Mesoanalysis at 1900 UTC showed increasing MLCAPE values to 1000-1500 J/kg from the Hudson River Valley with effective shear values of 35-45 knots. The Supercell Composite Parameter was 2-4+ over eastern NY.

1900 UTC 0-1 km SRH (m^2/s^2), LCL Heights (m) and PWATs (in)



0-1 km SRH 100-150+ m^2/s^2 across eastern NY in Hudson Valley

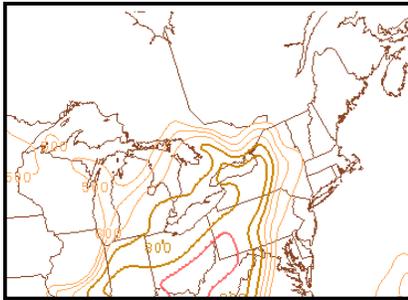
LCL Heights were low in the 500-750 m (1640 ft - 2460 ft) range

Anomalous PWATs in the 1.5-2.0" range over the ALY forecast area with surface dewpoints in the upper 60s to lower 70s

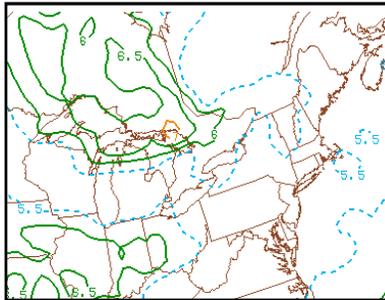


The SPC RAP Mesoanalysis at 1900 UTC showed 0-1 km SRH values increasing to 100-150+ m^2/s^2 across eastern NY in the Hudson River Valley. The LCL heights were low in the 500-750 meter range. Anomalous PWATs were in the 1.5-2.0" range over eastern NY and western New England with the surface dewpoints in the upper 60s to lower 70s.

1900 UTC 29 AUG 2020
RAP DCAPE (J/kg) & 700-500 hPa Lapse Rates ($^{\circ}\text{C}/\text{km}$)



Best DCAPE (J/kg) > 800 J/kg over western and central NY



700-500 hPa Lapse rates ($^{\circ}\text{C}/\text{km}$) are generally weak at < 6 $^{\circ}\text{C}/\text{km}$

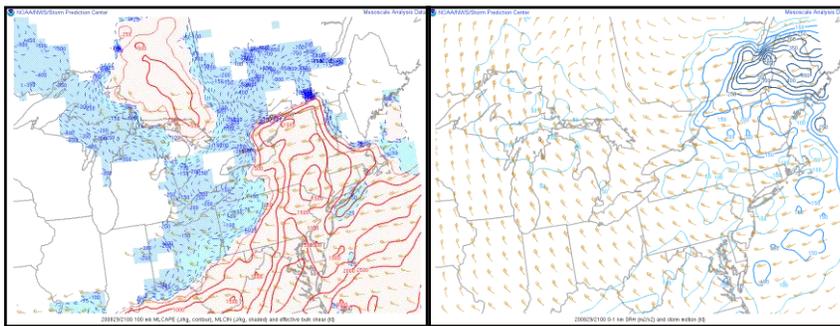


Conditions less favorable for widespread severe



The SPC RAP Mesoanalysis at 1900 UTC depicted DCAPE values > 800 J/kg over western and central NY. The 700-500 hPa lapse rates were generally weak less than 6 $^{\circ}\text{C}/\text{km}$. These conditions were less favorable for a widespread severe event.

2100 UTC 29 AUG 2020
RAP MLCAPE (J/kg) /MLCIN (J/kg)/Eff Shear (kts)
& 0-1 km SRH (m²/s²)



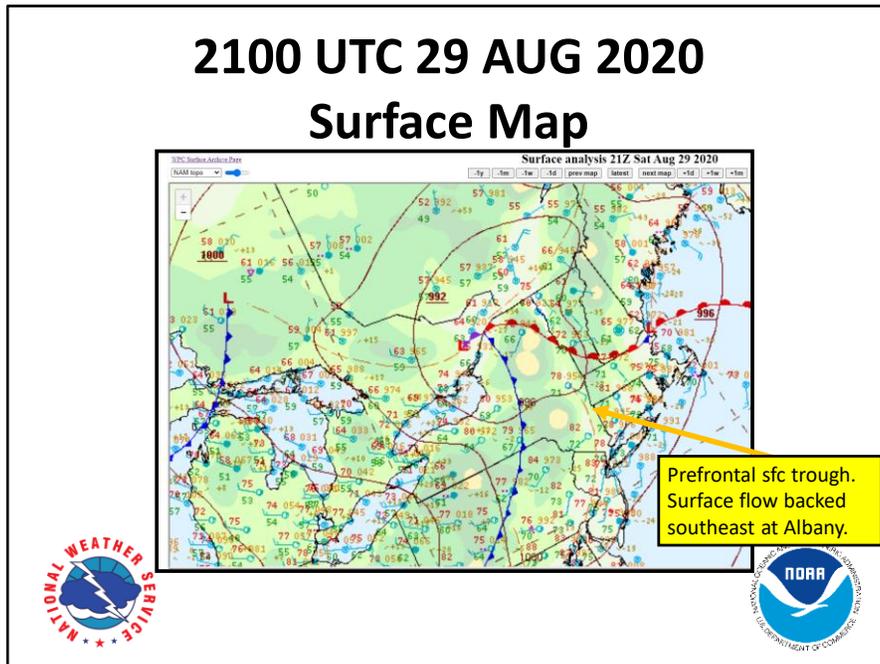
MLCAPE 500-1500+ J/kg with 35-45 kts of effective bulk shear across eastern NY into western New England. Supercells likely.

0-1 km SRH values 100-200 m²/s² across eastern NY into western New England with storm motions of 30-35 kts



The SPC RAP Mesoanalysis at 2100 UTC indicated a broad area of MLCAPE values of 500-1500+ J/kg over eastern NY into western New England. The effective bulk shear continued to be 35-45 knots. Supercells looked very likely. The 0-1km SRH values were in the 100-200 m²/s² range over eastern NY into western New England with storm motions of 30-35 knots. The chances of tornadic supercells in the Capital District into the upper Hudson Valley were increasing.

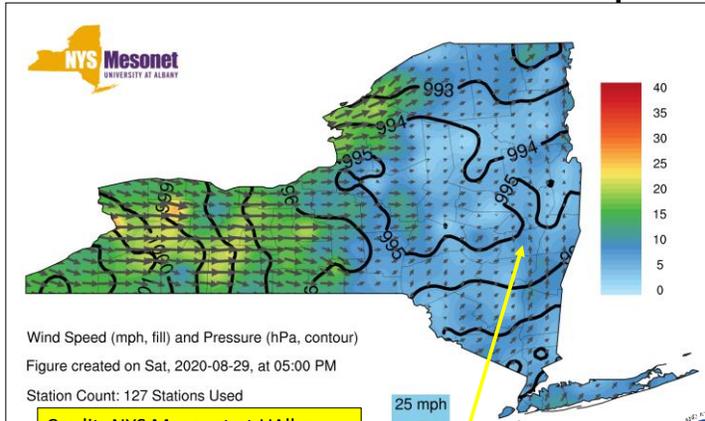
2100 UTC 29 AUG 2020 Surface Map



Most eastern NY and western New England entered a warm sector at 2100 UTC 29 AUG 2020. Surface dewpoints continued to rise into the lower 70s up the Hudson River Valley. A prefrontal surface trough formed in the Hudson River Valley as the surface flow backed to the southeast at Albany.

2100 UTC 29 AUG 2020

NYS Mesonet Surface Wind Speeds



Wind Speed (mph, fill) and Pressure (hPa, contour)

Figure created on Sat, 2020-08-29, at 05:00 PM

Station Count: 127 Stations Used

Credit: NYS Mesonet at UAlbany

25 mph

Data Valid: 2020/08/29 20:55:00 Z

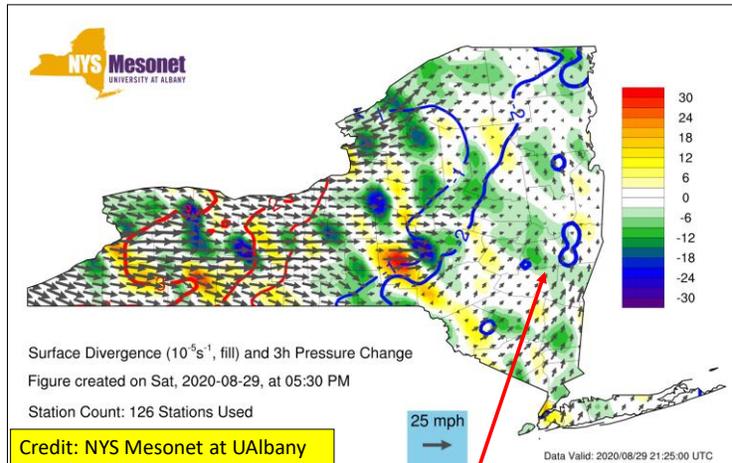


Note: Some backed surface flow to the southeast near Albany in the Capital Region



The 2100 UTC 29 AUG 2020 NYS mesonet surface wind data showed some backed surface flow to the southeast near Albany in the Capital Region and at the confluent area of the Mohawk and Hudson River Valleys.

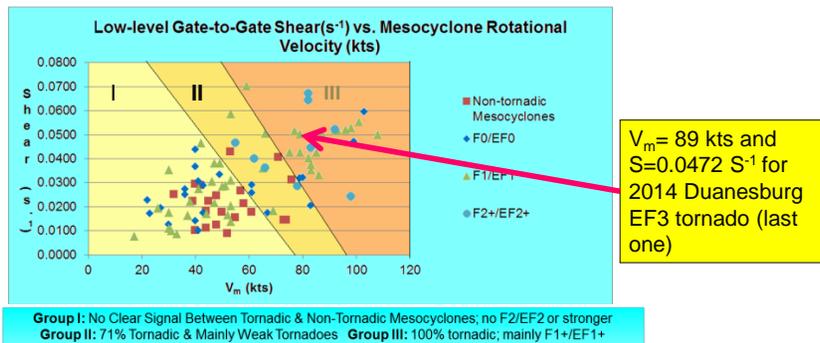
2130 UTC 29 AUG 2020 NYS Mesonet Surface Con/Div and 3-hr Pressure Change



Area of low-level convergence with 3-hr pressure fall near tornadogenesis around 2130 UTC.

At 2130 UTC 29 AUG 2020 NYS Mesonet surface convergence/divergence and 3-hr pressure change map indicated an area of low-level convergence with a 3-hr pressure fall near tornadogenesis in the Capital Region.

Nomogram: Gate to Gate Shear vs. Mesocyclone Rotational Velocity for 76 ALY TOR and 21 Null cases (2003-15)

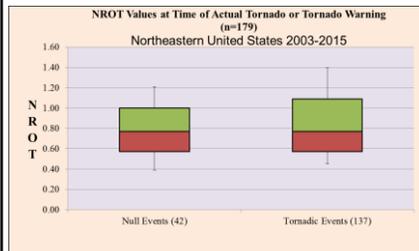


Frugis and Wasula 2013 NWA Preprint

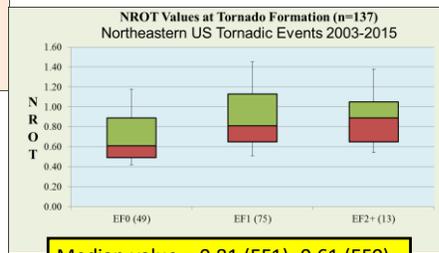


A nomogram showing Gate to Gate Shear (S) vs. Mesocyclonic Rotational Velocity (V_m) for 97 cases is shown in the ALY forecast area from 2003-15 is shown (Frugis and Wasula 2013). 76 of the cases were tornadoes. The last EF3 tornado on May 24, 2014 is plotted. It was the Duanesburg tornado with a $V_m = 89$ knots and $S = 0.0472$ s^{-1} . The greater the V_m and the S , then greater chance of a tornado. Group II accounts for 71% tornadoes that are mainly weak ones. Group III indicates 100% tornadoes with mainly EF1/F1's, but also some more intense ones.

Normalized Rotation (NROT) Tornado Study



Frugis and Wasula NWA 2015 Poster



Median value = 0.81 (EF1); 0.61 (EF0)

- Tough to use as a single discriminator for tornado warnings (median value similar for null and tornado events)
- EF2+ tornadoes have greater Nrot values
- Values of > 1.0 better indicator



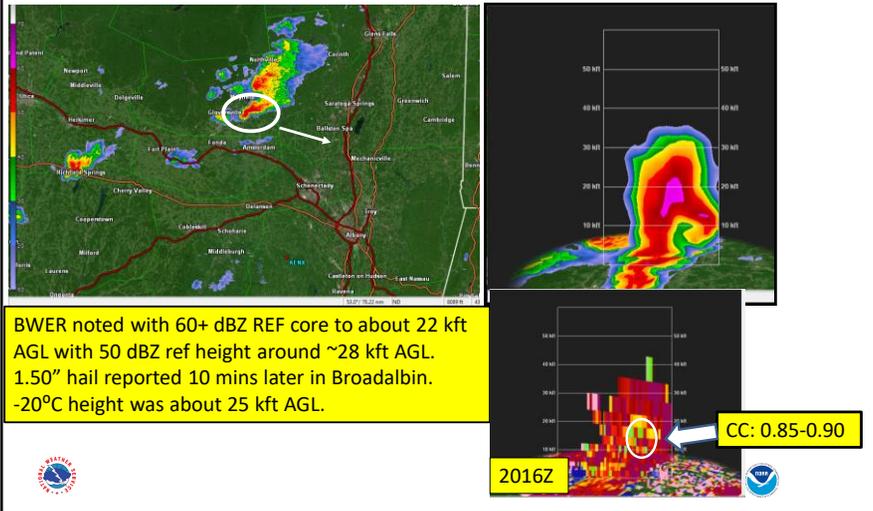
A normalized rotation (N_{rot}) tornado study for the Northeast by Frugis and Wasula (2015) showed from a total of 179 events (137 tornadoes) that this value is tough to use as a single discriminator for tornado warnings. Median values were similar for null vs. tornadic cases. EF2+ tornadoes have higher N_{rot} values. Values greater than **1.0** tend to be a better indicator for tornado potential. The median value for 75 EF1 tornadoes in the Northeast was 0.81 and the EF0 median value for 49 cases was 0.61.

2029-2300 UTC KENX Base REF loop (dBZ)



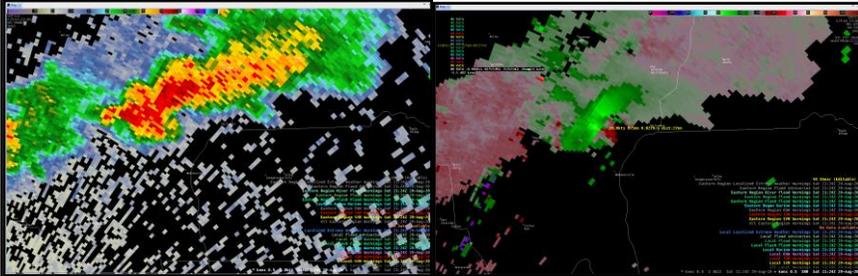
A reflectivity radar loop from 2029-2300 UTC shows a couple of developing lines of severe convection. The lead broken or mini-line began as a few supercells along the developing line over the eastern Mohawk Valley into the Capital Region. The tornadic cells that moved into southeast Saratoga and northern Rensselaer Counties drifting into southern VT and the Berkshires will be the focus of the storm-scale analysis.

2009 UTC KENX Base REF (dBZ) & Cross-section



At 2009 UTC a supercell was moving across southeast Fulton County. A cross-section through the supercell revealed an elevated reflectivity core of 60+ dBZ to around 22 kft AGL. The 50 dBZ reflectivity core was close to 28 kft AGL. A nice Bounded Weak Echo Region (BWER) showed up on the cross-section. The -20°C height was around 25 kft AGL on the 1800 UTC KALY sounding. The 2016 UTC correlation coefficient cross-section showed depressed values of 0.85-0.90 above the freezing level. Ping pong ball size hail (1.50" in diameter) was reported in Broadalbin 10 minutes later at 2019 UTC.

2124 UTC KENX 0.5°Base Ref (dBZ) & SRM (kts)



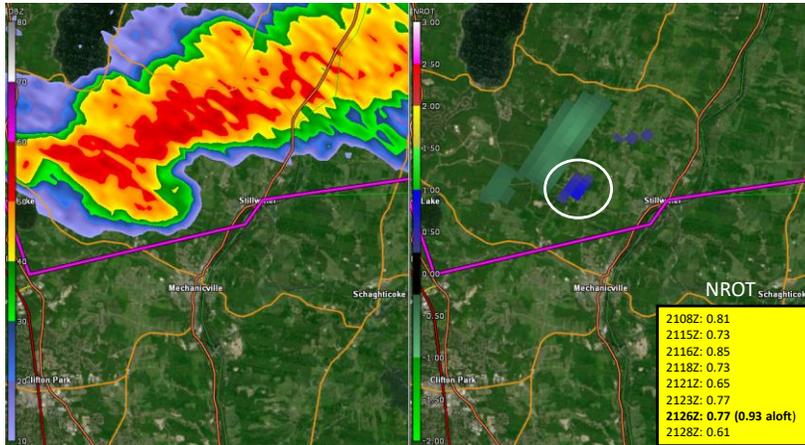
Hook echo forming with reflectivity inflow notch (northeast of RDA)

Low-level rotational value (V_r)=25 kts with a shear value= 0.0279 s^{-1} over a 0.5 nm diameter at a distance of 27 nm from the RDA. The couplet is near Mechanicville and Stillwater (2 mins before the tornado touchdown).



Around an hour later, the supercell became re-invigorated over the Capital District in southern Saratoga County. A hook echo formed with a reflectivity inflow notch northeast of the KENX RDA over extreme southeast Saratoga County. The V-R Shear tool calculated over a 0.5 nm diameter a low-level rotation value (V_r) of 25 knots with a shear value (S) = 0.0279 s^{-1} . The rotational couplet was near Mechanicville and Stillwater and it was about 2 mins before touchdown.

2126 UTC KENX 0.5° Base REF & NROT

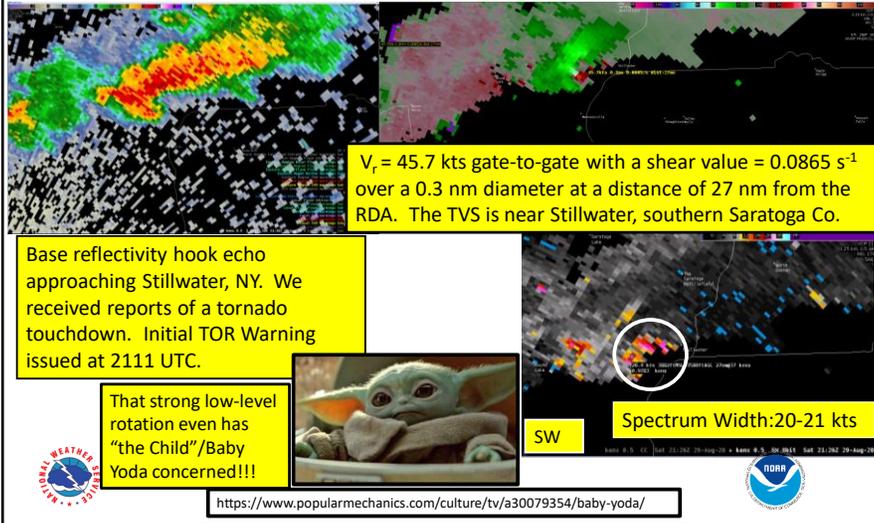


Hook echo reforming near Stillwater, Saratoga County.

NROT value peak = 0.85 with TOR touchdown at 2126 UTC with a damage to a mobile home, trees down, and one injury.

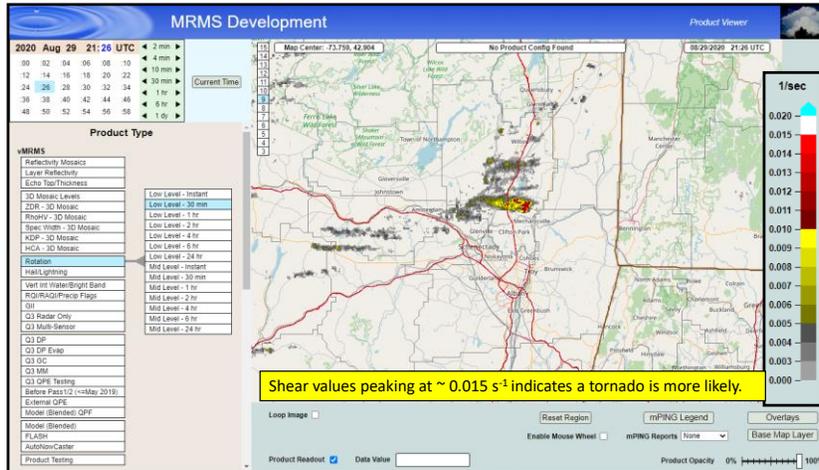
At 2126 UTC, the hook echo was reforming near Stillwater in southeast Saratoga County and the N_{rot} value peaked aloft at 0.93. Earlier at 2116 UTC the $0.5^\circ N_{rot}$ value was 0.85. The tornado warning was issued at 2111 UTC. An EF1 tornado touchdown was confirmed at 2126 UTC with damage to a mobile home, trees uprooted and one injury.

2126 UTC 29 AUG 2020
KENX 0.5° REF (dBZ), SRM (kts) and SW (kts)



At 2126 UTC, V_r was measured at 45.7 knots gate-to-gate with a shear value = 0.0865 s^{-1} over a 0.3 nm diameter at a distance of 27 nm from the KENX RDA. The TVS was near Stillwater in southeast Saratoga County. The KENX 0.5° spectrum width data peaked at 20-21 knots (which is high), which sometimes has been shown to be a predictor for tornadoes. The low-level rotational velocity was extreme impressing even "the Child" or "Baby Yoda"!

2126 UTC 29 AUG 2020 MRMS 0-2 km AGL 30-min Low-Level Azimuthal Shear Tracks



<https://mrms-dev.nssl.noaa.gov/qvs/vmrms/viewer/>

The 2126 UTC 29 AUG 2020 MRMS 0-2 km AGL 30-min low-level azimuthal shear rotational tracks were impressive across southern Saratoga County. The shear values peaked at around 0.015 s^{-1} which indicates a tornado is more likely (at or above 0.015 s^{-1}) from past work.

Stillwater, NY Tornado

Date: Aug 29, 2020
 Time: 526 pm EDT
 Maximum Rating: EF1
 Max Wind Speed: 100 mph
 Max path width: 50 yards
 Path length: 0.25 miles

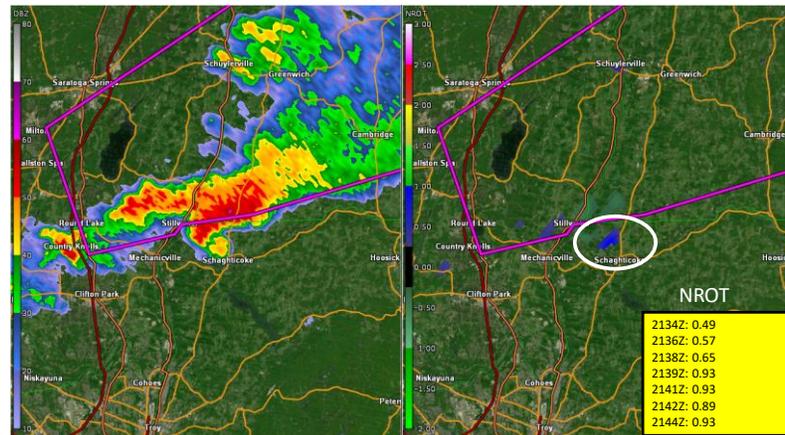
- Severe damage done to a mobile home
- One injury
- Several trees uprooted

View from the east near Easton, Washington Co.
 (trained spotter sent 526 pm)

Acknowledgement: Dan Thompson

The path of the EF1 Stillwater tornado is shown, as mostly tree damage occurred. The EF1 tornado peaked with a maximum wind speed estimated from the damage at 100 mph. It had a narrow path width and was on the ground for about a quarter of a mile. A picture from a trained spotter is shown from the east of the tornado near Easton, Washington County at 526 pm.

2141 UTC 0.5°KENX Base REF & NROT

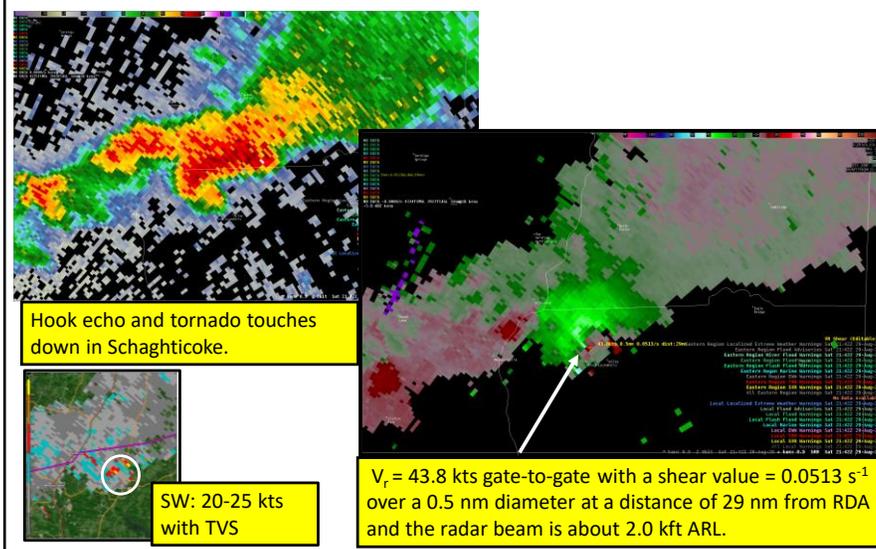


Hook echo reforming near Schaghticoke, Rensselaer County.

NROT value peak = 0.93 with TOR touchdown at 2142 UTC with a home losing a roof, shed destroyed and damage to a school roof.

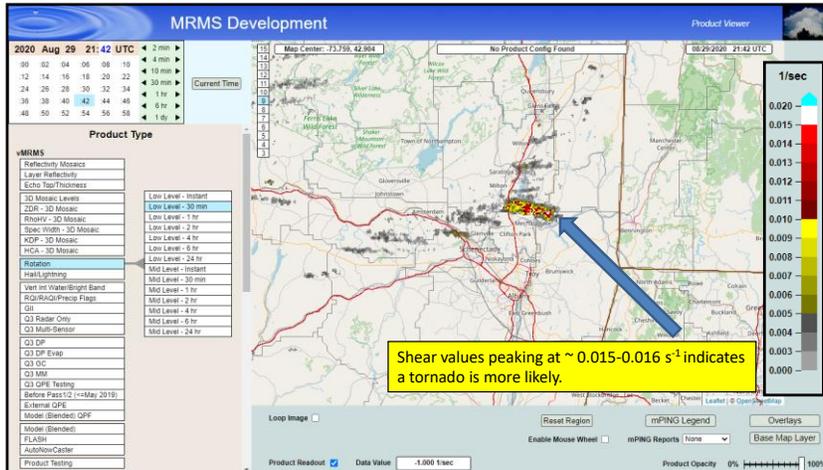
At 2141 UTC, the reflectivity data showed a hook echo forming with the supercell on a mini-line near Schaghticoke, NY in northwest Rensselaer County. The $0.5^\circ N_{rot}$ data peaked several times at 0.93 between 2139-2144 UTC. A tornado warning was issued at 2131 UTC. A tornado touchdown occurred at 2142 UTC with a home losing a roof, a shed destroyed and damage to a school roof.

2142 UTC 0.5° KENX Base REF (dBZ), SW (kts) & SRM(kts)



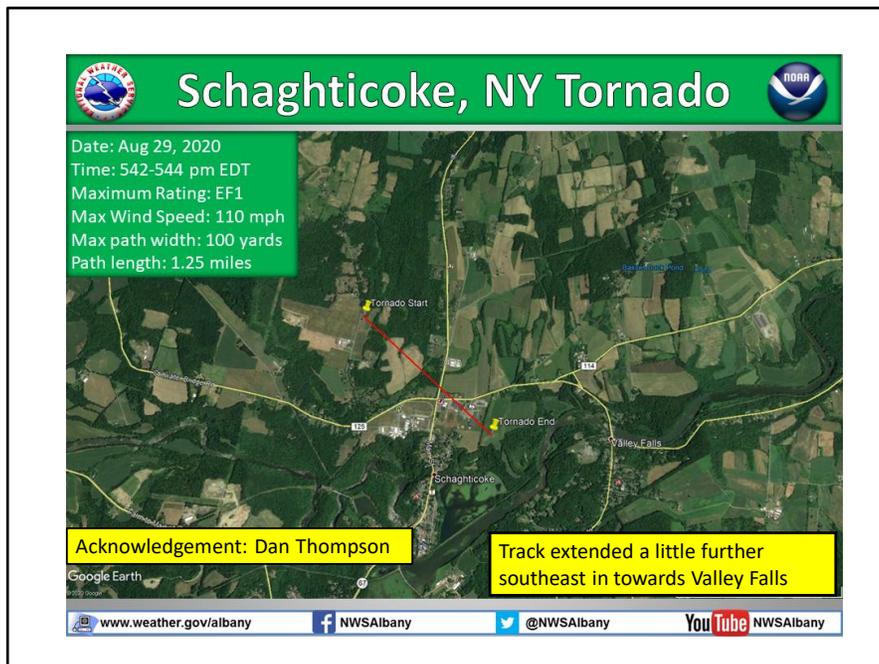
At 2142 UTC, V_r was measured at 43.8 knots gate-to-gate with a shear value = 0.0513 s^{-1} over a 0.5 nm diameter at a distance of 29 nm from the KENX RDA. The radar beam is about 2.0 kft ARL. The TVS moved through Schaghticoke in northwestern Rensselaer County. The KENX 0.5° spectrum width data peaked at 20-25 knots (which is very high), which sometimes has been shown to be a predictor for tornadoes.

2142 UTC 29 AUG 2020 MRMS 0-2 km AGL 30-min Low-Level Azimuthal Shear Tracks



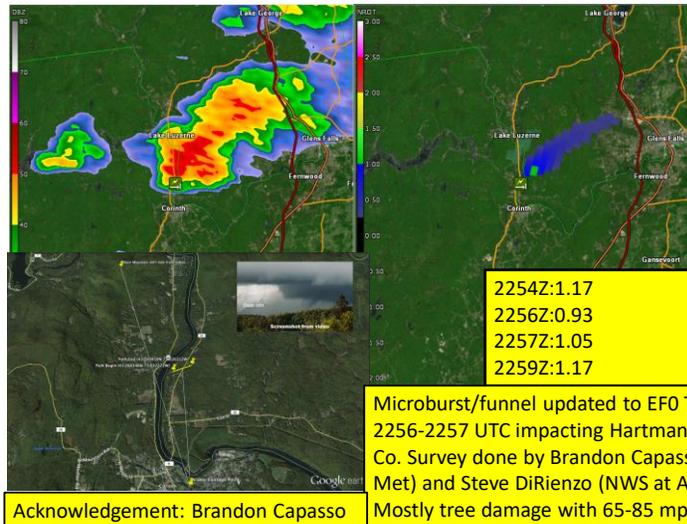
<https://mrms-dev.nssl.noaa.gov/qvs/vmrms/viewer/>

The 2142 UTC 29 AUG 2020 MRMS 0-2 km AGL 30-min low-level azimuthal shear rotational tracks were impressive across southern Saratoga County into northwestern Rensselaer County. The shear values peaked at 0.015-0.016 s⁻¹ which indicates a tornado is more likely (at or above 0.015 s⁻¹) from past work.



The path of the EF1 Schaghticoke tornado is shown. The EF1 tornado peaked with a maximum wind speed estimated from the damage at 110 mph. It had a path width of a 100 yards with a path length close to 1.25 miles. The path length was extended a little father southeast into Valley Falls later, where more tree damage occurred on some properties. The tornado did tear a roof off on a home, destroy a shed and damage the Hoosic Valley High School roof.

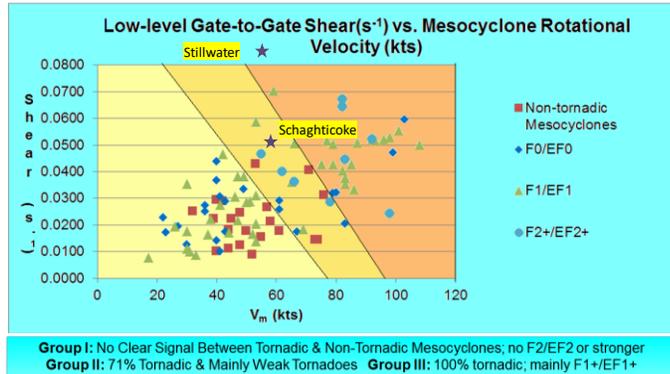
2257 UTC 0.5° KENX Base REF and NROT



A third tornado was confirmed in late October north of the Capital Region in the Upper Hudson Valley and southwest of Glens Falls. Initially, a storm survey classified the wind damage as a microburst and a funnel. A further, more detailed damage survey by private meteorologist Brandon Capasso with Steve DiRienzo determined an EF0 briefly touched down in the town of Hartman in Warren County. There was video evidence and an eyewitness report of a funnel kicking up water on the Hudson River just southwest of the town. About a dozen trees were uprooted and snapped with winds estimated at 65-85 mph. N_{rot} values actually peaked at almost 1.2 before the brief tornado touchdown. No warning was issued on this tornado.

29 AUG 2020 EF1 Tornadoes

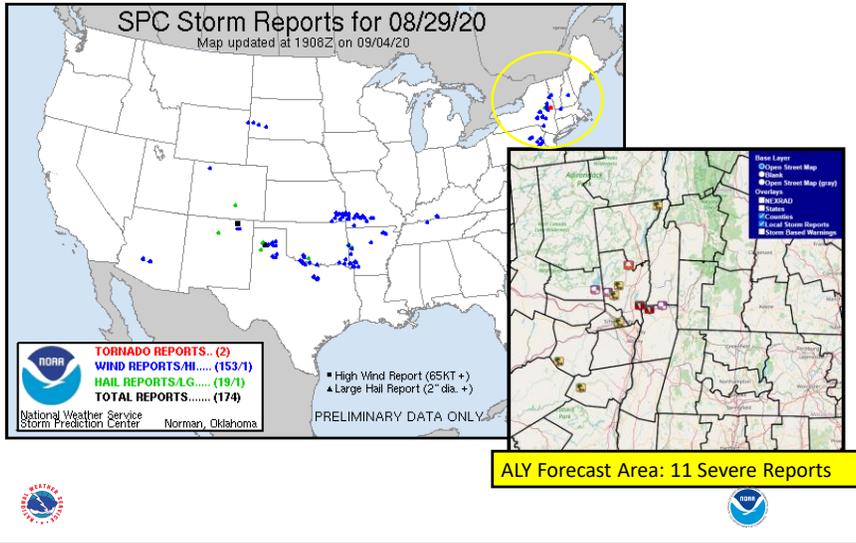
★ EF1 tornadoes in Stillwater and Schaghticoke fit into Group II or III



Lead Times: 15 and 11 mins on two EF1 tornadoes

The Stillwater tornado (purple star) was calculated to have a V_m of 57 knots (absolute value of maximum inbound velocity summed with the absolute value of the maximum outbound velocity over a distance of 3.5 nm) with a shear value = 0.0865 s^{-1} . The Schaghticoke tornado (purple star), V_m was calculated to be 58 knots with a shear value = 0.0513 s^{-1} . The two tornadoes fit into Group II or III on the nomogram with a high confidence for tornado warnings. The lead times were 15 and 11 minutes for the two EF1 tornadoes.

29 AUG 2020 Storm Reports



The severe weather reports were not particularly widespread on this day. A total of 11 damaging wind, large hail and tornado reports occurred mainly from the Capital Region and the eastern Mohawk Valley northward with a few to the west/southwest of Albany.

Preliminary Results

- Short-wave and pre-frontal surface trough ahead of the cold front helped focus severe convection
- Moderate instability and high shear environment (effective bulk shear 35-45+ kts) supported supercells/tornado threat
- Low LCL Heights (tropical-like environment) and enhanced 0-1 km SRH values of 100-200 m^2/s^2 favored tornadoes with some backed surface flow in the Hudson Valley/Capital Region
- Right moving supercell on a broken line produced 2 EF1 tornadoes in Capital Region. Separate EF0 was W/SW KGFL
- Application of V-R Shear and NROT studies useful in warnings
- MRMS 0-2 km Low-Level Azimuthal Tracks provided some guidance and peaked with tornado touchdowns



The initial results showed a short-wave and a pre-frontal trough ahead of the cold front were trigger mechanisms focusing the severe convection. A moderate instability and a high shear environment allowed some supercells to form with a tornado threat. LCL heights were low (tropical-like environment) with high 0-1 km SRH values and some backed flow in the Hudson River Valley/Capital Region enhanced the tornado threat. 2 EF1 tornadoes occurred with a right moving supercell along a mini or broken line. A separate EF0 tornado occurred north of the Capital Region near KGFL. V-R Shear and NROT local studies, as well as the MRMS 0-2 km Low-Level Azimuthal Shear Tracks helped with the tornado warning decision making.