Widespread Damaging Wind Severe Thunderstorm Event of 4 May 2018 Across the NWS Albany, NY County Warning Area

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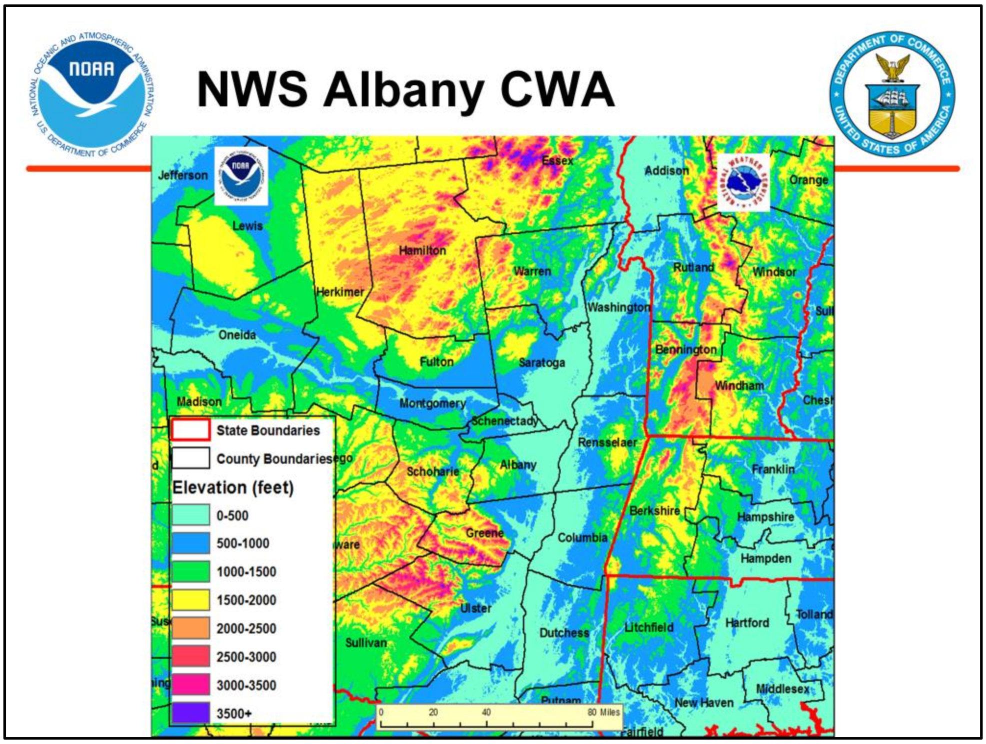


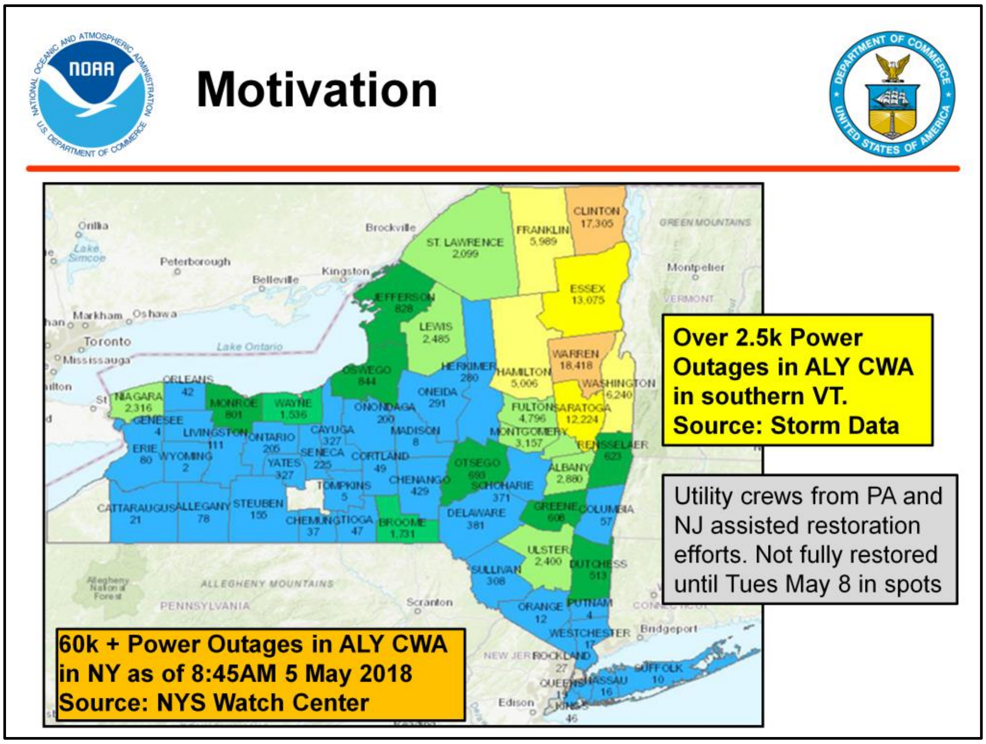
Here is a look at NWS Albany's County Warning Area (CWA) in eastern NY and western New England.

Motivation

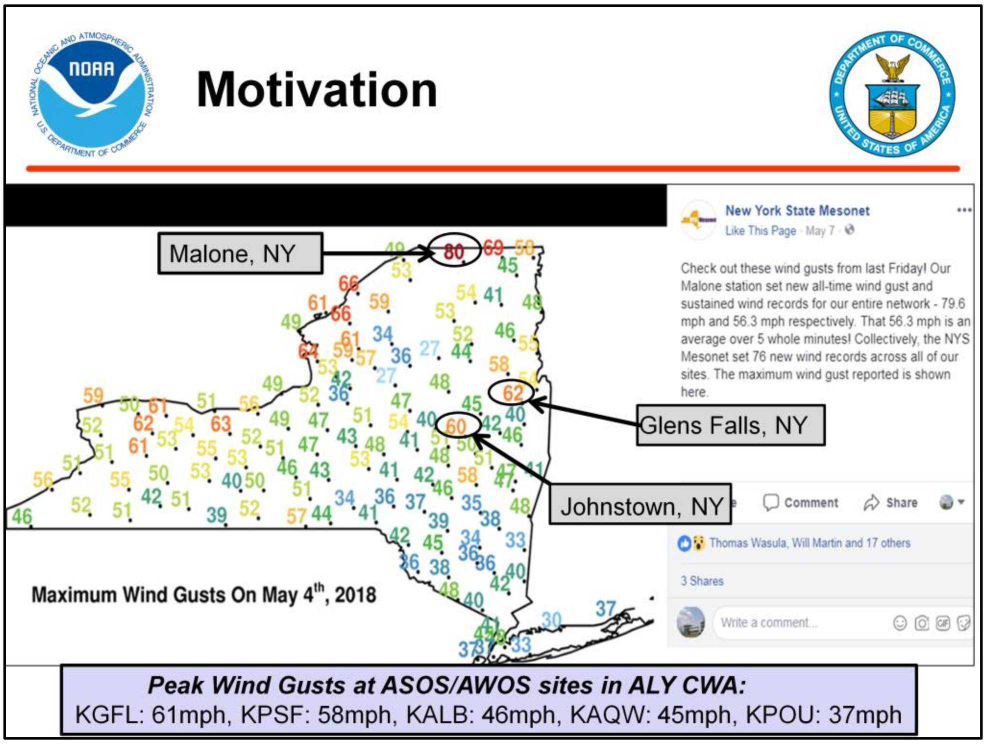
- Damaging straight line wind events frequently impact eastern NY/western New England
- Discriminating between low and high end events is ongoing challenge & research interest
- Impact-based Decision Support Services (IDSS) efforts will benefit from improved meteorological understanding of these events.
- Why May 4, 2018? SPC Moderate Risk with over **90** damaging wind reports in ALY CWA. NY Governor Cuomo declared state of emergency in Washington County, NY

Why is there an interest in damaging straight line wind events? First, they frequently impact eastern NY and western New England leading to power outages, downed trees, and damage to properties. Secondly, it is an ongoing challeng to discriminate between high impact and low impact straight line wind events and thus has become a popular research interest. Thirdly, with the NWS commitment to providing impact-based decision support services to our core partners, improved scientific understanding of straight line wind events will enhance our services. So why is the May 4, 2018 event of interest? Because it was the first event since 2012 where SPC issued a “moderate risk” in NWS Albany’s CWA. Also, this event proved to be a high impact straight line wind event where NY Governor Cuomo declared a state of emergency in Washington County, NY.

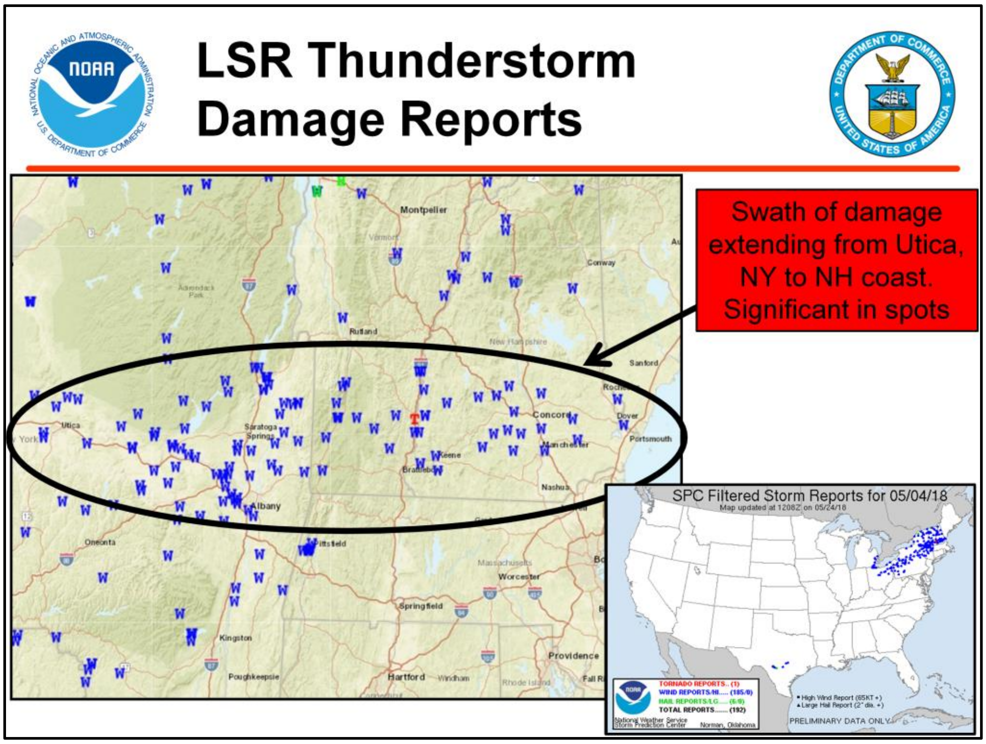
Here are some damage pictures from the May 4, 2018 event across the NWS Albany CWA. It is clear from these pictures that the damages from this event were due to straight line winds and not a tornado because the trees fell in the same direction. We also see the trees were sheared off cleanly rather than tangled in various directions as they would be from a tornado. Impressively, these strong winds also blew out fences, bent a flag pole and ripped siding off homes.



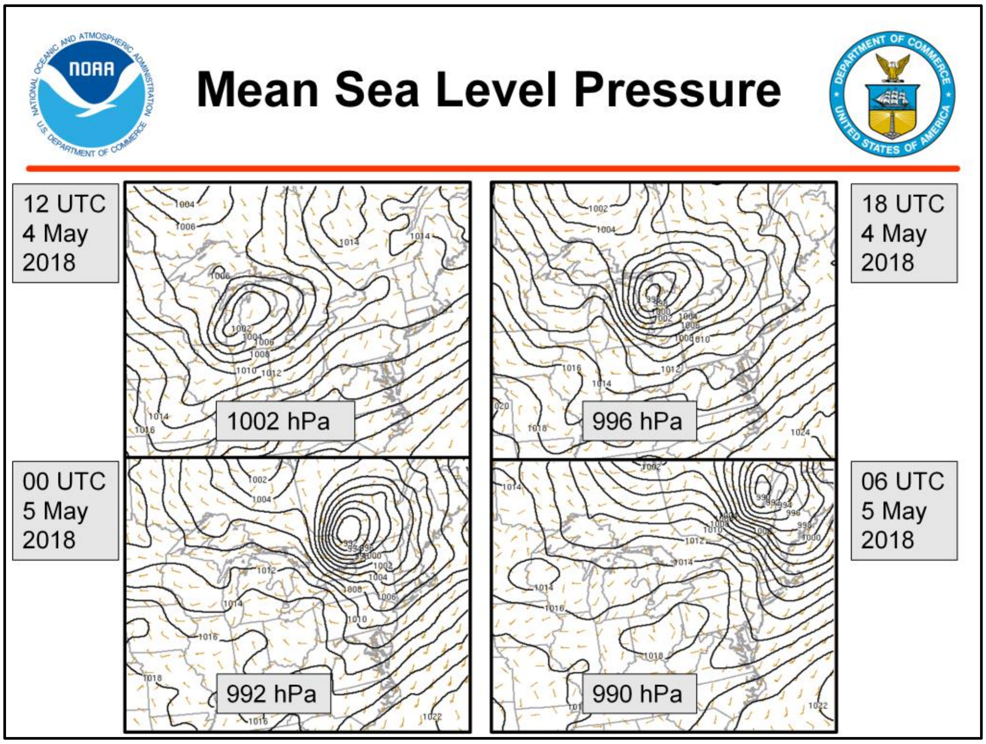
The NY State Watch Center issues maps daily illustrating the number of power outages per county in New York State. The map above shows the number of power outages as of 8:45AM May 5 2018. Notice the high number of outages in the Adirondacks, Lake George/Saratoga region and Upper Hudson Valley that resulted from the straight line wind events on May 4, 2018. In fact, news articles stated that utility crews from PA and NJ assisted restoration efforts and power was not fully restored until Tuesday May 8 in some areas. Southern Vermont also suffered power outages with over 2500 users without power on May 5, 2018 according the NWS Storm Data.



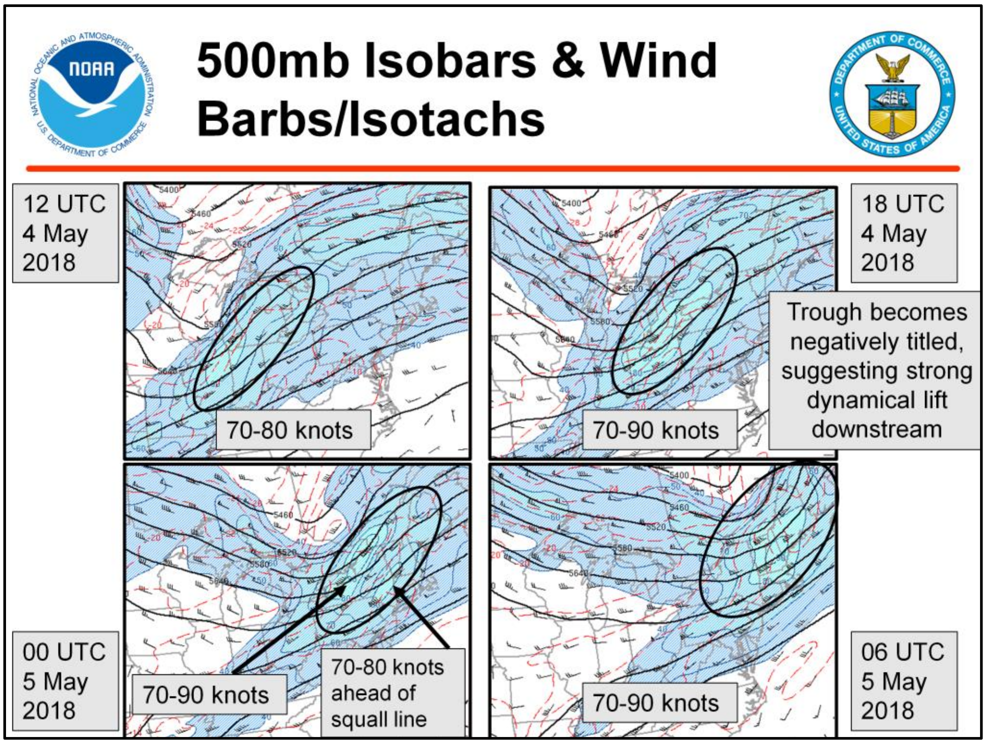
The NYS mesonet map here courtesy of the NYS mesonet Facebook page shows us the magnitude of the straight line winds with the peak values in Glens Fall, NY and Johnstown, NY. Also, ASOS stations measured the high wind gusts with Glens Falls and Pittsfield recording the highest gusts.



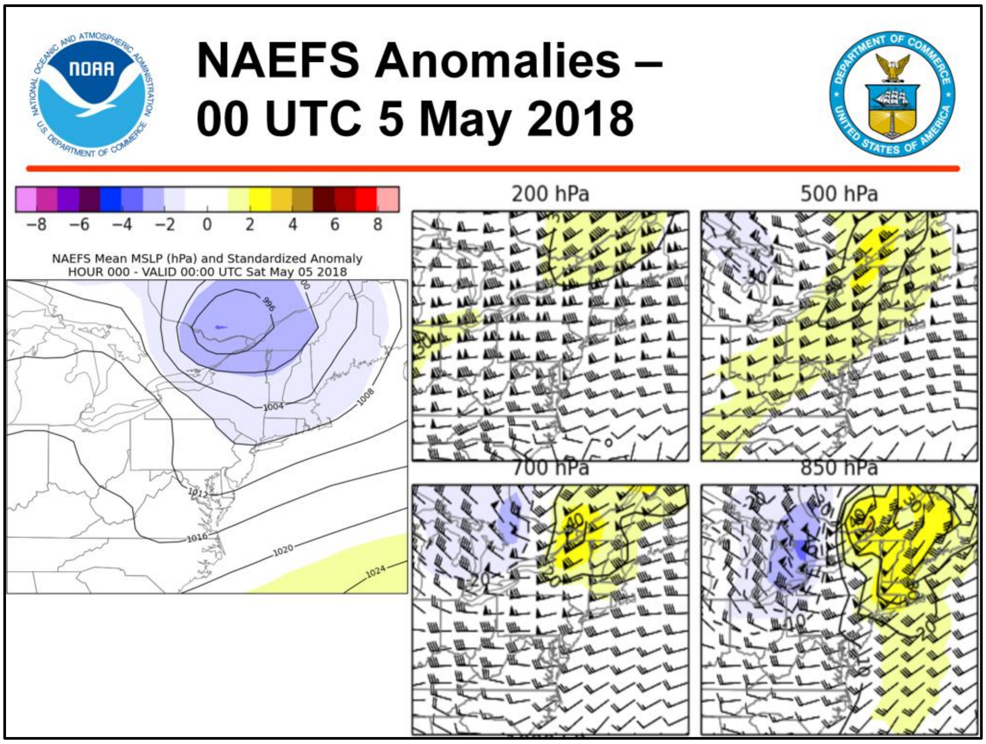
Mapping the local storm reports (LSRs) of damaging wind reports from the straight line event highlights the swath from Utica to coastal New Hampshire as the hardest hit area with a few significant wind reports recorded.



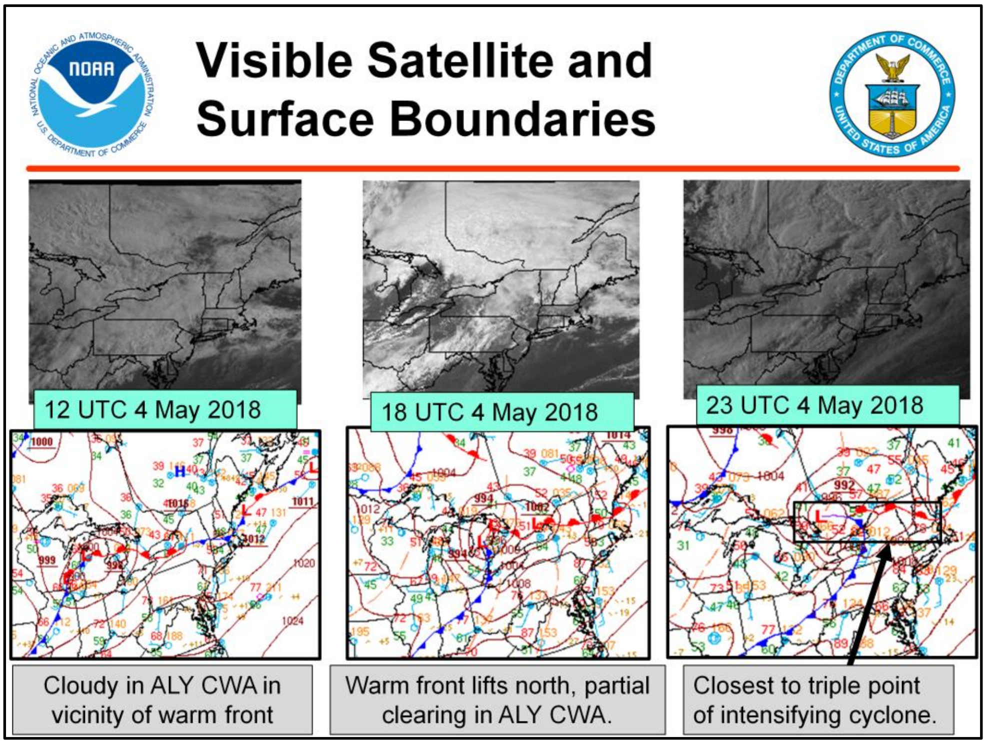
What happened synoptically to lead to such an intensive convective event? The MSL pressure images above courtesy of the SPC mesoanalysis page show us that a low pressure system from the Great Lakes intensified quickly as it advanced up the Saint Lawrence River Valley through the day on May 4, 2018. It strengthened from 1002hPa at 12UTC on 4 May to 992hPa in just 12 hours.



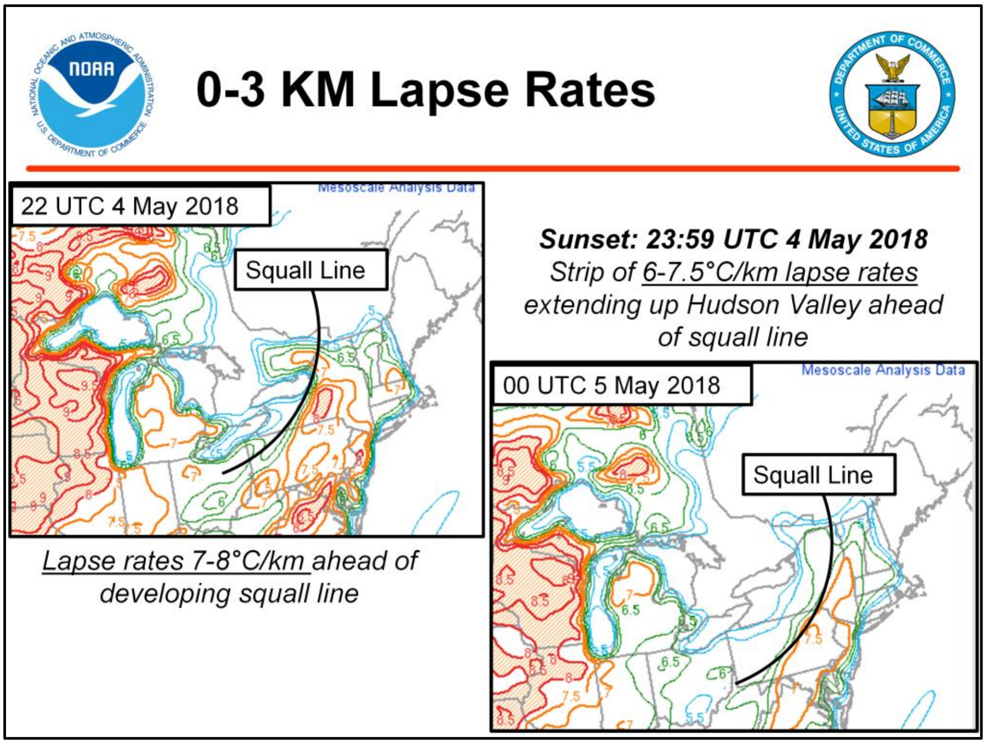
At 500hPA, we see an initially positively tilted trough at 12UTC 4 May quickly become negatively tilted by 18UTC 4 May suggesting strong dynamical lift. We also see a very impressive jet streak associated with this low with 500hPa winds ahead of the squall line at 00z 5 May reaching near 70-80 knots!



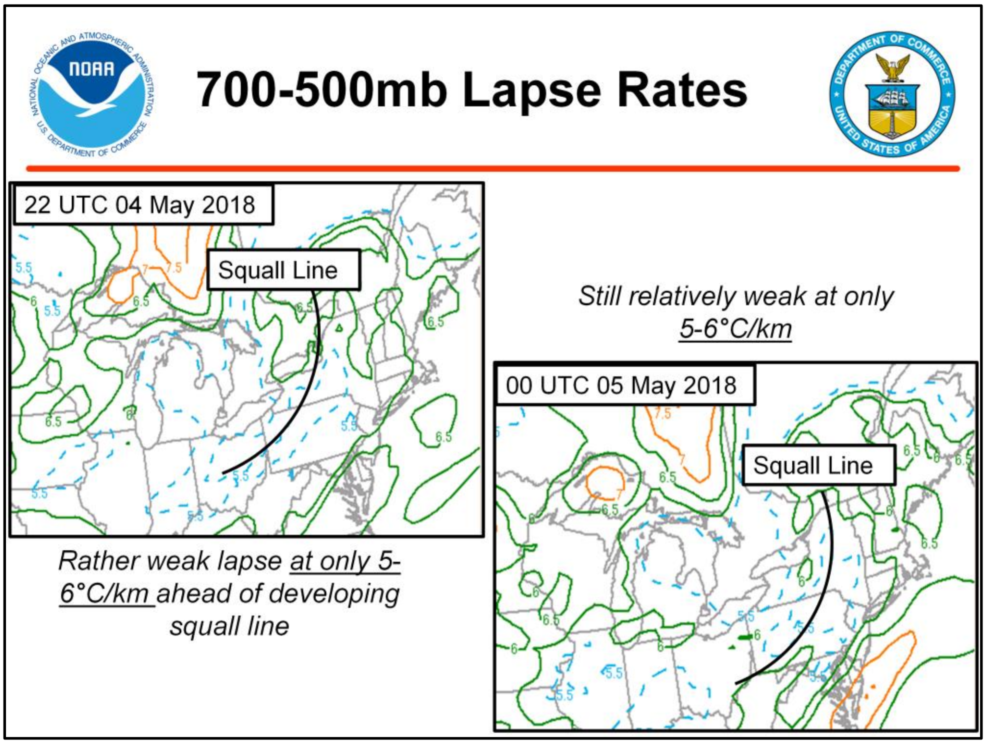
Just how unusual is it for such a system to impact the Northeast in May? According to the NAEFS (North American Ensemble Forecasting System), it is quite anomalous. The 850hPA, 700hPA and 500hPa winds were all 2 to 3 standard deviations above normal suggesting the winds were unusually strong for this time of year over the Northeast. Also, we see the strength of the surface low when it reached 990hPA by 00UTC 5 May 5 was 1 to 2 standard deviations below normal.



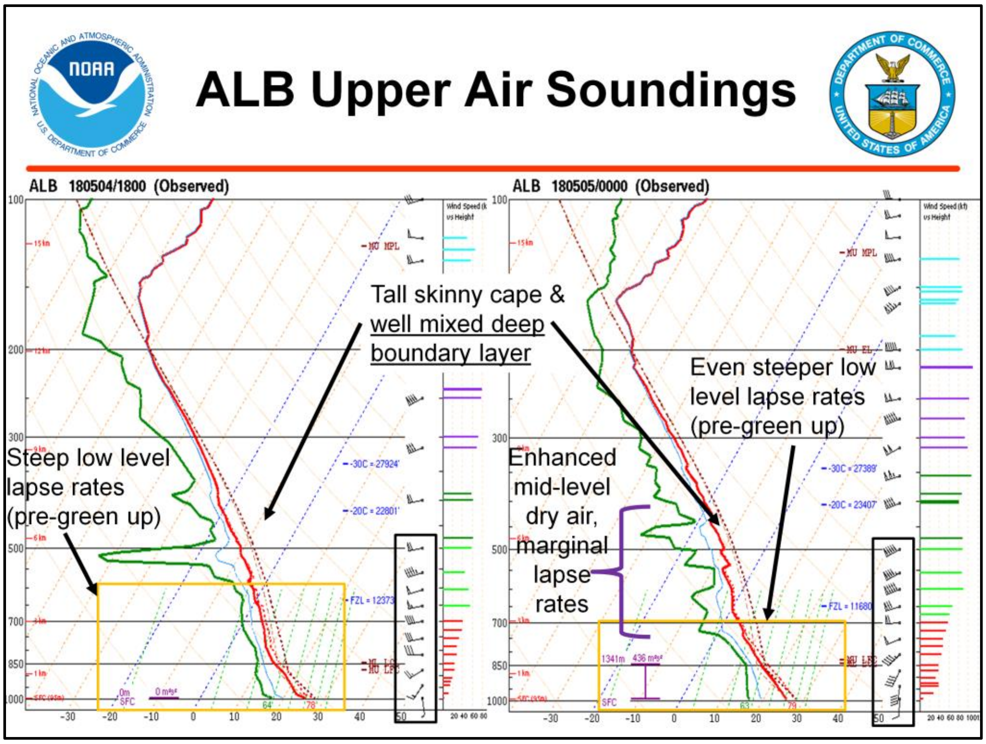
Now that we have clearer understanding of the upper level features, what happened thermodynamically? These three panels show the evolution of the cloud coverage and the surface warm front over the Northeast. We see a stationary boundary across NY and New England led to morning cloud coverage over the Albany CWA initially. By 18 UTC on 4 May, the low pressure system over the Great Lakes began intensifying, lifting the stationary boundary northward as a warm front. This allowed clouds to break and surface temperatures to rise into the 80s and dew points into the 60s. By 23UTC 4 May, the low pressure system strengthened enough and traveled far enough northward along the Saint Lawrence River Valley that its cold front started moving into western NY with the associated squall line racing through eastern NY and western New England. We also note that the previously highlighted area from Utica to coastal NH was closest to the system's triple point. This could serve as a warning sign for future events which areas could see the most damage.



At this point, we have established the Albany CWA entered the system's warm sector by the afternoon of 4 May 2018 with a warm, moist summer-like air mass overspreading the region. We also showed that this system's upper level dynamics were very impressive with an anomalous 70-80kt 500mb jet over eastern NY/western New England as the squall line moved through the area. For these reasons, we can hypothesis that the environmental lapse were steep enough ahead of the squall line to allow any strong winds in the 0-3km layer to mix down to the surface. Indeed, the above SPC mesoanalysis images displaying 0-3km lapse rates at 22UTC and 00UTC support our hypothesis. With lapse rates peaking up to 6-8C/km up the Hudson Valley by the squall line arrival time, this serves as another warning sign that high impact straight line winds may be possible.

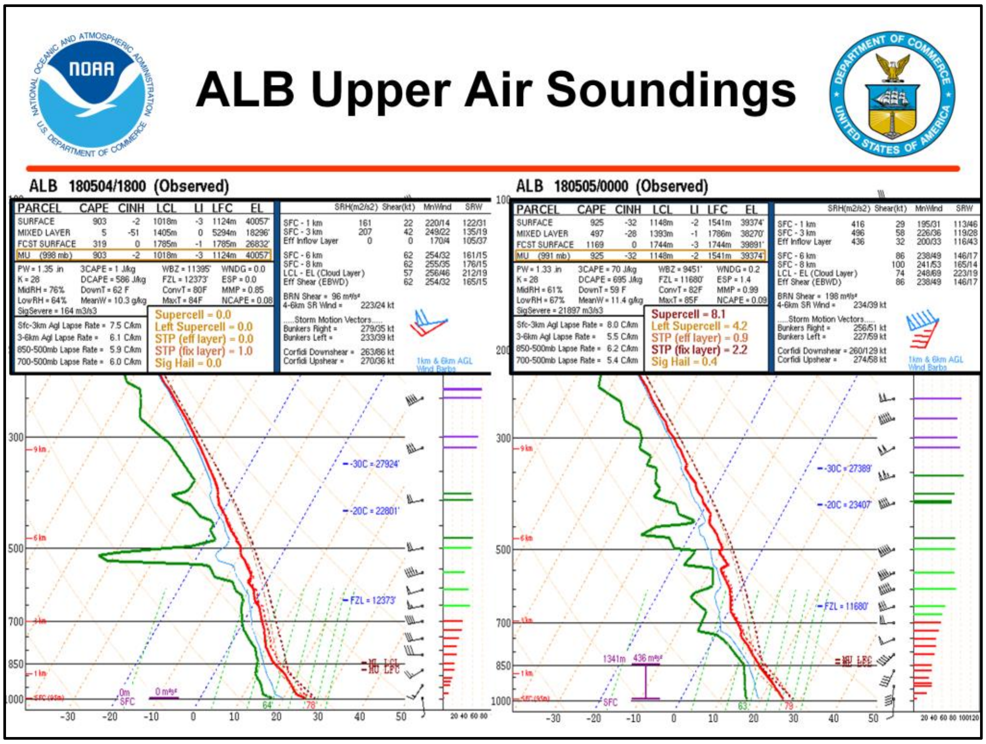


Of course, lapses rates in the low levels (0-3km) are not the only layer to analyze when deciding if high impact winds could mix down to the surface. Interestingly, the mid-levels, mainly 700-500hPa, were not very steep only reaching up to 5-6C/km ahead of the squall line. This implies that thunderstorms may not be very tall. With rather shallow convective towers, updrafts may not extend high enough to tap into the max winds of 70-80knots that we saw at 500mb and thus limits potential for these extreme winds to mix down to the surface. However, given how anomalous our low pressure system is and the strong kinematics at 500mb, we cannot discount the possibility that strong kinematics extend down into the boundary layer. If so, even shallow thunderstorms in the presence of very steep 0-3km lapse rates will have no issues mixing strong winds to the surface. A more in depth analysis of the sounding profile is needed to determine the peak mixing layer depth and max wind strength that could reach the surface.



Here is the special 18UTC 4 May and the 00UTC 5 May sounding from Albany, NY. The 18UTC sounding represents the environment within the warm sector. We can clearly see that strong kinematics are not reserved to the upper levels and exist through a deep column with 30knots to 40knots at 850mb and 700mb, respectively. Since most trees were without foliage on 4 May (leaves introduce water vapor to the atmosphere which can impede boundary layer mixing depths), the boundary layer extended through a deep layer up to about 600hPa! We also note steep lapse rates in the low levels with weaker lapse rates in the mid-levels. This can help explain why we see tall-skinny CAPE as opposed to tall-fat CAPE which is more common in environments with steep mid-level lapse rates.

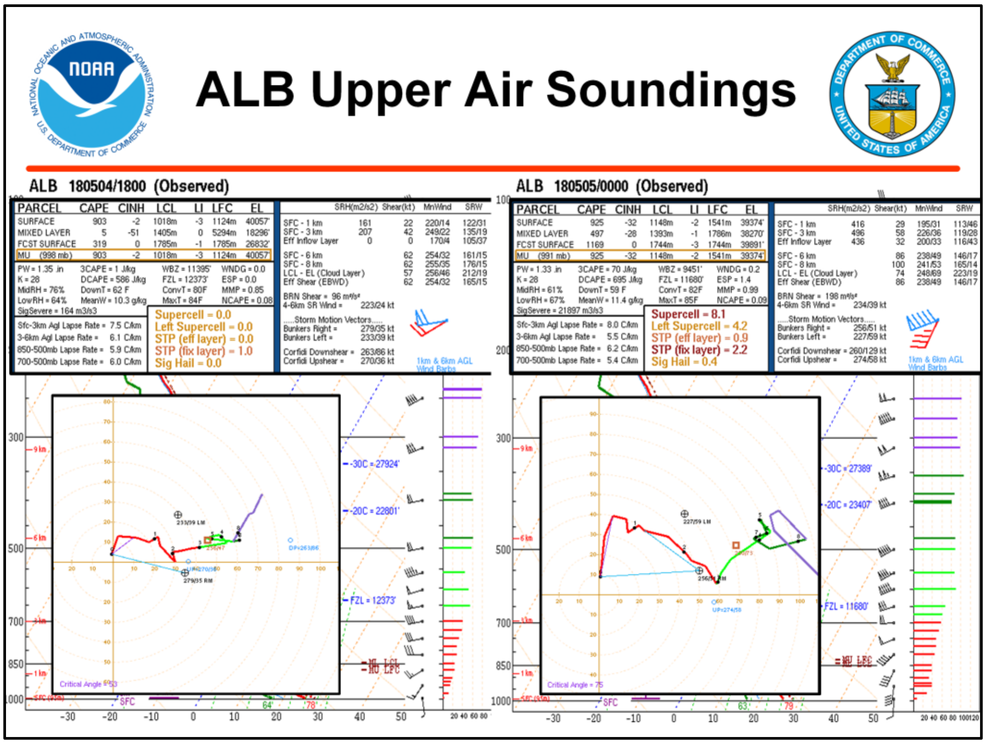
It is interesting to note that the 00UTC 5 May sounding represents the atmosphere in the 1-2 hours before the squall line moved through the Albany area. Here we note the very impressive kinematics throughout the column with 90knots at 500mb and 40 – 50knots even as low as 925mb! The mid-level lapse rates are still considered weak as shown in local NWS Albany research which helps explain why despite dew points in the 60s we still have tall-skinny CAPE. Even with weak mid-level lapse rates and rather low amounts of instability, our low level lapse rates are very steep and with such an impressive wind profile through the column, we do not need tall convective towers to produce damaging winds. There is also arguably a weak inverted-V signature which can enhance any downdrafts.



While the previous slide provided a qualitative analysis of the soundings, here is a quantitative look. Again, note the very steep low level (sfc-3km) lapse rates of 7.5C/km and 8.0C/km, the weak 700-500hPa lapse rates of 6.0C/km and 5.4C/km and low amounts of CAPE. Lastly, take a look at the significant sfc - 6km shear values on each sounding of 62knots and 86 knots. This is a testament to the extreme wind profile throughout the column. Notice the 00UTC 5 May 2018 sounding shows a veering wind profile in addition to a high wind field suggesting both speed and direction shear, although the speed shear is certainly more impressive. It is now clear we have a classic high shear, low CAPE environment. While this types of environments can also raise flags for potential tornadoes, our LCL heights are a bit high at over 1000m with shallow effective inflow layers which could hinder the tornado potential

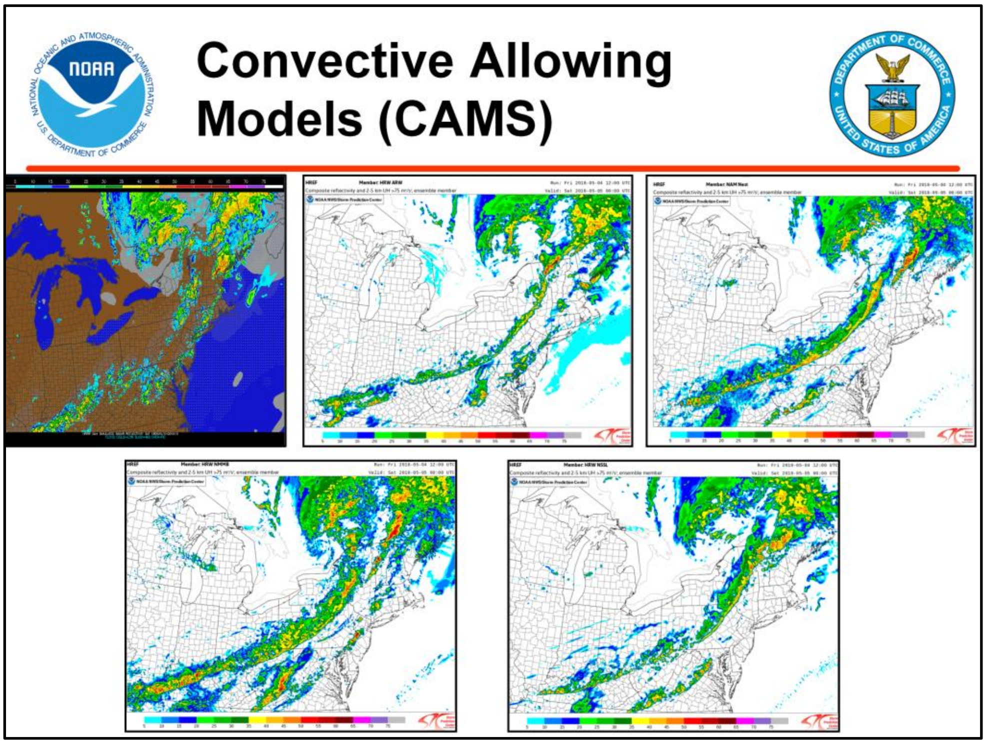
One parameter that has gained more attention in recent severe weather research is the Significant Severe (sigsevere) parameter which takes into account both MLCAPE and 0-6km shear to discriminate between thunder and significant events. Craven and Brooks, 2004 tells us that any value above 20,000 m3/s3 is favorable for significant wind/hail events and the value on our 00UTC 5 May 2018 sounding is 21897m3/s3. Given our analysis, we have enough support to say that the sigsevere value exceeds the significant wind/hail threshold due to the extreme 0-6km shear values. With no evidence of a strong upper level cold pool and weak mid-level lapse rates limiting potential for intense updrafts that could lead to large hail, we have reason to believe the sigsevere parameter is pointing to a significant wind event rather than a significant hail event.

DCAPE values are also good indicators of how much the strengthen of the convective cold pool from downdrafts could enhance environment winds mixing down to the surface. The DCAPE value on the 00 UTC 5 May 2018 ALY sounding is 600J/kg which is large enough to augment the strength of environmental winds mixing down to the surface; however, clearly in this case the strong near-surface environmental winds were most noteworthy and were a major factor for the damaging winds realized with the convection.

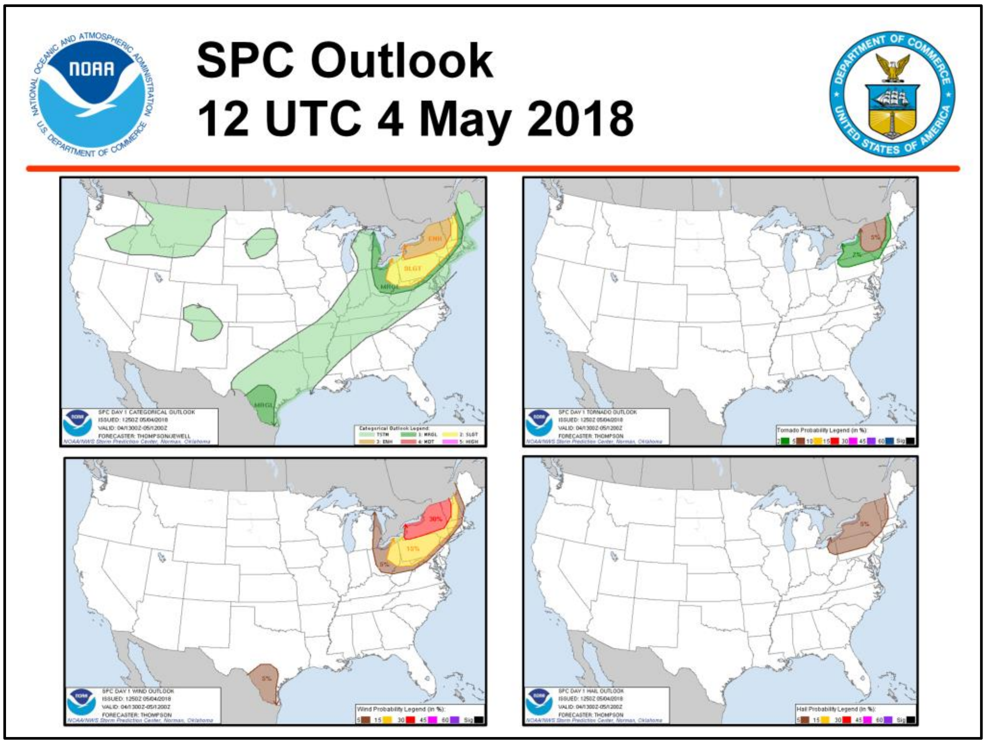


Here is a look at the respective hodographs from each sounding which can be helpful when deciding the convective mode. Given the environmental parameters, we have narrowed down the main severe weather hazard over the ALY CWA to severe wind but the directional and speed shear also alerted forecasters to possible tornadoes. Should the convective mode favor more discrete cells, tornadoes would be an increasing concern while a linear convective mode would favor more of a QLCS or quasi-linear convective system threat with potential for a few isolated tornadoes to develop along it.

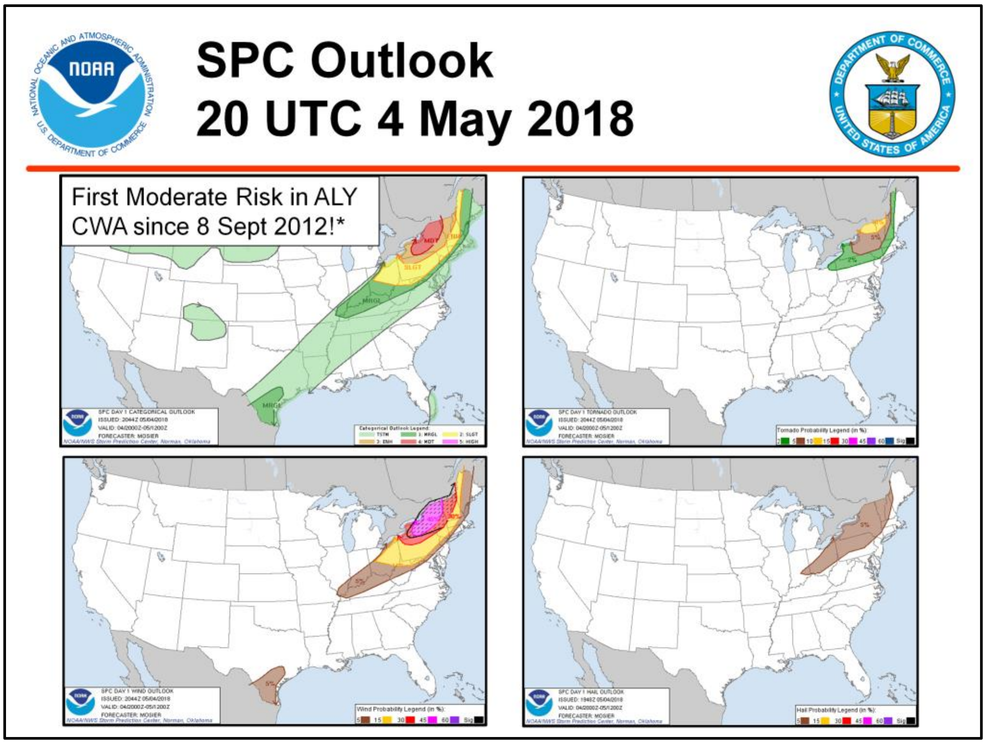
The lowest levels of the 00 UTC 5 May 2018 sounding show a strongly curved hodographs with the sfc – 1 km shear vector oriented around 200 degrees or roughly parallel to the line of the forcing, suggesting a linear convective mode. However, the sfc – 3km shear vector is oriented at 280 degrees or perpendicular to the line of forcing, suggesting discrete cells. So which convective mode should we favor? Given the discrepancies, we can turn to high resolution convective allowing models (CAMs) for guidance.



Displayed above are base and composite reflectivity images from (top left to bottom right) the HRRR, HRW ARW, NamNest, HRW NMMB and HRW NSSL. While the 13 UTC 4 May 2018 HRRR run implies more of a discrete mode valid at 01 UTC 05 May 2018, it seems to be the outlier. The 12 UTC 4 May 2018 run of the other CAMS all strongly suggest a linear convective mode valid at 00UTC 5 May 2018. Therefore, a linear convective mode mainly in the form of a QLCS is favored and given the impressive shear environment, forecasters should keep an eye out for mesovortices along it that may lead to isolated tornadoes.

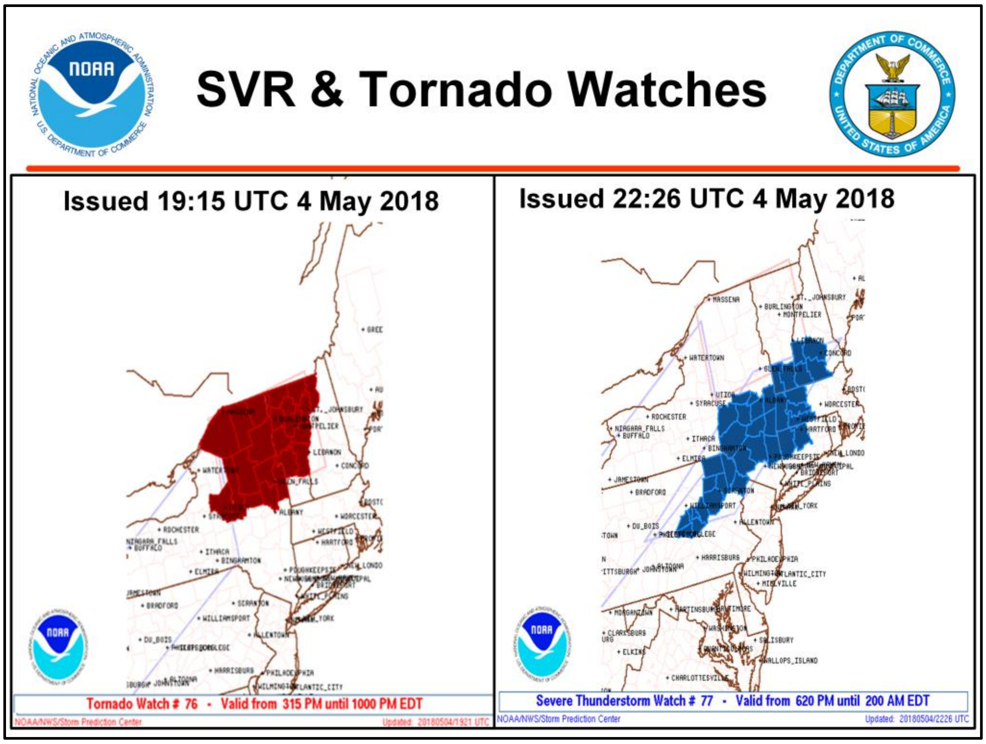


SPC outlook at 12UTC 4 May 2018 (top left) with the associated probabilities for tornado (top right), severe hail (bottom right) and severe wind (bottom left). This shows the greatest confidence for severe weather fell rightfully in the severe wind category with the 30% contour covering the northern half of the Albany CWA. Interestingly, the 5% tornado contour covers a good deal of the Albany CWA as well which makes sense given the intense speed and directional shear and thus potential for a spin up along the forthcoming QLCS.

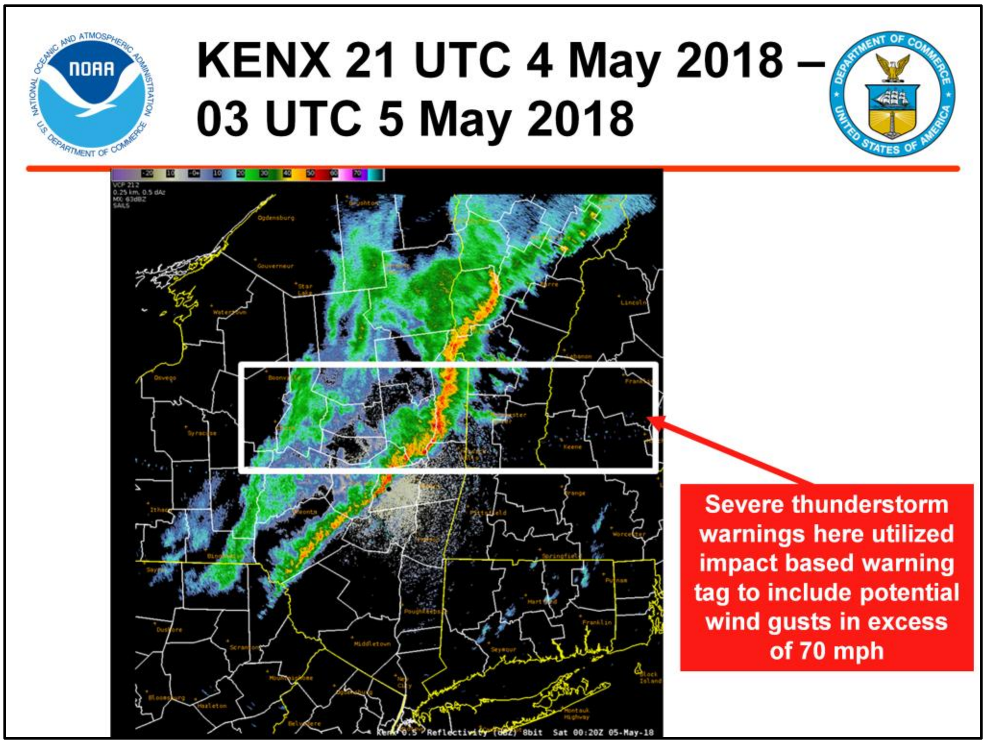


After viewing the special 18UTC 4 May 2018 ALY and BUF soundings, SPC rightfully increased the severe weather outlook to a moderate risk for western NY, the North Country and the southern Adirondacks at 20 UTC 4 May 2018. This was the first moderate risk to include Albany's CWA since 2012. SPC also increased the severe wind probabilities to 45% hatched (bottom left) to alert users for an enhanced damaging wind threat and extended the 30% contour further east into western New England. SPC also expanded the 5% tornado category a bit eastward to cover southern VT (top right).

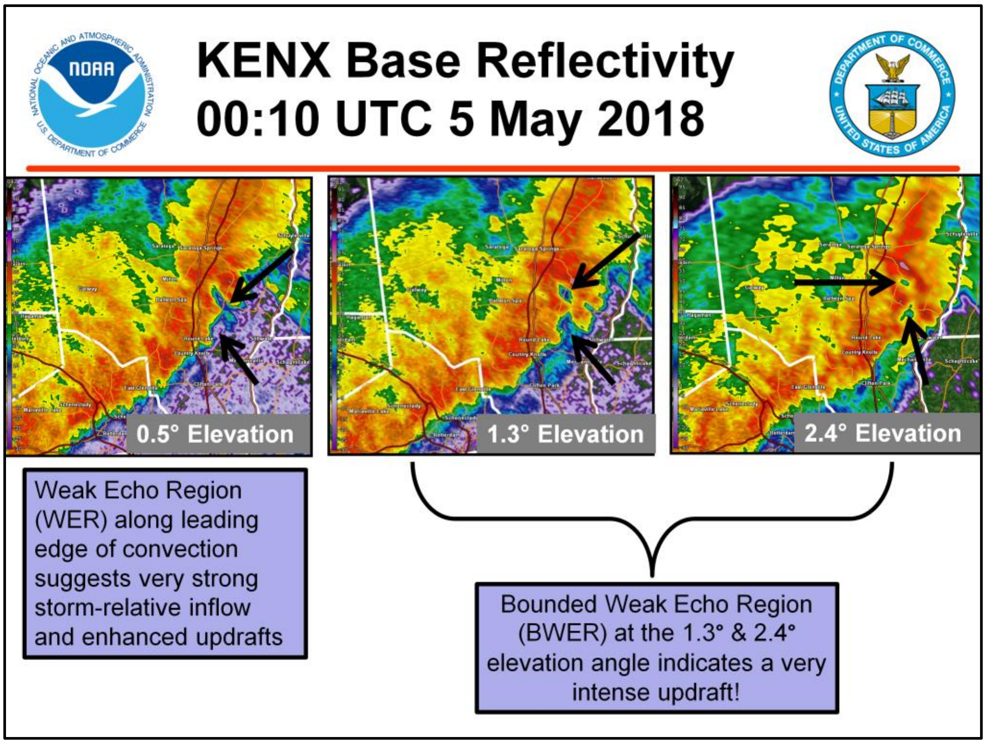
*note: SPC introduced the enhanced risk category to cover between slight and moderate risk in 2014. Since a moderate risk ranks as the second highest level in SPC's now 5 category ranking system, it is even more rare to see a moderate risk nowadays).



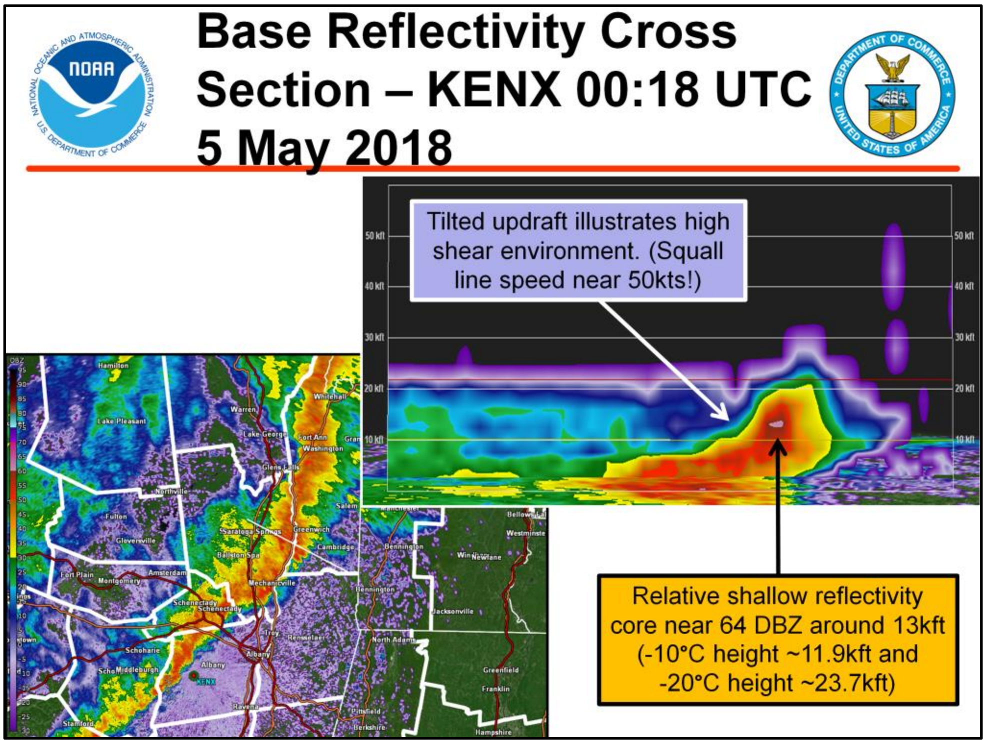
After viewing the impressive kinematics throughout the column in the special 18UTC soundings from BUF and ALB followed by extensive collaboration with neighboring offices and the Storm Prediction, a Tornado Watch was first issued at 19:15UTC covering the northern ALY CWA with a Severe Thunderstorm Watch at 22:26UTC covering the southern ALY CWA. While NWS Albany highlighted the severe thunderstorm threat and emphasized the high confidence for damaging winds with just a potential for isolated tornadoes, some users were most concerned with the tornado threat since tornados are rare in this part of the Northeast. We learned it is important to remind users that widespread damaging wind threats can impact a much larger area than an isolated tornado and, in most situations, similar damage.



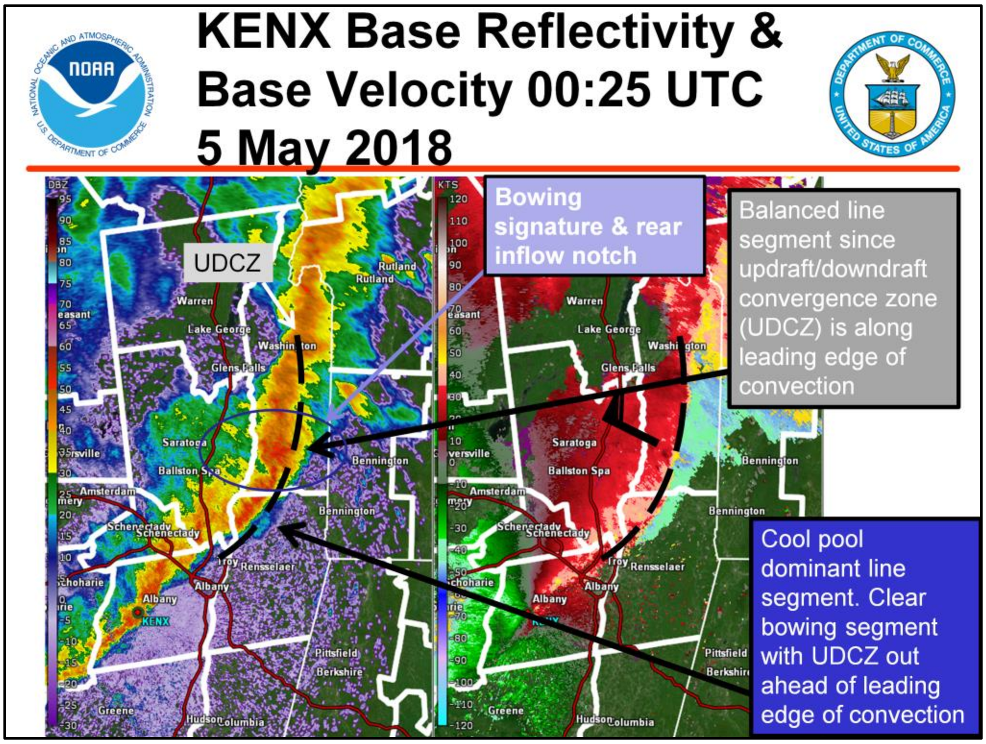
Here is a loop showing the radar evolution on 4 May 2018. Notice some showers and storms impacted the Capital District, mid-Hudson Valley and parts of western New England before 21UTC. This likely lowered the already limited instability values in the southern part of the ALY CWA and could be a reason why the most significant storms occurred across the northern half of the ALY CWA (highlighted in the white box). The eventual severe squall line/QLCS that occurred near and after 00UTC 5 May 2018 included radar signatures that suggested significant wind potential to the warning forecaster. This is why impact-based warning tags indicating increased confidence for winds in excess of 70mph winds accompanied the severe thunderstorm warnings.



Now let's interrogate radar signatures that alerted the warning forecaster to potential significant wind damage. On the left 0.5 degree base reflectivity image from the KENX radar from 00:10UTC 5 May 2018, we see two weak echo regions (WER) indicating very strong storm-relative inflow and thus enhanced updrafts. We also can see depressed reflectivity in the wake of these updrafts referred to as rear inflow notches which suggest strong downdrafts. Taking this same image but investigating higher tilts, we see signs of bounded weak echo regions at the 1.3 and 2.4 degree tilts above the WER seen at the 0.5 degree tilt. This suggests very intense updrafts that have height continuity along the leading edge of the convection. We also see the depressed reflectivity signature is maintained in higher elevation angles in the wake of the updrafts which increases confidence for significant downdrafts.

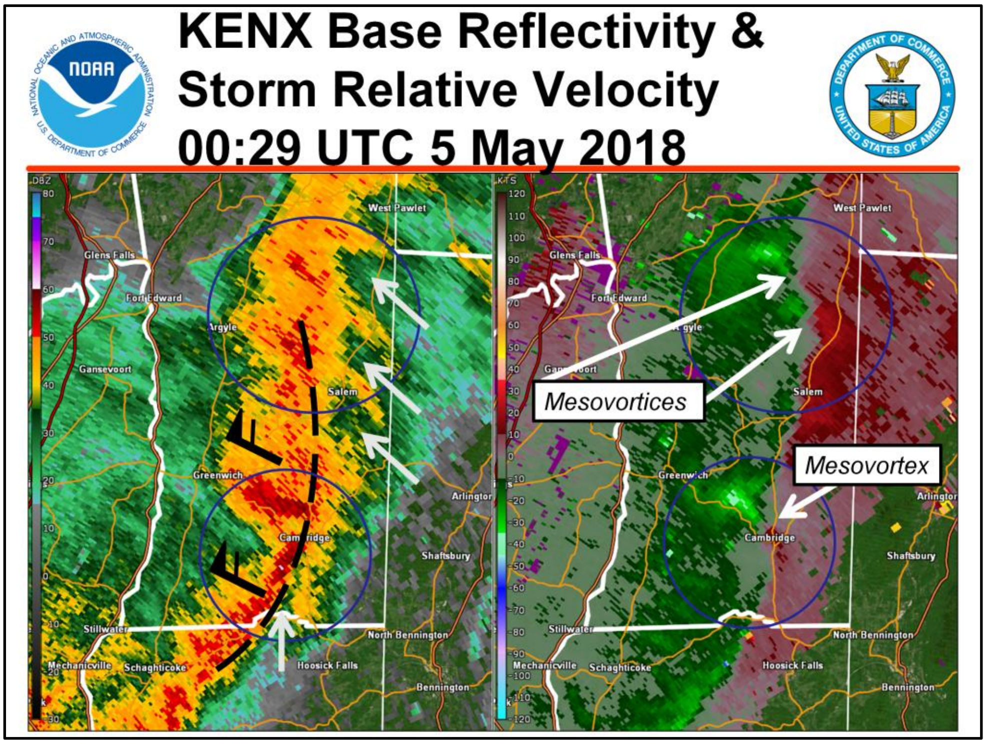


Now that the we have reason to believe the updrafts along the leading edge are very intense, let's look at a cross section to see how high the updrafts extend into the atmosphere. Based upon the weak mid-level lapse rates we noted in our sounding analysis, we do not expect the updrafts to be very tall but let's see if our hypothesis is correct. The top right image indeed agrees that our updrafts are shallow as the 64DBZ reflectivity only extends up to about 13kft which is just above the -10C height (yellow line). However, since very impressive kinematics extended through a deep column on this day, updrafts did not need to be very tall to tap into significant winds. Based on the 18 UTC ALY sounding, we had 60-90 knots at the -10C height which is plenty strong to lead to damaging winds at the surface. We also see the updraft in this cross section is tilted with WARNGEN analyzing our storm motion to be 50 knots, a testament to the directional and very impressive speed shear in the environment.



As forecasters interrogates a squall line/QLCS, they try to identify the areas that pose the greatest damaging wind threat. One of the ways to do this is to identify the updraft and downdraft convergence zone (UDCZ) on the base velocity imagery and compare its position to the leading edge of convection. Are they inline with each other? If so, the shear and cold pool circulation regime is balanced and updrafts will be sustained, posing the greatest damaging wind threat. If the UCDZ out runs the convection, it is cool pool dominant and the outflow tends to choke off the warm, moist air feeding the updrafts thus reducing the damaging wind threat with time. If the convection is ahead of the UDCZ, then our regime is considered shear dominant where updrafts are tilted forward and are weaker with little vertical growth.

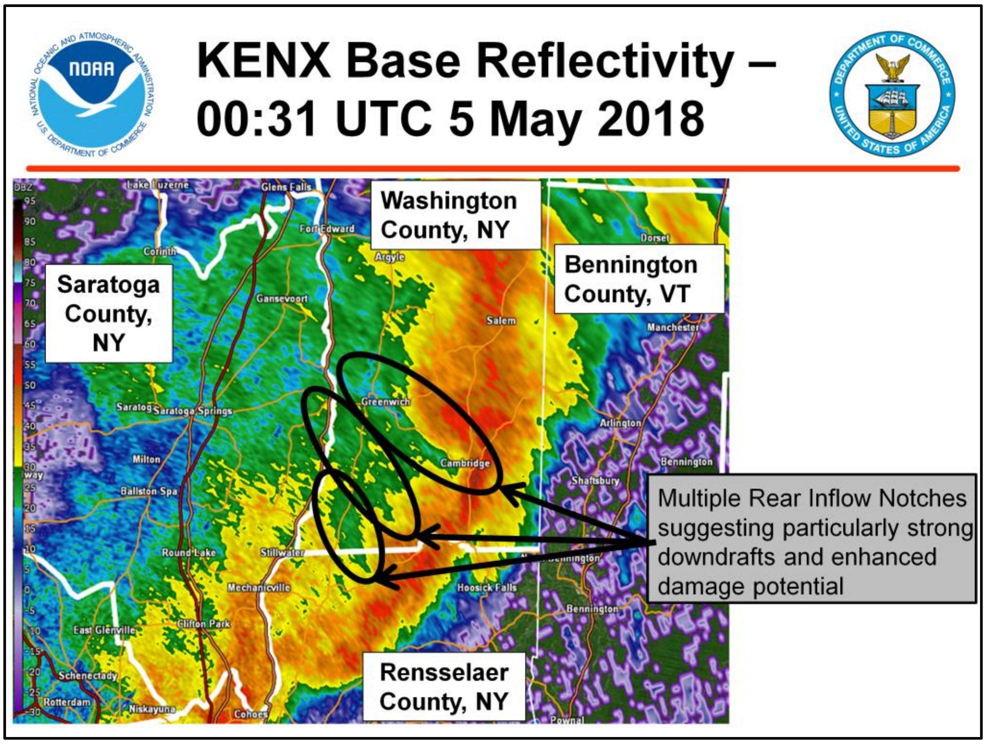
In the example shown here, we overlaid the UDCZ (black dotted line) over the reflectivity to better identify which portions of the QLCS pose the greatest wind damage threat. Notice our line segment is balanced and even slightly shear dominant through Washington County which severe weather research tells us is the most favored regime for the development of mesovortices and associated damaging winds. In addition, we also see pronounced rear inflow notches behind the leading edge of convection with our segment bowing in southern Washington County illustrating an enhanced damaging wind threat. Further south in Rensselaer County, the segment is cool pool dominant giving reason to think the damaging wind threat will weaken with time, reducing the wind threat for areas eastward in the Berkshires.



Let's focus our attention on the portion of the QLCS in southern Washington County. Remember our analysis of the 00UTC 5 May 2018 ALY sounding supported the potential for mesovortices which we know can lead to areas of significant wind damage as well as isolated tornadoes. Given our radar interrogation thus far highlighted this area as highly favorable for wind damage threat, let's investigate the potential for mesovortices.

In the previous slides we already noted two of the three main signatures, pointing out the balanced and even slightly shear dominant segment in Washington County with a bowing segment noted in southern Washington County. The third ingredient is for sfc-3km line normal bulk shear vectors to be 30 knots or larger. Upon overlaying our sfc-3km bulk shear vector noted from the 00UTC 5 May 2018 ALY sounding (black vectors) and comparing its orientation to the UDCZ (black dotted line), we satisfy this last requirement and should check the storm relative velocity for mesovortices. We should especially check areas with front inflow notches or reflectivity appendages (white arrows) on the base reflectivity. Looking at storm relative velocity (right image), we indeed see mesovortices along our QLCS. While the velocity couplets associated with these mesovortices are not tight enough where the forecaster would necessarily issue a tornado warning, mesovortices can give the warning forecaster enough confidence to add an impact-based warning tag to a severe thunderstorm warning. These tags alert users to a significant wind damage threat. That's exactly what the warning forecasters did in this situation, augmenting the severe thunderstorm warning over Washington

County to include a tag for potential winds gusts in excess of 70 mph.



On this 00:31UTC 5 May 2018 reflectivity image we have even higher confidence that significant wind damage likely occurred in Washington County due to multiple very well-defined rear inflow notches behind the leading edge of convection which implies powerful downdrafts. In the end, the wind damage was so significant that NY Governor Cuomo declared a state of emergency for Washington County.

Conclusions

1) Anomalous cyclone with very strong kinematics (40 – 90 knots from 925hPa to 500hPA) led to directional/speed shear & strong lift over the ALY CWA
2) Incredible effective shear 70 – 90 knots! *Tornado threat? Maybe not…*
   a) Weak mid level lapse rates 5.5-6.0°C/km led to shallow updrafts. Also LCL heights above 1000ft with shallow effective inflow layer. *These may have decreased the tornado potential*
3) SigSevere parameter helpful at evaluating both kinematics and thermodynamics in convective environments. Here, sigsevere ~22000 m3/s3 points to significant wind/hail (>65 knots, +2" hail), Craven and Brooks, 2004. Shallow updrafts and lack of upper level cold pool decreases hail potential
4) Impressive kinematics close to the surface in well mixed column with strong lift and marginal instability was enough that even shallow thunderstorms mixed strong winds to surface leading to ***significant wind event.***
5) Rear/front inflow notches, WER, BWER, location of UDCZ and interrogation of mesovortices assisted warning decisions, including usage of impact-based warning tags.

Acknowledgments

- NWS Albany Staff
- Warning Decision Training Division (WDTD) including Warning Operation Course - Severe
- NWS Louisville - Squall Line Reference Page
- Storm Predication Center