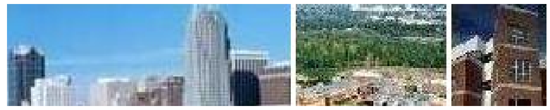
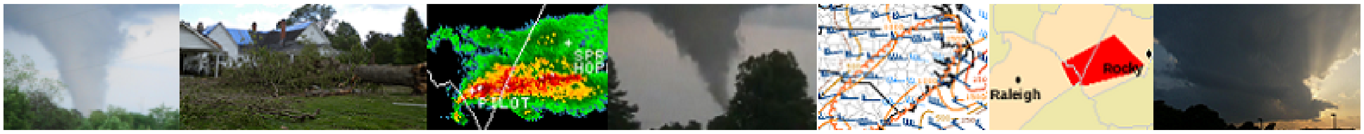
Event Summary
National Weather Service, Raleigh NC



April 25, 2010 Tornado Event

Note that this is a PDF version of the event summary and that some links, media or resources may not be avaiable in this format.



Event Headlines -
...An EF-0 Tornado with winds near 80 MPH touched down near Zebulon in Wake County and moved east-northeast into Franklin County on April 25, 2010 producing some damage but no injuries or fatalities...
...The tornado was produced by a resilient convective cell that eventually developed into a low precipitation supercell in an environment that was generally suppressing convection...
...High resolution model forecasts showed some skill in predicting the convective event and a comparison matrix of the forecasts is available below...

Event Overview -
A rain shower that developed in the Southern Piedmont of North Carolina between Wadesboro and Albemarle at around 2030 UTC on Sunday, April 25, 2010 moved northeast and began to intensify as it moved into Wake County a few hours later. While the low level environment featured rather steep low and mid level lapse rates with sufficient moisture, the mid and upper levels were rather dry and limited convective development despite the strong wind shear profiles which were supportive of supercells. The lone convective cell intensified into a low precipitation supercell that produced a weak Tornado as it moved across far eastern Wake County into far southern Franklin County.

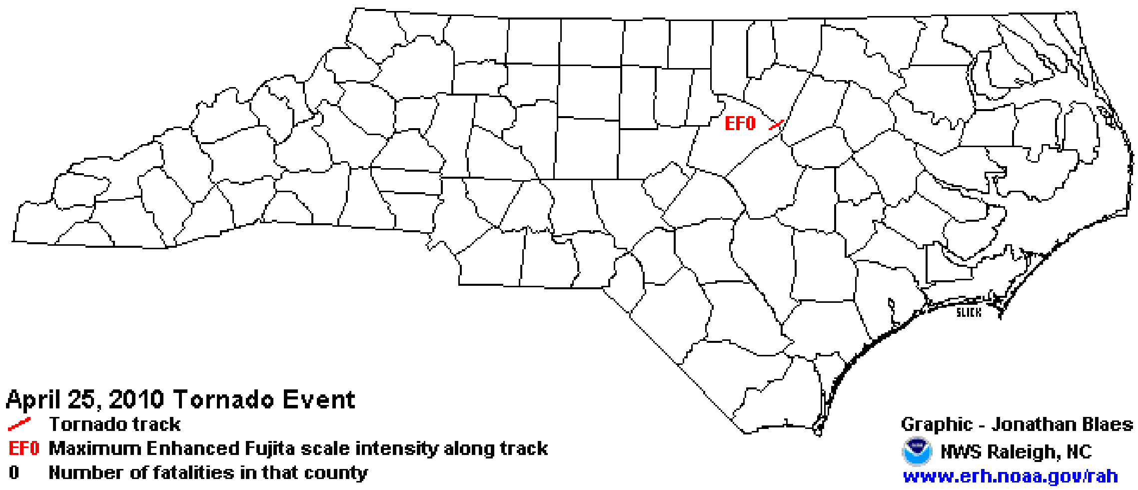
Event Details -
A deep 500 hPa low was centered over Indiana at 00 UTC Monday, April 26 with a 500 hPa trough extending south through the Tennessee Valley into the Deep South with a southwesterly flow aloft over the Carolinas. Mid and upper level drying was noted in the water vapor satellite imagery and RAOB data (GSO | FFC) across the Southeast. Between 70 and 100 meter height falls at 500 hPa were overspreading the region from the west at 00 UTC with broad and modest forcing for ascent present over the Carolinas. A strengthening 250 hPa jet was centered over the southeast coast, extending from Florida northeast along the Georgia and Carolina coasts with central North Carolina located on the cyclonic shear side of the 250 mb jet.

At the surface, a 989 MB vertically stacked low was centered over Indiana, with an occluded front extending eastward across Ohio, Pennsylvania, and West Virginia. A secondary 992 MB low was centered in northwestern Virginia. A strong warm front transitioning to a cold front extended east from the low through northern Virginia and the northern DELMARVA region, while a cold front extended southward through central Virginia, North Carolina, and South Carolina. In central North Carolina, the cold front extended north-northeast from near Albemarle to Burlington to Roxboro. Although temperatures varied little across the front in central North Carolina, dew points ranged from the mid 60s east of the front to the upper 40s and lower 50s west of the front. Temperatures in the Triangle area were in the mid 70s at 00 UTC, while dew points ranged between 60 and 65 degrees.

Data from SPC mesoanalysis indicated very steep 0-3 km lapse rates on the order of 7-7.5 C/km, with reasonably steep mid-level (500-700 hPa) lapse rates on the order of 6-6.5 C/km at 00 UTC Monday. At 00 UTC, the steep low-level and mid-level lapse rates combined with relatively moist surface dew points in the lower 60s resulted in mixed layer CAPE (MLCAPE) values of 1000-1500 J/kg along and east of the Triangle, with little or no CIN. A relatively pronounced moist axis extended ahead of the front from eastern South Carolina northeast into eastern North Carolina. Lifted condensation levels (LCL's) exhibited a tight gradient in the vicinity of the Triangle, with LCLs of 1500-2000 meters west of the Triangle, and 750-1000 meters along and east of the Triangle. Despite the lack of any pronounced surface wind backing, the veering of the environmental flow in the lowest 1 km resulted rather strong (30-40 knots) 0-1 km shear, and 0-1 km storm relative helicity (SRH) values analyzed by the SPC mesoanlaysis page were very high at 00 UTC, ranging from 250-350 m2/s2 over much of central North Carolina. The proximity RAOB soundings from 00 UTC at GSO and MHX suggest that 0-1km SRH values obtained via the SPC mesoanalysis page may have been slightly overdone, and the actual 0-1 km SRH values were more likely to be in the 150-250 m2/s2 range (still very significant). Effective bulk-shear values ranged from 50-60 knots at 00 UTC, supportive of organized convection with multicells and potential supercells.

Between 16 and 20 UTC, isolated enhanced cumulus clouds and towering cumulus were developing across western North Carolina, the Blue Ridge Mountains in Virginia, and along the cold front in the western Piedmont of North Carolina. Drying aloft (water vapor satellite | RUC sounding for KRDU | GPS MET data for Raleigh) resulted in limited cloudiness and strong surface heating while low level moisture transport kept dew points in the lower and mid 60s east of the front. The convection appears to have been forced in a slightly convergent surface flow along the cold front within a larger area of upper level height falls and modest large scale ascent. The convection had to battle dry mid level air that was overspreading the region and likely being entrained in the updrafts. As noted in the 2200 UTC SWOMCD product, one cell was able to sustain itself in this environment and strengthen into a low precipitation supercell and eventually produce a weak Tornado as it moved across far eastern Wake County into far southern Franklin County.

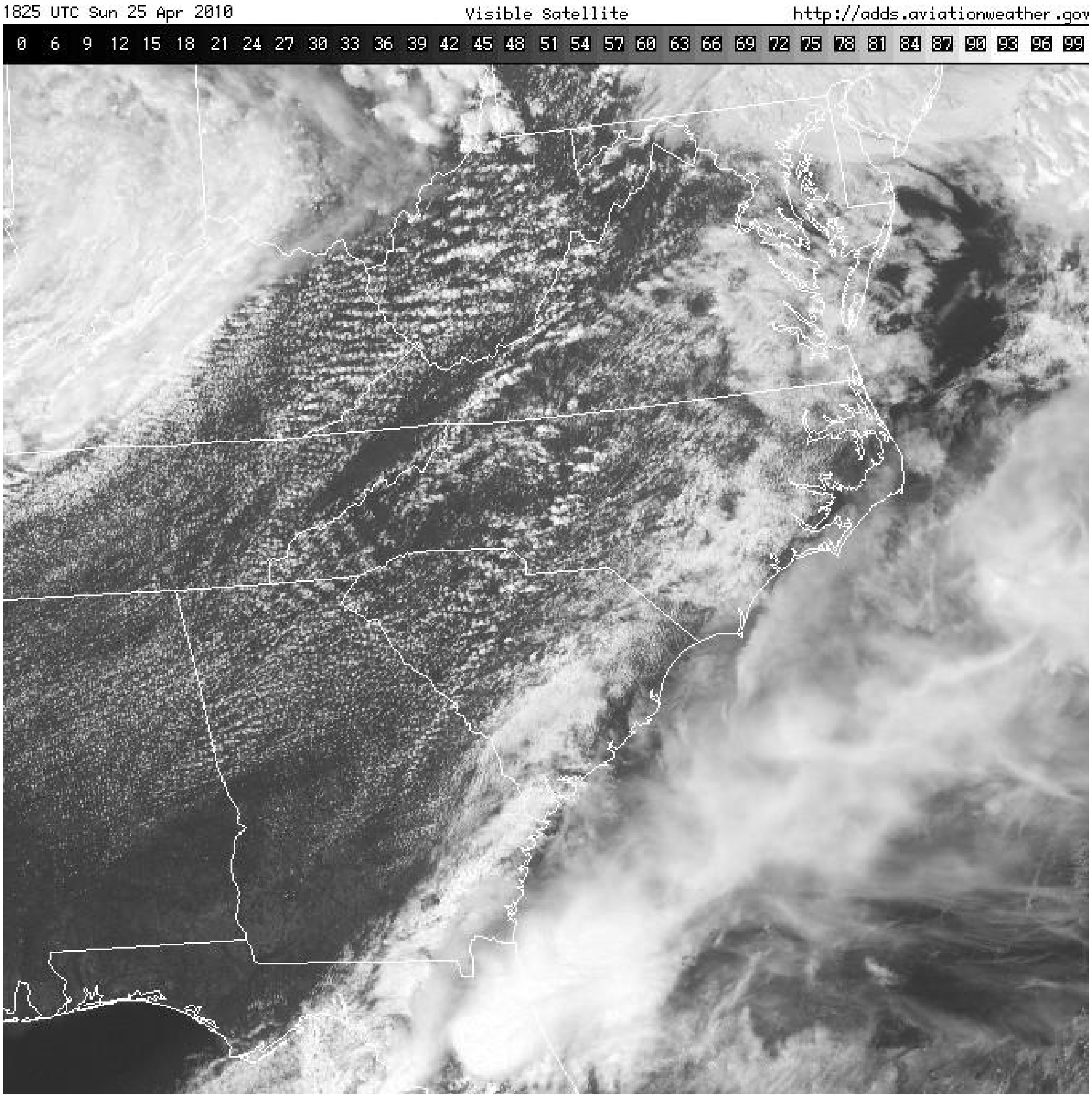
Tornado Track Map -



Satellite Imagery

Visible satellite imagery showed several features across the Carolinas and Virginia on April 25th including the cold front that was oriented north-northeast to south-southwest across the western Piedmont of the Carolinas, greater moisture across the eastern Carolinas with a fair amount of cloudiness, and significant drying across the western Carolinas. These features are prominent in the loop available below.

A **Java Loop** of visible satellite imagery from 1206 UTC through 2351 UTC on April 25, 2010 is available.

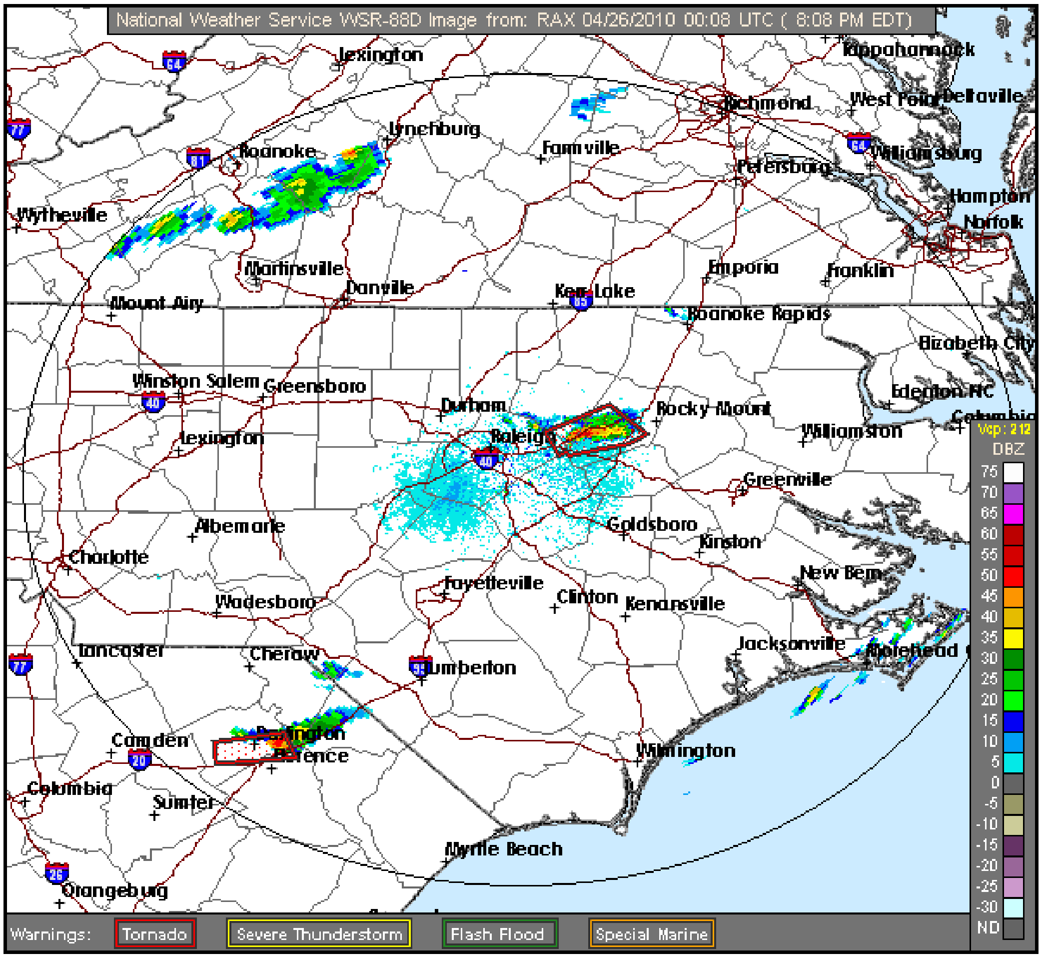


KRAX Radar Loops

Overview of the entire event with images from every 15 minutes between 2002 UTC on April 25 through 0202 UTC on April 26, 2010.
Java loop of KRAX reflectivity imagery every 15 minutes from 2002 UTC on April 25 through 0202 UTC on April 26, 2010.
Note - this loop includes 25 frames

Overview of the entire event with images from every volume scan between 2002 UTC on April 25 through 0202 UTC on April 26, 2010.
Java loop of KRAX reflectivity imagery from 2002 UTC on April 25 through 0202 UTC on April 26, 2010.
Note - this loop includes 77 frames

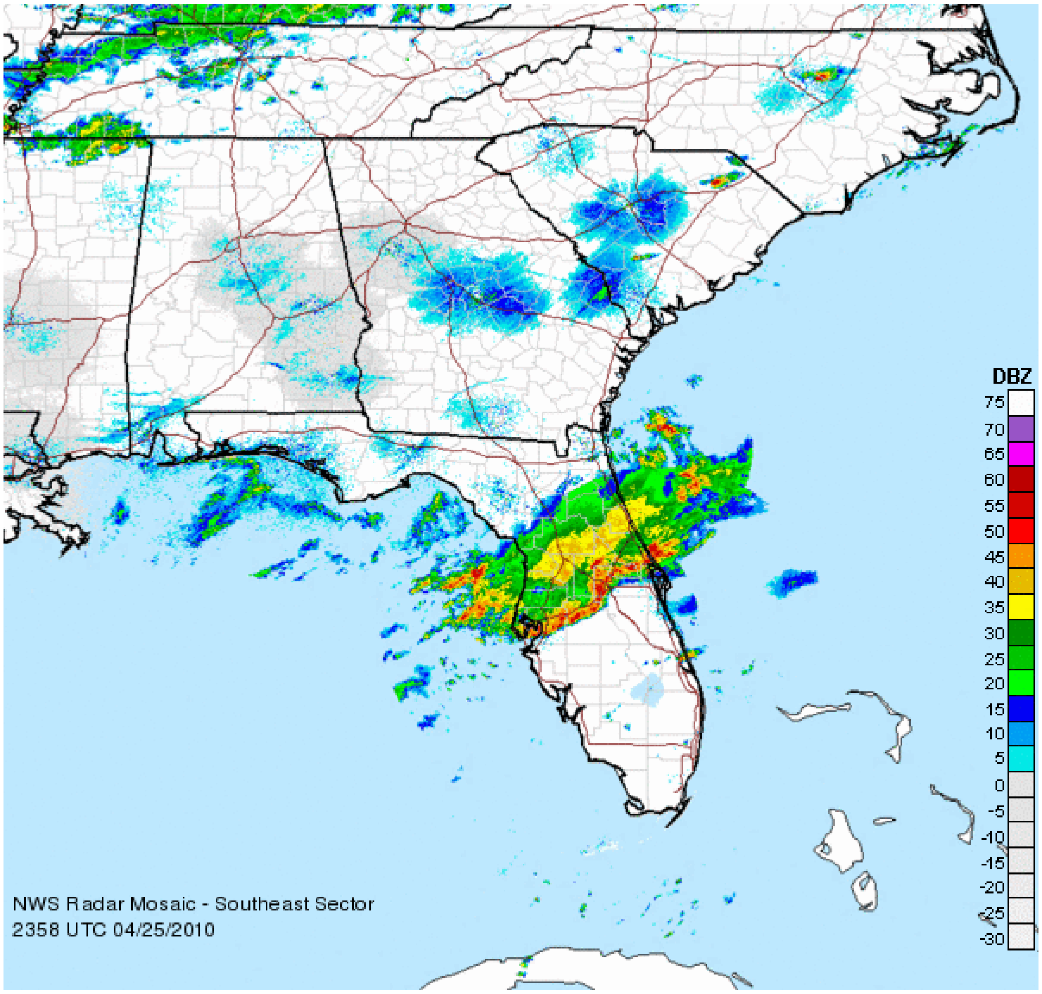
The KRAX reflectivity image below is from 0008 UTC on April 26, 2010 just as the tornado was moving across far southern Franklin County.



Regional Radar Loop

A Java loop of regional reflectivity imagery from 1958 UTC on April 25 through 0258 UTC on April 26, 2010 is available **here**. Note - this loop includes 15 frames.

The regional reflectivity image below is from 2358 UTC on April 25, 2010. This was just as the EF-0 tornado touched down in eastern Wake County. Note the limited amount of convection across the Carolinas with only three thunderstorms across all of North and South Carolina. Two of these thunderstorms produced tornadoes during the evening of April 25th, with one in North Carolina and another in South Carolina.



The Zebulon EF-0 Tornado

The National Weather Service in Raleigh NC confirmed that an EF-0 Tornado with winds near 80 MPH touched down near Zebulon in Wake County and moved east-northeast into far southern Franklin County North Carolina on April 25, 2010.

The tornado initially touched down near Bell Street just west of the Glaxo-Smith-Klein facility and the Zebulon municipal building. Both of these properties experienced large fallen trees which damaged fencing but no structural damage occurred to any of the buildings. One oak tree at the municipal building was nearly 4 feet in diameter. The tornado moved east across Highway 96 (North Arendell Avenue) producing minor damage to several businesses in the Triangle East Center. A McDonalds, Pizza Hut and other businesses in the shopping center experienced very minor damage. A four hundred pound condenser on the roof of the McDonalds was turned sideways. A couple of vehicles in the shopping center parking lot were moved about 10-15 feet and a number of vehicles had their windows shattered by debris from the tornado. Many patrons at the local restaurants saw the tornado before it struck and took cover. Tornado wind speeds in the shopping center were around 70 MPH.

The tornado crossed Highway 64/264 near Shepards School Road traveling parallel to the highway before crossing Old Bunn Road. Numerous trees were blown down and one shed was destroyed along Old Bunn Road with the strongest tornado damage evident at 1311 Old Bunn Road. Winds in this area increased to around 80 MPH. At this residence, a fair amount of minor roof damage was noted, a carport collapsed and numerous outbuildings were destroyed by a combination of tornadic winds and falling trees. Many of the trees which fell were large hardwood trees between 3-4 feet in diameter.

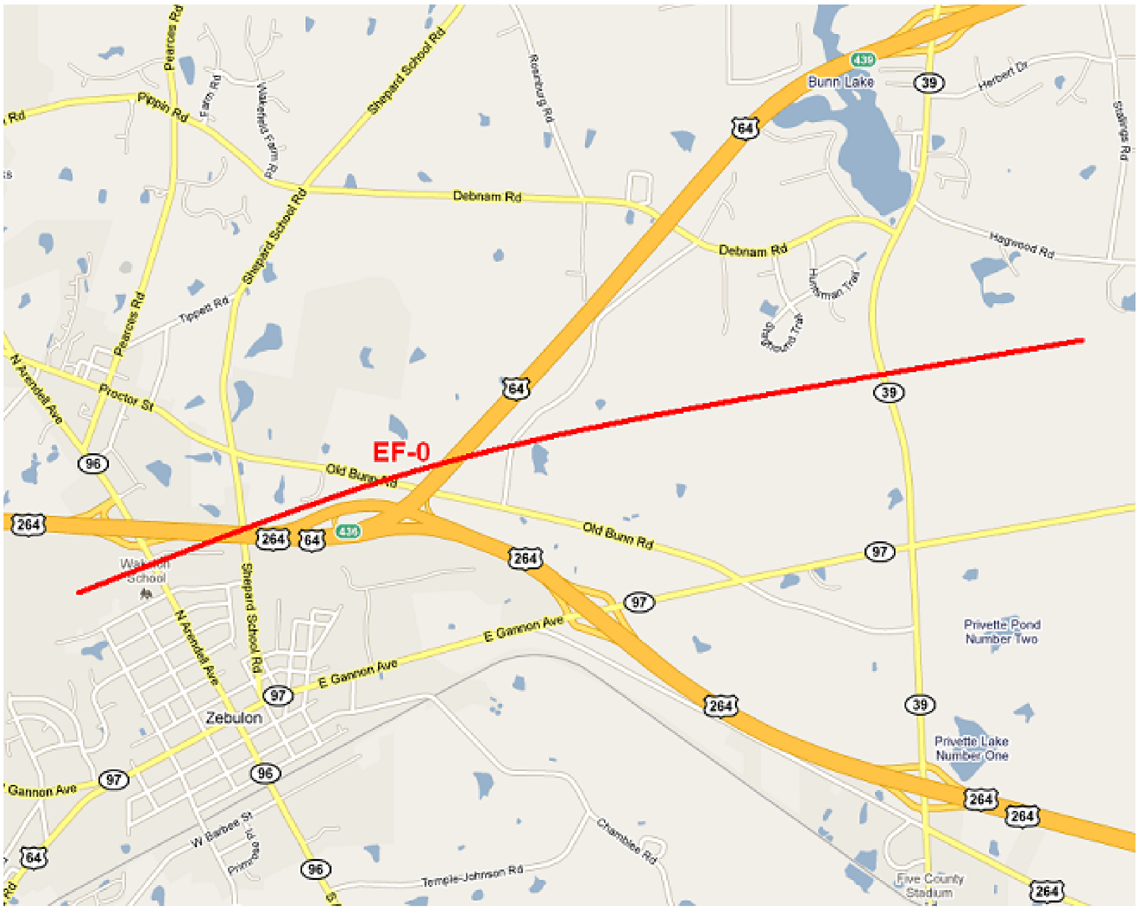
After striking the residence on Old Bunn Road the tornado again crossed Highway 64 eventually crossing Parks Village Road where another large hardwood tree fell destroying an outbuilding. The tornado then moved into a swampy area before crossing Highway 39 just north of the intersection of Highway 39 and Highway 97. Numerous trees at a residence were uprooted or snapped. A home in the area lost several shingles and some siding was damaged. Winds in this area were around 70 to 75 MPH. The tornado moved into southern Franklin County then lifted off the ground.

The overall storm track was around 3.5 miles and it appeared to be a continuous track tornado. The average path width was around 75 yards and the maximum wind speed was around 80 MPH.

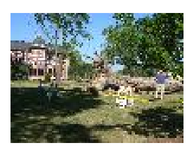
Although initially attributed to the tornado, damage to a carport/storage shed in Nash County near Spring Hope on Worth Road was not coincident to the tornado track and has been determined to have resulted from straight line winds. Residents along worth road reported large hail at least the size of quarters and a broken window and siding damage were attributed to the hail. Straight line winds near Spring Hope were estimated at around 65 MPH.

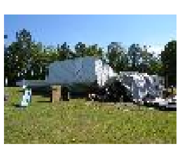
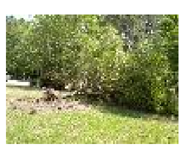
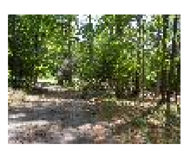
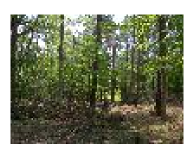
Location: Zebulon in eastern Wake County and far southern Franklin County North Carolina
Time/Date: 759 PM TO 806 PM EDT, Sunday April 25, 2010
Maximum EF-Scale rating: EF0
Estimated maximum Wind Speed: 80 MPH
Path Length: Approximately 3.5 miles
Maximum Path Width: 75 yards
Injuries: none
Fatalities: none

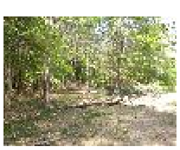
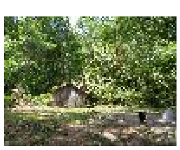
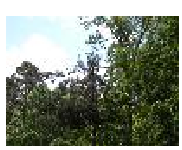
Zebulon Tornado Track -



Zebulon Tornado Damage Photos -
Photos courtesy of the National Weather Service.
(click on the image to enlarge)

Zebulon Tornado Videos -

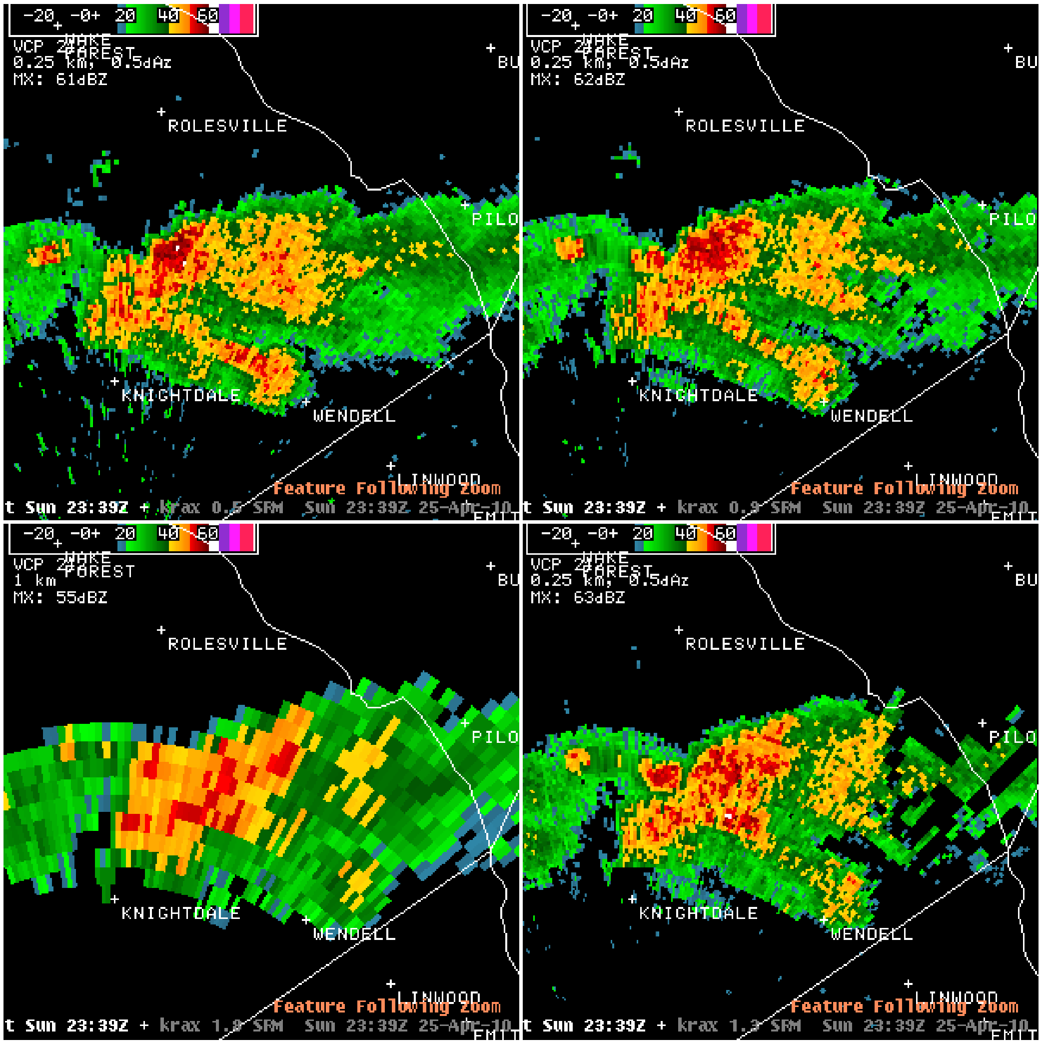
Videos courtesy of Jose Guzman taken near the intersection of Jack Mitchell Road and Riley Road just northwest of Zebulon between 755-800 PM EDT.

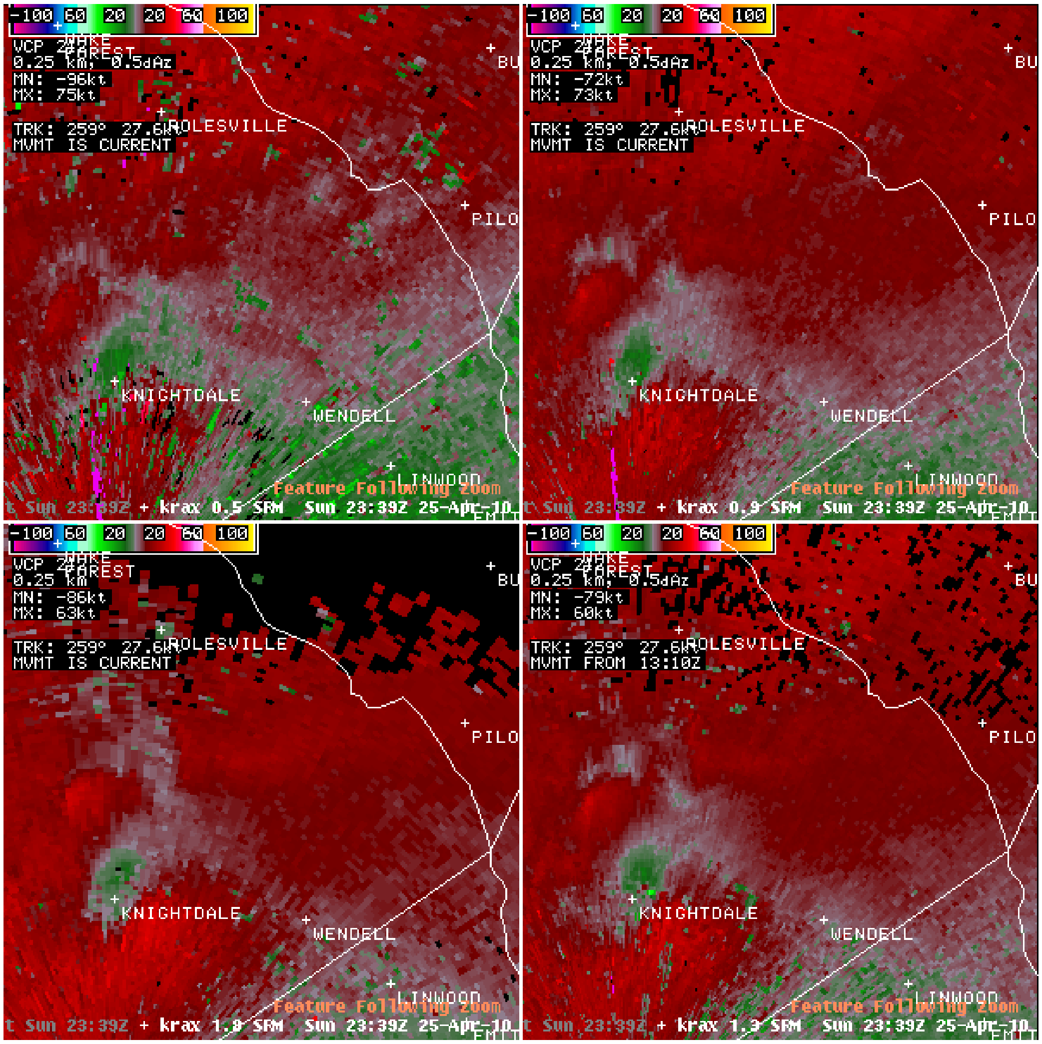
Video courtesy of Dale Pate taken at the intersection of Highway 96 and Glory Road looking southeast between 800-810 PM EDT.

Zebulon Tornado Radar Imagery -

A loop of KRAX 4 panel base reflectivity imagery from 2339 UTC on April 25 through 0109 UTC on April 26, 2010 is shown below. A Java loop in which the user can stop, start, and animate the imagery of the KRAX base reflectivity data from 2339 UTC on April 25 through 0109 UTC on April 26, 2010 is available **here**. Note - this loop includes 21 frames



A loop of the KRAX storm relative velocity imagery from 2339 UTC on April 25 through 0109 UTC on April 26, 2010 is shown below. A Java loop in which the user can stop, start, and animate the imagery of the KRAX storm relative velocity data from 2339 UTC on April 25 through 0109 UTC on April 26, 2010 is available **here**. Note - this loop includes 21 frames



Storm Scale and Radar Analysis

As noted previously, the tornadic thunderstorm developed in the Southern Piedmont between Wadesboro and Albemarle at around 2030 UTC. The rain shower moved northeast and began to intensify as it moved into Wake County a few hours later. The gradual increase in the amount of moisture and instability east of Raleigh likely supported convective development in a larger environment that was generally suppressing convection. The increased instability likely supported a stronger and more vigorous updraft. Vertical wind shear causes the development of dynamic processes in supercell thunderstorms that affect the evolution, strength, longevity, and motion of the storm. Given the strong shear profile, once the updraft became more established and a mesocyclone formed, the contribution of the perturbation pressure likely resulted in an even stronger updraft in the middle-levels. Another item to note is that the SPC mesoanalysis indicated an axis of increased surface vorticity just east of the Piedmont and nearly juxtaposed with the axis of increased low level instability (0-3km MLCAPE).

The shower quickly intensified between 2300 and 2330 UTC, with the first cloud to ground lightning strike occurring just southeast of downtown Raleigh during the 5 minute period ending at 2325 UTC. The next cloud to ground lightning strike occurred near the Wake-Franklin County border during the 5 minute period ending at 0000 UTC with the cloud to ground lightning activity increasing markedly between 0000 UTC and 0030 UTC. Because the convective cell was located so close to the KRAX WSR-88D, the radar data did not provide a complete depiction of the higher portions of the cell as it moved across central Wake County. With this in mind, the enhanced echo top product showed the vertical development of the cell as noted by the change between the 2330 UTC and the 0003 UTC product.

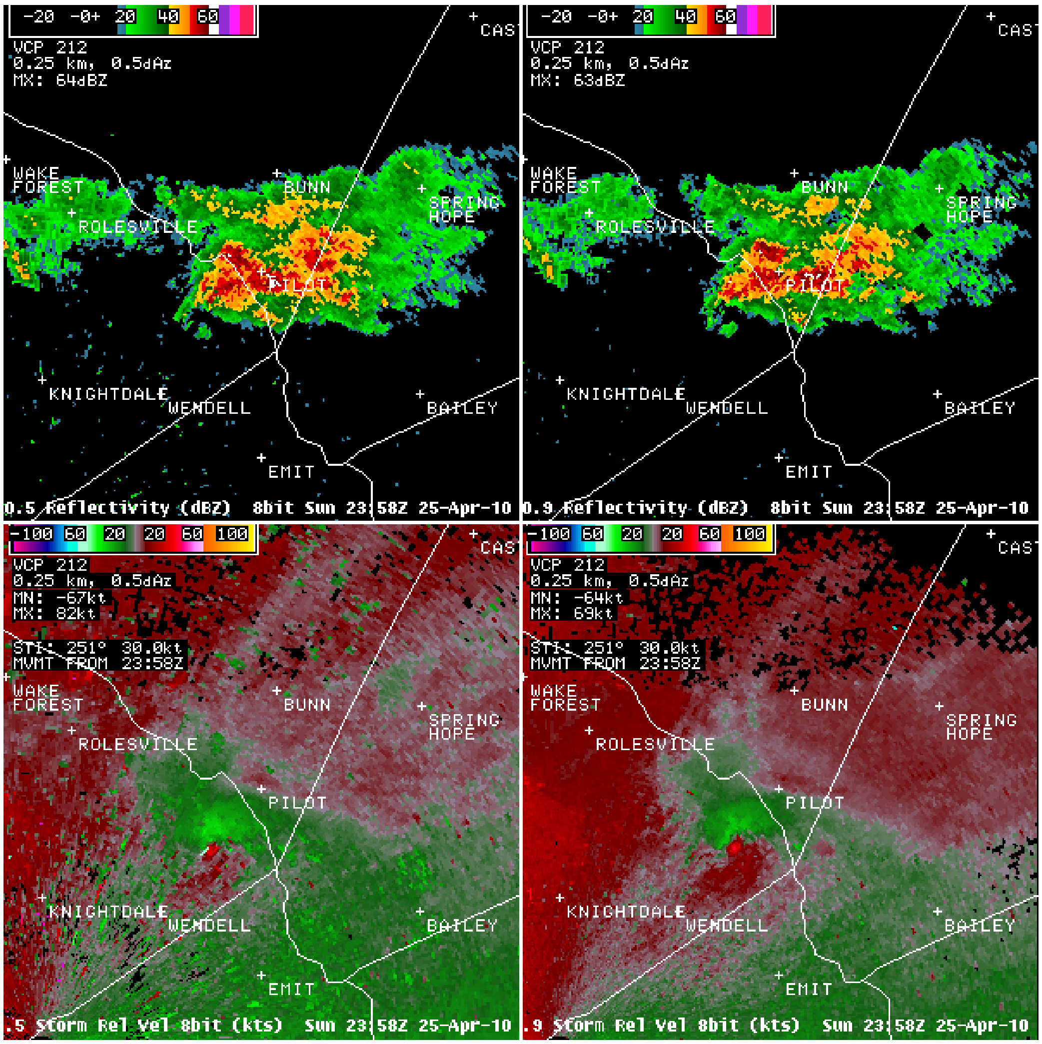
The first indications of a hook structure associated with the developing tornado is first noted in the 4 panel low level reflectivity imagery at 2349 UTC in the 0.9 and 1.3 degree elevations angles. The storm relative velocity imagery at the same time shows a broad and modest convergent circulation. The hook becomes more clearly evident in the next two volume scans as shown in the reflectivity imagery from 2353 UTC and 2358 UTC. The storm relative velocity imagery shows an intensifying low level circulation at 2353 UTC which strengthens even further at 2358 UTC. The strongest circulation was observed in the 2358 UTC volume scan with the circulation extending over a deep portion of the storm up to around 8,000 feet.

All of the elevation angles in the 2358 UTC volume scan from 1,400 feet up through 5,000 feet contained rotational velocities in excess of 29 kts. The 0.9 degree storm relative velocity data indicated an outbound velocity of 47 knots and an inbound velocity of 24 knots producing a rotational shear value of 35.5 knots at 13 nm from the RDA. The 35.5 knots of rotational shear at 13 nm from the radar with a mesocyclone diameter less than 1 nm corresponds to a low range moderate mesocyclone.

The enhanced echo top values of 40-43 kft, the persistent rotating updraft, the limited precipitation, and radar signature suggest the storm was a small, classic or low precipitation supercell thunderstorm.

It is also interesting to note that the thunderstorm appeared to intensify once again after 0045 UTC. The rotational velocity in the lowest elevation scan peaked again just west of Rocky Mount at 0050 UTC. A tornado warning was issued again but no tornado damage was observed. It is speculated that despite favorable shear values and rotation observed via radar, the boundary layer may stabilized sufficiently to inhibit tornadogensis. The stabilized boundary layer can be seen via a 0026 UTC observed AMDAR aircraft sounding from KRDU, the 3 hour change in the MLCAPE values as noted by the 01 UTC SPC analysis, and the increase in ground clutter just after sunset as observed in regional radar reflectivity imagery.

A loop of base reflectivity and storm relative velocity imagery from 2339 UTC on April 25 through 0031 UTC on April 26, 2010 shows the evolution of the tornadic portion of the event. The imagery contains the base reflectivity data in the top row and the storm relative velocity data in the bottom row. The data in the first column is from the 0.5 degree elevation angle and the data in the second column is from the 0.9 degree elevation angle. Note - this loop includes 12 frames



High Resolution WRF Model Output

High resolution Numerical Weather Prediction (NWP) models have been widely used to help with short range forecasting and warning operations. Recent advances in NWP and in computational efficiency have resulted in an improvement in and the availability of high resolution model forecasts on the convective scale.

The **High Resolution Rapid Refresh (HRRR)** model is a 3-km hourly updated nest inside of the Weather and Research Forecast (WRF) Rapid Refresh (RR) model. WRF RR is the next-generation version of the 1-h cycle system and will replace in 2010 the Rapid Update Cycle (RUC) which currently supports NWS operations. The RR uses a version of the WRF model and the Gridpoint Statistical Interpolation (GSI) analysis largely developed at NWS National Centers for Environmental Prediction (NCEP). The HRRR is initialized with latest 3-d radar reflectivity via 13km backup RUC at ESRL/GSD, which includes radar reflectivity assimilation via its radar-DFI (digital filter initialization) technique. The HRRR is believed to be the only hourly updated, radar-initialized, storm-resolving model running at this time over the US. Real-time HRRR data can be viewed at the ESRL HRRR page http://rapidrefresh.noaa.gov/hrrrconus/.

The **NCEP 4 km WRF-NMM run for SPC** uses the WRF-NMM model code very similar to that used in the operational HiresW. It is initialized from interpolated NAM model output. The basic physics selection the same as the NAM (Ferrier microphysics, GFDL radiation, MYJ PBL, and the NOAH land surface model) except for no parameterized convection. Also, the microphysics are tweaked to allow for larger raindrops and thus more intense simulated radar signals. Real-time NCEP 4 km WRF-NMM data can be viewed from the following web pages: 00 UTC run or the 12 UTC run.

During the past few years, NWS Raleigh has been developing a local high resolution modeling capability. We expect to use the model in both an operational and research capacity to help refine phenomena related to smaller scale weather events that are common to our area. Currently the **NWS Raleigh is running a 4km WRF-NMM** four times a day using 12km NAM initial/boundary conditions and no convective parameterization. Real-time WFO RAH 4KM WRF-NMM data can be viewed at the NWS Raleigh page http://www.erh.noaa.gov/rah/wrf/.

Real time high resolution convective modeling simulations have become more and more common in recent years. The growing exposure to and participation in modeling has resulted in an improved understanding of the role this data should provide. The Experimental Forecast Program at the NOAA Hazardous Weather Testbed (HWT) focuses on the application of cutting edge numerical weather prediction models to improve severe weather forecasts. Experience at local NWS Weather Forecast Offices, journal publications, and results from the HWT has provided many insights and lessons learned which are shown below:

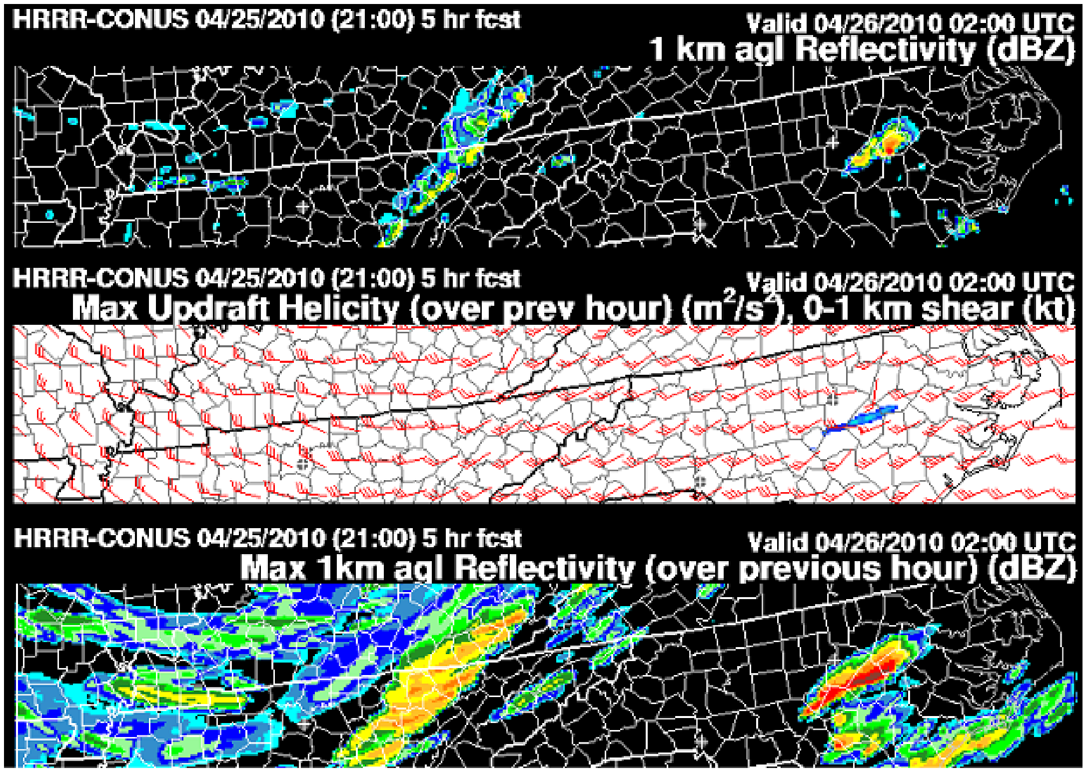
- The output from high resolution models remains strongly correlated to that of the parent model used to initialize.
- High resolution models regularly struggle when the synoptic scale forcing is weak. In addition, if the synoptic scale conditions are not reasonably well forecast, the modeling of mesoscale details will struggle.
- WRF simulations that explicitly handle convection typically take 2-3 hours to "spin up" convection, which significantly degrades the accuracy and utility of the first few hours of model data. Forecasters need to recognize this limitation and balance the notion that the most recent model run is the best with what model run is likely the most appropriate.
- Given the spin up issues, model initialization sensitivity, and other issues, the timing of convection can struggle, but often times the pattern and big picture depiction is handled well.
- Recent studies have shown that reducing the horizontal grid spacing to 1 or around 2km provides limited improvement over 4km simulations with increased computational cost.
- A participant in the HWT notes that while there have been many changes and improvements to modeling in recent years (microphysics schemes, PBL schemes, radar assimilation, etc), several longstanding problems still exist (sensitivity to initial conditions, sensitivity to model physics, parameterization of features, upscale growth, etc).
- Despite the limitations, recent experience shows that high resolution models still provided valuable guidance to forecasters including a general depiction of convective coverage, geographical location, storm initiation, convective mode, and precipitation pattern to forecasters. Although the location/timing of features may not be exactly correct, seeing the overall “character of the convection” can still be of great utility to forecasters especially considering they are not available in the current suite of operational models (i.e. NAM/GFS).
- Participants in the HWT note that one of the big challenges in the future will be how to best incorporate high resolution model guidance into the forecast process. Many forecasters already feel that they are at or even past the point of data overload, they need proof that these models are useful and good use of their time. In addition, an efficient way to use and view the data is needed.
- Another lesson learned from the HWT is that training is a critical issue with using high resolution models to ensure that the data is used effectively and efficiently. Given the wide range in methods to view the data (single deterministic run, multiple deterministic runs, probabilistic guidance) and the numerous new (simulated reflectivity, updraft helicity, updraft/downdraft strength), significant training is going to be required regarding both what to view, and how to view it.
- The future of high resolution modeling likely won’t be driven by single, deterministic model forecasts but rather an ensemble of convective resolving models and probabilistic guidance from storm scale ensembles to address the uncertainty that accompanies all weather forecasts.

It is interesting to note the success the 5 hour forecast from the 21 UTC High Resolution Rapid Refresh (HRRR) valid at 02 UTC on 4/26 had in the placement and intensity of the isolated convective cell east of Raleigh. The images to the right show the HRRR forecast of reflectivity and updraft helicity were near the location of the supercell thunderstorm that produced the Zebulon tornado.

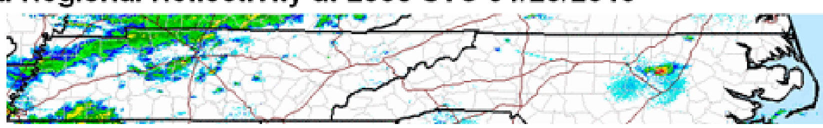
The top portion of the image to the right shows the HRRR 1km AGL reflectivity product valid at 02 UTC which placed a small area of convection to the east of Raleigh. This forecast is very similar to the observed regional reflectivity product valid at 2358 UTC on 4/25 shown in the bottom portion of the image to the right. While the timing is nearly 2 hours later then observed, the placement is impressive. The timing issue could result from numerous factors including the time it takes for the HRRR to develop or "spin up" convection after the initialization time.

The HRRR one hour maximum updraft helicity product shown as the second segment of the image to the right is very close to the observed tornado track shown in the bottom segment of the image to the right. The location, length and orientation of the track are very similar.

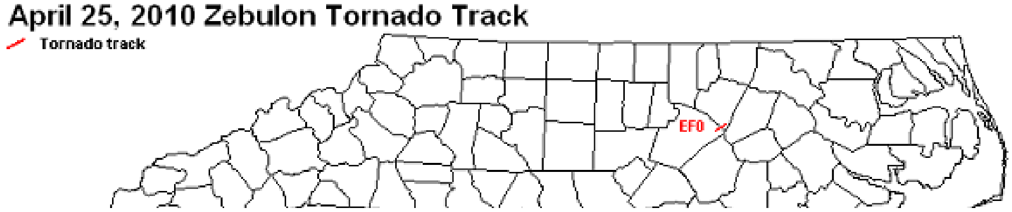
The chart below allows the viewer to compare low level, simulated radar reflectivity forecasts from various sets of high resolution model guidance described above and the observed radar reflectivity. Multiple runs of the HRRR are shown in the first 5 rows, the next two rows show the NCEP 4 km WRF-NMM run for SPC, with the NWS Raleigh 4km WRF-NMM shown next. The horizontal axis begins at 22 UTC and continues through 02 UTC and is centered at around the hour in which the tornado is observed (00 UTC). **Move your cursor over the thumbnails in the matrix below to view popup windows with enlarge imagery of forecast and observed reflectivity or click on the individual pane to open a larger version of that image**.



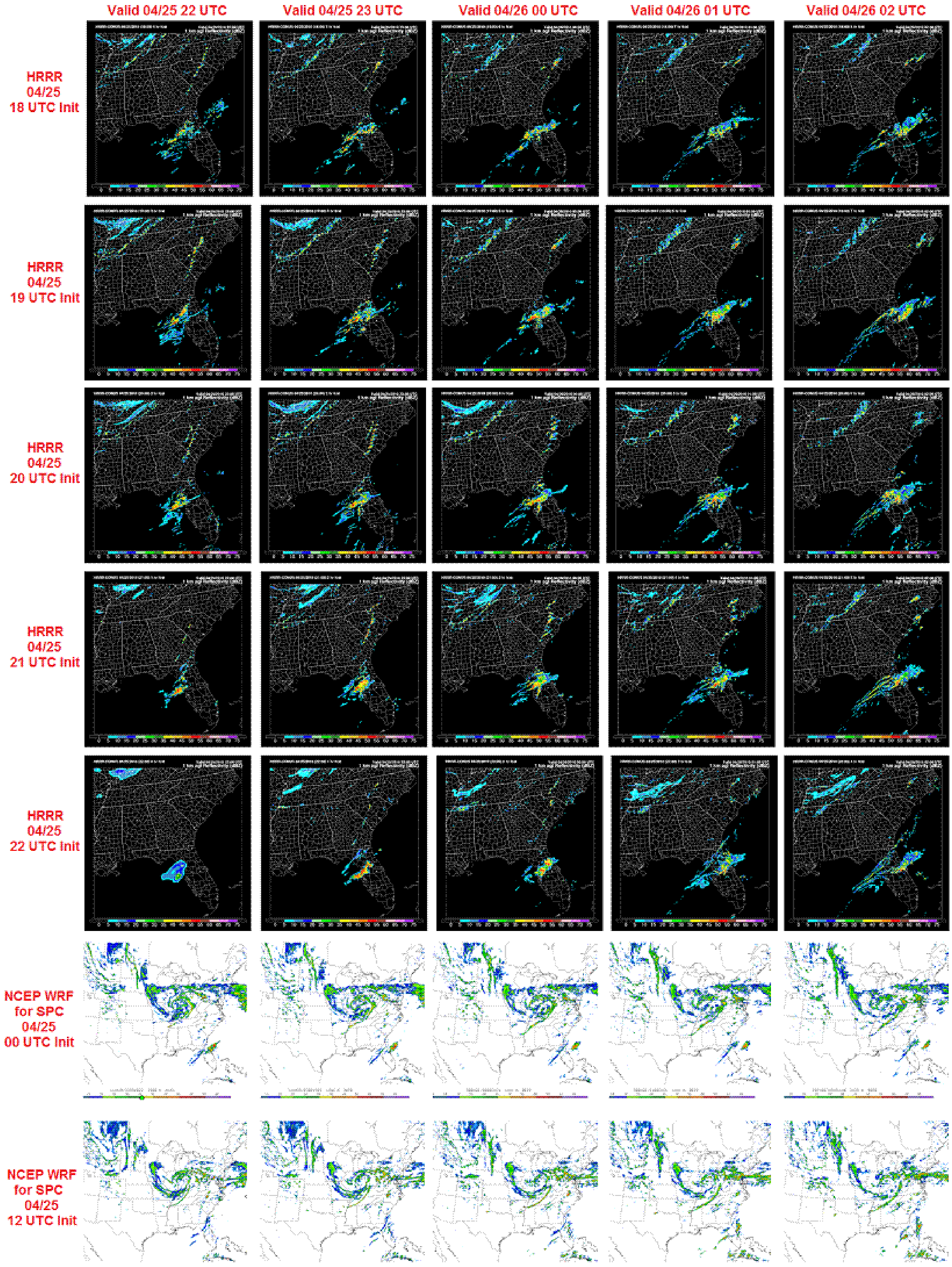
Observed Regional Reflectivity at 2358 UTC 04/25/2010



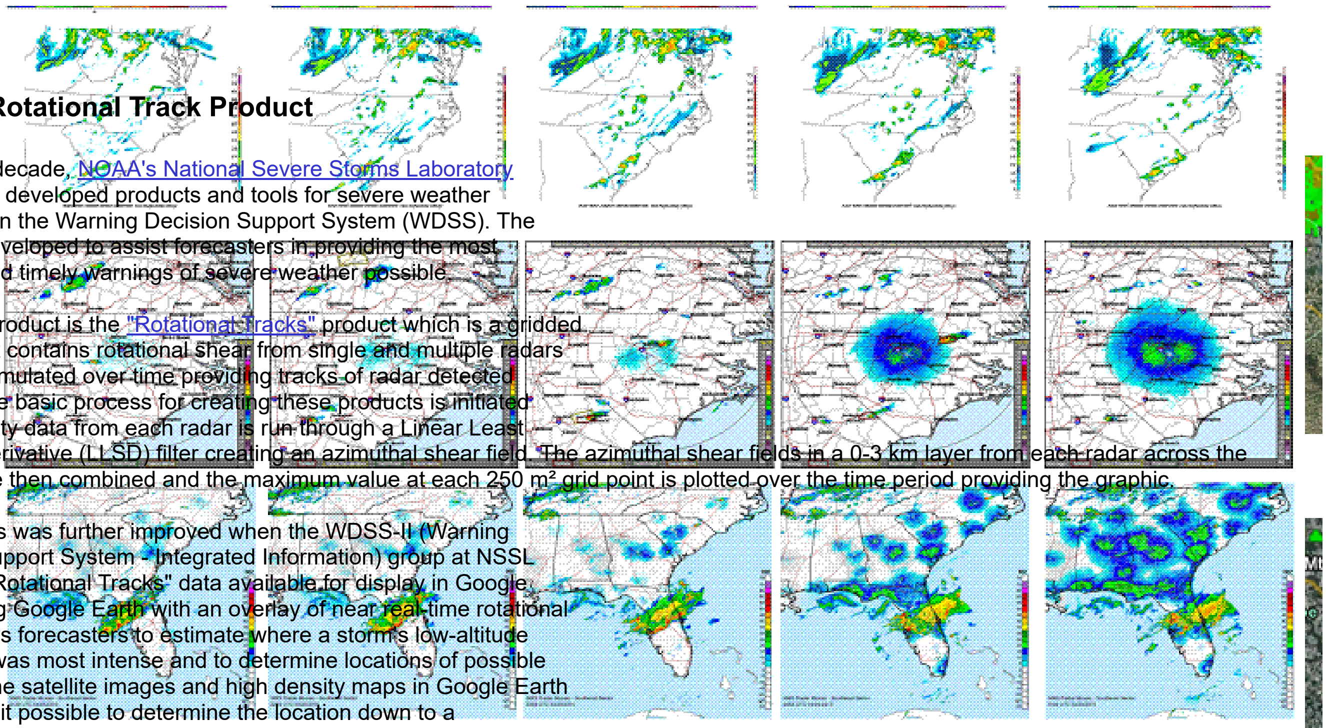
April 25, 2010 Zebulon Tornado Track



Comparative matrix - move mouse over image to open a larger view



NSSL's Rotational Track Product

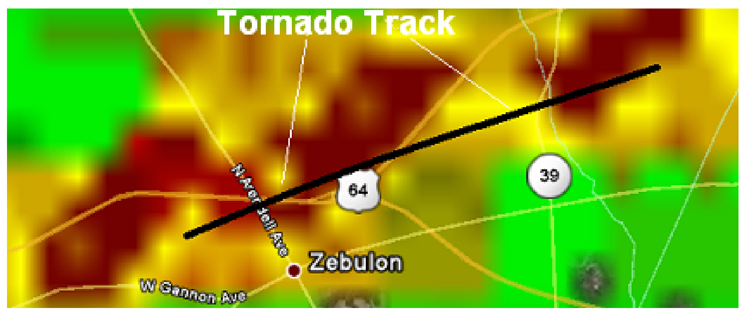


For over a decade, NOAA's National Severe Storms Laboratory (NSSL) has developed products and tools for severe weather operations in the Warning Decision Support System (WDSS). The tools are developed to assist forecasters in providing the most accurate and timely warnings of severe weather possible.

One such product is the "Rotational Tracks" product which is a gridded dataset that contains rotational shear from single and multiple radars that is accumulated over time providing tracks of radar detected rotation. The basic process for creating these products is initiated when velocity data from each radar is run through a Linear Least Squares Derivative (LLSD) filter creating an azimuthal shear field. The azimuthal shear fields in a 0-3 km layer from each radar across the CONUS are then combined and the maximum value at each 250 m^2 grid point is plotted over the time period providing the graphic.

The process was further improved when the WDSS-II (Warning Decision Support System - Integrated Information) group at NSSL made the "Rotational Tracks" data available for display in Google Earth. Using Google Earth with an overlay of near real-time rotational tracks allows forecasters to estimate where a storm's low-altitude circulation was most intense and to determine locations of possible damage. The satellite images and high density maps in Google Earth often make it possible to determine the location down to a neighborhood or the street. This simplifies the verification process by reducing the amount of time that is spent searching for reports.

The first image, shown in the upper right includes the 24 hour rotational track product ending at 0400 UTC on April 26, 2010. The shaded areas represent areas where the radar detected rotation, and the yellows and reds are indicative of the strongest rotation. Note that the cell that produced the tornado over eastern Wake and southern Franklin Counties appears as if it can be traced back to the Sandhills region (Moore County). The track also suggests a slight bend in the track to the right despite a fairly unidirectional southwesterly flow.



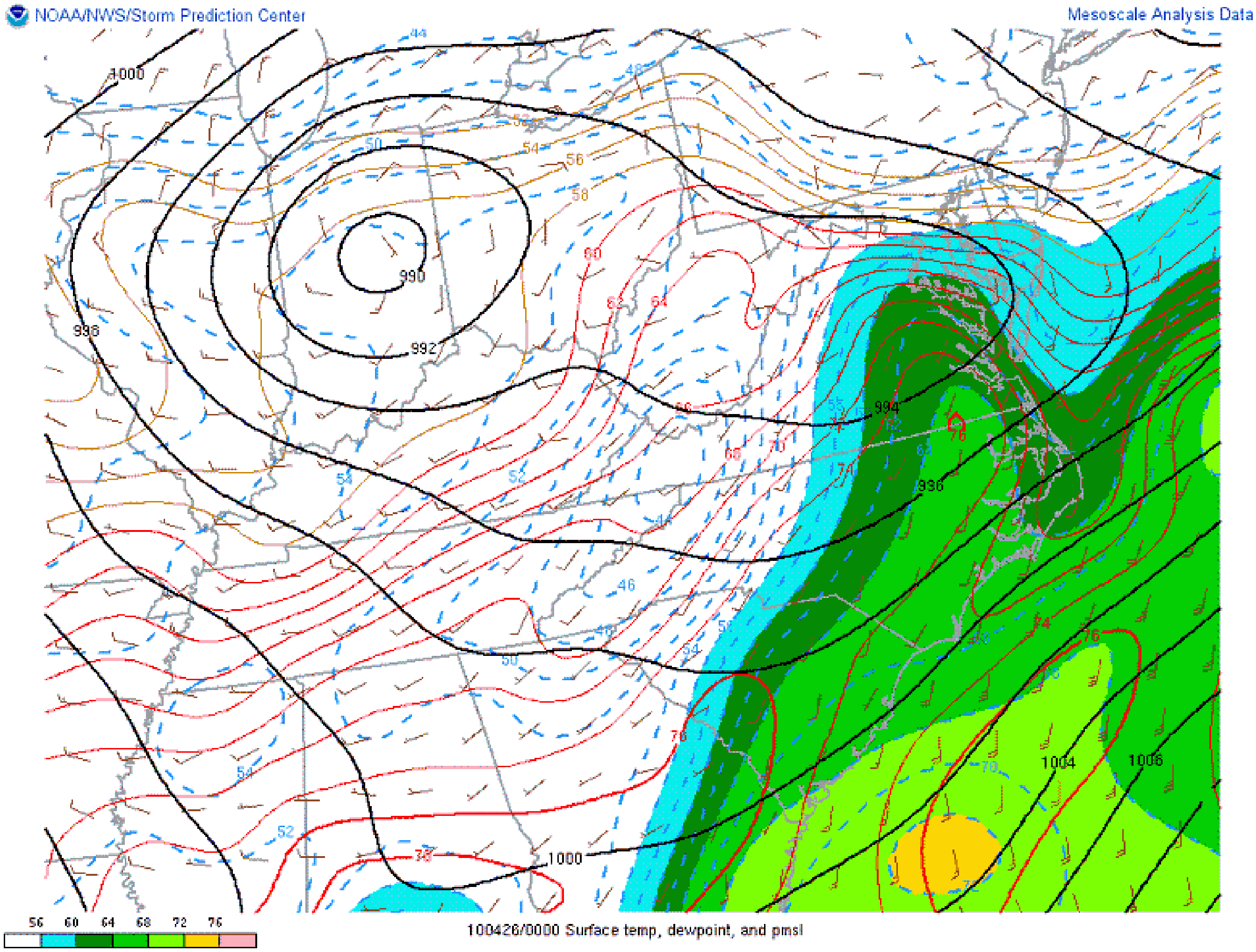
The second image, shown in the middle, is focused more on the region where the thunderstorm became tornadic. Note that in a general sense the rotation increases across Wake County and moves east-northeast into Franklin County and persists into Nash County.

The third image, shown in the lower right, provides a zoomed in view of the rotational tracks data along with the actual tornado track superimposed. This image shows the utility in combining the rotational track product with Google Earth since it allows NWS personnel to target locations when seeking ground truth damage reports and during subsequent storm surveys.

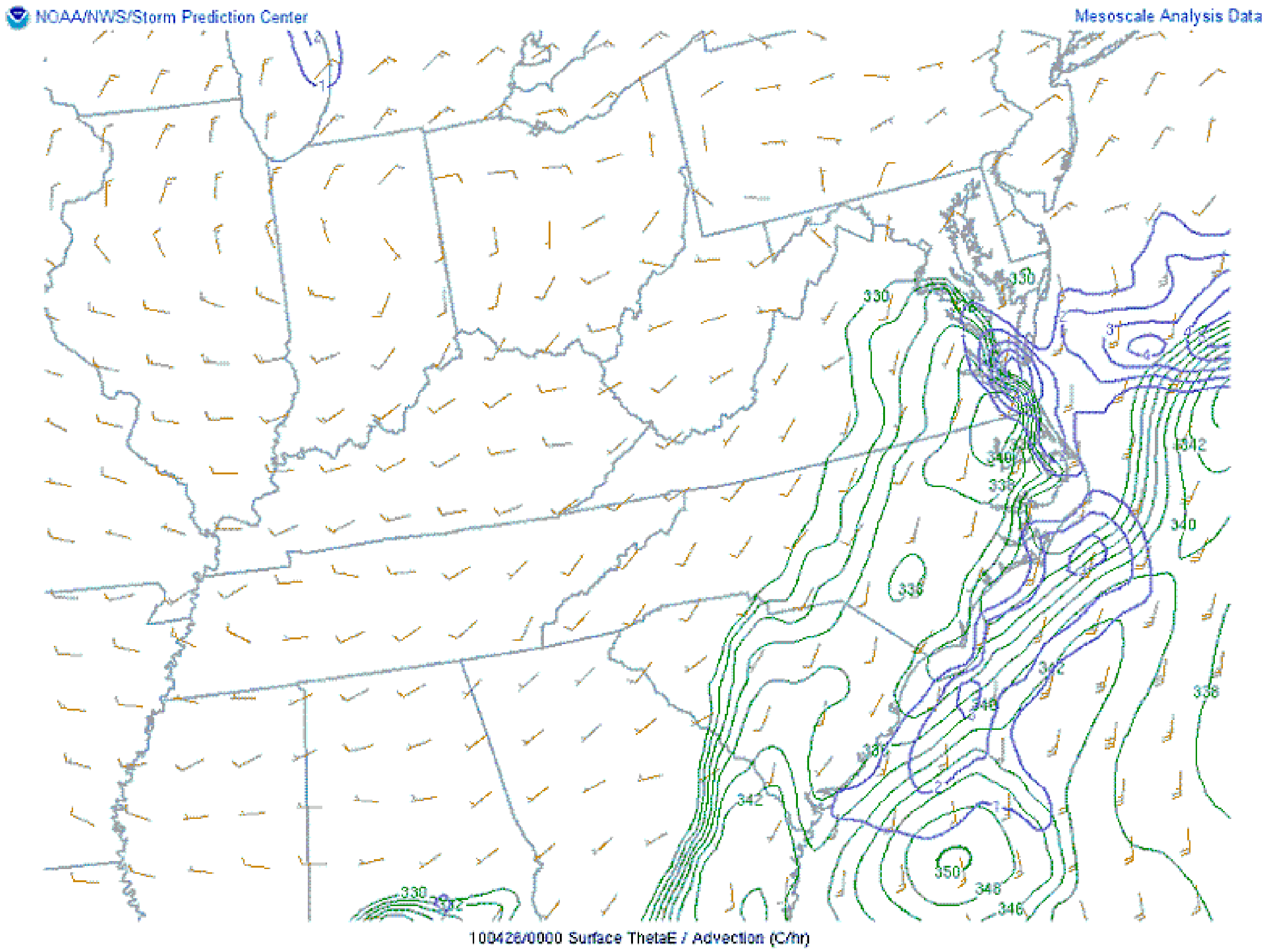
Mesoscale Data

Forecasters at RAH routinely use the SPC meso-analysis products during severe weather operations. The images and discussion below highlight several of the SPC meso-analysis products that provide insight into the evolution of the severe weather event. These images are not only used in real time but they are archived locally for use in post event analysis and training.

Analyzed surface temperatures (red), dew points (blue) and shaded, and wind barbs from SPC at 0000 UTC on Monday, April 26, 2010
A surge of higher dew points can be seen extending northeast across the eastern Carolinas with dew points in the 60-65 degree range. Cooler and drier air was located further west across the western Carolinas and Virginia. The convective cell intensified as it moved into an increasingly moist air mass in the eastern Piedmont.
(Click on the image below to enlarge)



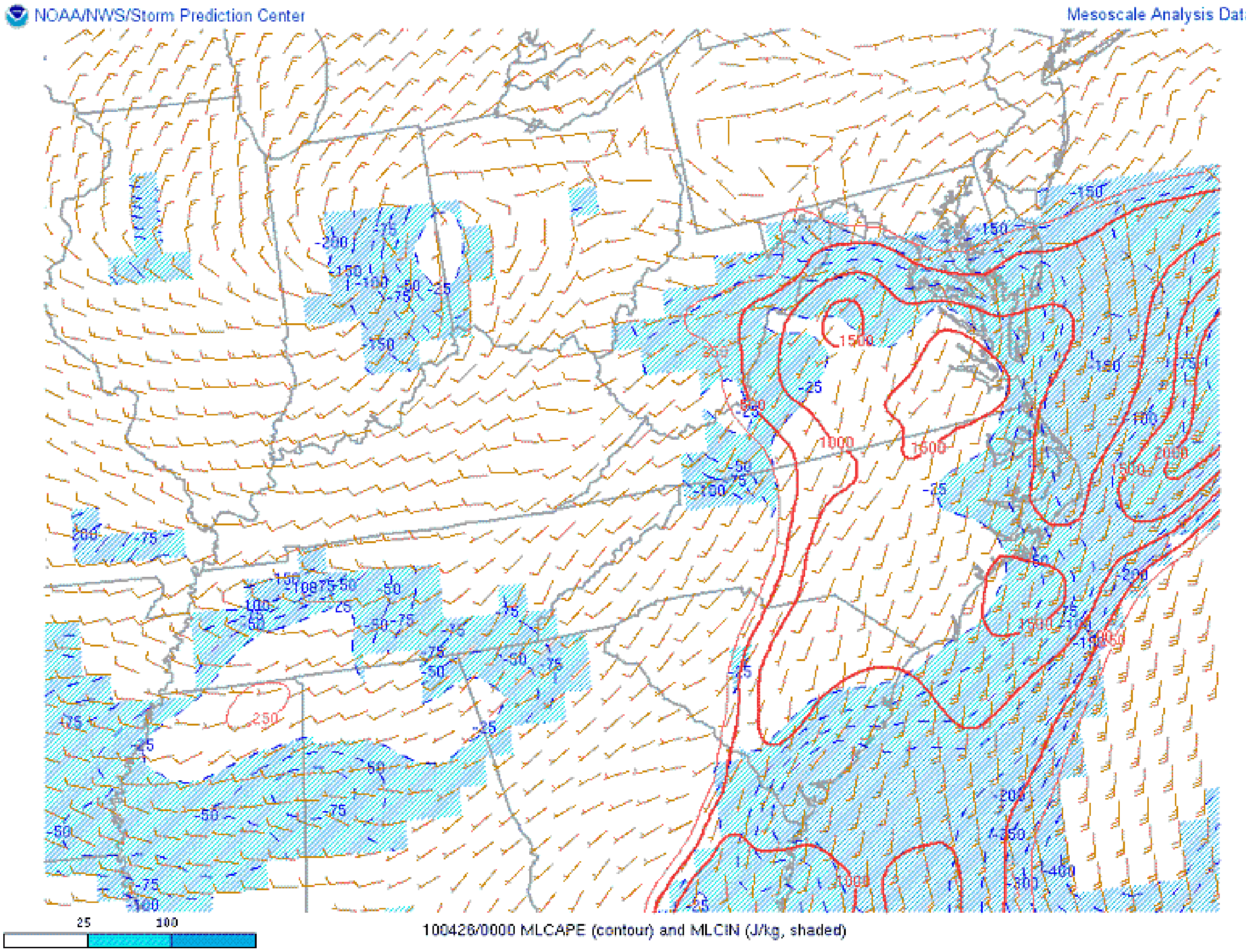
Analyzed surface Theta-e (green contours), Theta-e convergence (purple contours) and wind barbs from SPC at 0000 UTC on Monday, April 26, 2010
At 0000 UTC, theta-e values ranged between 336-338 degrees K across the eastern Piedmont and western Coastal Plain where the tornado occurred. An axis of greater instability extended northeast across the Coastal Plain.
(Click on the image below to enlarge)



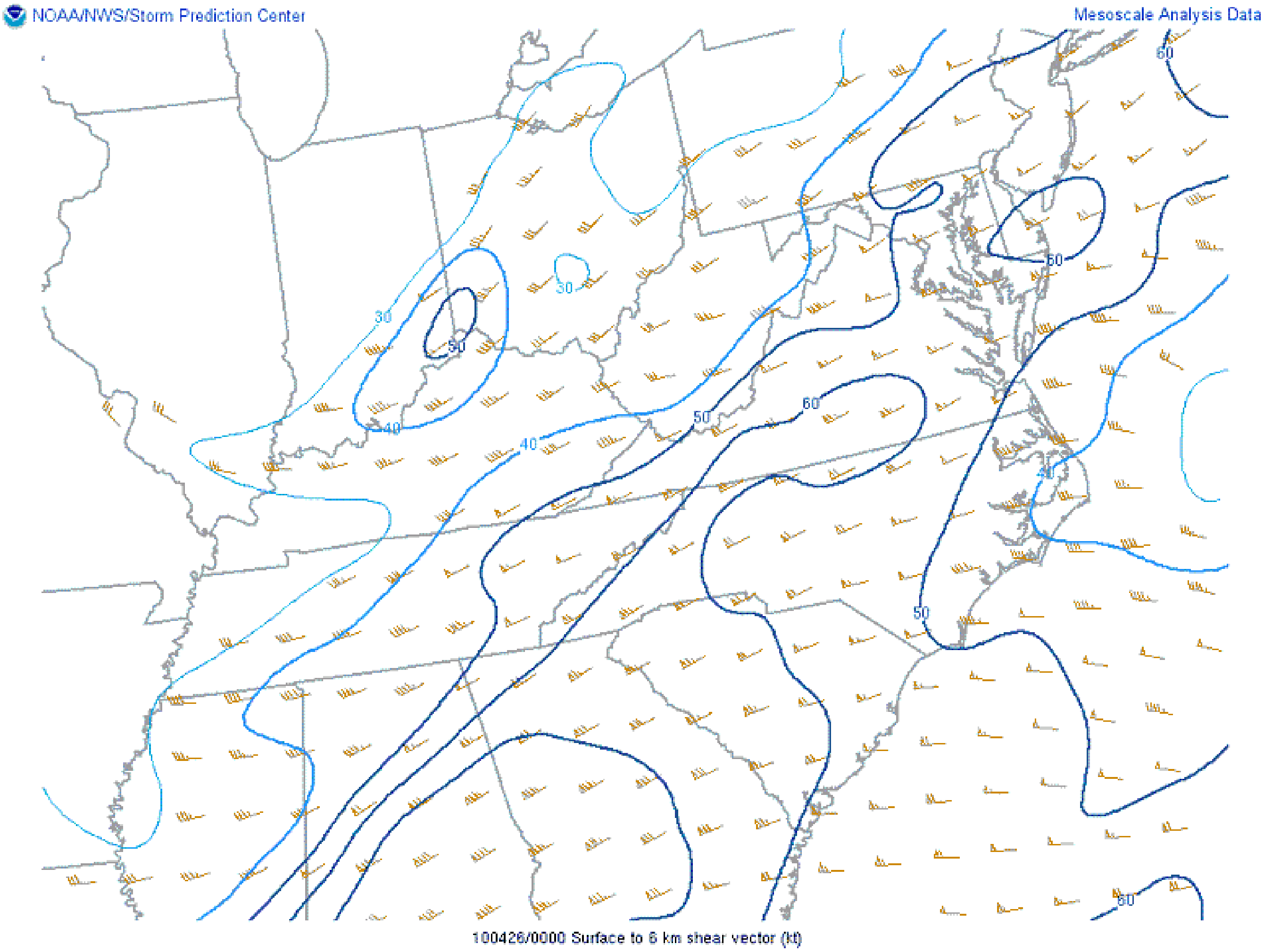
Analyzed mixed layer convective available potential energy (MLCAPE) (red) and mixed layer based convective inhibition (MLCIN) (blue lines - shaded) from SPC at 0000 UTC on Monday, April 26, 2010

MLCAPE values ranged between 1000 and around 1500 J/kg across the eastern Piedmont and the Coastal Plain with little or no CIN. This region of moderate instability provided enough instability to enhance updrafts and promote the stretching of vorticity vertically to support tornadogenesis.

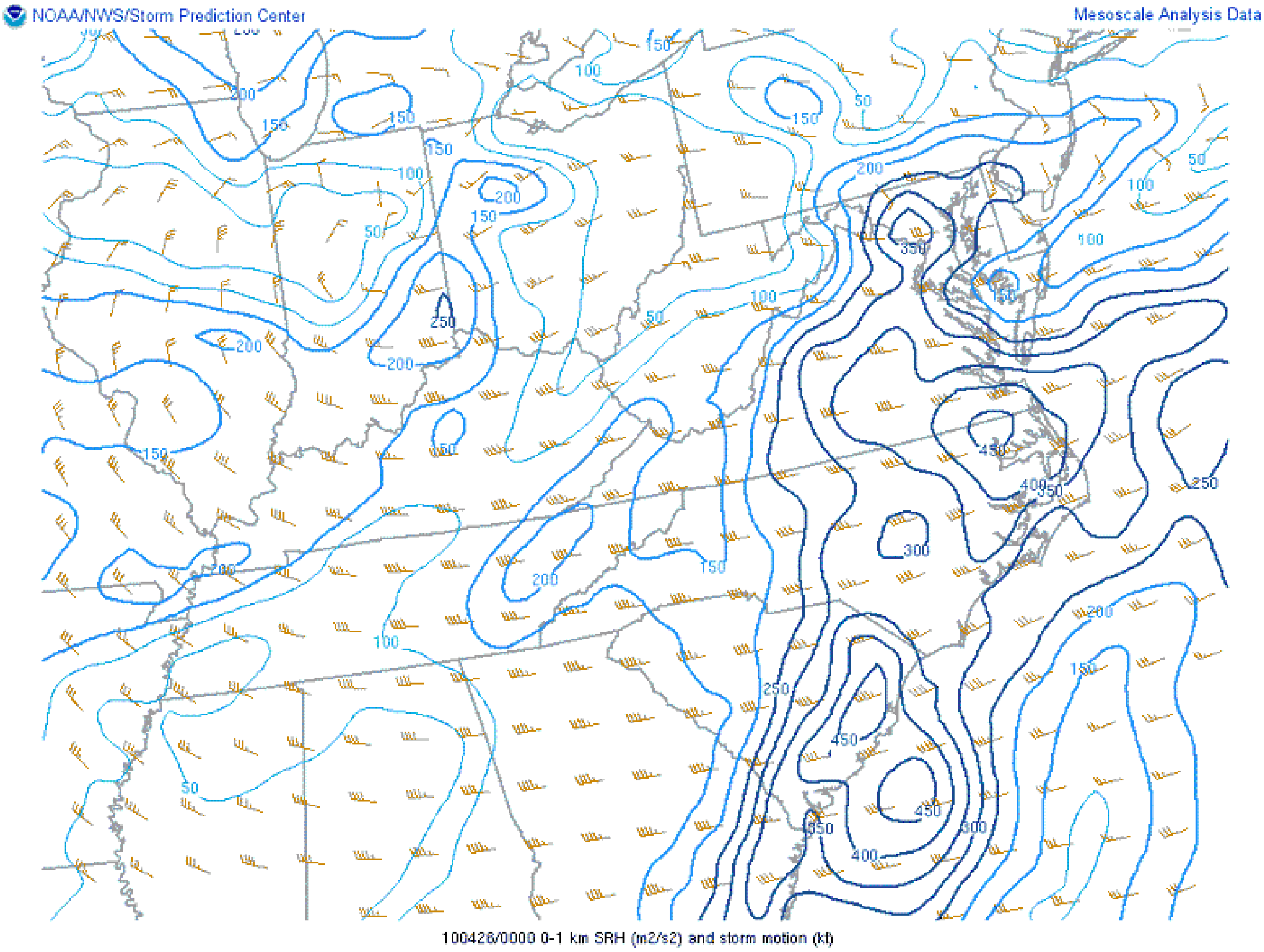
(Click on the image below to enlarge)



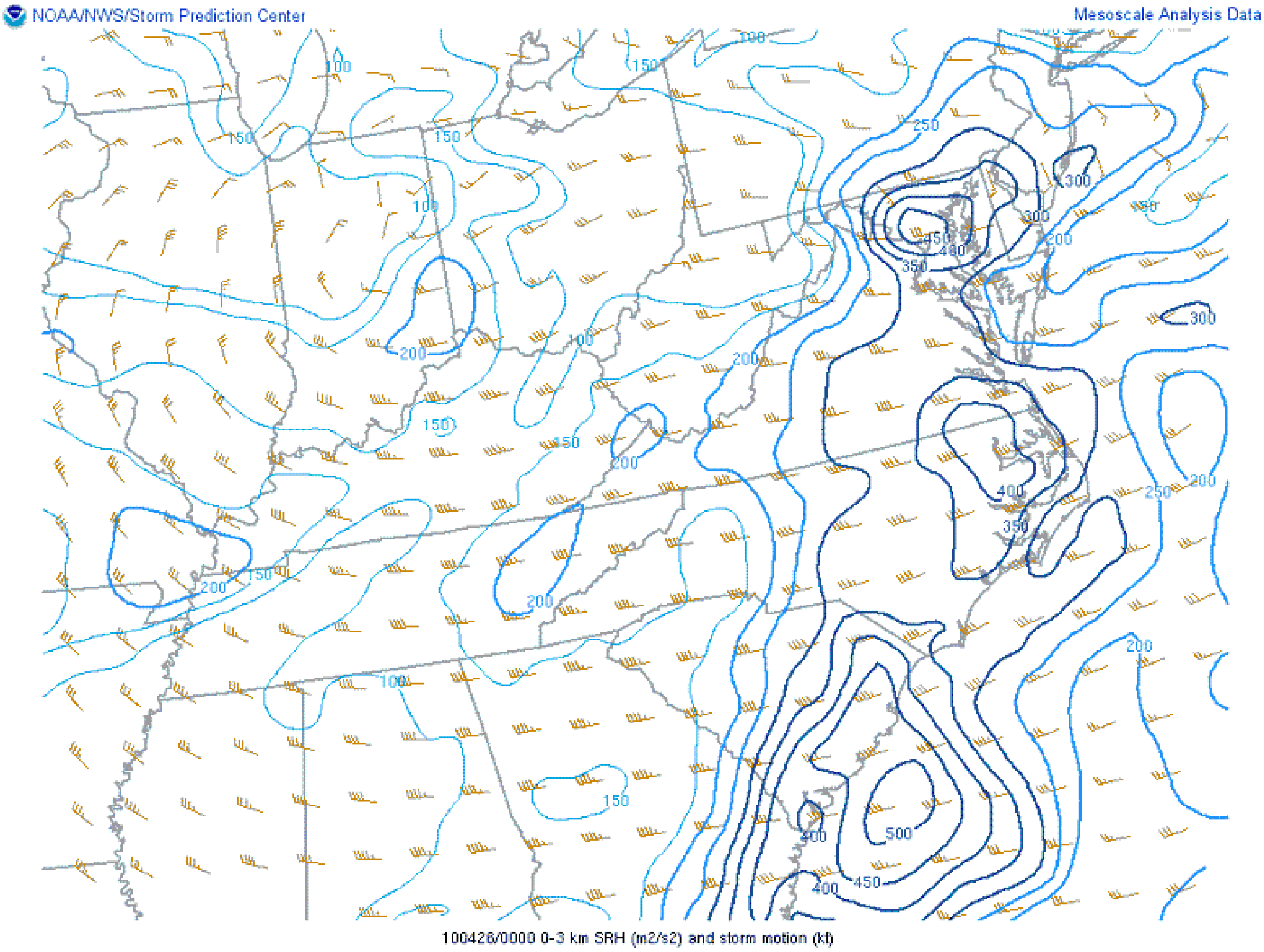
0-6 km Bulk Shear (blue) and storm motion (brown) from SPC at 0000 UTC on Monday, April 26, 2010
The 0-6 km bulk shear values ranged between 50-60 knots across the eastern Piedmont and Coastal Plain. Given sufficient instability, thunderstorms tend to become more organized and persistent as vertical shear increases. Supercells are commonly associated with vertical shear values of 35-40 knots and the analysis at 0000 UTC supports the potential of supercells.
(Click on the image below to enlarge)



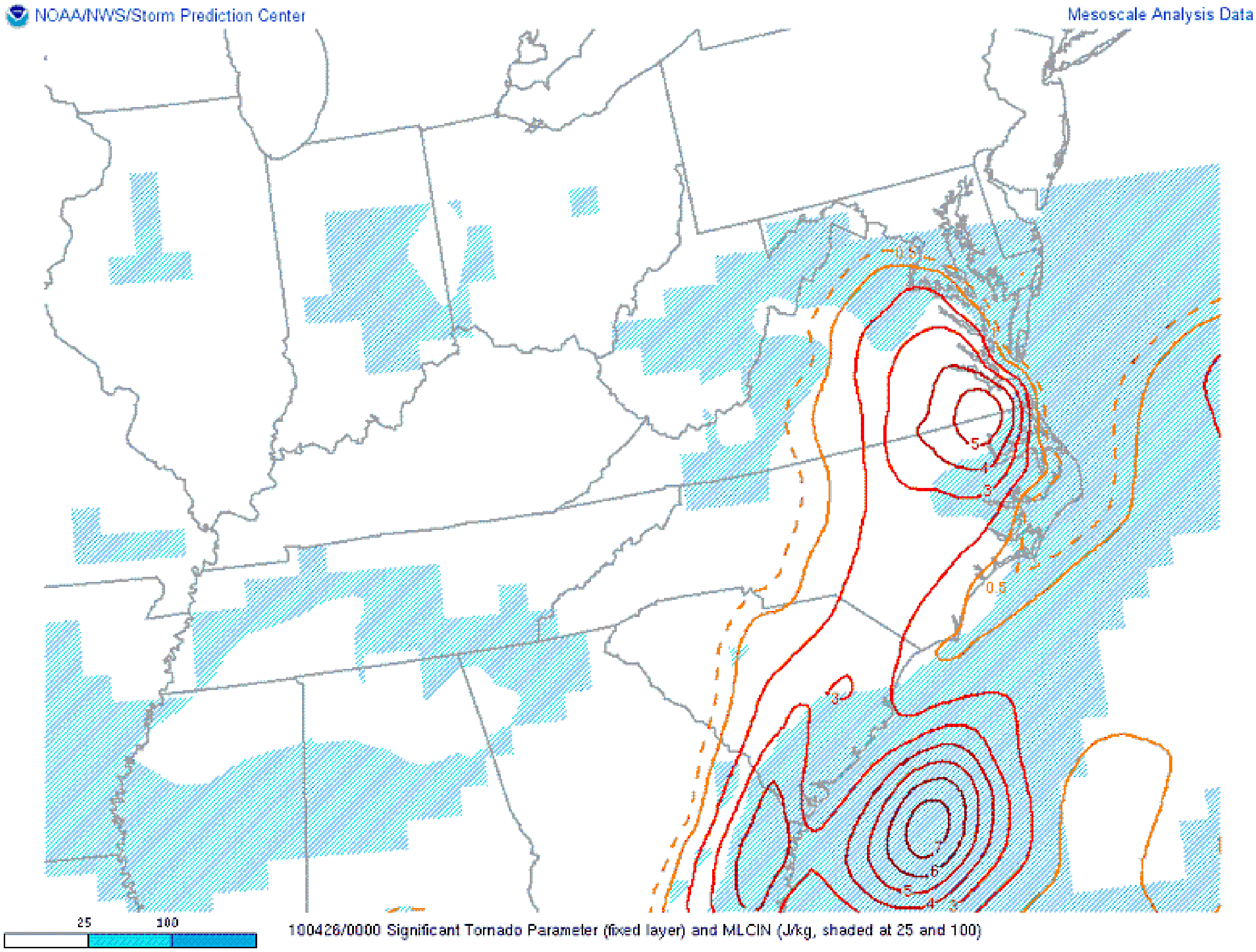
0-1 km Storm Relative Helicity (SRH) (shown in blue) and storm motion (brown) from SPC at 0000 UTC on Monday, April 26, 2010
Note that the 0-1 km SRH values ranged around 300 m^2/s^2 across the eastern Piedmont and Coastal Plain of North Carolina. The SRH is a measure of the potential for cyclonic updraft rotation in right-moving supercells. Studies have shown that larger values of 0-1 km SRH, greater than 100 m^22/s^2, suggests an increased threat of tornadoes and that very large values of 0-1 km SRH (perhaps greater than 200 to 300 m^2/s^2) are indicative of significant tornado potential.
(Click on the image below to enlarge)



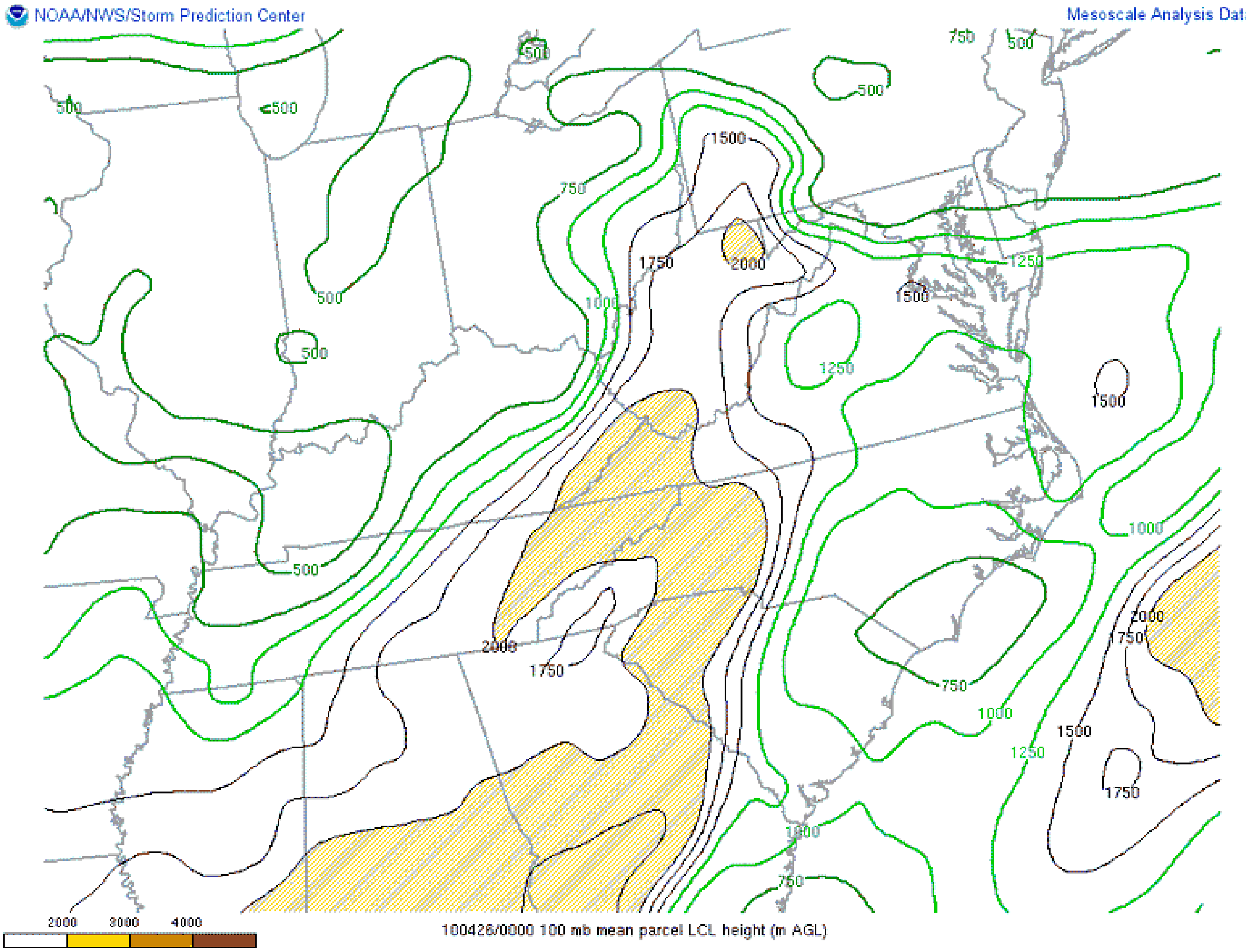
0-3 km Storm Relative Helicity (SRH) (shown in blue) and storm motion (brown) from SPC at 0000 UTC on Monday, April 26, 2010
Note that the 0-3 km SRH values ranged between 300-350 m²/s² across the eastern Piedmont and Coastal Plain of North Carolina. The SRH is a measure of the potential for cyclonic updraft rotation in right-moving supercells. Larger values of 0-3 km SRH (greater than 250 m²/s²) suggest an increased threat of supercells and tornadoes. Some studies suggest that the 0-3 km SRH is a better indicator of storm rotation, which is related to tornadoes, but not directly the potential for tornadoes themselves.
(Click on the image below to enlarge)



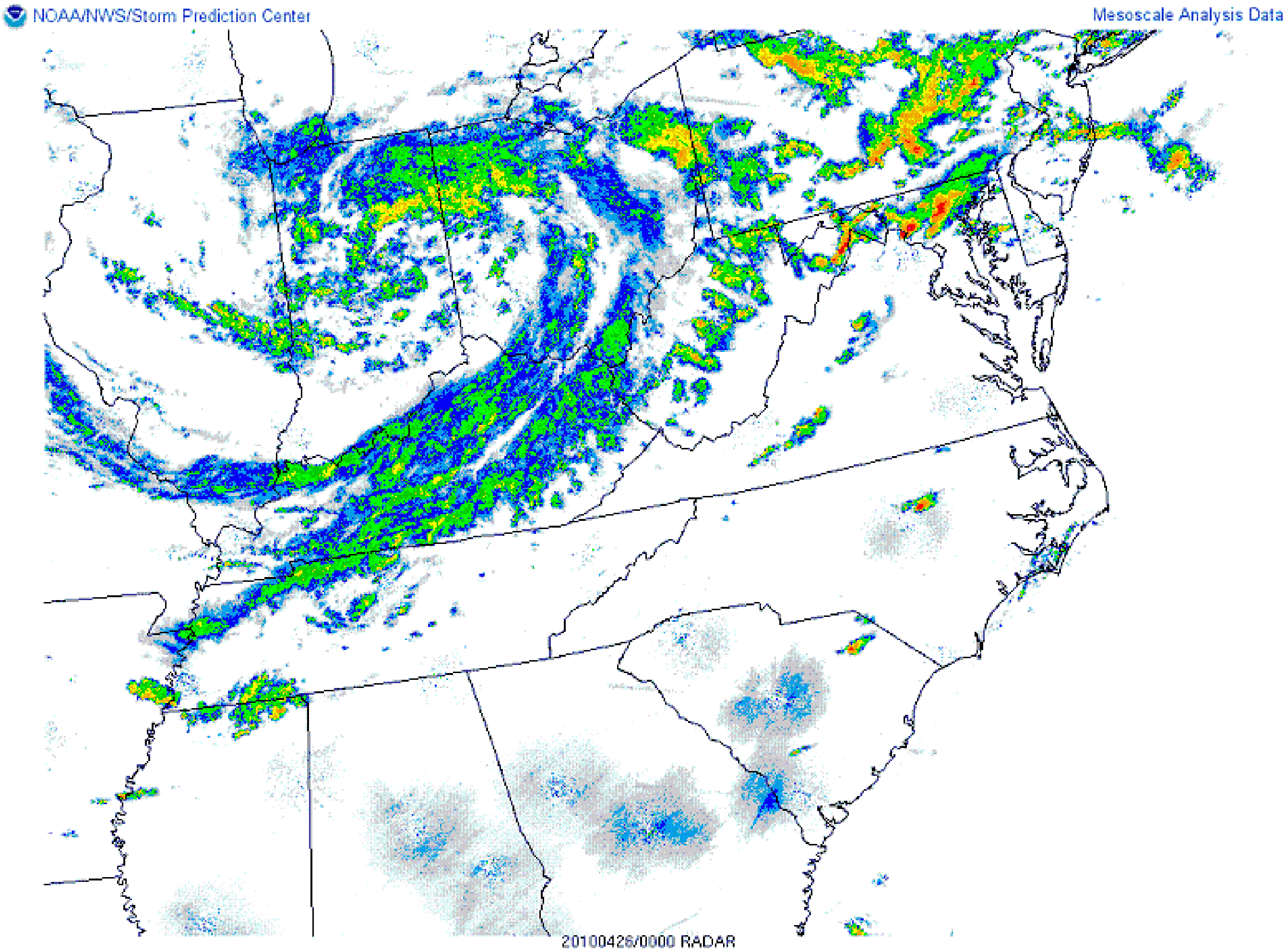
Analyzed Significant Tornado Parameter (STP) (effective layer) (shown in yellow and red) and the mixed layer convective inhibition (MLCIN) from SPC at 0000 UTC on Monday, April 26, 2010
The STP is designed to highlight areas favoring right-moving tornadic supercells. The STP is a multiple ingredient, composite index that includes effective bulk wind difference (EBWD), effective storm-relative helicity (ESRH), 100-mb mean parcel CAPE (MLCAPE), 100-mb mean parcel CIN (MLCIN), and 100-mb mean parcel LCL height (MLLCL). Analyzed STP values across the eastern Piedmont and western Coastal Plain range between 2 and 3. Additional details on the Analyzed Significant Tornado Parameter (STP) is available in this reference.
(Click on the image below to enlarge)



Analyzed Lifting Condensation Level (red, blue, and green) from SPC at 0000 UTC on Monday, April 26, 2010
The LCL height is the height at which a parcel becomes saturated when lifted dry adiabatically. The importance of LCL height is thought to relate to sub-cloud evaporation and the potential for outflow dominance. Low LCL heights imply less evaporational cooling from precipitation and less potential for a strong outflow that would likely inhibit low-level mesocyclone development. Thunderstorms that produce significant tornadoes generally have a lower LCL height with LCL heights less than 1,000 meters typically favorable for tornado development. The LCL values across the eastern Piedmont and western Coastal Plain during this event ranged around 1000 meters.
(Click on the image below to enlarge)



NWS composite radar reflectivity imagery from 0000 UTC on Monday, April 26, 2010.
The composite reflectivity imagery is from the approximate time in which the analysis imagery above is valid. Note the very limited amount of convection across the eastern Carolinas.



Archived Text Data from the Severe Weather Event

Select the desired product along with the date and click "Get Archive Data."
Date and time should be selected based on issuance time in GMT (Greenwich Mean Time which equals EST time + 4 hours).

Product ID information for the most frequently used products...

RDUAFDRAH - Area Forecast Discussion
RDUZFPRAH - Zone Forecast Products
RDUAFMRAH - Area Forecast Matrices
RDUPFMRAH - Point Forecast Matrices
RDUHWORAH - Hazardous Weather Outlook
RDUNOWRAH - Short Term Forecast
RDUSPSRAH - Special Weather Statement
RDULSRRAH - Local Storm Reports (reports of severe weather)
RDUSVRRAH - Severe Thunderstorm Warning
RDUSVSRAH - Severe Weather Statement
RDUTORRAH - Tornado Warning

RDUTORRAH from April 25 2010

Get Archive Data

Final Thoughts

The threat of severe weather across the eastern Piedmont, Coastal Plain and Sandhills region was highlighted in advance of the event in the

regular zone and graphical forecasts as well as the Area Forecast Discussion and the Hazardous Weather Outlook:
315 AM EST, Saturday, April 24 Area Forecast Discussion
457 AM EST, Saturday, April 24 Hazardous Weather Outlook
300 PM EST, Saturday, April 24 Area Forecast Discussion
515 PM EST, Saturday, April 24 Hazardous Weather Outlook
308 AM EST, Sunday, April 25 Area Forecast Discussion
415 AM EST, Sunday, April 25 Hazardous Weather Outlook

The thunderstorm that eventually produced the tornado developed in the Southern Piedmont of North Carolina during the late afternoon and moved northeast into Wake County. The storm went over the NWS Raleigh office and only produced 0.11 inches of rain. As the stormed moved east, it could be seen out the office window and the CB was described as a "lower cloud group 3" or “CB Calvus” and did not have an anvil at 745 PM. Subsequent radar imagery and storm reports indicate that the storm was rapidly intensifying at this time and would later produce a tornado. The rapidly evolving situation necessitated the good situational awareness that was demonstrated by the forecast staff and is a good reminder of the need for a good situational awareness during the weather watch.

This was a challenging event to forecast. While low level moisture was present, there was strong drying occurring in the mid levels as noted by water vapor imagery. It was difficult to determine whether convection would develop and if so, how much.

High resolution model forecasts showed some skill in predicting the convective event in terms of area coverage, location and intensity of the storm. In particular, the 21 UTC HRRR provided an excellent 5 hour forecast of the event. High resolution modeling still struggles to find its way into routine forecast operations and the forecast process. As this data becomes more available and better integrated into applications used by forecasters it is expected to be used more and more.

This was a difficult warning situation with no TDWR data, an intensifying thunderstorm with a rapidly developing mesocyclone that was in very close proximity to the radar. Adjacent radars were of limited value given the rotation within the storm was confined to low levels. The severity of the storm was realized during its rapid intensification and as it exited the region of reduced sampling in the immediate vicinity of the radar.

The radar operator was examining the storm closely as it rapidly intensified. There was concern over the hook signature which was developing in the low level reflectivity data but the rotational velocity was fairly weak and the lack of cloud-to-ground lightning was a concern. On the next volume scan at 758 PM the rotational velocity increased, especially on the 1.3 elevation where gate to gate shear was noted. This combined with the onset of a flurry of calls of funnel clouds, especially from a couple of trusted sources, led to the tornado warning.

A couple of reports which came directly to the office between 750 and 800 PM proved extremely valuable in building confidence that a funnel cloud and then a tornado was developing.

The limited number of first hand or direct reports of a tornado damage during the event led to a delay in the issuance of Local Storm Reports (LSR). A recommended practice is to share some initial damage reports (downed trees, broken glass, etc) as "Thunderstorm wind damage" in the LSR and note in the comments section of the LSR that the damage may be from a tornado. In addition, passing along credible second hand reports from the media via an LSR is also a good practice, especially if it is noted as a second hand report.

References

The High Resolution Rapid Refresh (HRRR): Recent enhancements and evaluation during the 2009 convective season. Stephen S. Weygandt, NOAA/ESRL/GSD, Boulder, CO; and T. G. Smirnova, C. R. Alexander, S. G. Benjamin, K. J. Brundage, B. D. Jamison, and S. R. Sahm

The High Resolution Rapid Refresh (HRRR): an hourly updated convection resolving model utilizing radar reflectivity assimilation from the RUC / RR. Stephen S. Weygandt, NOAA/ESRL/GSD, Boulder, CO; and T. G. Smirnova, S. G. Benjamin, K. J. Brundage, S. R. Sahm, C. R. Alexander, and B. E. Schwartz

Acknowledgements

Many of the images and graphics used in this review were provided by parties outside of the NWS Raleigh. The surface analysis graphics were obtained from the Hydrometeorological Prediction Center. GOES satellite data was obtained from National Environmental Satellite, Data, and Information Service along with the Aviation Weather Center. SPC meso-analysis graphics provided by the Storm Prediction Center. Base maps for the tornado tracks were provided by Google Maps and Google Earth - Google Earth map imagery used under license. NSSL's Rotational Track product provided by the WDSS-II (Warning Decision Support System - Integrated Information) group at NSSL. AMDAR aircraft sounding data was obtained from the Earth System Research Laboratory - Global Systems Division. GPS-MET data provided by NOAA/GSD Ground-Based GPS Meteorology at the Earth System Research Laboratory - Global Systems Division. Photographs provided by Jose Guzman and Gerardo Somarriba. Videos provided by Jose Guzman, Dale Pate.

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