Experiences with DUAL POLARIZATION Radar in Operations at Newport/Morehead City NC

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ABSTRACT

Dual Polarization capabilities will be added to all National Weather Service (NWS) WSR-88D Doppler Radars over the next couple of years. The first NWS field office to receive the upgrade to Dual Polarization was Phoenix, AZ. The second site was Newport/Morehead City, NC (MHX) in mid-June, 2011. This exciting modernization will allow NWS forecasters to better estimate rainfall amounts, and will aid in other severe weather operations, namely hail detection and estimation of hail size. This paper will discuss how the NWS office at Newport/Morehead City, NC prepared for this upgrade, specifically the operational forecaster training that was completed prior to, during and post installation. The training included online modules from the Warning Decision Training branch (WDTB), Weather Event Simulator (WES) warning exercises, and live training from the WDTB. Moreover, the paper will detail our operations during the actual upgrade. And finally, this paper will show examples and some short case studies of phenomenon that have been detected on the radar since the upgrade. These examples consist of several hail events, including one hail event that occurred just 11 minutes after the radar returned to operations following the upgrade, precipitation amount comparisons between the legacy precipitation algorithm and the Dual Polarization algorithm, and Dual Polarization interpretation of various boundaries (sea breeze, outflow). Lastly, Dual Pol products during Hurricane Irene of August, 2011, will be discussed.

INTRODUCTION

In June, 2011, the National Weather Service Office in Newport/Morehead City NC (MHX) became the second operational NWS office in the country to turn on Dual Polarization capabilities on our WSR-88D Doppler Radar, after Phoenix, AZ. Workers arrived on station and began work on June 13, installing the necessary hardware for the transition. Meteorologists from the Radar Operations Center (ROC) arrived the following week. They worked with the station's radar focal point to ensure he was comfortable with the upgrade. At 623 pm on June 22, we turned our radar back on, and began receiving Dual Polarization products. As luck would have it, we were in the midst of a severe weather event, and immediately began to see the benefits of Dual Pol products.

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TRAINING

The original deployment schedule has MHX slated to get Dual Pol capabilities in August 2010. Therefore we started our Dual Pol training in 2009 by having our staff complete the various trainings available in the NWS Learning Management System. We also upgraded our GR2Analyst program so we could view available Dual Pol data. The recommendation from the WDTB was to complete Dual Pol training sessions no more than 3 months prior to installation. Therefore we held off on doing more intense training until we had a more firm installation date.

In early 2011, we began our training in earnest. The WDTB made available a number of online training modules. There were modules for each of the Dual Pol products, including Correlation Coefficient, Differential Reflectivity, Specific Differential Phase, Hydrometeor Classification, Melting Layer, and the various Quantitative Precipitation Estimate products. Modules on how Dual Pol can be used in various situations were also available, which include Winter Weather, Hail, Tornadic Debris Signature, Updraft Detection/ZDR Columns, Heavy Rain, and Non-precipitation Echo Detection. In addition to these modules, two Radar Data Acquisition and three Radar Product Generator modules were available. These 5 modules were required for the radar focal point and for the Science and Operations Officer, but we encouraged all staff members to complete these additional modules as we felt they included good information. The two RDA modules were Generation of Dual Pol Base Data, and Sensitivity, Calibration, Attenuation, and Non-Uniform Beam Filling. The three RPG modules included Life without CMD, Dual Pol Preprocessing, MLDA and HCA, and lastly QPE. A large amount of written material was also available on the WDTB site. This includes a number of graphs that we printed out and placed at each of our workstations (and also put on our Situational Awareness Display) that showed representative values of base data for various hydrometeor types, including Light to Moderate Rain, Heavy Rain, Big Drops, Hail and Hail-Rain Mixtures, Graupel, Dry Snow, Wet Snow, and Ice Crystals.

The WDTB held weekly "Storm of the Week" webinars in April and May, which they recorded. The webinars showed various storms as seen with the new Dual Pol products from Vance Air Force Base and Norman, OK radars. These recorded webinars were made available to those on station who were not able to attend the live webinar. In May, 2011, the WDTB started holding weekly, 1 hour webinars to support the Dual Pol Beta Test sites. These webinars were designed to supplement the available on-line trainings, and described each of the new Dual Pol products. Examples from the Vance AFB and Norman radars were included in these webinars, and they also included examples from Phoenix, AZ, which turned on their Dual Pol capabilities in May, 2011.

DURING THE UPGRADE

As the beta site deployment schedule was being set up, we requested that we not be scheduled for our Dual Pol upgrade during the Hurricane Season. We were also concerned about other types of severe weather that may occur during our down-time. We took several measures to ensure we continued to provide high quality service to our customer during the installation.

Special radar procedures were set up so we could continue to monitor the weather over our CWA while we were down for the Dual Pol installation. These used our neighboring radars (Wilmington NC, Raleigh NC, and Wakefield VA) to monitor conditions. We also configured our Wide Area Network (WAN) so we could receive radar data from our surrounding radars through the WAN instead of using dial up procedures.

We also reminded the staff on the procedures to request Rapid Scan Satellite operations. This was planned since our surrounding radars' beams would overshoot any activity that would form over our Outer Banks and coastal waters.

For our customers, we changed the radar page on our internet site so that it pointed to the Southeast Regional Radar Composite instead of our local radar. While this was not "seamless" to the public, they could continue to monitor radar activity during our downtime.

The installation did occur in late June, but we were able to get it done without any tropical activity. However, we did experience active weather on a number of days during our Dual Pol installation. Thunderstorms occurred on June 13, 16, 17, 18, 19, 20, 21, and 22, with severe thunderstorms observed on June 17, 19, 20, 21, and 22. Severe weather over our Marine areas occurred on June 17 and 20.

The office faced a worst case scenario during the pre-dawn hours of June 20, 2011, when Eastern North Carolina was affected by a rapidly developing complex of thunderstorms that brought widespread wind damage with gusts of up to 82 mph. The midnight shift issued five severe thunderstorm warnings, and verified all of them with a lead time of 23 minutes and no missed events. They managed this utilizing a great situational awareness of the warning environment and the strategies that were developed ahead of time.

Only one major complaint was received by the public during our down time. A man who is involved with the Marlin Fishing Tournament called the office on several occasions to complain about the lack of radar coverage during the Tournament. He expressed anger that the upgrade was scheduled while a large number of people were in the area for the Tournament.

PRODUCTS

There are a number of new products offered by the Dual Pol technology, and training is available on each of these products through the Learning

Management System and from the WDTB. Below is a brief overview of the products.

Differential Reflectivity: ZDR helps identify the dominant target shape. Positive ZDR means the hydrometeors are more horizontal in orientation, indicating rain drops. Near zero ZDR values indicate the hydrometeors have a similarity in size in the vertical and horizontal, which is indicative of hail. Negative ZDR points to ice crystals or graupel.

Correlation Coefficient: CC helps distinguish uniform precipitation from non-uniform precipitation hydrometeors, by helping to determine if the targets have similar shape and type (e.g. pure snow or rain) or if more of a mixture exits (e.g., rain mixed with snow).

Specific Differential Phase: KDP helps identify regions of heavy rain. The higher the values are, the more intense the rain will be even if hail is present. KDP is immune to hail effects.

Hydrometeor Classification: HC tries to discriminate between different echo types. It uses the height of the melting layer and vertical profiles of reflectivity in relation to the melting layer.

Melting Layer: This algorithm uses reflectivity, differential reflectivity, and CC to determine the top and bottom of the Melting Layer (ML).

QPE products: A number of Dual Pol Quantitative Products are available, including One Hour Accumulation, Storm Total Accumulation, One Hour Difference, Storm Total Difference, Instantaneous Precipitation Rate, and others. Dual Pol uses three different algorithms to help estimate rainfall, based on Reflectivity, Specific Differential Phase, and/or Differential Reflectivity. This helps make better estimates in heavy precipitation versus light precipitation, and helps to mitigate hail contamination, among others.

EXAMPLES

Here are some screen shots of interesting phenomenon as seen on our radar.

Sea Breeze and Outflow Boundaries

Reflectivity (figure 1): The sea breeze (southeast boundary) and an outflow boundary from active thunderstorms to the northwest are seen in Z.

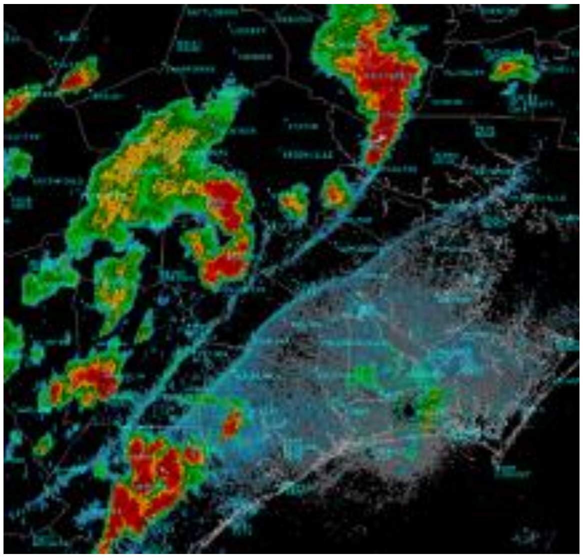

Figure 1: Reflectivity, Sea Breeze and Outflow

Correlation Coefficient (figure 2): The boundaries show different values of CC in the 0.5 to 0.7 range. Using the values that were developed by the WDTB, the outflow boundary is tagged as Biological targets, while the sea breeze shows a clutter/AP signature, with the actual boundary getting lost in the clutter.

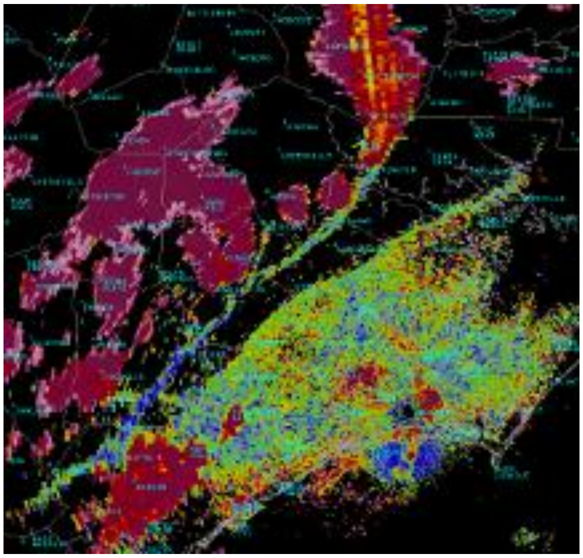

Figure 2: Correlation Coefficient, Sea Breeze and Outflow

Differential Reflectivity (figure 3): The high values of ZDR in both boundaries indicate biological targets.

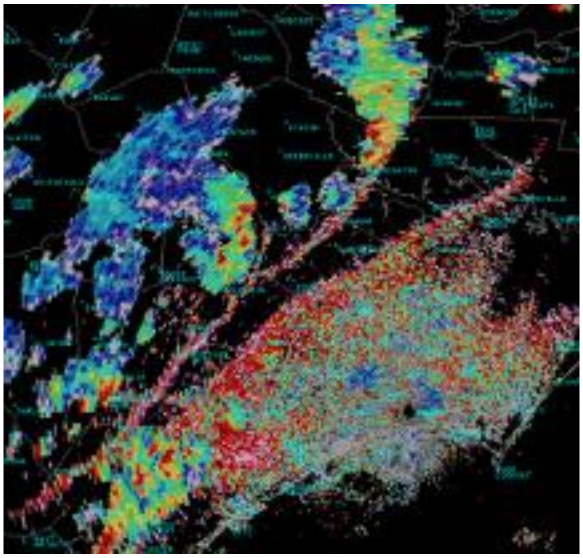

Figure 3: Differential Reflectivity, Sea Breeze and Outflow

Hydrometeor Classification (figure 4): HC also indicates Biological targets.

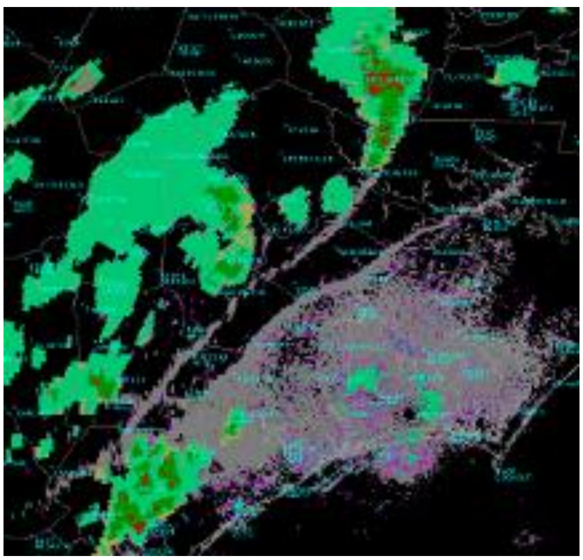

Figure 4: Hydrometeor Classification, Sea Breeze and Outflow

Chaff

Chaff is a common occurrence of many parts of the country. This section shows what chaff looks like in Dual Pol products.

Reflectivity (figure 5): Streaks of chaff are seen offshore just south of the radar.

Figure 5: Reflectivity, Chaff

Differential Reflectivity (figure 6): ZDR is noisy.

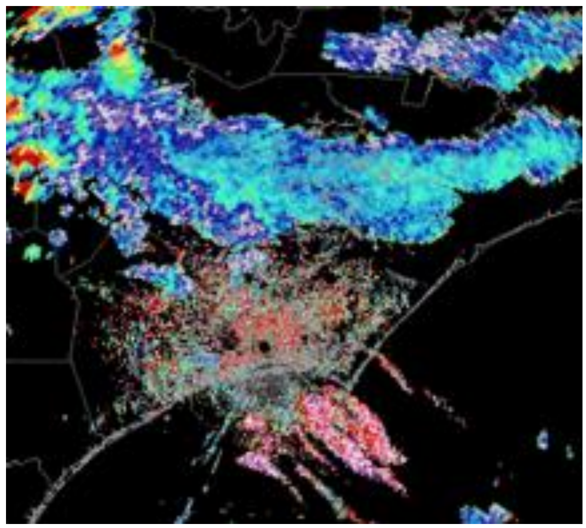

Figure 6: Differential Reflectivity, Chaff

Correlation Coefficient (figure 7): CC is very low, indicating low correlation in the shape and size of the hydrometeors.

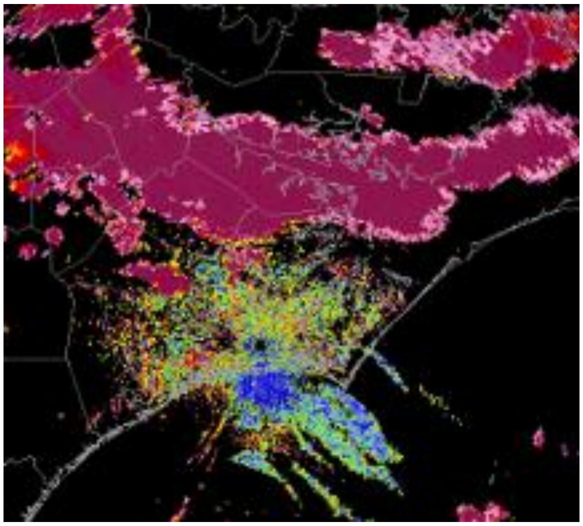

Figure 7: Correlation Coefficient, Chaff

Specific Differential Phase (figure 8): KDP is not calculated due to such low CC.

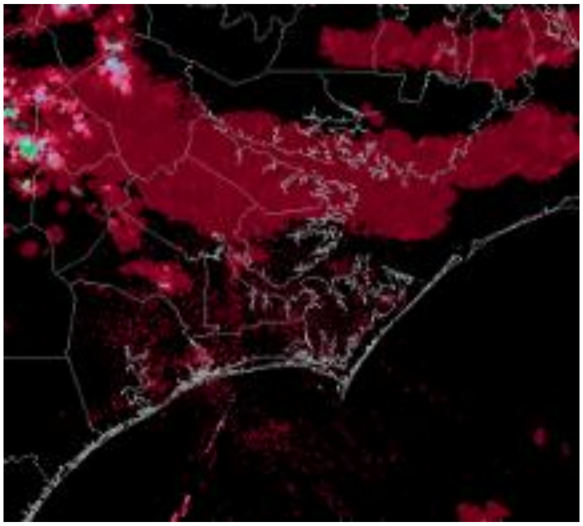

Figure 8: Specific Differential Phase, Chaff

Hydrometeor Classification (figure 9): HC sees the chaff as a biological return.

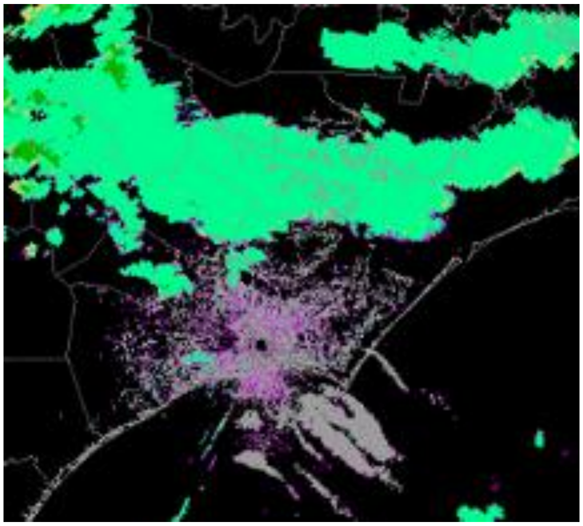

Figure 9: Hydrometeor Classification, Chaff

One Hour Accumulation (figure 10): The QPE products are recognizing, based on other Dual Pol products, that the chaff is not precipitation, and therefore is not creating an accumulation.

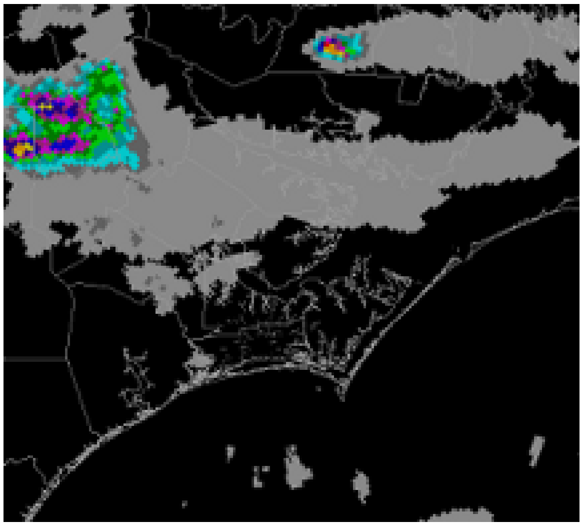

Figure 10: One Hour Accumulation, Chaff

Clutter/AP

With the installation of Dual Polarization capabilities at the WFOs, the Clutter Mitigation Decision algorithm will be temporarily unavailable (it will become available again in a later build). Clutter mitigation will need to be done manually until the algorithm is once again available.

Following is an example of clutter and anomalous propagation. Clutter/AP is seen near the radar and over the waters south of the radar.

Satellite (figure 11): The satellite picture shows isolated activity near the radar, but none over the waters south of the radar.

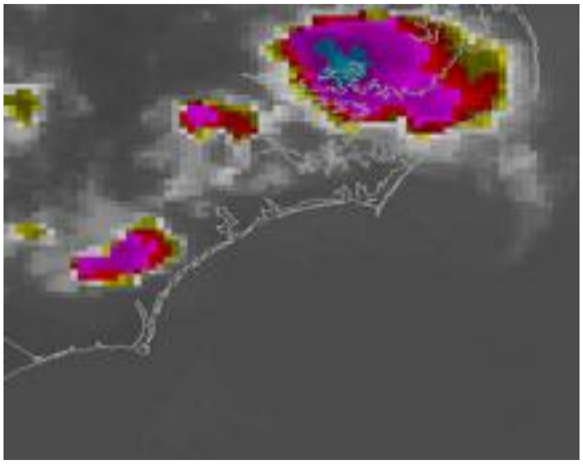
Figure 11: Satellite, Clutter/AP

Reflectivity (figure 12): With no clutter mitigation, areas around the radar and south of the radar show radar returns.


Figure 12: Reflectivity, Clutter/AP

Differential Reflectivity (figure 13): ZDR values are very low.

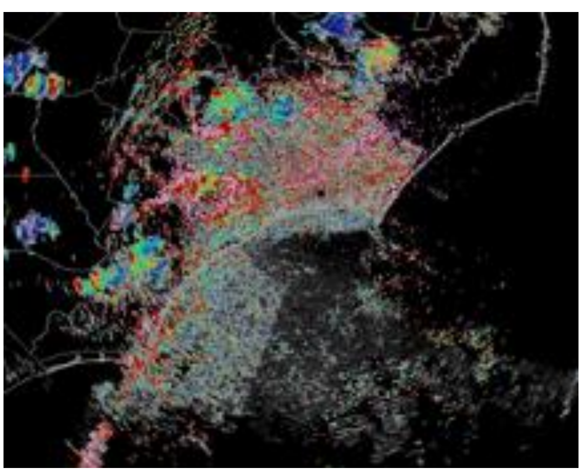
Figure 13: Differential Reflectivity, Clutter/AP

Correlation Coefficient (figure 14): CC is very low.

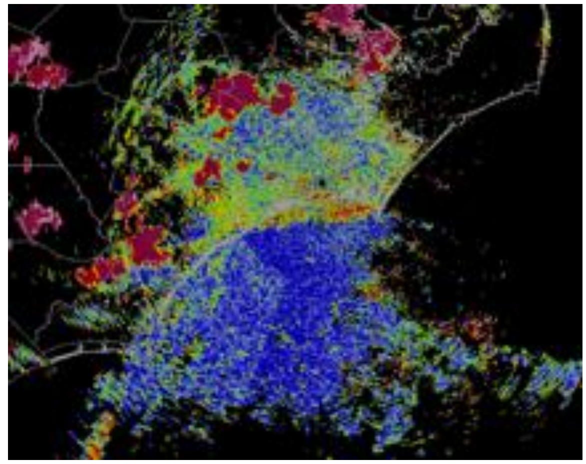
Figure 14: Correlation Coefficient, Clutter/AP

Specific Differential Phase (figure 15): KDP is not calculated due to extremely low CC.

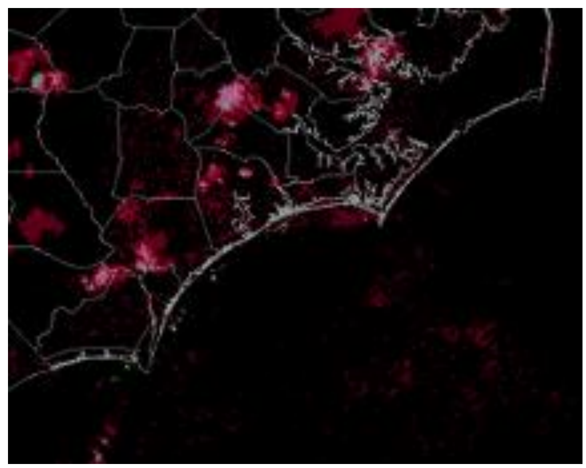
Figure 15: Specific Differential Phase, Clutter/AP

Hydrometeor Classification (figure 16): HC recognizes the clutter and AP as non-meteorological returns.

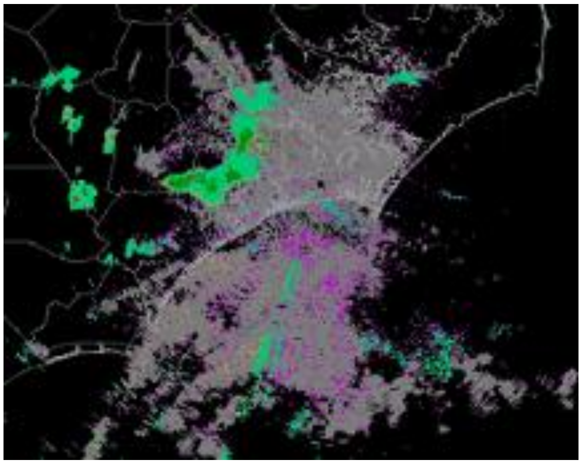

Figure 16: Hydrometeor Classification, Clutter/AP

Quantitative Precipitation Estimate: Both Legacy (figure 17) and Dual Pol QPE (figure 18) algorithms interpret the AP over the waters as precipitation.

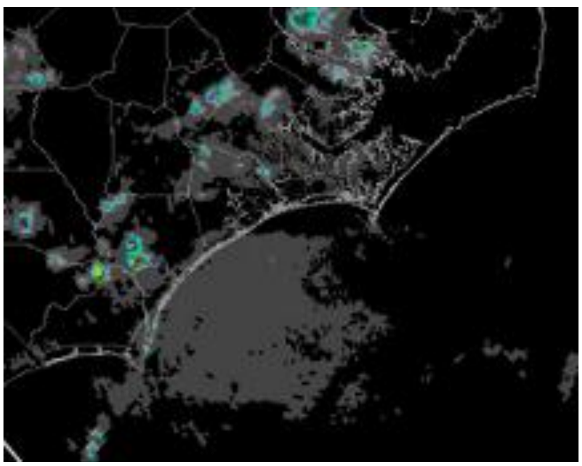

Figure 17: Legacy QPE, Clutter/AP

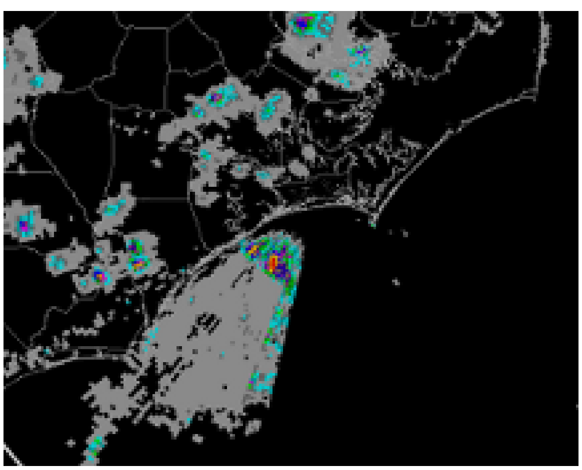

Figure 18: Dual Pol QPE, Clutter/AP

An attempt was made to manually suppress the noise, as seen in several of the products. Even given the suppression and several of the DP products indicating the returns were not precipitation, DP QPE algorithm still created accumulations. This needs to be watched until the new Clutter Mitigation Decision algorithms are re-instated.

Sea Spray

The following example shows two problem areas. One is the area just south of the radar over the waters. Dual Pol was able to identify this as non-meteorological and filter it out of the QPE algorithm. However, the other area which is along the immediately coastal regions running from the radar southward to near Cape Fear and is commonly seen from the KMHX radar, still presents a problem. The radar beam is quite high by the time it reaches Cape Fear, however, the common belief is that what we see along the coast at times is sea spray with possible insects and/or birds.

Reflectivity (figure 19): There were strong winds and rough seas on this day, allowing the sea spray south of the radar to be seen on radar. Looking closely, the returns along the coast are also seen. The strong return in Pender County is a wildfire.

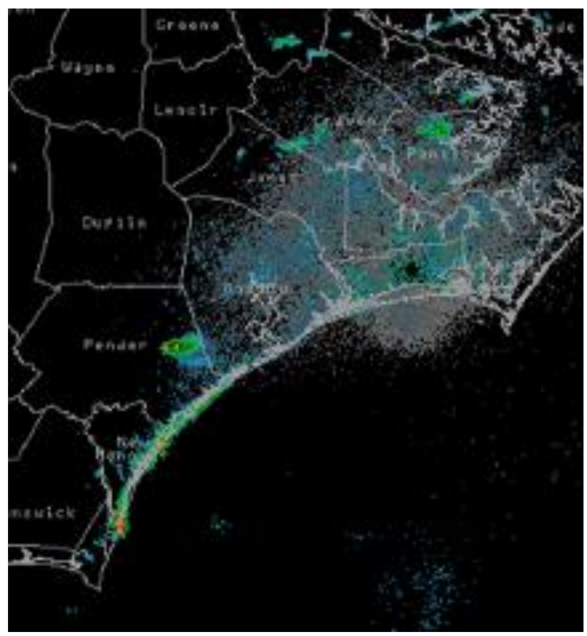

Figure 19: Reflectivity, Sea Spray

Hydrometeor Classification (figure 20): HC classifies the area near the radar as unknown echoes. The returns along the coast are classified as Biological.

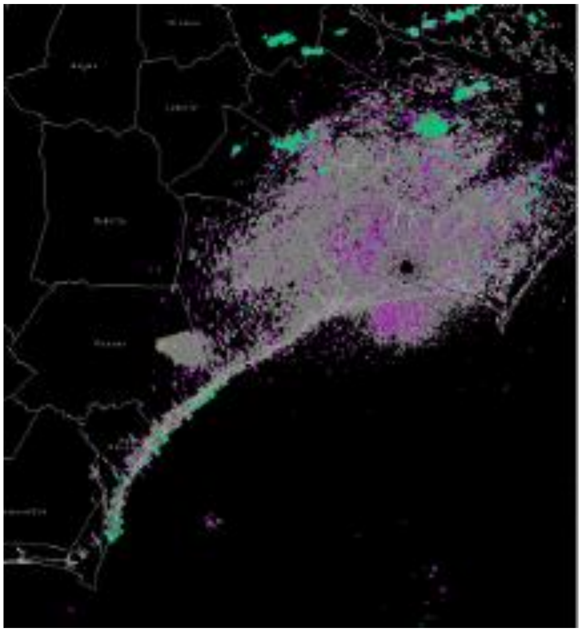

Figure 20: Hydrometeor Classification, Sea Spray

Correlation Coefficient (figure 21): CC is low offshore, indicating tumbling and differently sized particles. In the coastal region is also low, but not as low as in the other area.

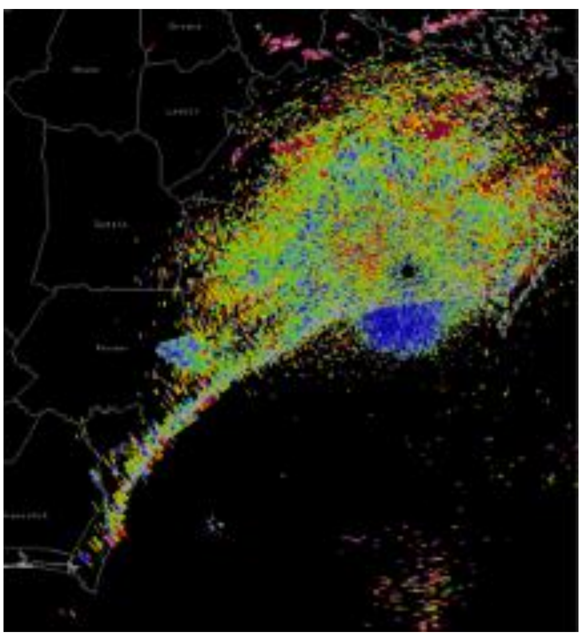

Figure 21: Correlation Coefficient, Sea Spray

Specific Differential Phase (figure 22): KDP is not calculated near the radar due to low Correlation Coefficient values. However along the coast, KDP is low.

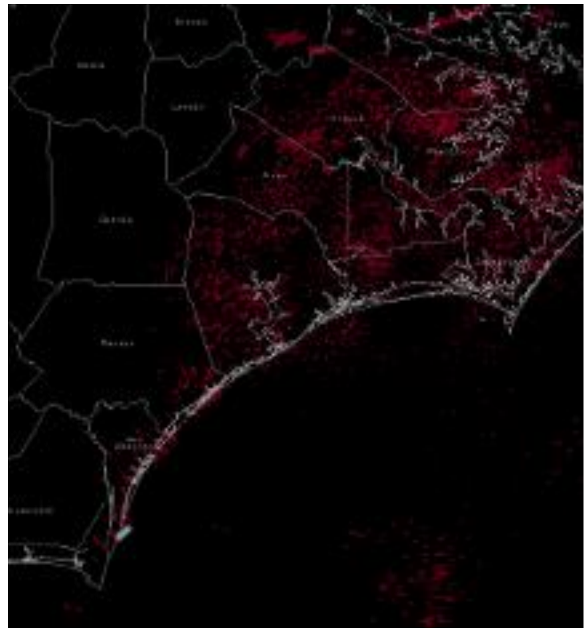

Figure 22: Specific Differential Phase, Sea Spray

Differential Reflectivity (figure 23): ZDR is inconclusive in both area, other products need to be used.

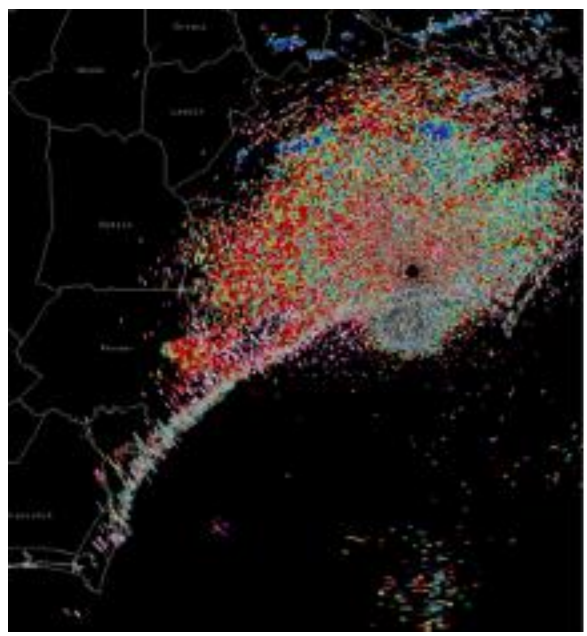

Figure 23: Differential Reflectivity, Sea Spray

One Hour Accumulation (figure 24): Based on other Dual Pol products, QPE algorithms effectively ignored the spray near the radar, but still produced accumulations along the coast south of Onslow County.

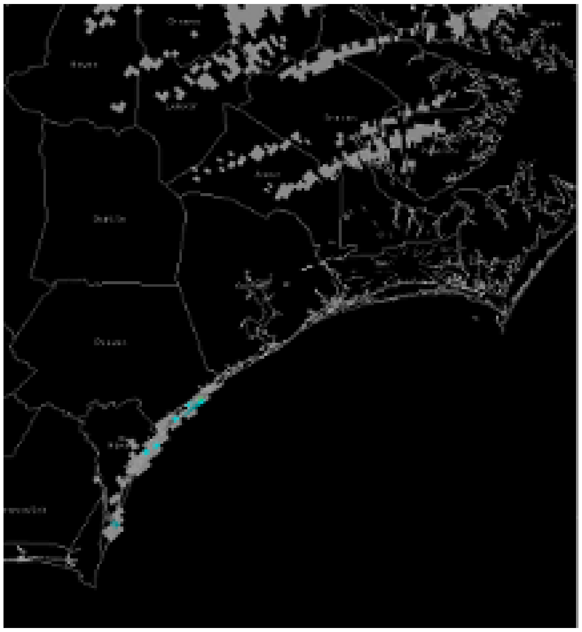

Figure 24: Dual Pol One Hour Accumulation, Sea Spray

Hail Identification

White Lake June 22, 2011, 1.75" Hail

Our radar was turned back on after the Dual Pol upgrade at 623 pm on June 22, in the midst of severe weather. Severe hail (1.75") was reported at White Lake (in ILM's CWA) at 634 pm.

Reflectivity (figure 25): Values of 60dBZ are seen near White Lake.

Figure 25a: Reflectivity, Hail 2223Z

Figure 26b: Reflectivity, Hail 2230Z

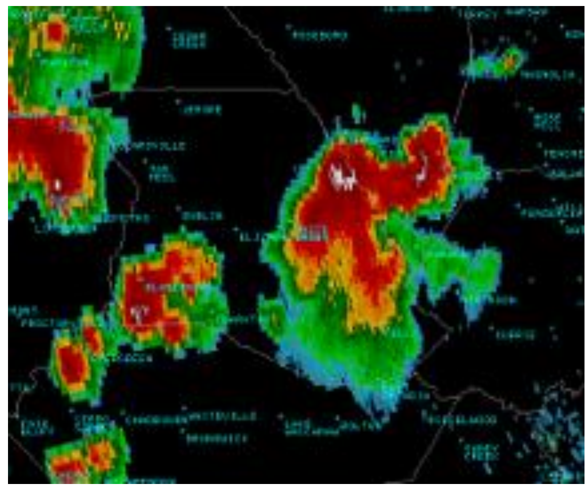

Figure 27c: Reflectivity, Hail 2236Z

Specific Differential Phase (figure 26): KDP is immune to hail contamination, and therefore can have just about any value in hail, but these high values indicate heavy rain is falling in the rain shaft.

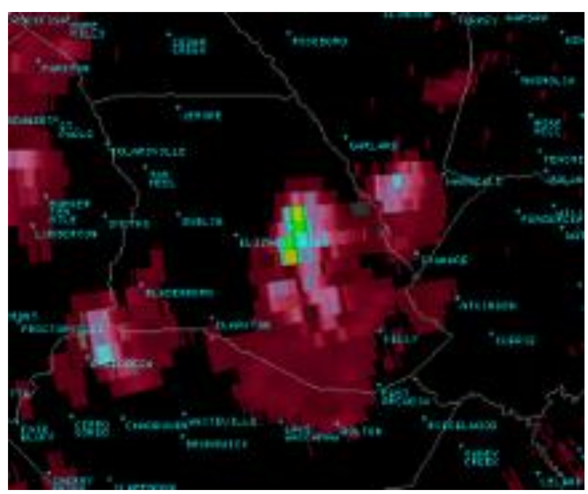

Figure 28a: Specific Differential Phase, Hail 2223Z

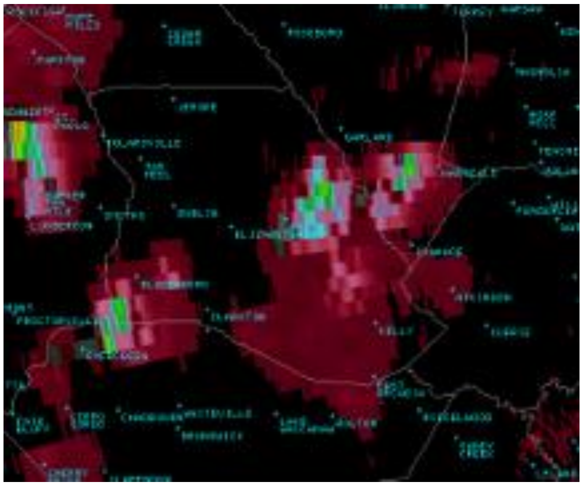

Figure 29b: Specific Differential Phase, Hail 2230Z

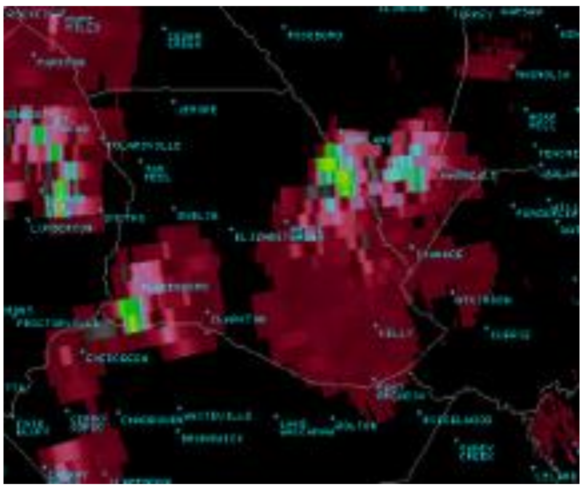

Figure 30c: Specific Differential Phase, Hail 2236Z

Differential Reflectivity (figure 27); Near zero values of ZDR are expected in a hail situation, but it has been found locally that ZDR values need not be near zero, but a local minimum is observed near reported hail. This is the case near White Lake.

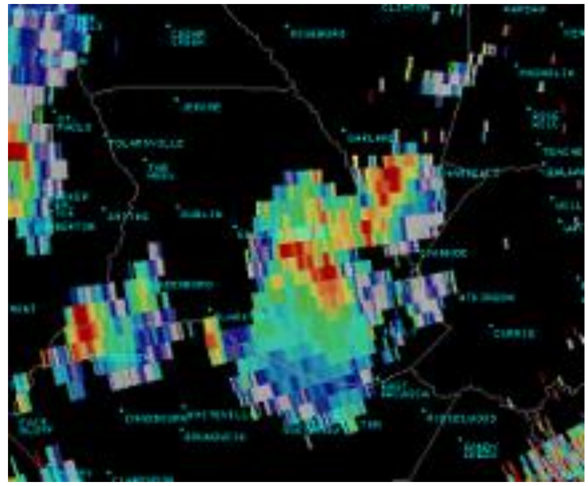

Figure 31a: Differential Reflectivity, Hail 2223Z

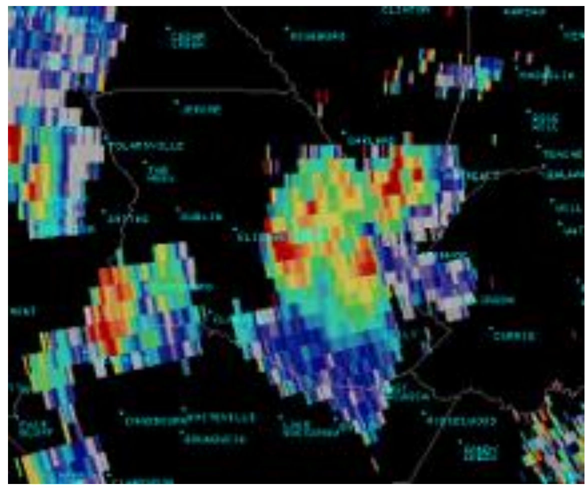

Figure 32b: Differential Reflectivity, Hail 2230Z

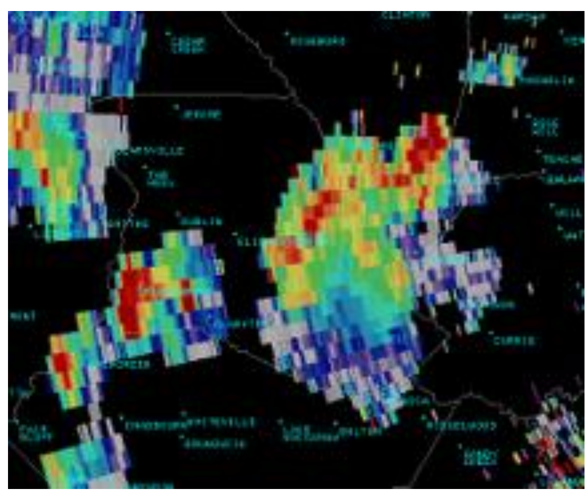

Figure 33c: Differential Reflectivity, Hail 2236Z

Correlation Coefficient (figure 28): CC is noisy in the area.

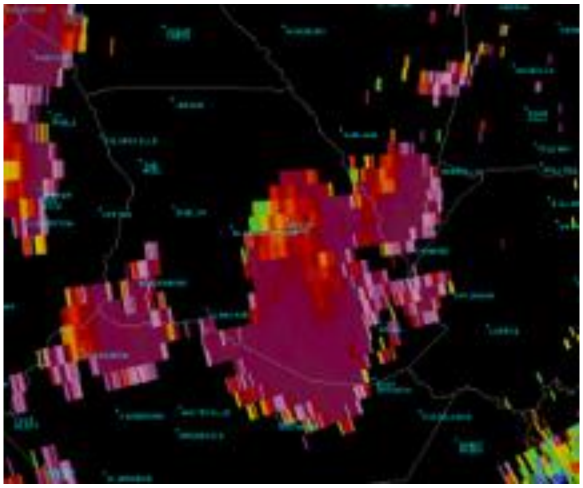

Figure 34a: Correlation Coefficient, Hail 2223Z

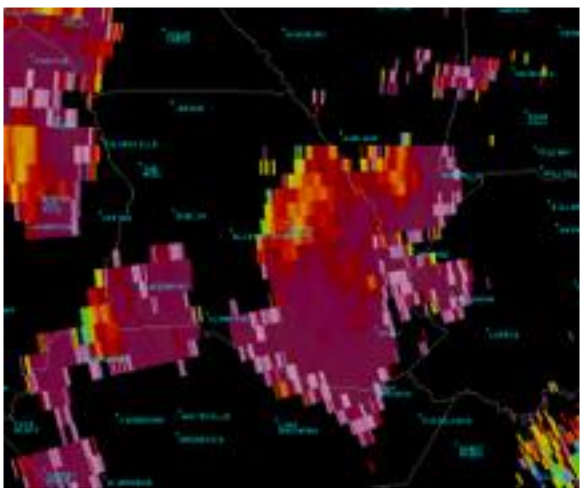

Figure 35b: Correlation Coefficient, Hail 2230Z

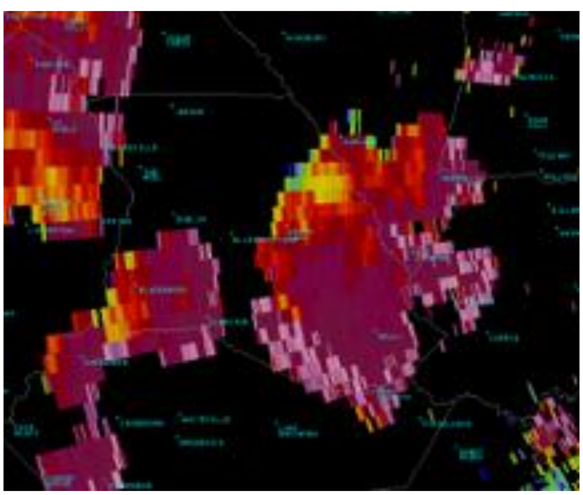

Figure 36c: Correlation Coefficient, Hail 2236Z

Hydrometeor Classification (figure 29): HC is showing a large area of Hail.

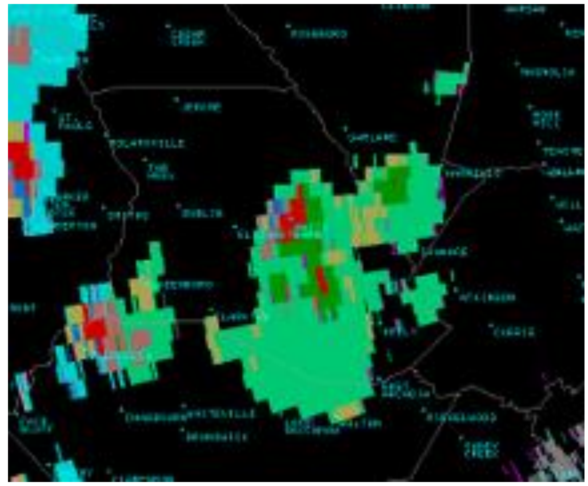

Figure 37a: Hydrometeor Classification, Hail 2223Z

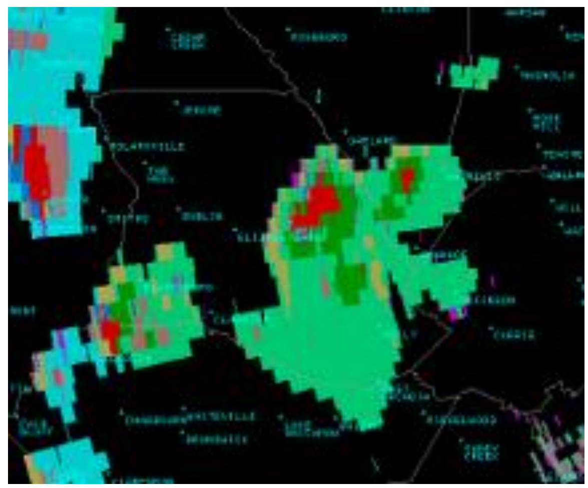

Figure 38b: Hydrometeor Classification, Hail 2230Z

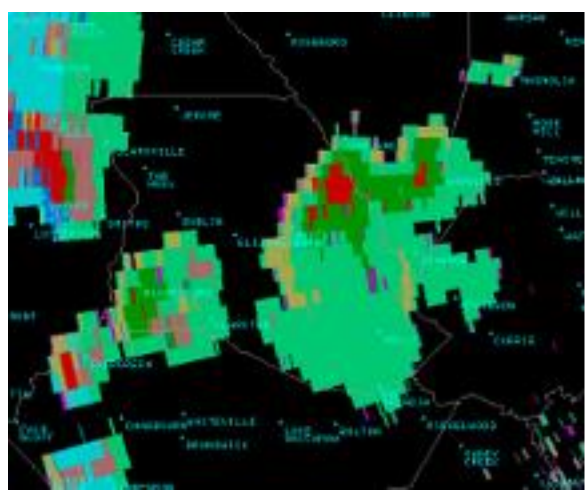

Figure 39c: Hydrometeor Classification, Hail 2236Z

Magnolia June 22, 2011, 0.75" Hail

This case was a little more subtle than the last one. The storm was starting to lose its intensity, with reflectivity (figure 30) values dropping to near

50dBZ. KDP (figure 31) values have dropped, also indicating a drop in rainfall intensity. ZDR (figure 32) is the first indication that there is a continued threat of hail, with a marked decrease in dB. Noisy CC (figure 33) and a couple pixels of Hail in the HC (figure 34) product both support the idea that hail is present in the storm. The hail that was reported was sub-severe, being less than 1”.

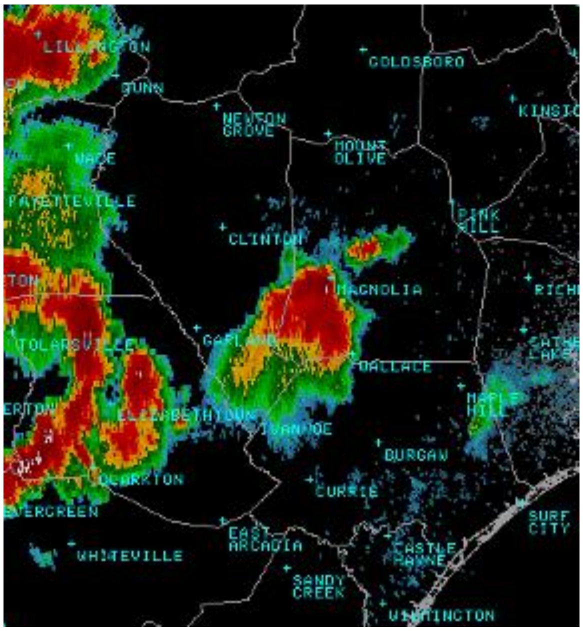

Figure 40a: Reflectivity, Hail 2308Z

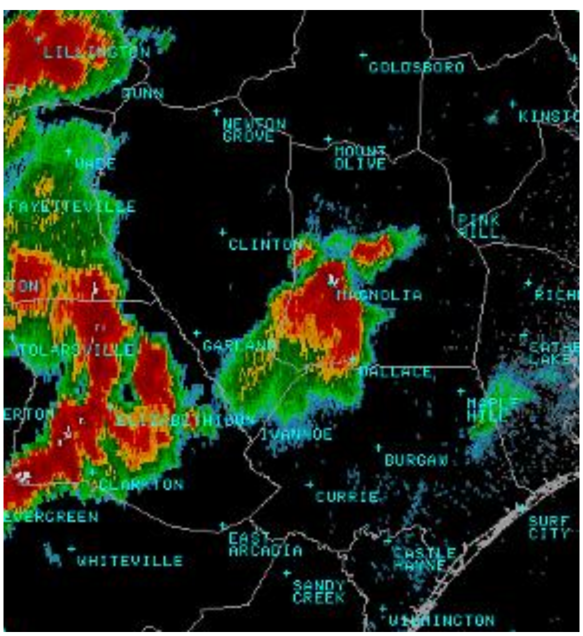

Figure 41b: Reflectivity, Hail 2312Z

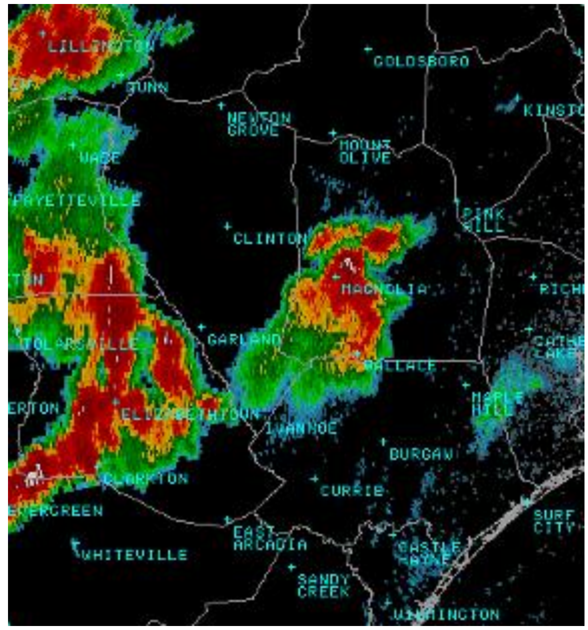

Figure 42c: Reflectivity, Hail 2316Z

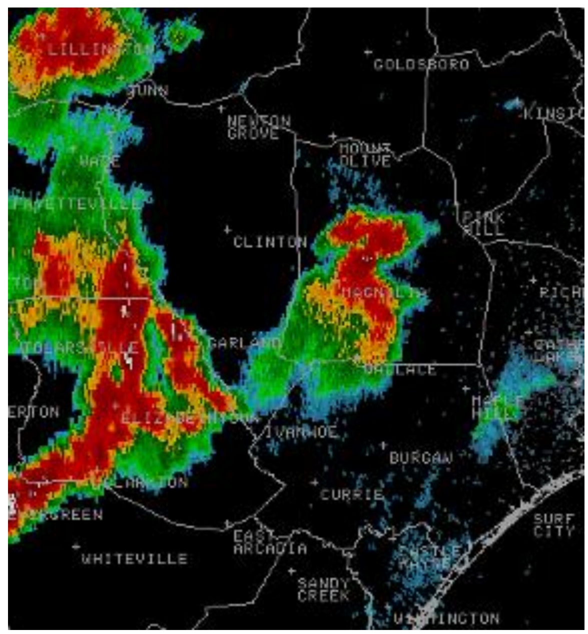

Figure 43c: Reflectivity, Hail 2321Z

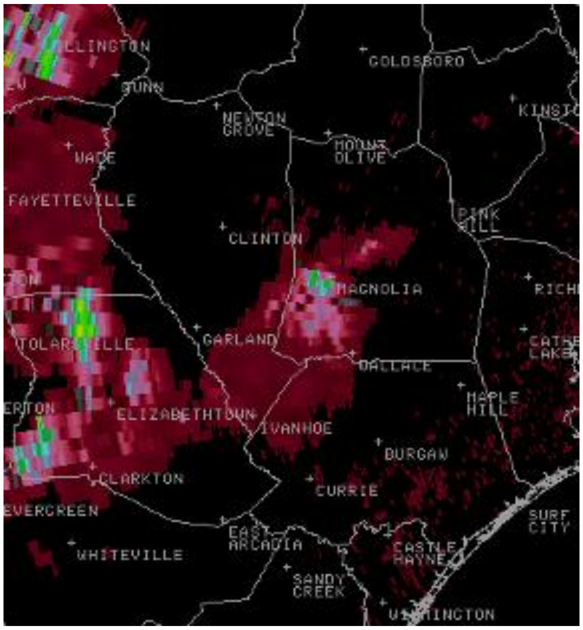

Figure 44a: Specific Differential Phase, Hail 2308Z

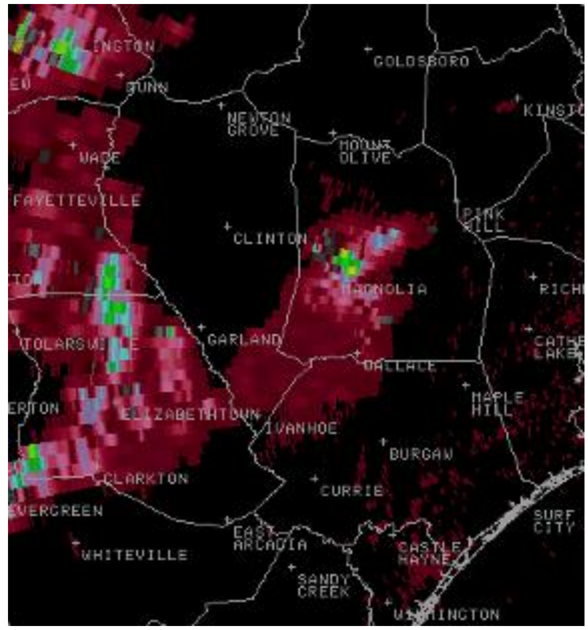

Figure 46c: Specific Differential Phase, Hail 2316Z

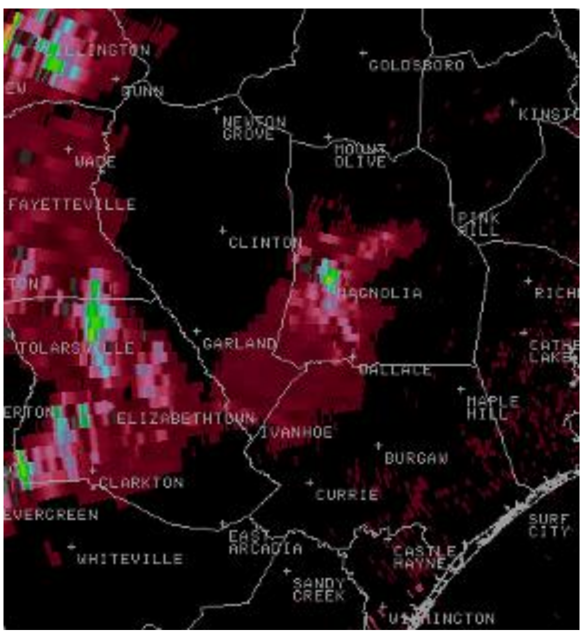

Figure 45b: Specific Differential Phase, Hail 2312Z

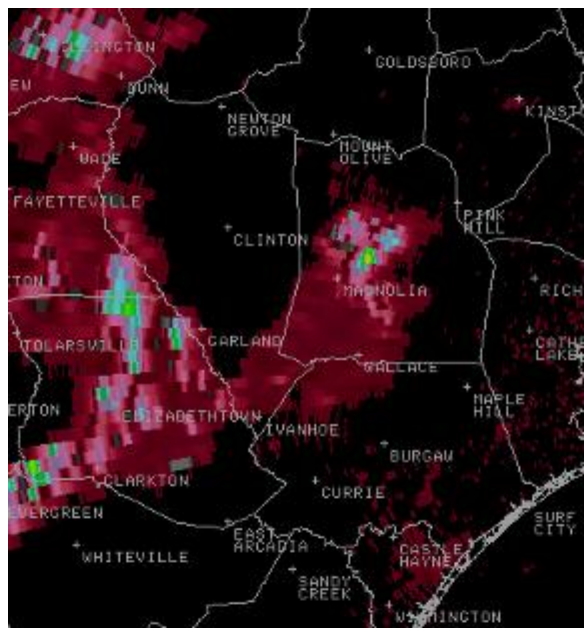

Figure 47c: Specific Differential Phase, Hail 2321Z

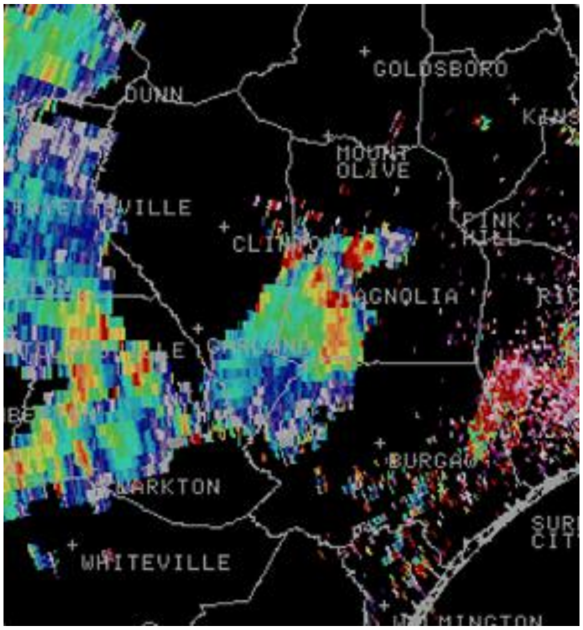

Figure 48a: Differential Reflectivity, Hail 2308Z

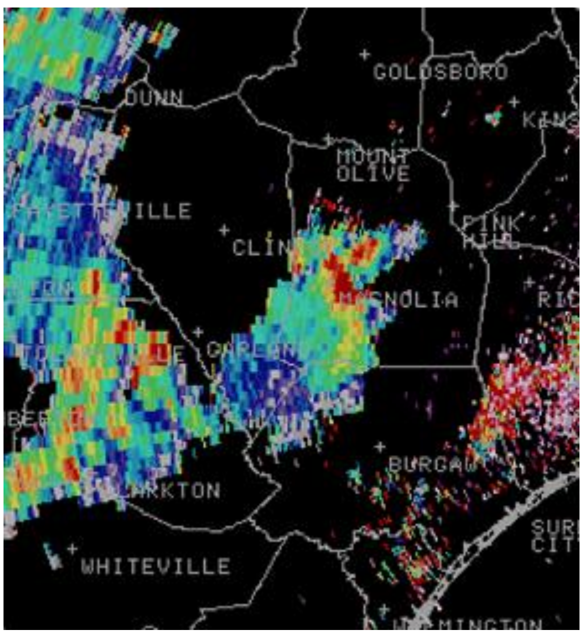

Figure 49b: Differential Reflectivity, Hail 2312Z

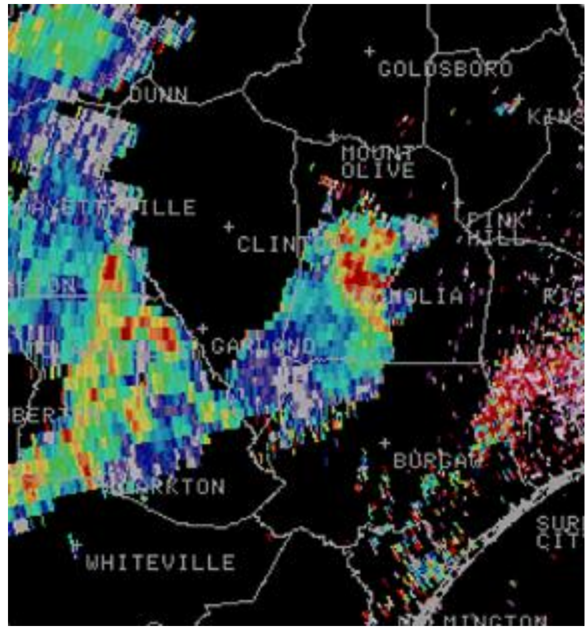

Figure 50c: Differential Reflectivity, Hail 2316Z

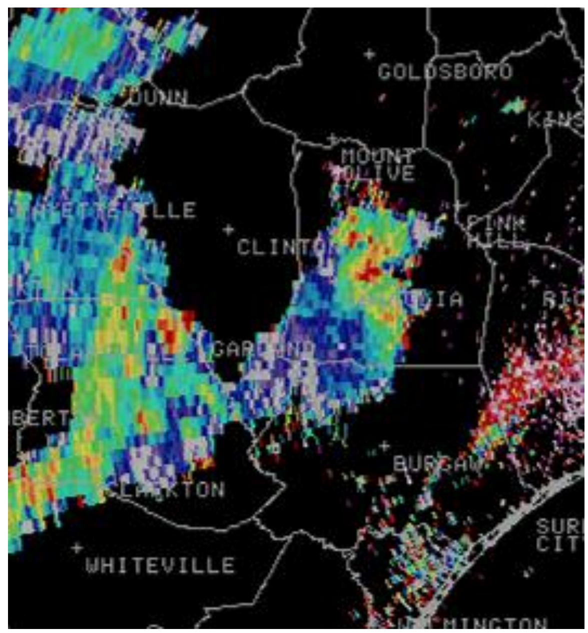

Figure 51d: Differential Reflectivity, Hail 2321Z

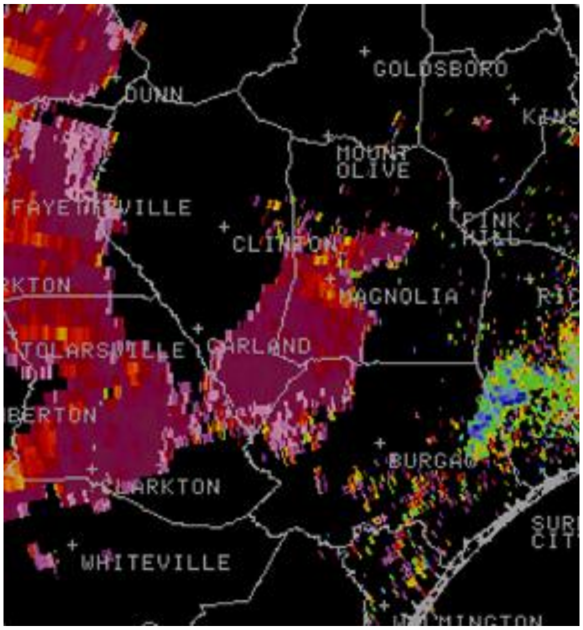

Figure 52a: Correlation Coefficient, Hail 2308Z

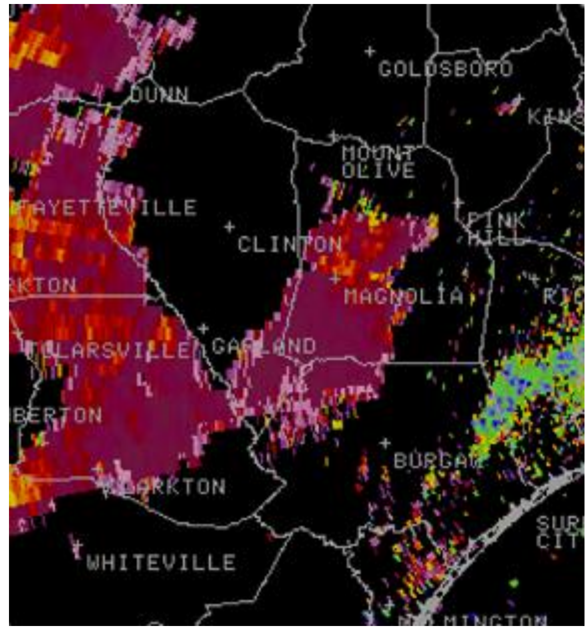

Figure 54c: Correlation Coefficient, Hail 2316Z

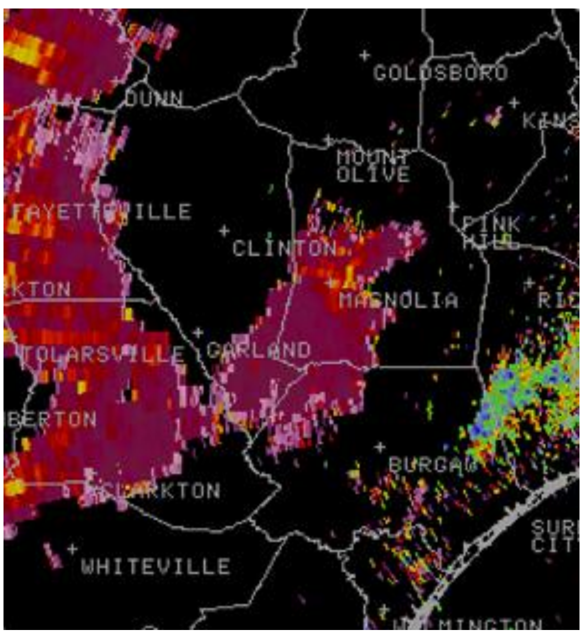

Figure 53b: Correlation Coefficient, Hail 2312Z

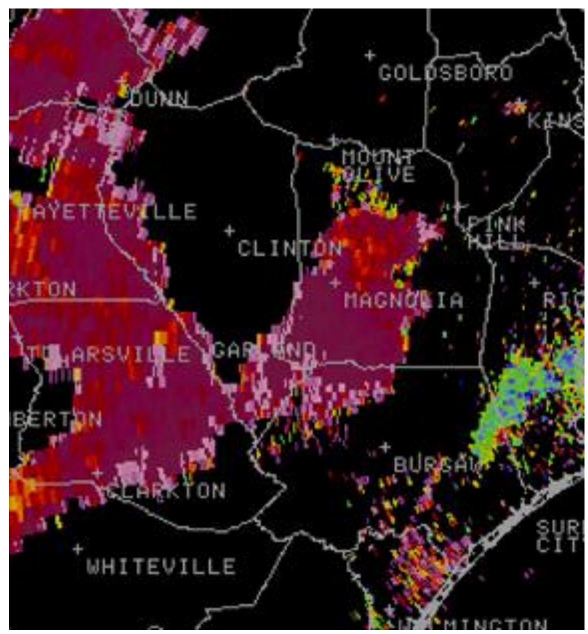

Figure 55d: Correlation Coefficient, Hail 2321Z

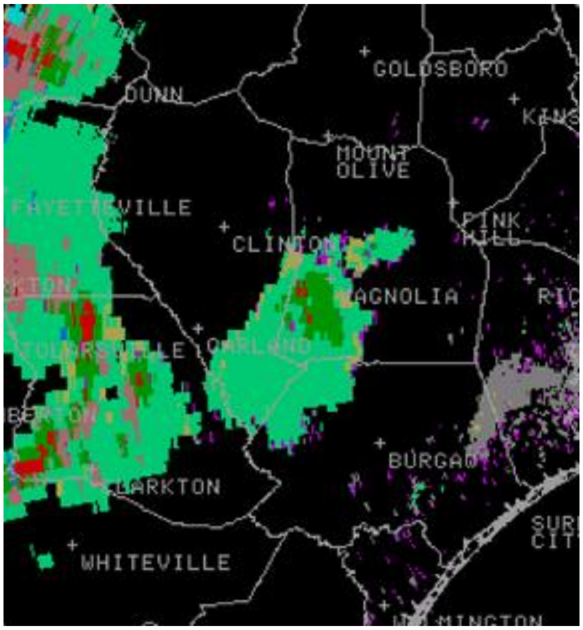

Figure 56a: Hydrometeor Classification, Hail 2308Z

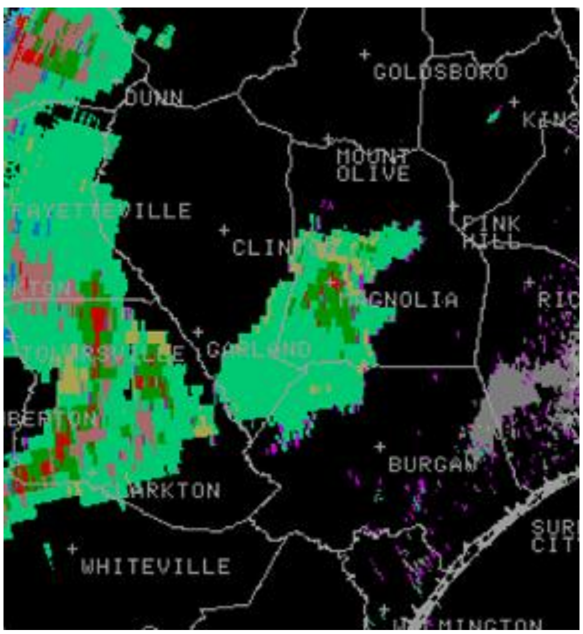

Figure 57b: Hydrometeor Classification, Hail 2312Z

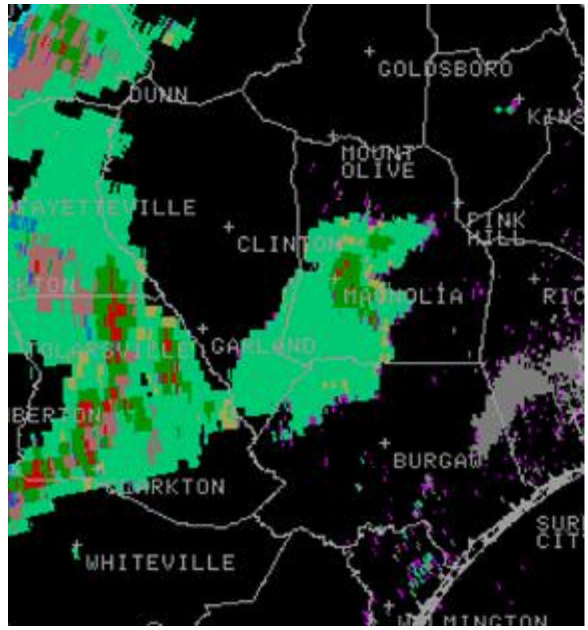

Figure 58c: Hydrometeor Classification, Hail 2316Z

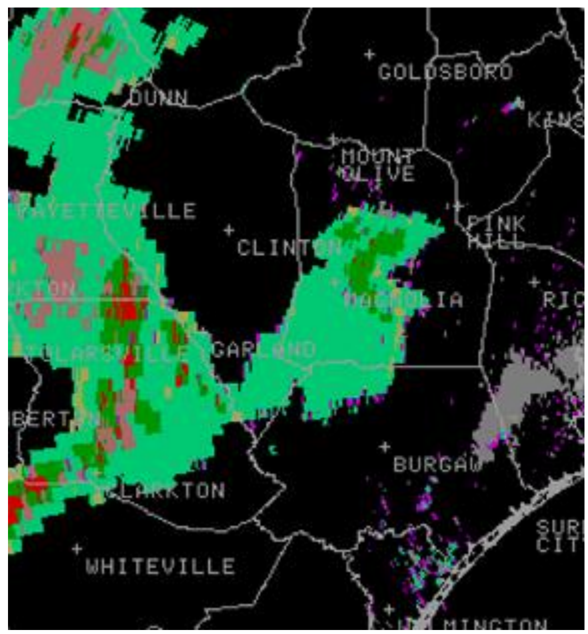

Figure 59d: Hydrometeor Classification, Hail 2321Z

Updraft Precursor

This was the same storm as seen in the two Hail cases above. As the storm continues north, it begins to intensify again, as seen in reflectivity (figure 35). We see that in the third reflectivity graphic as a rear inflow notch. The Storm Relative Velocity (figure 36) doesn't give any hints of intensification. Looking at the Differential Reflectivity (figure 37), there is evidence of a ZDR column in the form of a large area of red. This is a precursor of an updraft. In an operational setting, we would get an earlier clue of re-intensification by looking at the ZDR, and in cross section, we would be able to see a ZDR column.

Figure 60a: Reflectivity, Updraft Precursor 2338Z

Figure 61b: Reflectivity, Updraft Precursor 2342Z

Figure 62c: Reflectivity, Updraft Precursor 2347Z

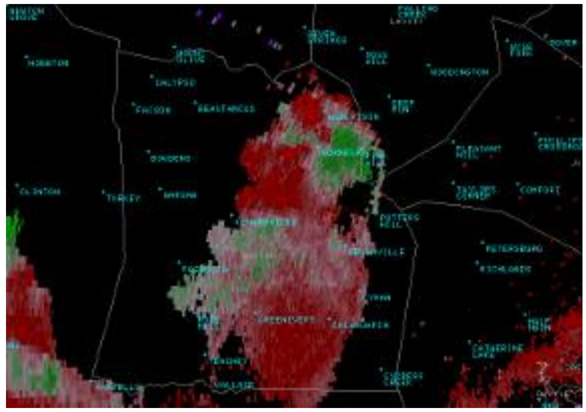

Figure 63a: Storm Relative Velocity, Updraft Precursor 2338Z

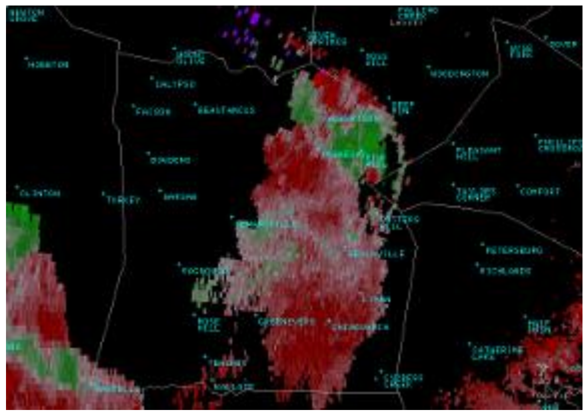

Figure 64b: Storm Relative Velocity, Updraft Precursor 2342Z

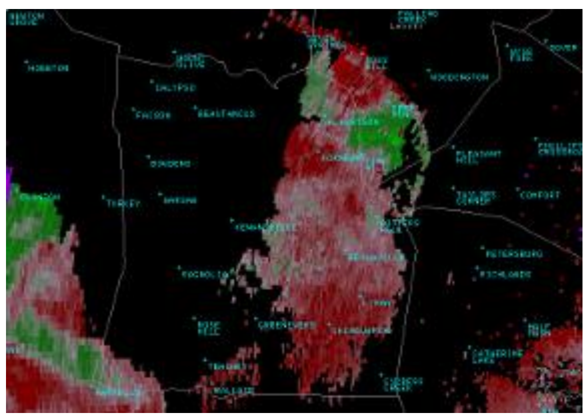

Figure 65c: Storm Relative Velocity, Updraft Precursor 2347Z

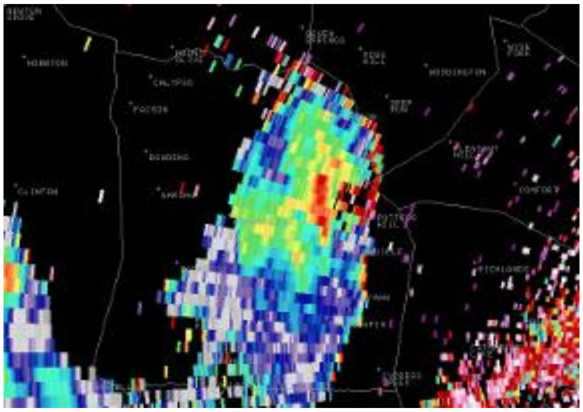

Figure 66a Differential Reflectivity, Updraft Precursor 2338Z

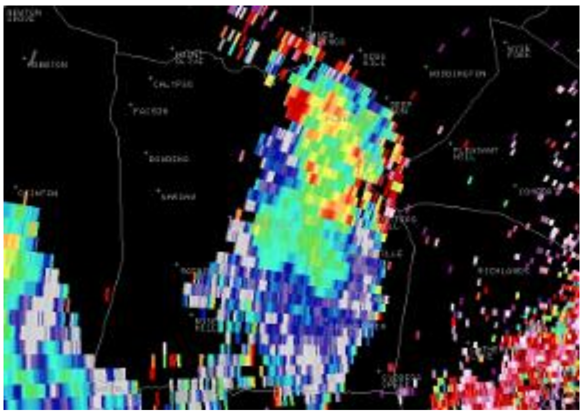

Figure 67b: Differential Reflectivity, Updraft Precursor 2342Z

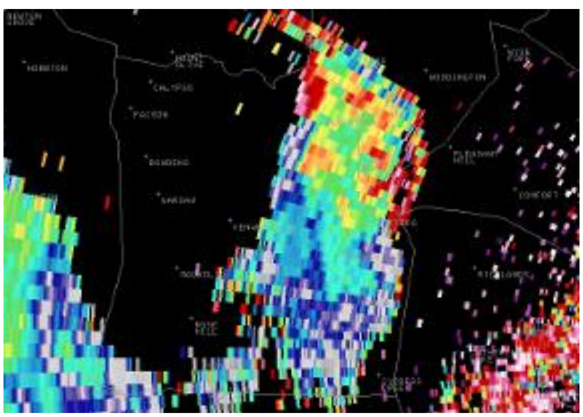

Figure 68c: Differential Reflectivity, Updraft Precursor 2347Z

There was thunderstorm wind damage in Albertson at 2342Z, and the damage continued between Albertson and Kinston over the next half hour.

Heavy Precipitation

Thunderstorm cells trained over coastal Onslow County, NC between 12Z and 18Z June 29. We had no ground truth in that area. However, closer to the radar, Dual Pol OHA verified better than Legacy OHP rainfall amounts, based on COCORAHS data.

One Hour Precipitation (figure 38): Legacy OHP calculated up to around 10” in coastal Onslow County.

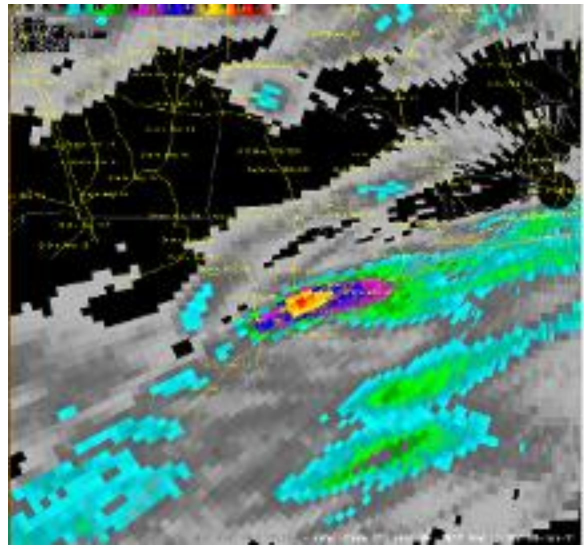

Figure 69: Legacy One Hour Precipitation

One Hour Accumulation (figure 39): Dual Pol OHA showed amounts in the 7” range in the same area.

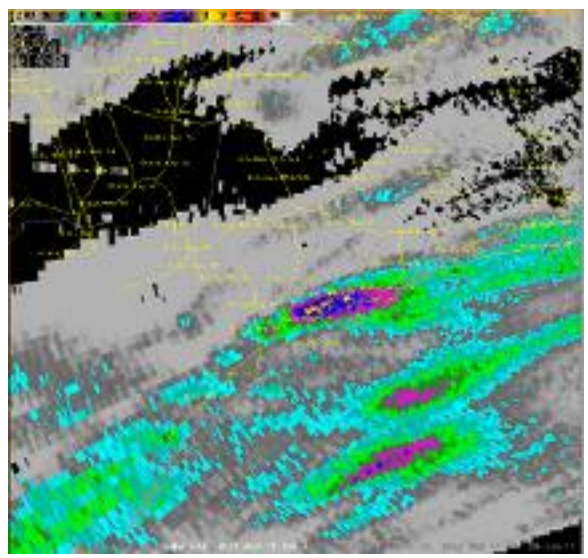

Figure 70: Dual Pol One Hour Precipitation

Storm Total Difference (figure 40): The DSD product shows 3” or more difference between Dual Pol QPE and legacy QPE, with Dual Pol estimates being less than legacy estimates.

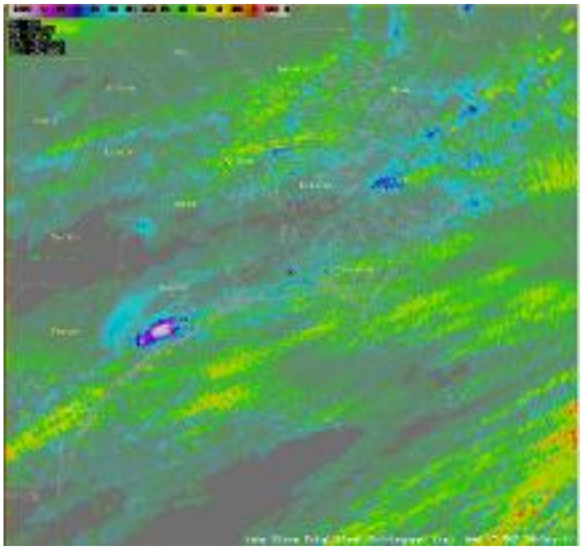

Figure 71: Storm Total Precipitation Difference

Reflectivity (figure 41): 3 hours of Z showing training cells over coastal Onslow County.

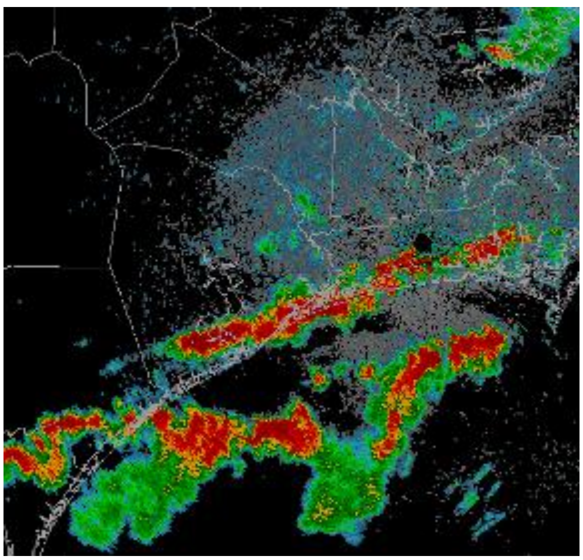

Figure 72a: Reflectivity, Heavy Rain 1401Z

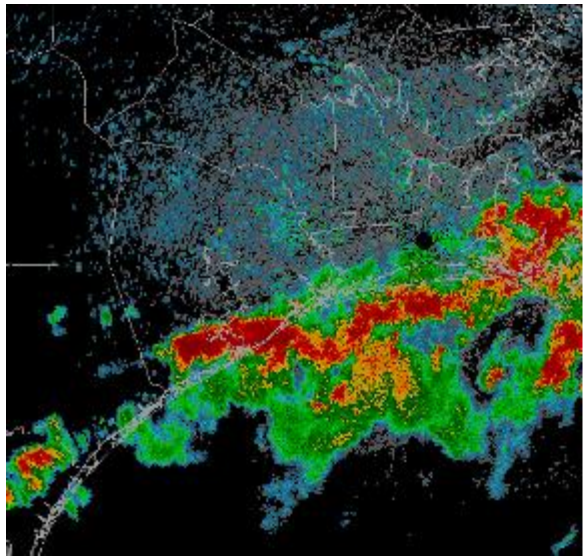

Figure 73b: Reflectivity, Heavy Rain 1502Z

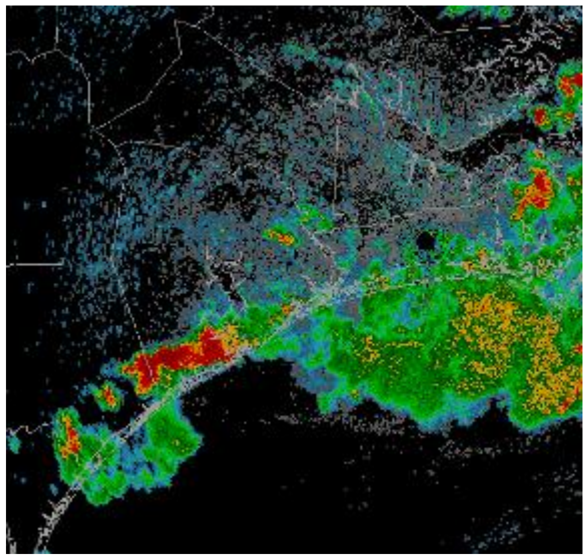

Figure 74c: Reflectivity, Heavy Rain 1603Z

Differential Reflectivity (figure 42): ZDR was high. With a mixture of hydrometeors, ZDR is biased toward the dominant scatterer, and may not add value. In this case, the big drops were dominant, hail less so.

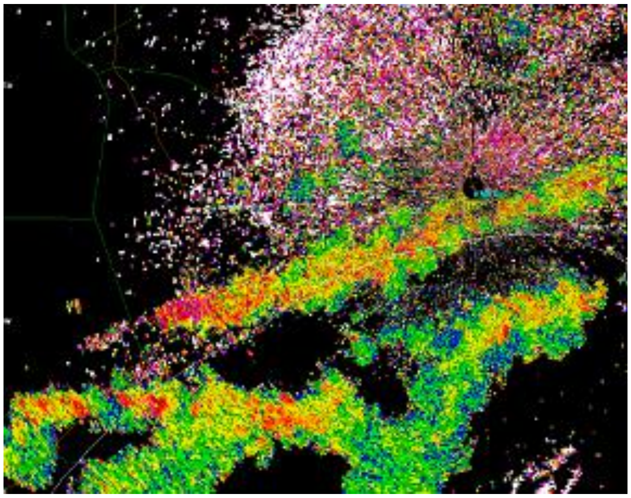

Figure 75a: Differential Reflectivity, Heavy Rain 1401Z

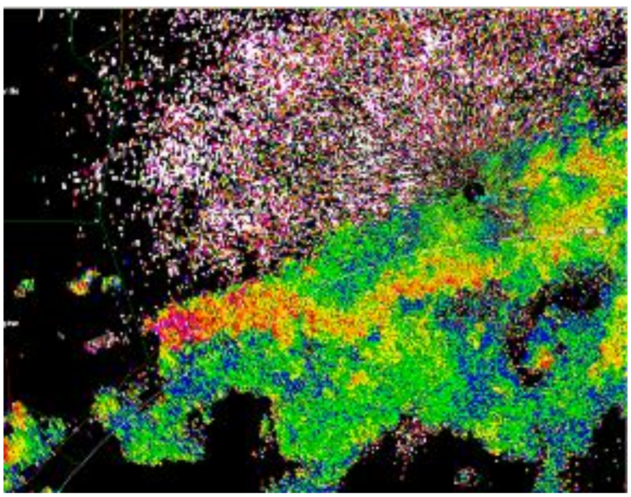

Figure 76b: Differential Reflectivity, Heavy Rain 1502Z

Correlation Coefficient (figure 43): RHO (CC) was noisy and low, indicating mixture of drop sizes, types, and orientations. There were no indications of large hail.

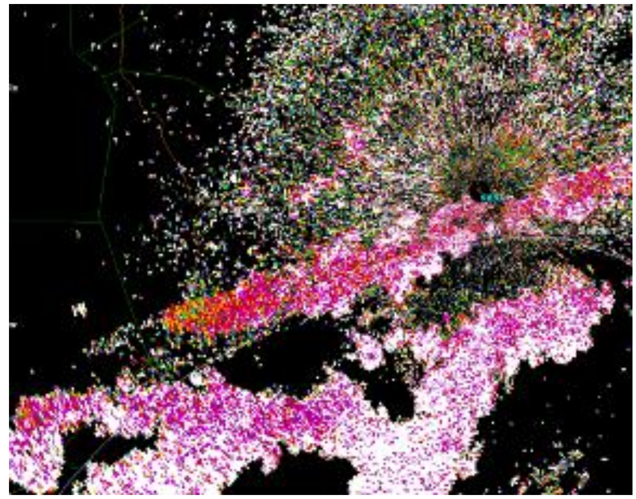

Figure 77a: RHO (CC), Heavy Rain 1401Z

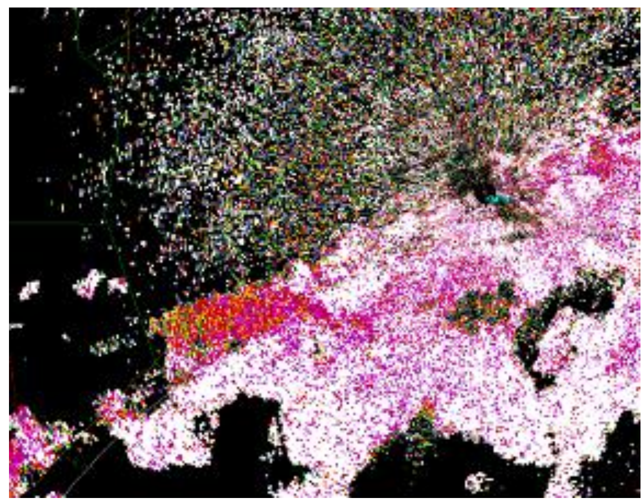

Figure 78g: RHO (CC), Heavy Rain 1502Z

Specific Differential Phase (figure 44): KDP was extremely high, which is common in a mixed rain/hail situation. This is indicative of bigger drops and a larger concentration of drops.

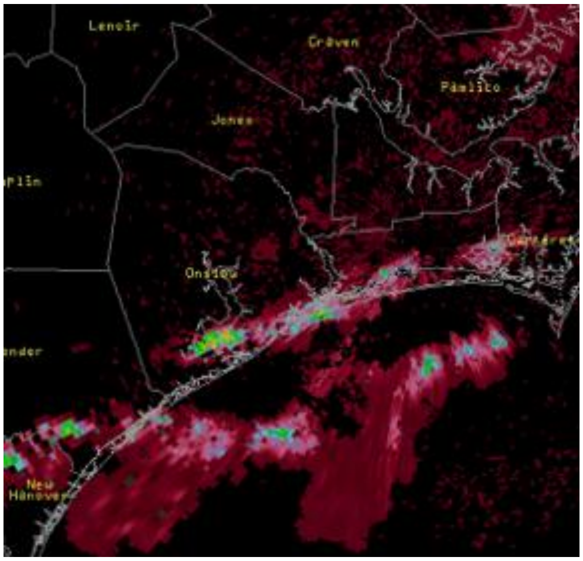

Figure 79a: Specific Differential Phase, Heavy Rain 1401Z

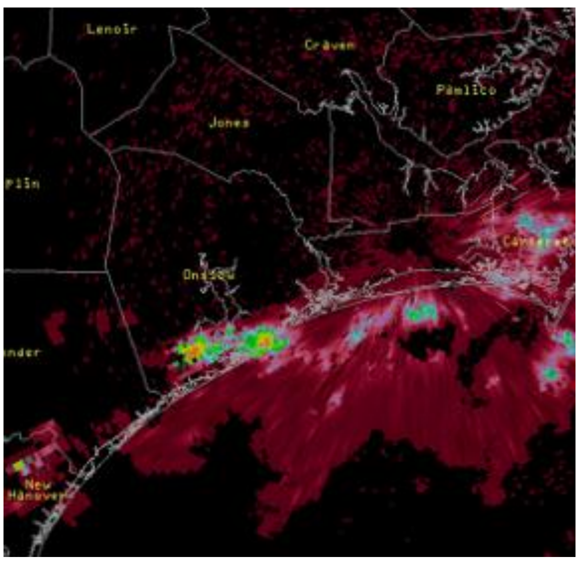

Figure 80b: Specific Differential Phase, Heavy Rain 1502Z

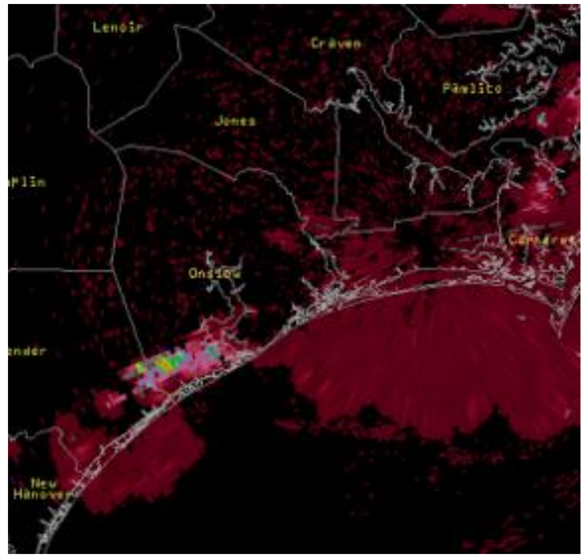

Figure 81c: Specific Differential Phase, Heavy Rain 1603Z

Hydrometeor Classification (figure 45): HC is showing BD (Big Drops) and HR (Heavy Rain) mixed with isolated hail. So the assumption was huge liquid drops with tiny ice cores, mixed with small amounts of pure hail.

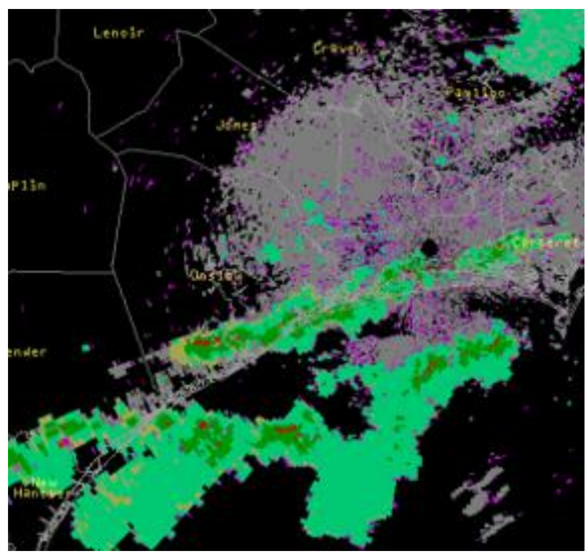

Figure 82a: Hydrometeor Classification, Heavy Rain 1401Z

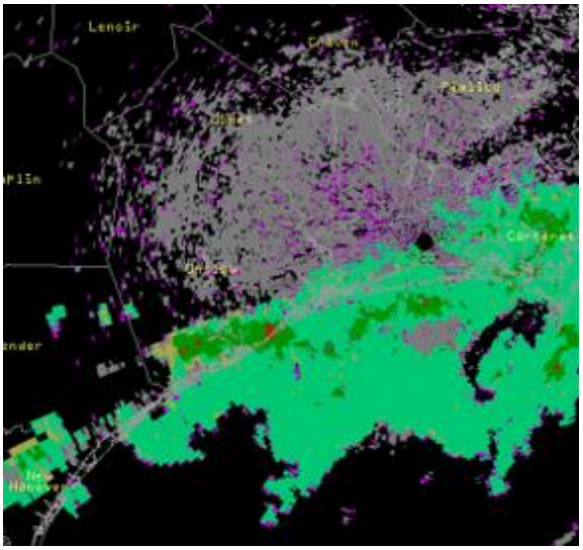

Figure 83b: Hydrometeor Classification, Heavy Rain 1502Z

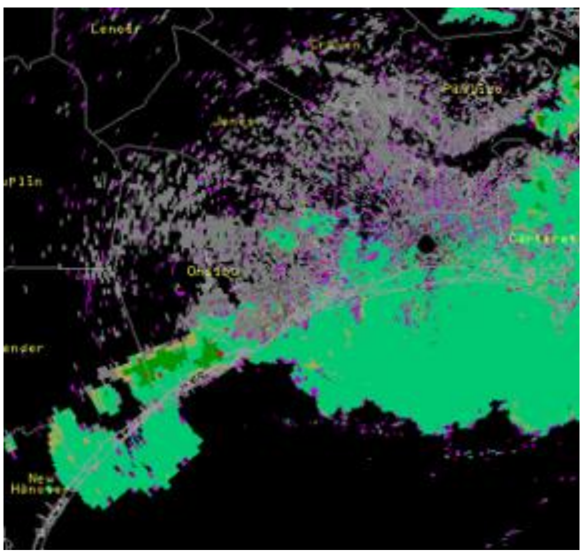

Figure 84c: Hydrometeor Classification, Heavy Rain 1603Z

If the bin was tagged as HA, the R(KDP) QPE algorithm was probably used, the other bins most likely used the Z/ZDR relationship. This ability to use different rainfall algorithms based on the determined precipitation type in the bin helps mitigate hail contamination and account for different drop sizes, this helps Dual Pol QPE provide better estimates than legacy QPE.

Hail Contamination

A line of thunderstorms moved through the northern parts of the MHX CWA on July 5, 2011. Differences in rainfall amounts between the Legacy OHP and the Dual Pol OHA of around 3 inches were noted, with hail contamination being suspected. The observation from Gum Neck, the only observation site in the area, was a storm total of 2.28”.

Storm Total Precipitation (figure 46): Legacy STP showed between 6 and 7 inches of precipitation near Gum Neck, NC. There is also an area west of Gum Neck that has heavy rainfall being indicated.

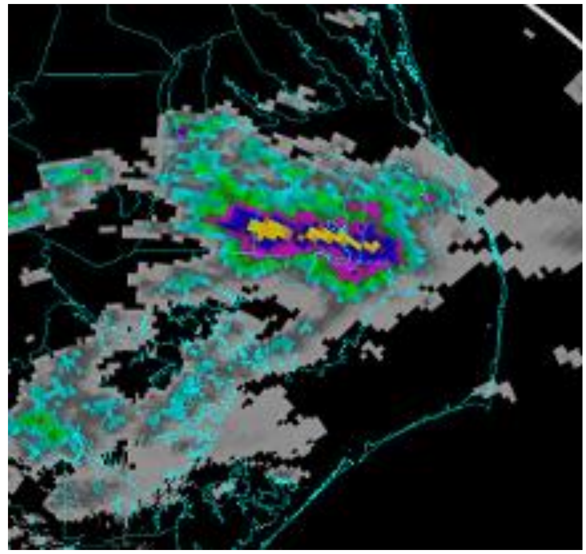

Figure 85: Legacy Storm Total Precipitation, Hail Contamination

Storm Total Accumulations (figure 47): Dual Pol STA indicated 3 to 4 inches near Gum Neck. Notice the western maximum is similar to the legacy STP.

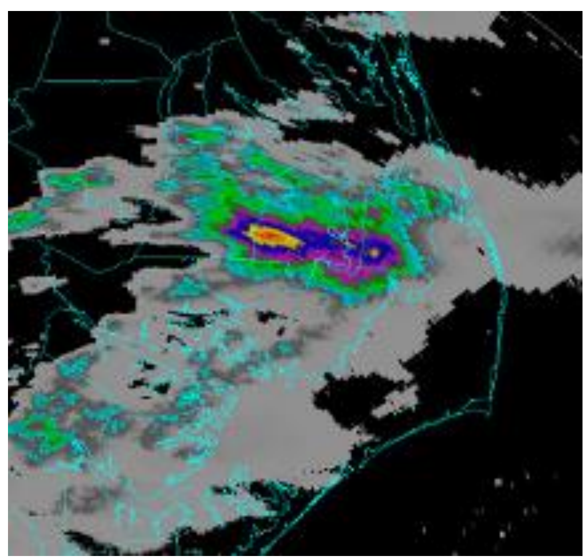

Figure 86: Dual Pol Storm Total Accumulation, Hail Contamination

Reflectivity (figure 48): High values of Z are noted in both areas.

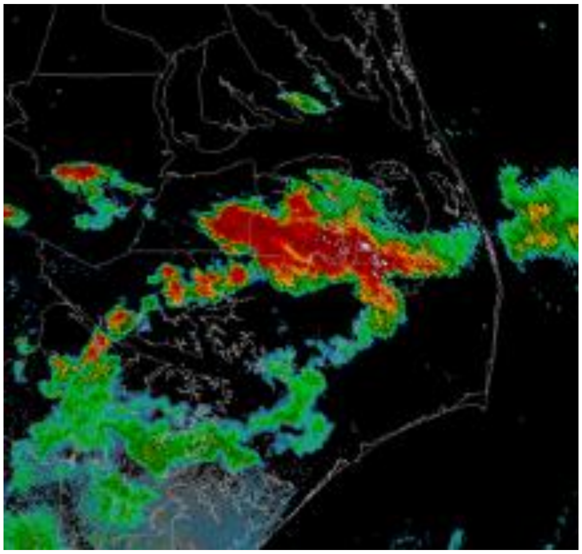

Figure 87: Reflectivity, Hail Contamination

Correlation Coefficient (figure 49): CC values were noisy, with values of .9 to .95, indicative of Hail in the eastern area. The western area also has low CC values, but not as widespread as the eastern area.

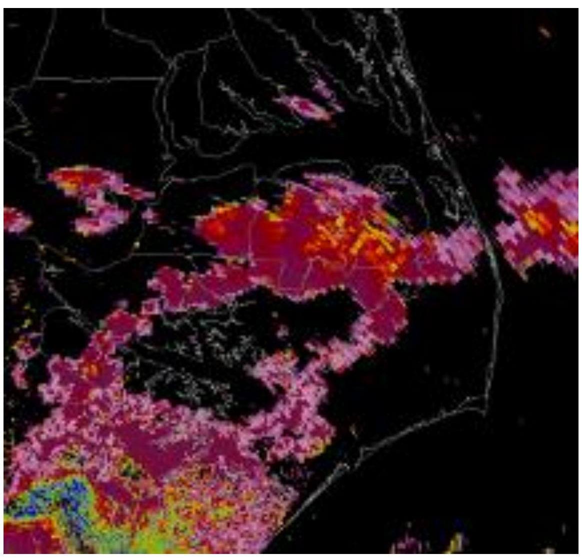

Figure 88: Correlation Coefficient, Hail Contamination

Hydrometeor Classification (figure 50): HC indicates large areas of Hail in the eastern area, with only isolated areas in the western section.

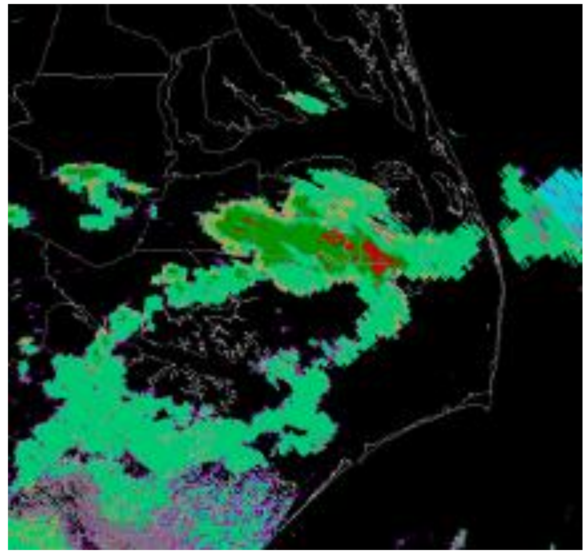

Figure 89: Hydrometeor Classification, Hail Contamination

It can be seen that Legacy QPE was overestimated in the eastern storm center due to hail contamination. In the western area, Dual Pol and Legacy QPEs were similar, and most likely close to the true amount, as hail contamination was not so much a problem in this area.

HURRICANE IRENE

Hurricane Irene of August 27-28, 2011 was the first hurricane sampled by NWS Dual Pol radar. The hurricane was eagerly awaited so we could see how Dual Pol performed in tropical situations.

Dual Pol performance during Irene was interesting and intricate. It warrants a full paper on its own. However, below are a couple of examples of how the hurricane appeared with Dual Pol products.

In the Eye

An interesting thing that was seen as the eye of Hurricane Irene approached eastern North Carolina was low Correlation Coefficient (figure 51) and high Differential Reflectivity (figure 52) in the eye of the hurricane. This signature was also seen at 1.5 degrees in Correlation Coefficient (figure 53). It is believed that this may be showing birds flying in the eye of the storm. Another suggestion is that it's side lobes from the radar beam bouncing off the rough waters.

Figure 90: Correlation Coefficient, Eye of Hurricane Irene

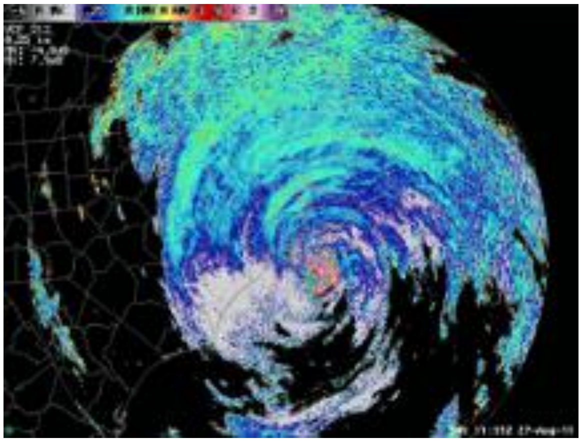

Figure 91: Differential Reflectivity, Eye of Hurricane Irene

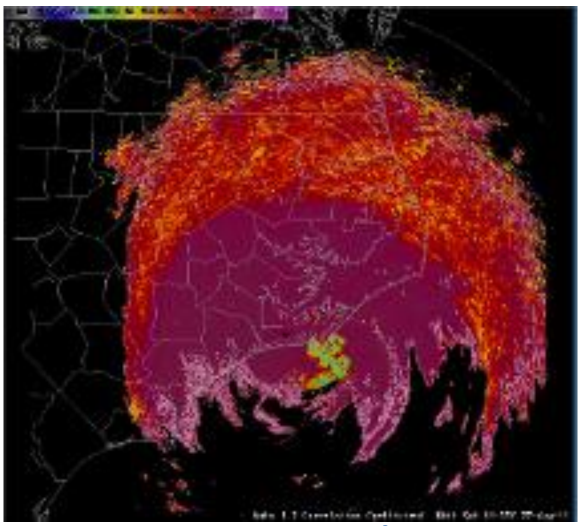

Figure 92: Correlation Coefficient, 1.5°, Eye of Hurricane Irene

Precipitation

Hurricane Irene stalled over central North Carolina for a few hours, allowing a large amount of rain to fall over those counties. The heaviest precipitation fell over Beaufort County. The highest report received was 15.66 inches at Bunyon (BNYN7). The color scale on the MHX radar was capped at 15 inches, but the STA (figure 54) was showing a maximum of 20.5 inches, and STP (figure 55) a maximum of 18.34 inches. Overall, the difference product (figure 56) showed STA was estimating an average of about 2 inches higher than STP, and observations support the higher estimates.

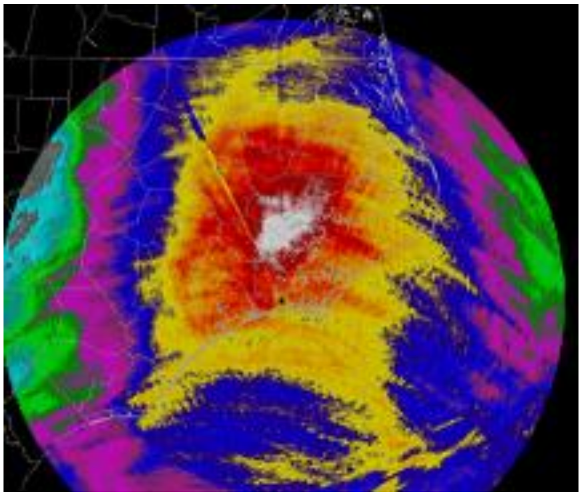

Figure 93: Dual Pol Storm Total Accumulation, Hurricane Irene

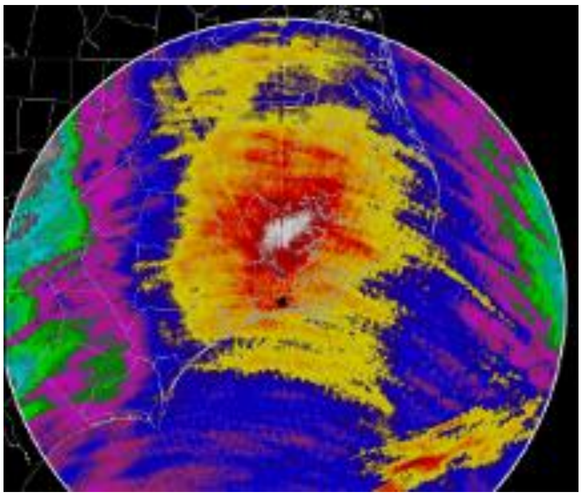

Figure 94: Legacy Storm Total Precipitation, Hurricane Irene

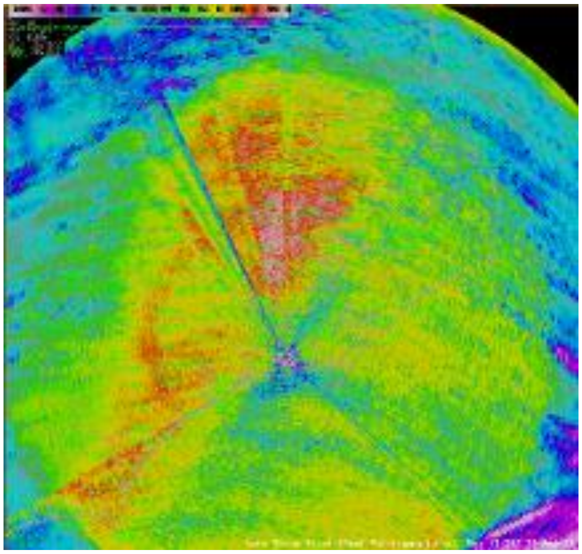

Figure 95: Dual Pol minus Legacy Storm Total, Hurricane Irene

Dual Pol QPE algorithms showed an improvement over the Legacy algorithms, but still remained below observed storm total precipitation. The Dual Pol precipitation estimation algorithms will need to be modified as time goes on based on observations to produce estimates approaching ground truth.

Dual-pol QPE does not use a bias to help with precipitation estimates. Instead, a number of different relationships are used based on the calculated hydrometeor in each bin. During Irene, it is expected that the R(Z,ZDR) relationship was used over the majority of the area. Legacy QPE used a bias factor of 1.2 in addition to using the tropical Z-R relationship that has been used in the past. Irene has shown that Dual Pol QPE algorithm is an improvement over the Legacy QPE algorithm.

0126Z, Unconfirmed Tornado

As the outer rain bands moved over the MHX CWA, a number of velocity couplets were observed on Storm Relative Velocity (SRM.) There were only three confirmed tornadoes during Irene. However, there aren't too many people outside during a hurricane, and as the tornadoes would have been rain-wrapped, they would have been difficult to see. So there may have been more tornadoes that were not reported.

At 0107Z, there was a line of rotational signatures in the SRM (figure 57) along the western Pamlico Sound. One of the couplets over the Pamlico Sound had lower CC (figure 58) associated with it, suspected to be a debris ball. Other couplets also looked strong, but there were no areas of lower CC (indicating debris balls) associated with them.

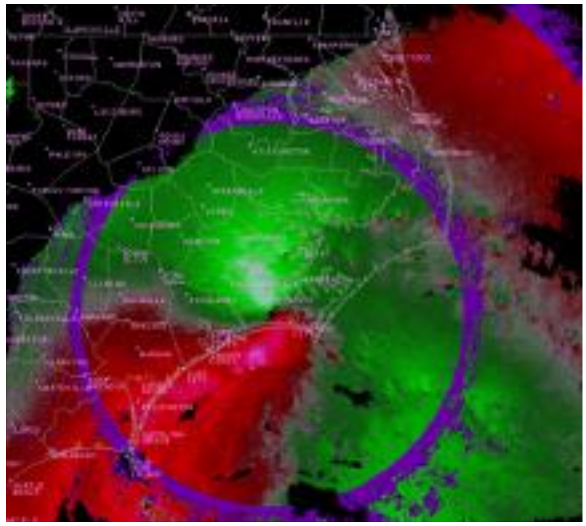

Figure 96: Storm Relative Velocity, Unconfirmed Tornado, Hurricane Irene

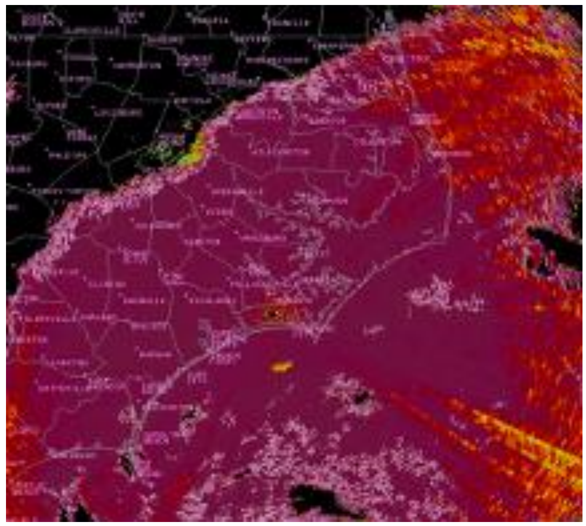

Figure 97: Correlation Coefficient, Unconfirmed Tornado, Hurricane Irene

A few volume scans later, at 0121Z, the rotational signatures were still present in SRM (figure 59), but the associated CC (figure 60) had increased a bit.

Figure 98: Storm Relative Velocity, Unconfirmed Tornado, Hurricane Irene

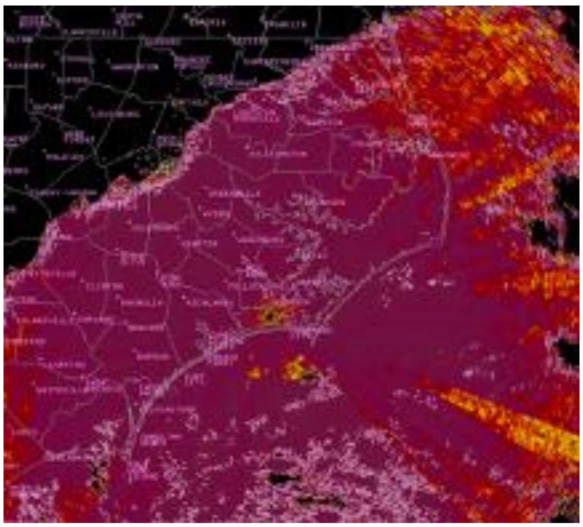

Figure 99: Correlation Coefficient, Unconfirmed Tornado, Hurricane Irene

In the next volume scan, 0126Z, the SRM (figure 61) shows continued good rotation with decreased CC (figure 62), around 0.85, associated with the rotation, and ZDR (figure 63) had decreased to around 0, all pointing to a good tornado debris ball. These signatures were around 57 nm from the radar. To see this type of signature at that distance means it was pretty significant.

Figure 100: Storm Relative Velocity, Unconfirmed Tornado, Hurricane Irene

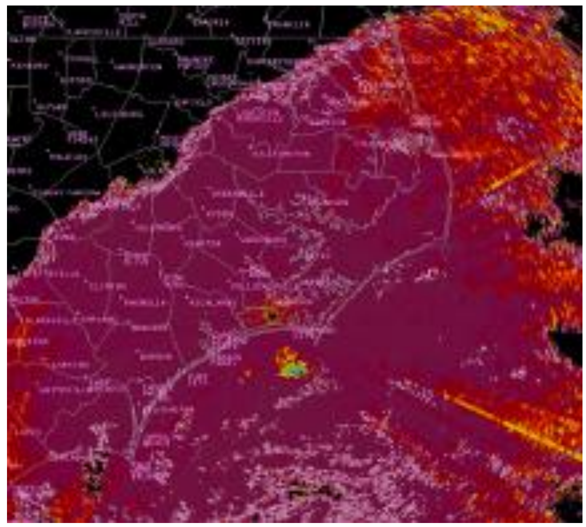

Figure 101: Correlation Coefficient, Unconfirmed Tornado, Hurricane Irene

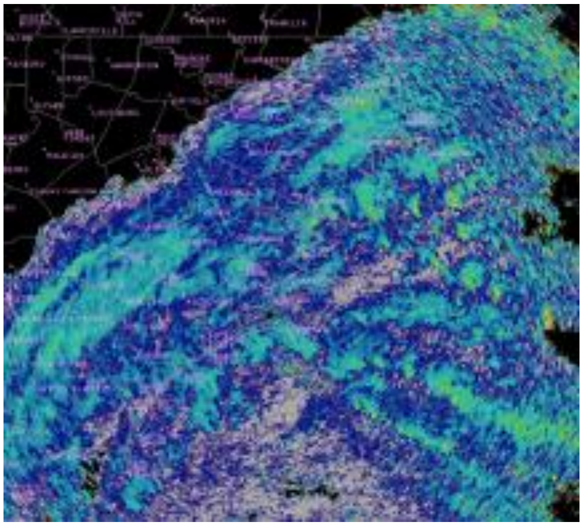

Figure 102: Differential Reflectivity, Unconfirmed Tornado, Hurricane Irene

There is a good chance that this was a tornado that was not reported.

At 0130Z, we are still seeing the strong rotation in SRM (figure 64) with decreased CC (figure 65). On the other hand ZDR (figure 66) has started to increase, even though it is still showing a local minimum. It is likely that most of the debris has fallen below the radar beam at this point.

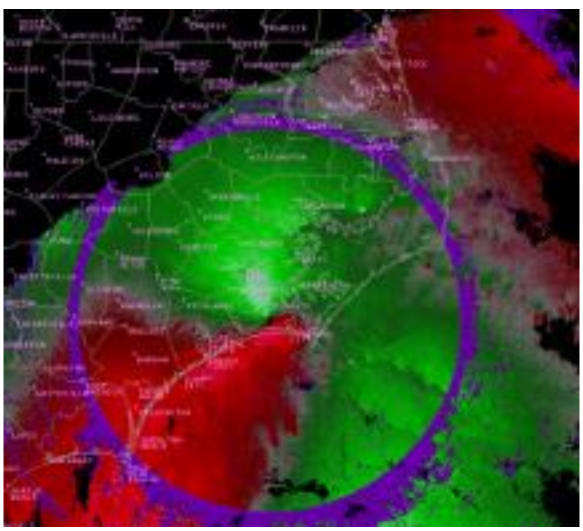

Figure 103: Storm Relative Velocity, Unconfirmed Tornado, Hurricane Irene

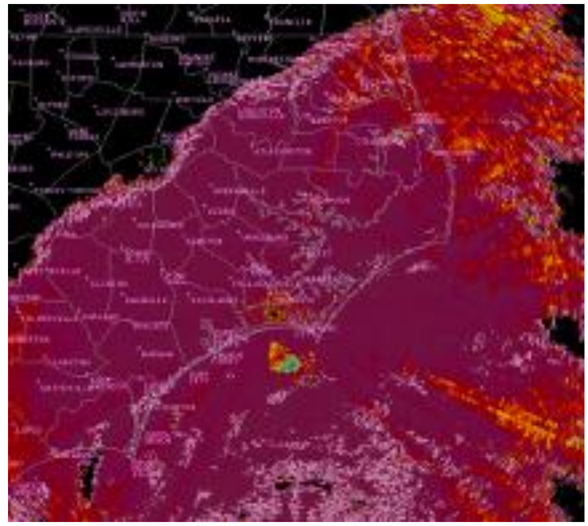

Figure 104: Correlation Coefficient, Unconfirmed Tornado, Hurricane Irene

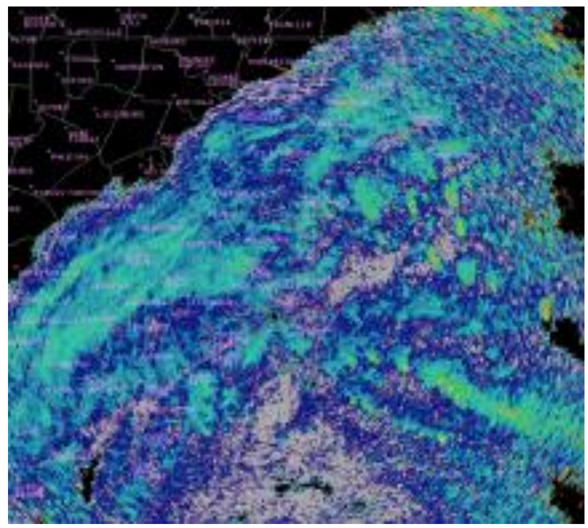

Figure 105: Differential Reflectivity, Unconfirmed Tornado, Hurricane Irene

That last volume scan for this event, at 0140Z, showed decreased rotation in SRM (figure 67) for the storm of interest. There are still other rotational signatures, but CC (figure 68) shows no sign of debris.

Figure 106: Storm Relative Velocity, Unconfirmed Tornado, Hurricane Irene

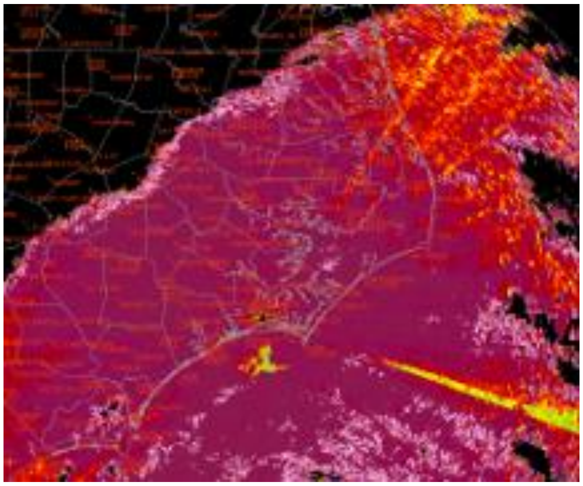

Figure 107: Correlation Coefficient, Unconfirmed Tornado, Hurricane Irene

Here are a couple more examples. In the first SRM (figure 69) we see a strong couplet south of Cape Hatteras. Looking at the CC (figure 70), we see a minimum, so this could have been a tornado, with the debris actually being sea water.

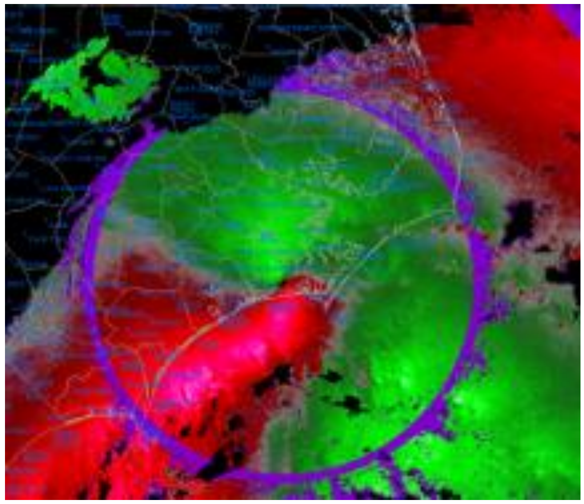

Figure 108: Storm Relative Velocity, Unconfirmed Tornado near Cape Hatteras, Hurricane Irene

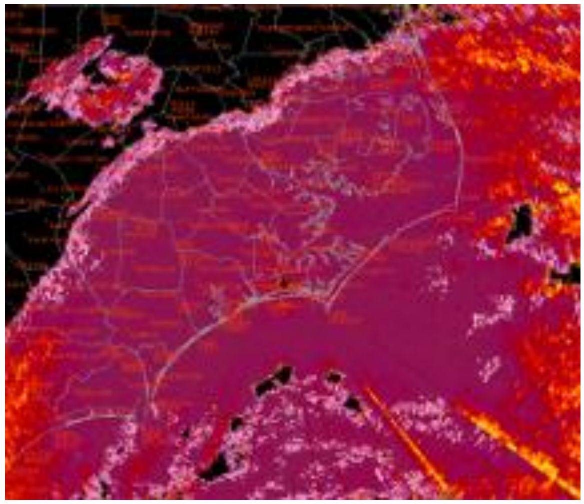

Figure 109: Correlation Coefficient, Unconfirmed Tornado near Cape Hatteras, Hurricane Irene

This second example shows a line of couplets extending westward from Cape Hatteras, with another one south of Cape Hatteras in the SRM data (figure 71). Only the one south of Cape Hatteras and the one immediately west of Cape Hatteras show a decent decrease in CC (figure 72). The other rotational signatures show little if any decrease in CC, so are not suspected tornadoes.

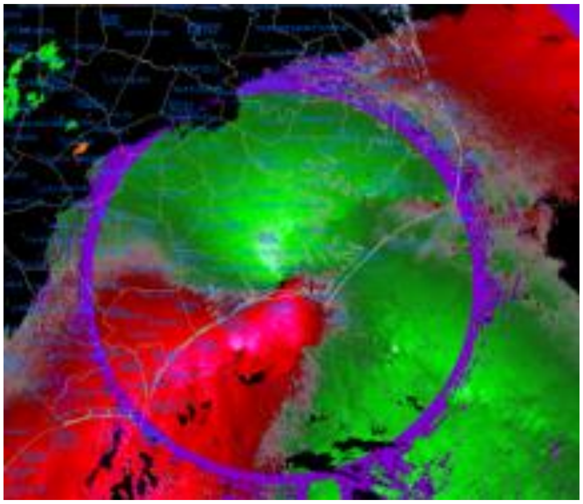

Figure 110: Storm Relative Velocity, more unconfirmed tornadoes, Hurricane Irene

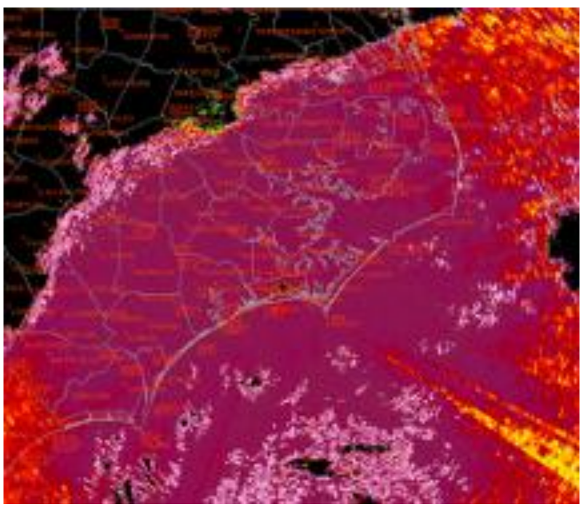

Figure 111: Correlation Coefficient, more unconfirmed tornadoes, Hurricane Irene

The final example (figure 73, figure 74) shows similar signatures as the previous two, but again this was over the waters, and there were no confirmations.

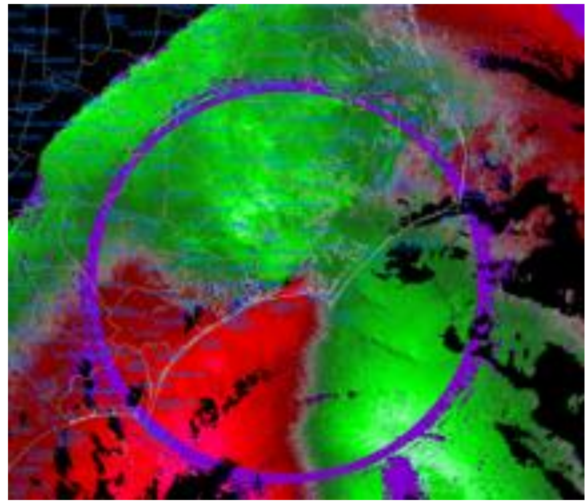

Figure 112: Storm Relative Velocity, spin-ups over water, Hurricane Irene

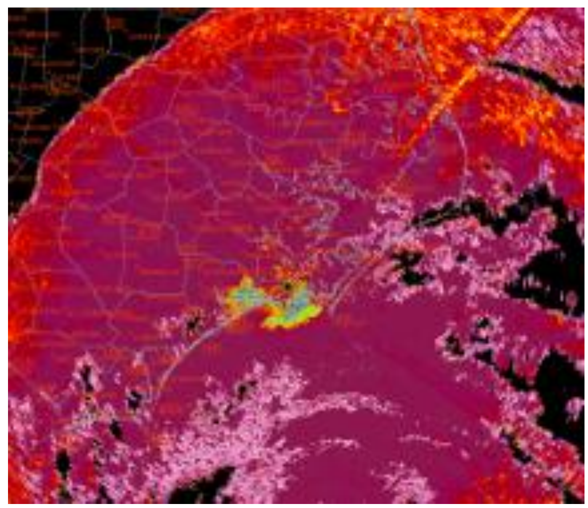

Figure 113: Correlation Coefficient, spin-ups over water, Hurricane Irene

0203Z, Belhaven Tornado

Let's look at the case of the confirmed tornado near Belhaven at 0212Z on August 27.

Reflectivity (figure 75): A number of mini supercells were observed in the right front quadrant of the storm.

Figure 114: Reflectivity, Belhaven Tornado, Hurricane Irene

Storm Relative Motion (figure 76): SRM showed couplets associated with many of the supercells, including the one in the vicinity of Belhaven.

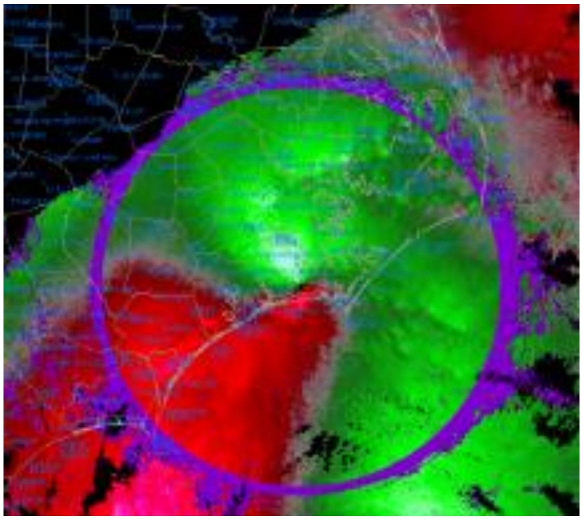

Figure 115: Storm Relative Velocity, Belhaven Tornado, Hurricane Irene

A tornado warning was in effect for the area based on base radar products.

Correlation Coefficient (figure 77): CC near Belhaven was around 0.90. There's also an area north of Bayboro with low CC. However, that area is associated with low Reflectivity, therefore it is not significant.

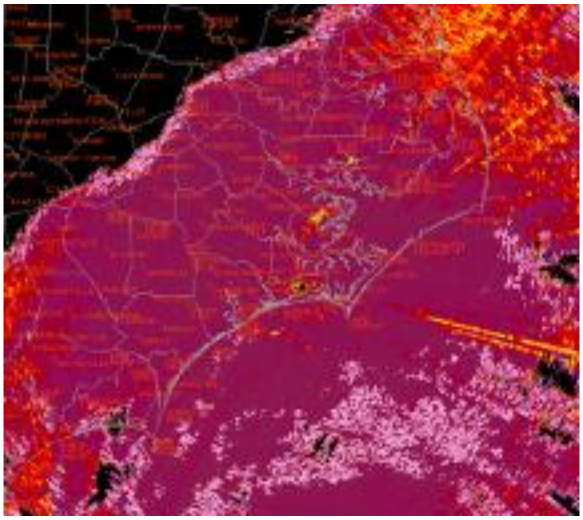

Figure 116: Correlation Coefficient, Belhaven Tornado, Hurricane Irene

Differential Reflectivity (figure 78): ZDR is pretty noisy, but we can see a good local minimum associated with the lower CC, indicating possible "tumbling objects".

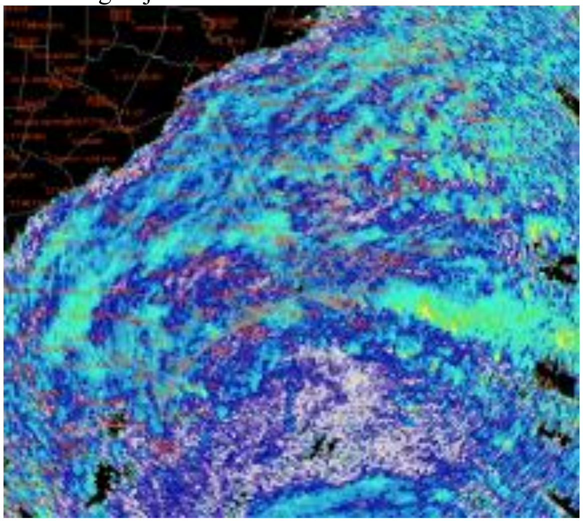

Figure 117: Differential Reflectivity, Belhaven Tornado, Hurricane Irene

The debris ball could be seen up at 1.5 degrees in Correlation Coefficient (figure 79). This circulation was around 50 nm from radar.

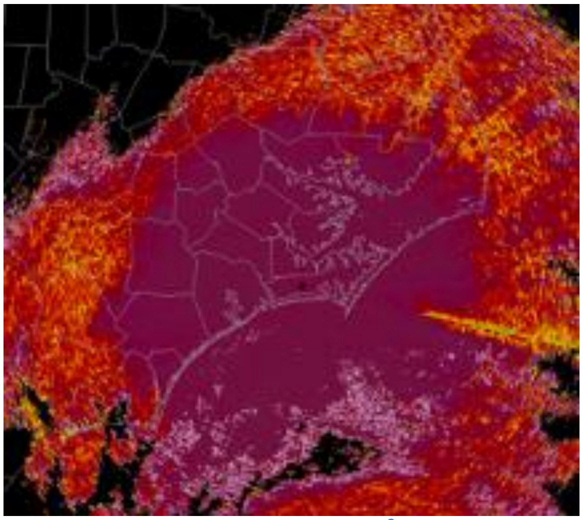

Figure 118: Correlation Coefficient 1.5°, Belhaven Tornado, Hurricane Irene

The debris ball was tracked in CC through at least 0226Z. The debris probably stayed aloft so long due to strong horizontal flow associated with the hurricane.

0355Z, Columbia Tornado

There was a confirmed EF2 tornado in Columbia around 0355Z, Aug 27, 2011.

Storm Relative Motion (figure 80): Unfortunately, this tornado occurred in the area of "purple haze" on our radar, so the rotational signature was not seen very well.

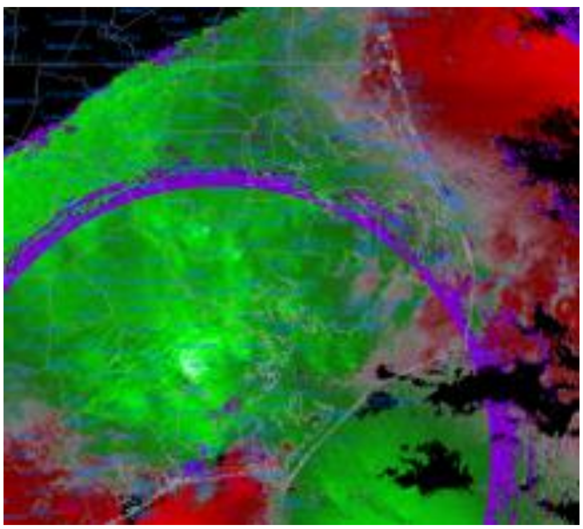

Figure 119: Storm Relative Velocity, Columbia Tornado, Hurricane Irene

Correlation Coefficient (figure 81): The debris ball was very evident in CC.

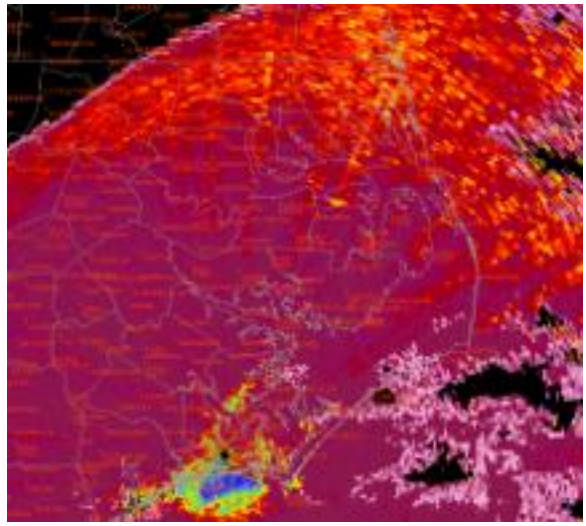

Figure 120: Correlation Coefficient, Columbia Tornado, Hurricane Irene

With CC well below 0.80, and a confirmation of an EF2 tornado, we are seeing a nice example of tornadic debris. Given that this storm was over 75 nm away from the radar, there must have been a lot of debris picked up to a large distance aloft. With the SRM signature being hidden by the purple haze, this is a good case where Dual Pol products were invaluable during the hurricane.

Hail?

While looking at Dual Pol products during Hurricane Irene, one of the things that that was of concern was how Hydrometeor Classification (figure 82) algorithm was indicating Hail associated with the rotational couplets (figure 83). Hail is unlikely in tropical situations, so these indications were called to question. After discussion with the Radar Operations Center, it was determined that what we were seeing were debris balls.

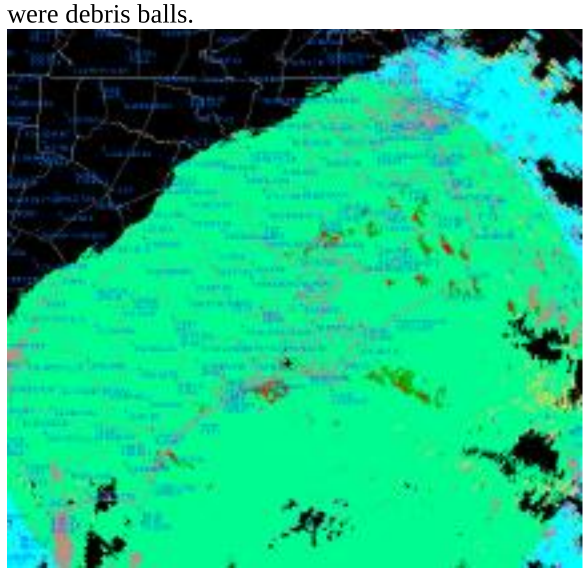

Figure 121: Hydrometeor Classification, Hurricane Irene

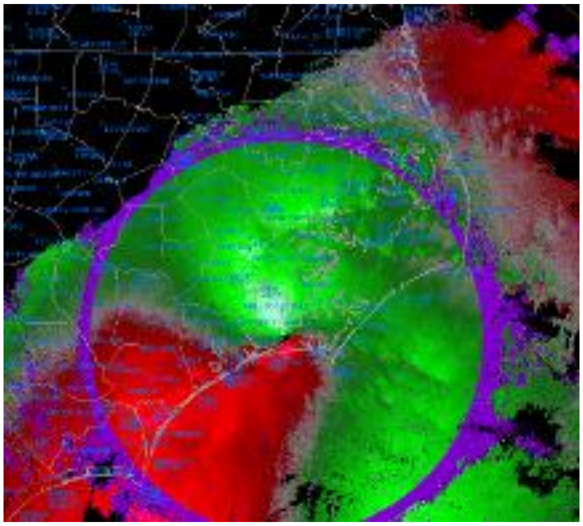

Figure 122: Storm Relative Velocity, Hurricane Irene

The high reflectivity due to the small raindrops collocated with lower Differential Reflectivity resulted in the hail classification in the HC. Not noticed during the storm, but discovered upon further investigation was that the Hail classifications were not limited to areas of SRM couplets. Areas where Reflectivity was 45-50 dBZ and Differential Reflectivity was less than 1 dB is where hail gets classified. This is explained by looking at the actual algorithms; Z and ZDR are weighted the highest. The higher ZDR values indicate bigger drops. One explanation for bigger drops in a tropical environment follows.

The smaller drop sizes in a hurricane are due to droplet collision, breaking a droplet into several smaller droplets. In a small area that is rotating, part of the rotation is embedded in the strong environment flow, and the relative speeds are lower. There is less collision between the drops in these area, allowing the drops to remain larger than in the overall tropical environment. This gives larger values of ZDR, and tricks Dual Pol Hydrometeor Classification algorithm into identifying Hail in those areas.

CONCLUSION

In the past 6 months since Dual Pol capabilities became available at the Newport/Morehead City NC WFO, we have seen many benefits of this radar advancement. This includes better confidence in identifying areas of hail and better rainfall amount estimates in areas that have hail contamination.

Improved QPE was quite evident during Hurricane Irene in August, 2011. Many cases of tornado debris balls were seen during the hurricane, and this will increase our confidence in issuing tornado warnings during future hurricanes.

Further investigation is needed on how to possibly tweak the Hydrometeor Classification algorithm to better filter out Hail classification during hurricanes. Research is also needed on how to better differentiate between severe hail and non-severe hail using Dual Pol products.

Lastly, while we saw vastly improved QPE during Hurricane Irene, estimated rainfall amounts were still less than what was observed. Continued work needs to be done to tweak rainfall estimation.