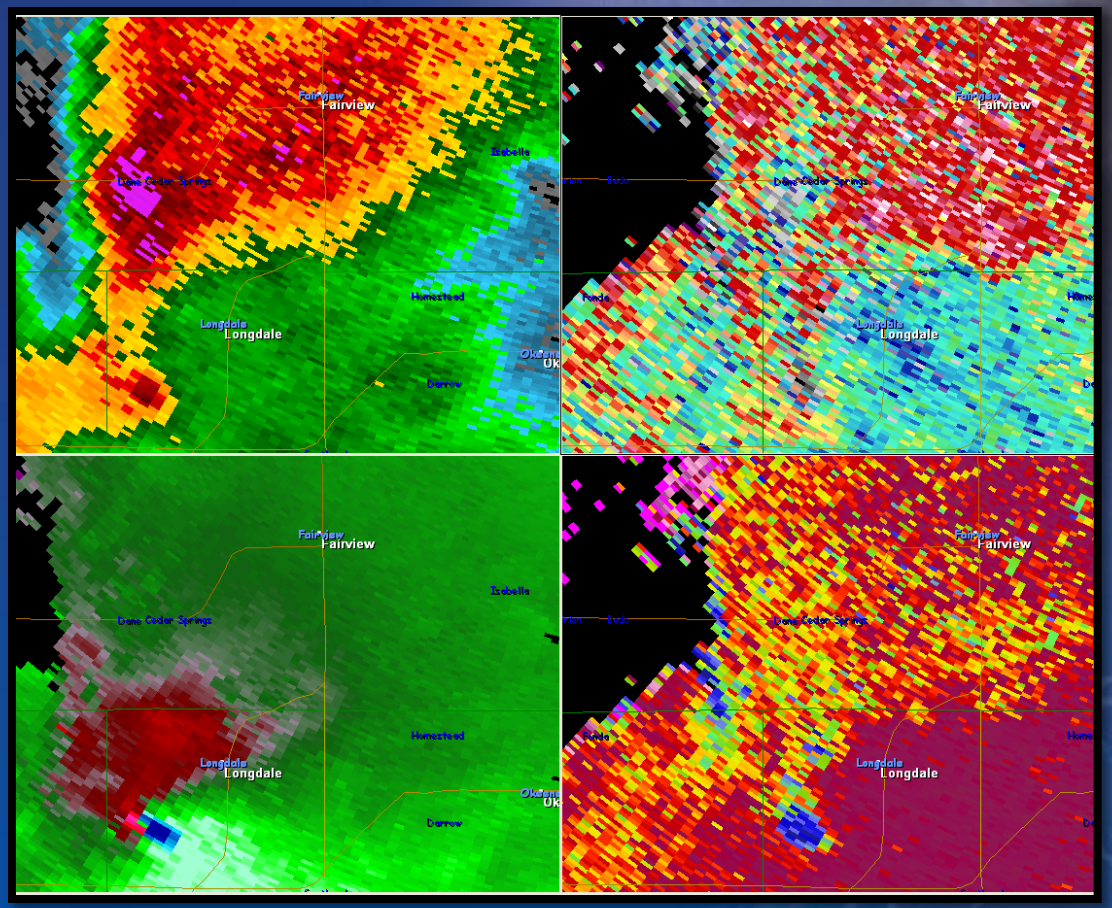
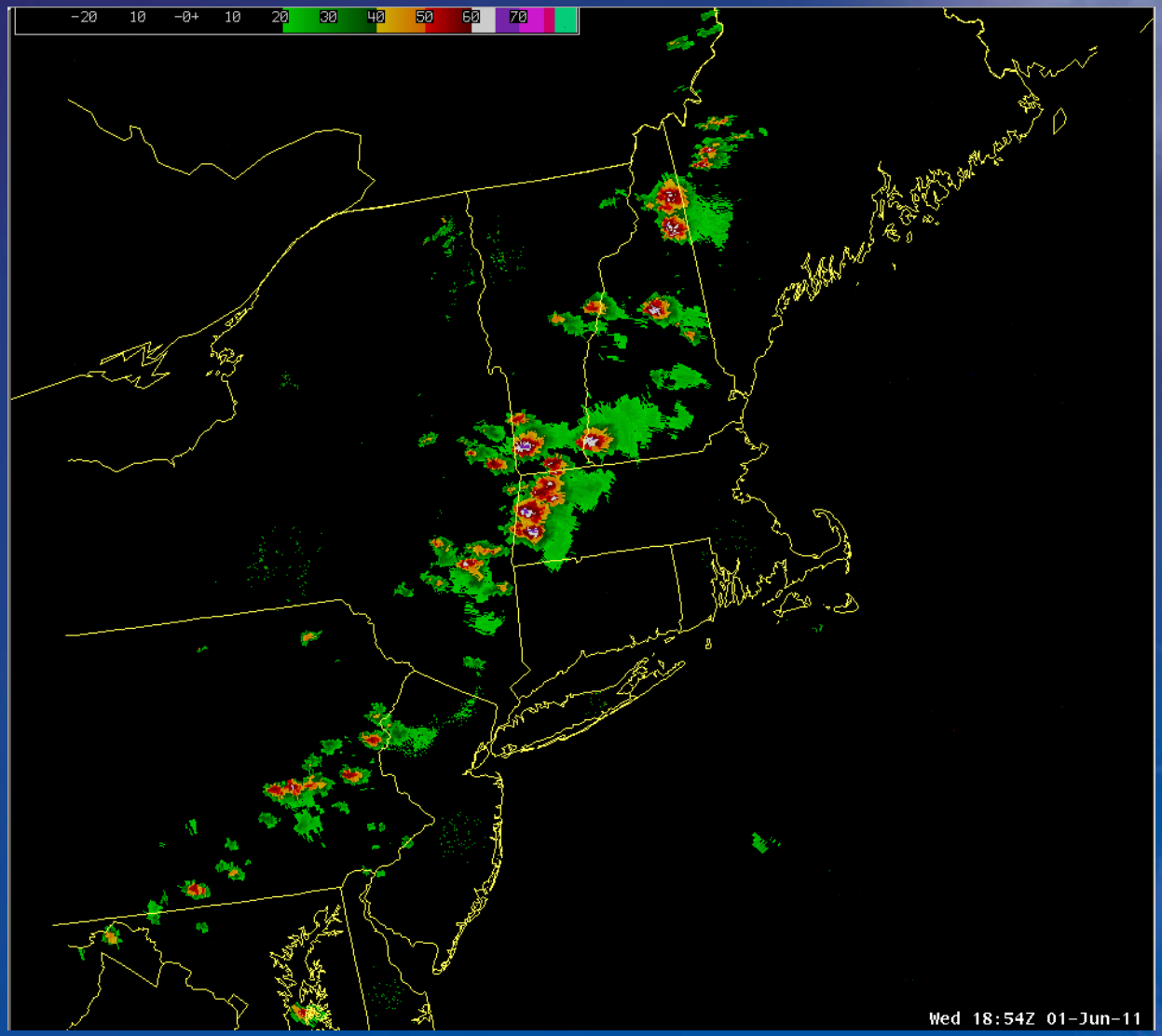
Applications of Dual-Pol Radar Data For Different Types of Weather

Outline

- Weather Scenarios
  - Severe Weather
  - Winter Weather
  - Tropical Weather
  - Precip Estimates

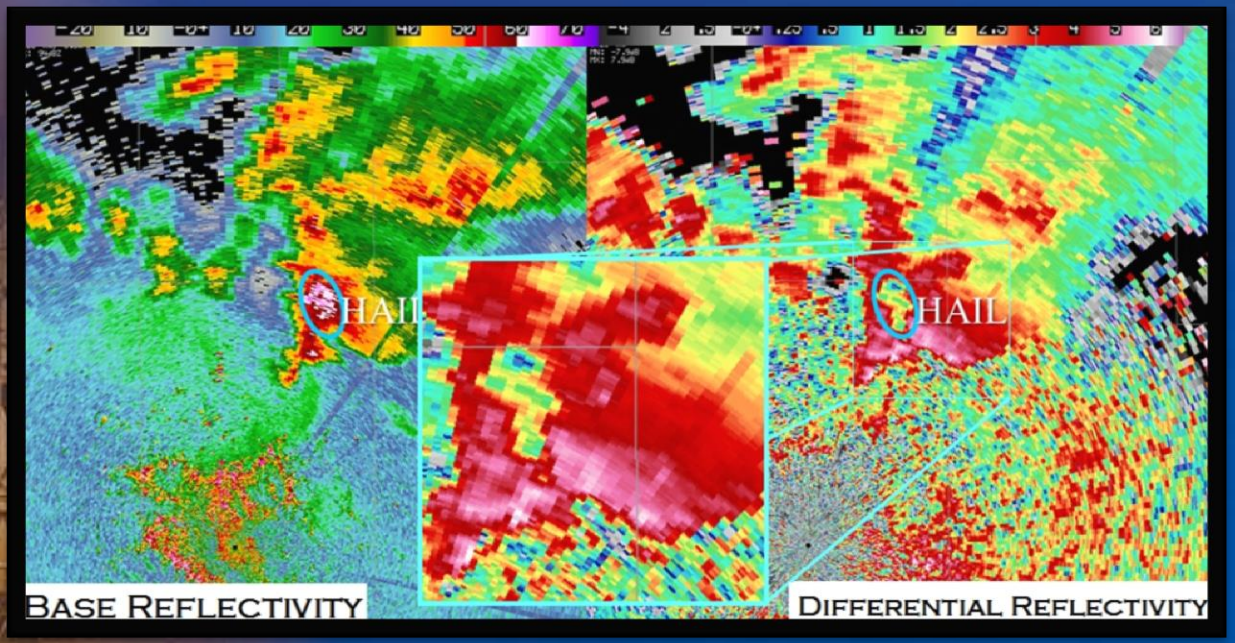


Severe Weather Applications

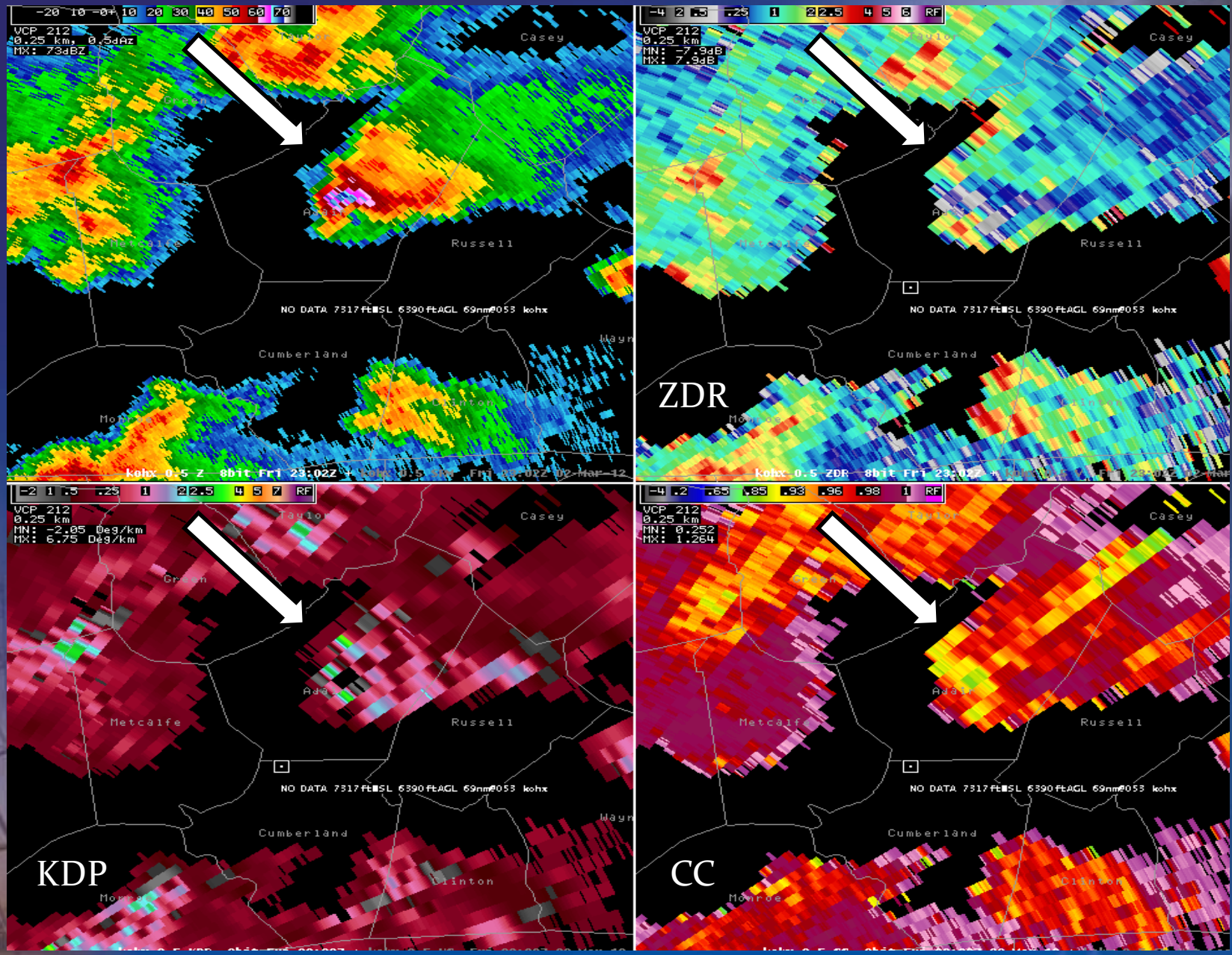


Dual-Pol Base – Hail Detection

- Very high Z (> 55 dBZ)
- Variable ZDR:
  - Usually low (-0.5 - +1.5dB)
  - Positive when mixed with rain!
- Low CC (0.70-0.95)
- If melting hail, high KDP (>1.5 deg/km)

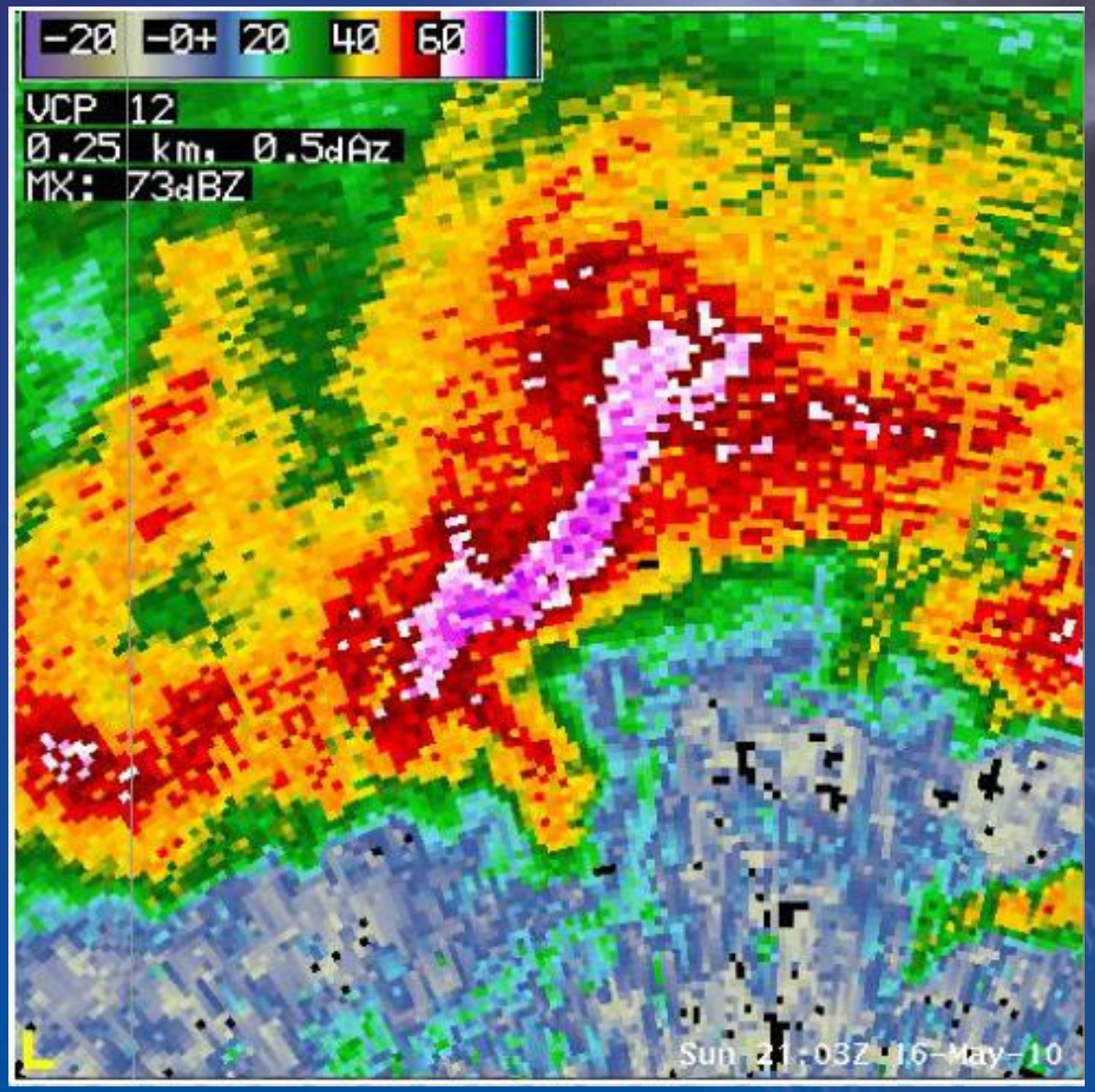


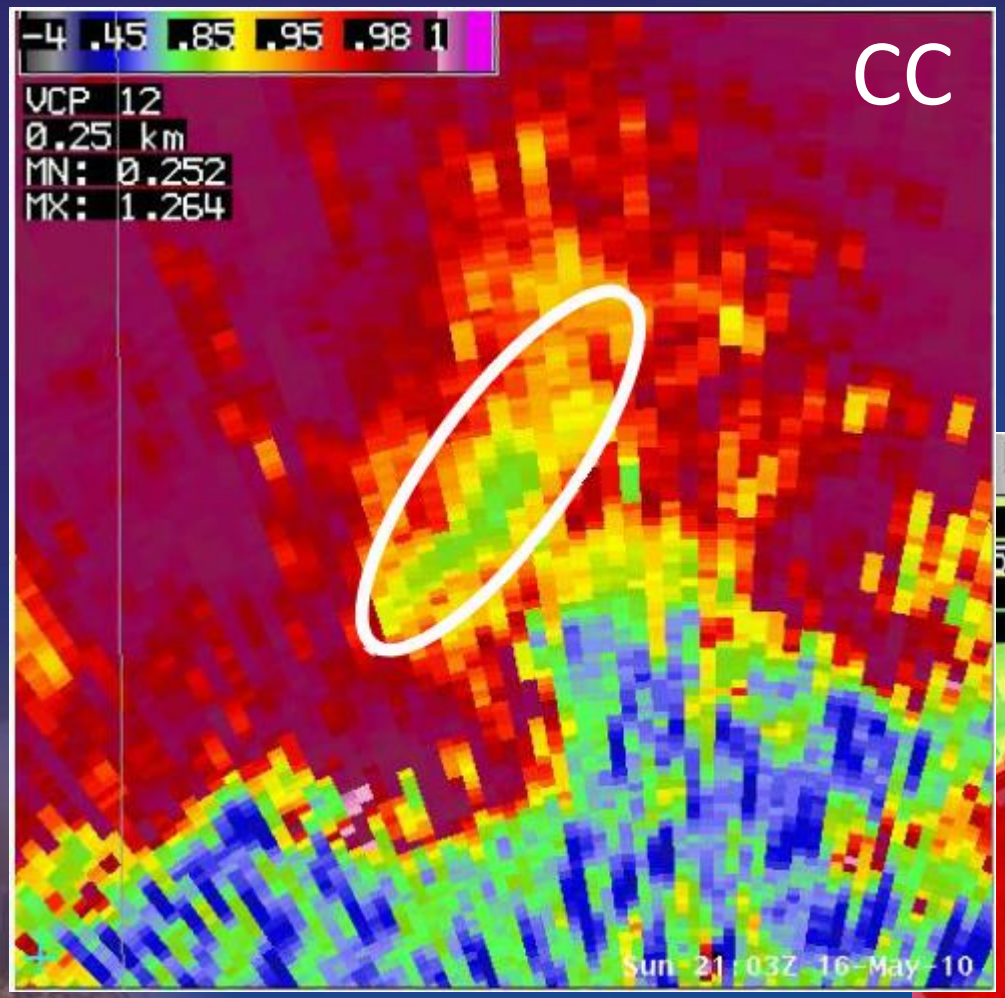
March 2, 2012 Damaging Hail in Adair Co., KY



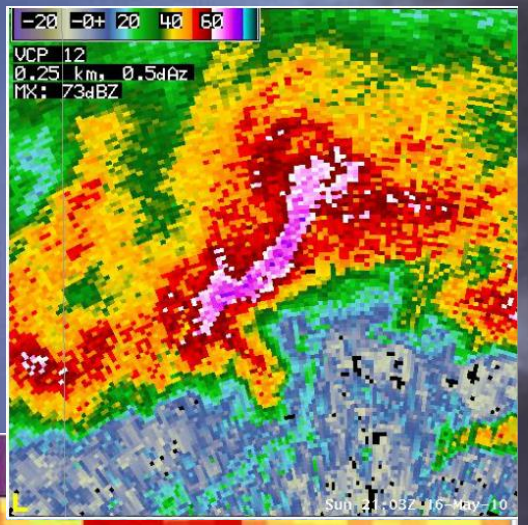
Special Case of Giant Hail > 2 inches

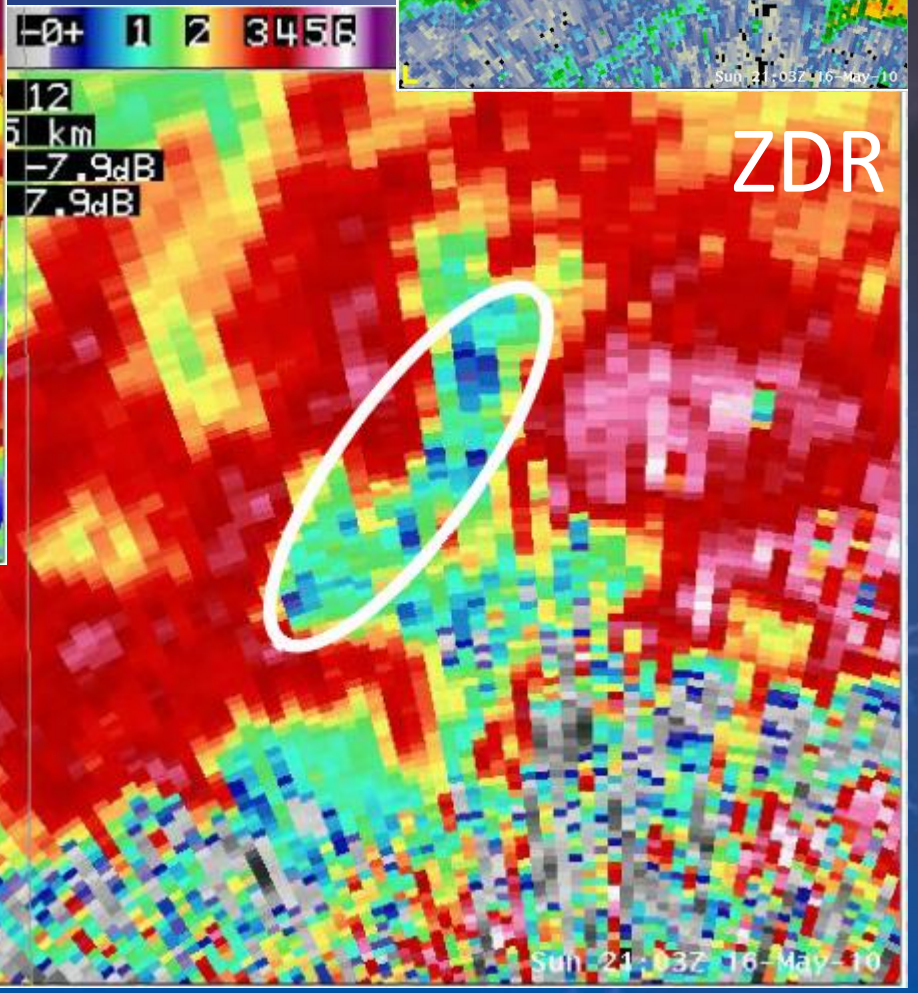
This storm produced softball sized hail just prior to this image.





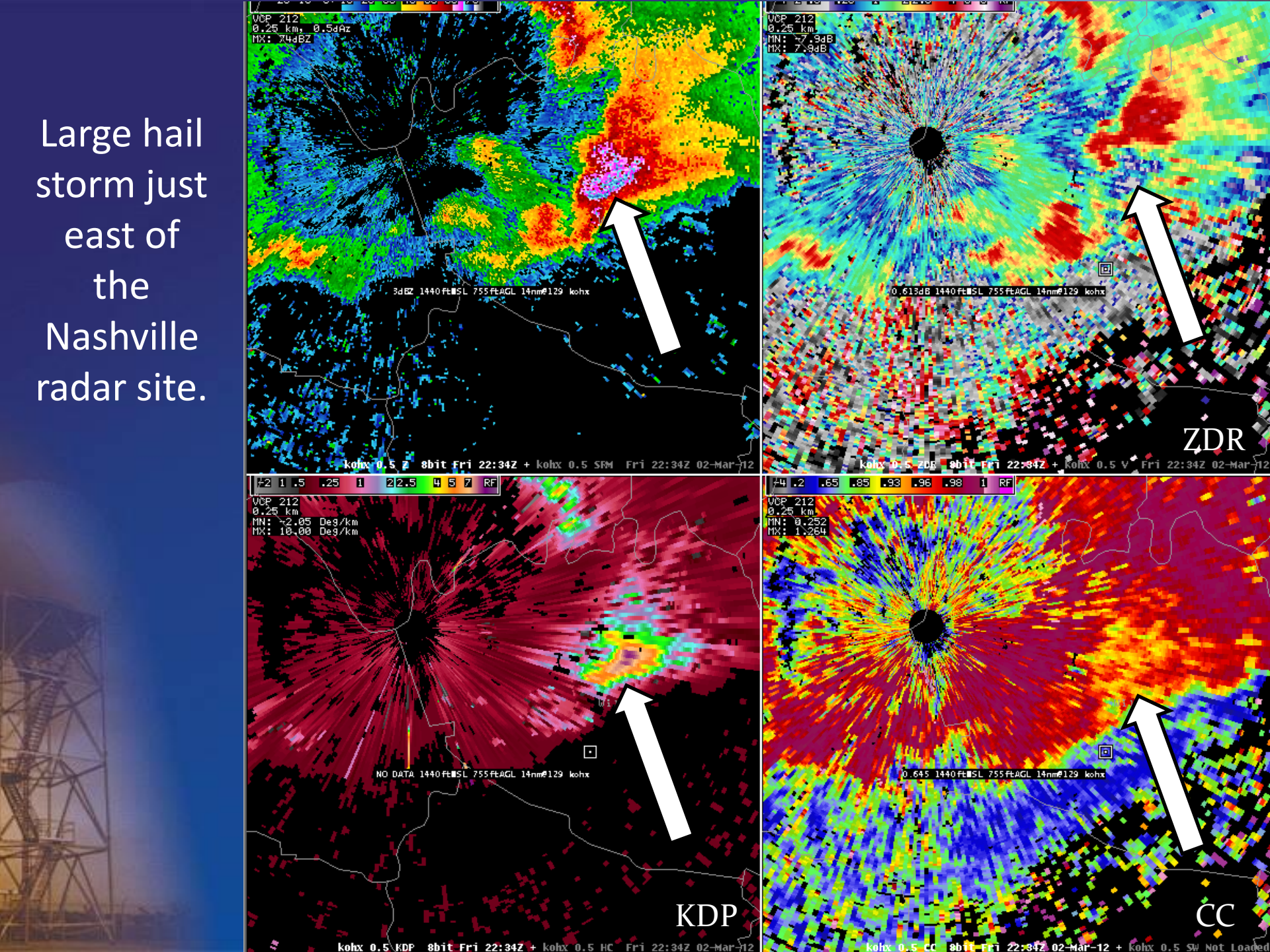
CC is less than 0.85 in the core of the storm.



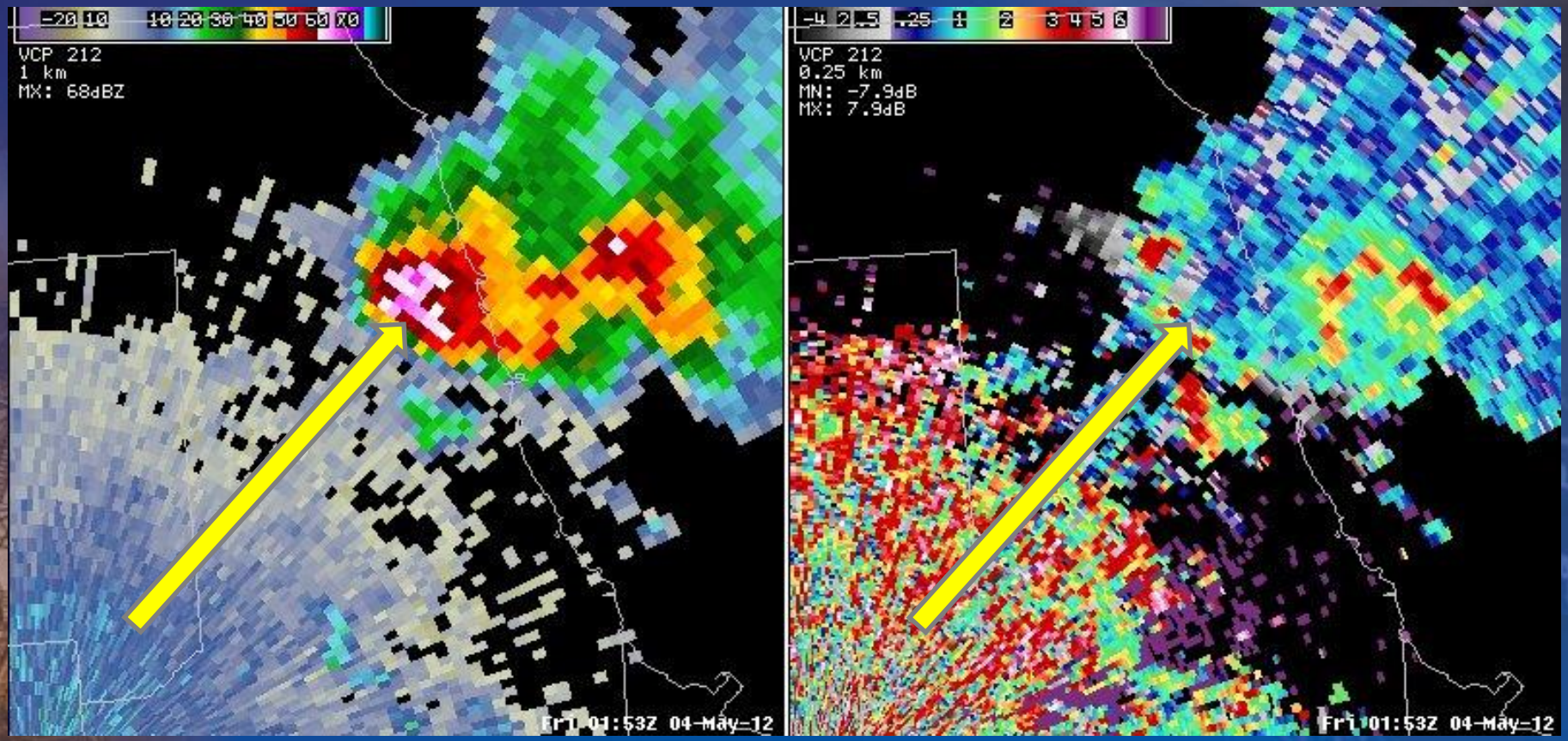


ZDR is very low, with even some negative values associated with Mie scattering.

Large hail storm just east of the Nashville radar site.

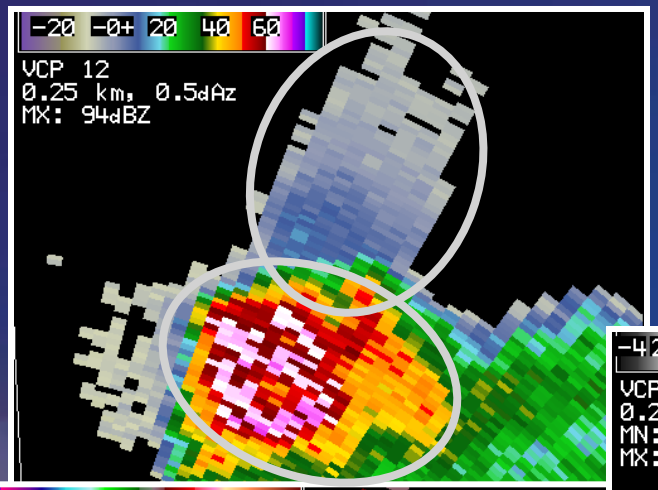


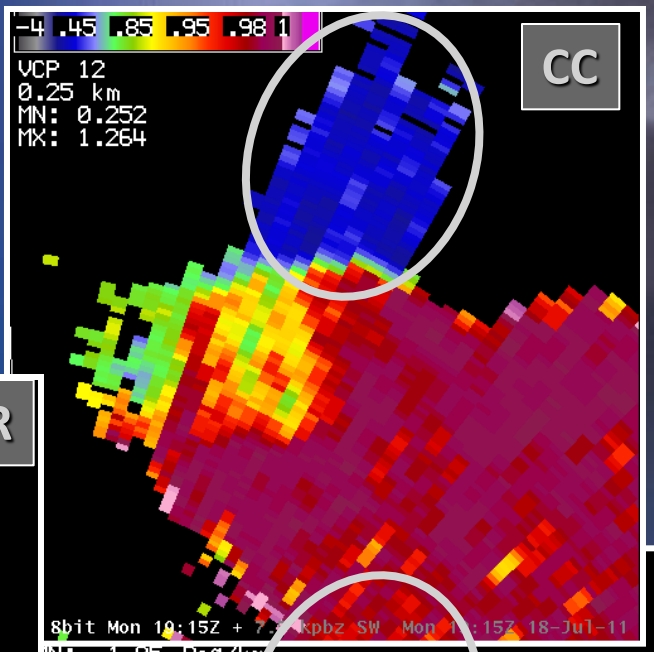
Intense reflectivity on the left corresponds with low ZDR. This storm produced golfball sized hail north of Chicago.

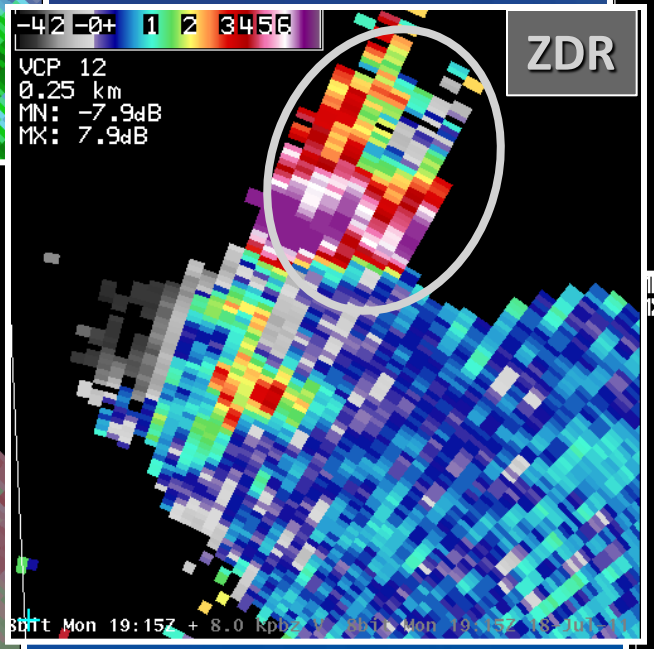


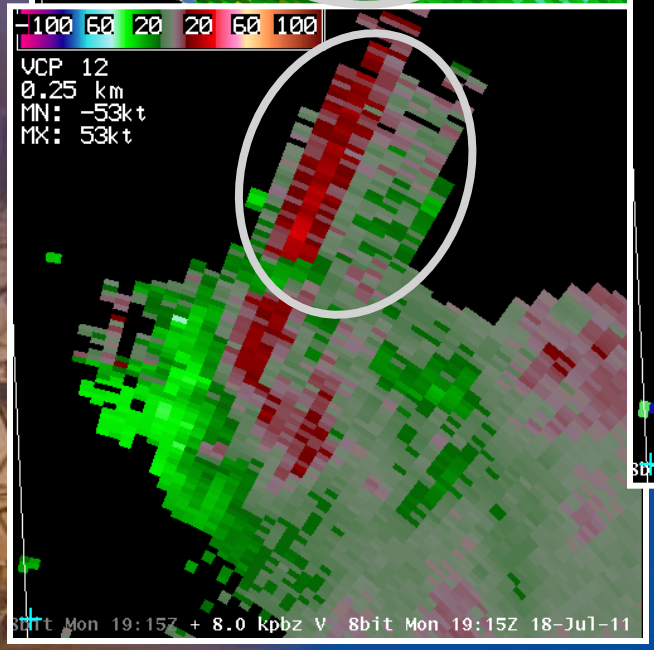
TBSS Example from Pittsburgh, PA

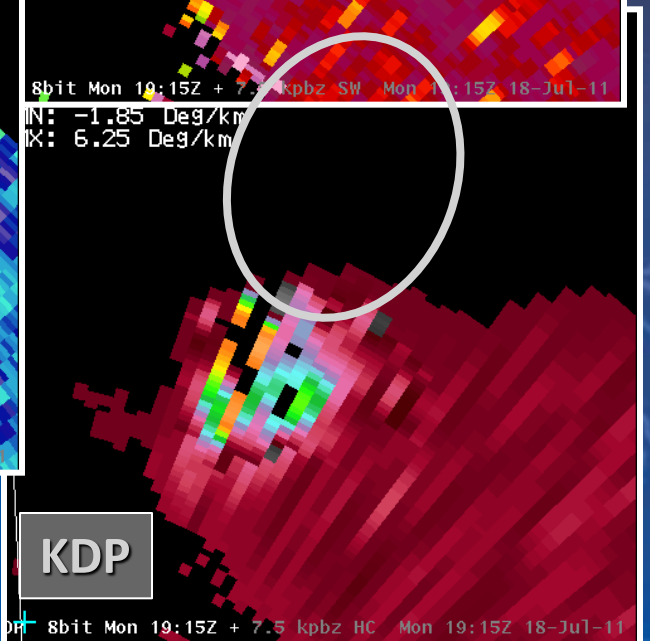
7/18/11
19:15Z
8.0°





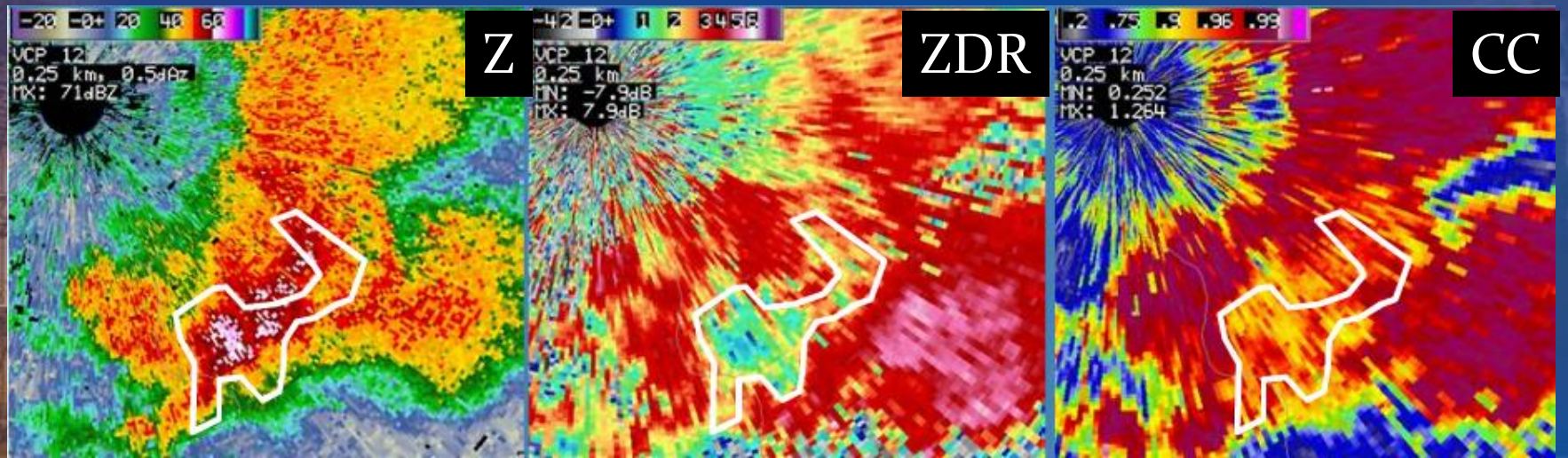






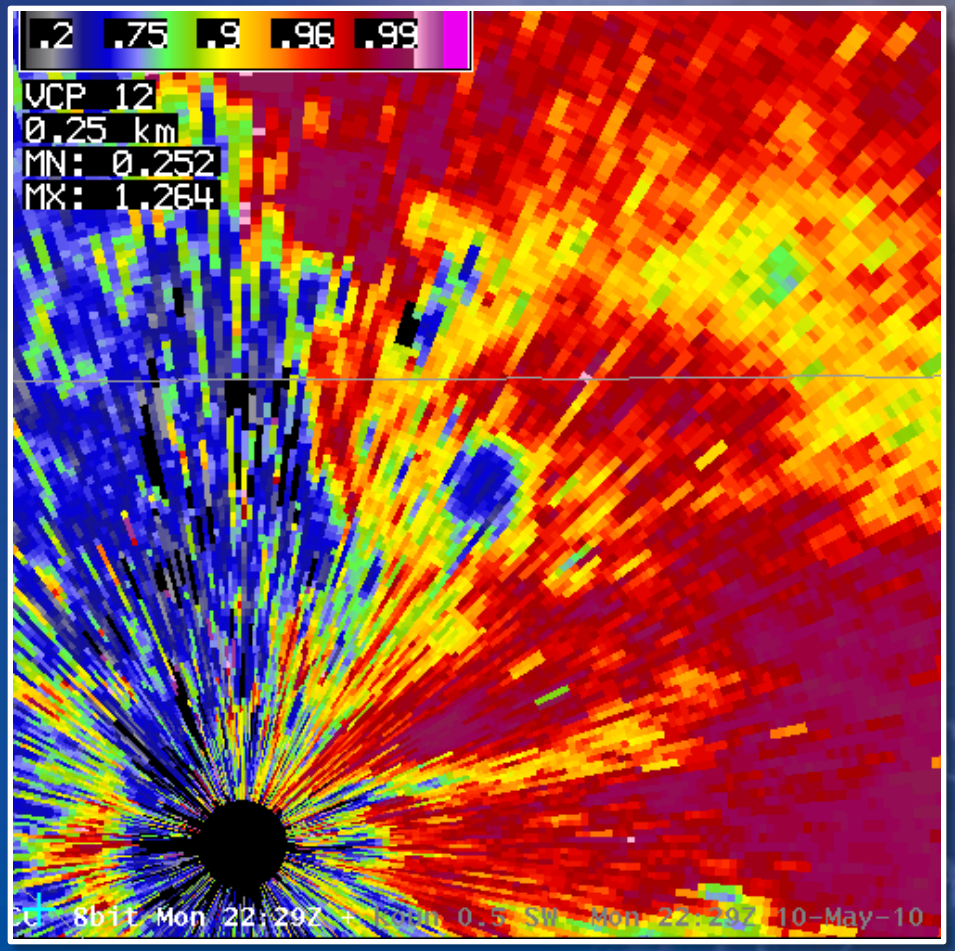
Strengths and Limitations of Dual-Pol Hail Detection

- **Strengths**
  - More robust than using Z alone
    - Can see hail signature in ZDR and/or CC even when Z is questionable
  - Can detect significant hail (> 2 inches diameter)
  - TBSS easier to detect
- **Limitations**
  - No explicit size estimation
    - No differentiation between marginally severe and non-severe hail
  - If hail is detected, sometimes not possible to tell if it's reaching ground

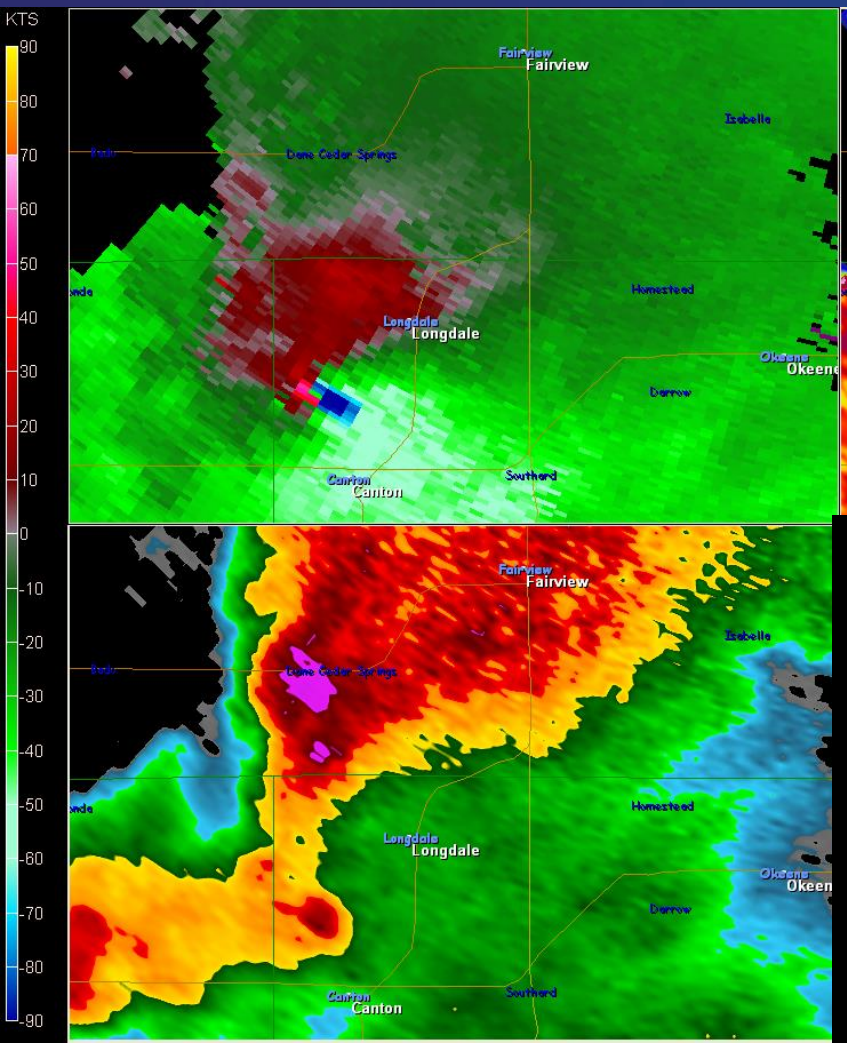


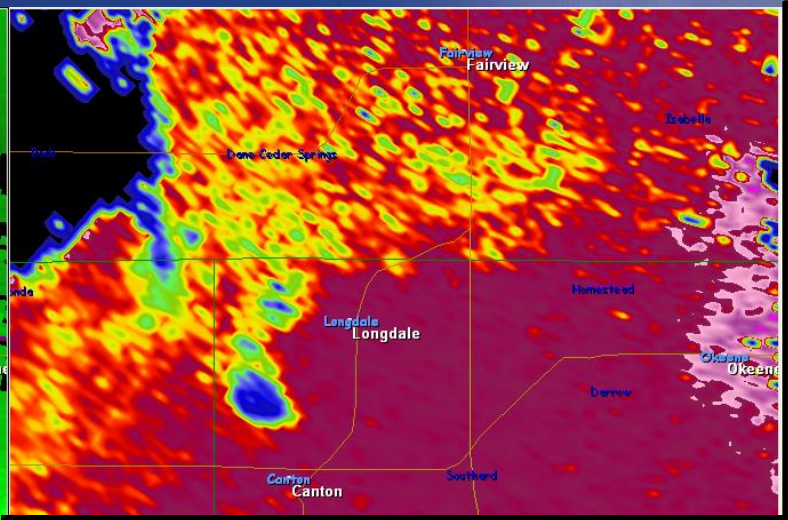
Dual-Pol – Tornadic Debris Signature

- Must have strong rotational signature in SRM
- High reflectivity
- CC typically less than ~0.80
- It really helps if feature is close to the radar



Tornadic Debris Aloft from Vance AFB, OK – 5/24/11

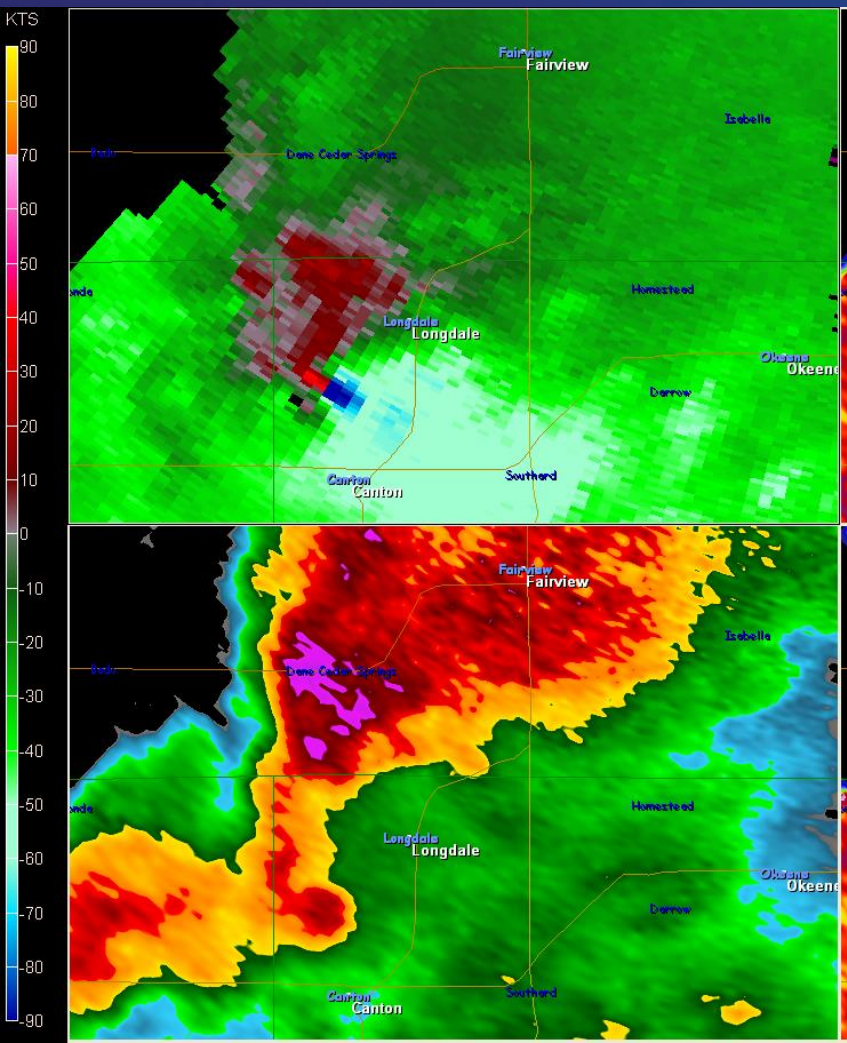


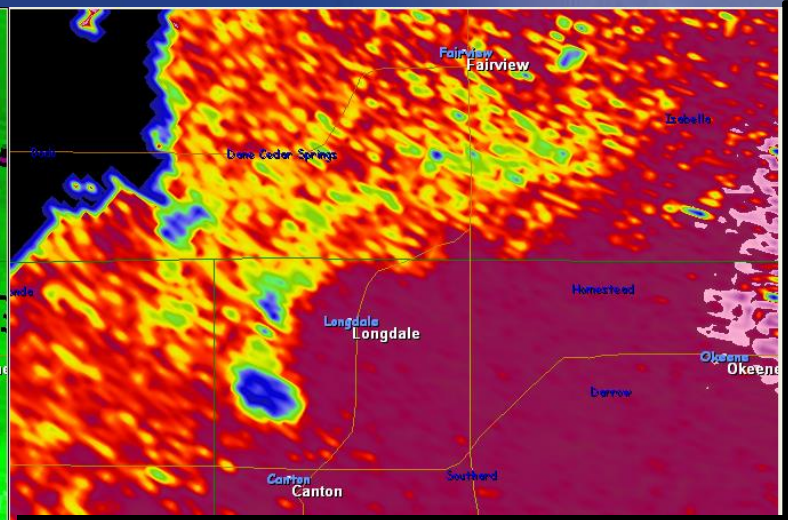


4,000 ft

- CC at 0.5°
- Debrid ball signature
- Low CC values – less than 0.7

Tornadic Debris Aloft from Vance AFB, OK – 5/24/11

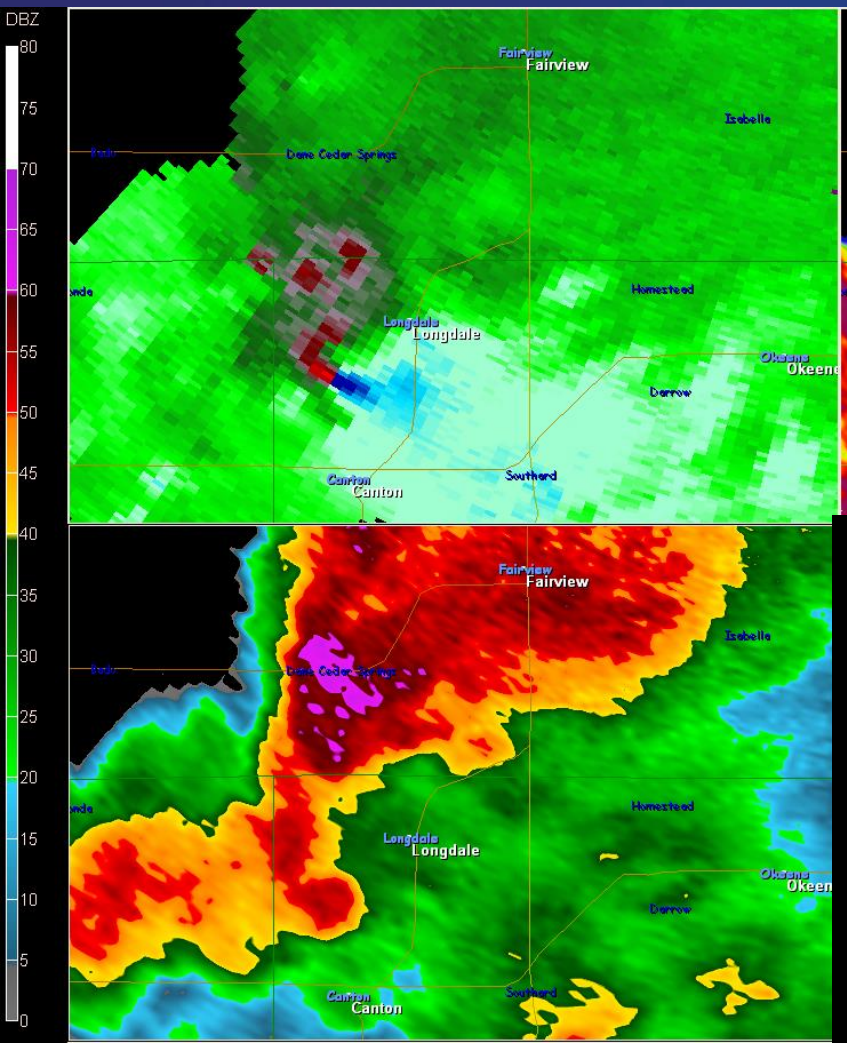


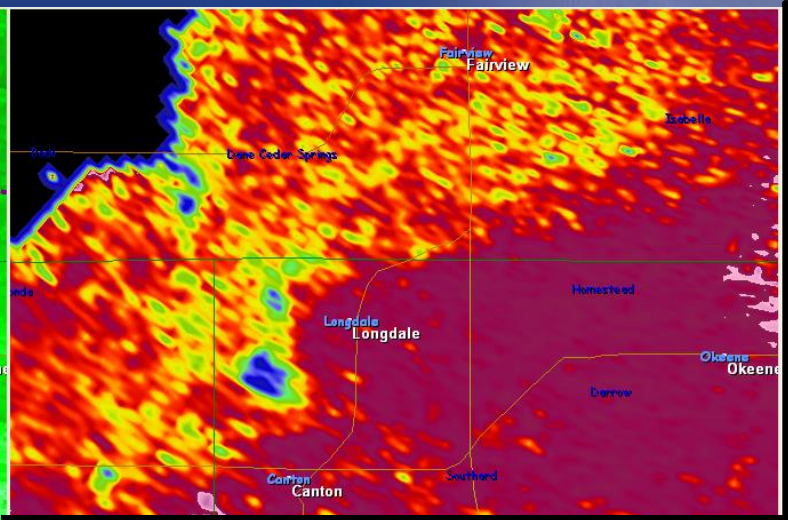


5,800 ft

- CC at 0.9°
- Debris ball signature
- Low CC values – less than 0.7

Tornadic Debris Aloft from Vance AFB, OK – 5/24/11

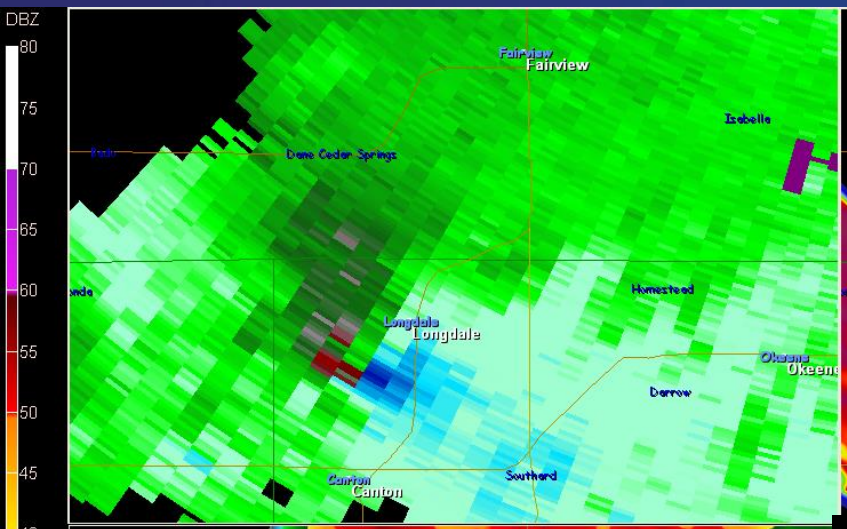


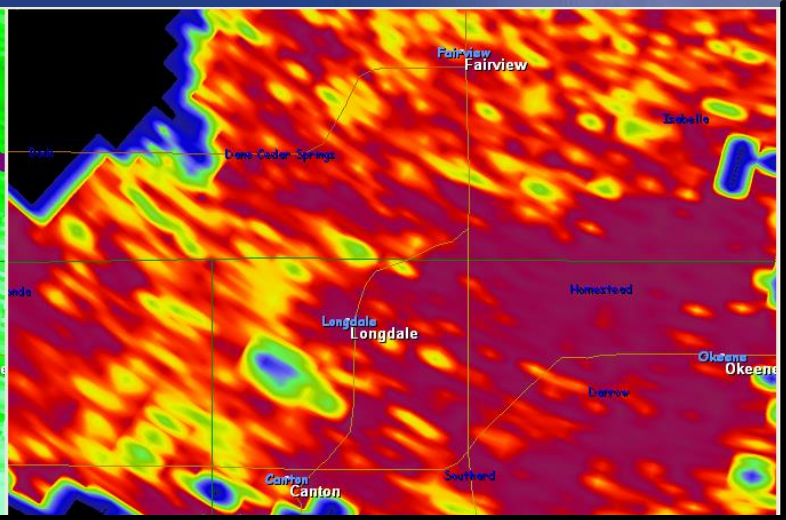


7,600 ft

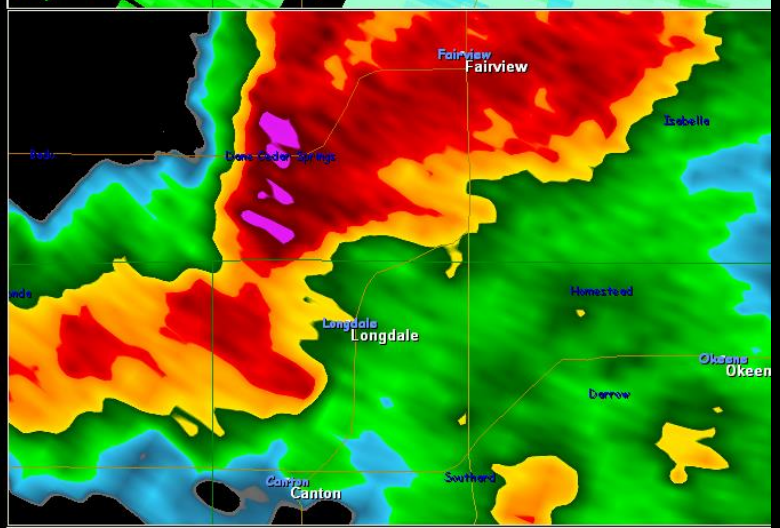
- CC at 1.3°
- Debris ball signature still impressive
- Low CC values – less than 0.7

Tornadic Debris Aloft from Vance AFB, OK – 5/24/11



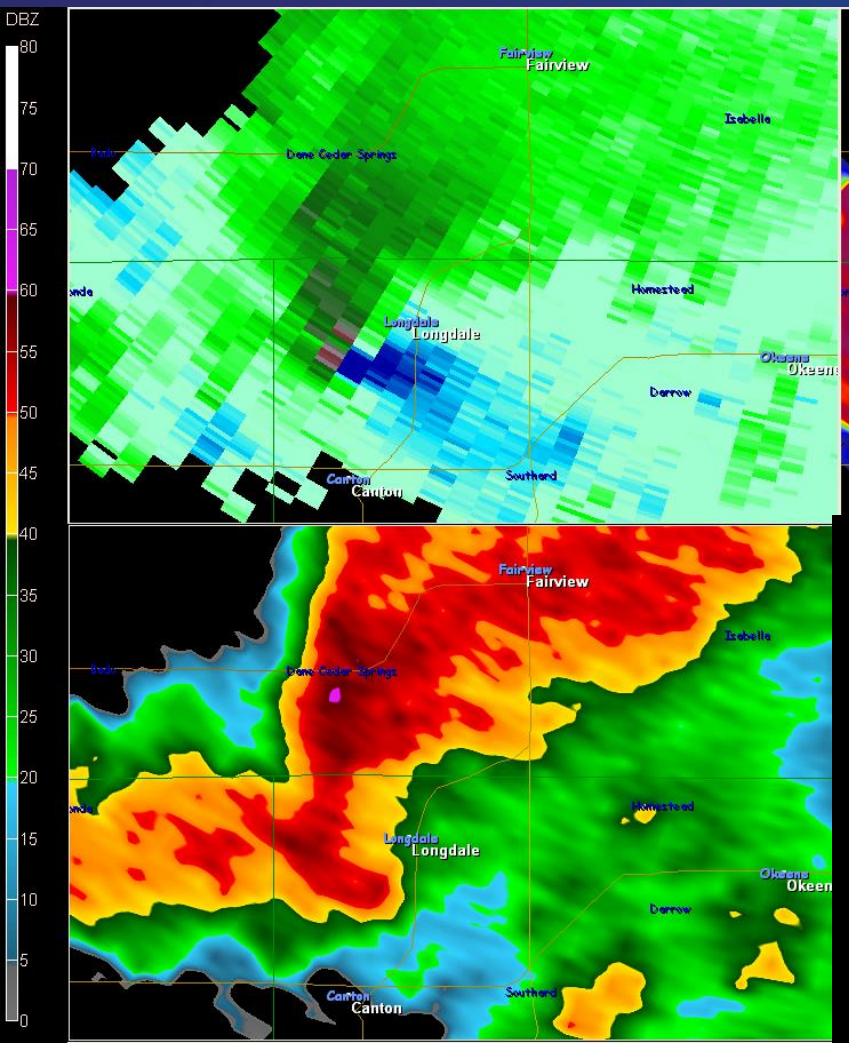


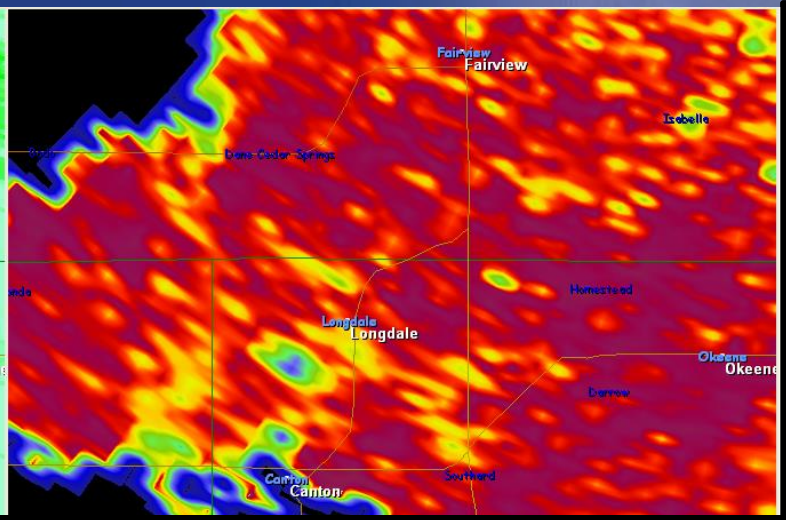
10,000 ft



- CC at 1.9°
- Debris ball signature not as impressive but still noticeable
- Low CC values – less than 0.75

Tornadic Debris Aloft from Vance AFB, OK – 5/24/11

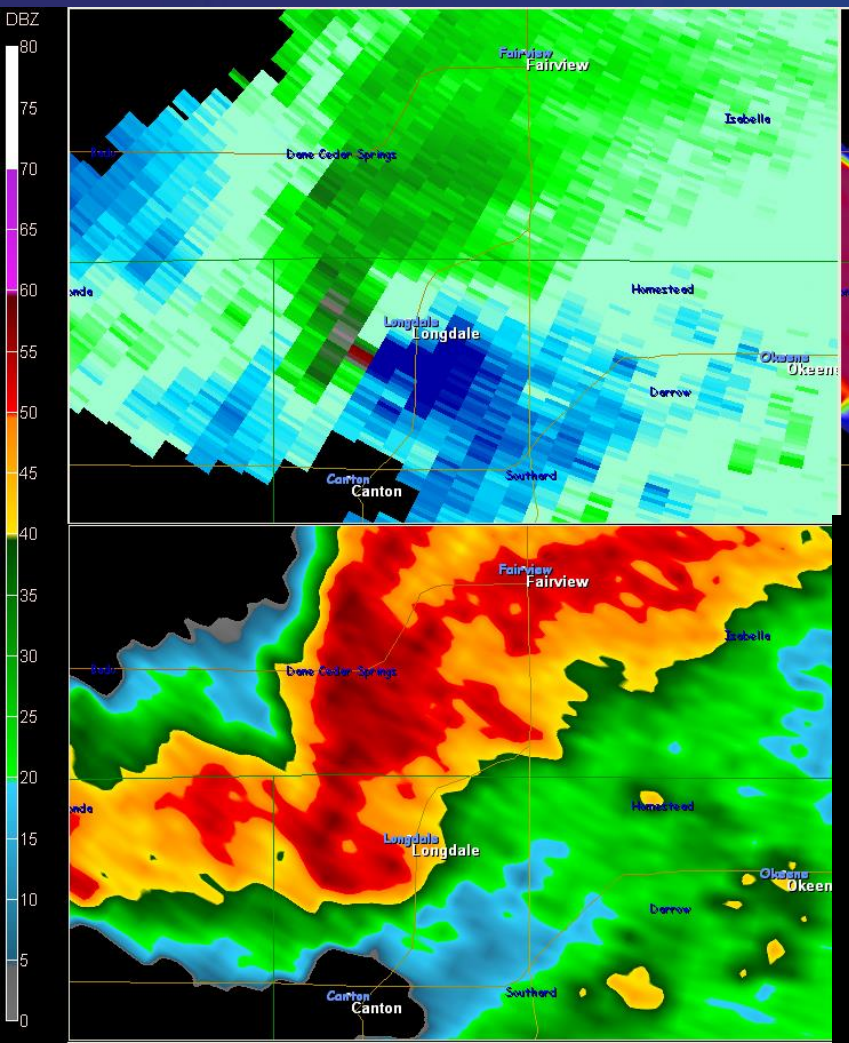


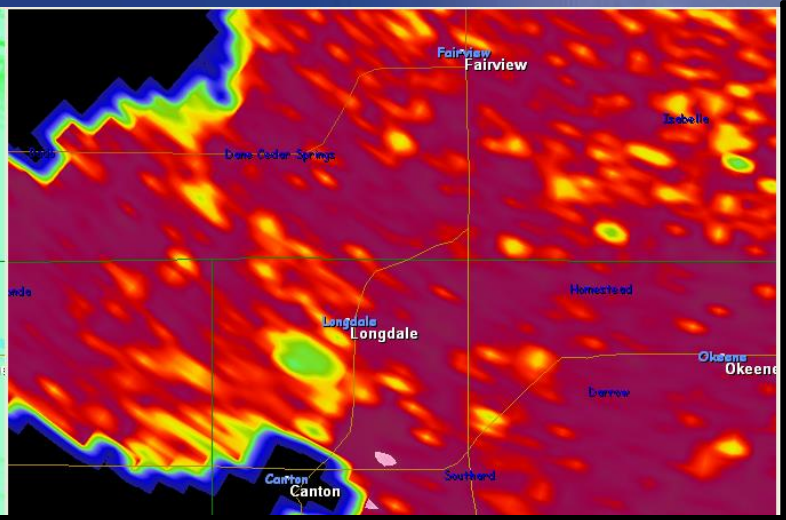


12,700 ft

- CC at 2.5°
- Debris ball signature still there, but less noticeable
- Low CC values – less than 0.75

Tornadic Debris Aloft from Vance AFB, OK – 5/24/11

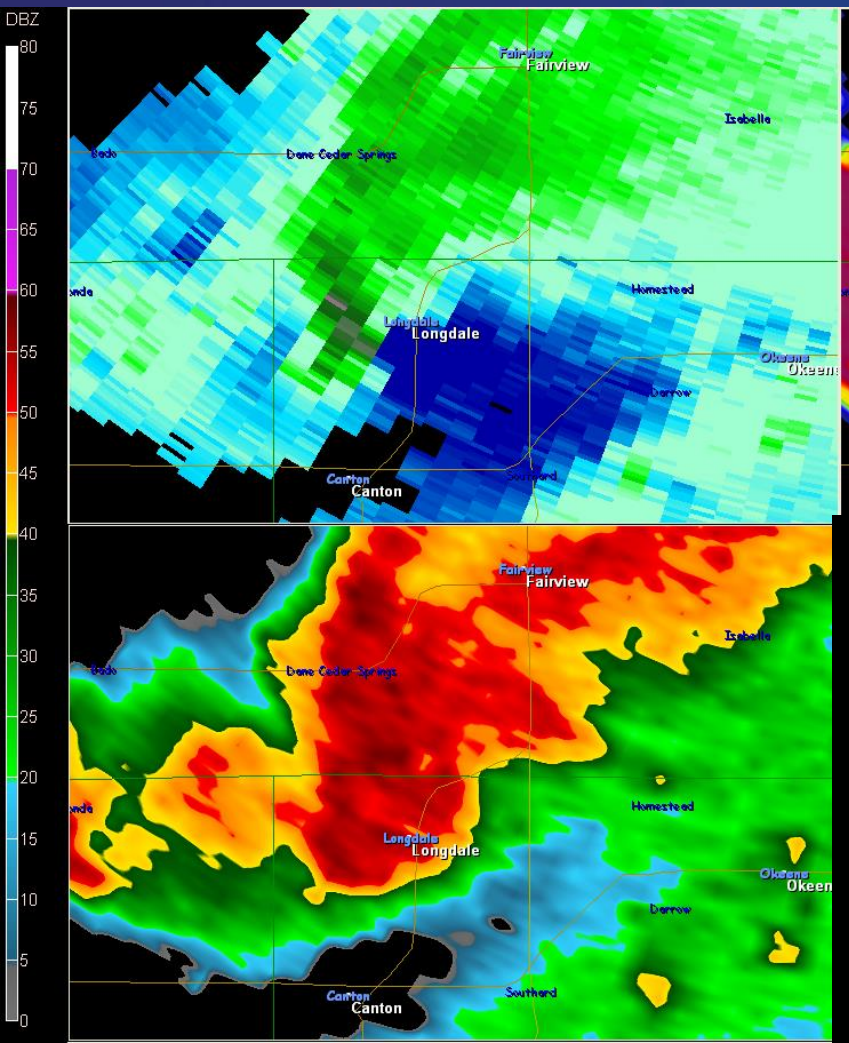


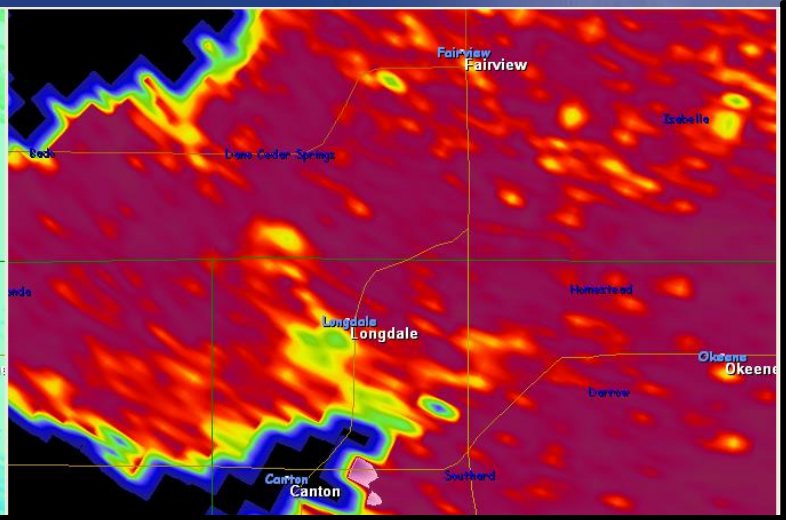


16,000 ft

- CC at 3.2°
- Debris ball signature still noticeable
- Low CC values – less than 0.85

Tornadic Debris Aloft from Vance AFB, OK – 5/24/11

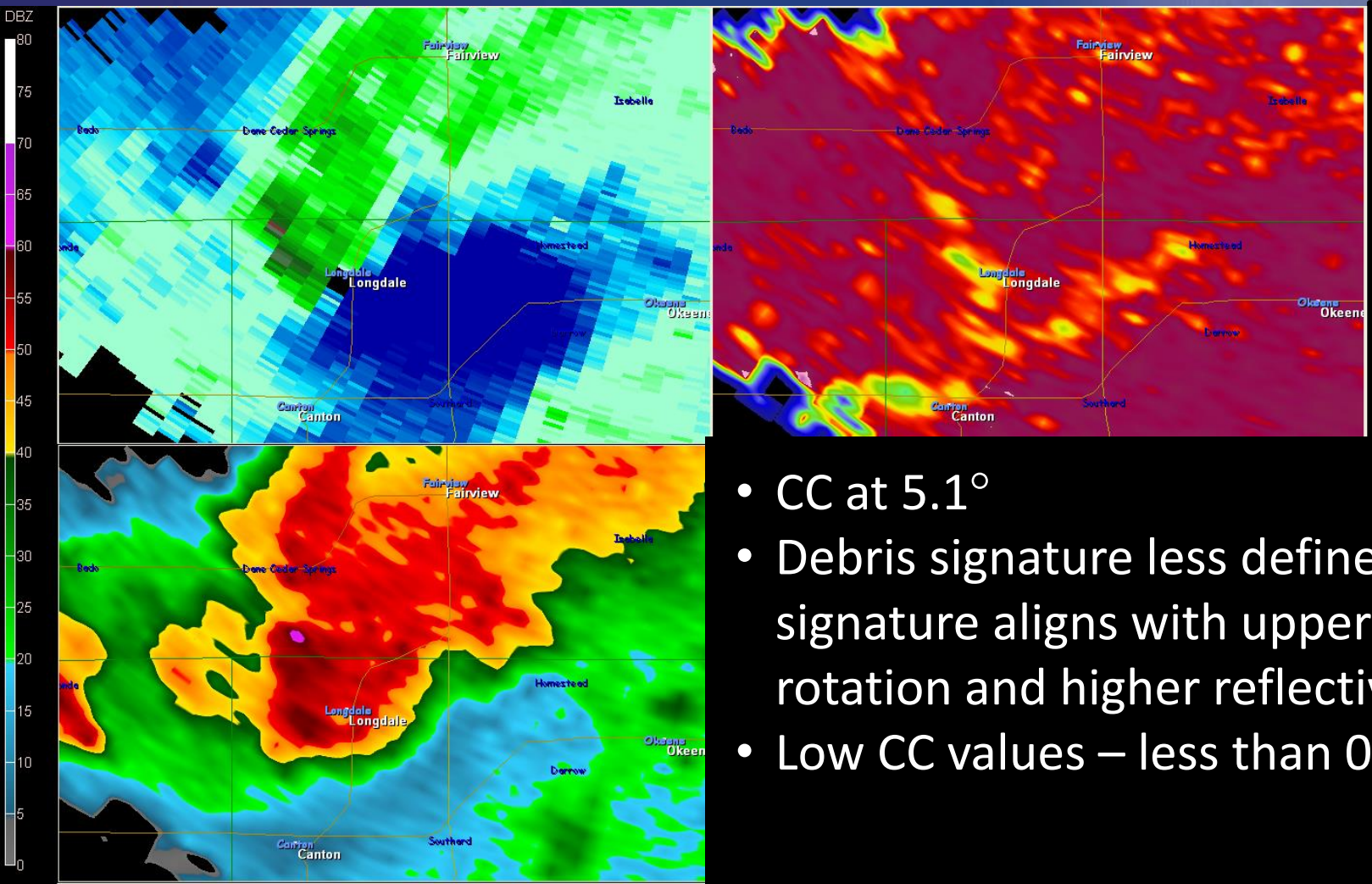




19,300 ft

- CC at 4.0°
- Debris ball signature still there, showing debris being lofted 19,000 ft +
- Low CC values – less than 0.85

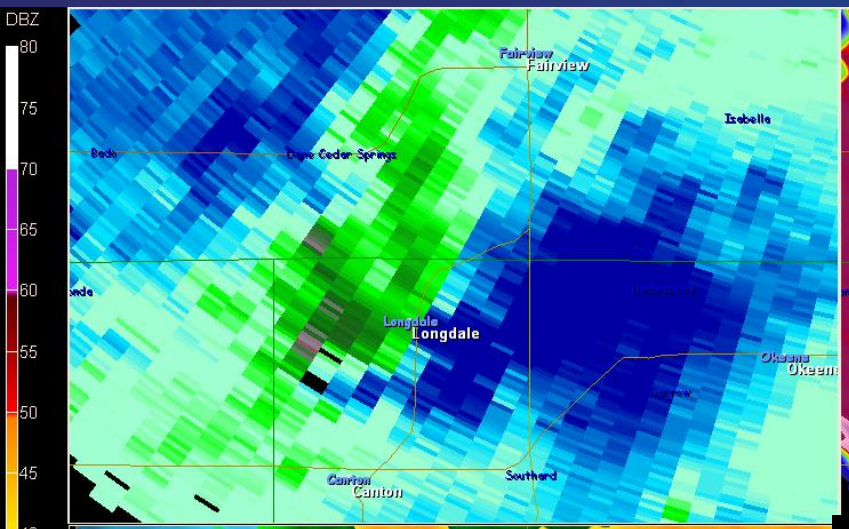
Tornadic Debris Aloft from Vance AFB, OK – 5/24/11

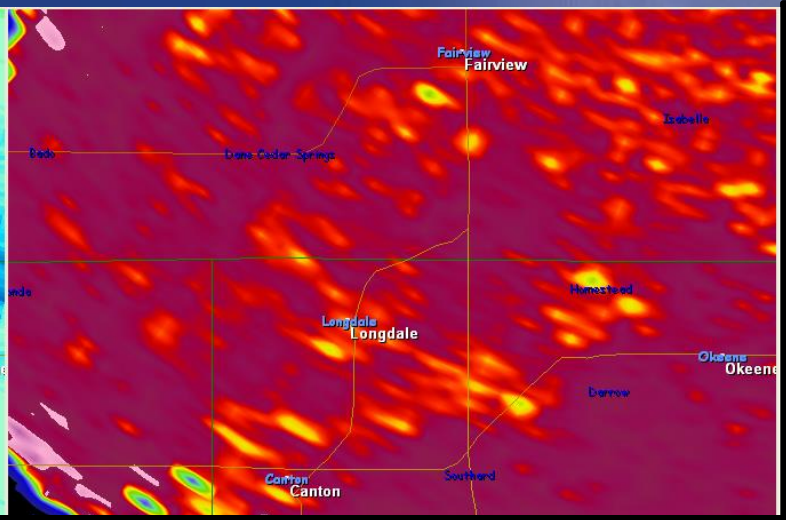


24,000 ft

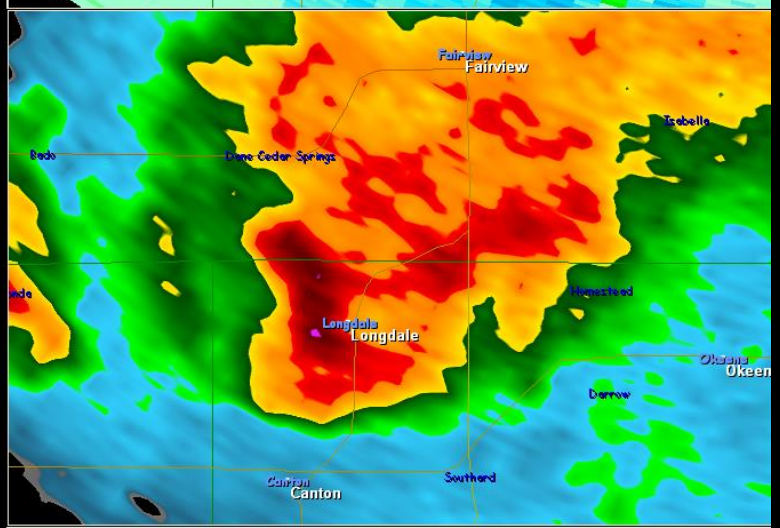
- CC at 5.1°
- Debris signature less defined. The signature aligns with upper level rotation and higher reflectivity.
- Low CC values – less than 0.85

Tornadic Debris Aloft from Vance AFB, OK – 5/24/11





30,000 ft



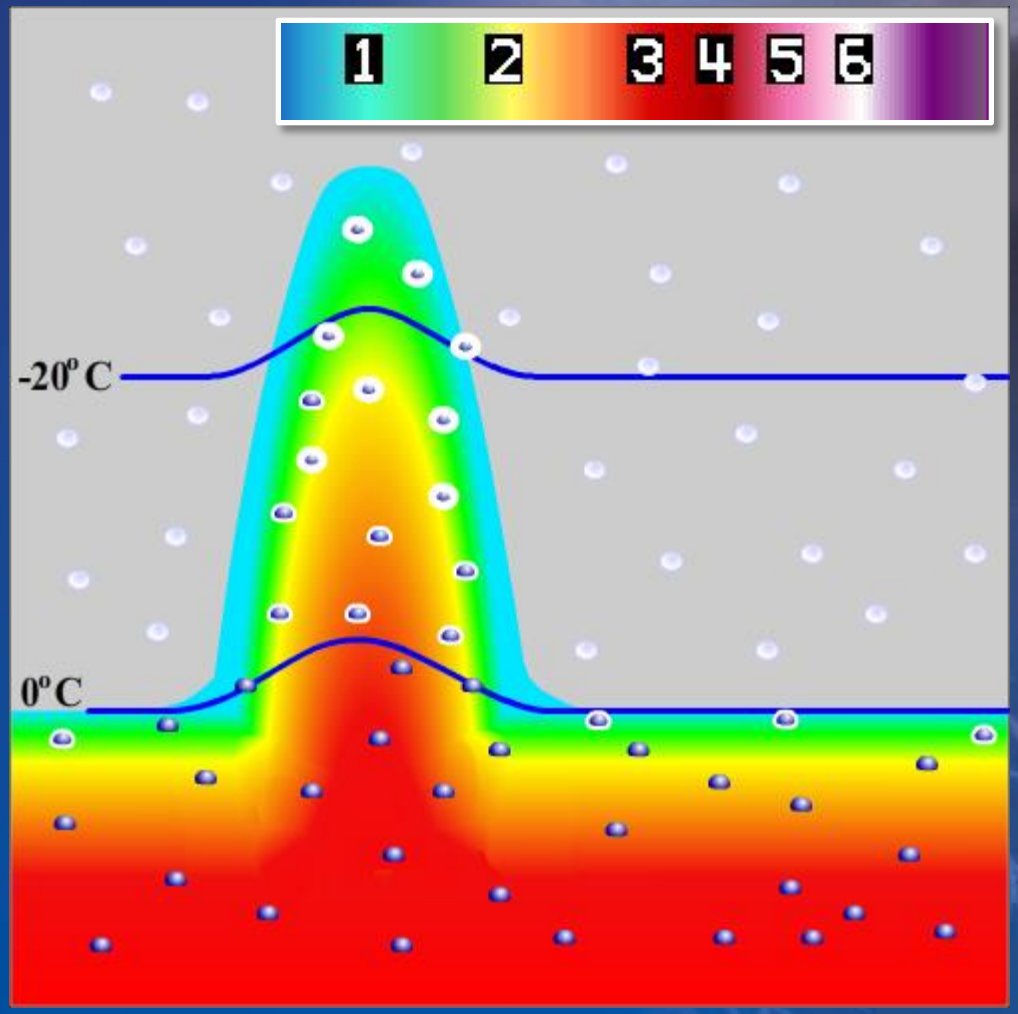
- CC at 6.4°
- Debris signature hardly noticeable, however there is an area of low CC where there is rotation and higher level of reflectivity aloft
- Low CC values – less than 0.92

Strengths and Limitations of Dual-Pol Tornadic Debris Detection

- **Strengths**
  - Indicates a tornado *is* occurring and that it is doing damage
  - Allows for specificity within a mile or less of the location of the tornado and tornado damage (pursuant to standard radar location errors)
- **Limitations**
  - Not a predictor of a tornado!
  - Must be close range
  - Tornado must hit something to produce a signature
  - Maximum Dependable Range 60km (strong tornadoes farther)

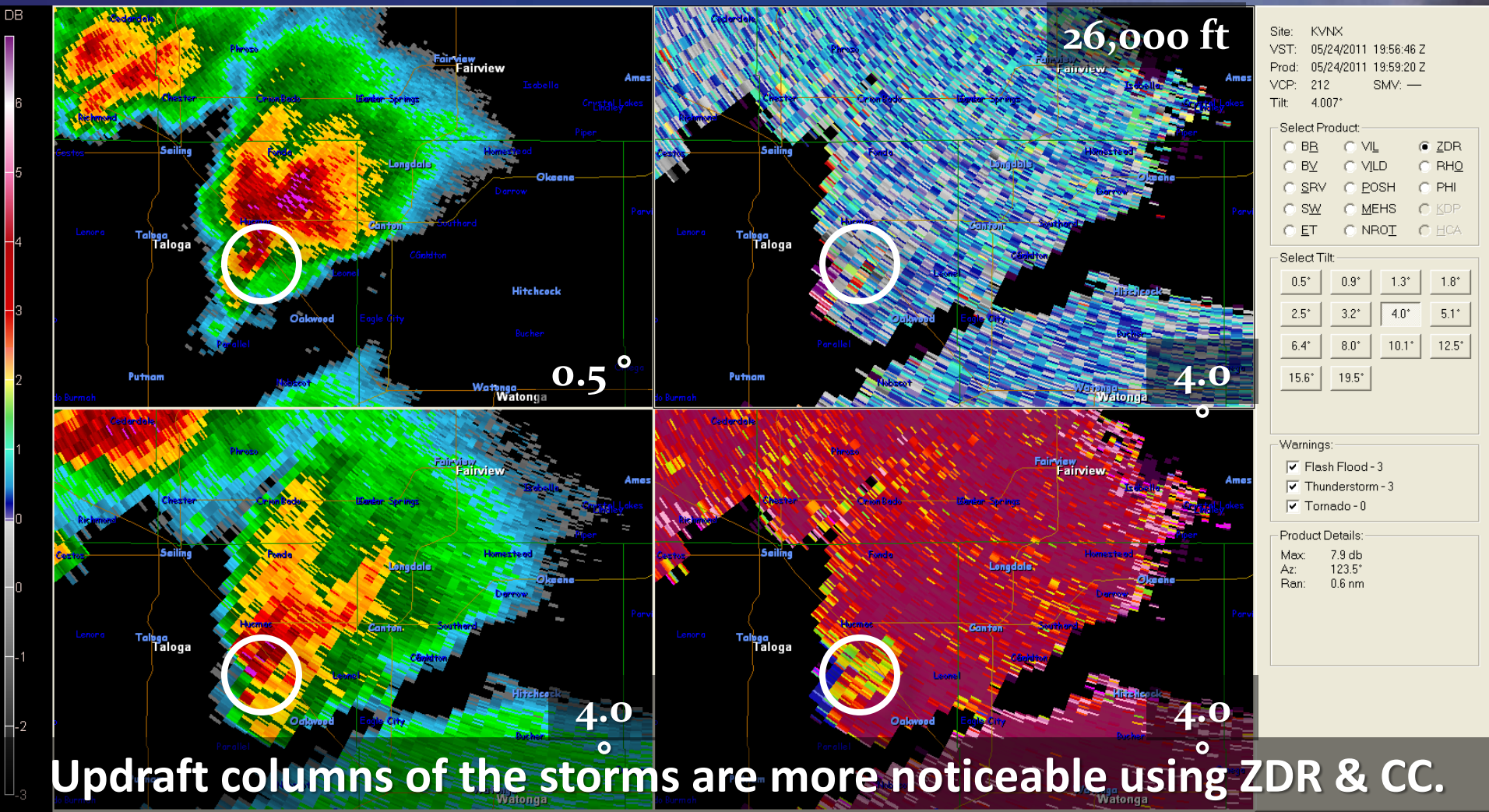
Dual Pol – Updraft Detection

- "ZDR columns" – Regions of liquid water (strongly positive ZDR) found above the environmental 0°C height



Updraft Detection

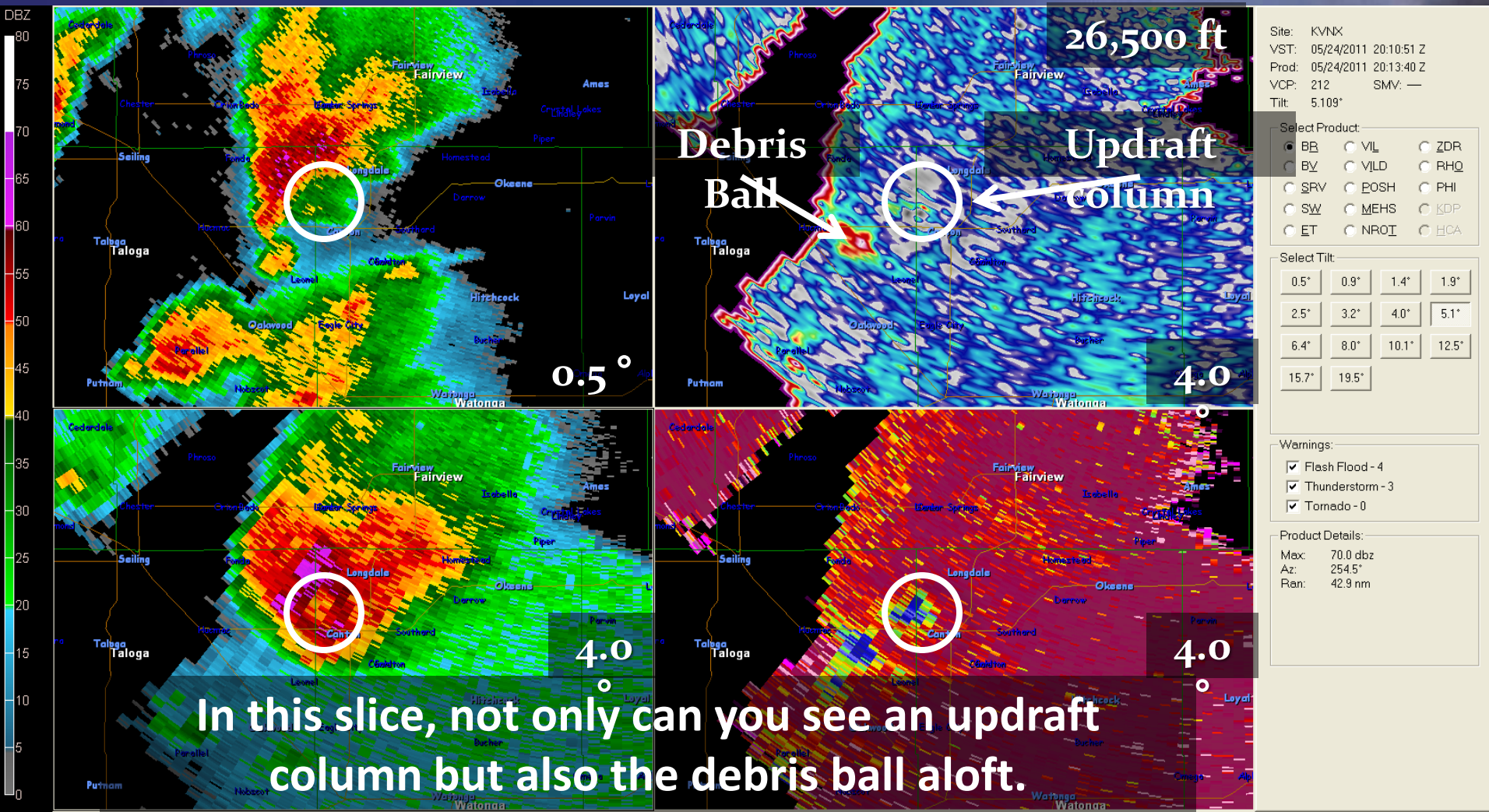
ZDR Column from KVNX on 05/24/11



Updraft columns of the storms are more noticeable using ZDR & CC.

Updraft Detection

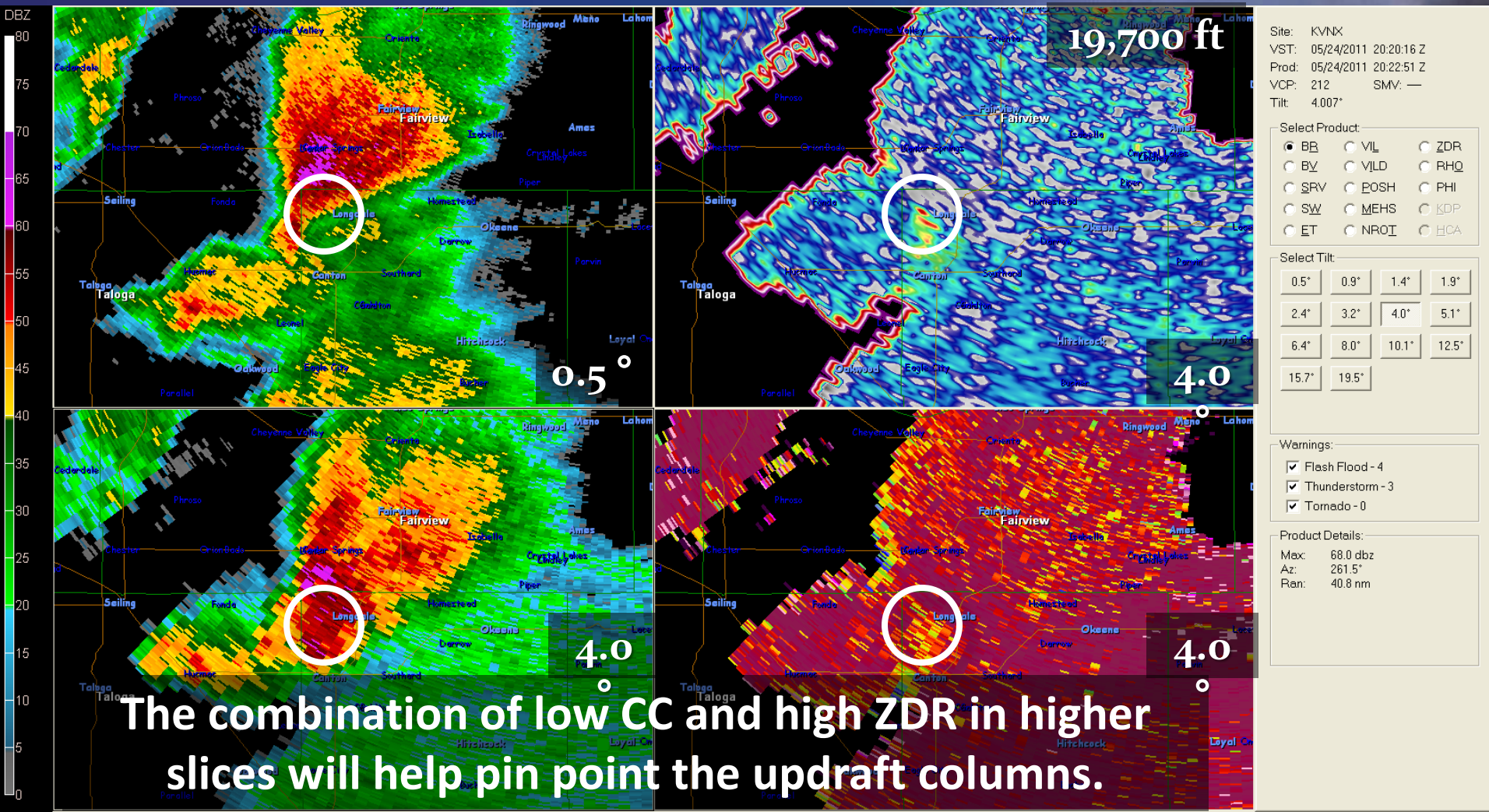
ZDR Column from KVNX on 05/24/11



In this slice, not only can you see an updraft column but also the debris ball aloft.

Updraft Detection

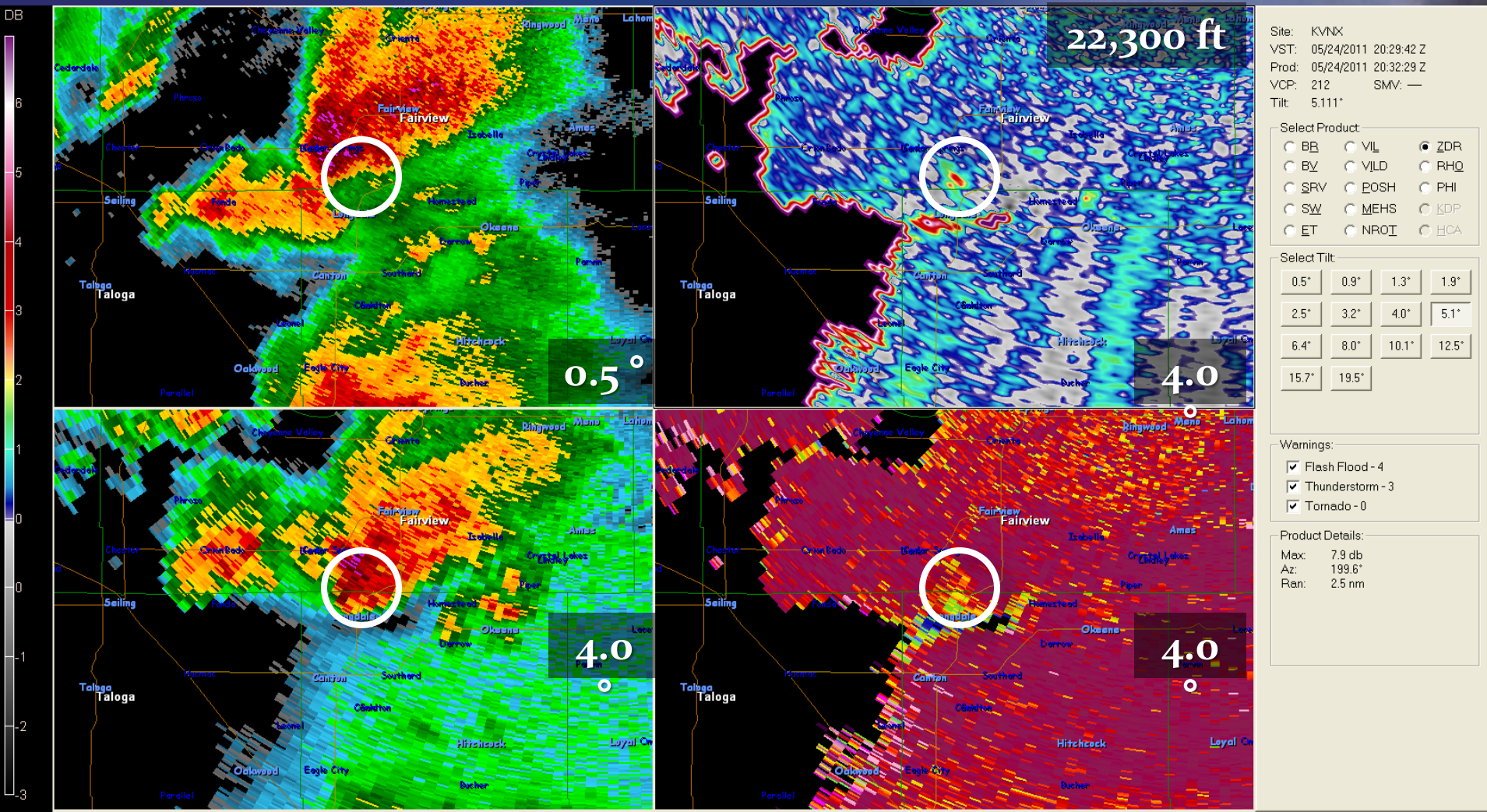
ZDR Column from KVNX on 05/24/11



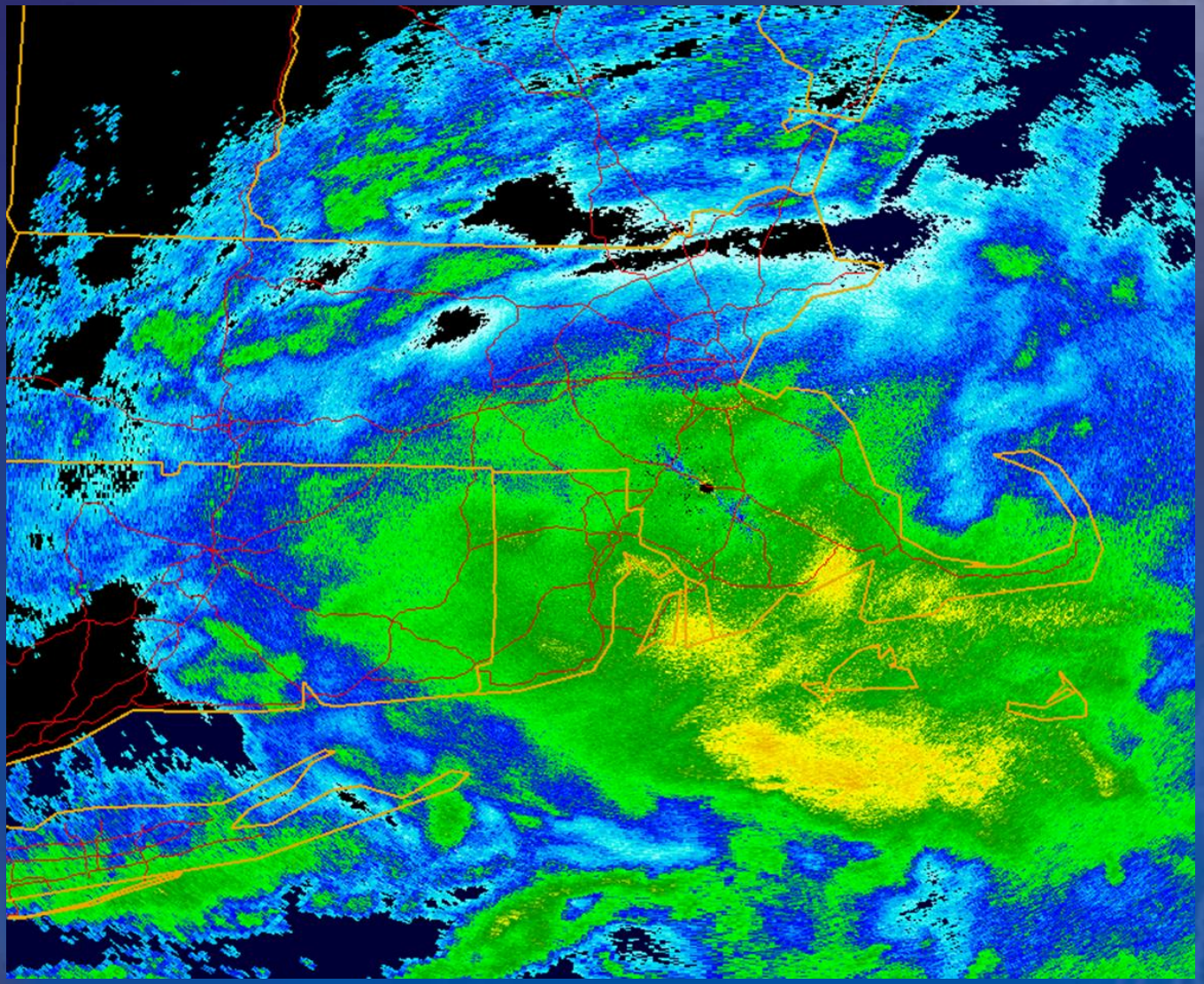
The combination of low CC and high ZDR in higher slices will help pin point the updraft columns.

Updraft Detection

ZDR Column from KVNX on 05/24/11

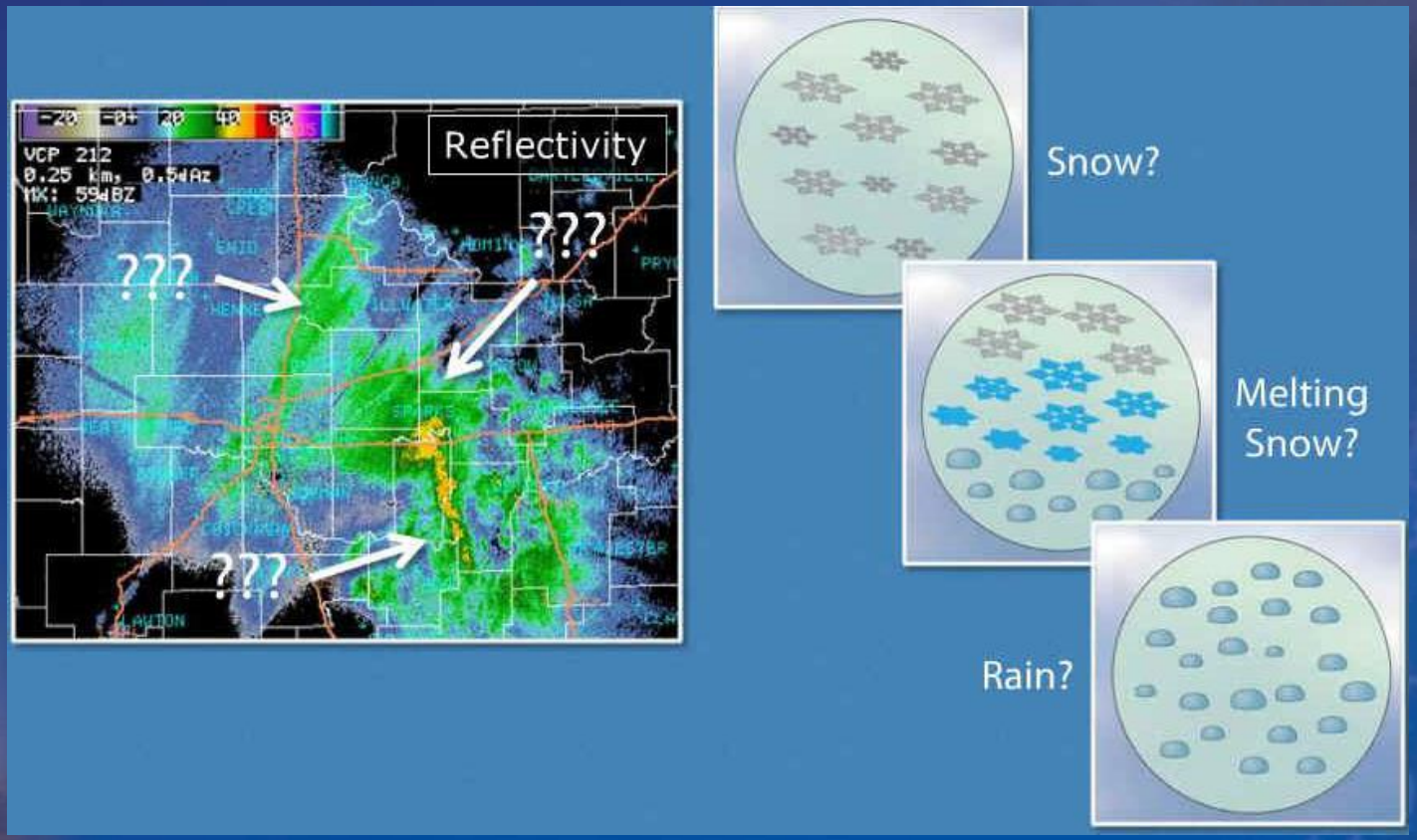


Winter Weather Applications



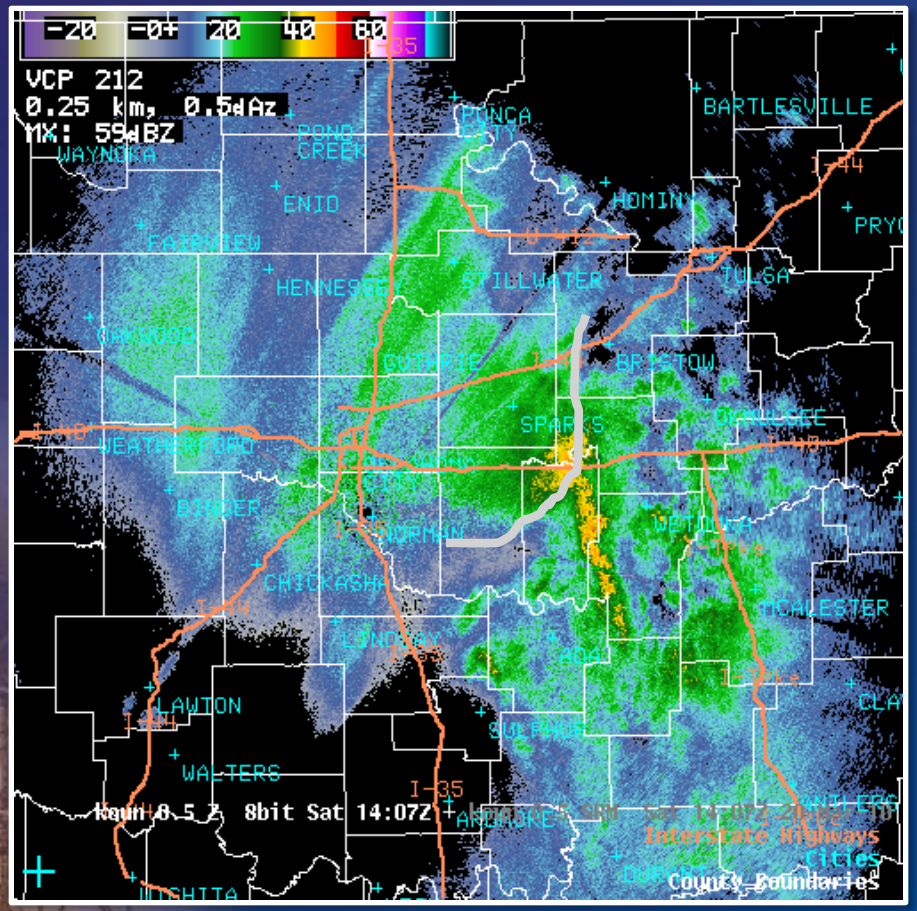
Dual Pol – Winter Weather

- The use of the new dual-pol variables will help identify between frozen and liquid hydrometeors. They will also help identify areas of homogeneous and non-homogeneous hydrometeors.

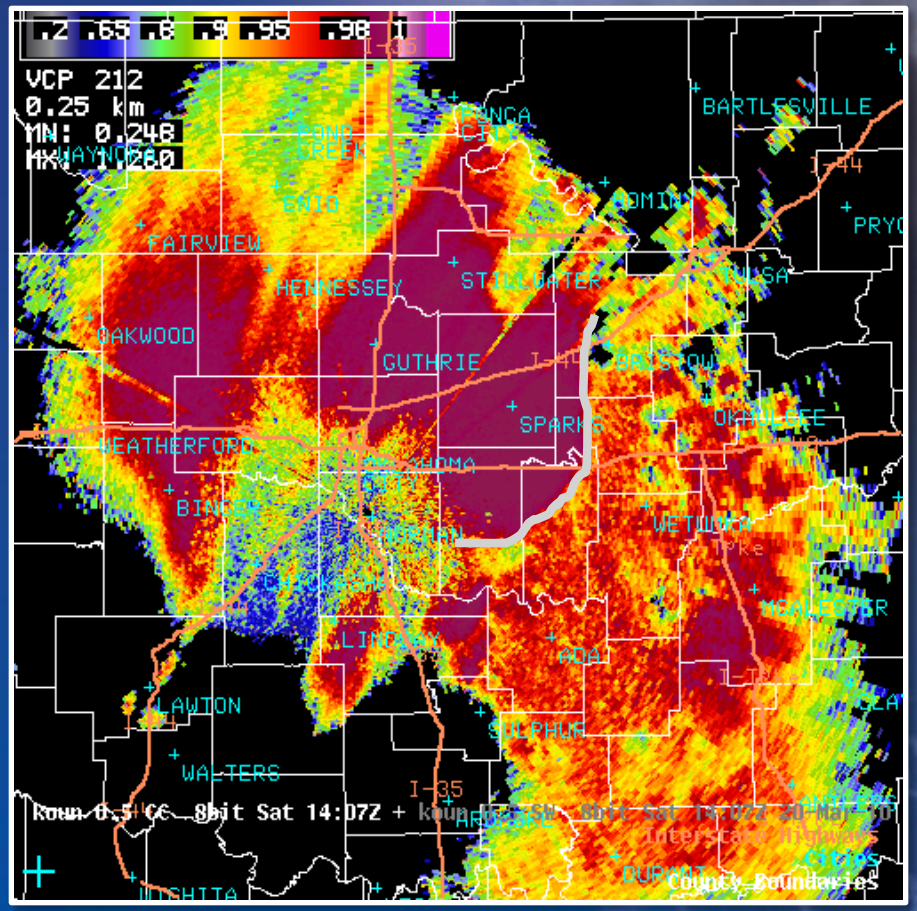


Rain vs. Snow

Reflectivity



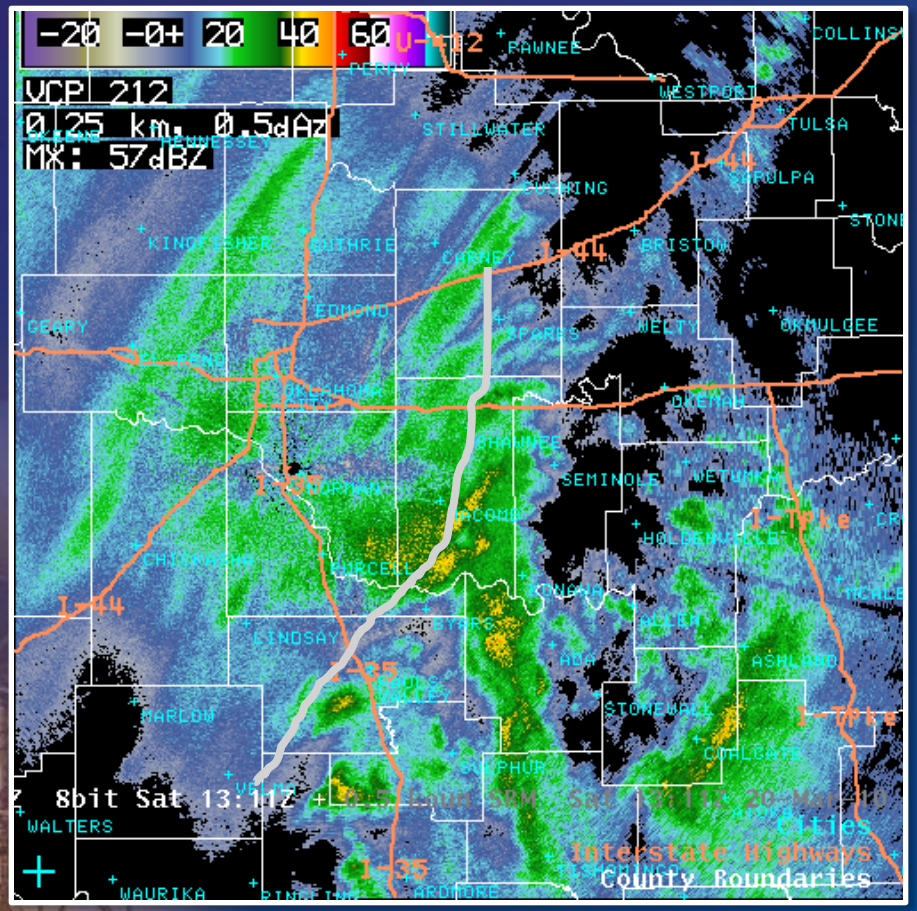
Correlation Coefficient



Transition from high to low CC marks rain/snow transition line

Rain vs. Snow

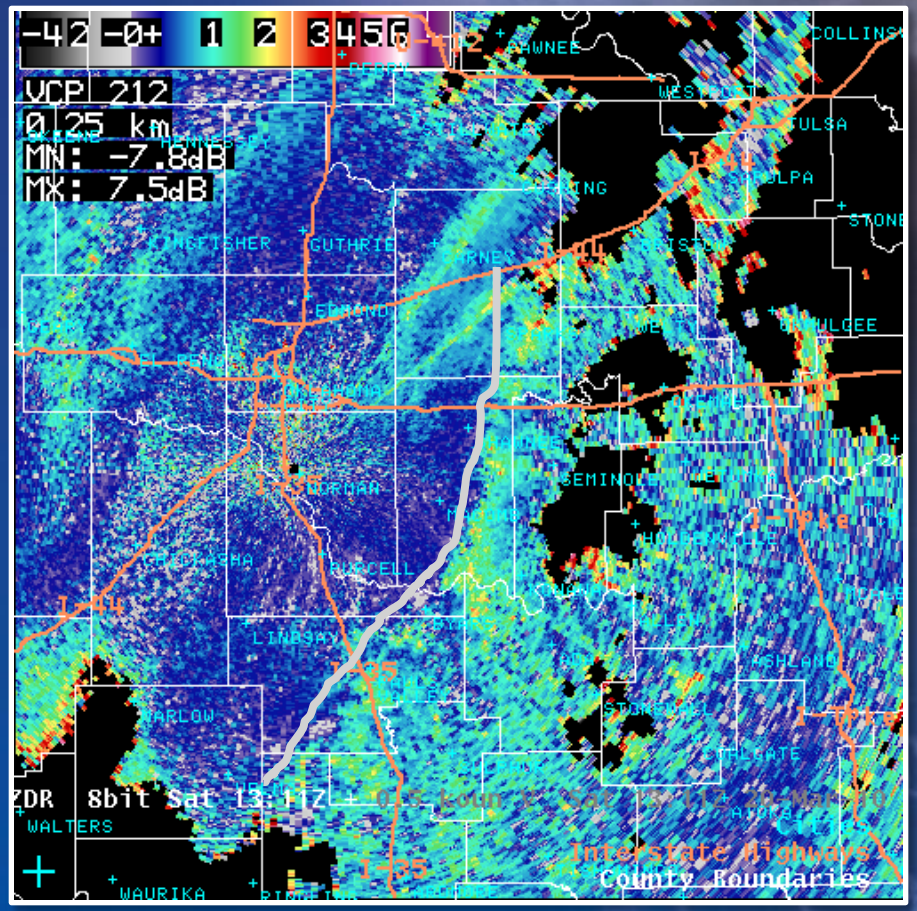
Reflectivity



Rain/Melting Layer

ZDR > 1 dB and Generally Noisy

Differential Reflectivity

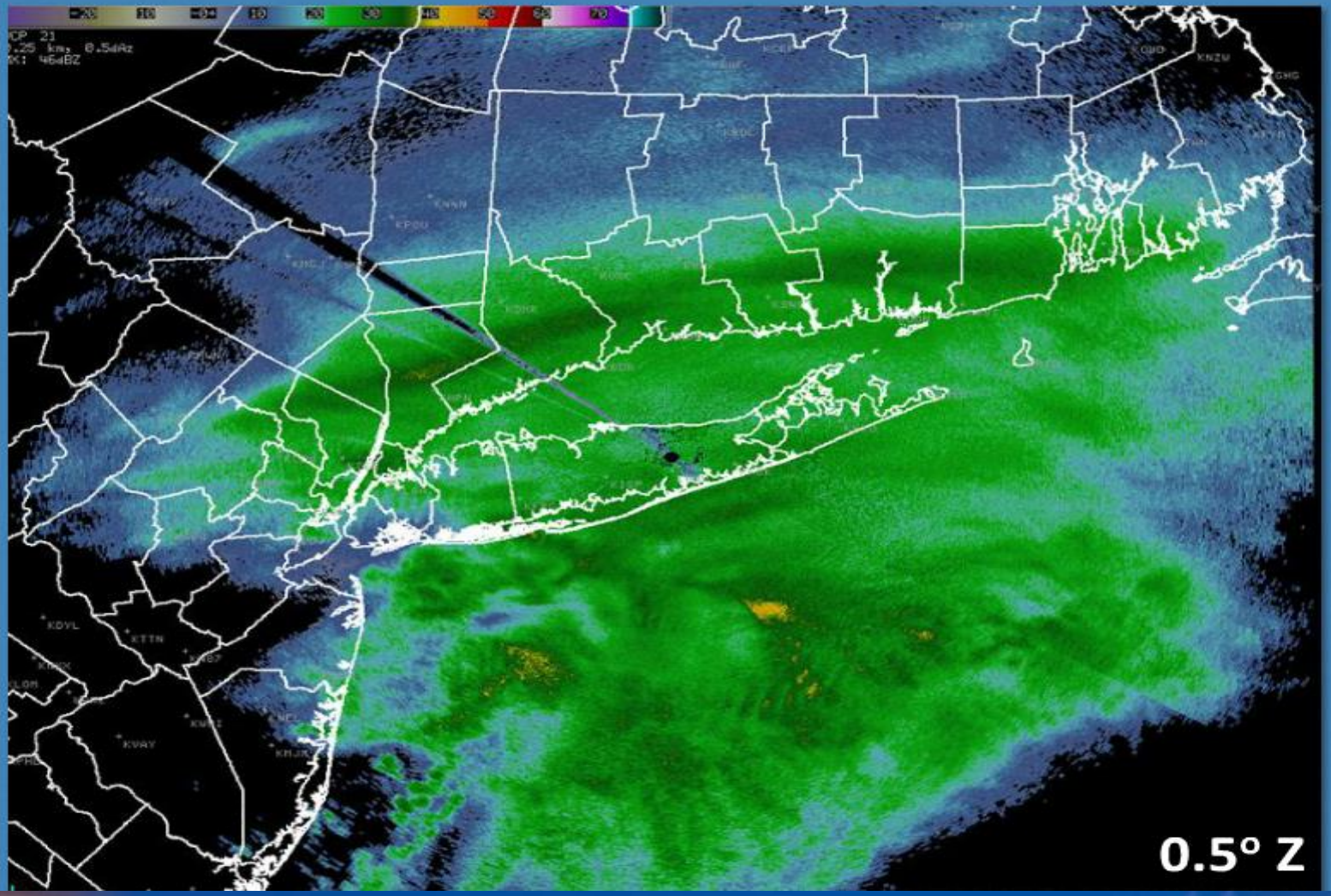


Snow

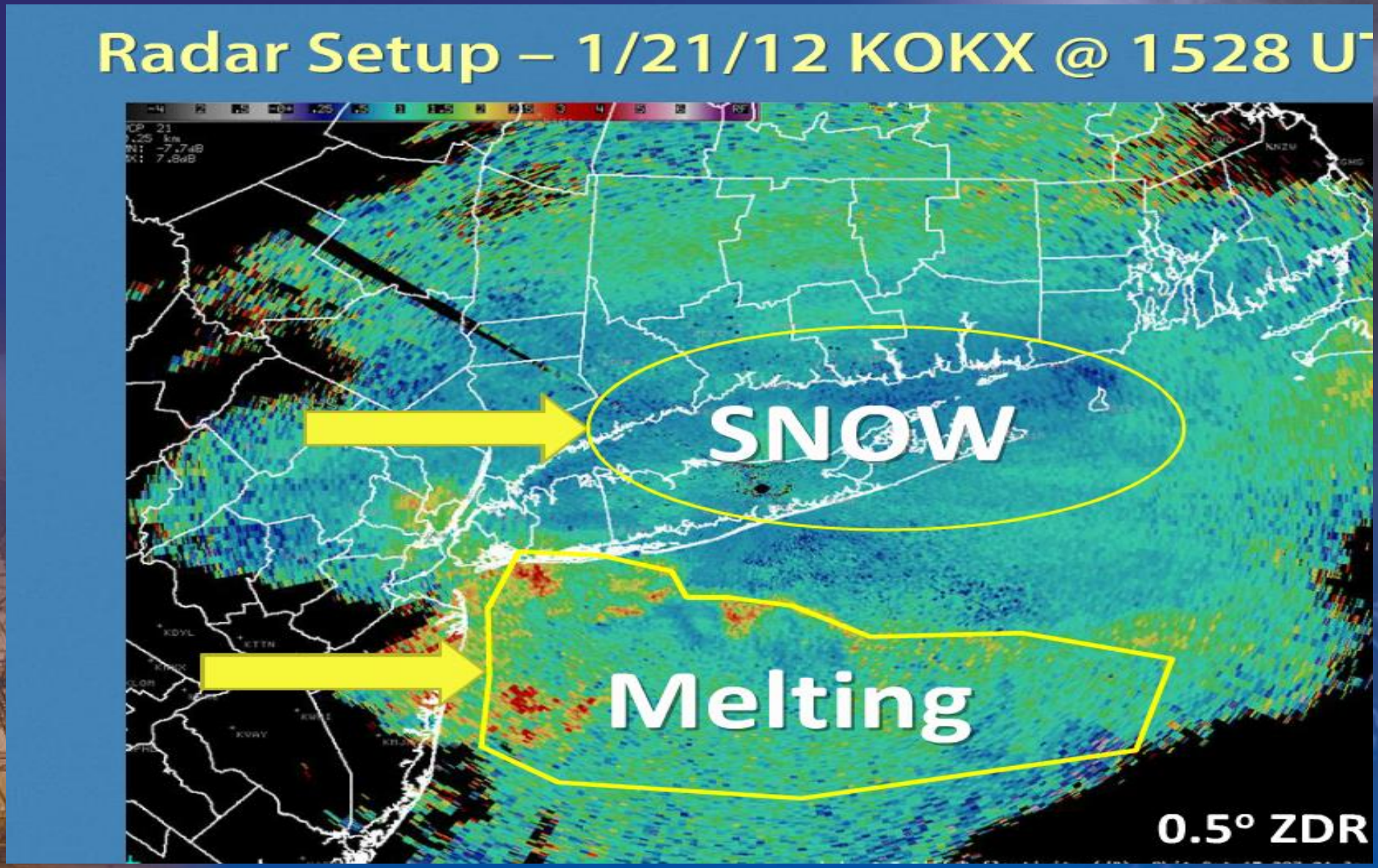
ZDR < 0.5 dB

Snow over Long Island

Radar Setup – 1/21/12 KOKX @ 1528 UTC

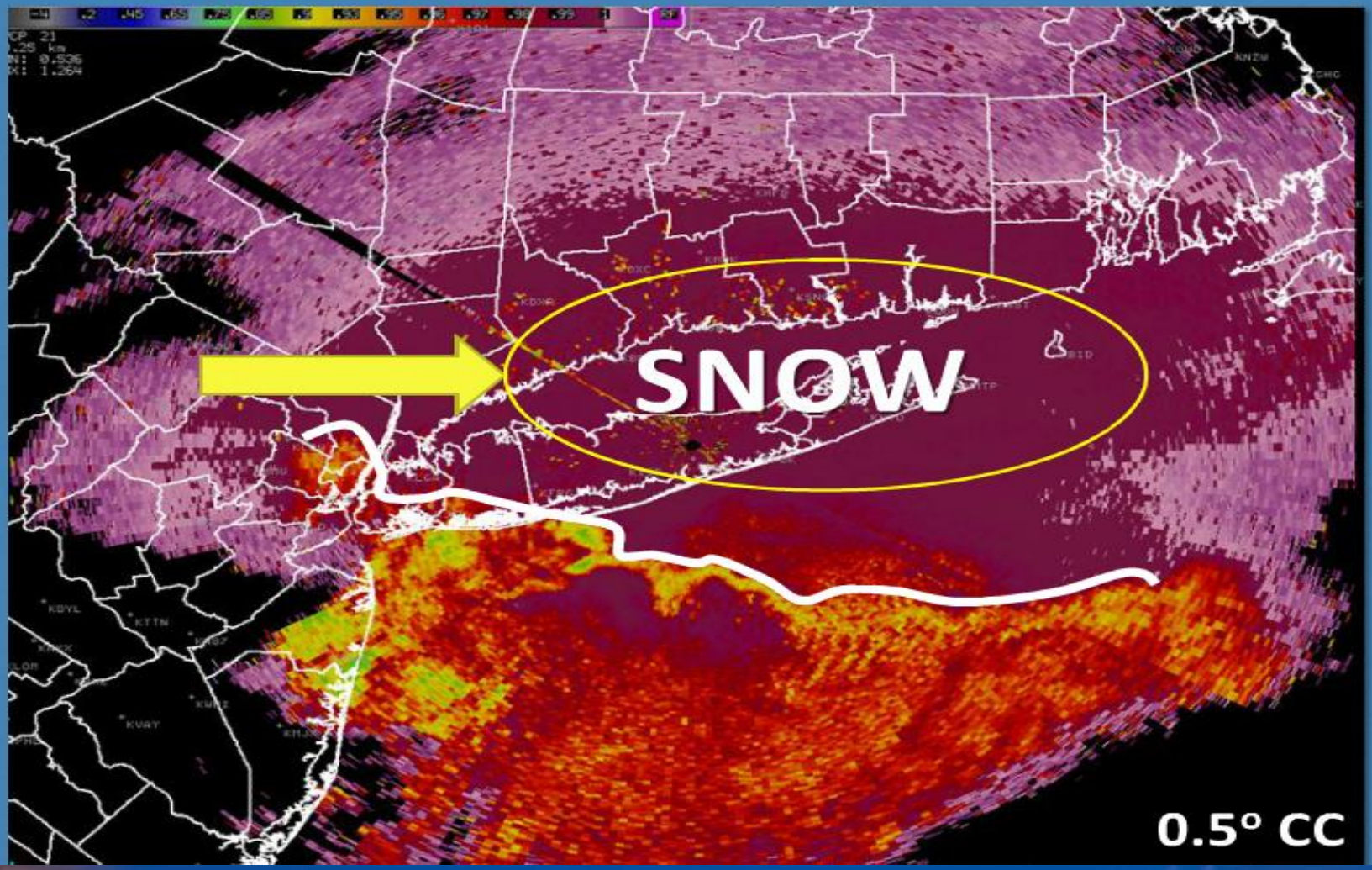


Snow has a low ZDR … < 1



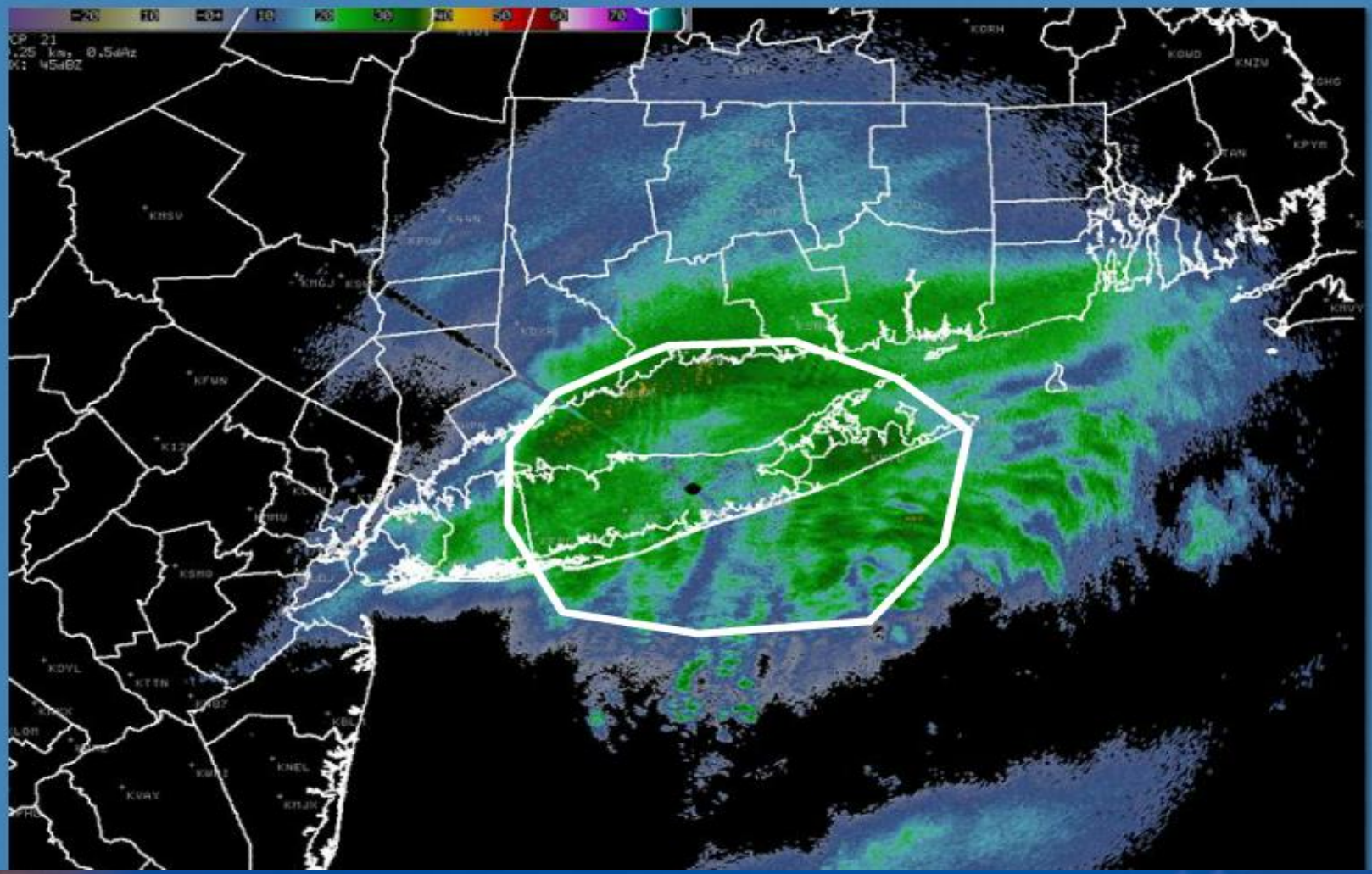
Snow has a very high CC …. > 0.97

Radar Setup – 1/21/12 KOKX @ 1528 UTC



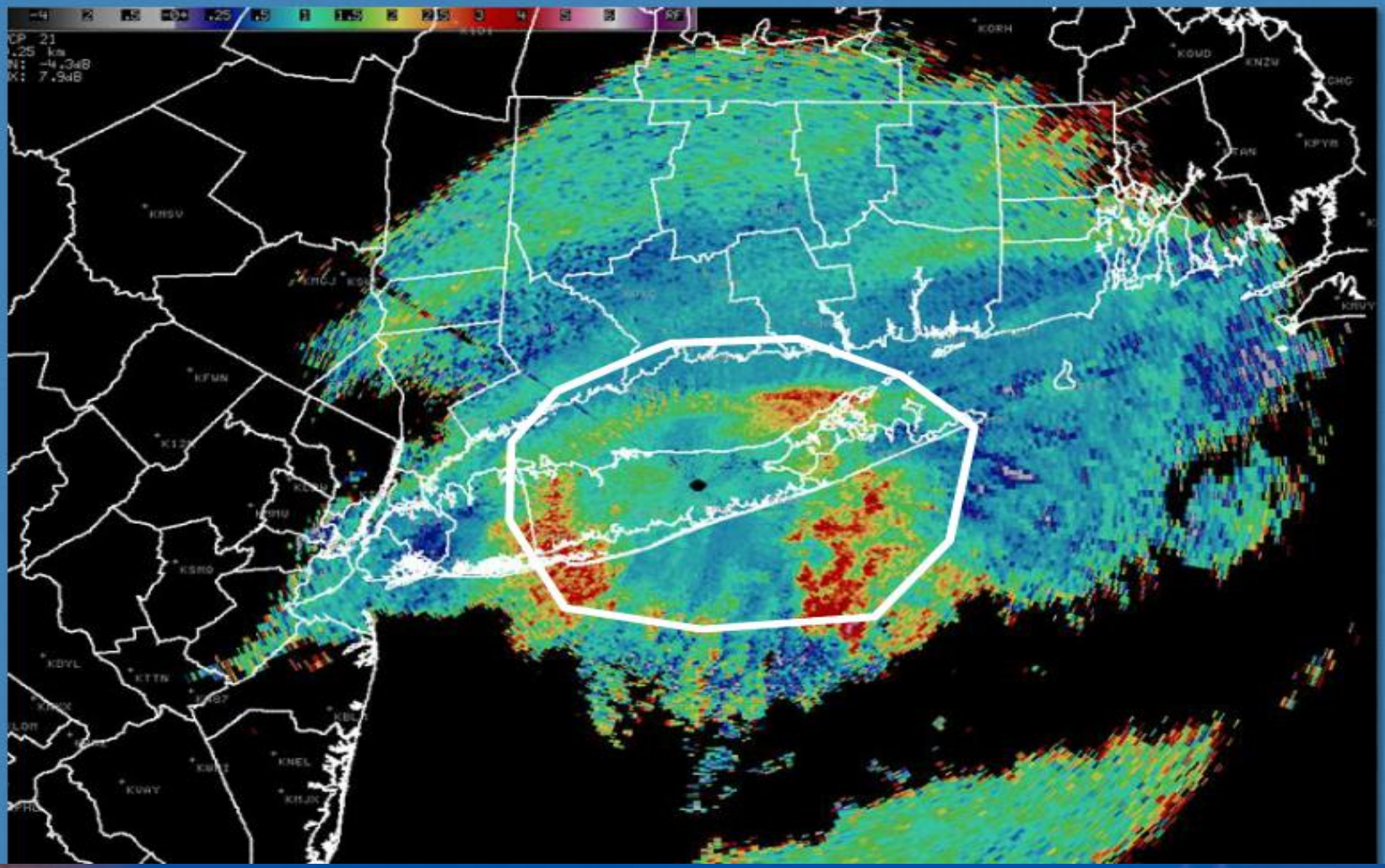
A bit hard to tell rain from snow

Radar Setup – 1/21/12 KOKX @ 1725 UTC



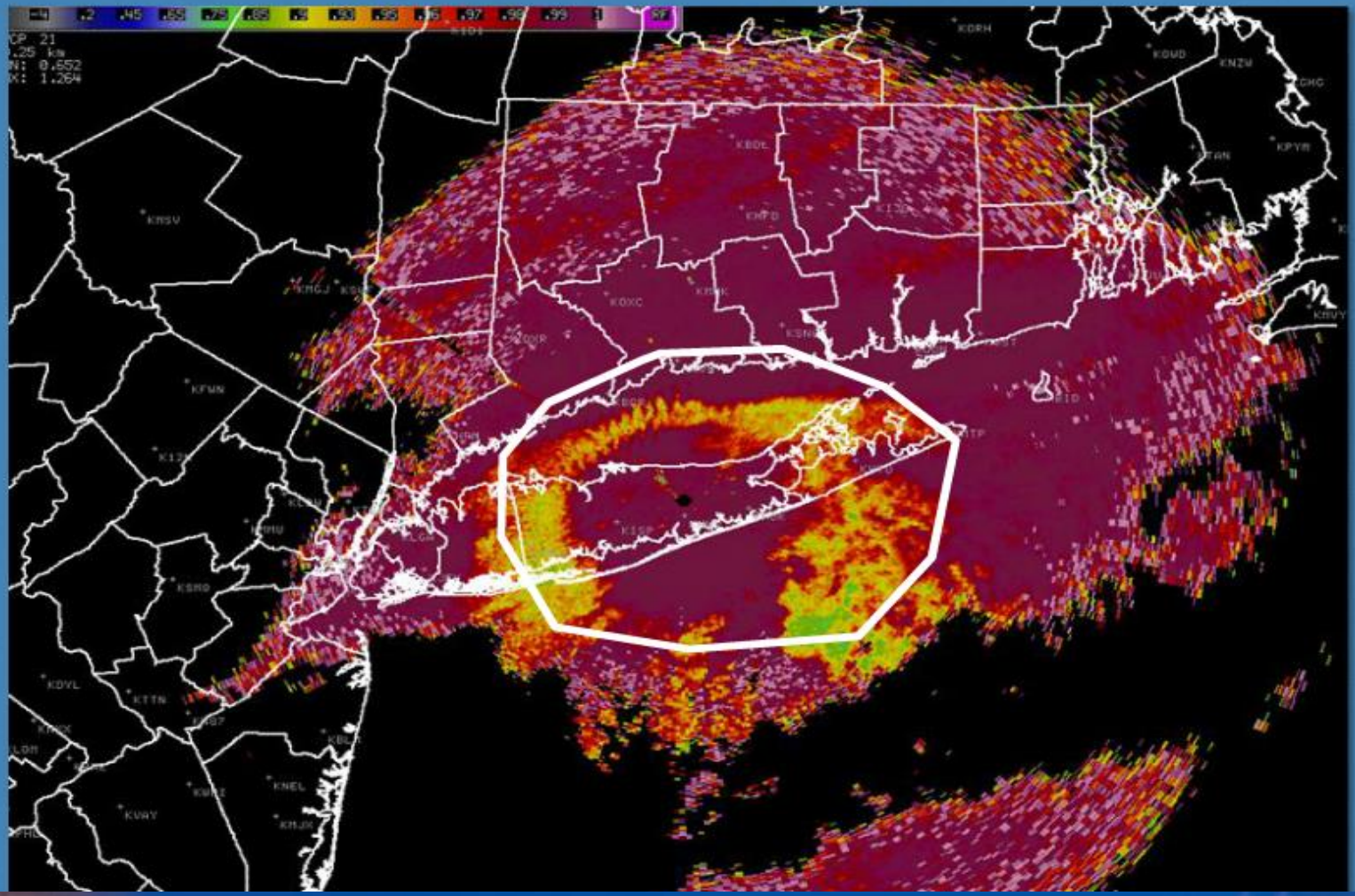
Now a bright band is noticeable

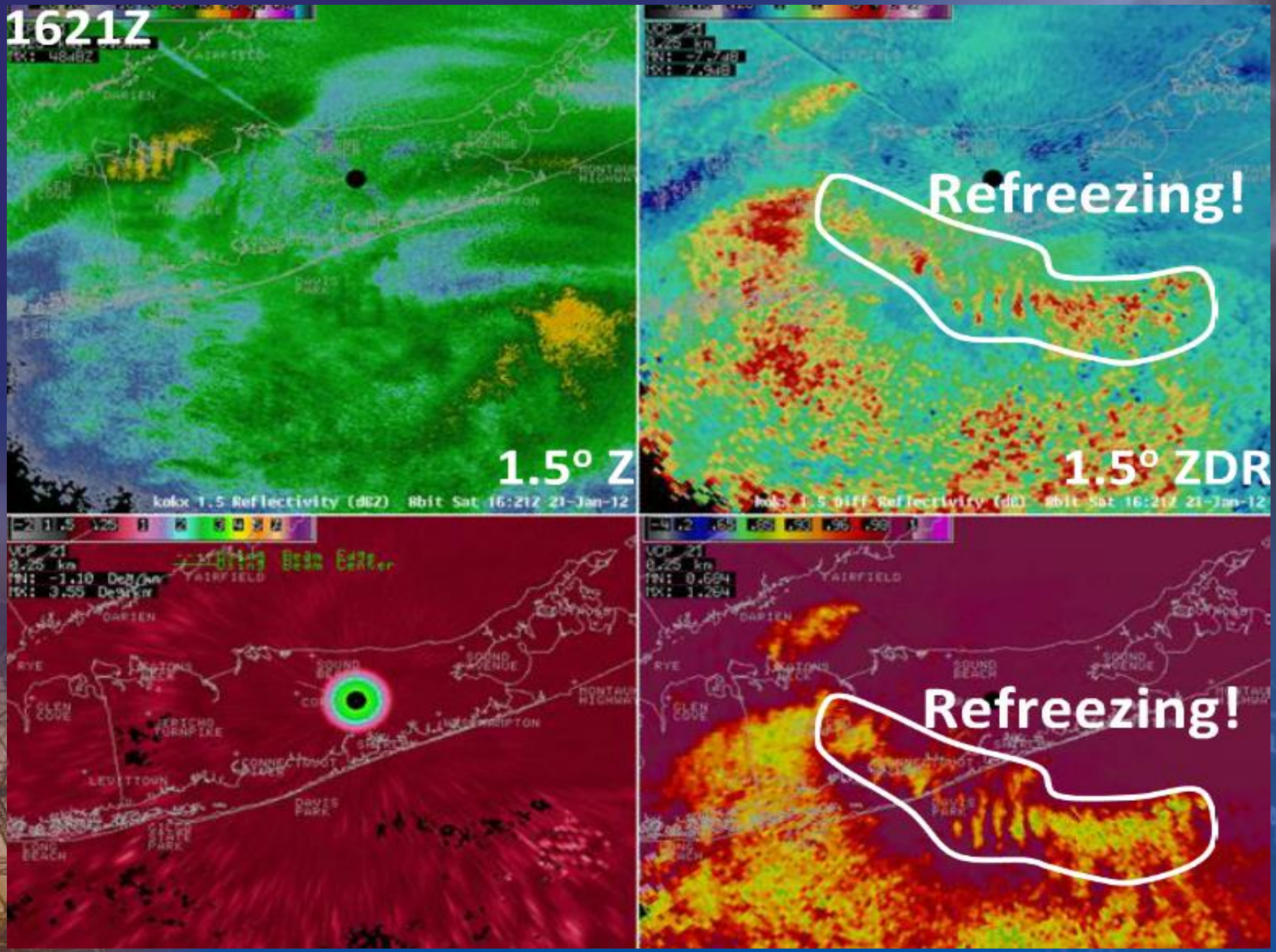
Radar Setup – 1/21/12 KOKX @ 1725 UTC



Freezing rain right over Radar

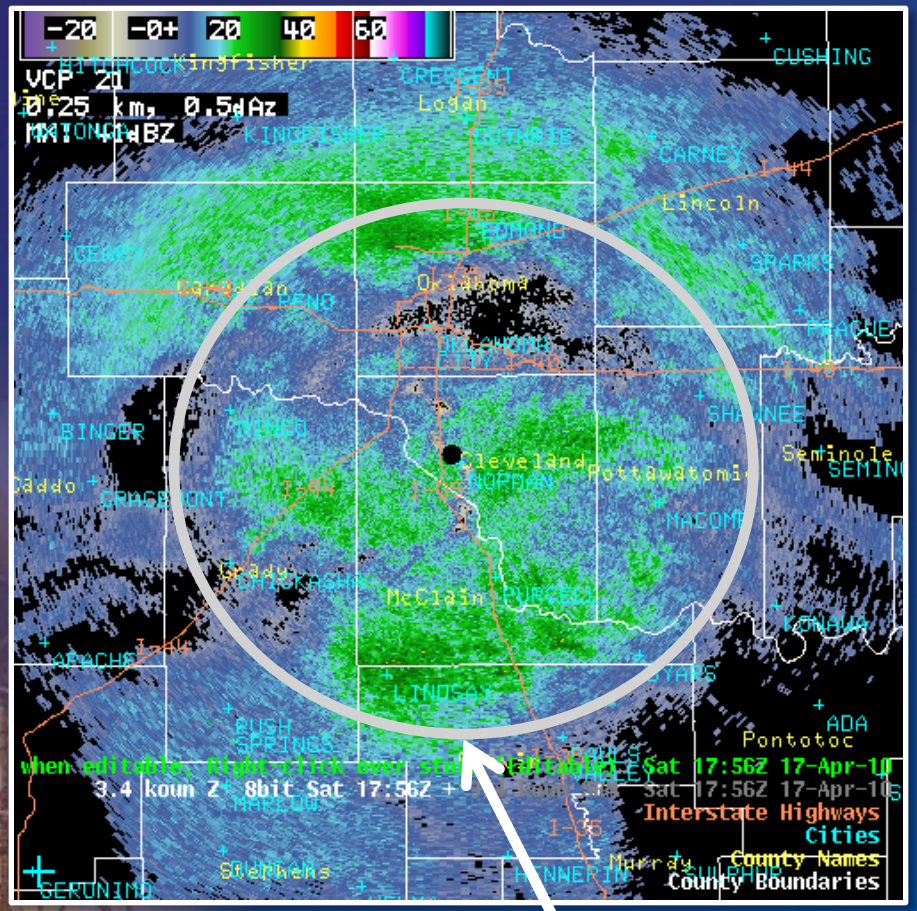
Radar Setup – 1/21/12 KOKX @ 1725 UTC



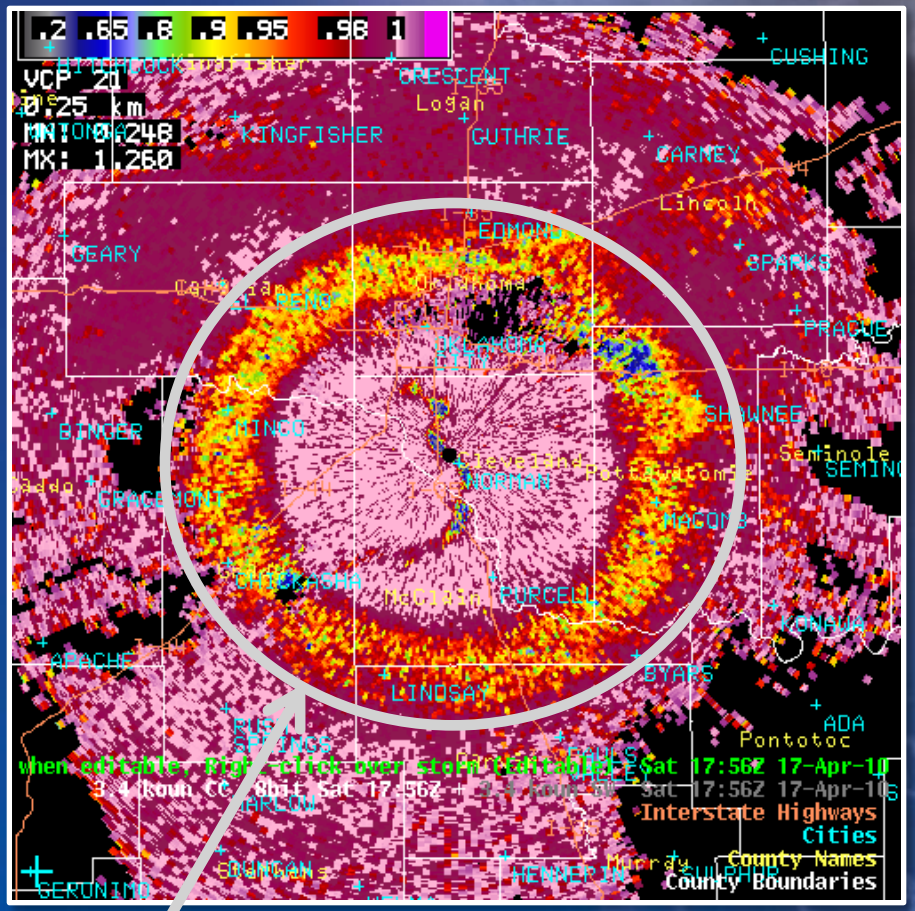

1621Z
1.5° Z
Refreezing!
1.5° ZDR
Refreezing!

Melting Layer

Reflectivity

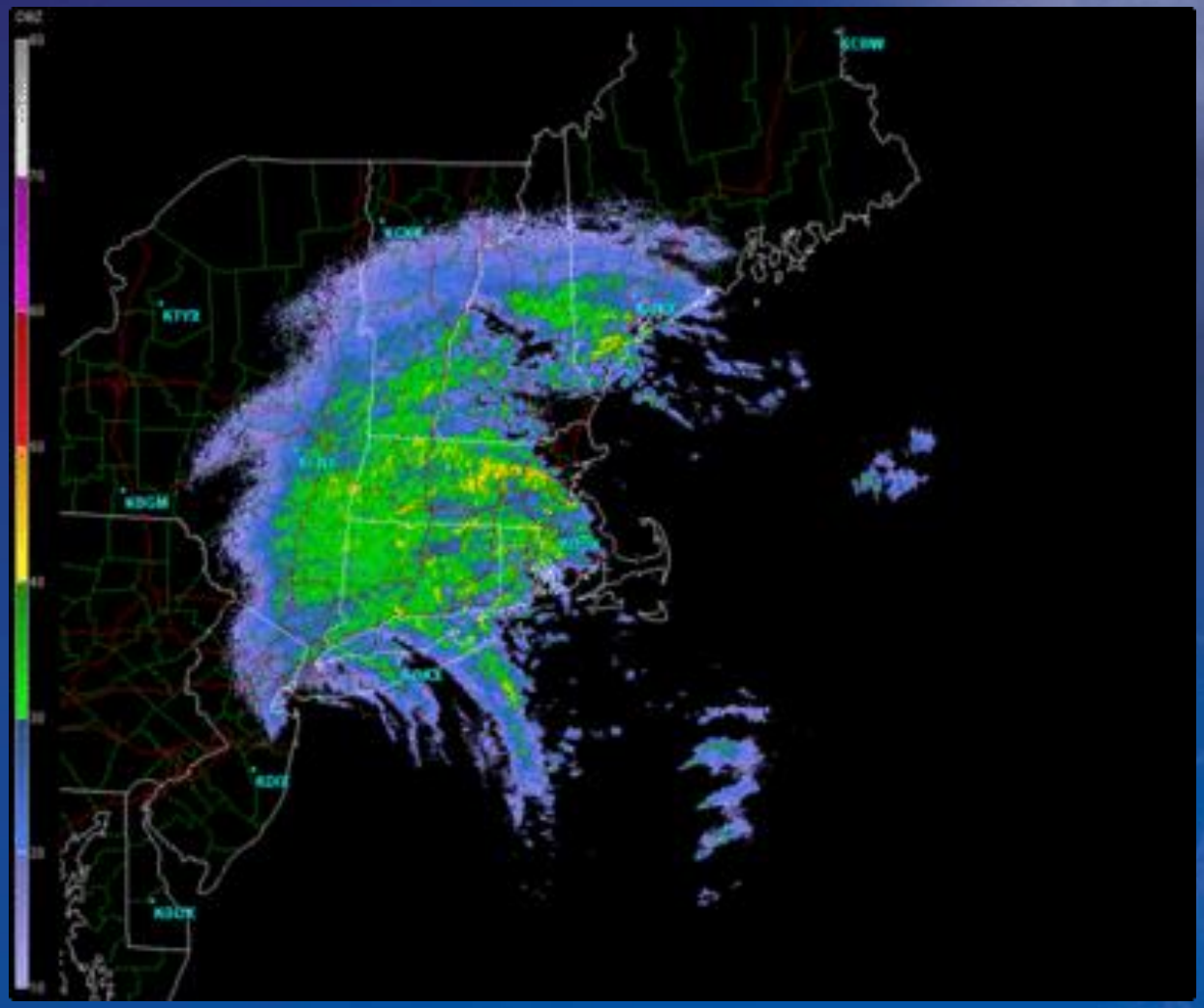


Correlation Coefficient



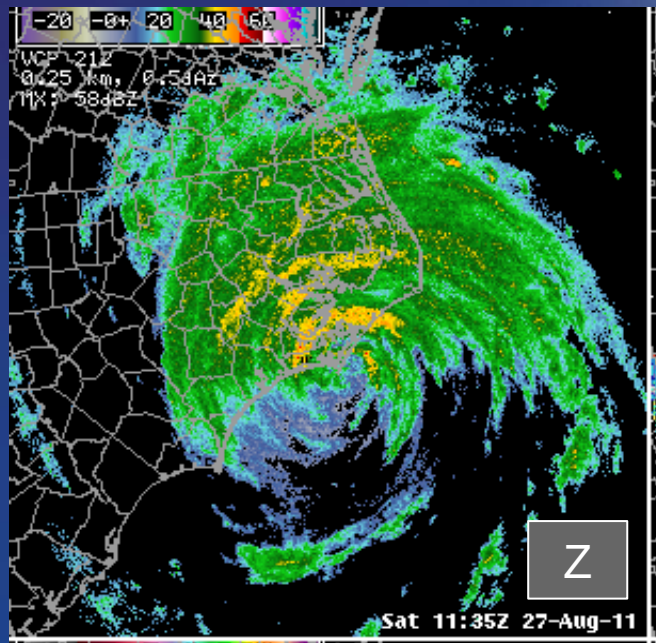
- Bright band not always visible
- Shows up as a ring of low correlation coefficient

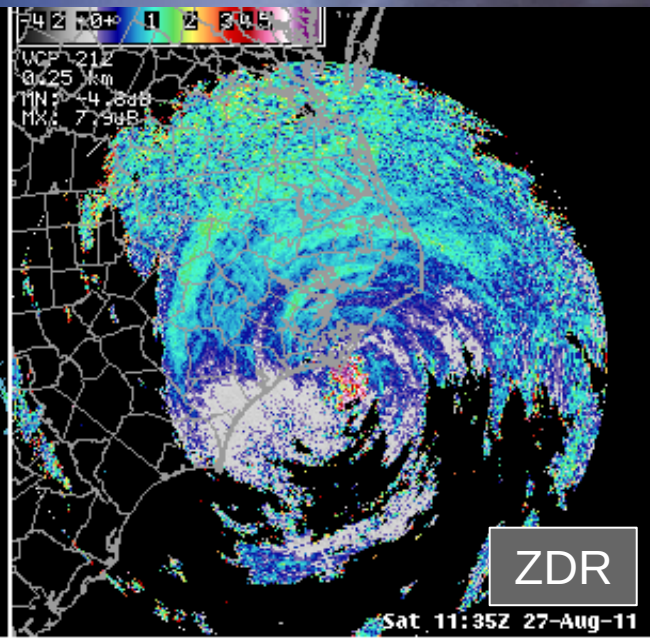
Tropical Weather Applications

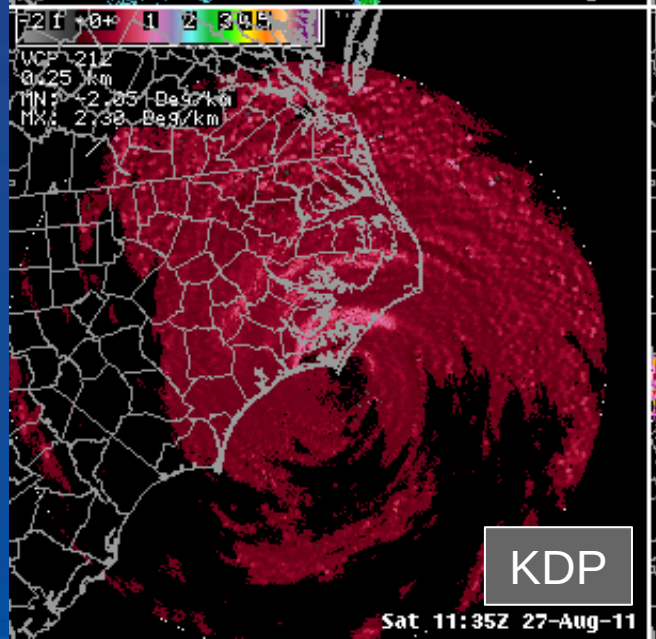


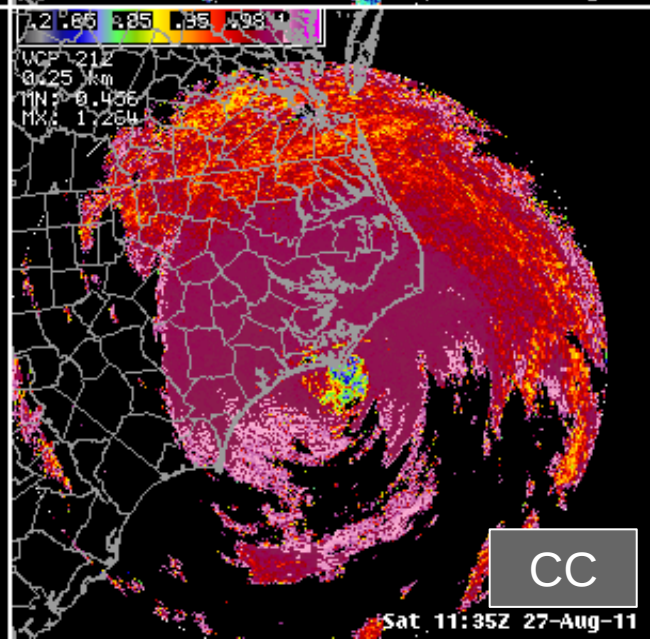
Hurricane Irene

- Moderate reflectivity (35-50 dBZ)
- Low ZDR (< 2 dB)
- Moderate KDP (up to 2 deg/km)



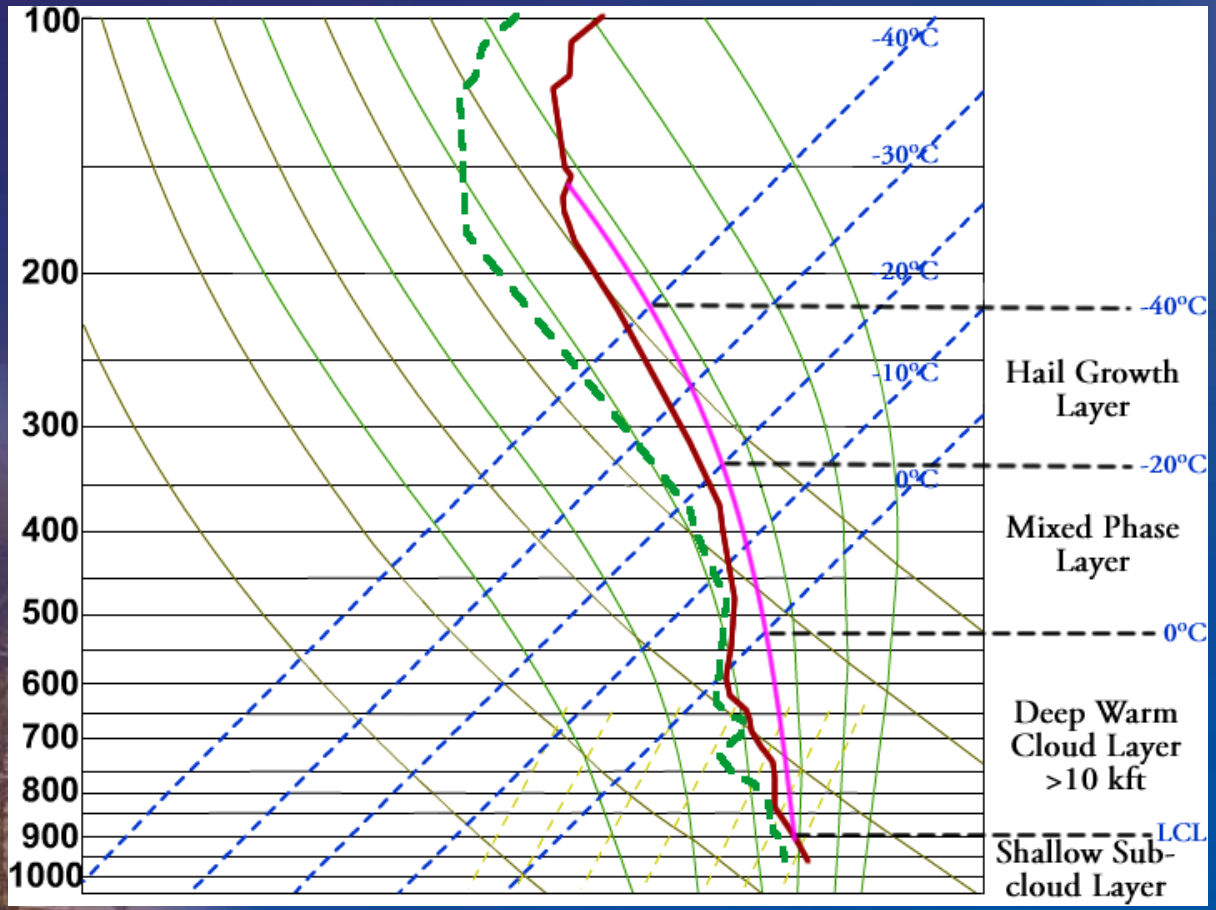






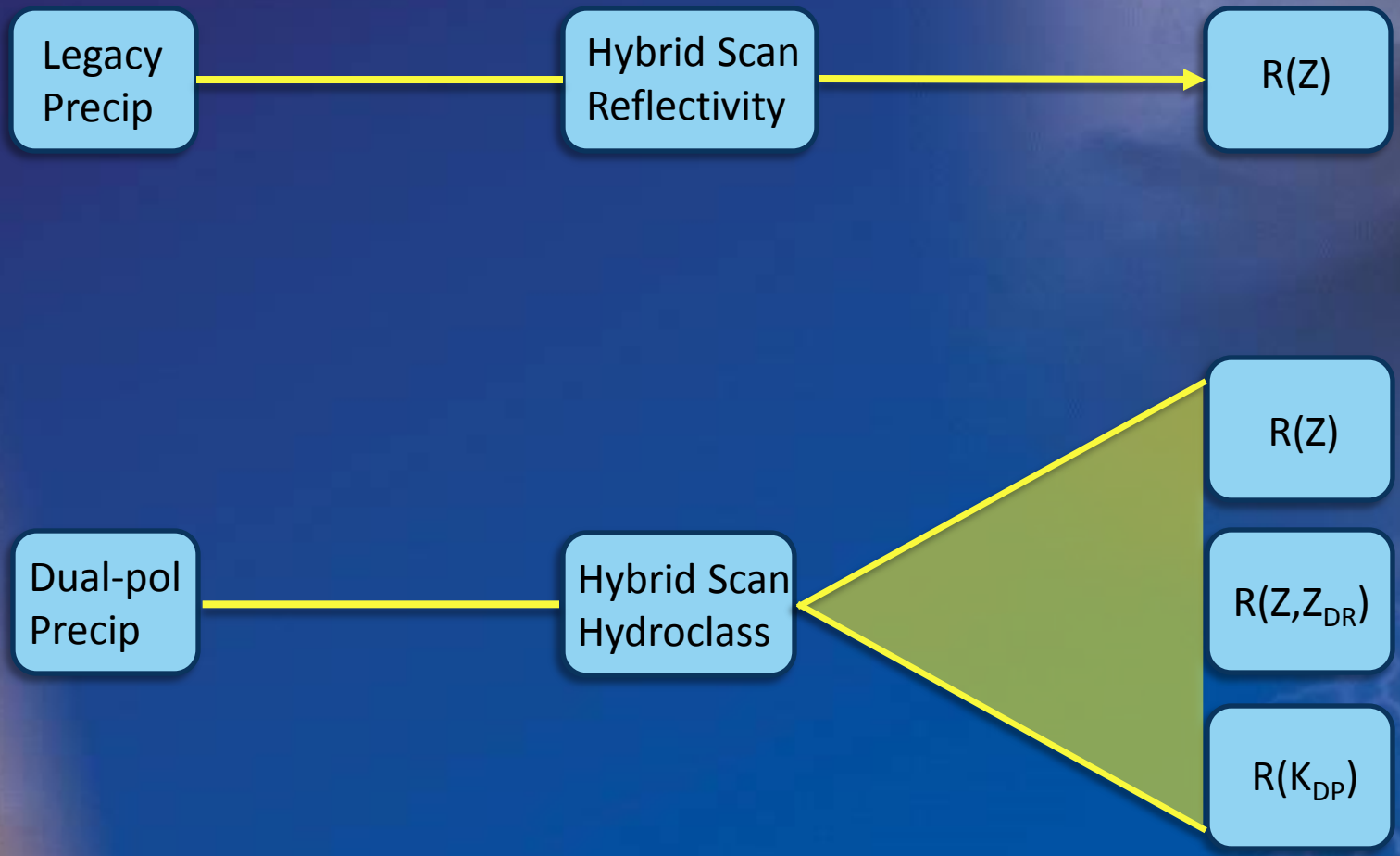
Precipitation Estimates

Dual Pol – Precipitation Estimates



- Provides expectations of rainfall signatures one should expect
  - Tropical
  - Cold rain processes
  - Possibly mixed with hail

Purpose: QPE Specific to Hydrometeor Type



- QPE uses only one Z_R relationship:
  $Z = 300\ R^{1.4}$ . . . Or . . . $R(Z) = (0.017)Z^{0.714}$

- Cool east stratiform and Marshall-Palmer Z_R relationships not used!

But . . .

- Z_R relationship is modified by the hydrometeor classification and the detected melting layer. QPE applies R(Z), R(Z, ZDR) or R(KDP)

- $R\ (Z, ZDR) = (0.0067)Z^{0.917}\ (ZDR^{-3.43})$

- $R\ (KDP) = 44\ [KDP]^{0.822}$ …(if KDP > 0)

- Dry snow above the melting layer?
  Rate = 2.8 R(Z)
- Wet snow such as is found in the melting layer?
  Rate = 0.6 R(Z)
- Heavy or light rain?
  Rate = R(Z, ZDR). In this case, Z and ZDR kind of balance each other out. The negative exponent for ZDR mitigates the overestimation of QPE due to lots of large raindrops
- Got Graupel?
  Rate = 0.8 R(Z)
- Got Hail?
  Rate = R(KDP) if KDP is positive. KDP is a measure of the total liquid content in a radar's volume scan and is immune to hail contamination

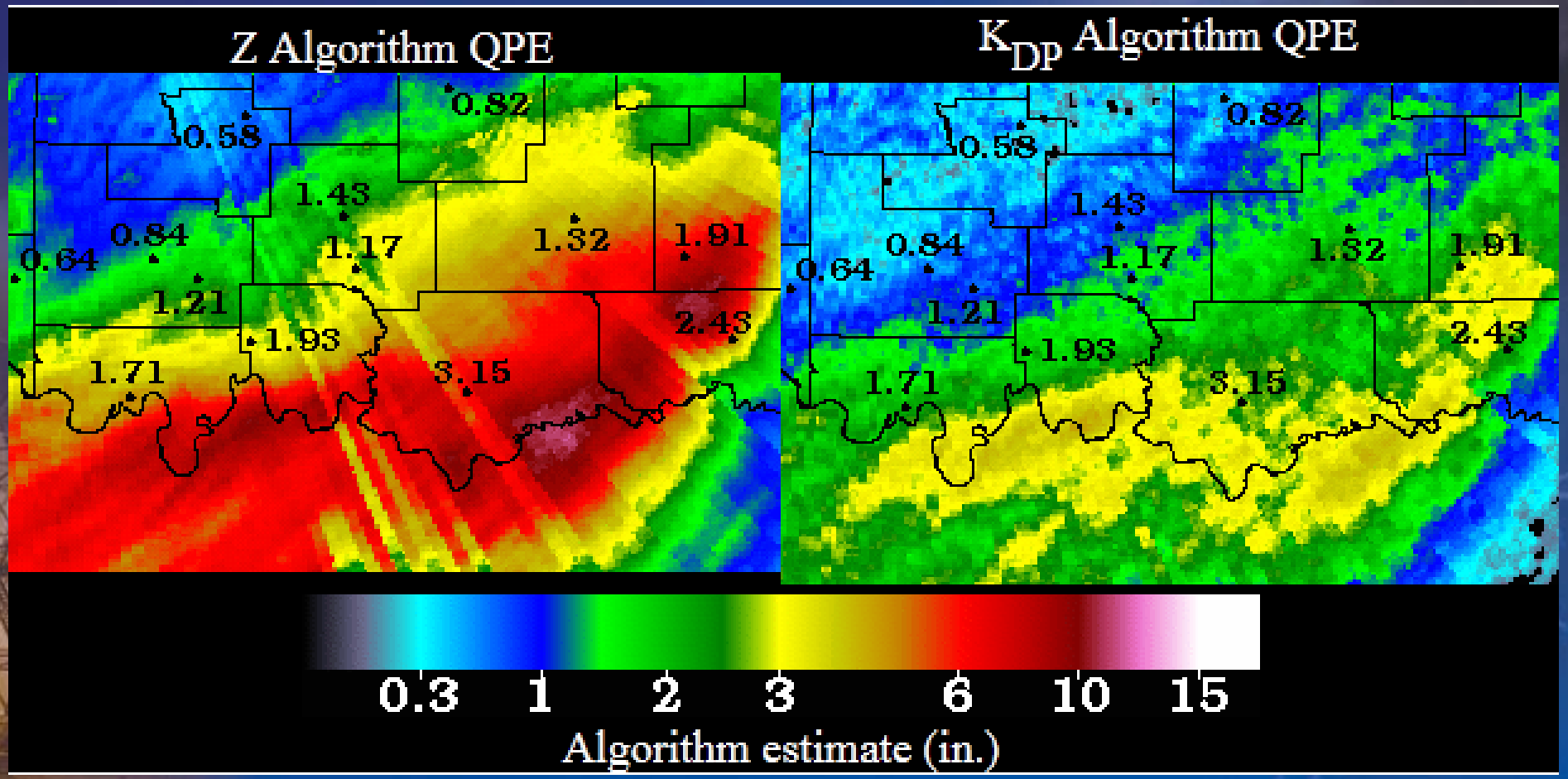
Hydro Met Precip

- **Strengths**
  - More accurate
  - Rain rate relations specific to hydrometeor types
  - Lower sensitivity to hail or bright banding
  - Non-met scattering doesn't contribute to accumulation
- **Limitations**
  - Misclassification of hydrometeor types
  - No bias applied

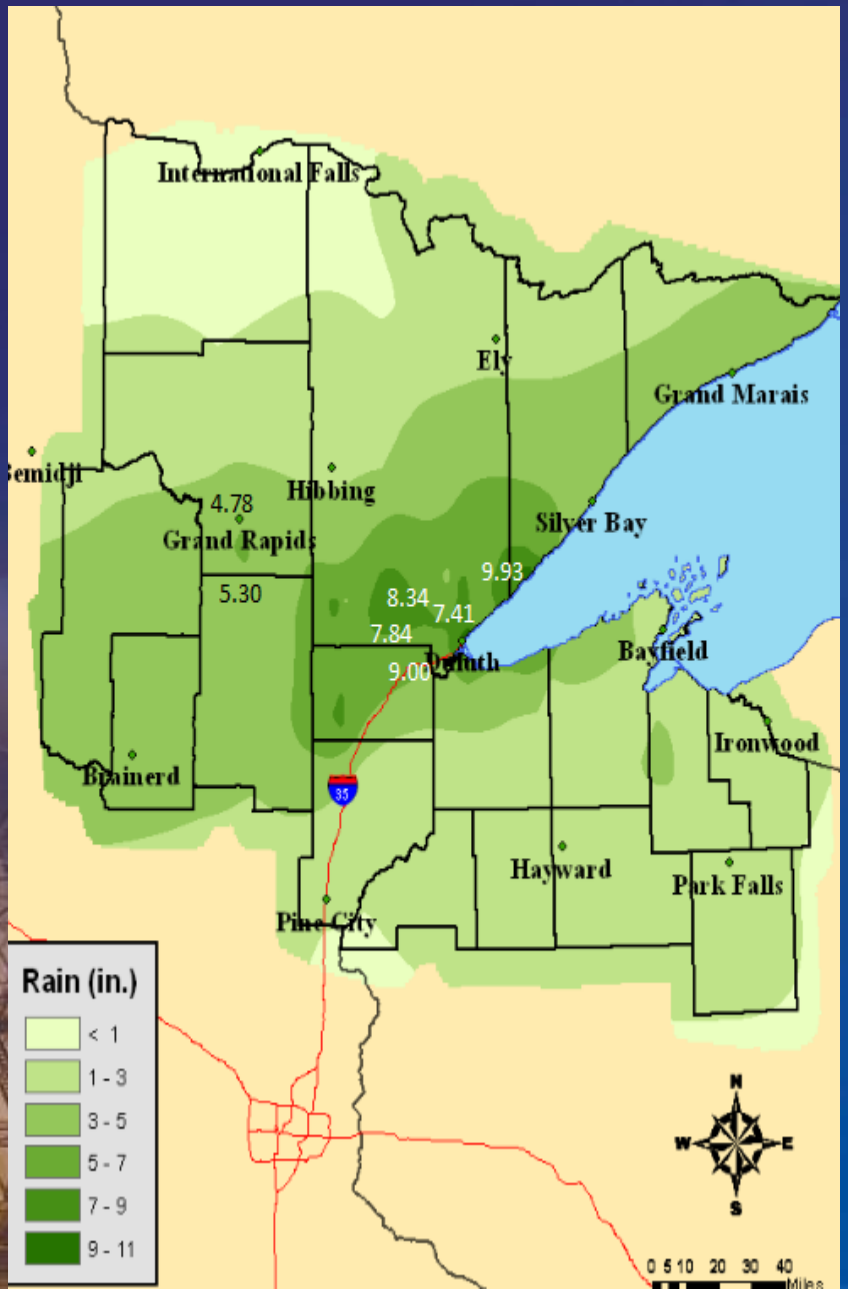
Product Type	Product Name	Abbreviation
Instantaneous	1. Hybrid Hydroclass	HHC
	2. Digital Precipitation Rate	DPR
Accumulation	3. Digital Accumulation Array	DAA
	4. One Hour Accumulation	OHA
	5. Digital Storm Total Accumulation	DSA
	6. Storm Total Accumulation	STA
Difference	7. Digital One Hour Difference	DOD
	8. Digital Storm-Total Difference	DSD
User-selectable	9. Digital User-Selectable Accumulation	DUA

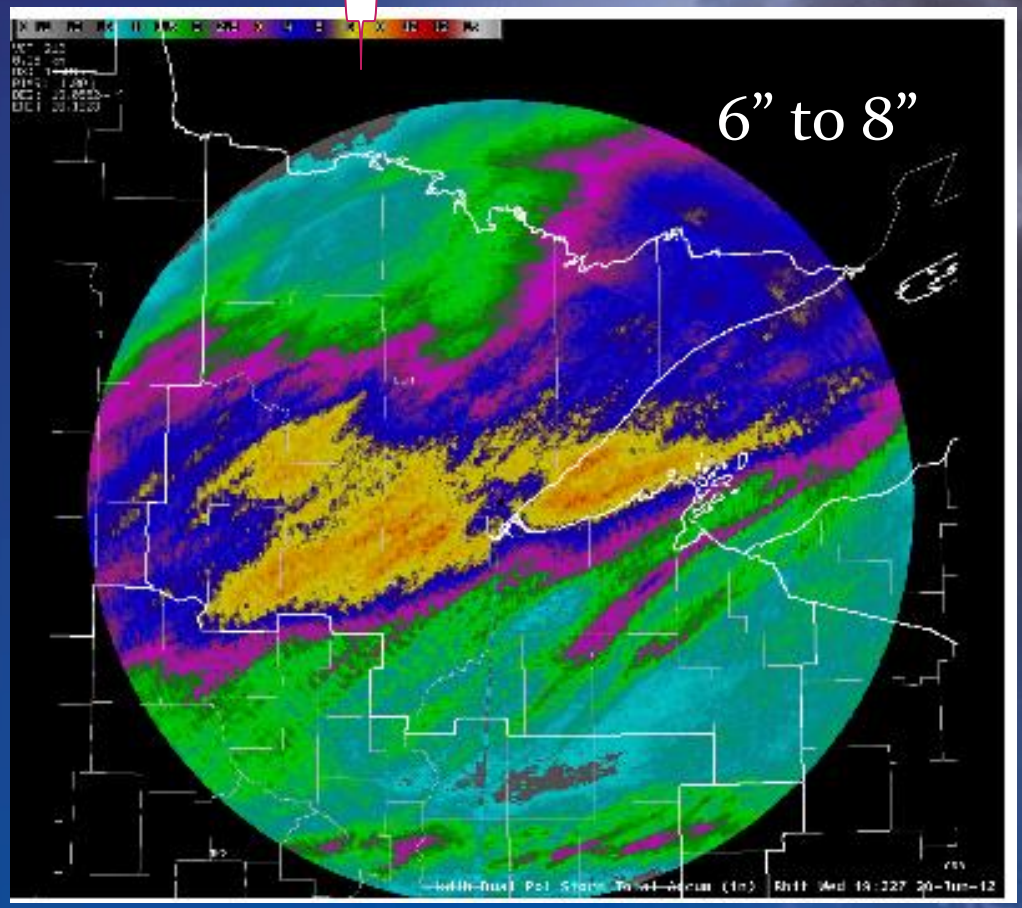
Advantages of HCA Scheme for QPE Estimation

Below is a storm total rainfall estimate compared with Oklahoma Mesonet gauges. The KDP algorithm has is almost dead-on accurate compared with the legacy $Z = 300 (R)^{1.4}$ relationship.

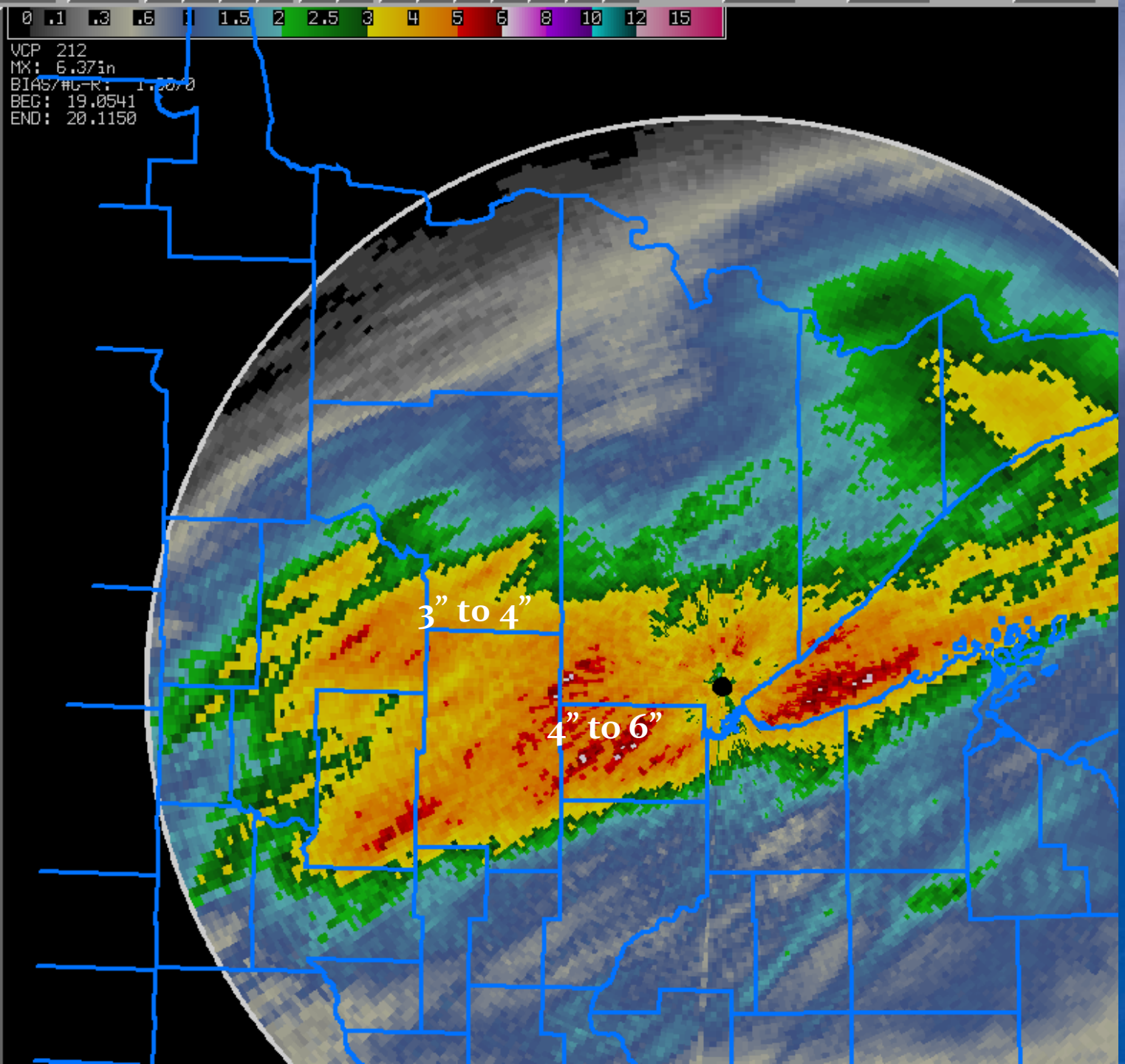


Dual Pol Precip Estimation – Duluth, MN



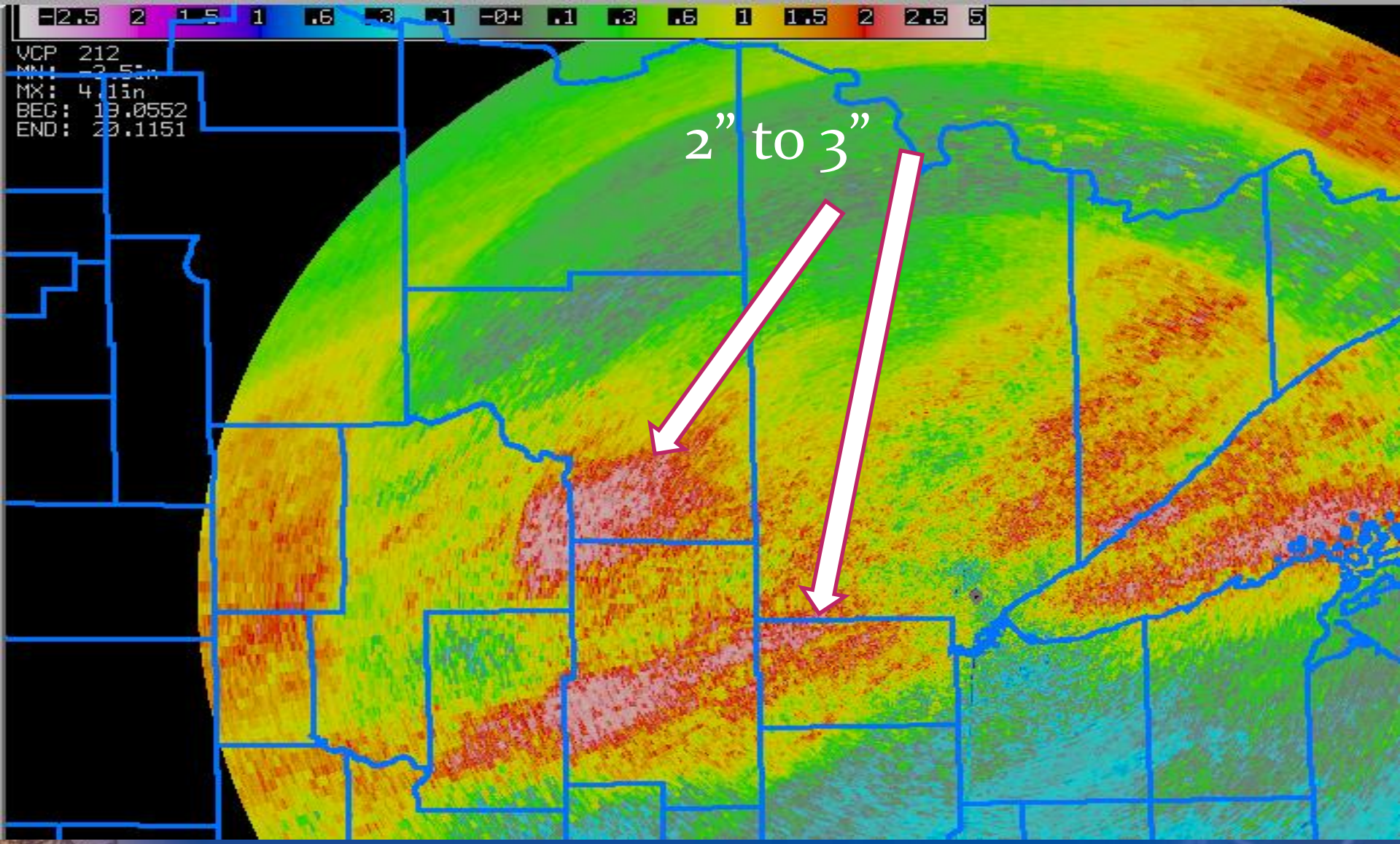


In this case, the dual-pol precipitation estimate of the overnight excessive rains that fell across Duluth through the morning of June 19, 2012 was very close to obs. The legacy STP under-estimated total rainfall amounts by 2 to 3 inches.



Precipitation totals highlighted show the storm total QPF estimated by the legacy precipitation algorithm.

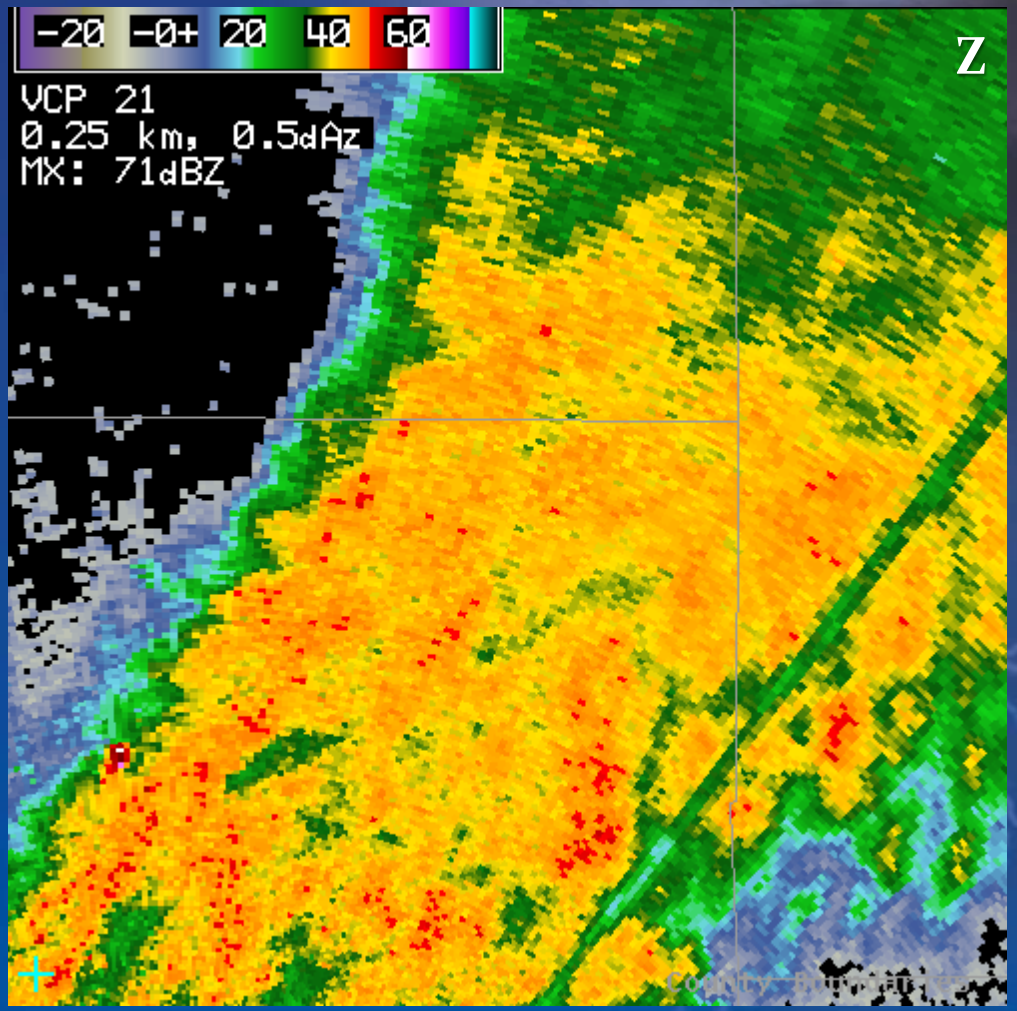
3-4" is up to 2" shy. So is the 4-6" estimate.



The arrows show where the legacy precipitation algorithm estimated total QPF around 2” to 3” less than dual pol.

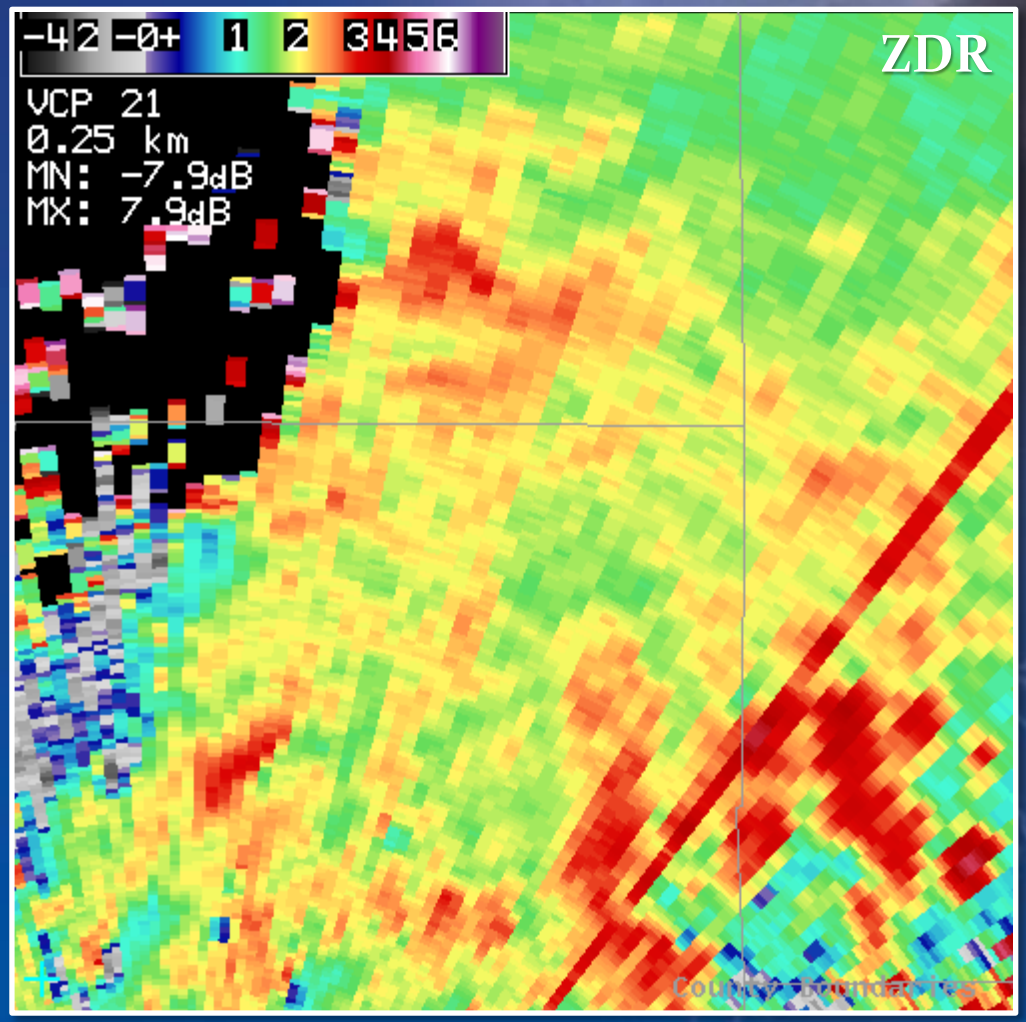
Dual-Pol Base Data Characteristics of Heavy Rain: Tropical

- Fairly high reflectivity
  $40 < Z < 55$ dBZ



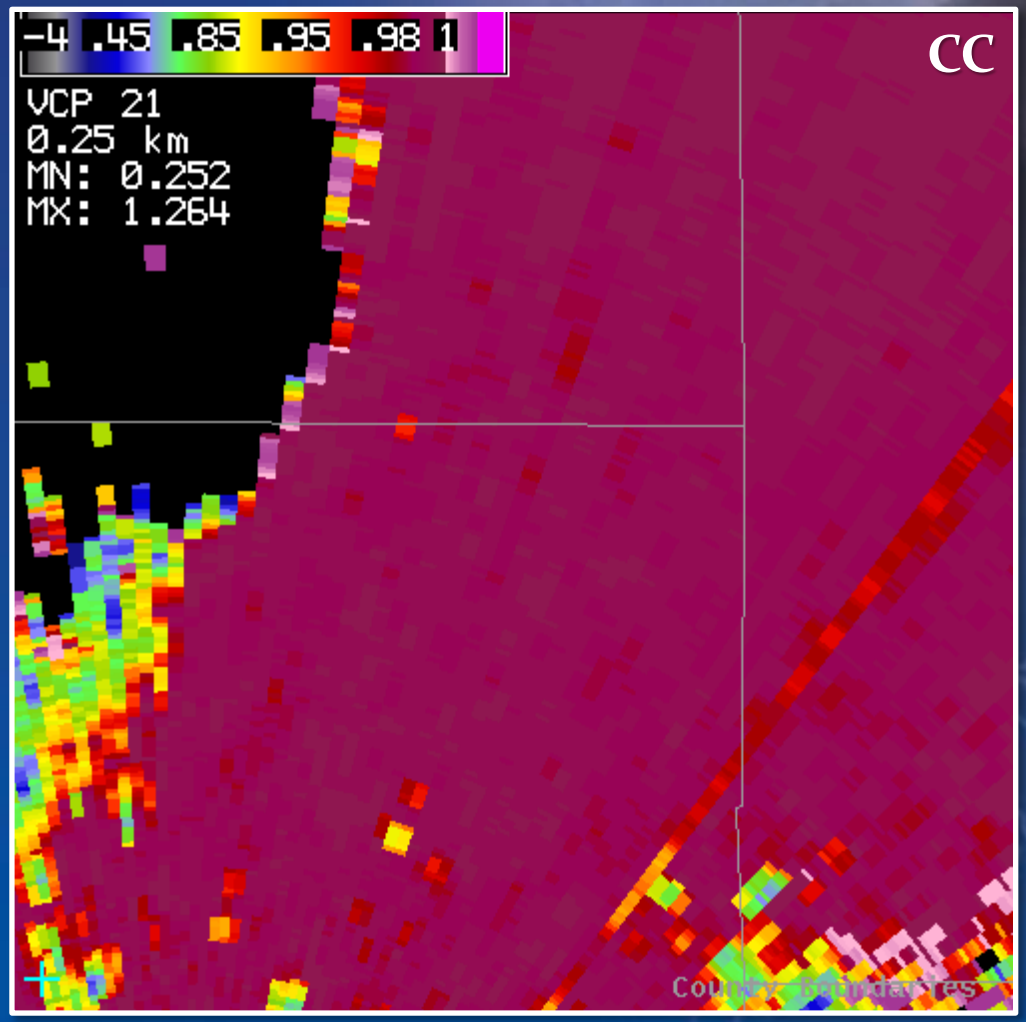
Dual-Pol Base Data Characteristics of Heavy Rain: Tropical

- Fairly high reflectivity
  $40 < Z < 55$ dBZ
- $0.5 < ZDR < 3.0$ dB



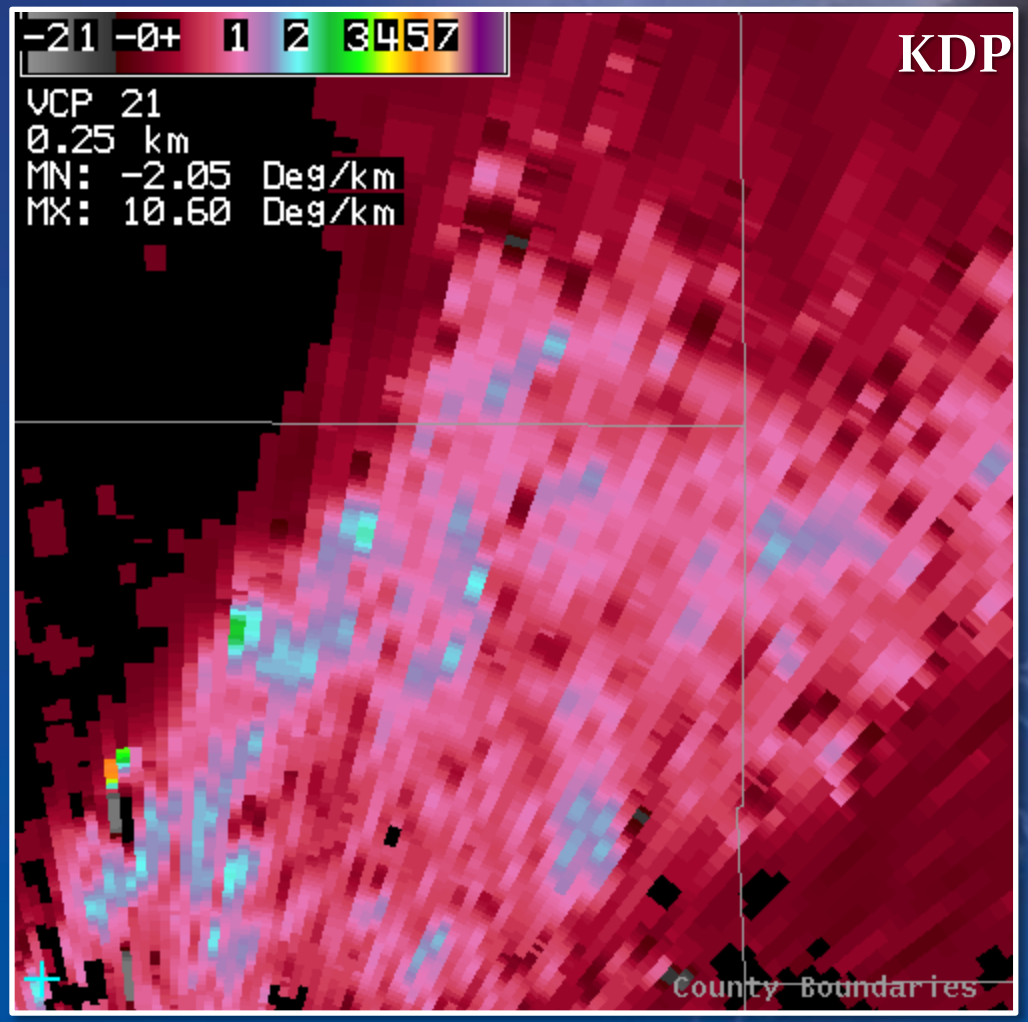
Dual-Pol Base Data Characteristics of Heavy Rain: Tropical

- Fairly high reflectivity $40 < Z < 55$ dBZ
- $0.5 < ZDR < 3.0$ dB
- $CC > 0.98$



Dual-Pol Base Data Characteristics of Heavy Rain: Tropical

- Fairly high reflectivity $40 < Z < 55$ dBZ
- $0.5 < ZDR < 3.0$ dB
- $CC > 0.98$
- KDP > 1.0 deg/km



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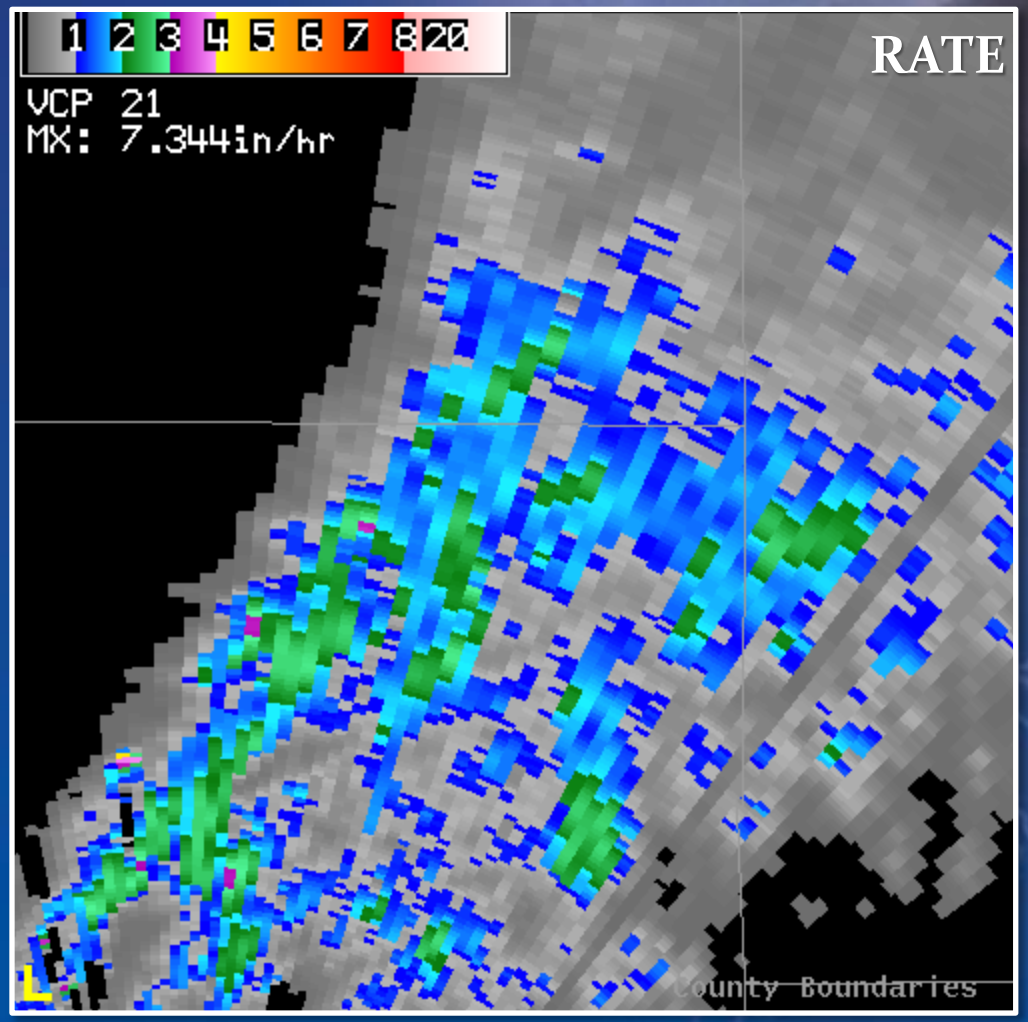
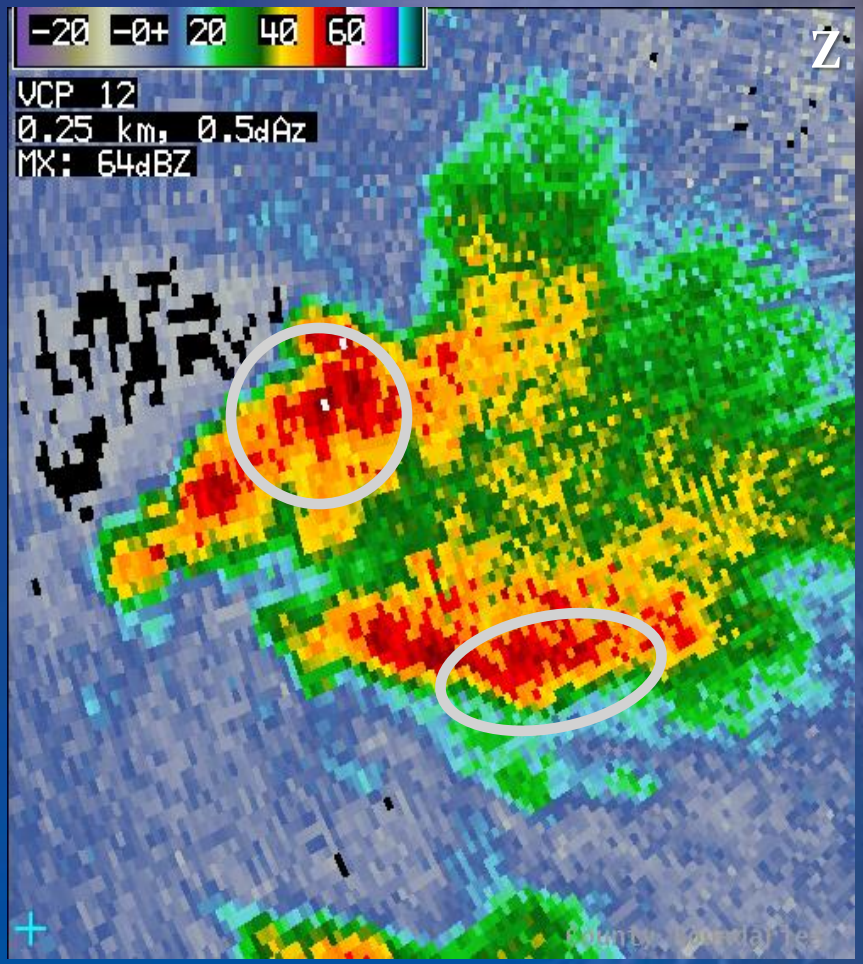


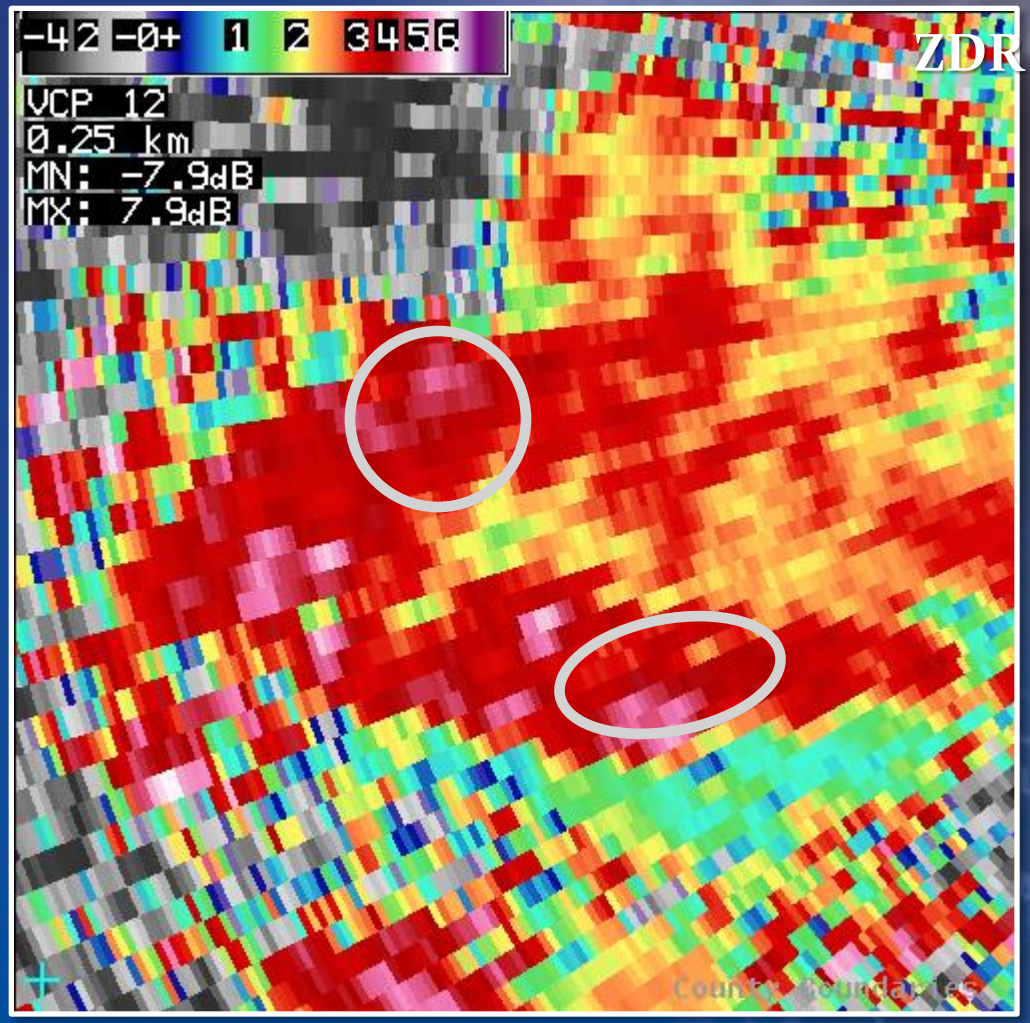
Dual-Pol Base Data Characteristics of Heavy Rain: Continental

- High reflectivity
  50 < Z < 60 dBZ



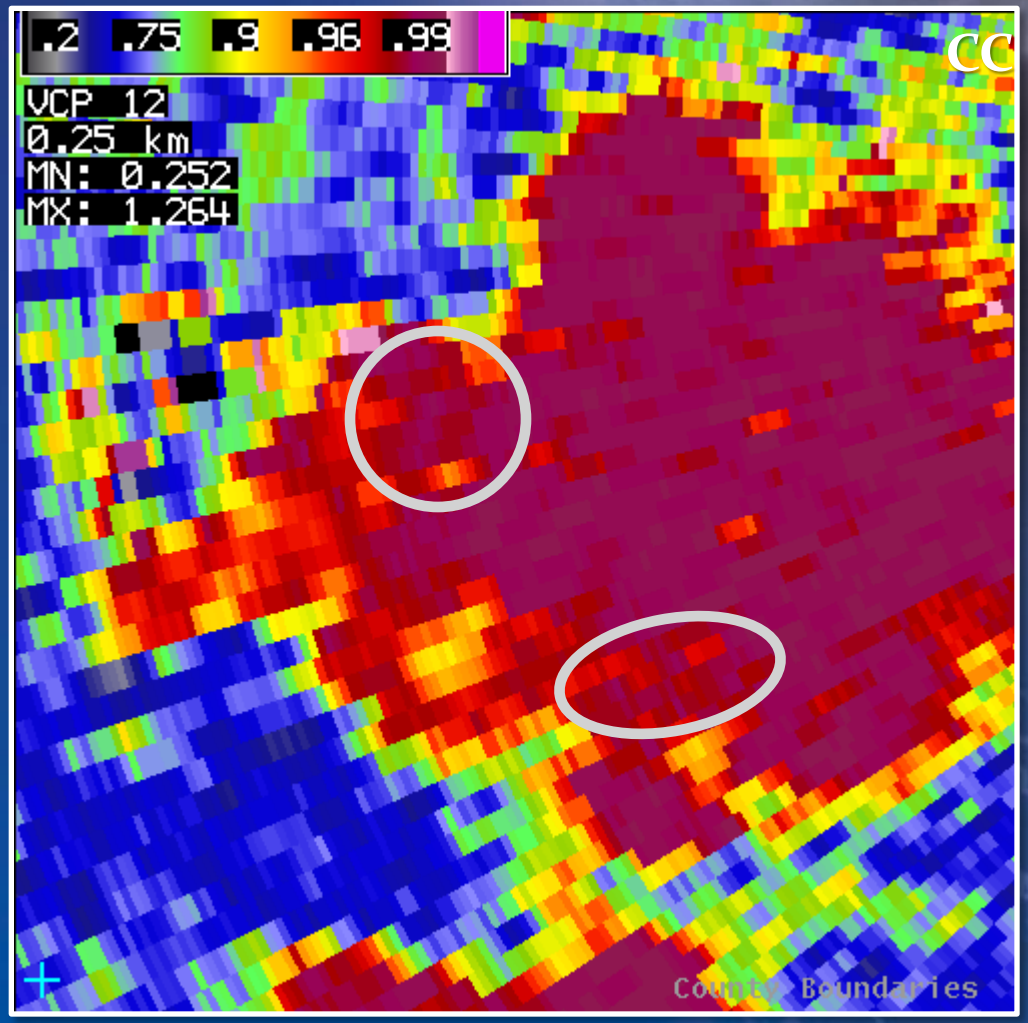
Dual-Pol Base Data Characteristics of Heavy Rain: Continental

- High reflectivity
  50 < Z < 60 dBZ
- 2.0 < ZDR < 5.0 dB



Dual-Pol Base Data Characteristics of Heavy Rain: Continental

- High reflectivity
  50 < Z < 60 dBZ
- 2.0 < ZDR < 5.0 dB
- CC > 0.96



Dual-Pol Base Data Characteristics of Heavy Rain: Continental

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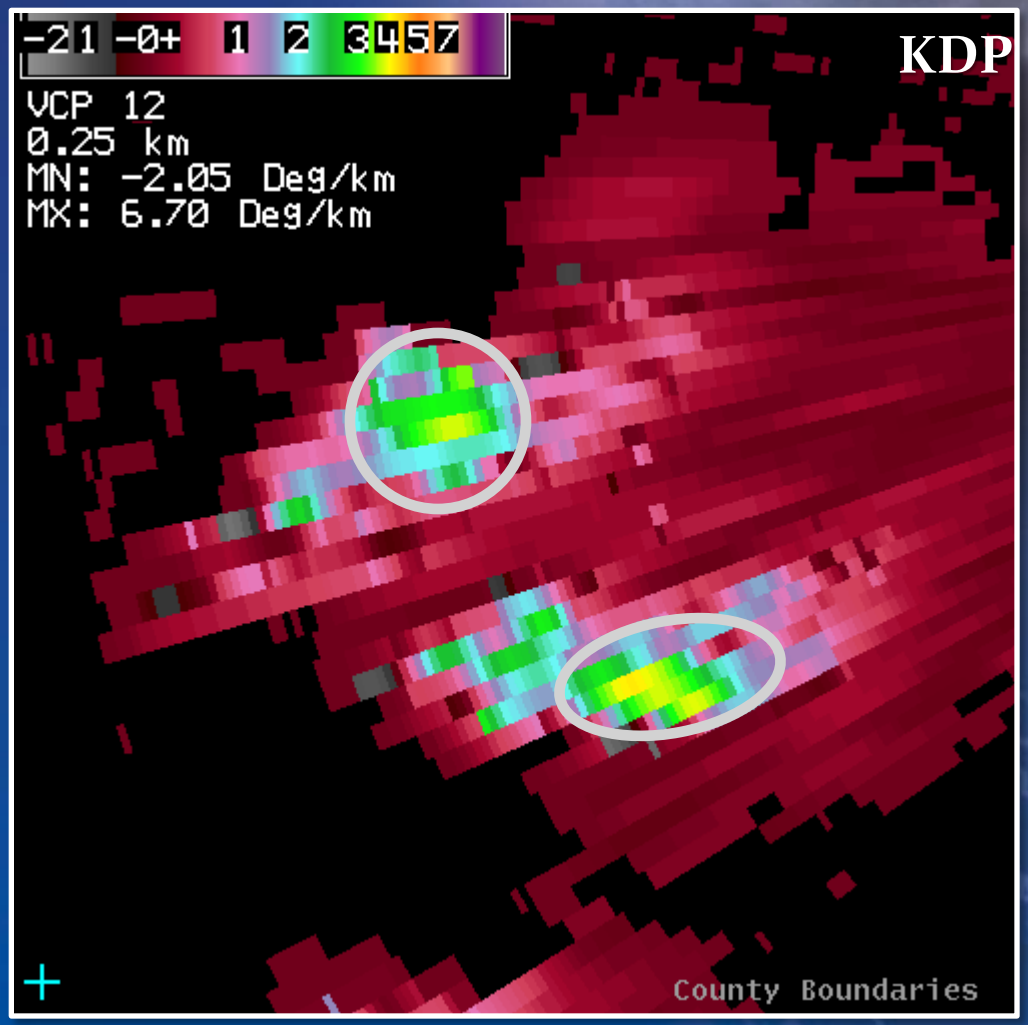

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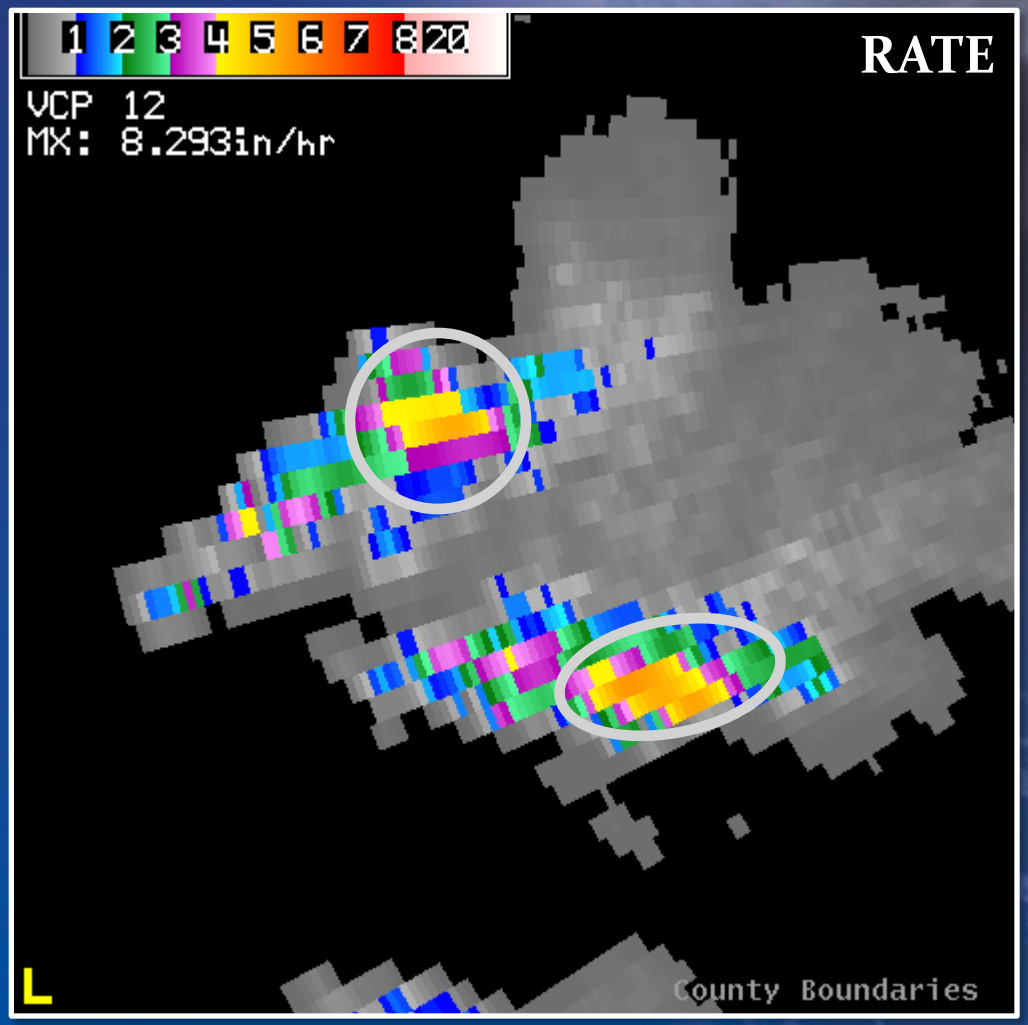

Wrap-Up

- Dual-pol products can enhance the severe weather warning decision analyst's confidence in hail size and location, tornadic debris, precipitation estimates, rain/snow line, and updraft column.

- Forecasters should use dual-pol data in conjunction with reflectivity, velocity (storm-relative and ground-relative), and spectrum width data to properly analyze severe storm structure and evolution.