# Dual Polarization Radar Interpretation, Applications and Examples


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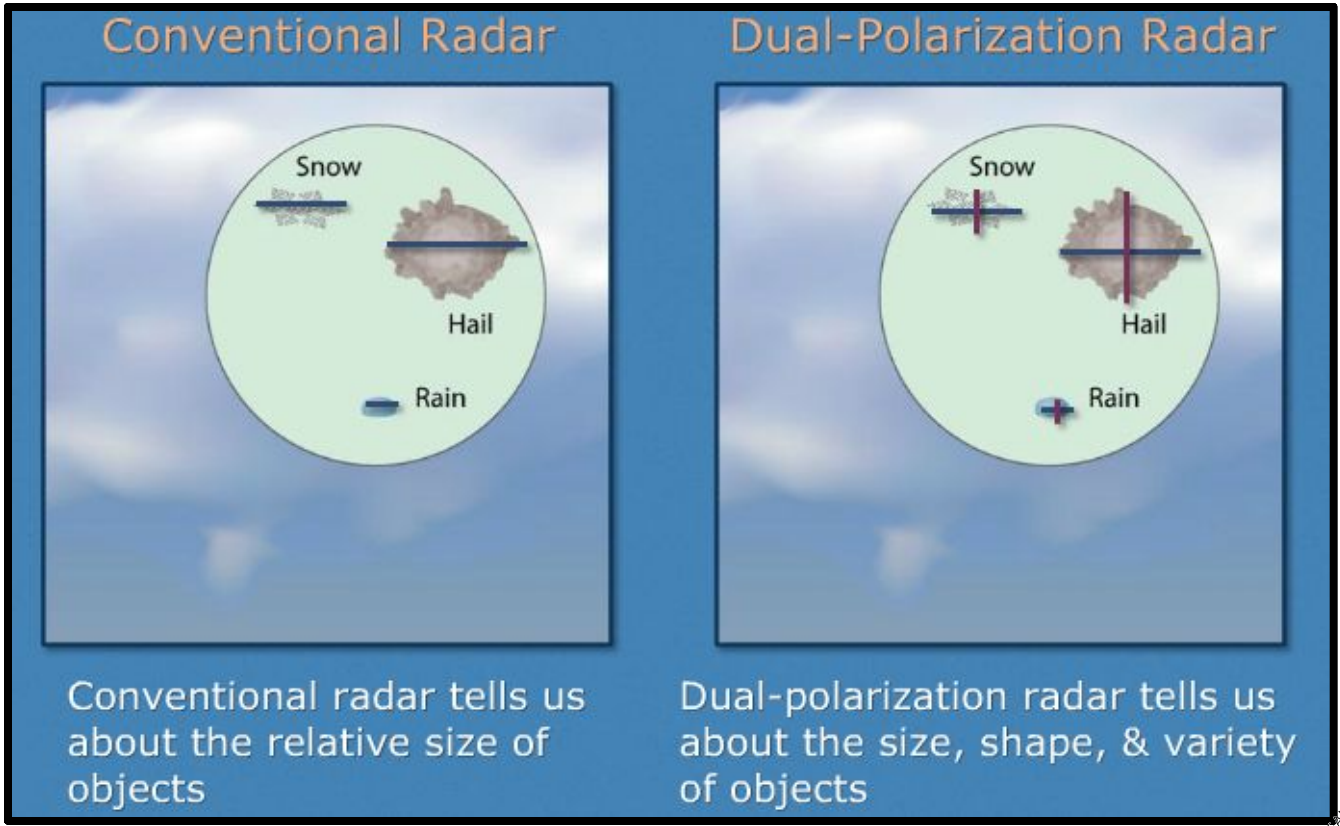
# Outline

- Conventional vs. Dual Pol radars (differences)
- Dual Polarization base products, uses, and examples
  - Differential Reflectivity ($Z_{DR}$)
  - Correlation Coefficient (CC)
  - Specific Differential Phase ($K_{DP}$)

# Dual Polarization Radar

- The KENX radar upgraded: 23-27 April 2012
- The radar now has the ability to transmit and receive both horizontal and vertical pulses
- Helps forecasters gain more info. about particle (droplet) size and distribution and helping to more accurately determine precipitation type and rate

# Difference between Conventional WSR-88D Radar & Dual-Pol Radar



# Impacts of Dual-Pol Radar

- We still receive the 3 legacy base products
  - Reflectivity (in the horizontal), Velocity and Spectrum Width (determines turbulent flow)
- The Dual Polarization Radar now gives us 3 brand new additional base products
  - Also, several new derived and precipitation products as well (We will not review Hydrometeor Classification Algorithm (HCA), MLDA and Dual Pol precipitation products)
- Gives us more physical data to use during storm interrogation (Warm and Cool season) for Warning Decision Making

# Dual Pol Base Products

- Differential Reflectivity ($Z_{DR}$)
- Correlation Coefficient (CC)
- Differential Phase ($\Phi_{dp}$)
  - We will use this product as Specific Differential Phase ($K_{DP}$)

Info. Dual Polarization Products:
https://training.weather.gov/wdtd/courses/rac

# $Z_{DR}$ – Differential Reflectivity (dB)

## Definition

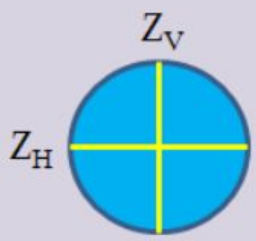
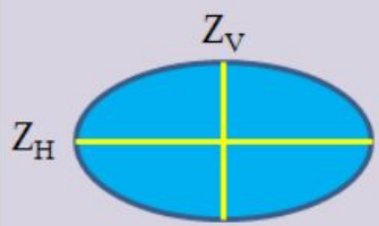
- Difference between the horizontal and vertical reflectivity factors (in dB units)

$$ZDR = Z_H - Z_V$$

$$Z_{DR} = 10\log\left(\frac{\langle S_{hh}^{\prime 2}\rangle}{\langle S_{vv}^{\prime 2}\rangle}\right)$$

- $Z_{DR}$ is a ratio of the horizontal and vertical power returns
- $Z_{DR}$ will give the forecaster a good idea of the mean droplet size and shape

# $Z_{DR}$ (dB) Interpretation

| **Spherical** (drizzle, small hail, etc.) | **Horizontally Oriented** (rain, melting hail, etc.) | **Vertically Oriented** (i.e. vertically oriented ice crystals) |
|---|---|---|
|  |  |  |
| $Z_H \sim Z_V$ | $Z_H > Z_V$ | $Z_H < Z_V$ |
| $Z_H - Z_V \sim 0$ | $Z_H - Z_V > 0$ | $Z_H - Z_V < 0$ |
| ZDR ~ 0 dB | ZDR > 0 dB | ZDR < 0 dB |

**Key**: Indicator of dominant drop shape

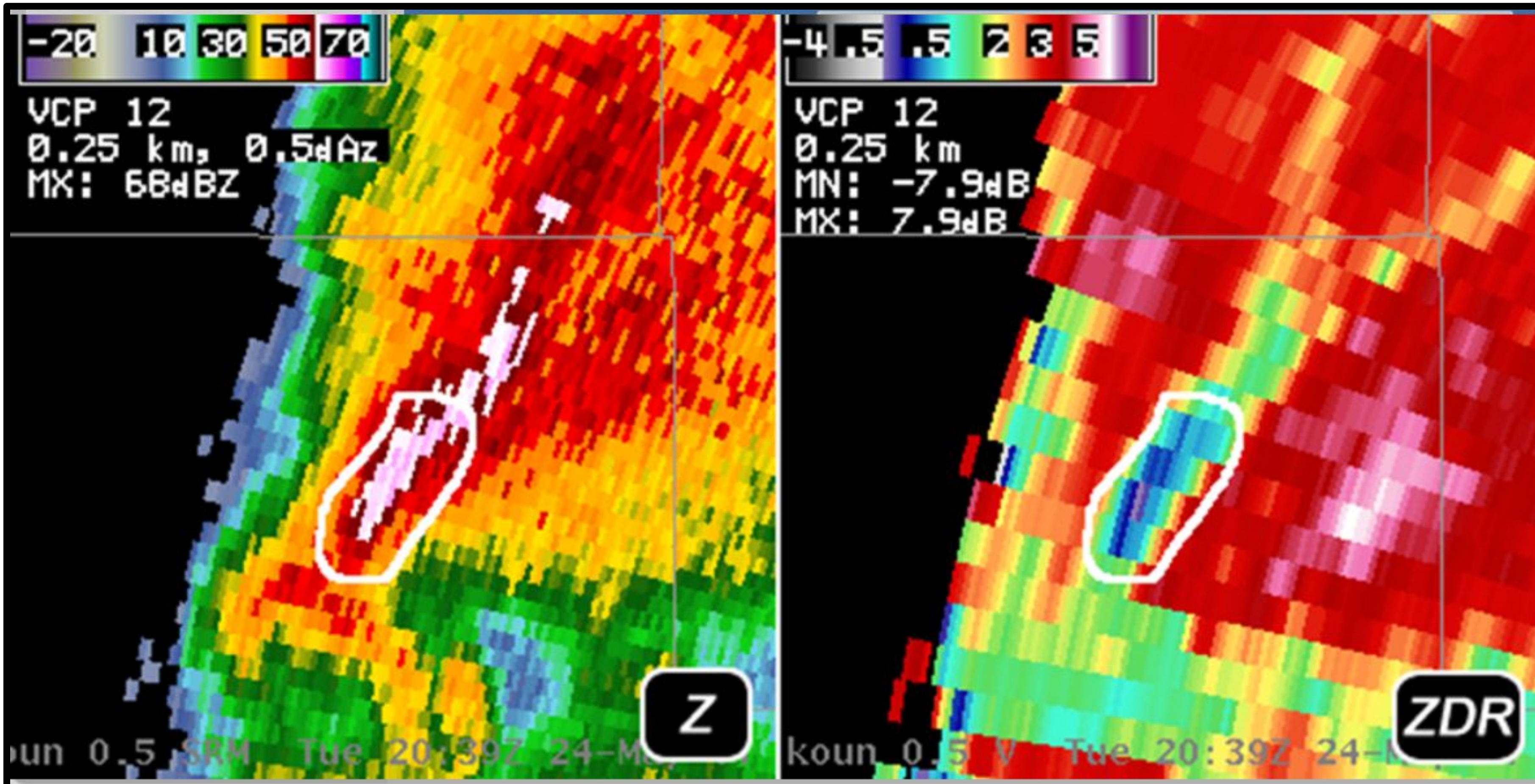
# $Z_{DR}$ (dB) for Rain

**Direct Relationship**: The larger the droplet size, the larger the ZDR

| Major Axis Diameter (mm) | Image | ZDR (dB) |
|---|---|---|
| < 0.3 mm | | ~ 0.0 dB |
| 1.35 mm |  | ~ 1.3 dB |
| 1.75 mm |  | ~1.9 dB |
| 2.65 mm |  | ~2.8 dB |
| 2.90 mm |  | ~3.3 dB |
| 3.68 mm |  | ~4.1 dB |
| 4.00 mm |  | ~4.5 dB |

https://training.weather.gov/wdtd/courses/rac/products/zdr

# $Z_{DR}$ (dB) for Hail

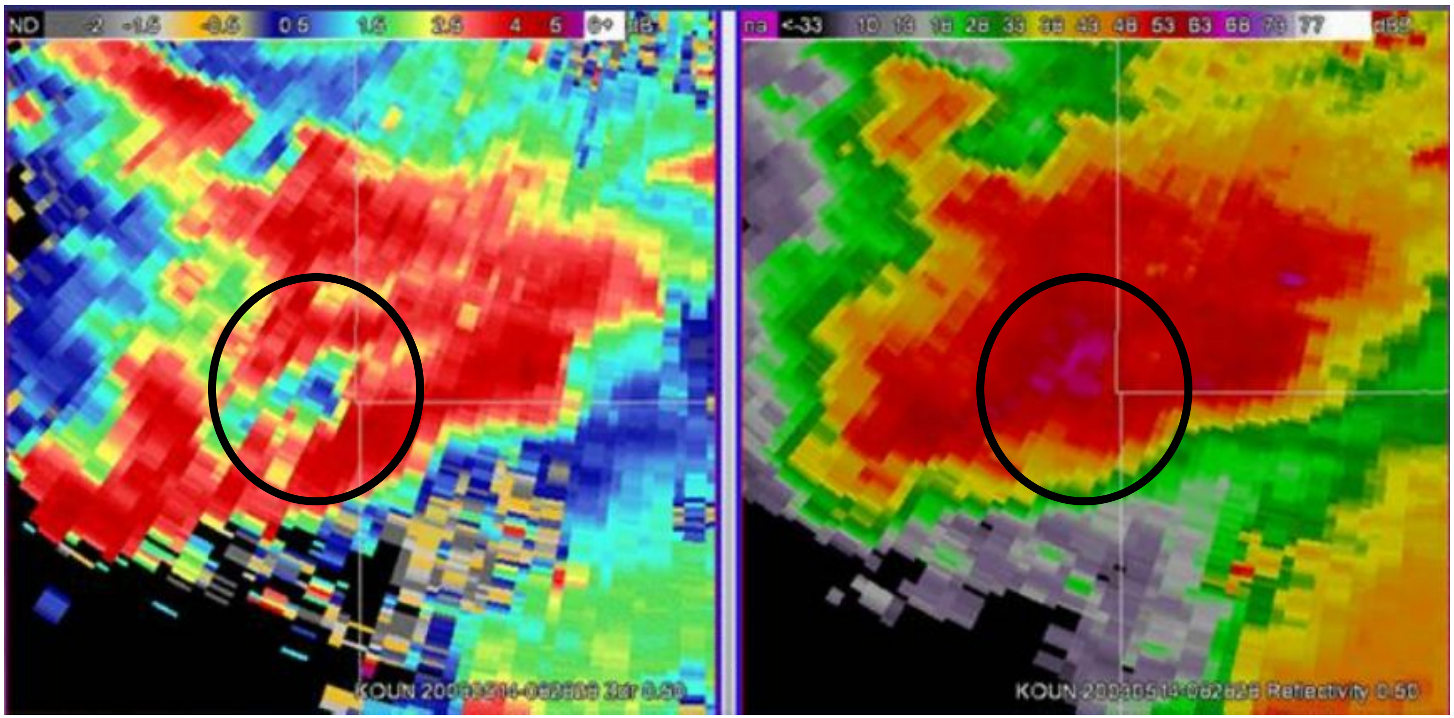



- Hail has a high Z (dBZ) and low ZDR (~0 dB), especially if falling or tumbling
- Small hail that is melting has a high ZDR, like giant rain drops (5-6 dB's)

# $Z_{DR}$ Uses/Applications

- Locations of hail shafts if the $Z_{DR}$ ~ 0 dB (near spherical hydrometeors) coincident with high Z (REF)
- $Z_{DR}$ much greater than 0 dB indicates large rain drops
- Identification of strong updraft area in thunderstorms ($Z_{DR}$ columns) with liquid drops well above freezing/melting Layer
- Determination of Wet vs. Dry Snow in Cool Season
- Areas of small hail mixed with rain could have high $Z_{DR}$ (water covered hail stones)

# Severe Weather Example of $Z_{DR}$ for a Supercell



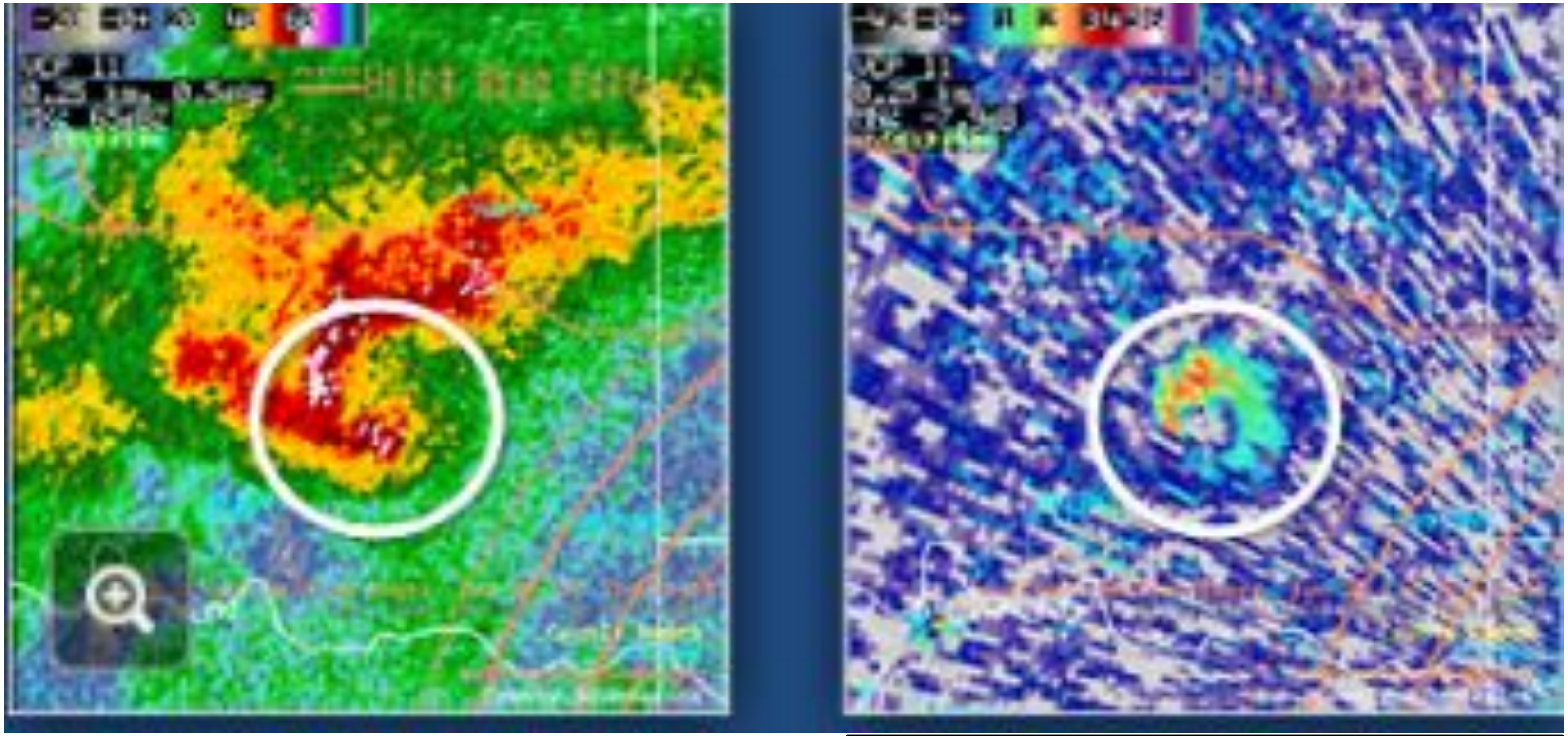
**Differential Reflectivity ($Z_{DR}$)**

**Reflectivity (Z)**

**Values of $Z_{DR}$ near zero along with high values of Z indicate a hail shaft.**

# $Z_{DR}$ Applications/Uses: ZDR Columns

**ZDR Columns: strong/intense updraft identification**
**ZDR is usually > 1 above the melting layer/freezing layer**
***Brian F. will review more examples in the next presentation***



High Z (dBZ) above the FZL

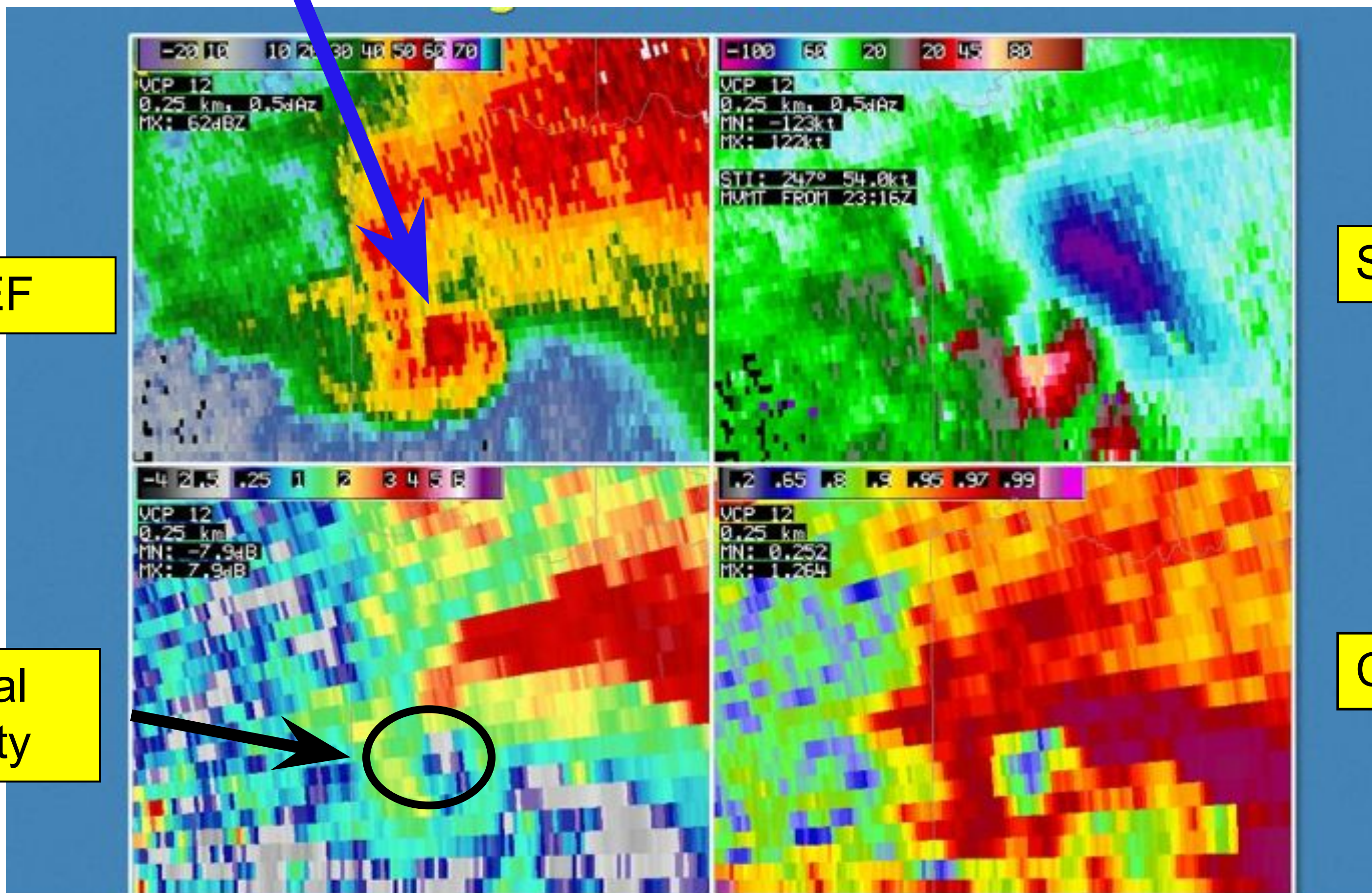
ZDR greater than > 1 dB above FZL

# Tornadic Debris Signature (TDS) Use

Insulation and shingles lofted

Base REF

SRM



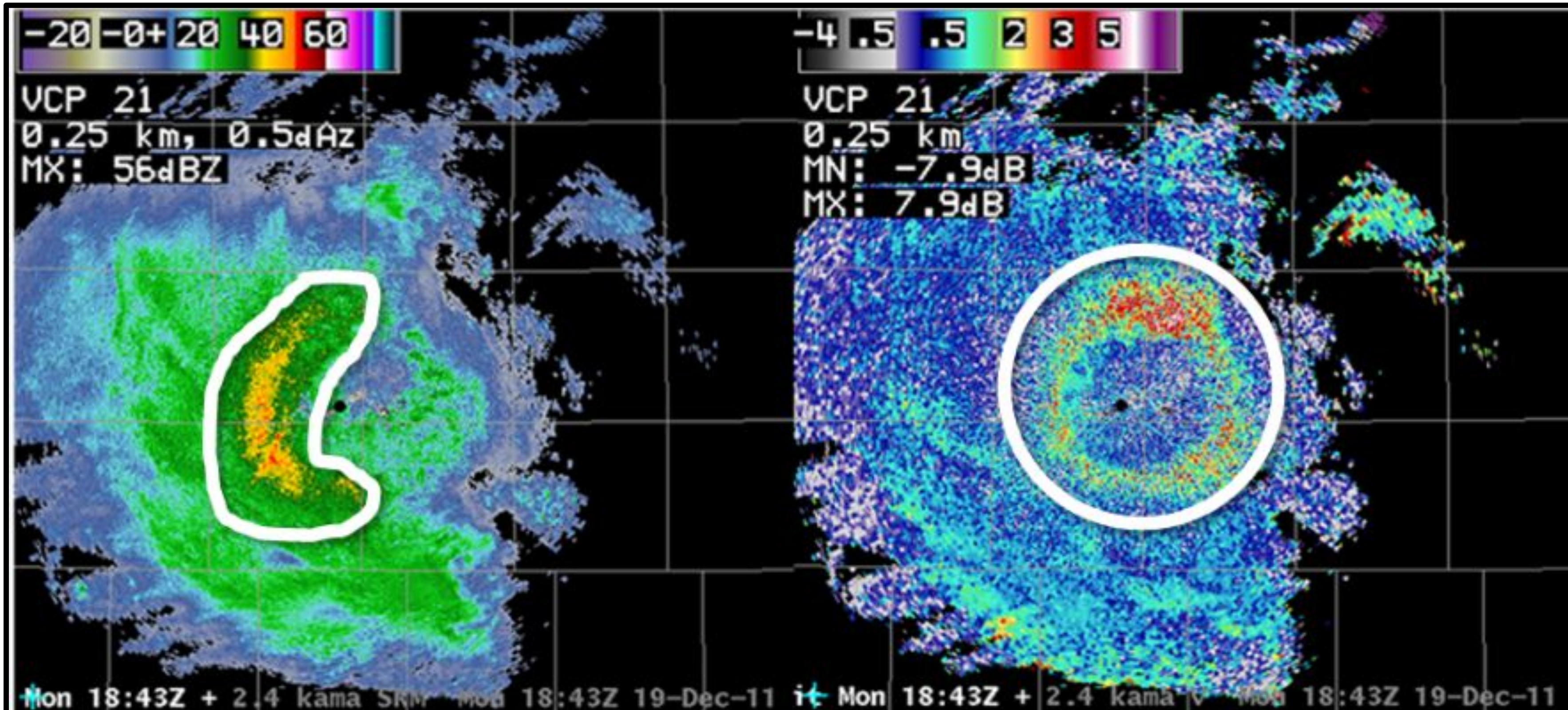

Differential Reflectivity

Corr. Coeff

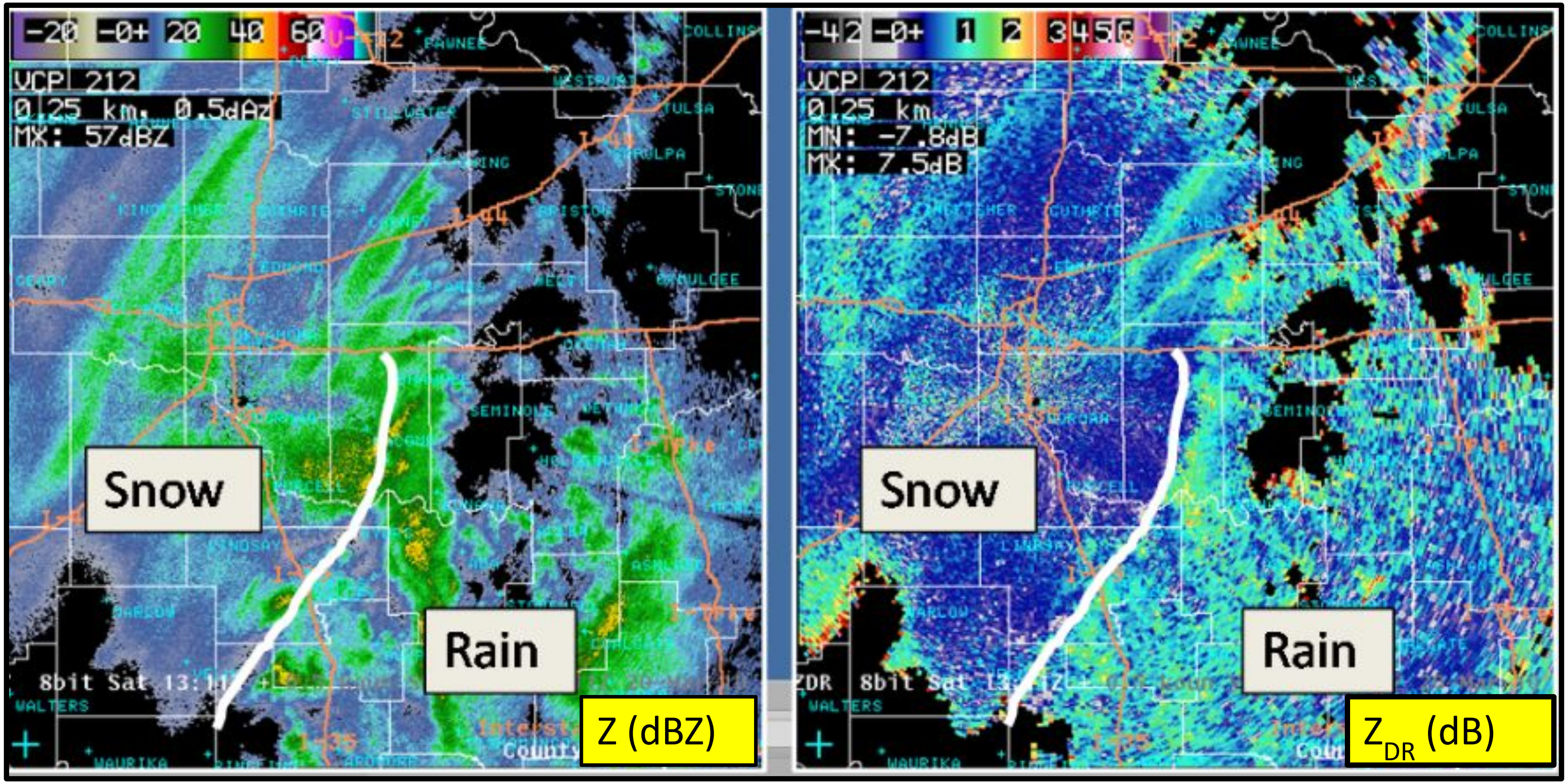
Low $Z_{DR}$ ~ 0 dB in area of possible tornado

# Melting Layer Identification

- Identified as region of high $Z_{DR}$ (dB)



# Rain vs Snow Usage ($Z_{DR}$)




**Rain vs Snow lines or transition zones: (1) Rain area – > ZDR > 1 dB**
**(2) Snow area – > ZDR ~ 0 dB**

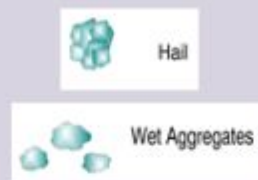
# Correlation Coefficient (CC)

- A measure of the correlation between the horizontal and vertical back-scattered pulses from the scatterers within a sample volume scan of the radar (some similarities to spectrum width)
- Mathematically known as $\rho_{hv\ (\text{unit less})}$
- Can determine precipitation type, meteorological vs. non-meteorological echoes

# CC Interpretation Table

*** Hydrometeors more uniform with high CC values in the right column**

Jar Jar Carbonite –
Non-met target (sort of)

| Non-Meteorological (birds, insects, etc.) | Metr (Non-Uniform) (hail, melting snow, etc.) | Metr (Uniform) (rain, snow, etc.) |
|---|---|---|
|  |   |  |
| Complex scattering from pulse-to-pulse. | Somewhat complex scattering from pulse-to-pulse. | Well-behaved scattering from pulse-to-pulse. |
| **Low CC (< 0.8)** | **Moderate CC (0.80 to 0.97)** | **High CC (> 0.97)** |

# Correlation Coefficient

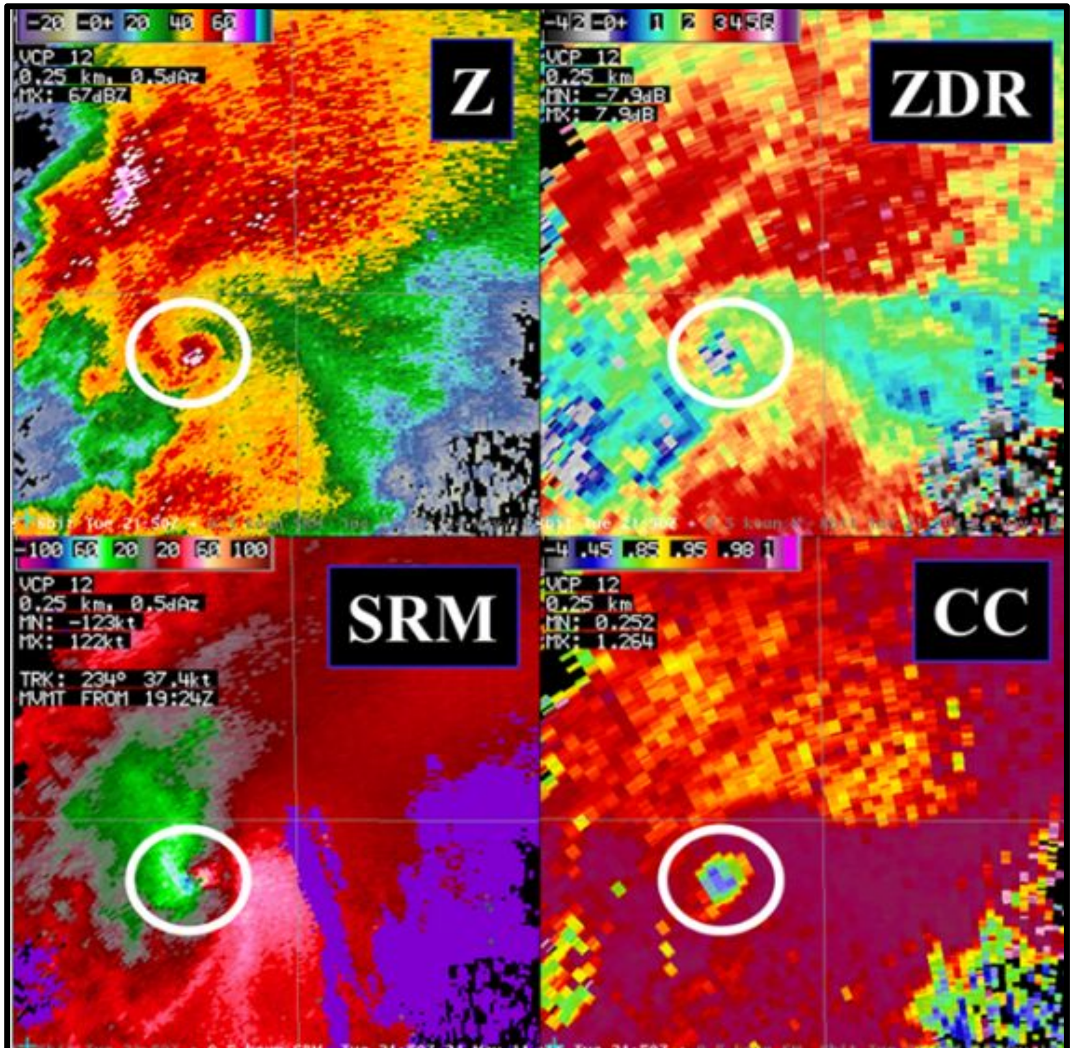
- Values > 0.97 indicate a consistent size, shape, orientation, and/or phase of hydrometeors
- CC 0.80 to 0.97 indicates a mixture of the size, shape, and orientation and/or phase of hydrometeors
- CC < 0.80 is usually non-meteorological scatterers (birds, insects, buildings) and sometimes large hail

Values of greater than 1.00 are possible in areas of noisy data at a far range and low SNR (signal to noise ratio) and these values should just be ignored.

# CC Uses/Applications: TDS

Z > 30 dBZ

ZDR ~ 0 dB



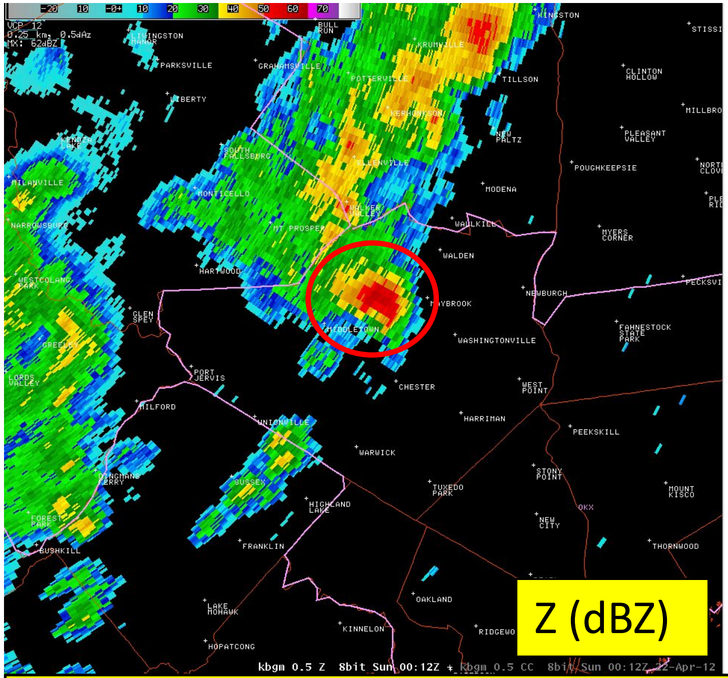

Tornadic velocity couplet in SRM

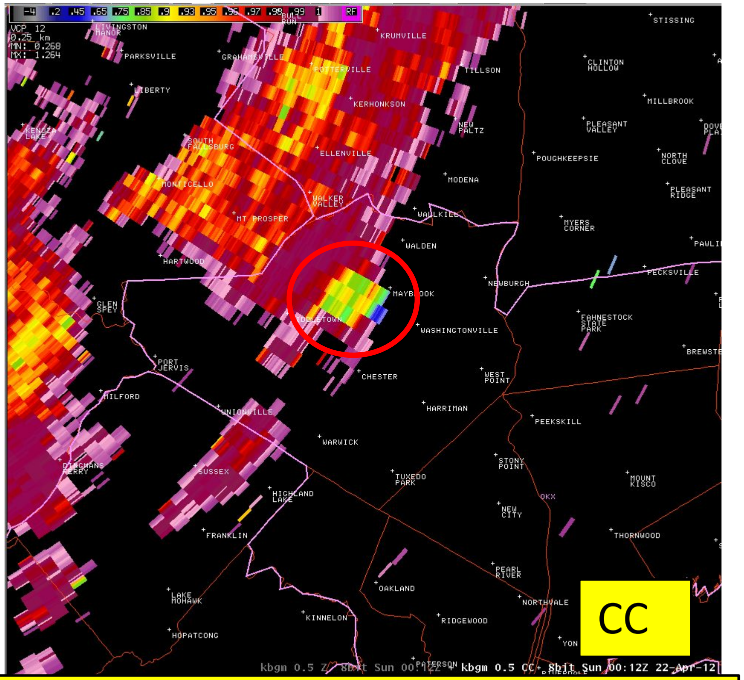
CC < 0.80

Tornadic Debris Signature (TDS) has low CC due to shingles, siding, leaves, and other non-meteorological debris lofted

# CC Uses/Applications: Severe Hail

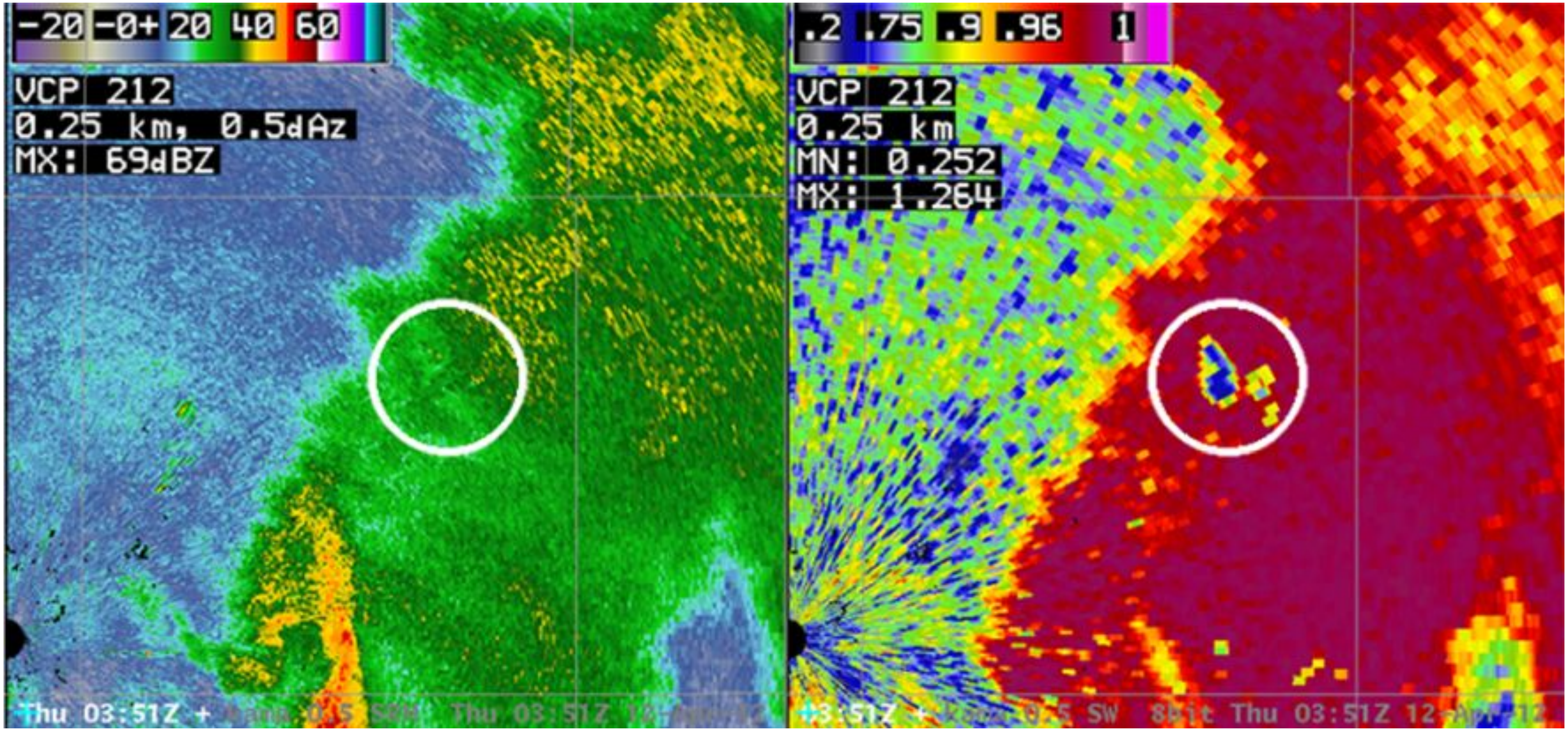
Severe Hail Guidance: (1) CC < 0.90 is 2”+ diameter hail
(2) CC < 0.75 can be large, spiky hail




Radar images from KBGM from the evening of April 21, 2012 with Z (REF) on the left and CC (Correlation Coefficient) on the right. Notice the area of lower CC values (0.85-0.90) along with high Z values indicate hail aloft.

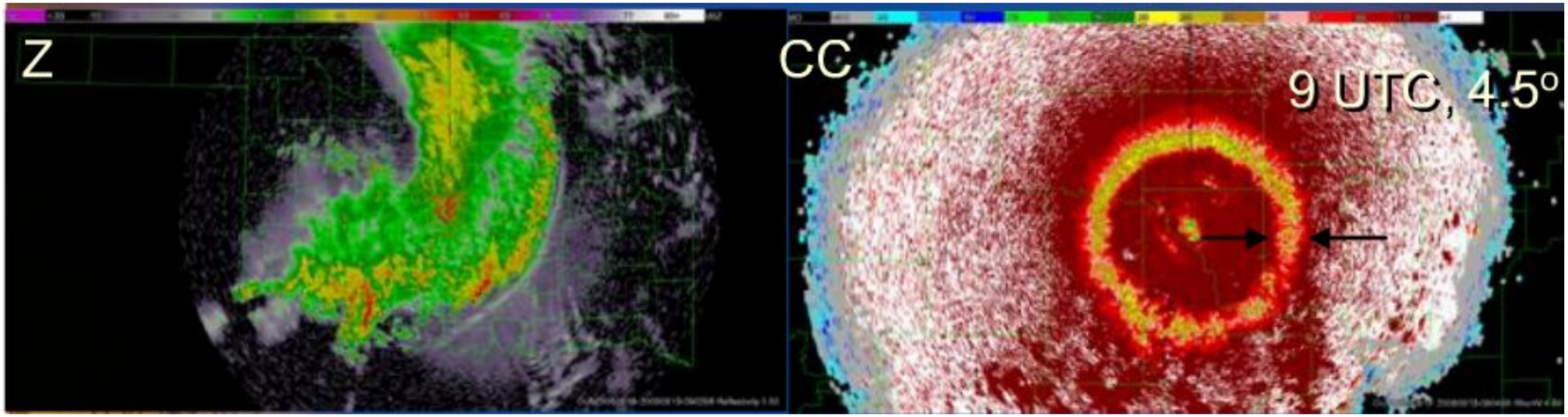
# CC Uses/Applications: Meteorological vs. non Meteorological Echoes




General rain, but a tower or some non-meteorological target picked up.
Recall: CC > 0.80 meteorological targets, and CC < 0.80 non-meteorological echoes.

# CC Use/Applications: Melting Layer Detection

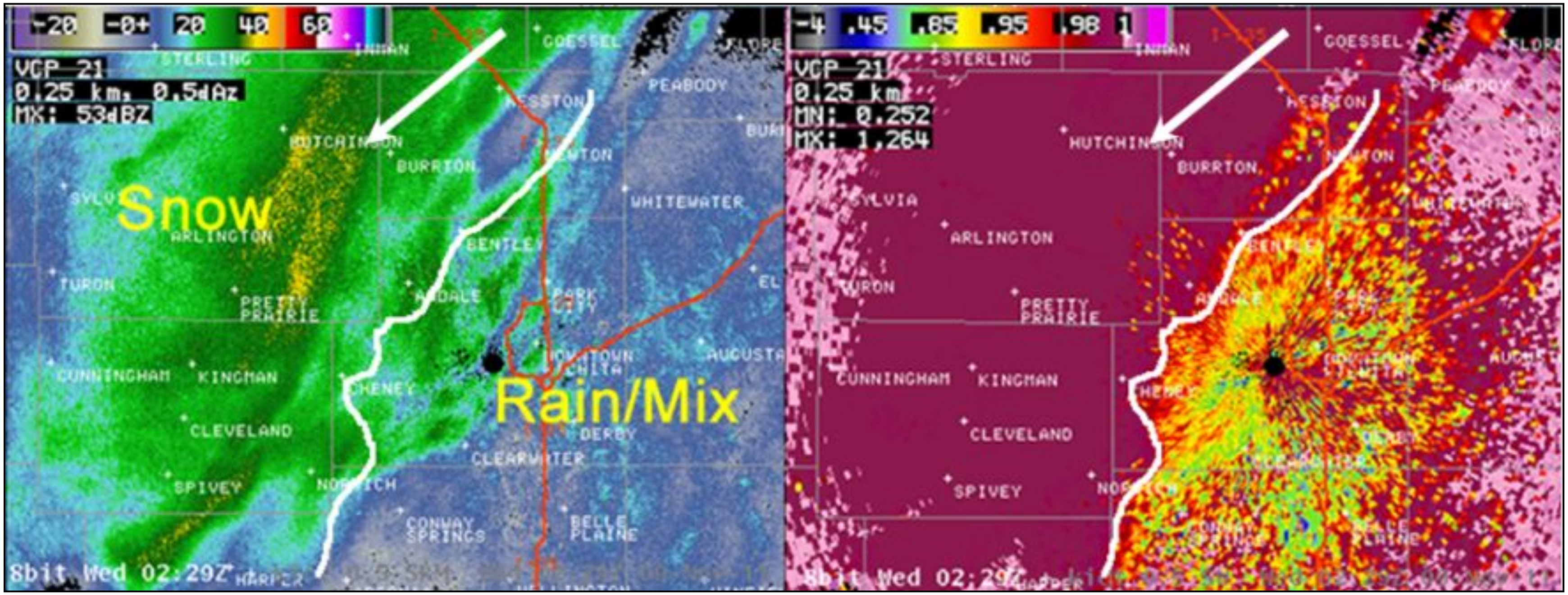
- Good for detecting the melting layer (ring of lower CC)
- Look at a higher radar elevation angles for values around 0.90 or less



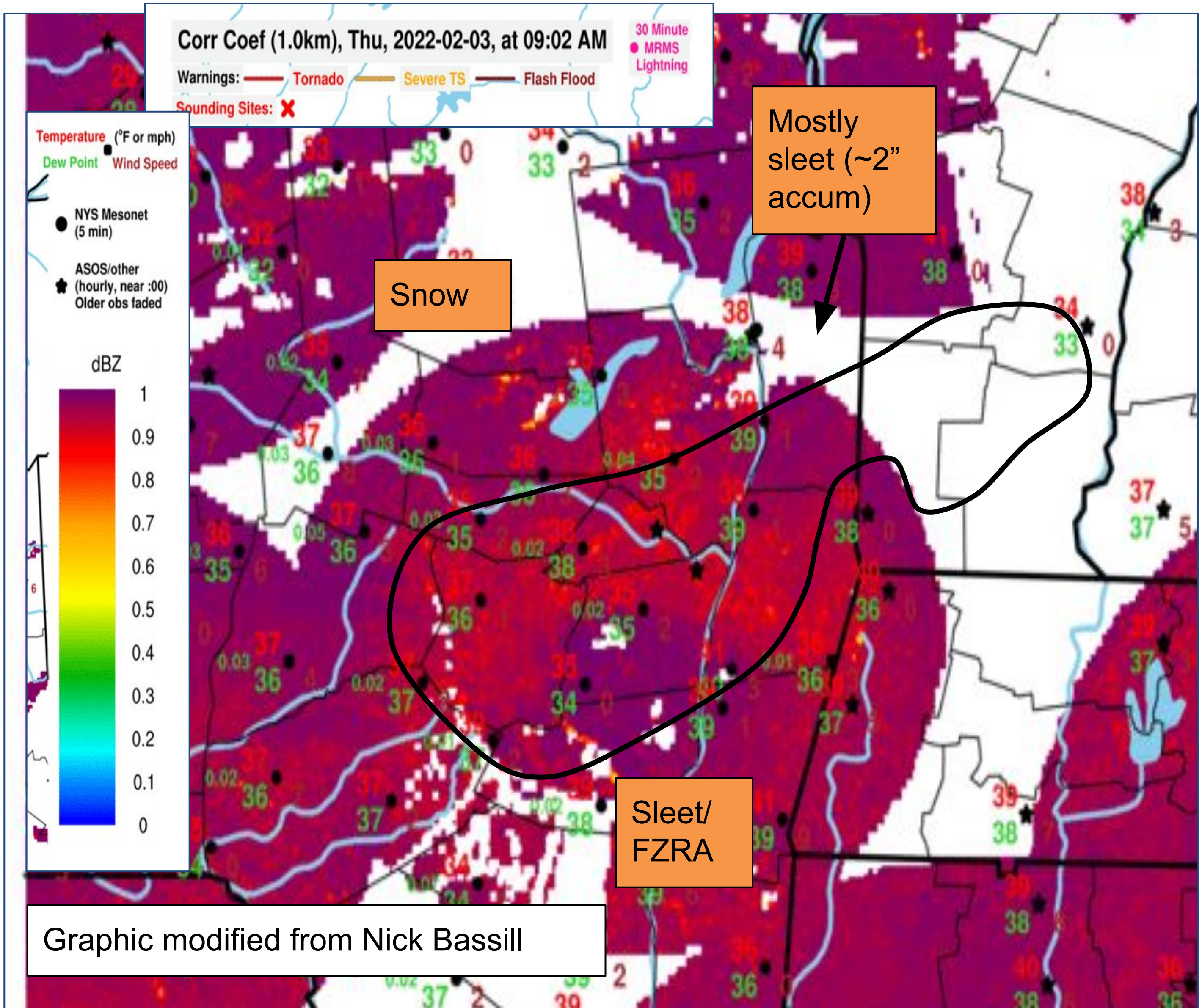
# CC Use/Applications: Snow vs Rain/Mixed Precipitation

Identification of Precipitation transition zones:

- In the example all snow ptype where CC > 0.97
- Rain/Icy mix where CC < 0.97



# Correlation Coefficient and Obs: Feb 3-4, 2022 “Sleet Bomb” Event



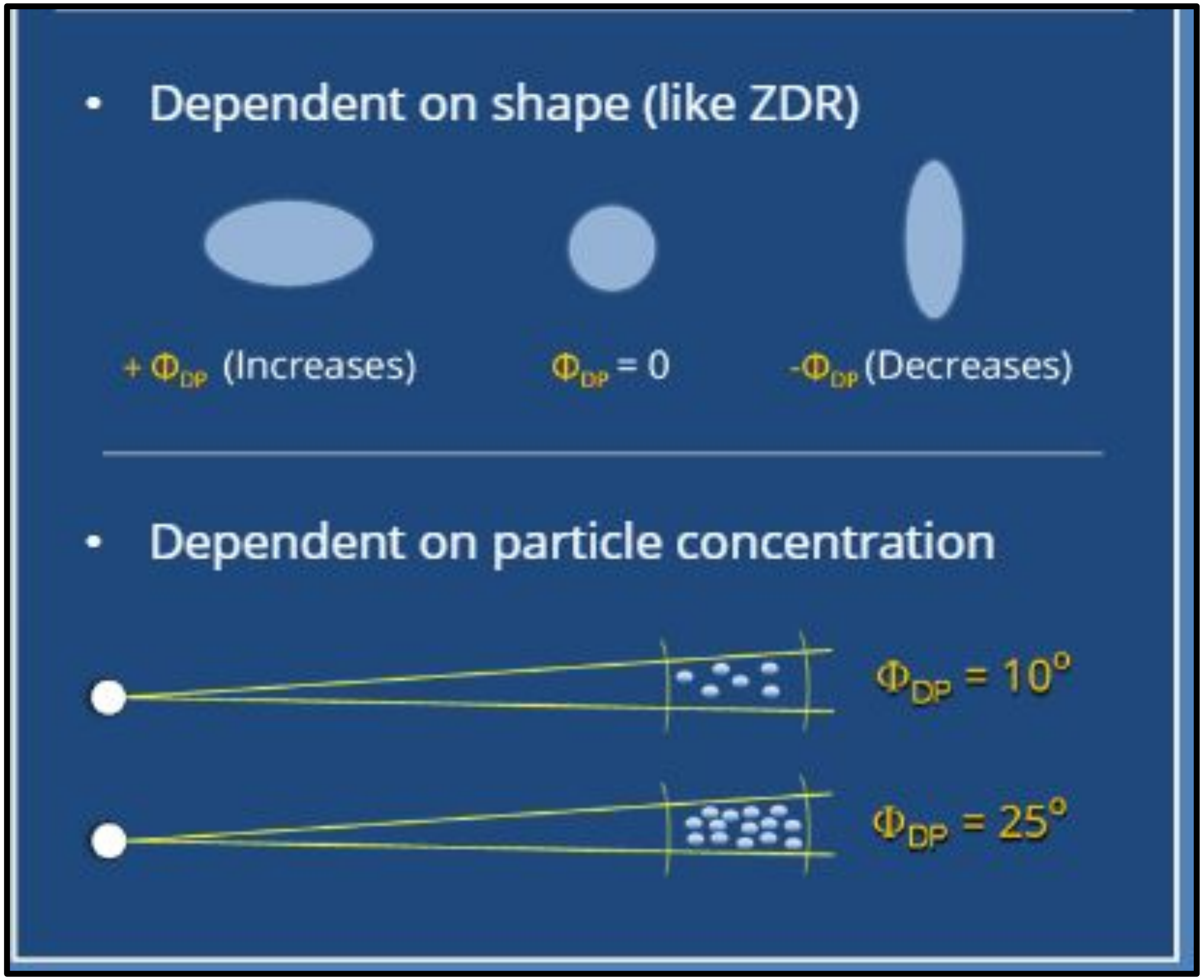
# Differential Phase ($\Phi_{dp}$)

$\Phi_{dp}$: The difference in phase shift between horizontal and vertical polarized returned energy due to forward propagation

$$\boxed{\phi_{DP} = \phi_{hh} - \phi_{vv}}$$

We are concerned more with Specific Differential Phase

# Differential Phase ($\Phi_{dp}$) Interpretation

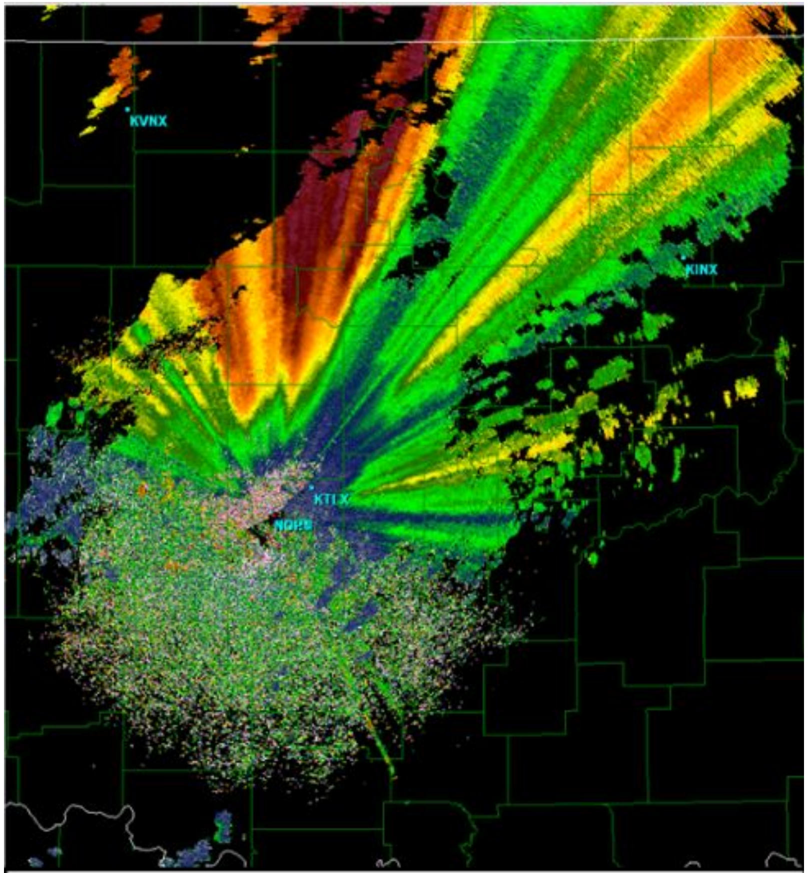


# Specific Differential Phase ($K_{DP}$)

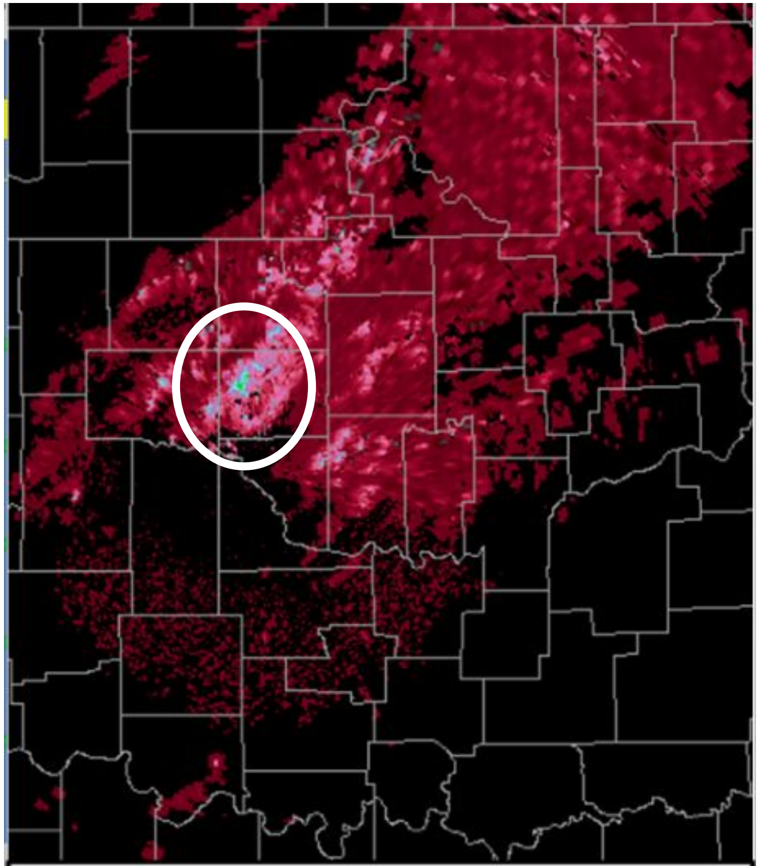
$$K_{DP} = \frac{\phi_{DP}(r_2) - \phi_{DP}(r_1)}{2(r_2 - r_1)}$$

- A derived product display what we learn from $\Phi_{DP.}$
- Since $\Phi_{DP}$ is cumulative, we use $K_{DP}$
  - It's basically the range derivative $\Phi_{DP}$ , but integrated along a radar radial
- Increasing values of $K_{DP}$ imply significant amounts of liquid water regardless of ice content in a radar cross section
- Cannot be calculated for areas of very low CC (<0.90)

# $\Phi_{dp}$ vs. $K_{DP}$ (deg/km)



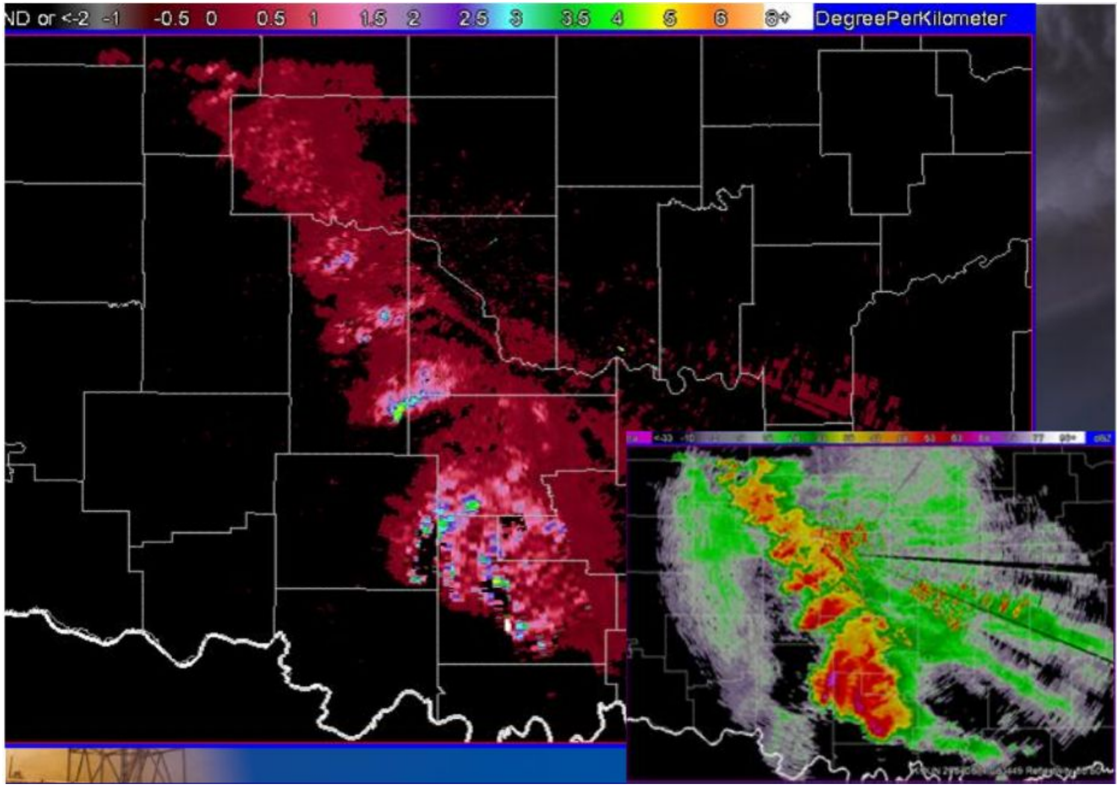

(Raw) Differential Phase ($\Phi_{DP}$)



Specific Differential Phase (KDP)

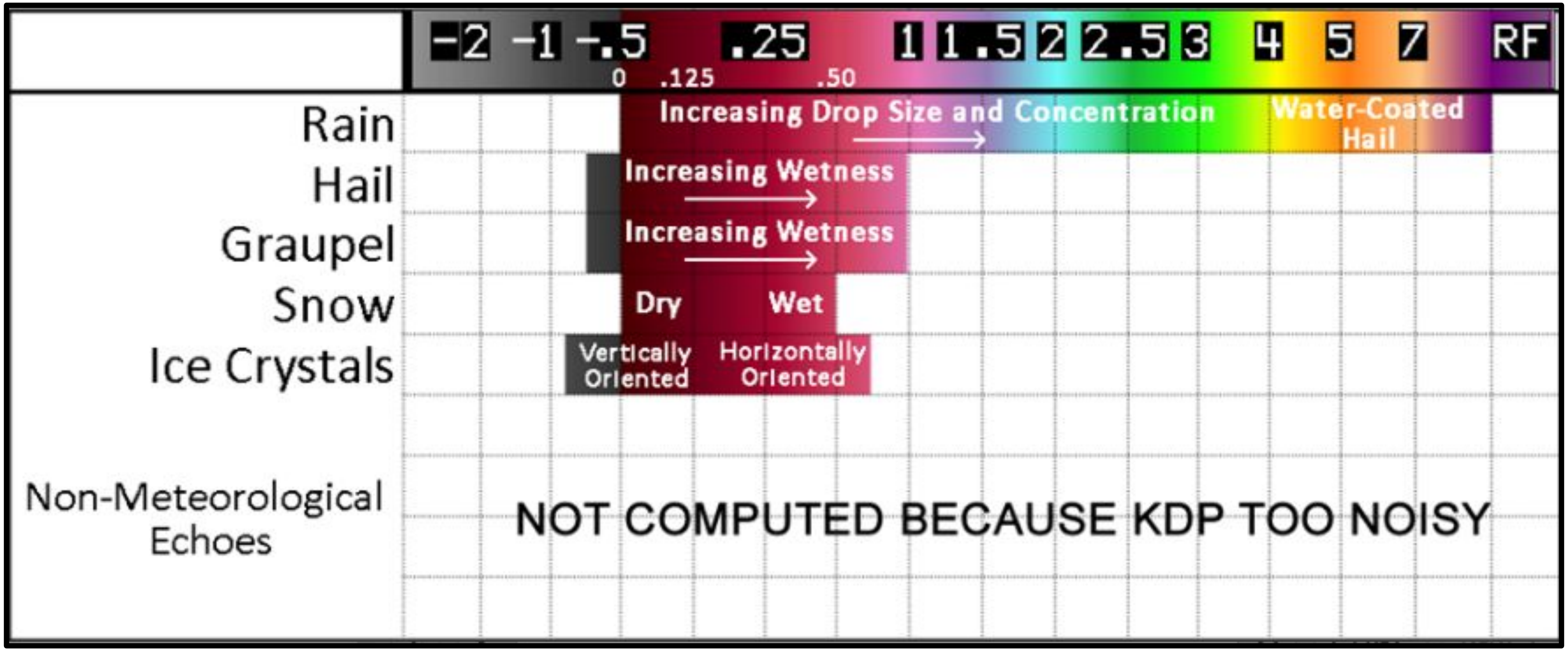
We use KDP since rain from a thunderstorm is easily able to be identified

# A Radar Example of $K_{DP}$




The higher the values of $K_{DP}$, the higher the concentration of large liquid raindrops.

# Values of $K_{DP}$ (deg/km)

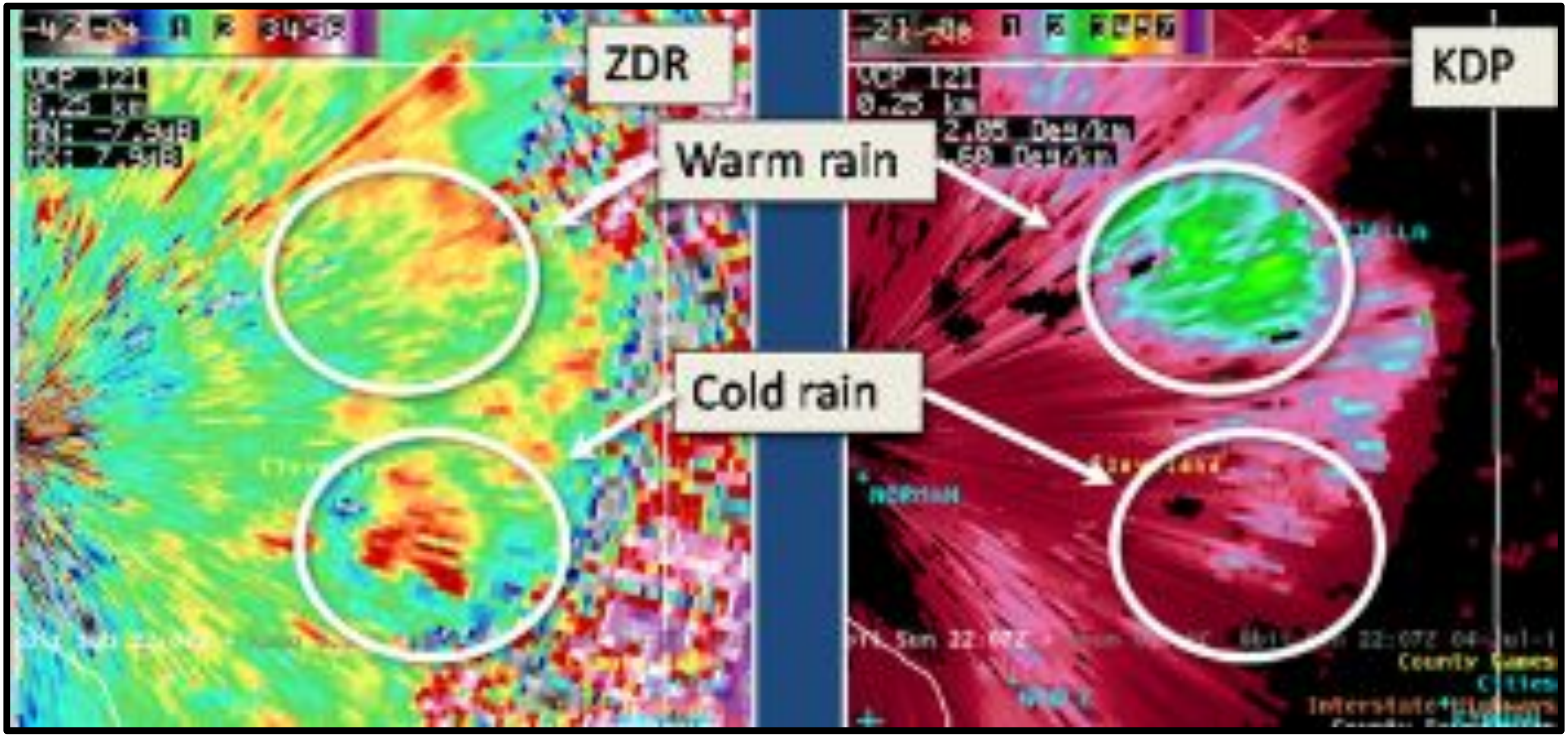



- Wide range of values for rain
- CC <0.90 ,then no KDP calculation

# $K_{DP}$ Uses/Applications

- Heavy Rain (examples shown)
- Rain/Hail Mixtures
- Small Hail Caveat (high KDP with rain, and melting hail or small hail stones)
- Warm vs Cold Rain (example next slide)

# Warm vs Cold Rain Example




Identification of warm (efficient) rain processes vs. Cold (inefficient) processes

# Dual Polarization Summary

- Dual Pol data helps improve hydrometeor detection, shape, distribution and orientation
- Identification of non-meteorological targets more easily
- Improvement on the detection of hail in a thunderstorm (Large Hail, Hail vs. Rain, etc.)
- Differentiate between rain, snow, and mixed pcpn
- Detection of areas of heavy rain/flooding better
- Tornado Debris Signature (TDS) identification
- Identification of the melting layer/bright band