What is Dual-Polarization Radar and What Can It Do for Me?

National Weather Service
Louisville, KY

Benefits of Dual-Polarization

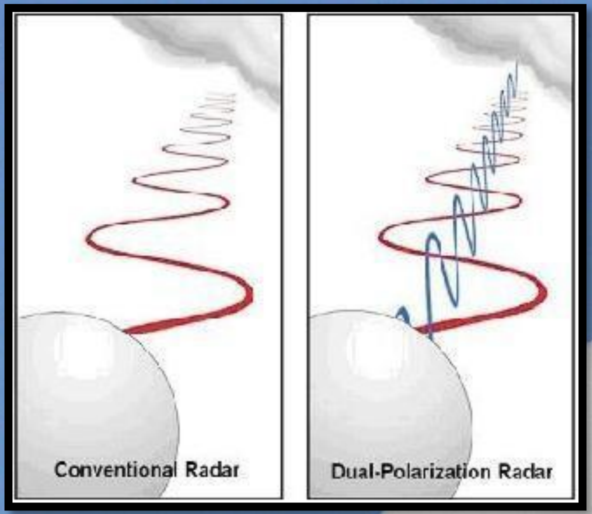
- Theoretically, improve the accuracy of precipitation estimates, leading to better flash flood detection (questionable at this time)
- Ability to discern between heavy rain, hail, snow, and sleet
- Improved detection of non-meteorological echoes (e.g., ground clutter, chaff, anomalous propagation, birds, and tornado debris)
- Identification of the melting layer (e.g., bright band)

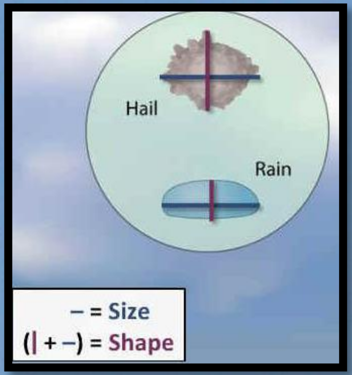
What Dual-Polarization is Not

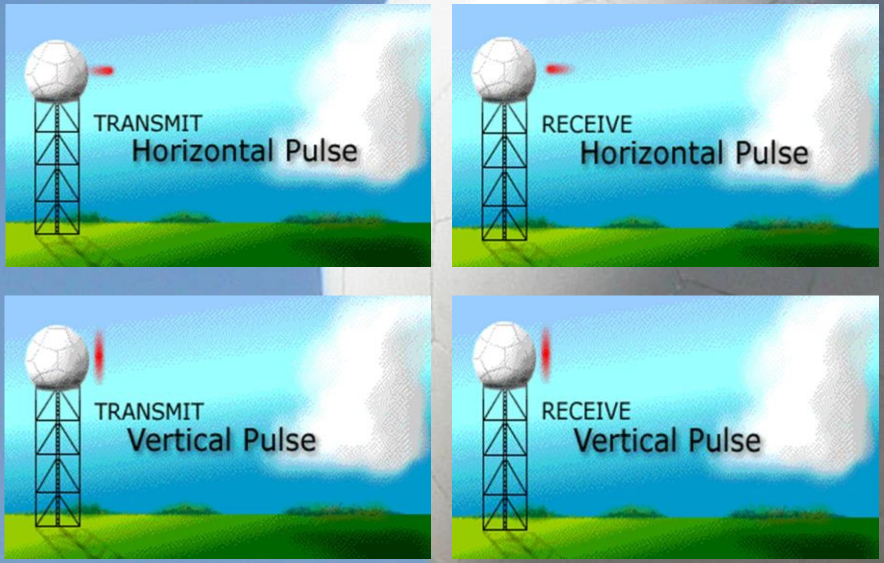
- Will not improve tornado lead times
- Will not provide exact precipitation type at ground level

What is Dual-Polarization & How Is It Different from Current Radar??

- Many radars transmit and receive radio waves with a single horizontal polarization
- Polarimetric radars transmit and receive both horizontal ***and vertical polarizations***
- Can determine:
  - SIZE
  - SHAPE
  - VARIETY

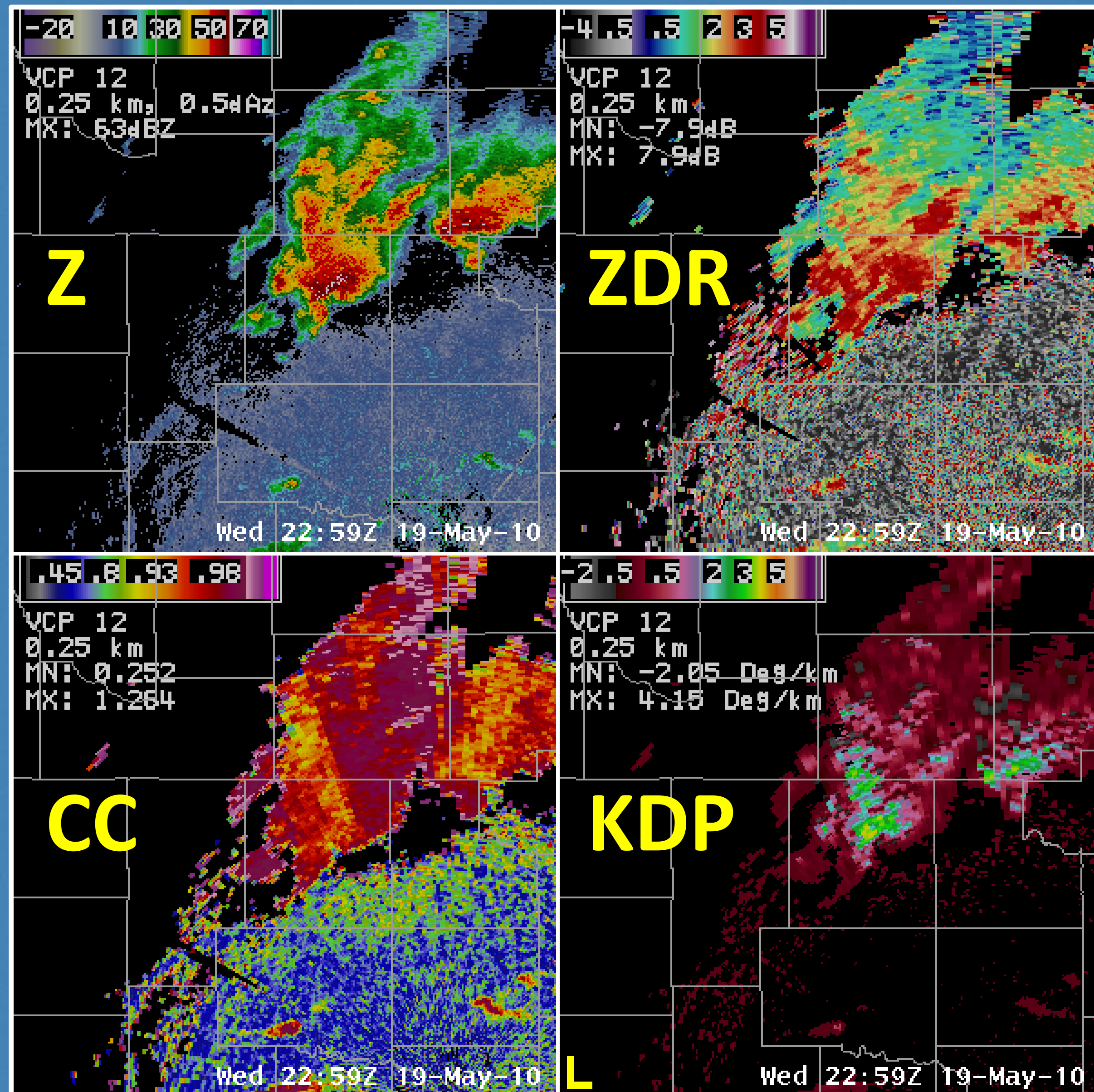






Base Products Available with Dual-Pol

- *Still get:*
  - **Reflectivity (Z)**
  - **Velocity (V)**
  - **Spectrum Width (SW)**
- *Plus:*
  - **Differential Reflectivity (ZDR)**
  - **Correlation Coefficient (CC)**
  - **Specific Differential Phase (KDP)**

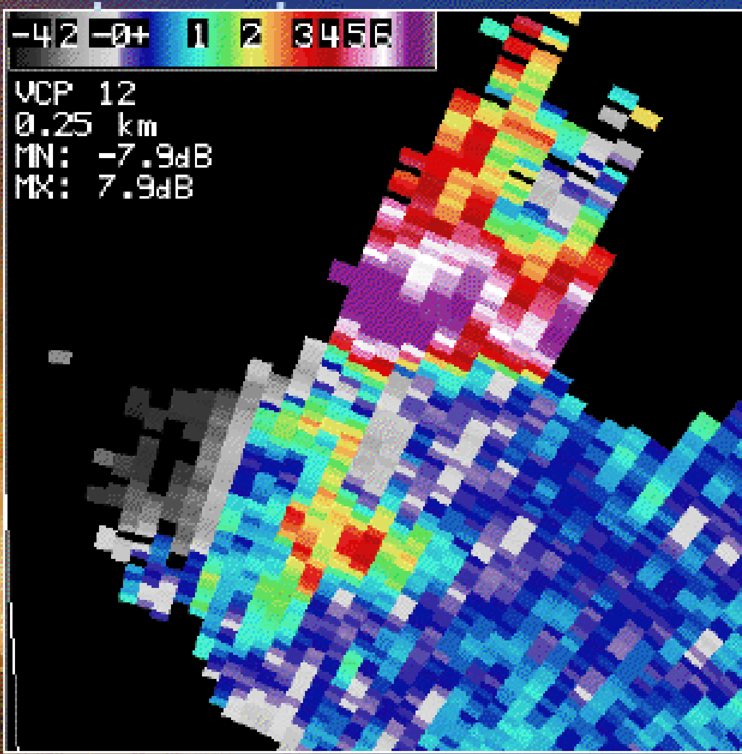


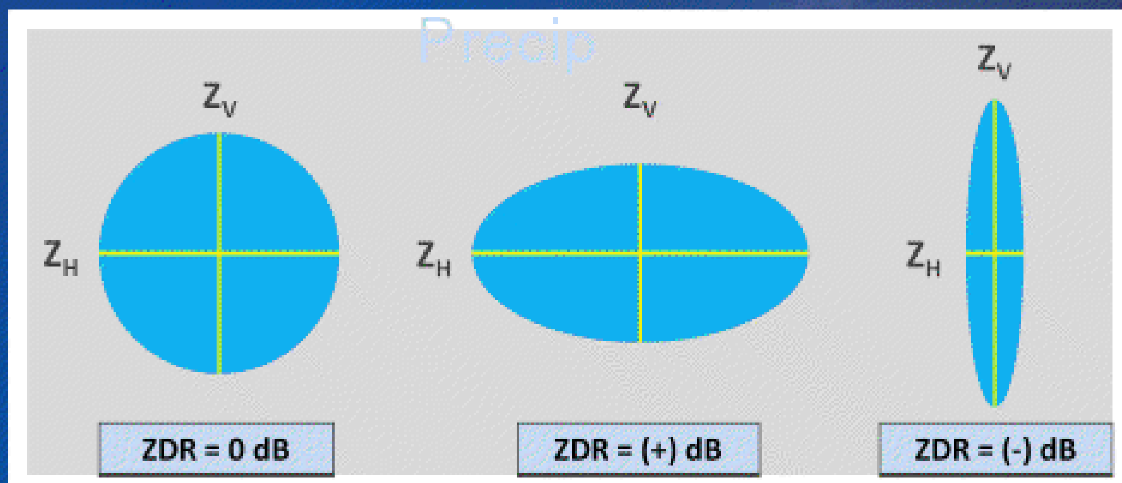
Differential Reflectivity

ZDR

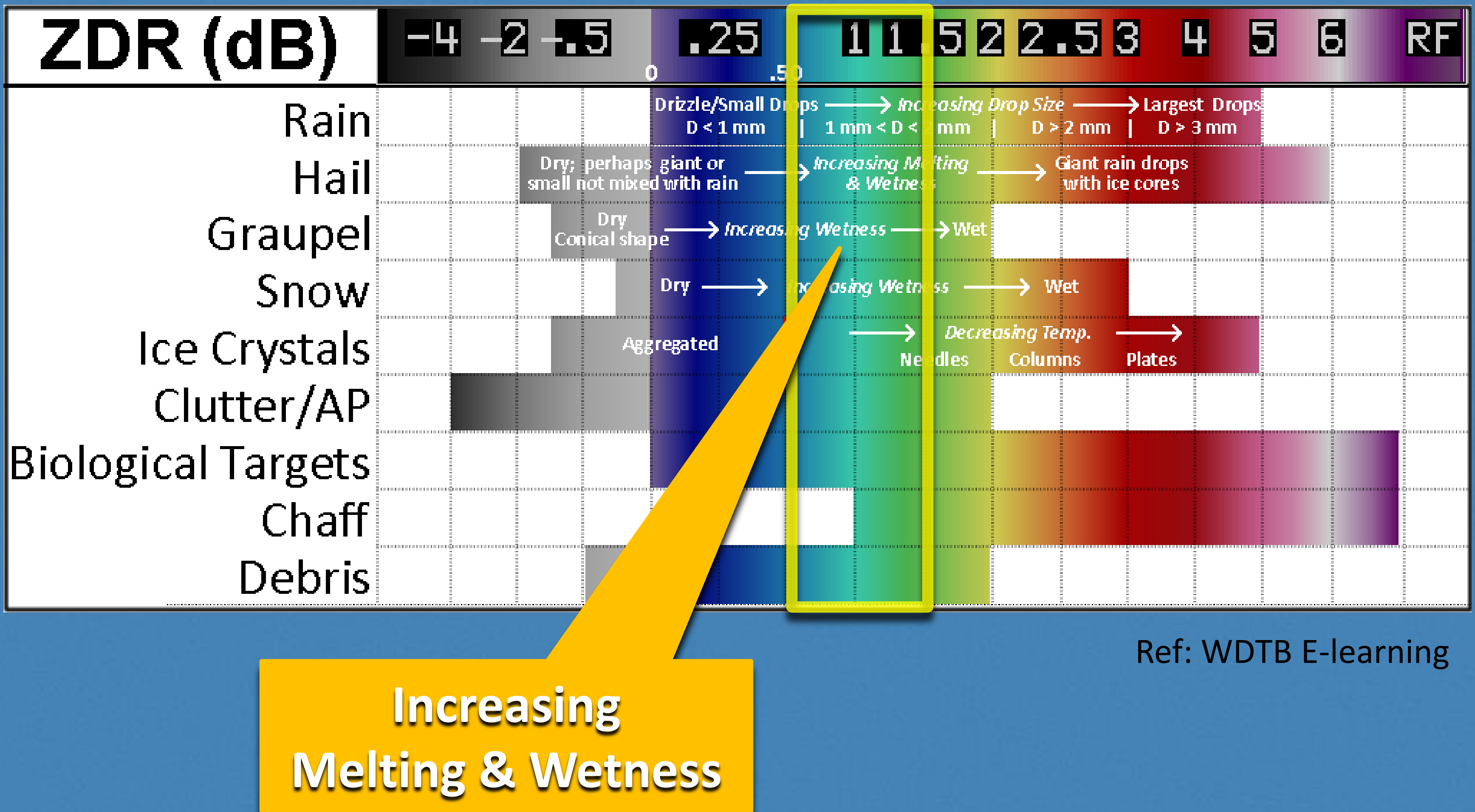
- Diff between the Horizontal & Vertical reflectivity factor
- Defines the drop size
- Good indicator of mean

- Used for:
  - Hail
  - Melting Layer
  - Updraft
  - Tornadic Debris
  - Rain vs Snow
  - Diff Types of Frozen Precip





Typical Values of ZDR



Ref: WDTB E-learning

Differential Reflectivity - ZDR

- Definition:
  - Difference between horizontal and vertical reflectivity factors = Drop Shape
  - ZDR values for rain typically > 1 to as high as 5 for large drops
  - ZDR values for snow typically less than 0.5 (except for wet or melting snow when it's much higher)
  - ZDR for hail generally between -1 and +1 (larger values for melting)

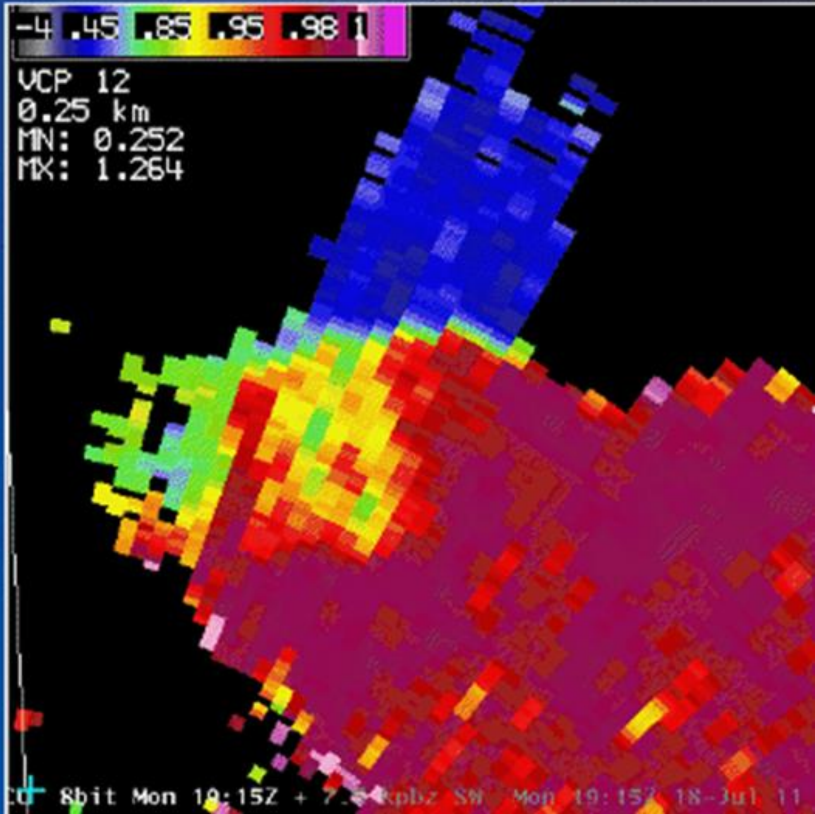
Range of Values	Units	Abbreviations
-7.9 to 7.9	**decibels (dB)**	**ZDR or Z_{DR}**

Correlation Coefficent

CC

- Used for:
  - Large Hail
  - Tornadic Debris
  - Rain vs Snow
  - Melting Layer
  - Irregular hydro shapes
- Measure of how similarly the horizontally and vertically polarized pulses are behaving in a pulse volume
- Great at discriminating non vs met echoes

Hydrometeors	CC	Values
Non-meteorological	Low CC	< 0.8
Meteorological – non uniform	Mod CC	0.8-0.97
Meteorological - uniform	High CC	> 0.97

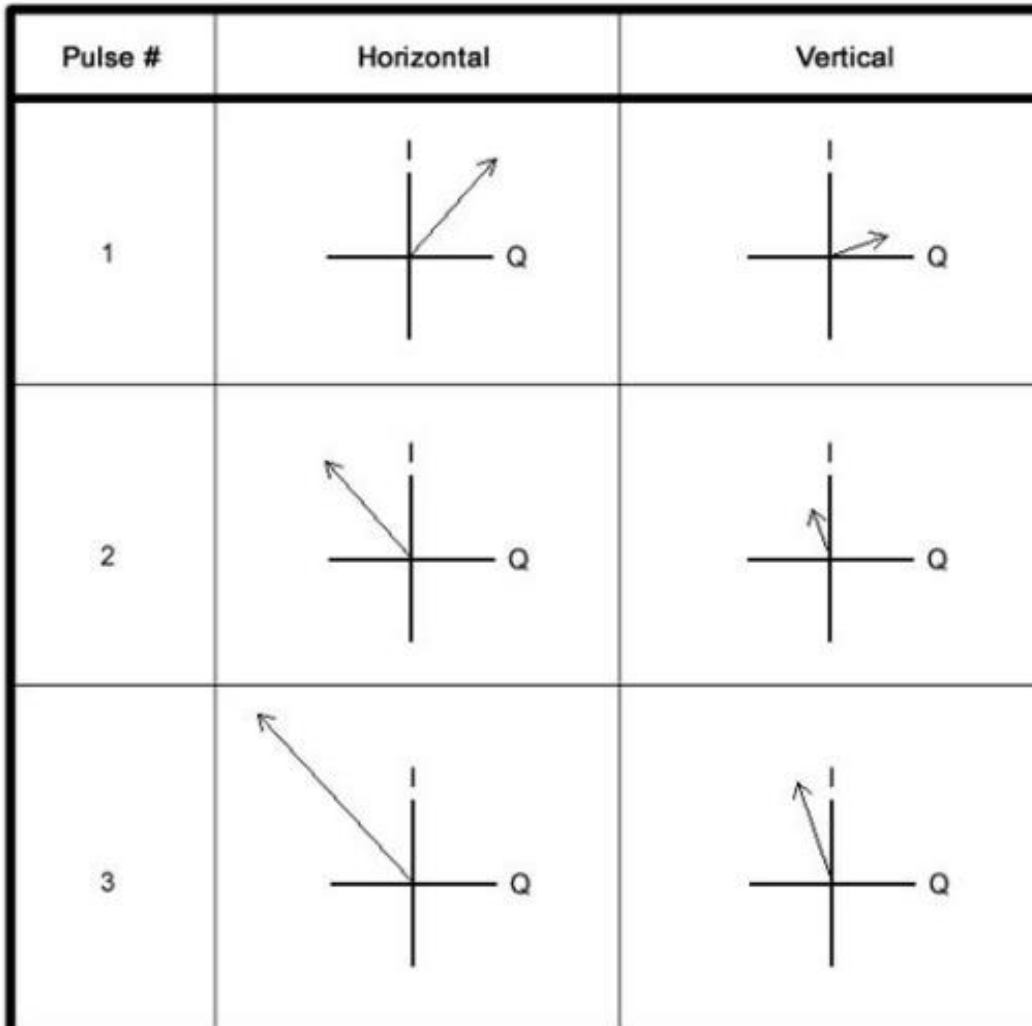


What does it mean for the pulses to behave similarly?

- From pulse-to-pulse
  - Magnitude, Phasor angle or both ***change in a similar*** manner for horizontal and vertical pulses

- Result is ***high CC***

High Correlation Coefficient



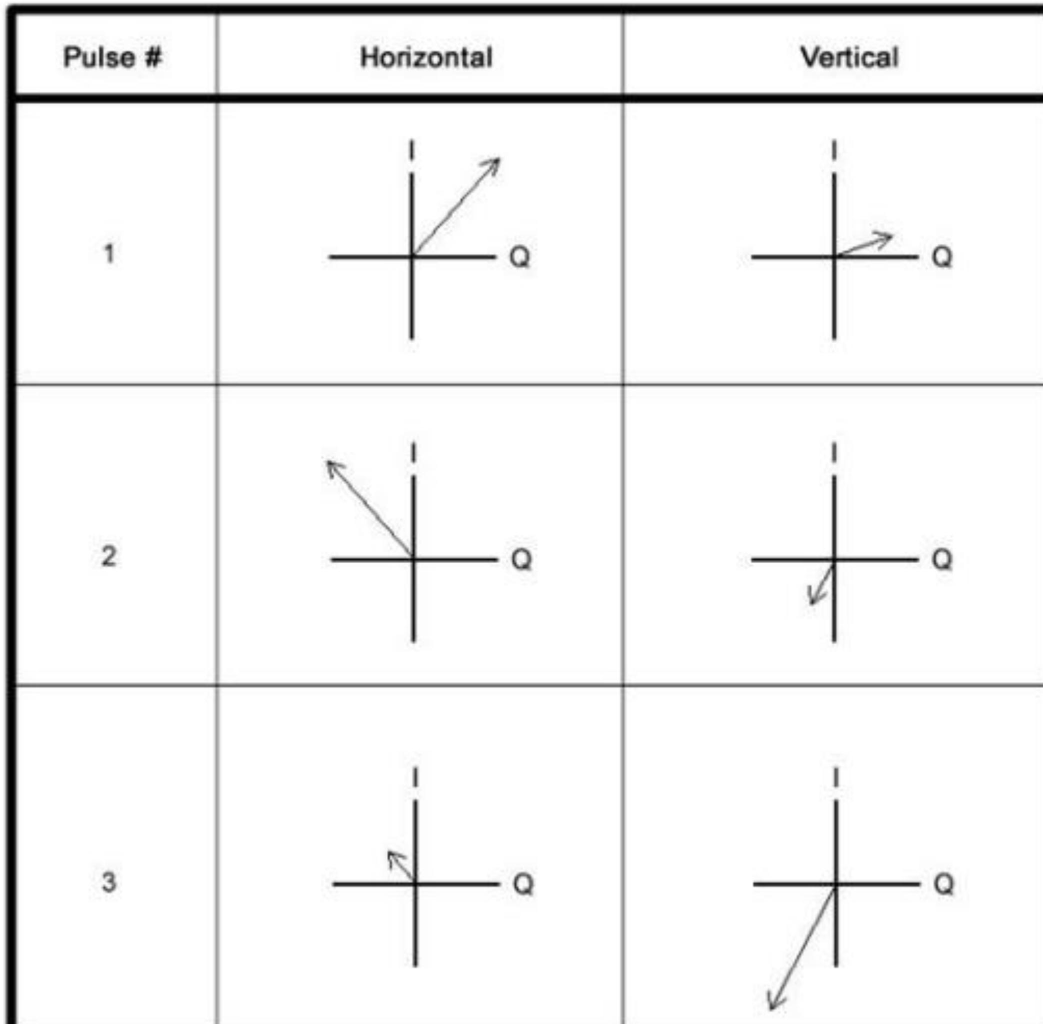
From pulse to pulse, the H and V pulses change in similar manners. If the phase angle changes for H, the V channel changes in a similar nature (Pulse 1 to 2). If the power changes for H, the V channel power changes in a similar manner (Pulse 2 to 3). This similar change in characteristics between the H and V pulses from pulse to pulse result in high CC.

What does it mean for the pulses to behave differently?

- From pulse-to-pulse
  - Magnitude, Phasor angle or both ***change differently*** for the horizontal and vertical pulses

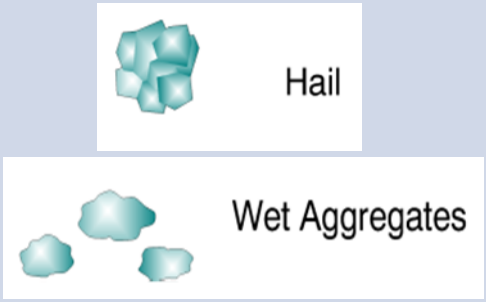
- Result is ***low CC***

Low Correlation Coefficient



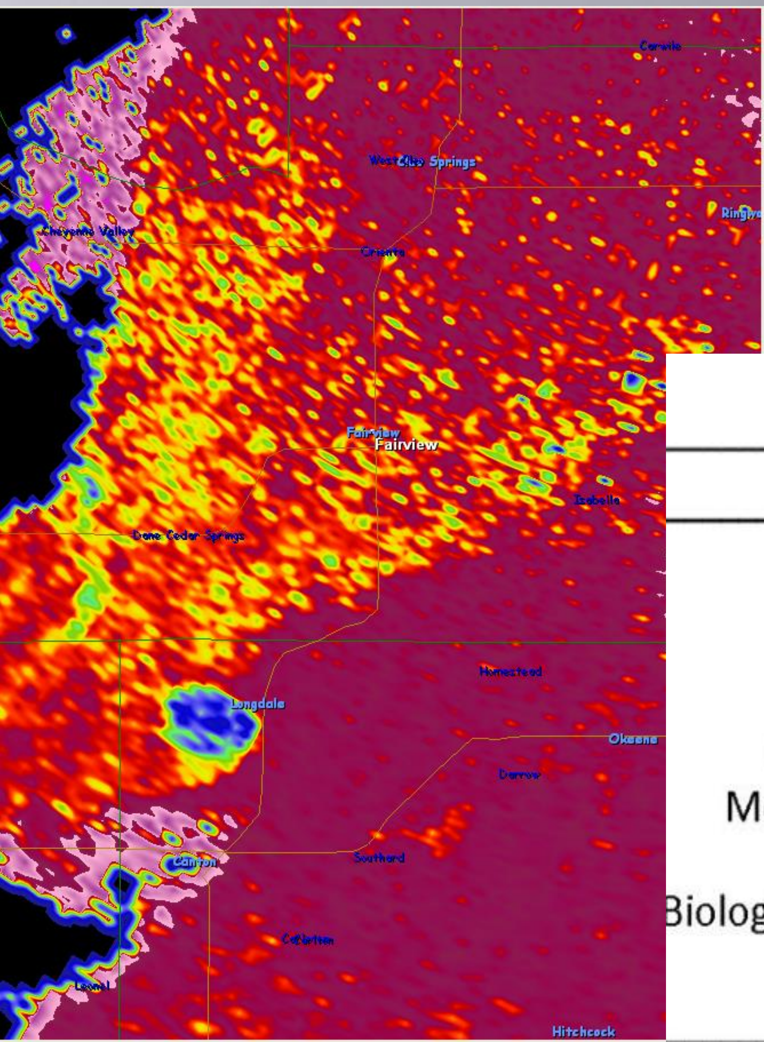
From pulse to pulse, the H and V channels change in completely different ways. The powers remain similar from pulse 1 to 2, but the phase angle change in the H channel is different than the change in phase angle in the V channel. From pulse 2 to 3, the power increases in the V channel but decreases in the H channel. This type of behavior between the H and V pulses from pulse to pulse results in low CC.

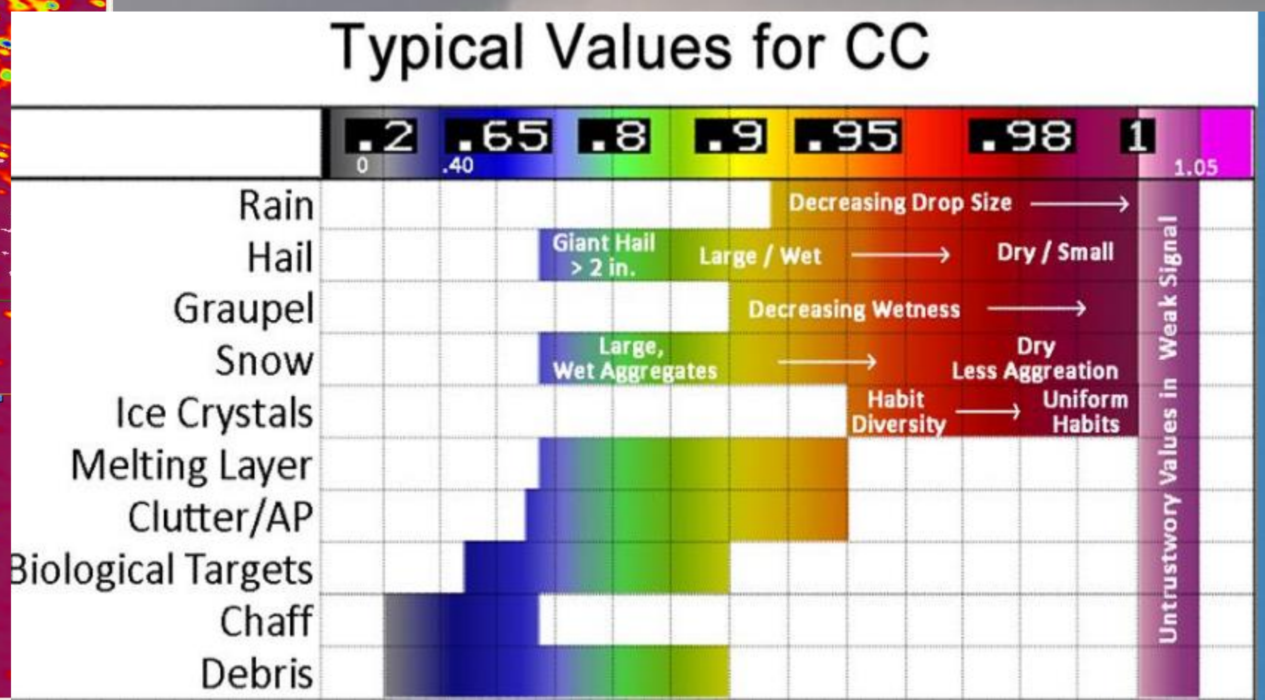
How Do I Interpret CC?

Non-Meteorological (birds, insects, etc.)	**Metr (Non-Uniform)** (hail, melting snow, etc.)	**Metr (Uniform)** (rain, snow, etc.)
		
Complex scattering from pulse-to-pulse. Horizontal and vertical pulses change in different manners from pulse-to-pulse	Somewhat complex scattering from pulse-to-pulse. Moderate differences from pulse-to-pulse for the horizontal and vertical pulses	Well-behaved scattering from pulse-to-pulse. Little differences from pulse-to-pulse for the horizontal and vertical pulses
Low CC (< 0.8)	Moderate CC (0.80 to 0.97)	High CC (> 0.97)

Correlation Coefficient (CC)

- **Measure of how similarly the horizontally & vertically polarized pulses are behaving within a pulse vol.**
- **Great at discriminating non vs. meteorological echoes**



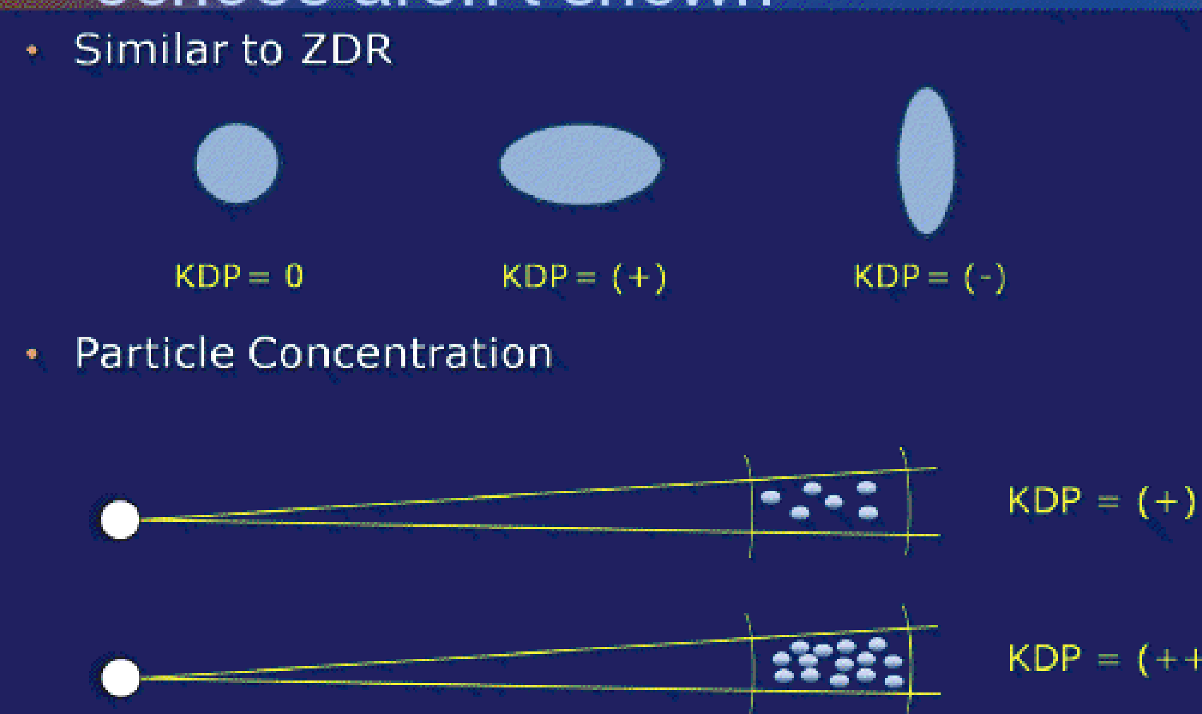


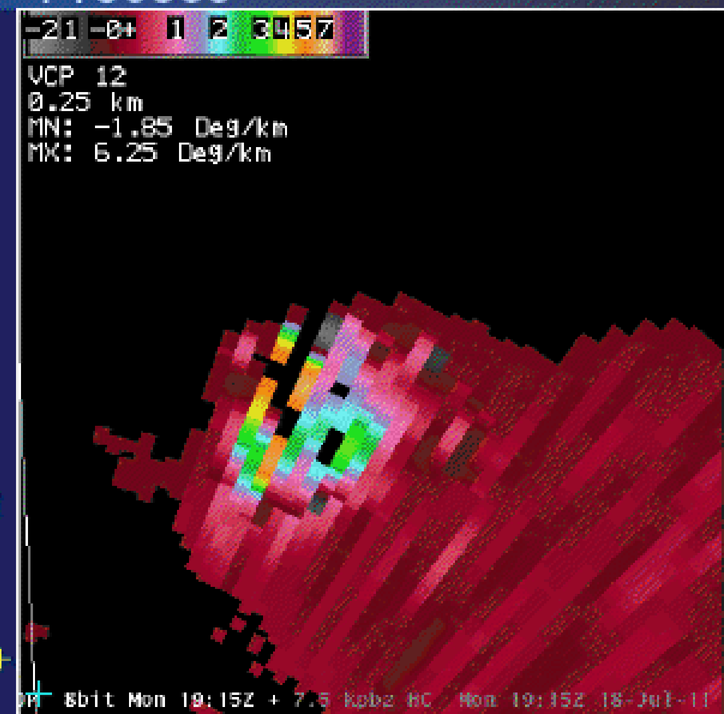
Specific Differential Phase

KDP

- Range derivative of the differential phase shift along a radial
- Non meteorological echoes aren't shown

- Used for:
  - Heavy Rain
    - Heavy Rain mixed with hail
    - Cold vs. Warm Rain Process





Typical KDP Values

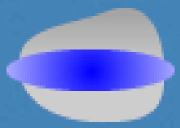
1) Hail – KDP near 0 (except near 3 for melting)

2) Snow – KDP typically between -1 and +0.5

3) Rain – KDP between 0 and +5 (larger number indicates larger drops and/or increased drop concentration)

4) KDP values for non-meteorological echoes are not shown

Typical Values (Hail)

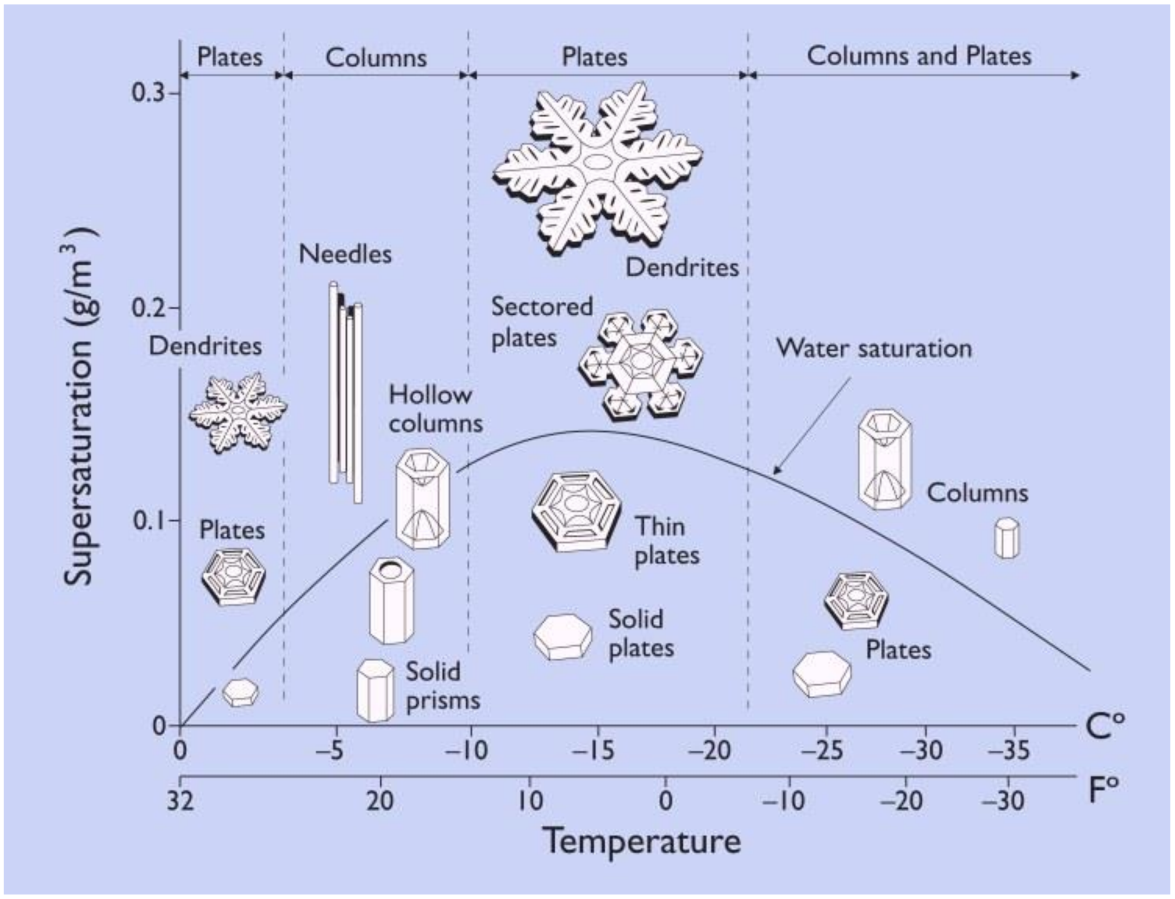


	Classic	*Melting*	*Large (D >= 2”)*
Z	> 55 dBZ	> 60 dBZ	40 – 80 dBZ
ZDR	0 – 1 dB	> 1 dB	-0.5 – 1 dB
CC	0.95 – 0.97	~ 0.95	< 0.9
KDP	~ 0 deg/km	> 3 deg/km	N/A

Typical Values (Snow/Ice)

Z (dBZ)	ZDR (dB)	CC	KDP (deg/km)
< 40	0.2 to 0.5	> 0.97	-1 to +0.5

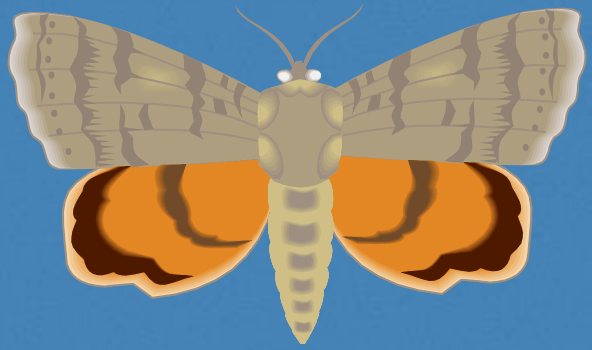
- Density affects ZDR
- Melting snow will have lower CC



Courtesy: SnowCrystals.com

Typical Values (Clutter/Biologicals)

	Clutter	Biologicals
Reflectivity (Z)	Anything	< 40 dBZ
Differential Reflectivity (ZDR)	Noisy	Depends on Orientation
Correlation Coefficient (CC)	< 0.8	< 0.8
Specific Differential Phase (KDP)	N/A	N/A



Algorithms Available to Dual-Pol

HCA – Hydrometeor Classification

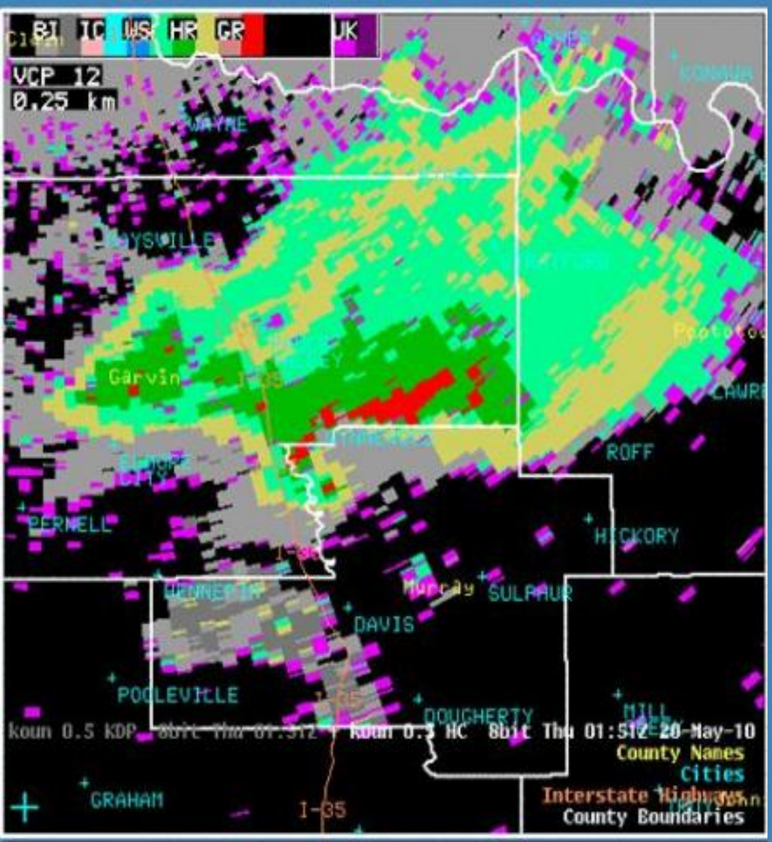
ML – Melting Layer

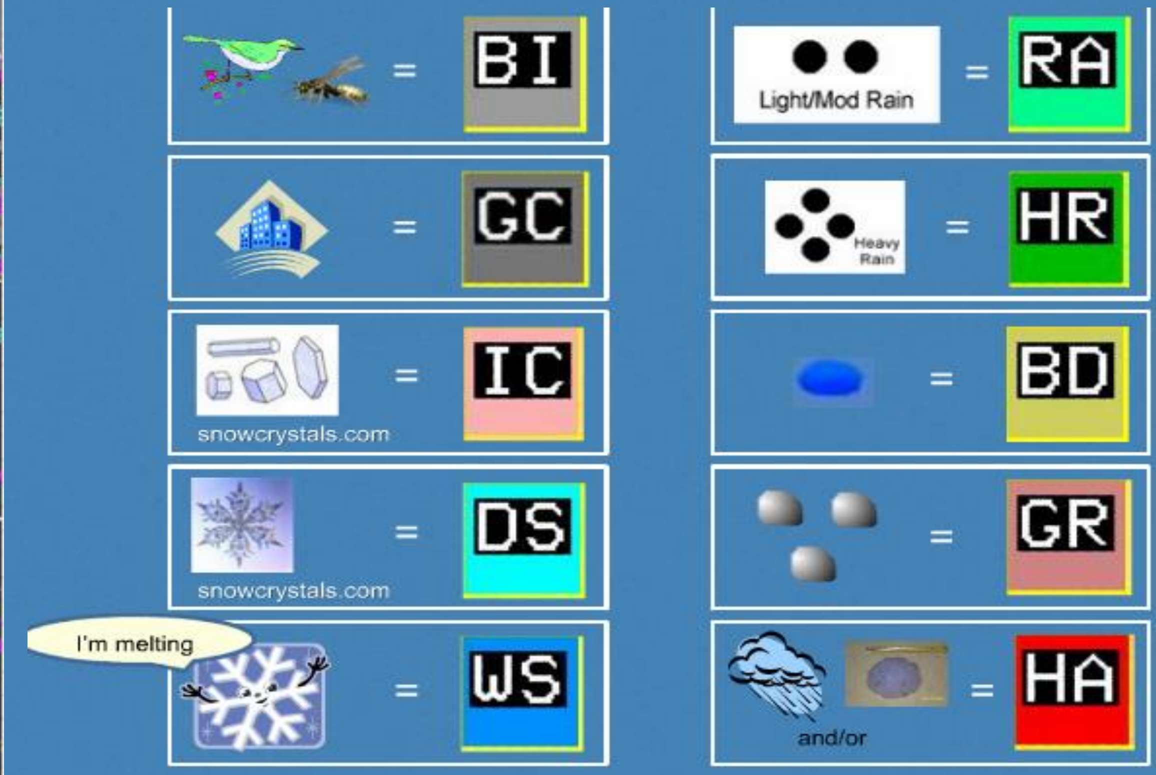
Precipitation Algorithms

- Storm Total
- One Hour Accumulation
- One Hour Unbiased Accumulation
- Instantaneous Precipitation Rate
- User Select Accumulation
- Etc.

Hydrometeor Classification Algorithm

- **HCA uses data to make a guess at precip type**
- **Quick look at regions of interest**
- **Used as input for improved QPE**
- **Limitations = subjectivity & Overlay**



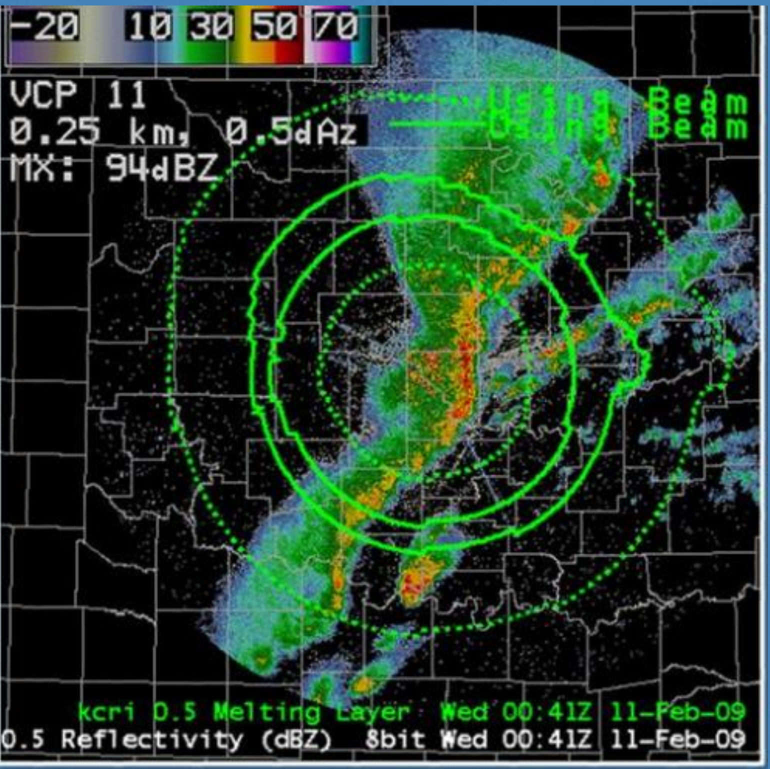


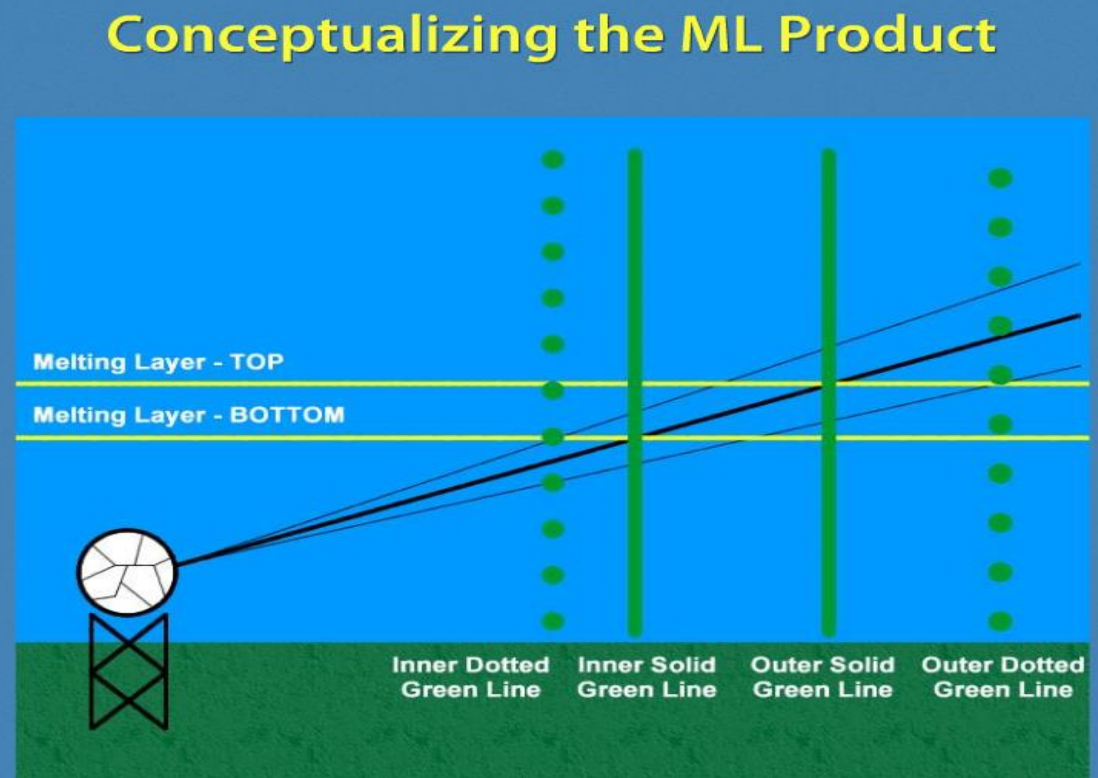
Melting Layer

Provides height of the top and bottom of the melting layer; updated every volume scan

Factors:

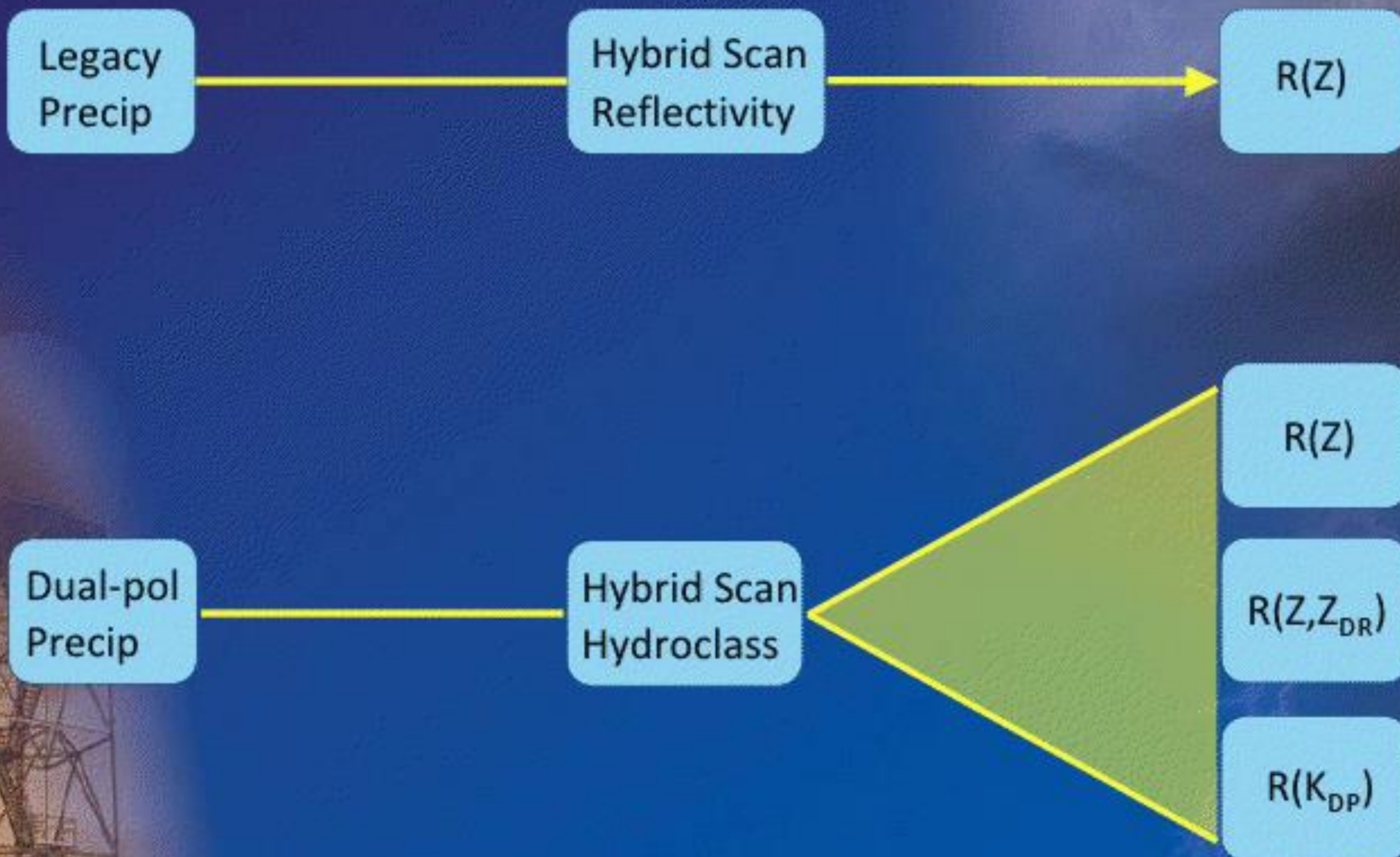
- Fast moving cold fronts
- Events with small areas of stratiform
- Major area below freezing





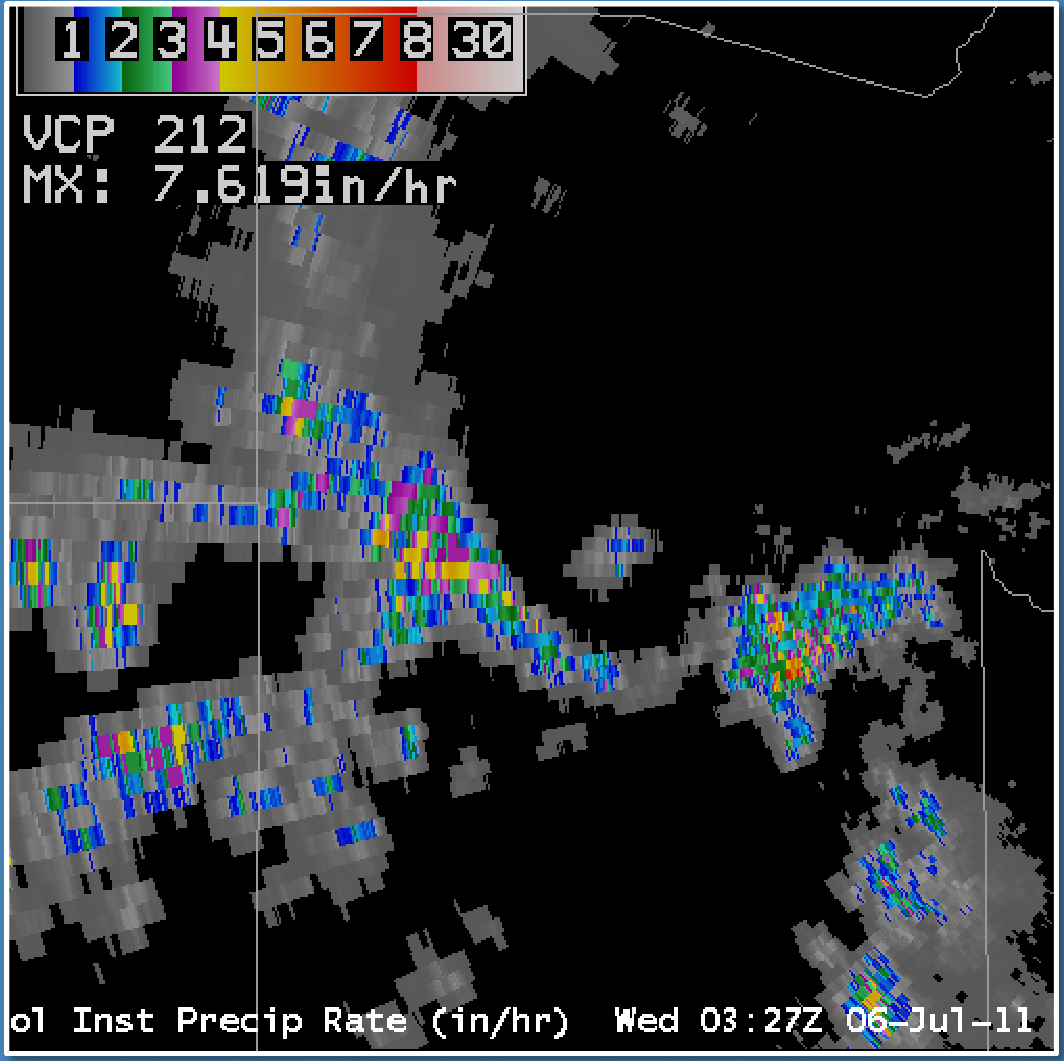
Precipitation Estimates

Purpose: QPE Specific to Hydrometeor Type!



Precipitation (QPE) Products

- 9 new products
  - Instantaneous
    - HHC
    - DPR
  - Accumulation
    - STA (i.e. STP)
    - DSA (i.e. STP)
    - OHA (i.e. OHP)
    - DAA (i.e. OHP)
    - DUA (i.e. USP)
  - Diff (DP – Legacy)
    - DSD
    - DOD

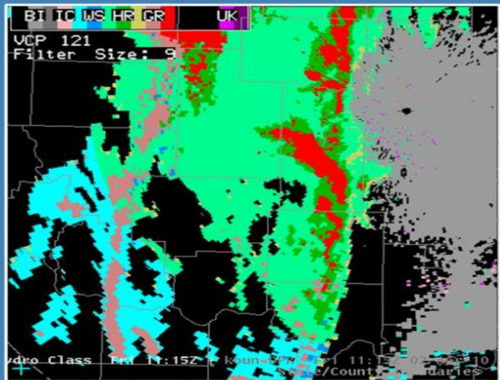


Hydro Met Precip

- Strengths: more accurate
  - Rain rate relations specific to hydromet types
  - Lower sensitivity to hail or bright banding
  - Non-met scat don't contribute to accum
- Limitations
  - Misclassification of hydromet types
  - No bias applied

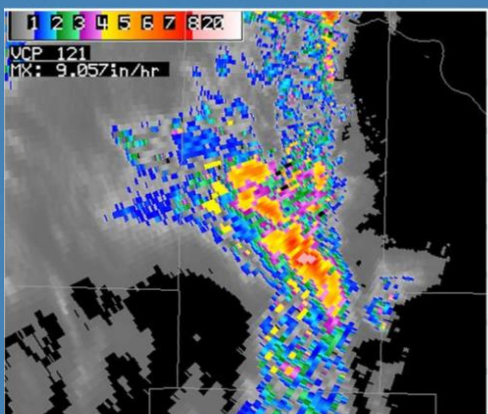
Product Type	Product Name	Abbreviation
Instantaneous	1. Hybrid Hydroclass	HHC
	2. Digital Precipitation Rate	DPR
Accumulation	3. Digital Accumulation Array	DAA
	4. One Hour Accumulation	OHA
	5. Digital Storm Total Accumulation	DSA
	6. Storm Total Accumulation	STA
Difference	7. Digital One Hour Difference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

1. Hybrid Hydroclass (HHC)



- Classification used to choose rain rate relationship
- 8-bit (256 data levels)

2. Digital Precipitation Rate (DPR)

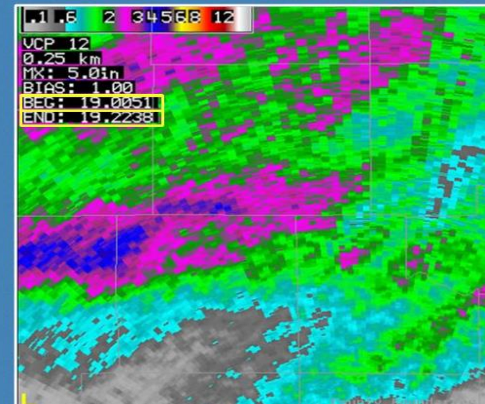


- Displays instantaneous precipitation rate!
- 250 m resolution
- 16-bit product (65536 data levels)
- Caution: Large product size

3. Digital Accumulation Array (DAA)

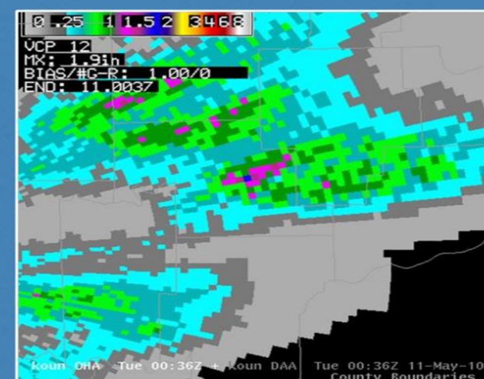
- 1 hour accumulation
- No bias!
- 250 m resolution
- 8-bit (256 data levels)

5 and 6. Storm Total Accumulation Products



- Digital Storm-total Accumulation (DSA)
  - Accumulated rainfall since start of event
  - 8-bit (256 data levels)
  - 1 degree by 0.25 km
- 2 km resolution, 4-bit version: Storm Total Accumulation (STA)

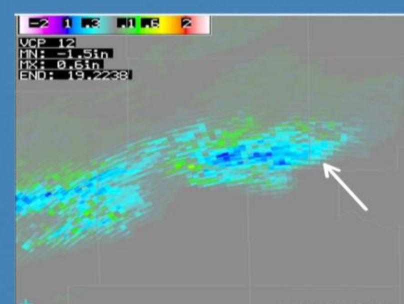
4. One Hour Accumulation (OHA)



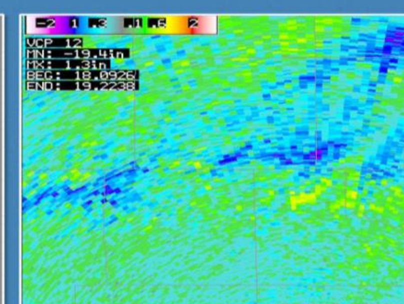
- 1 hour accumulation
- 4-bit (16 data levels)
- 2 km resolution

Difference Product Examples

Digital One-hour Difference



Digital Storm-total Difference



- Application: can see differences at a glance
- Caution: differences say nothing about accuracy of legacy or dual-pol QPE

Summary

- Send/receive H & V polarization
- 3 new base products
  - ZDR, CC, KDP
- Base products help with
  - Drop shape (ZDR)
  - Variety (CC)
  - Liquid water content (KDP)
- Additional information seen in
  - Rain, Hail, Snow/ice and Clutter/Biologicals

- *Dual-Pol Training for NWS Partners:*
  www.wdtb.noaa.gov/courses/dualpol/outreach/