EXPLORING THE WEATHER RADAR

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What is Weather RADAR?

- **RADAR:** Radio Detection And Ranging

- A methodology that uses Electromagnetic waves to detect, determine the location, intensity, and movement of precipitation and meteorological phenomena in the atmosphere.

- Weather RADAR is used to provide meteorologist and weather forecasters with real information about the current weather conditions and to track the development of the storms.

Historical Development of Weather RADAR

- **World War II:** Was developed for military purposes during World War II, then noticed that radar could also detect precipitation in the atmosphere.
- **Weather RADAR**
- **Doppler RADAR:** Allows meteorologists to measure the speed and direction of precipitation particles.
- **Dual Polarization RADAR:** This technology provides more detailed information about the size and shape of precipitation particles, enhancing the accuracy of precipitation type identification.
- **Advancements in RADAR Technology**: Improvements in radar resolution, computer processing capabilities, and data visualization.

Why we need Weather RADAR?

- Clouds and mesoscale phenomena are too small to be resolved by conventional surface and upper-air networks, and too large to be observed locally

- Radar is most effective instrument for obtaining observations in cloud systems.

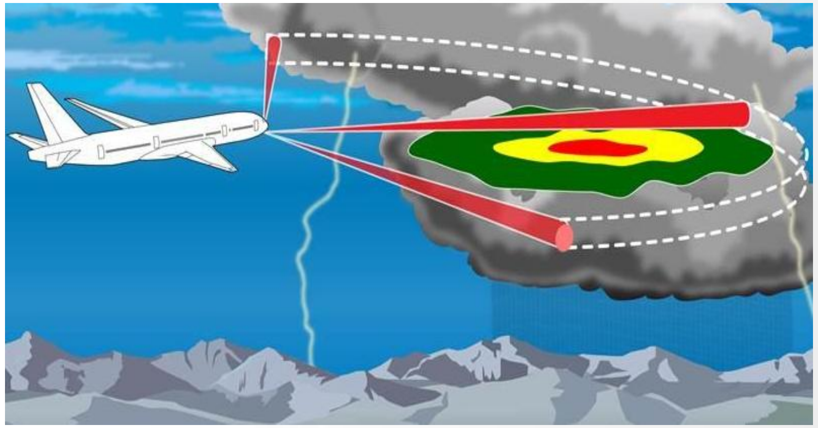
- Radar can observe the precipitation with mesoscale coverage (~200km) and convective-scale resolution (~1km)

Weather Radar Types:

Ground-Based Radar

Satellite Radar

Airborne Radar



How RADAR Works?

Weather radar operates based on the principles of:

- Radio wave transmission
- Reflection
- Reception

Weather RADAR Applications :

Weather monitoring and forecasting

- **Precipitation Detection:** Detecting and monitoring various forms of precipitation, such as rain, snow, hail, and sleet.

- **Storm Tracking:** It helps meteorologists monitor storm intensity, movement, and potential hazards. Doppler radar is particularly valuable for tracking severe weather detection.

- **Severe Weather Warnings:** Timely warnings for severe weather events. Doppler radar helps identify rotation in thunderstorms, indicating the potential for tornado formation. This information is vital for public safety and emergency preparedness.

- **Hydrology and Flood Prediction:** Weather radar data is used in hydrology to monitor rainfall patterns and assess the potential for flooding. This information is valuable for flood prediction, early warning systems, and water resource management.

Weather RADAR Applications

Aviation

- Detecting and avoiding hazardous weather conditions
- Pilots use radar information to navigate around thunderstorms, turbulence, and other weather-related challenges during flight.

Agriculture

- Monitor precipitation patterns and make informed decisions about irrigation, planting, and harvesting.
- This helps optimize agricultural practices and manage water resources efficiently.

More Weather RADAR Applications

- Research and Scientific Studies
- Environmental Monitoring
- Disaster Management
- Public Information and Education

RADAR Types & Applications

CAA
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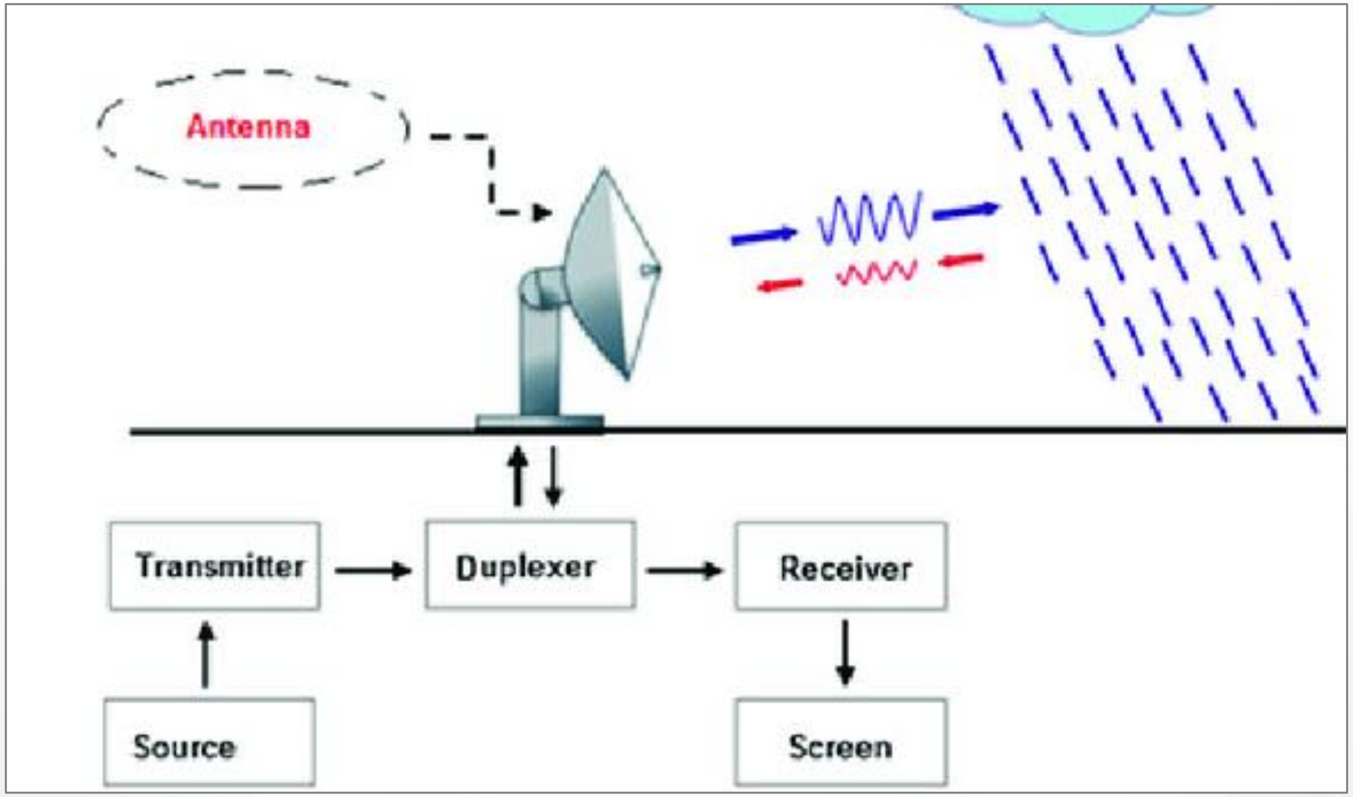
Frequency (MHz)	Wavelength band	Wavelength	Main purpose / application area
30-300	VHF	10-1 m	Wind profilers, clear air returns, turbulence and refractive index structure
2,000 – 4,000	S	15.0-7.5 cm	Tropical cyclone, severe weather detection, precipitation estimation
4,000 – 8,000	C	7.5-3.75 cm	(severe) Weather phenomenon detection, precipitation measurements
9,000-11,000	X	3.3-2.7 cm	Thunderstorm and associated weather phenomenon detection
12,000-40,000	K	2.5-0.75 cm	Cloud micro physics, tornado detection, precipitation estimation from attenuation.
40,000-220,000	Millimeter	7.5-1.30 mm	Cloud microphysics, ceilometer, tornado detection

Basic RADAR Components

- Transmitter
- Antenna
- Duplexer
- Receiver
- Signal Processer
- Display System



Basic RADAR Components

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Transmitter:

The transmitter generates short pulses of electromagnetic waves (with specific power, frequency, and duration). These pulses are directed into the atmosphere to interact with precipitation particles.

Antenna:

The radar antenna is responsible for both transmitting the radar pulses and receiving the signals that are scattered back by precipitation particles waves.

Duplexer:

The duplexer is a switching device that alternates the radar system between the transmission and reception modes.

Receiver:

The receiver is a critical component for interpreting the radar echoes and extracting meteorological information

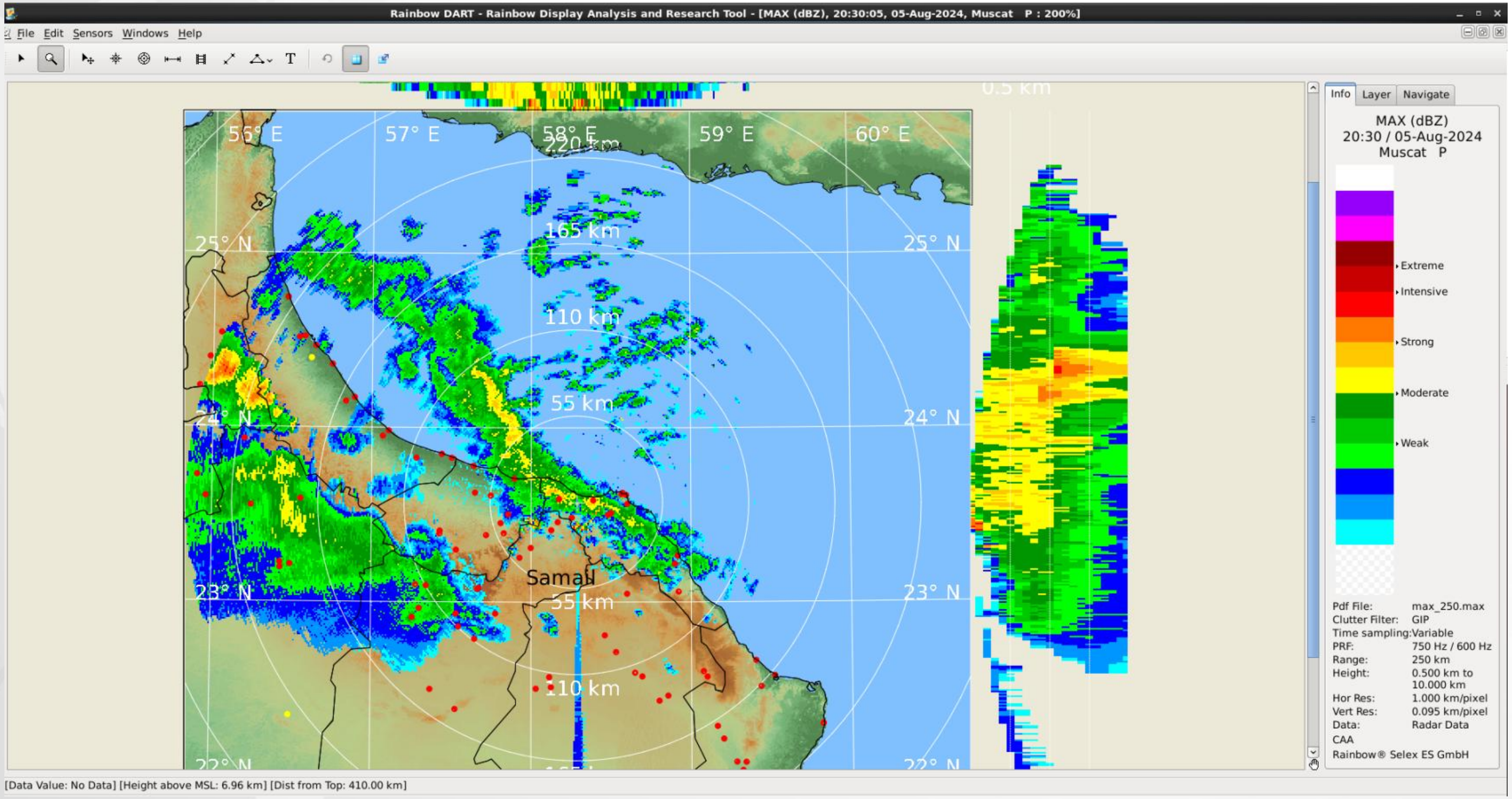
Signal Processer:

The signal processor analyzes the data received from the receiver. It performs various functions such as filtering, amplification, and signal processing algorithms to enhance the quality of the radar data and extract meaningful information about precipitation.

Display System:

Maps or images with different colors on the display represent different levels of precipitation intensity, allowing meteorologists to interpret and analyze the information.

Basic RADAR Components : Display System



RADAR Equation

$$P_r = P_t \cdot G \cdot \frac{\lambda^2 \cdot \sigma}{(4\pi)^3 \cdot R^4}$$

- Pt - Transmitted power (Watts)
- G - Antenna gain
- λ - Wavelength of the radar signal (meters)
- σ - Radar Cross Section (meters squared)
- R - Distance from the radar to the target (meters)
- Pr - Received power (Watts)

RADAR Equation

$$P_r = P_t \cdot G \cdot \frac{\lambda^2 \cdot \sigma}{(4\pi)^3 \cdot R^4}$$

Pt - Transmitted power (Watts)

- This is the power of the radar signal transmitted by the radar transmitter.
- Unit: Watts (W).

G - Antenna gain

- Represents how effectively it concentrates the transmitted power in a particular direction
- It is dimensionless.

λ - Wavelength of the radar signal (meters)

- The length of one cycle of the radar signal. It is inversely proportional to the radar frequency
- Unit: Meters (m).

σ - Radar Cross Section (meters squared)

- A measure of the reflectivity of the target. It represents the effective area that scatters the radar signal back to the radar.
- Unit: Square meters (m^2).

RADAR Equation

$$P_r = P_t \cdot G \cdot \frac{\lambda^2 \cdot \sigma}{(4\pi)^3 \cdot R^4}$$

R - Distance from the radar to the target

- The radial distance from the radar to the point in the atmosphere where the radar signal is scattered
- Unit: Meters (m)

Pr - Received power

- This is the power of the radar signal after it has interacted with the atmosphere and targets and is received by the radar receiver
- Unit: Watts (W)

RADAR Reflectivity

- Radar reflectivity is a measure of how well a target reflects radar waves.
- When radar beams encounter precipitation particles in the atmosphere, such as raindrops or snowflakes, some of the radar energy is scattered back towards the radar site
- The amount of energy returned, or reflected, is measured and represented as reflectivity.

Reflectivity Scale

- Reflectivity is typically measured in decibels of Z (dBZ)

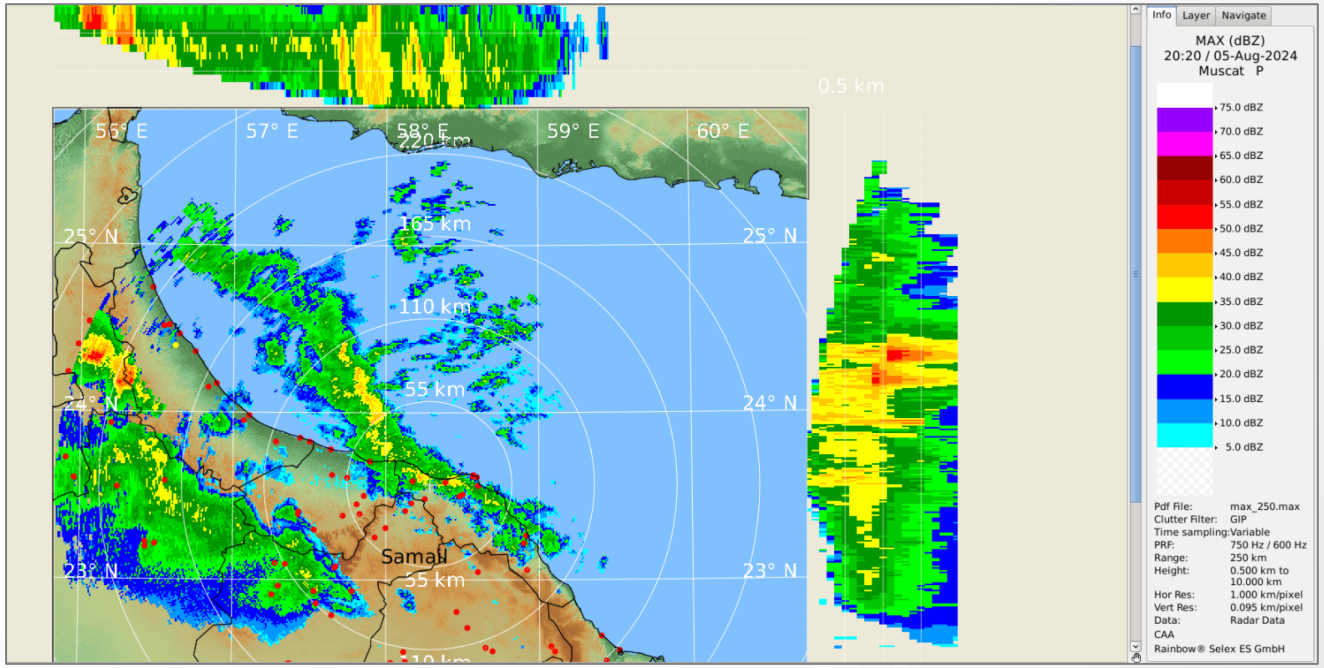
- The reflectivity scale is logarithmic, and higher dBZ values correspond to larger and more reflective precipitation particles

$$Z = \Sigma D^6$$

- Signal varies with 6th power of raindrop diameter

Interpretation of Reflectivity

	Reflectivity	Type of precipitation
Light precipitation:	below 20dBZ	light rain, drizzle, or light snow
Moderate precipitation	between 20 and 40dBZ	moderate rain or snowfall
Heavy precipitation:	above 40dBZ	heavy rain or intense snow.

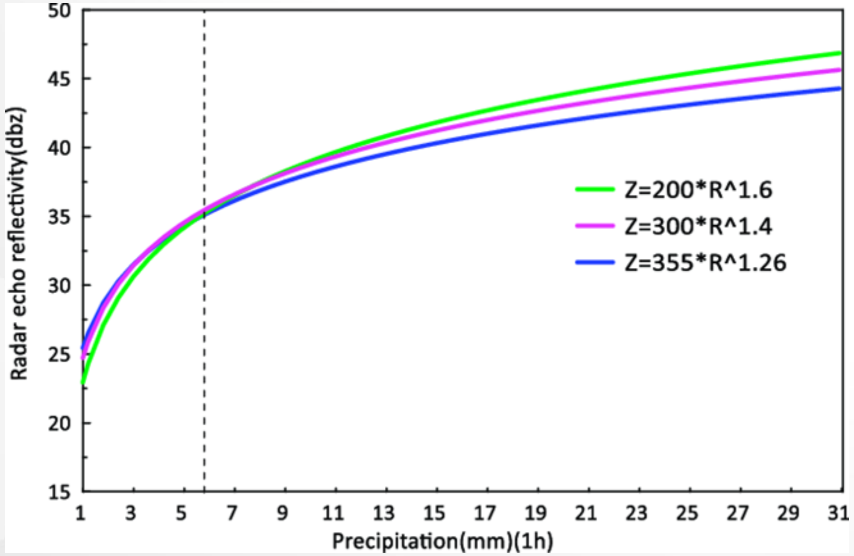


RADAR to Rainfall

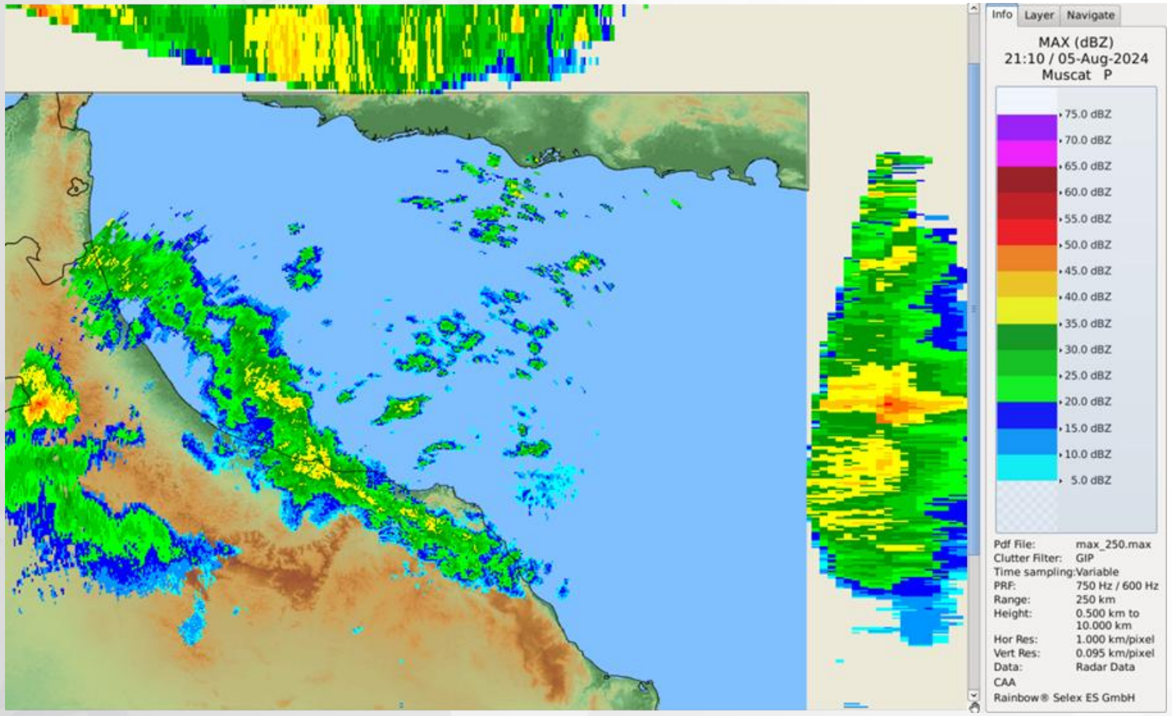
$$Z = \sum D^6 = aR^B$$

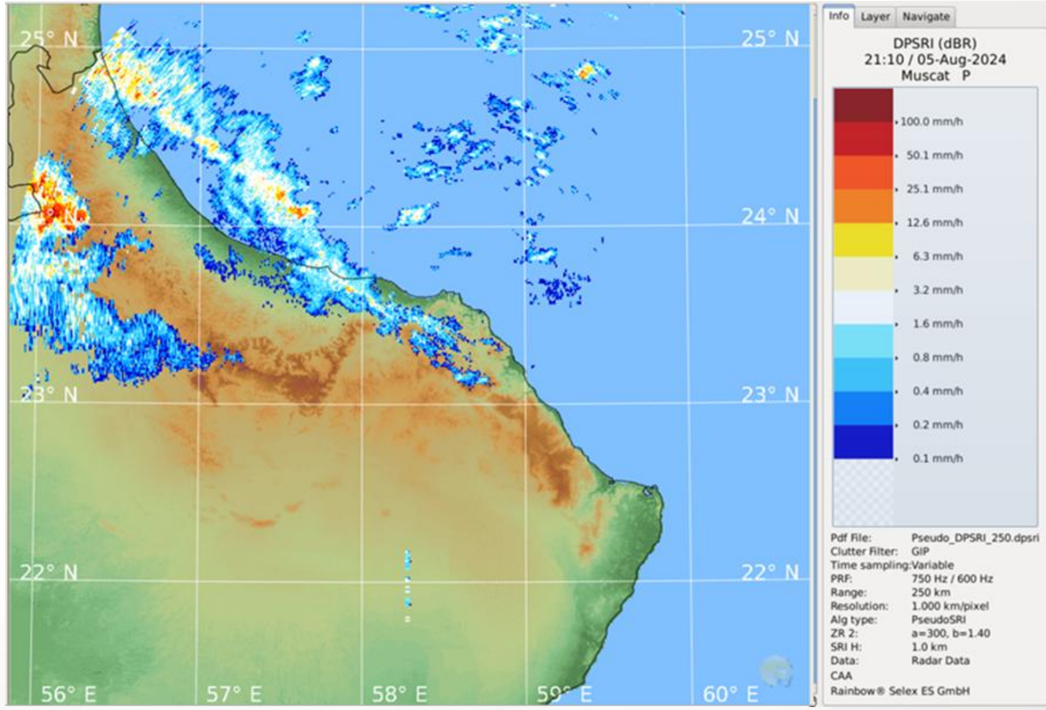
- R = Rainfall Rate

A and b are empirical constants



RADAR to Rainfall





RADAR Limitations

- Range Limitations
- Resolution
- Clutter
- Weather Interference
- Limited Elevation Coverage
- Cost and Complexity

Doppler Effect

- The Doppler Effect in weather radar helps measure the velocity of moving precipitation particles, providing valuable information about the dynamics of the atmosphere.
- As the radar waves interact with the moving particles, the frequency of the reflected waves is shifted.
- If the particles are moving toward the radar, the frequency increases (positive Doppler shift).
- If the particles are moving away, the frequency decreases (negative Doppler shift).

Velocity Calculation by Doppler Effect

- By measuring the Doppler shift, the radar system can calculate the radial velocity of the precipitation particles along the radar beam. Radial velocity is the component of motion along the line of sight between the radar and the moving particles.

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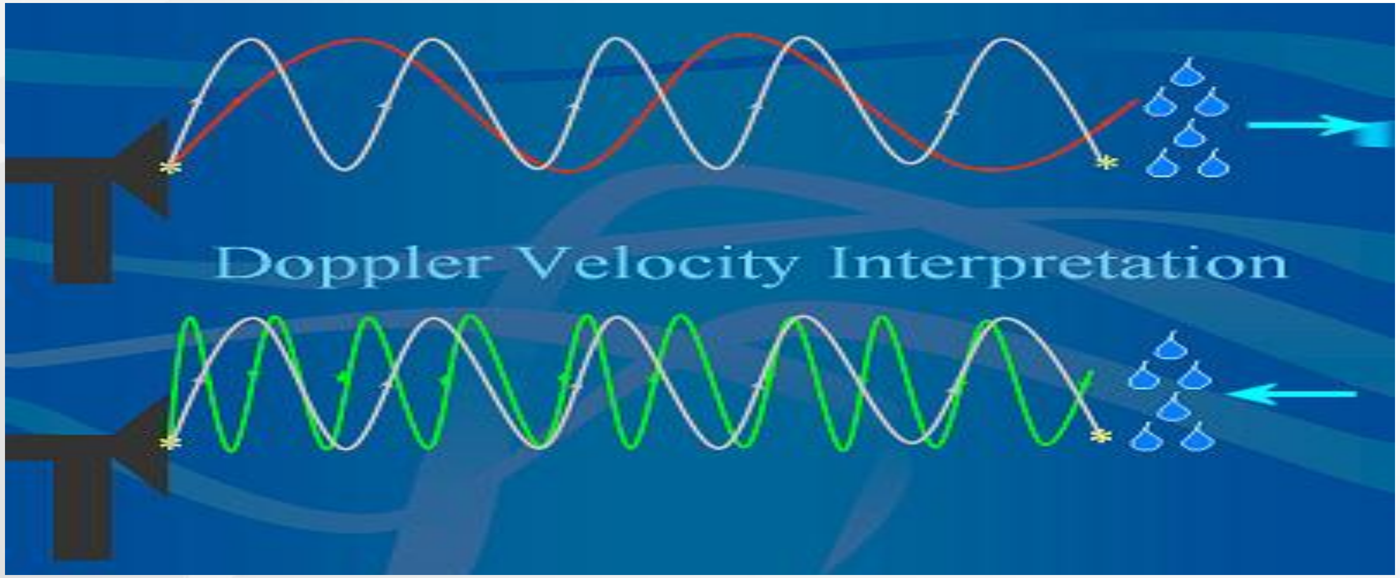

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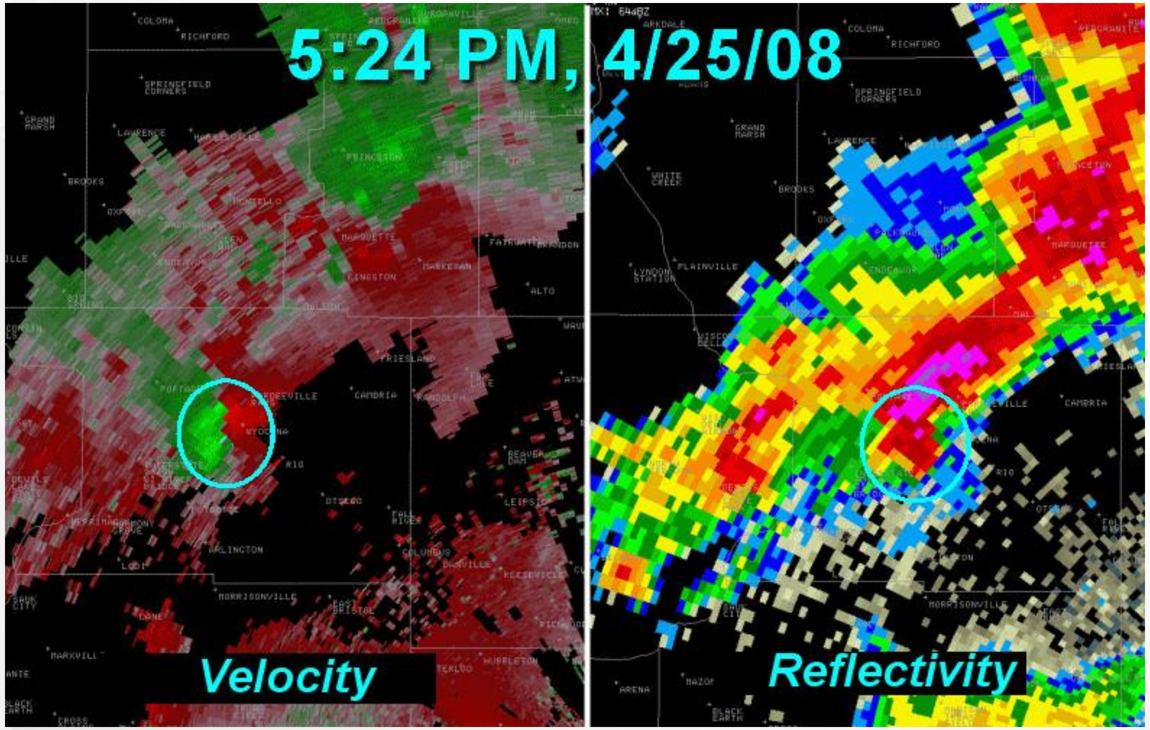
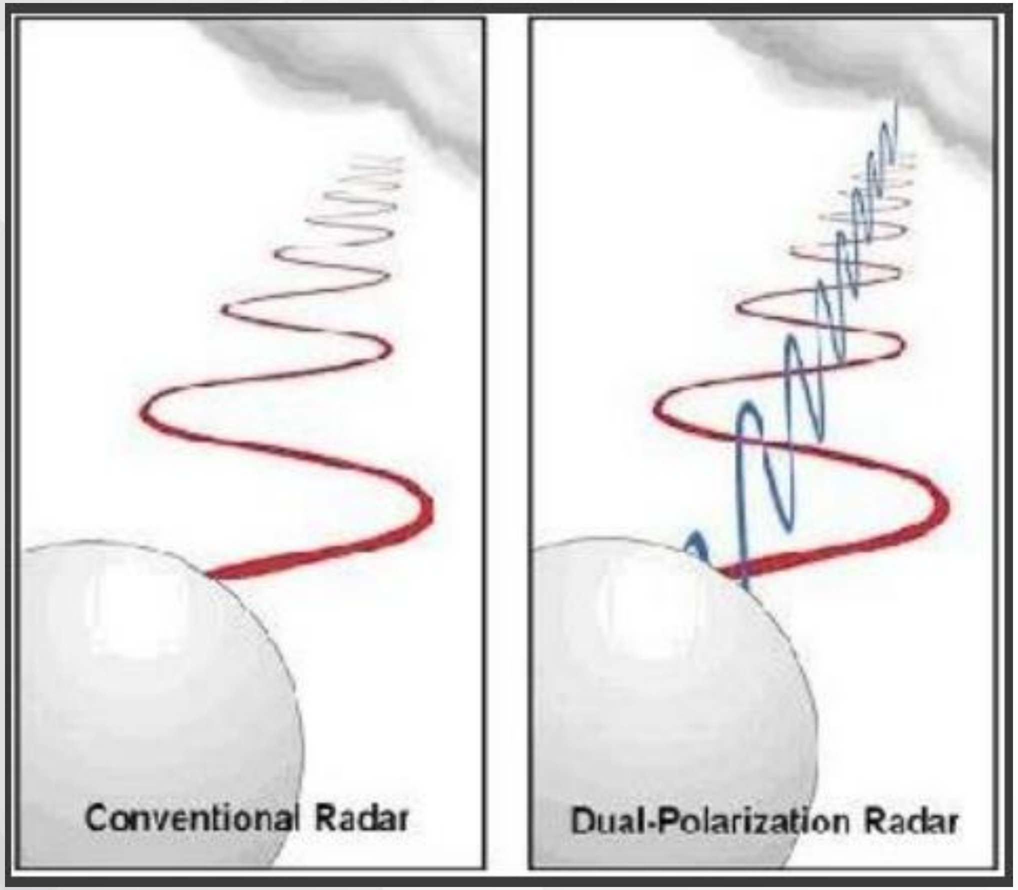


Dual Polarization

- Dual-polarization radar is an advancement in radar technology that utilizes both horizontal and vertical polarizations of radar waves
- Doppler velocity measurements, dual-polarization radar provides information about the shape, size, and type of precipitation particles.

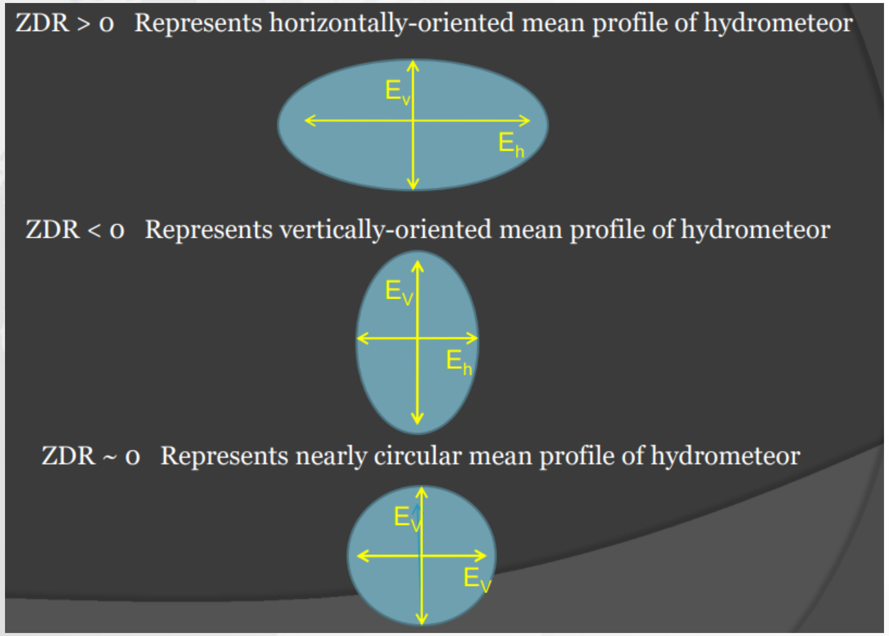
Dual Polarization

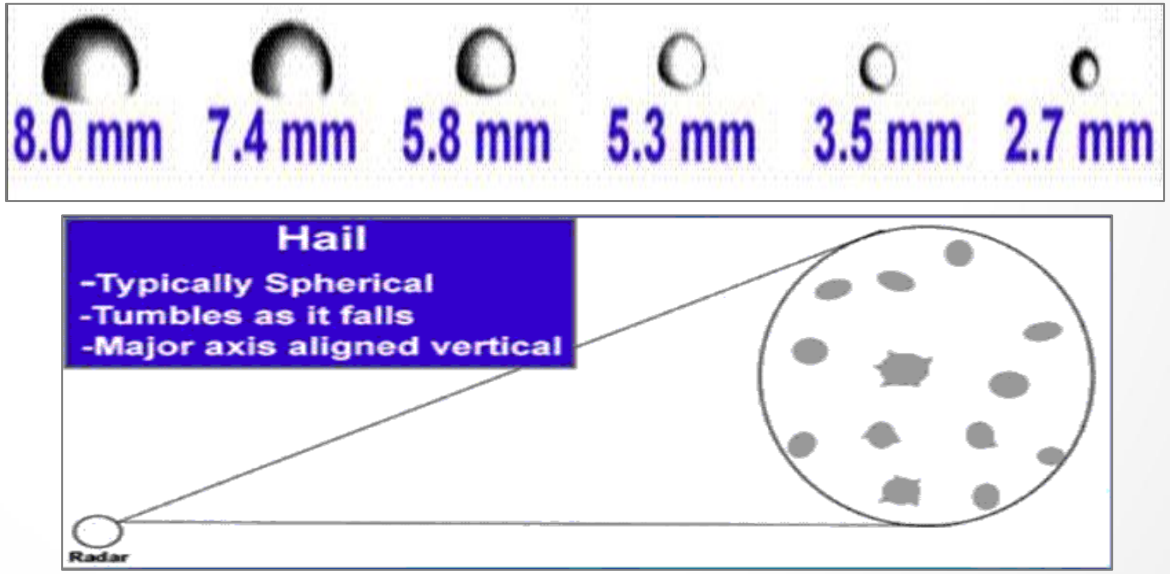


New Variables available

- Differential Reflectivity (ZDR)
- Correlation Coefficient (CC)
- Differential Phase (DP)

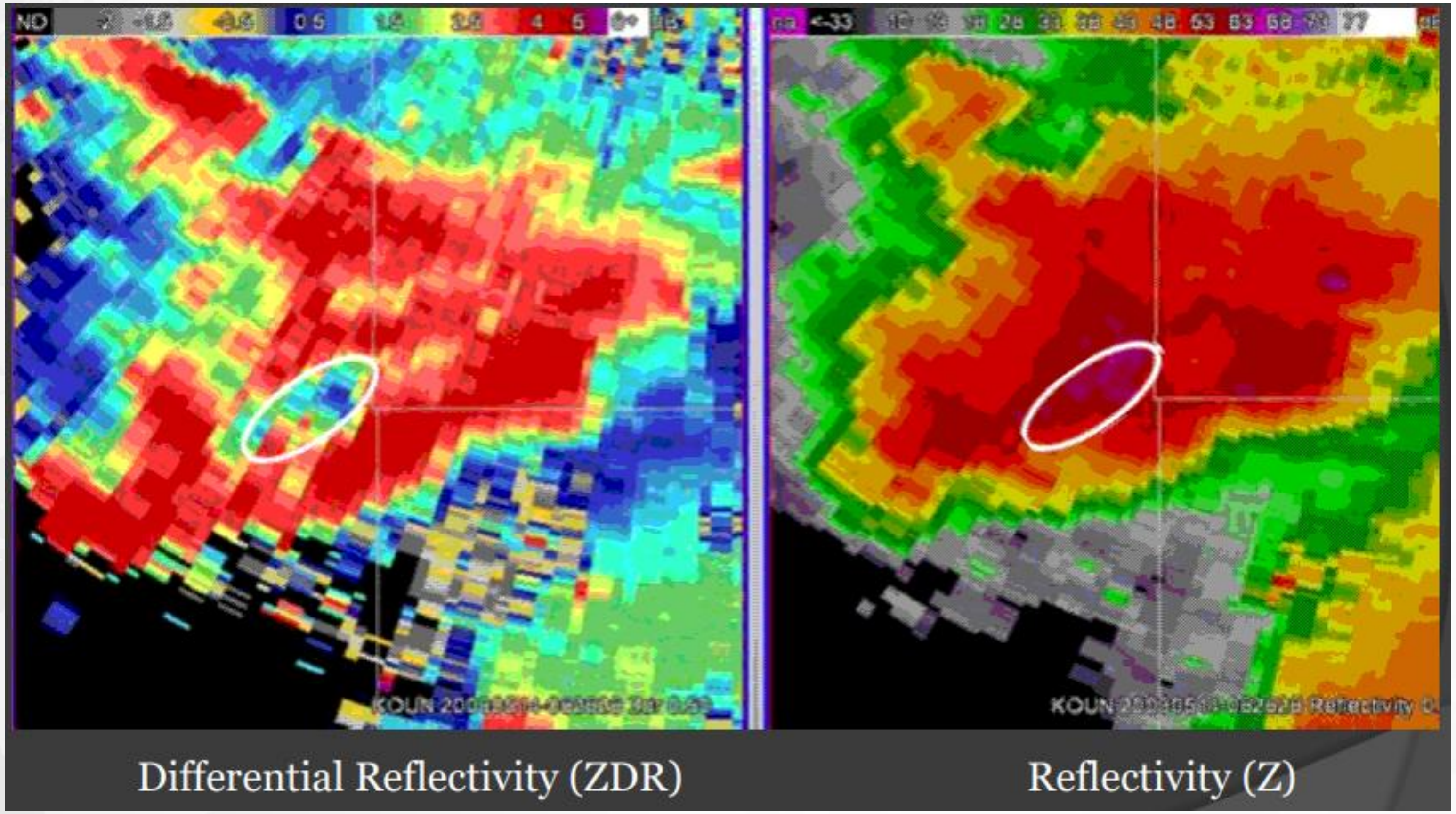
Differential Reflectivity (ZDR)





shape and orientation of precipitation

Differential Reflectivity (ZDR)

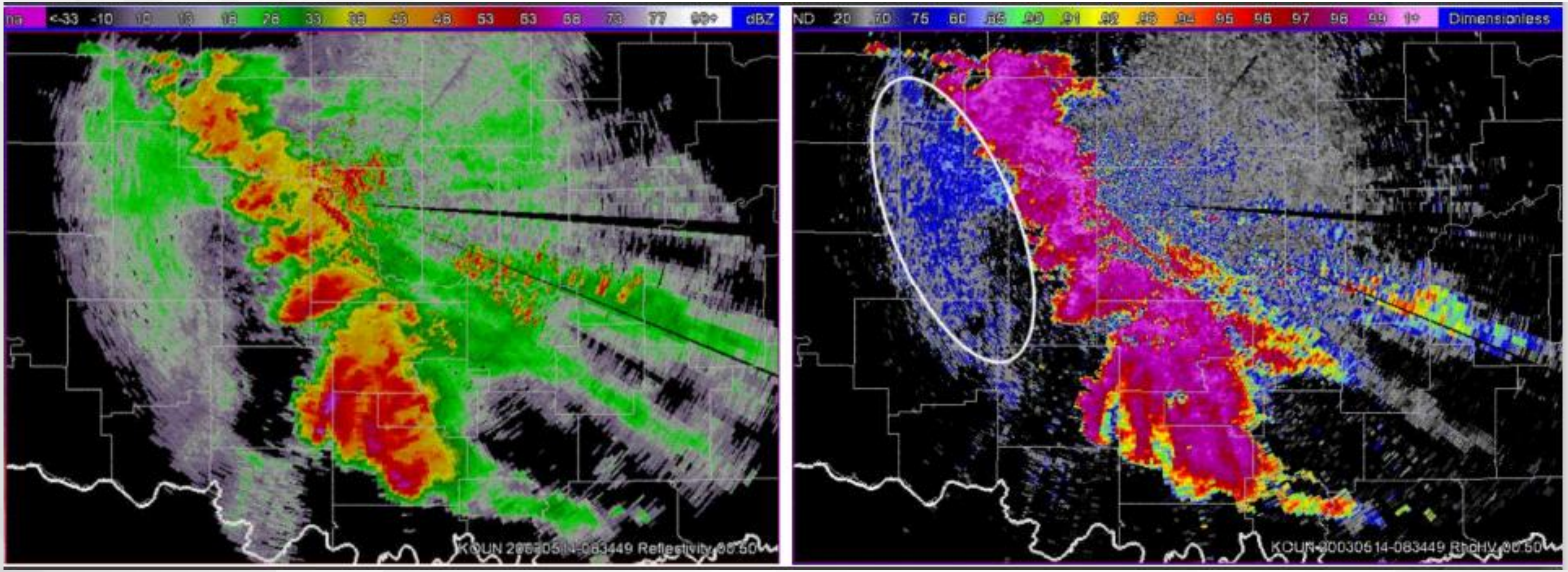


Correlation Coefficient (CC)

0.96 to 1 volume	*Small diversity in hydrometeors within the sample*
0.85 to 0.95	*Large diversity in hydrometeors*
Less than 0.85	*Non-hydrometeorological targets*

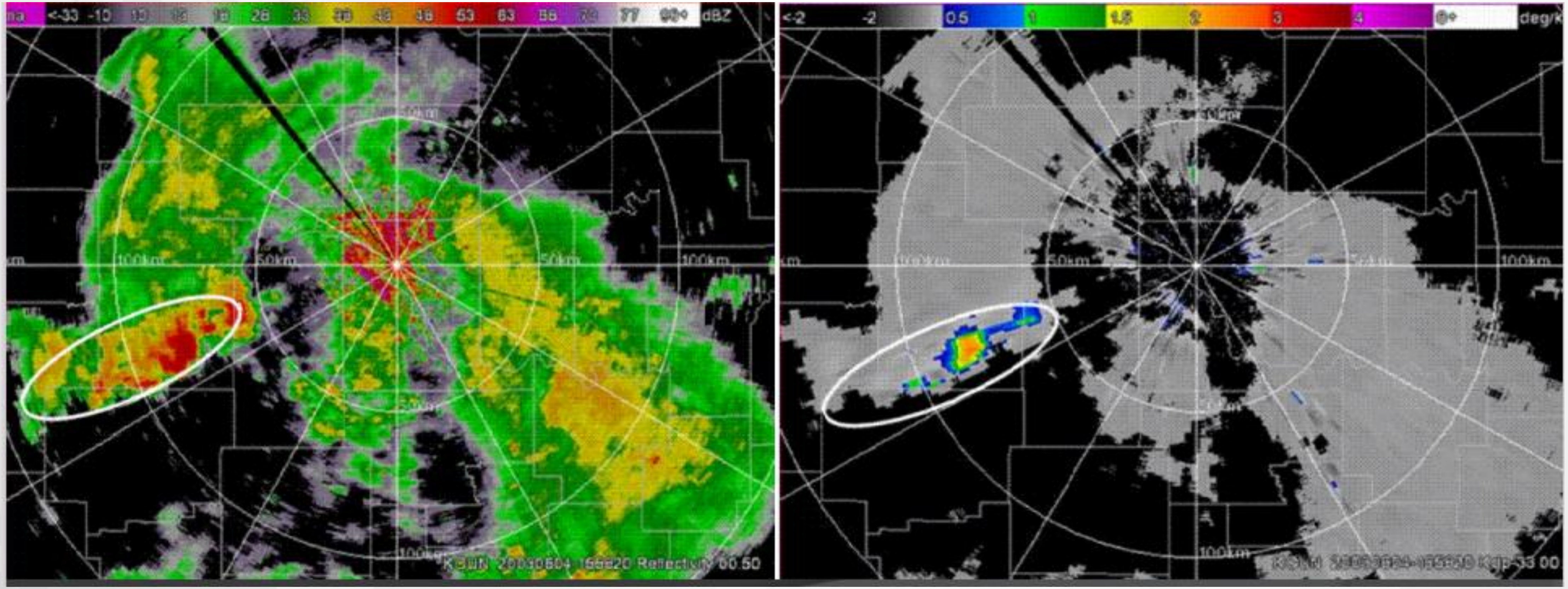
Diversity of precipitation

Correlation Coefficient (CC)

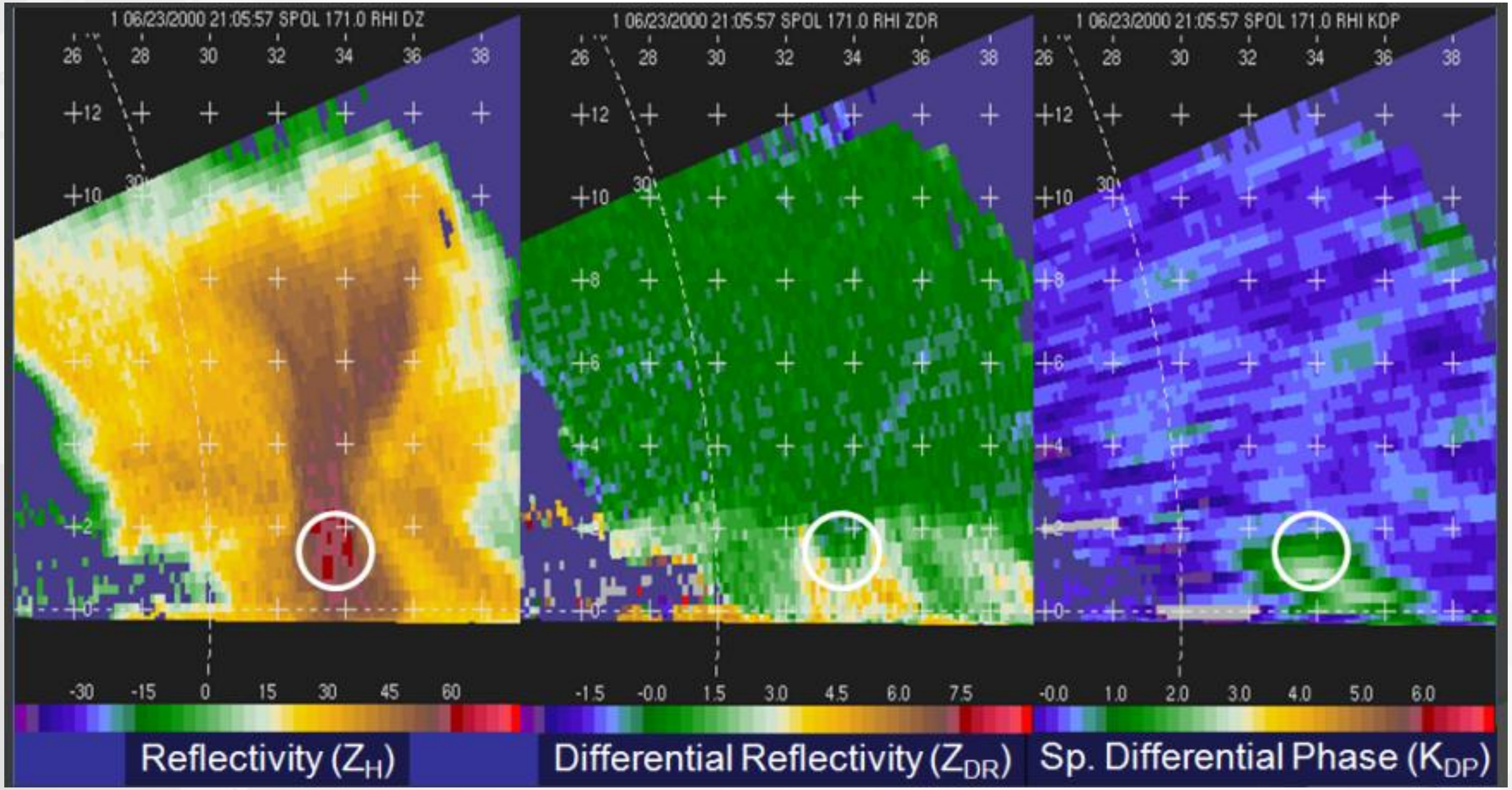


Differential Phase (DP)

Intensity of precipitation



Exercise



1 06/23/2000 21:05:57 SPOL 171.0 RHI DZ
1 06/23/2000 21:05:57 SPOL 171.0 RHI ZDR
1 06/23/2000 21:05:57 SPOL 171.0 RHI KDP
-30 -15 0 15 30 45 60
-1.5 -0.0 1.5 3.0 4.5 6.0 7.5
-0.0 1.0 2.0 3.0 4.0 5.0 6.0
Reflectivity (Z_H)
Differential Reflectivity (Z_{DR})
Sp. Differential Phase (K_{DP})

Thanks

Please Scan the Q-code