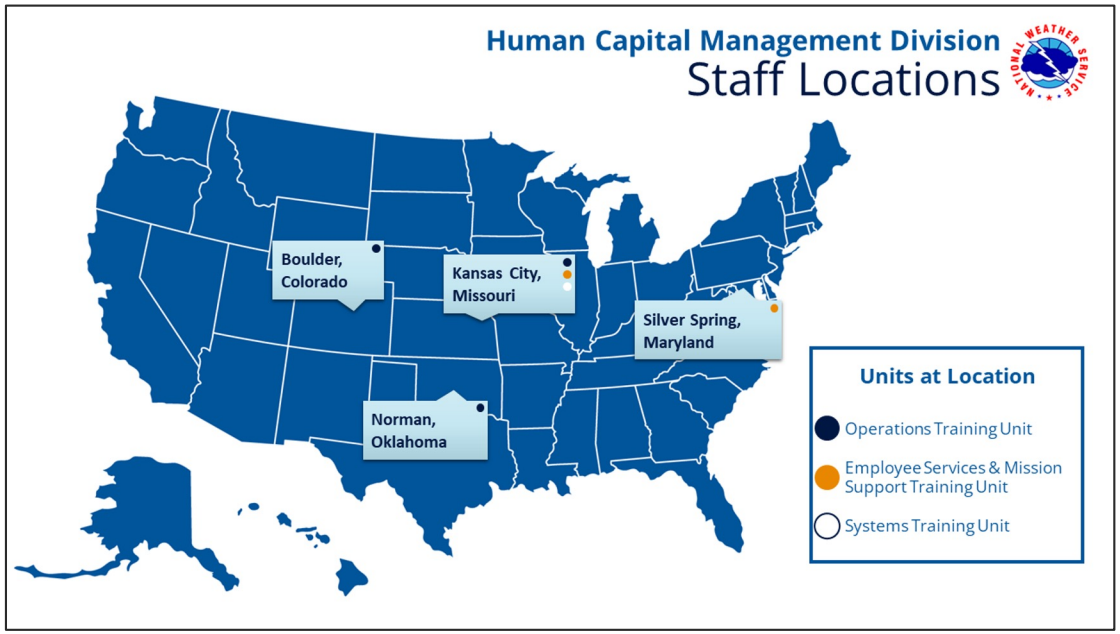
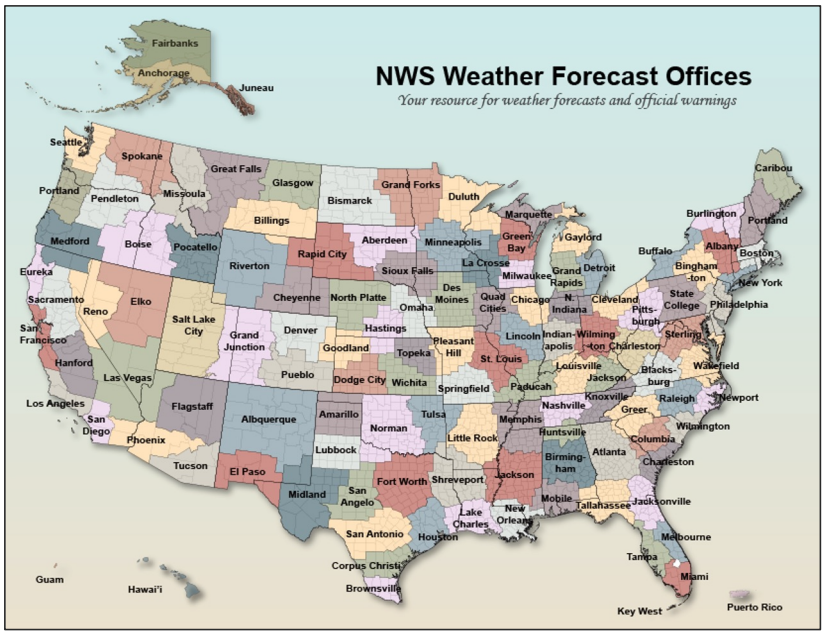
Application of Meteorological Theory to Severe Thunderstorm Forecasting

Title: Intro to Radar Principles and Dual-Pol Parameters

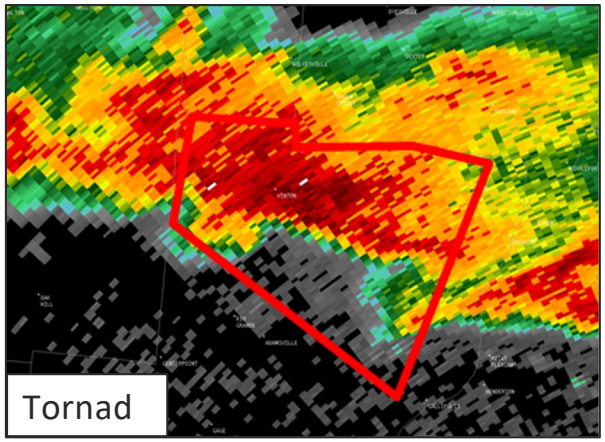
Why Us (OTU Feds & CIWRO)?

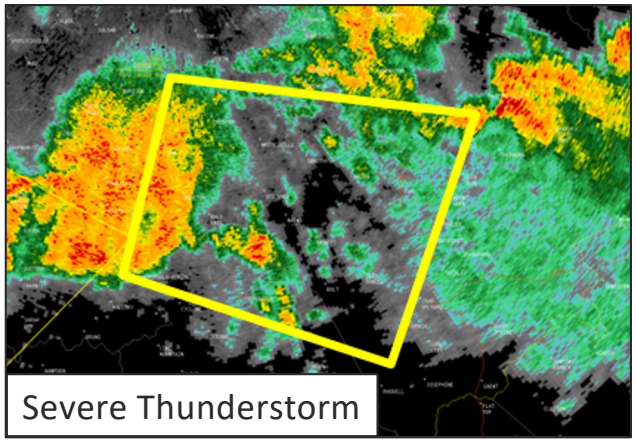


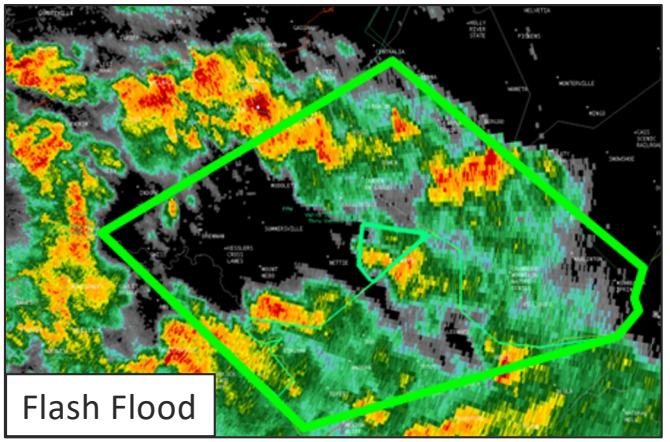


Operations Training Unit (formerly Warning Decision Training Division) teaches weather radar theory & applications to NWS forecasters for use in warning operations

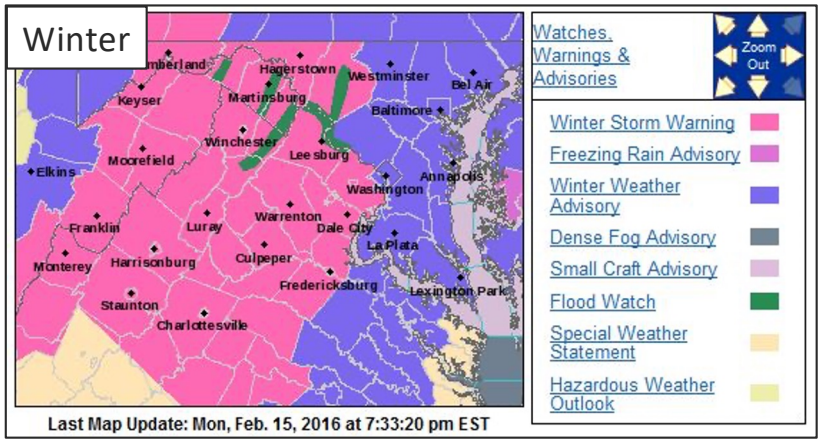
We Train on Warning Decision Making & Other Operational Tasks


Tornado


Severe Thunderstorm


Flash Flood

- Job-centered
- Time-sensitive tasks
- Evidence-based
- Focus on service to the public

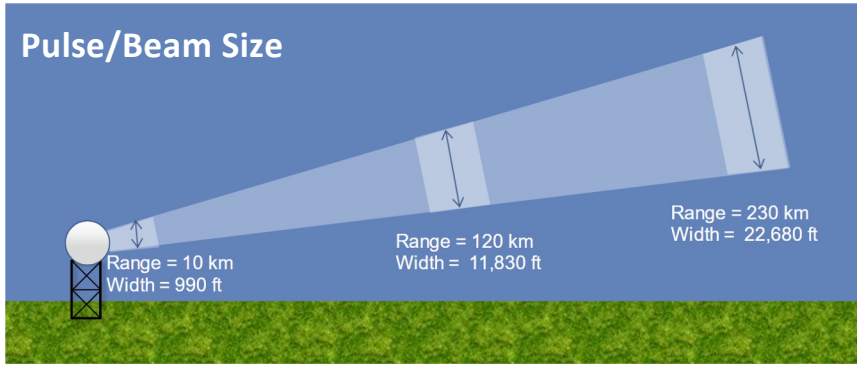


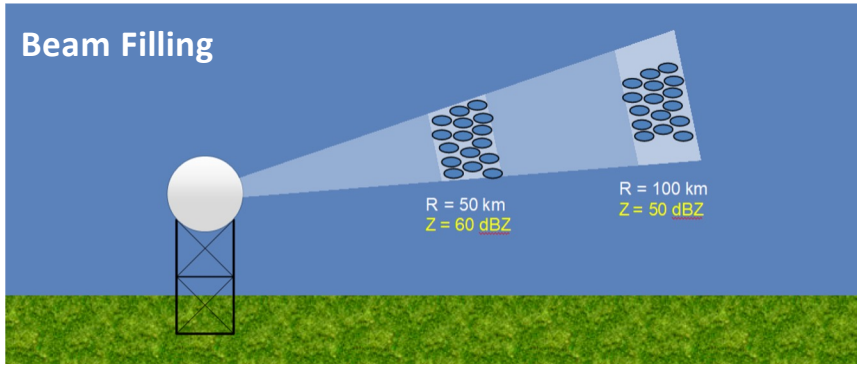
Goals for Today

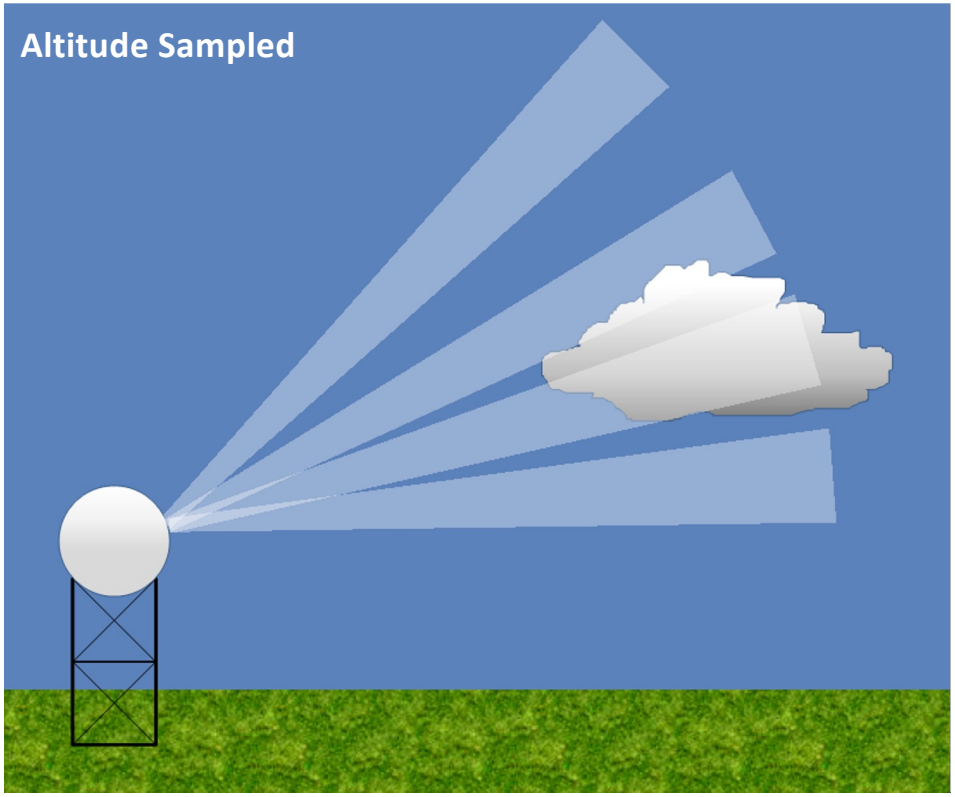
- Part 1: Radar basics related to severe thunderstorms
- Part 2: Radar analysis using Dual-Pol
- Part 3: What can go wrong?

Why Range to Target Matters

Target range impacts:

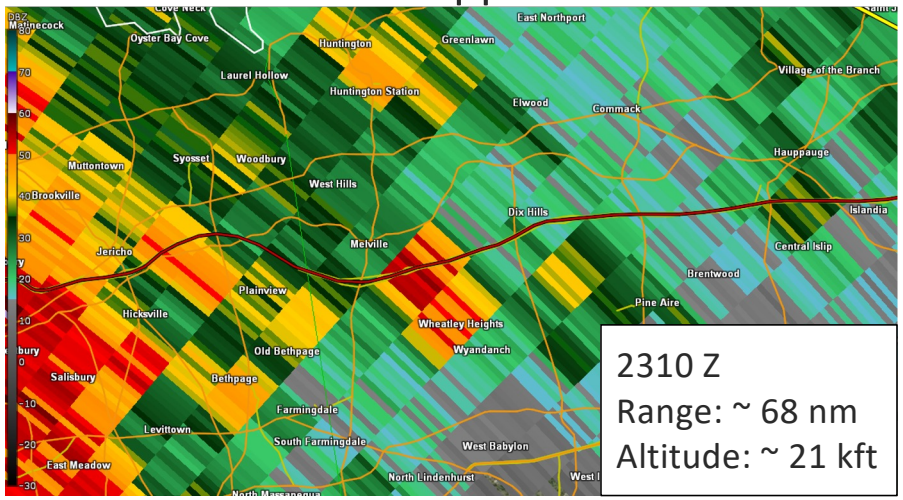


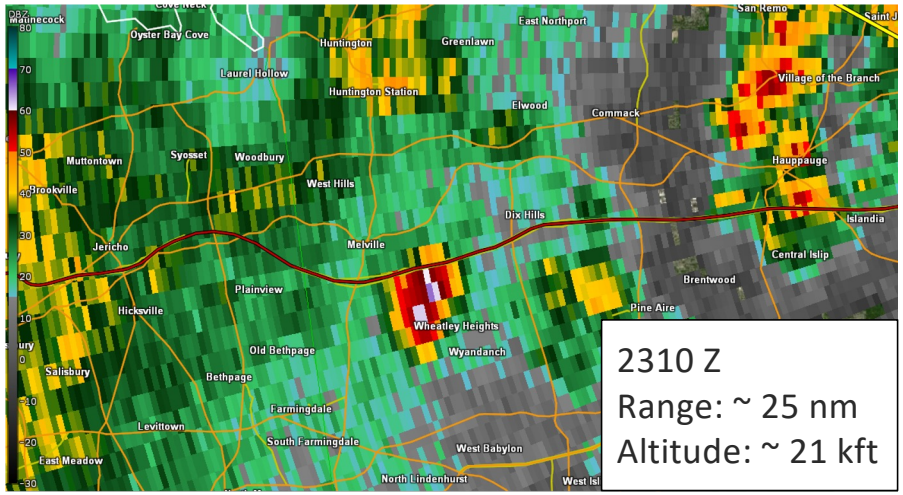




Example of How Target Range to Radar Impacts Appearance

- Same storm, same time, same approximate height, but different ranges
- Storm on left is farther, on lower tilt (2.4°):
  - Resolution poorer
  - Features smoothed out
- Storm on right is closer, on higher tilt (8.0°):
  - Resolution finer
  - More detail apparent





Which of the following terms describes the model used to estimate radar beam height as a function of range?

0

Black body

0%

Standard atmosphere

0%

Atmospheric dispersion

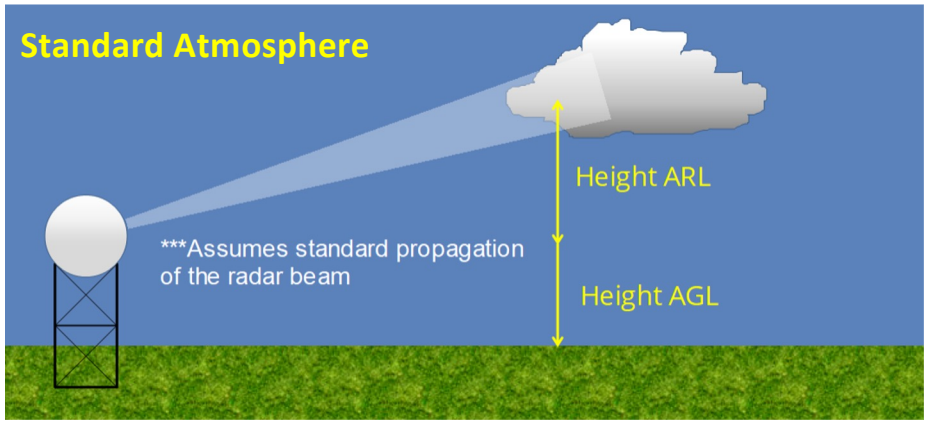
0%

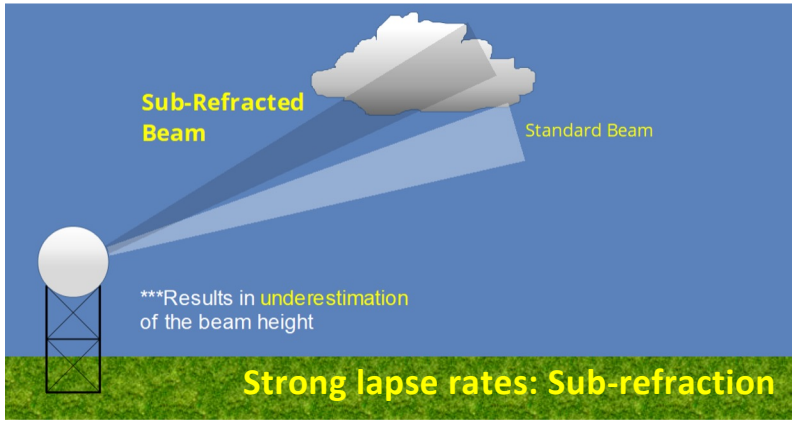
Radiative transfer

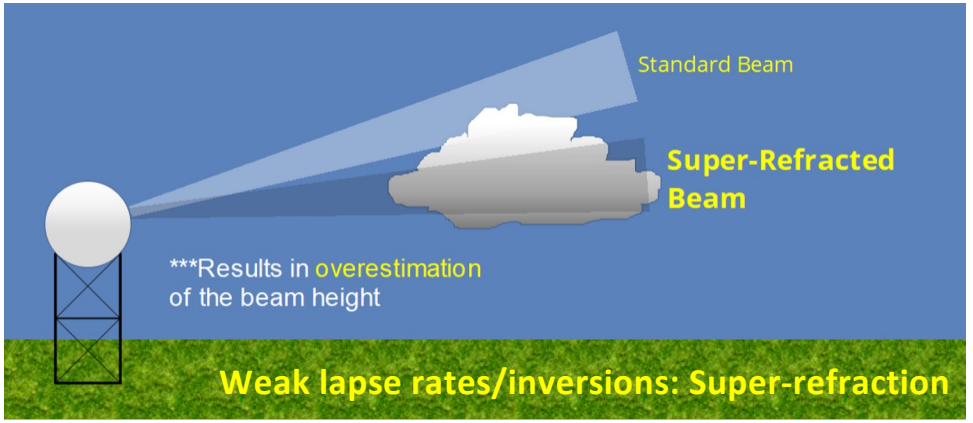
0%

Radar Sampling Height, The Standard Atmosphere, and Uncertainty

Estimated beam heights based on standard atmosphere assumption:



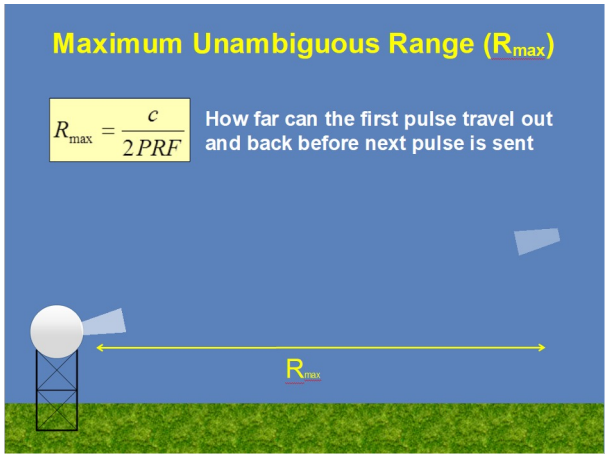


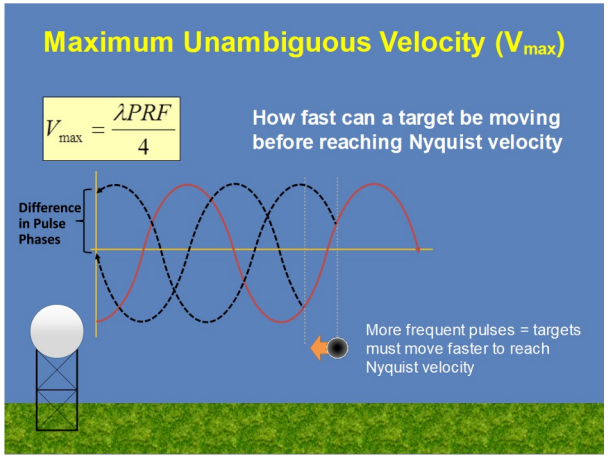


The problem: The atmosphere is rarely like “the standard”

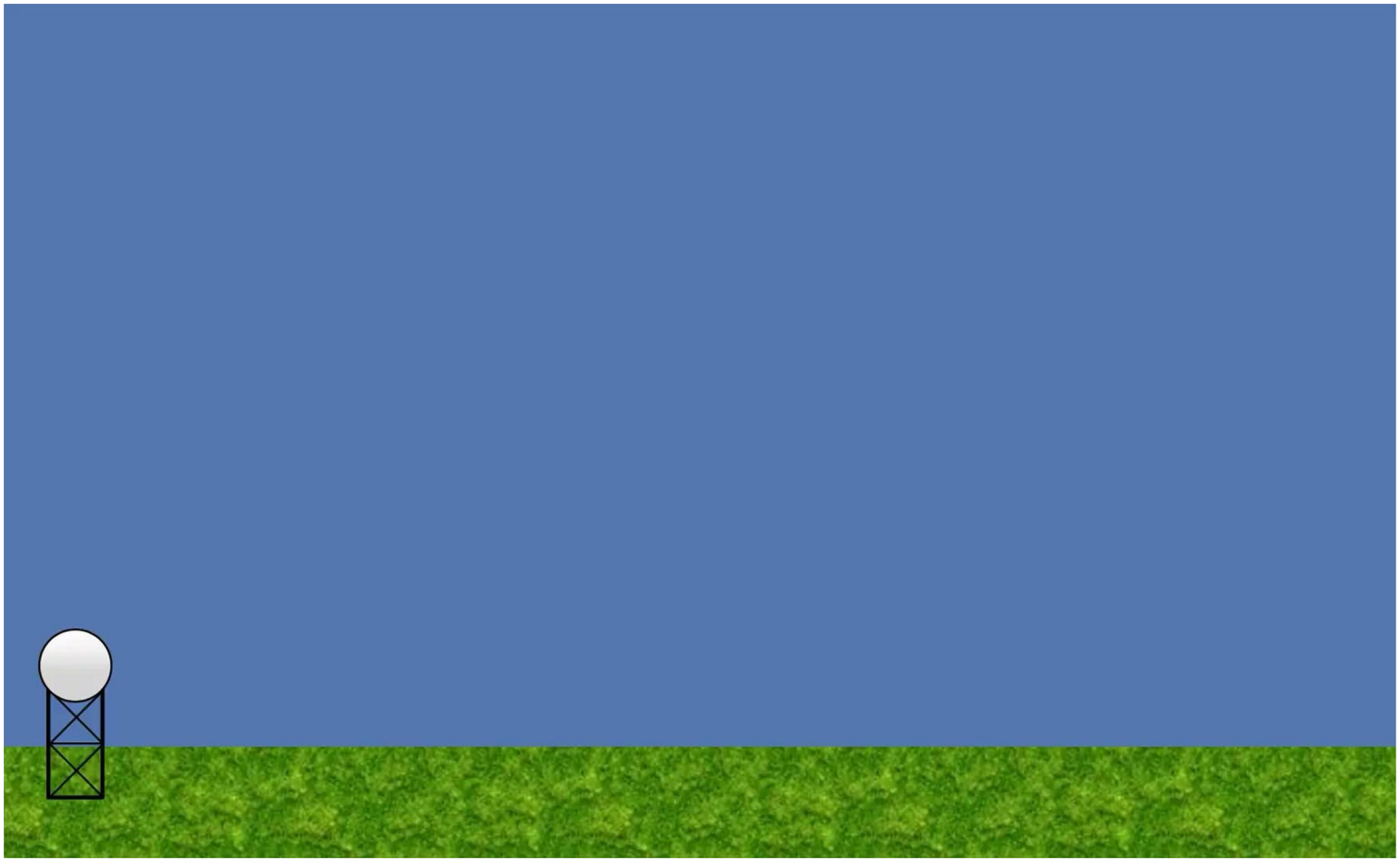
The Doppler Dilemma: Mitigation Takes Time!

- Radar range and velocity determination are inversely related to each other
- The WSR-88D uses several techniques to mitigate this issue
- Unfortunately, these techniques result in longer data collection times

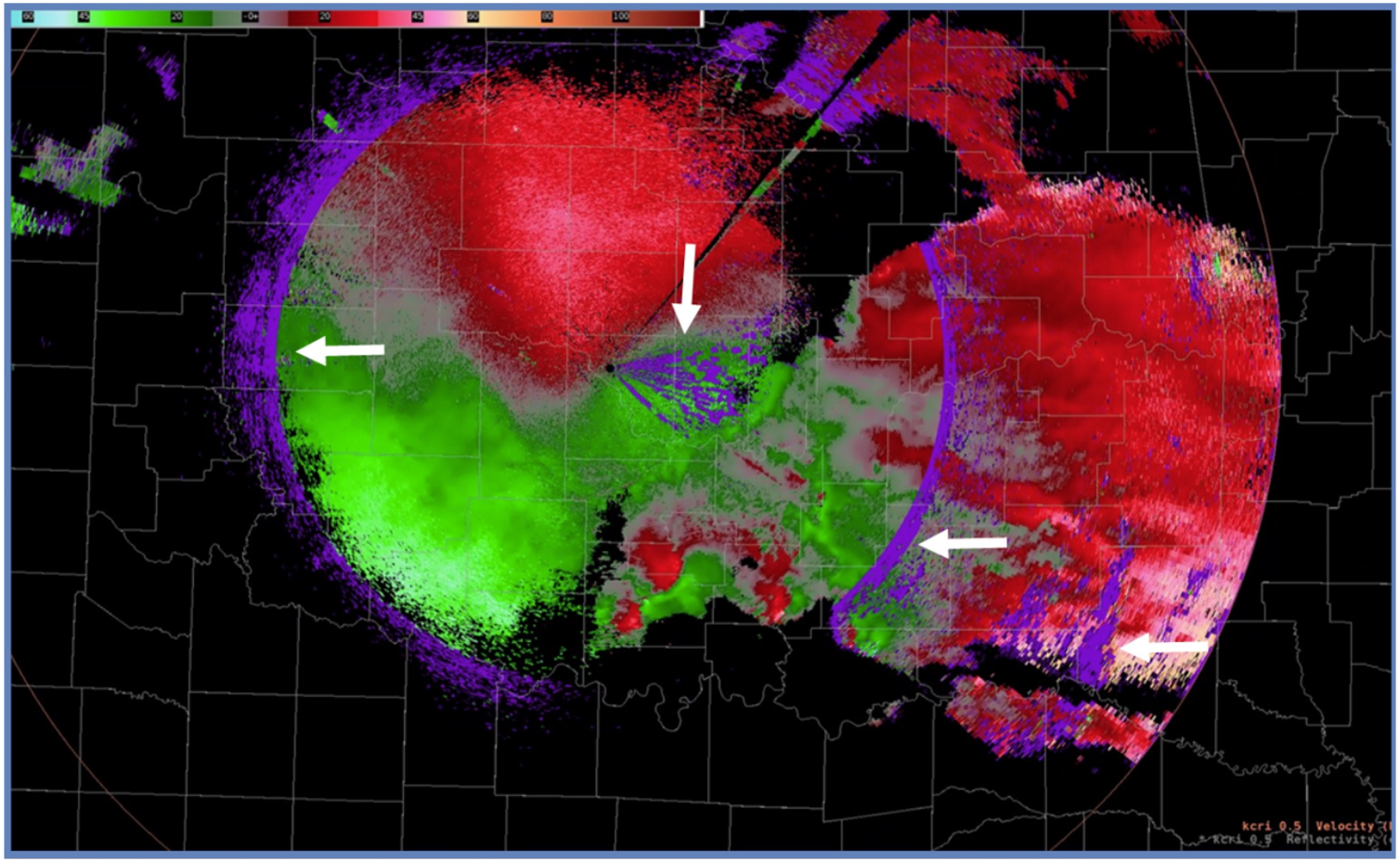




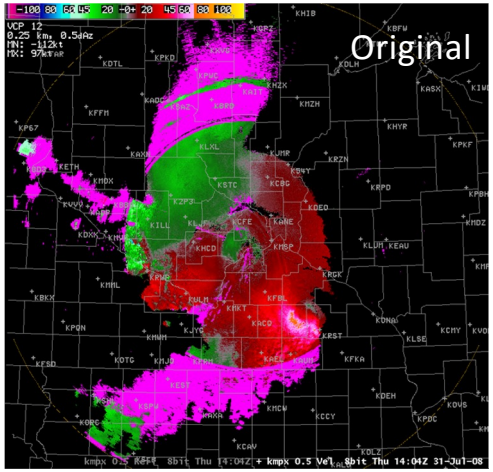
Why Mitigate the Doppler Dilemma? Well, Range Folding

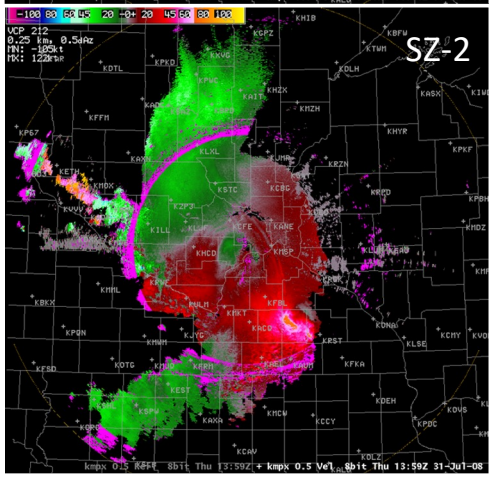


Range Folding Example



Doppler Dilemma Mitigation Strategies & Their Tradeoffs

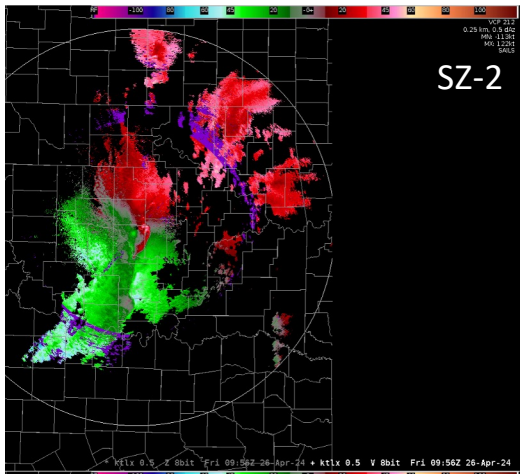


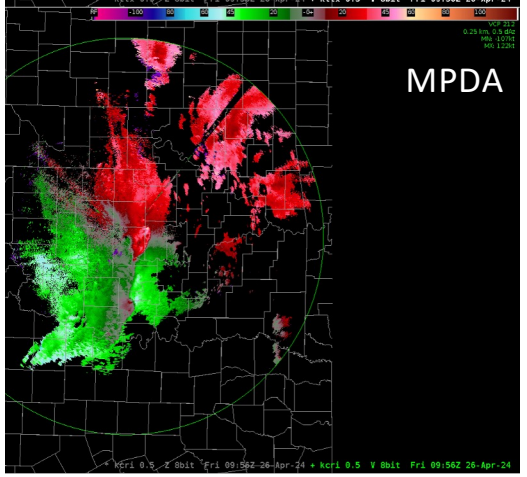


Sachidanada-Zrnic 2 (SZ-2) often can recover velocity data from multiple trips of overlaid echoes, reducing RF

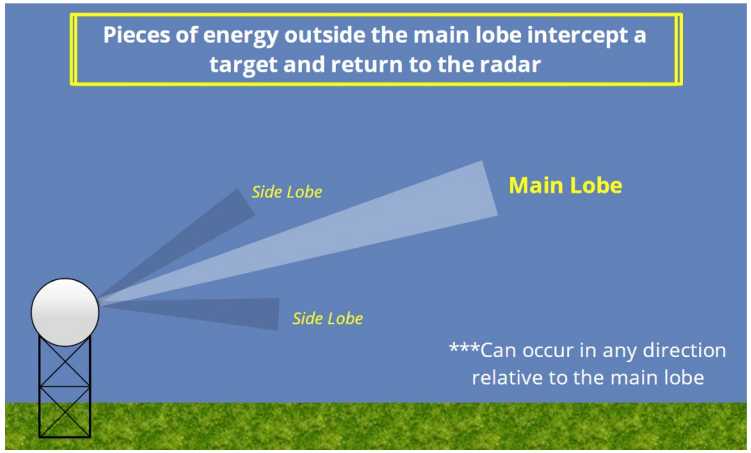
Multiple PRF Dealiasing Algorithm uses multiple velocity scans at different PRFs to recover velocity data

While both techniques work well, they do add a significant amount of time to volume scans

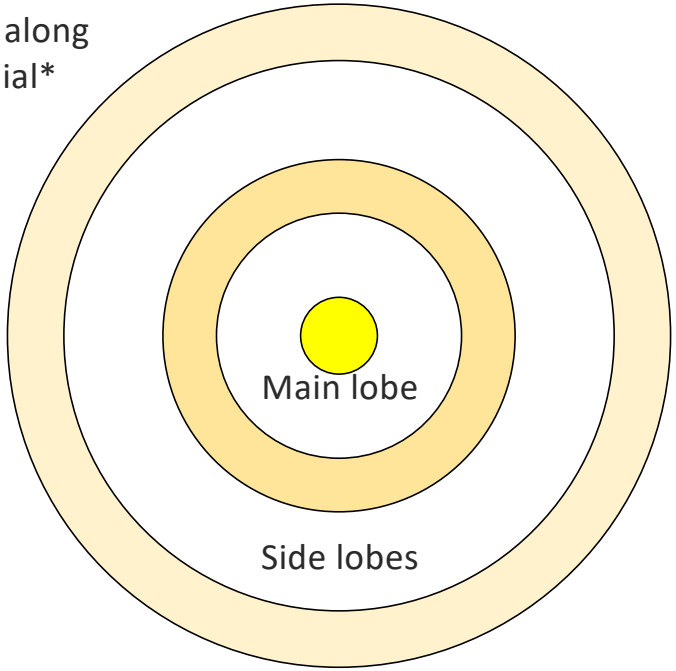




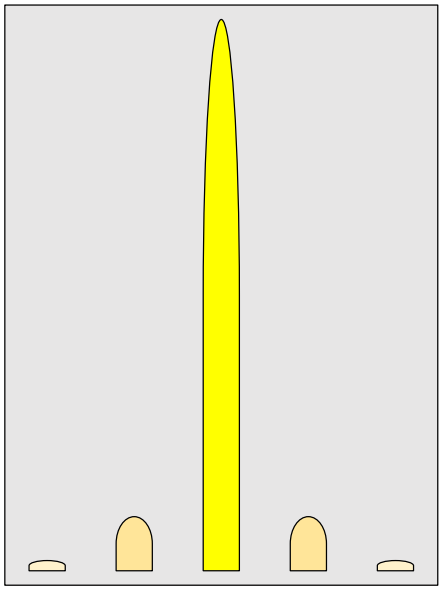
What Are Side Lobes & Why Are They Important?



View along radial*



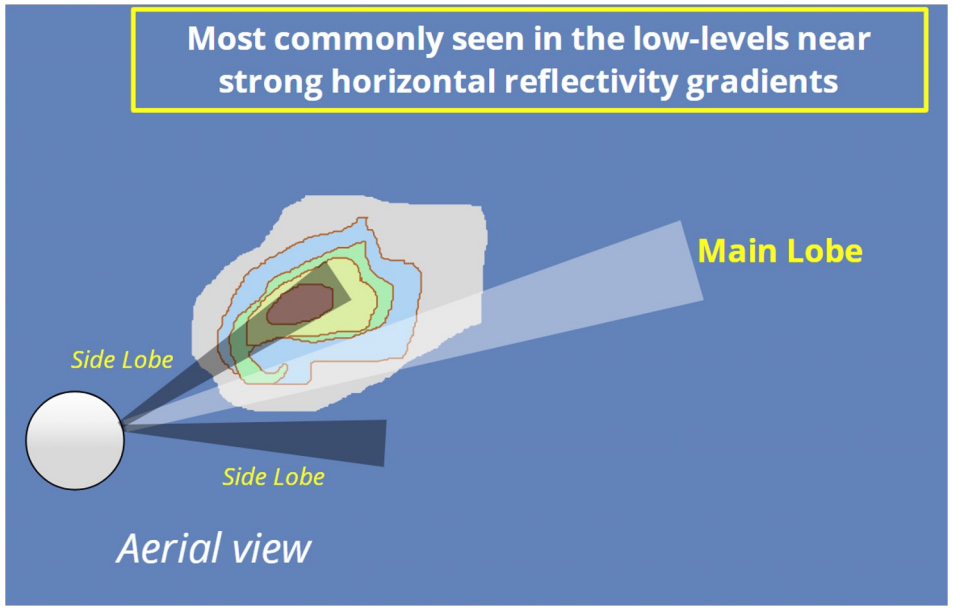
Relative energy in each lobe*



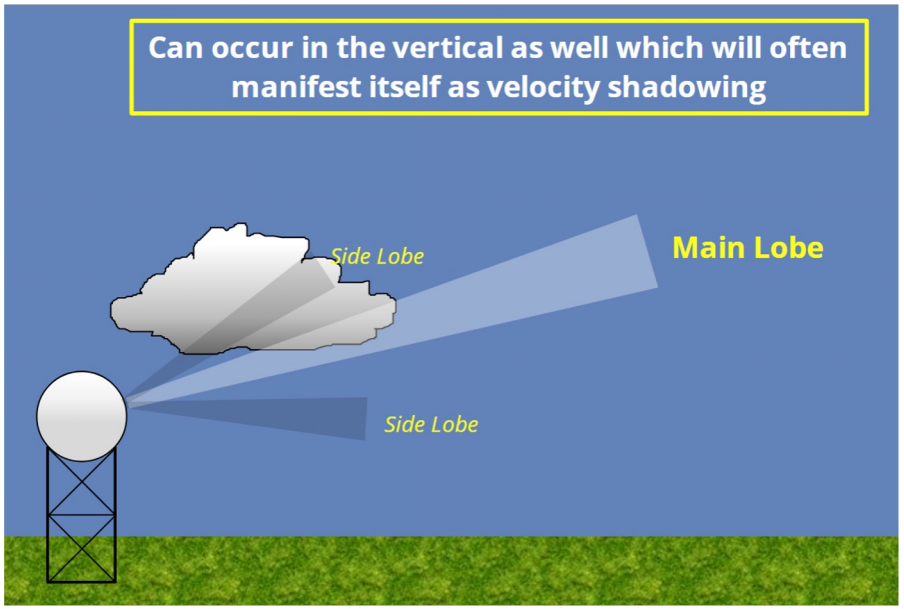
*not to scale

Side Lobe Contamination: When Energy from Side Lobes Is Significant

Horizontal Contamination

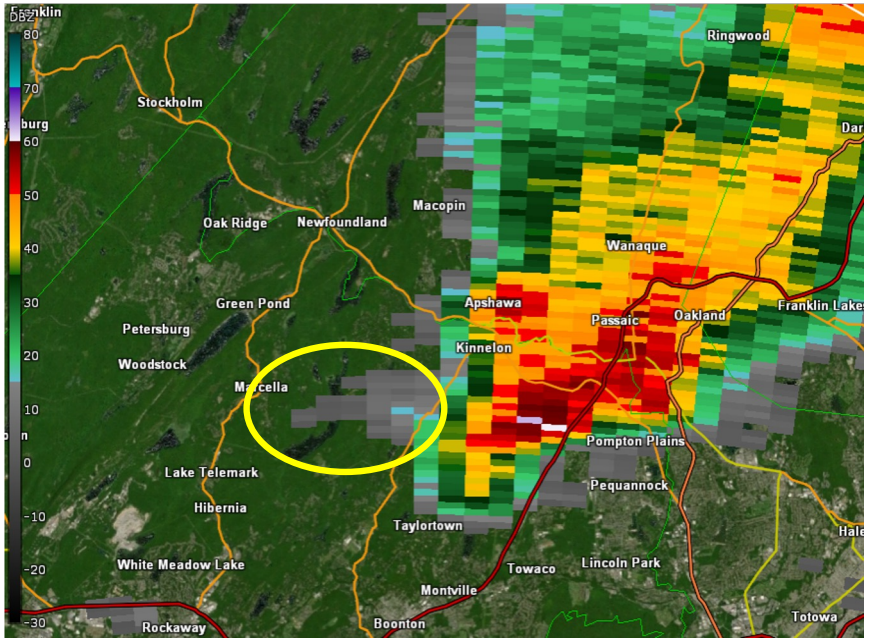


Elevation-Based Contamination

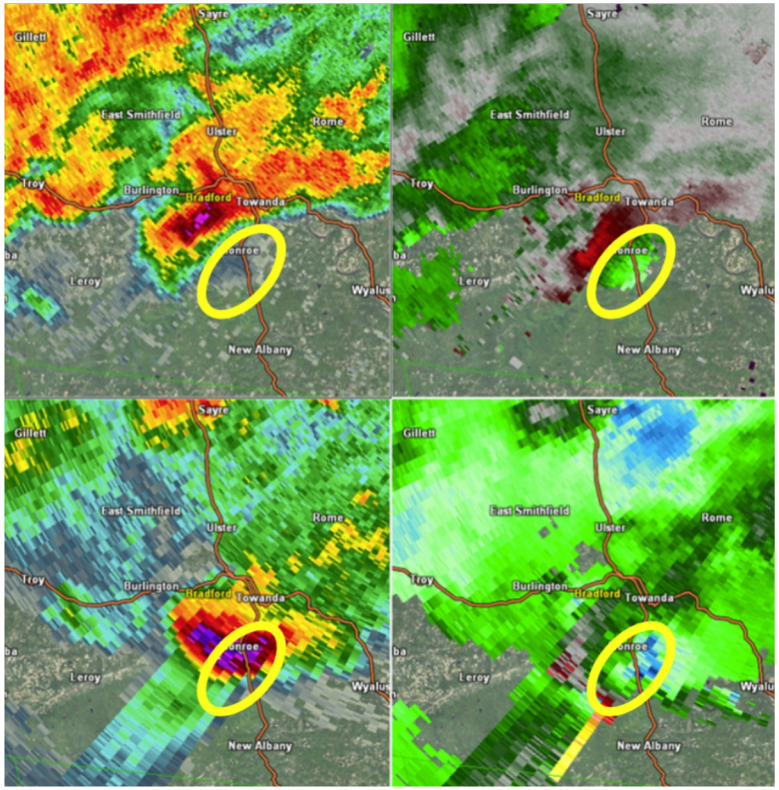


Side Lobe Contamination Examples

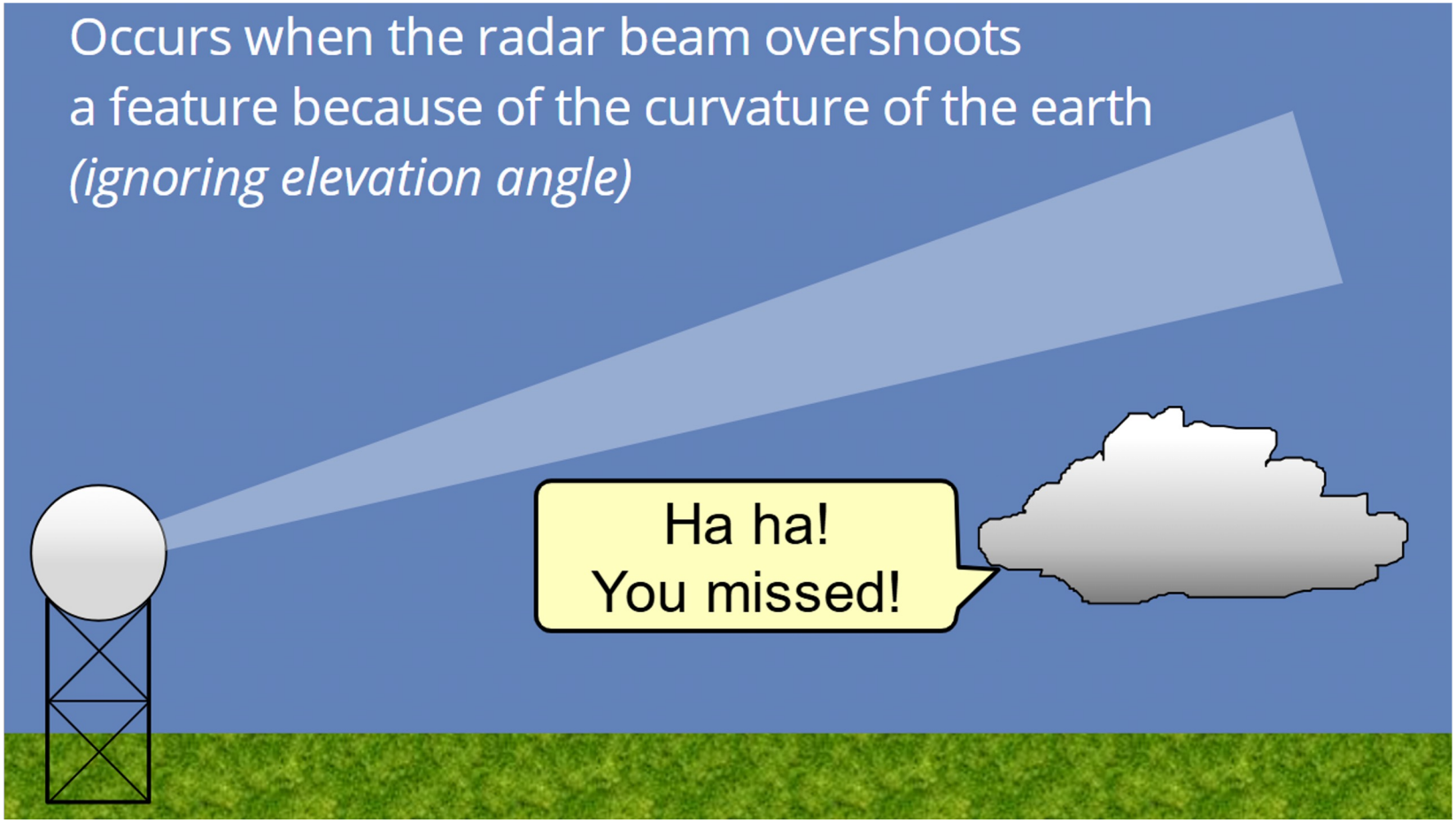
Horizontal



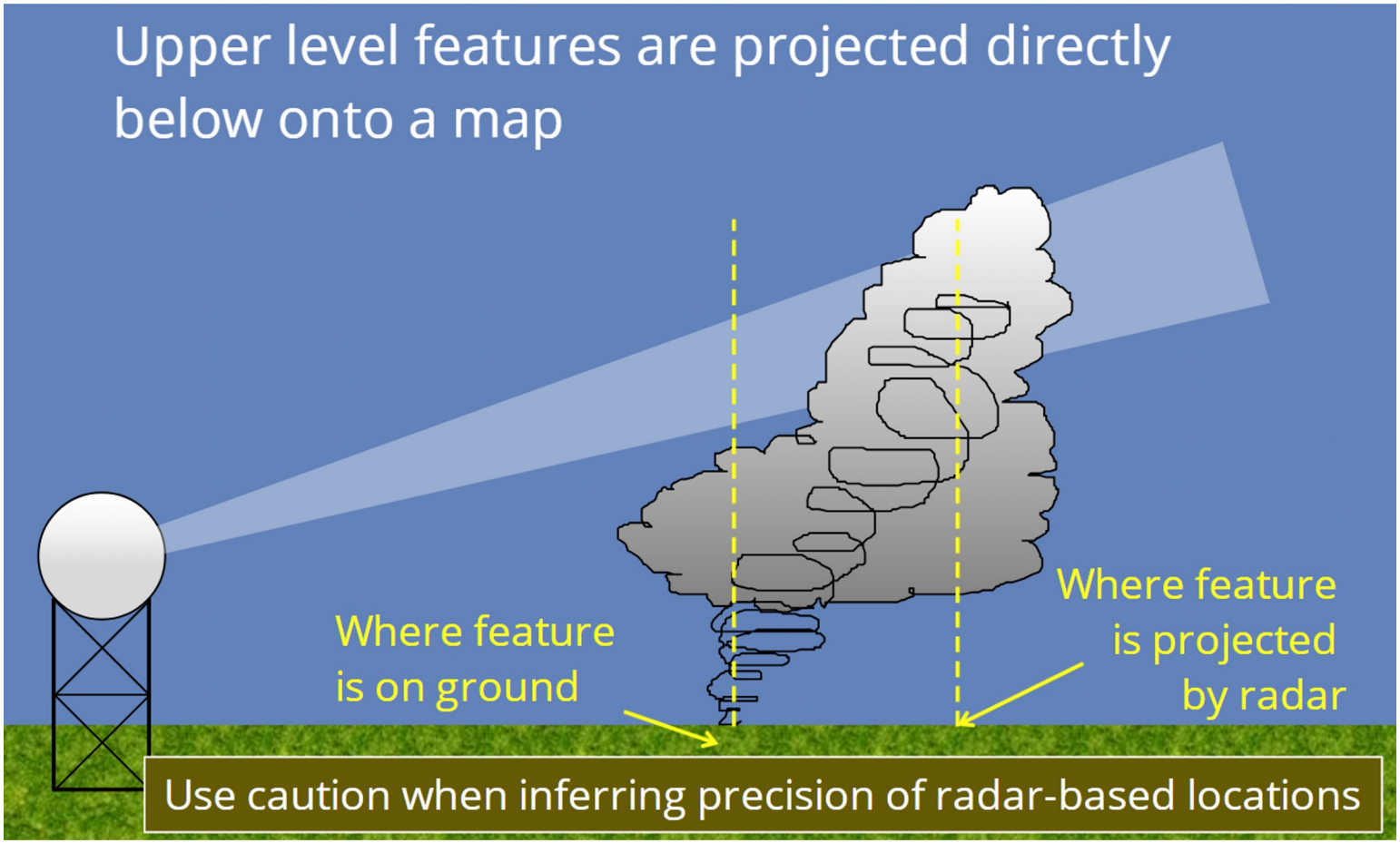
Elevation-Based



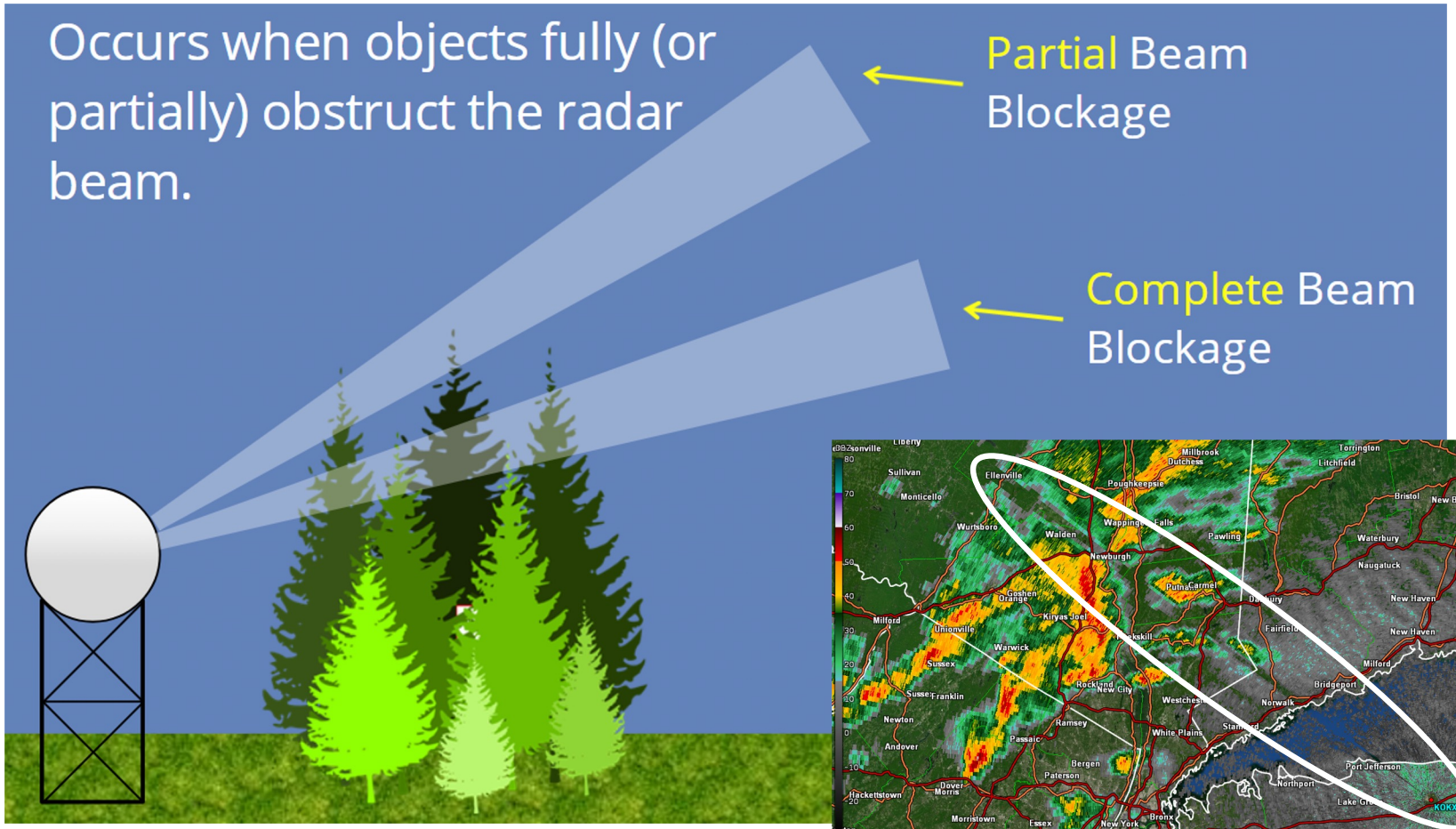
What's Happening Below the Lowest Beam?



The Radar Locations Errors

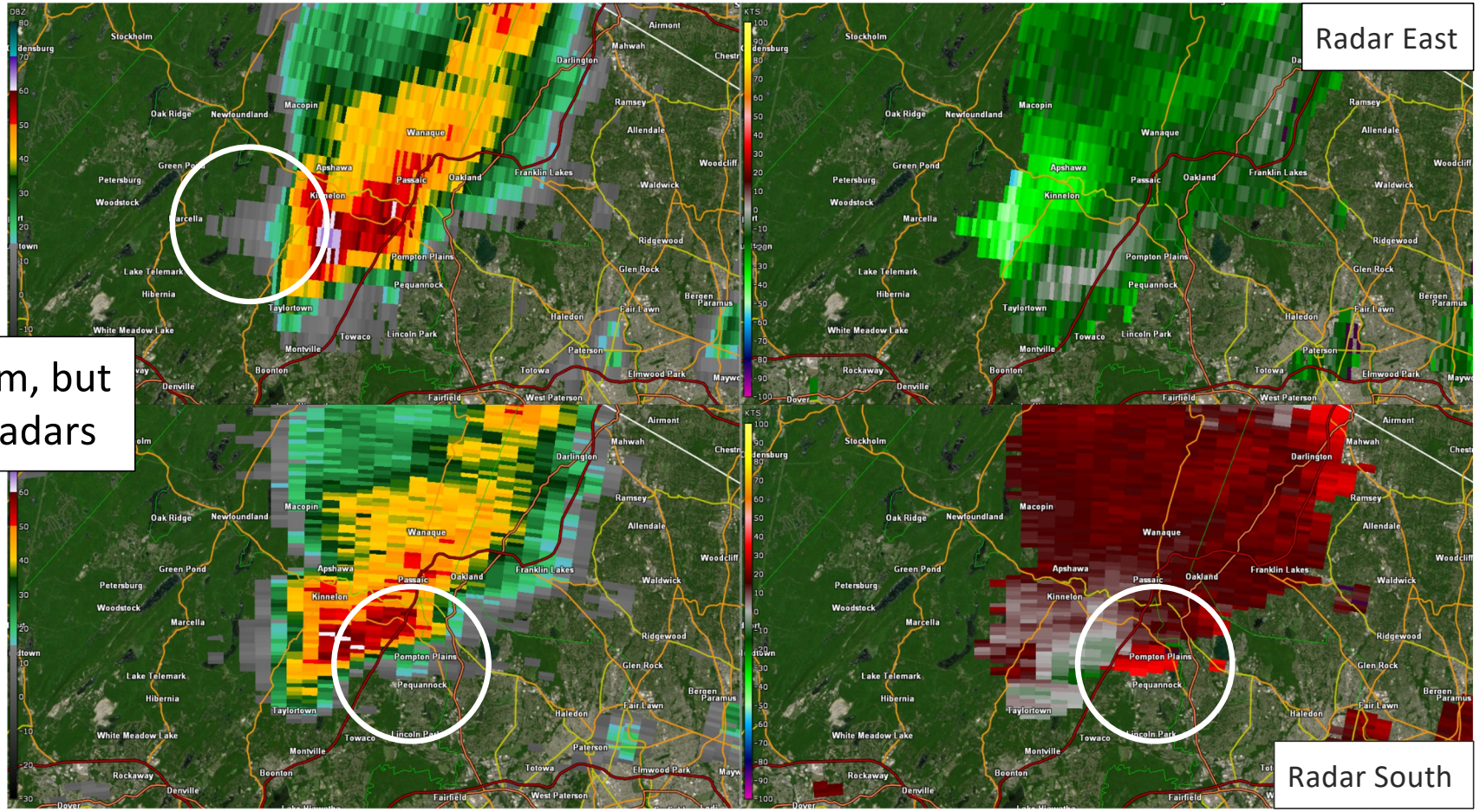


Beam Blockage



Viewing Angle Matters

Same storm, but different radars



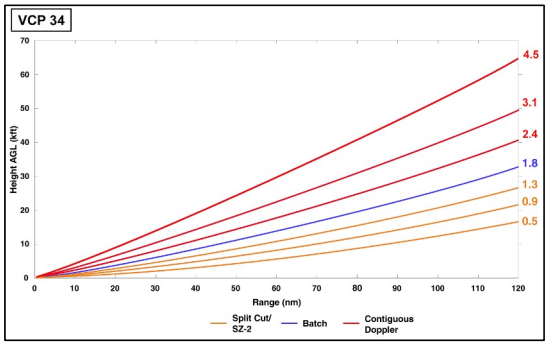
Operational Modes

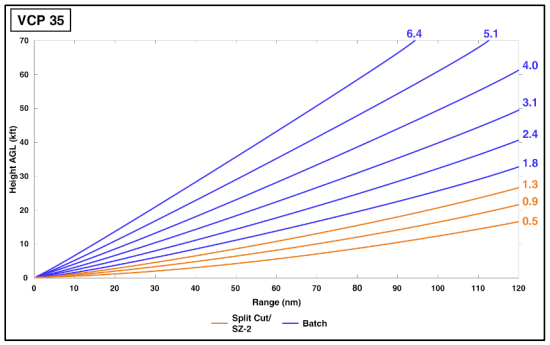
CLEAR AIR: Designed for events with no detectable precipitation or when precipitation is light or small in areal coverage

PRECIPITATION: Designed for use when significant precipitation is present within the radar umbrella

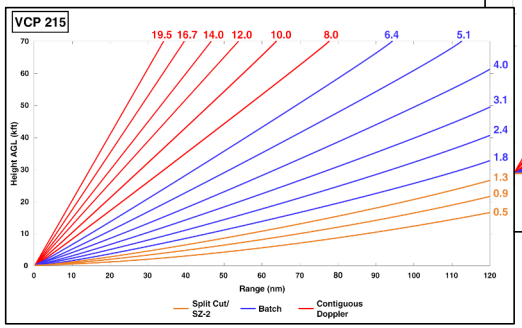
Radar Follows a Pre-Defined Scanning Strategy

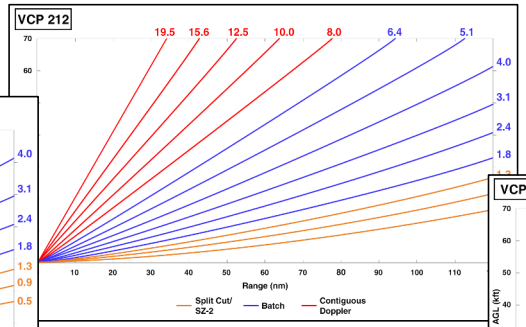
Clear Air:

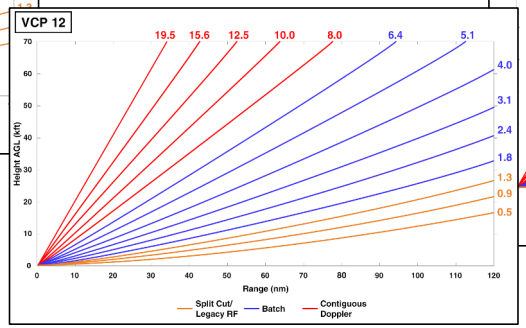


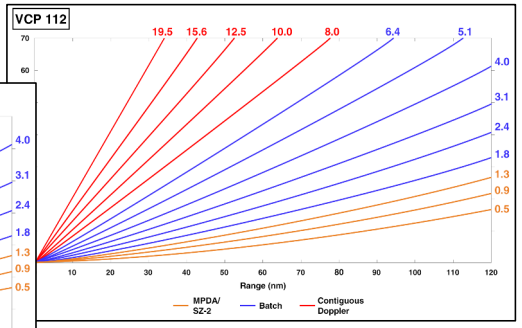


Precipitation:



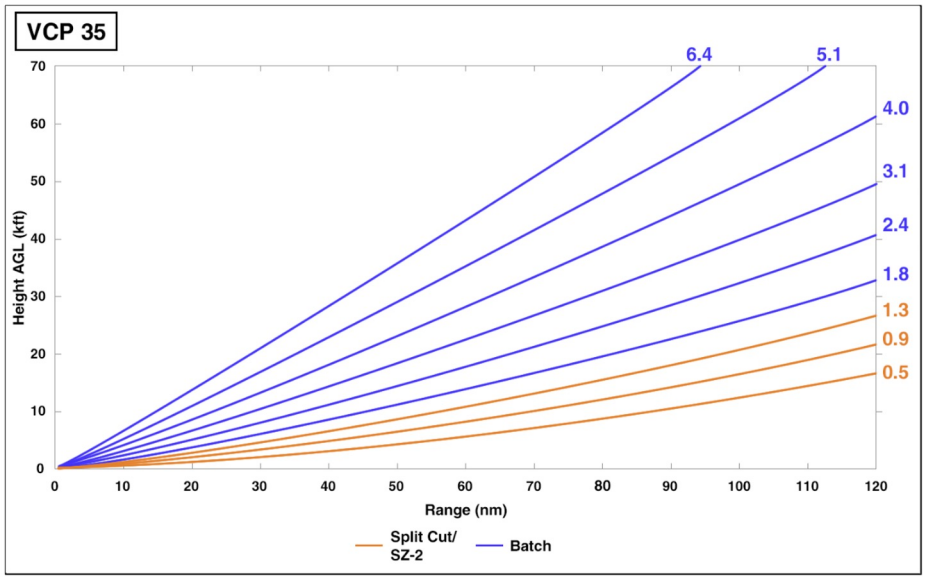


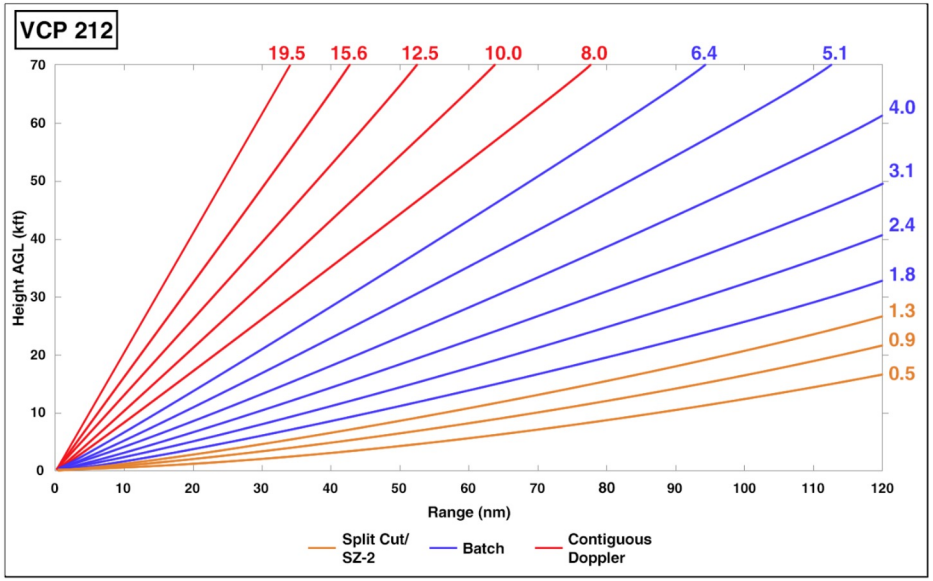




How High Up In the Atmosphere Is the Radar Sampling?

Depends on the VCP **and** the dynamic scanning settings (i.e., AVSET)!



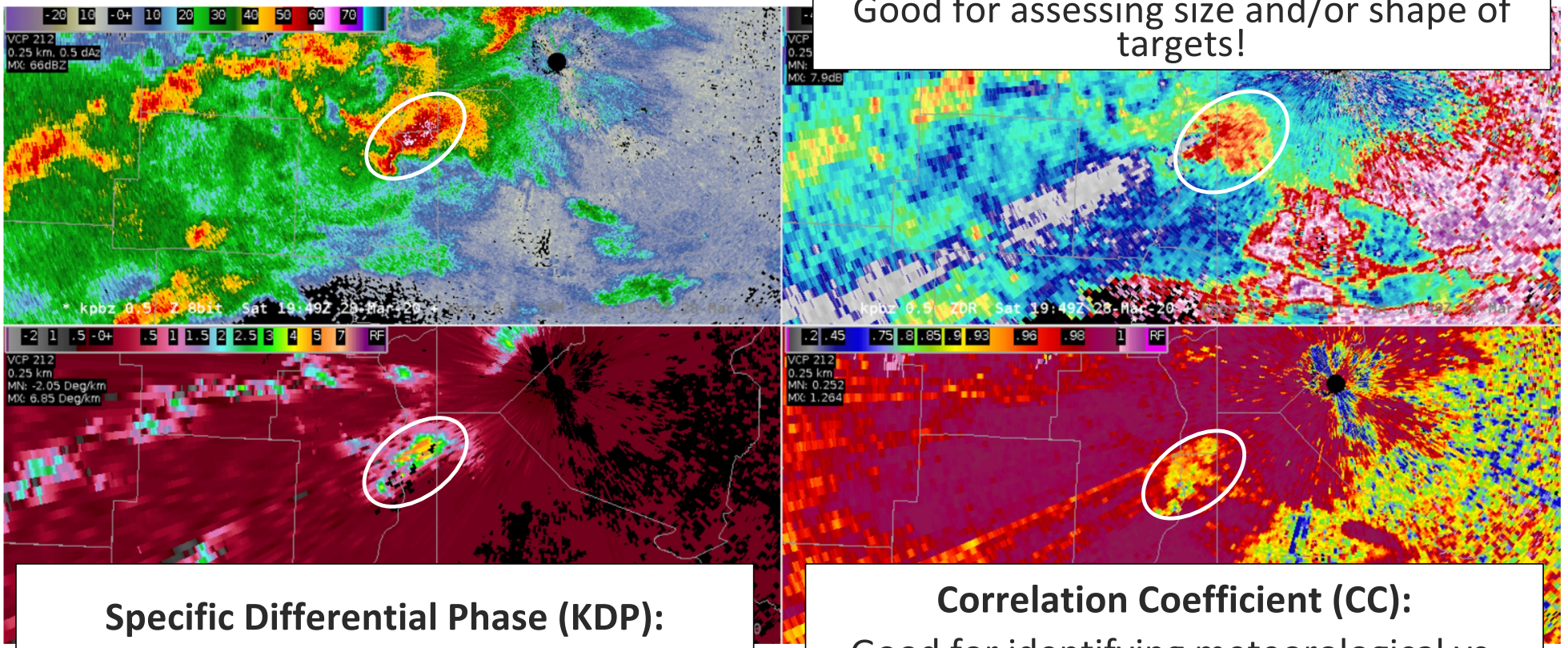


Currently, amost every WSR-88D has AVSET enable all of the time

Dual-Pol Review

Differential Reflectivity (ZDR):

Good for assessing size and/or shape of targets!



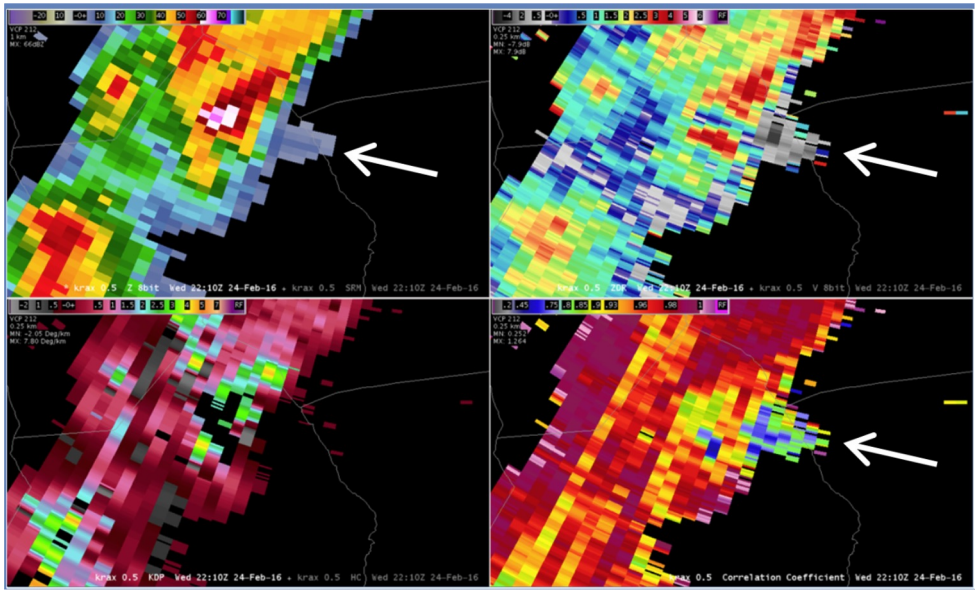
Specific Differential Phase (KDP):

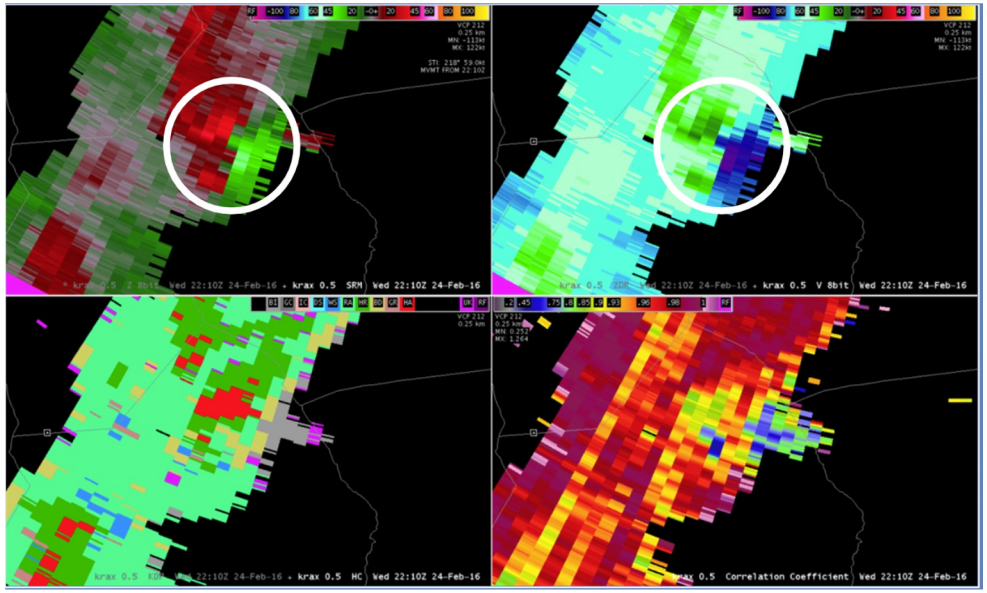
Good for assessing liquid water content!

Correlation Coefficient (CC):

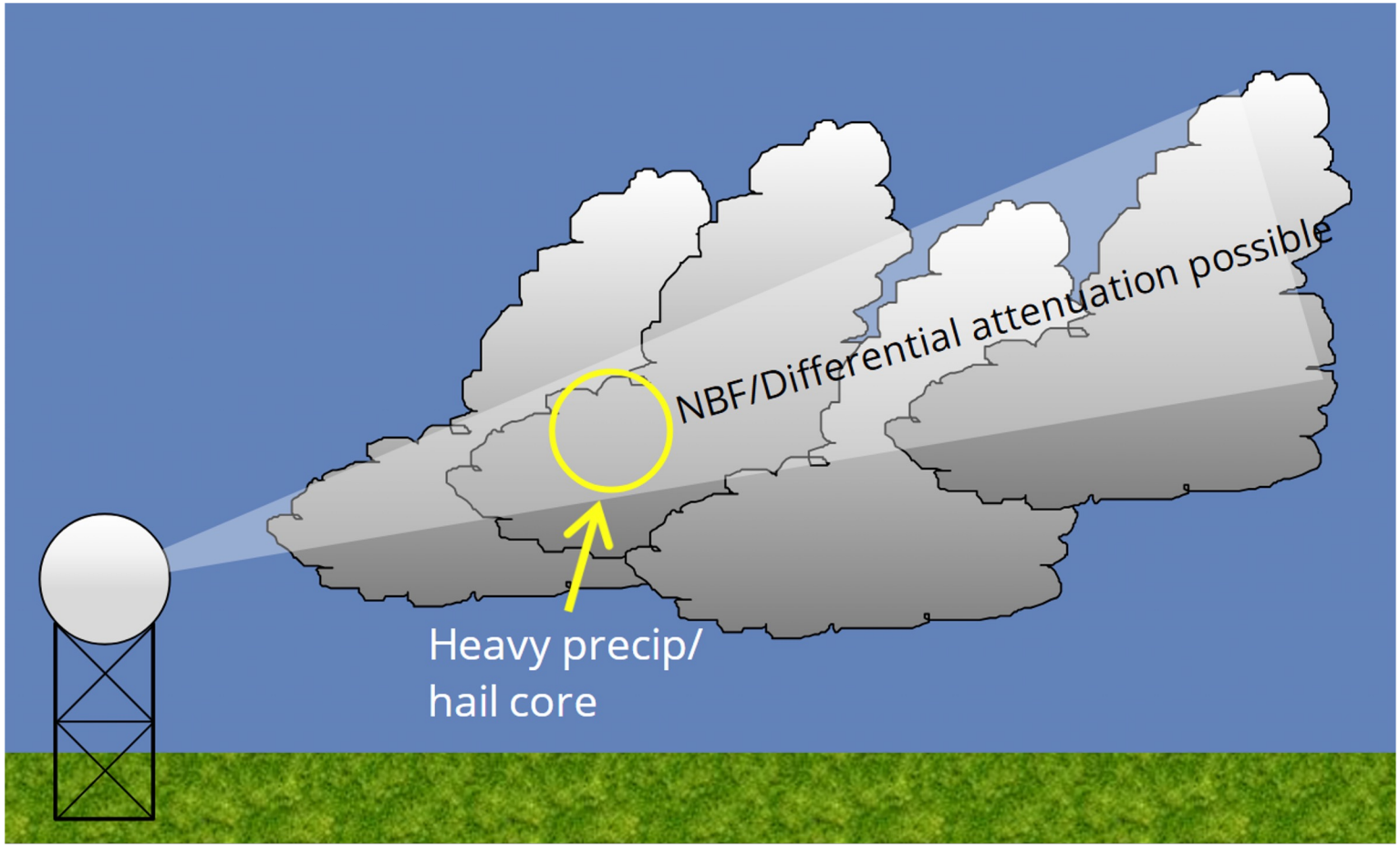
Good for identifying meteorological vs. non-meteorological targets!

Horizontal Side Lobe Analysis using Dual-Pol

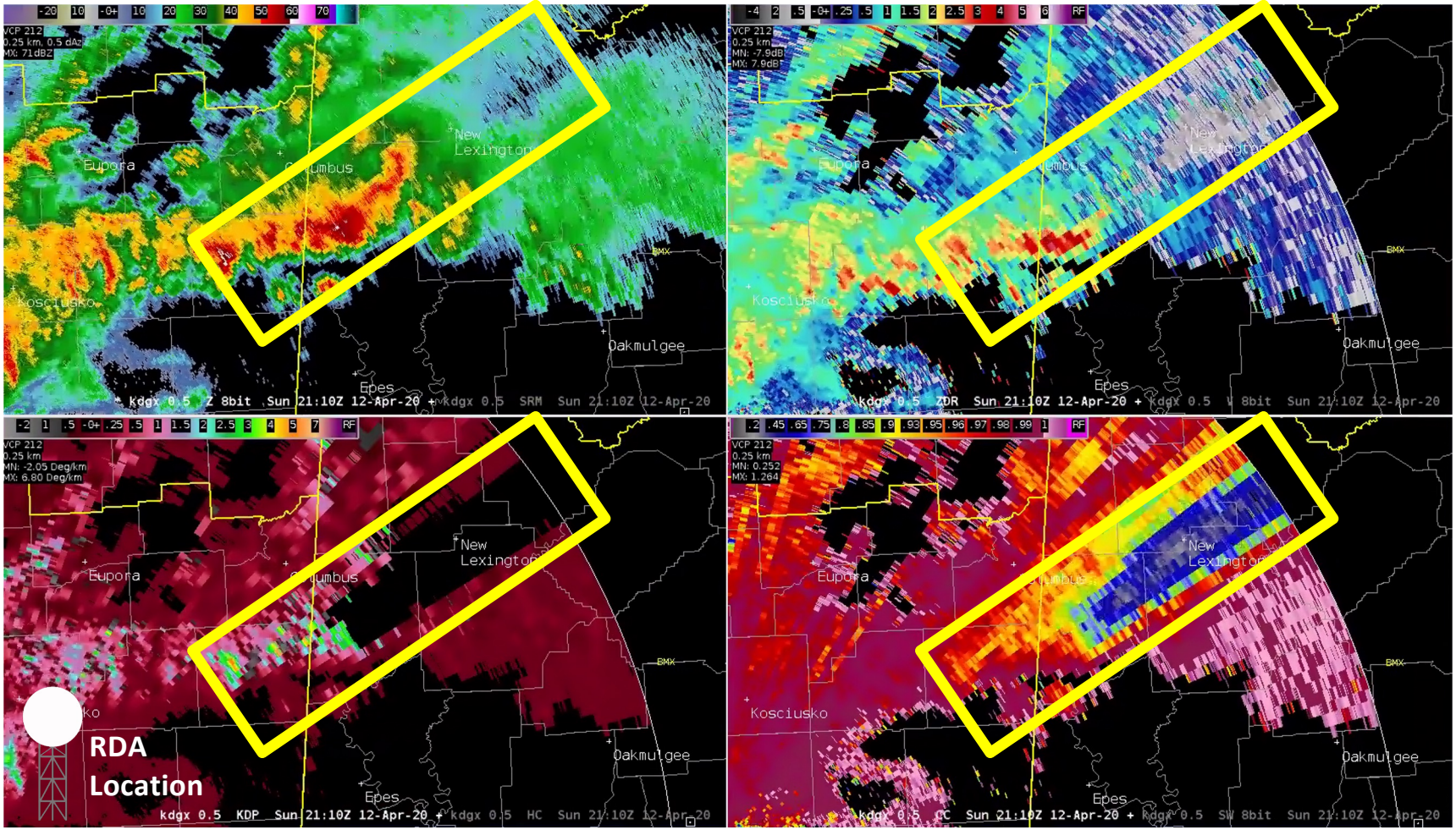




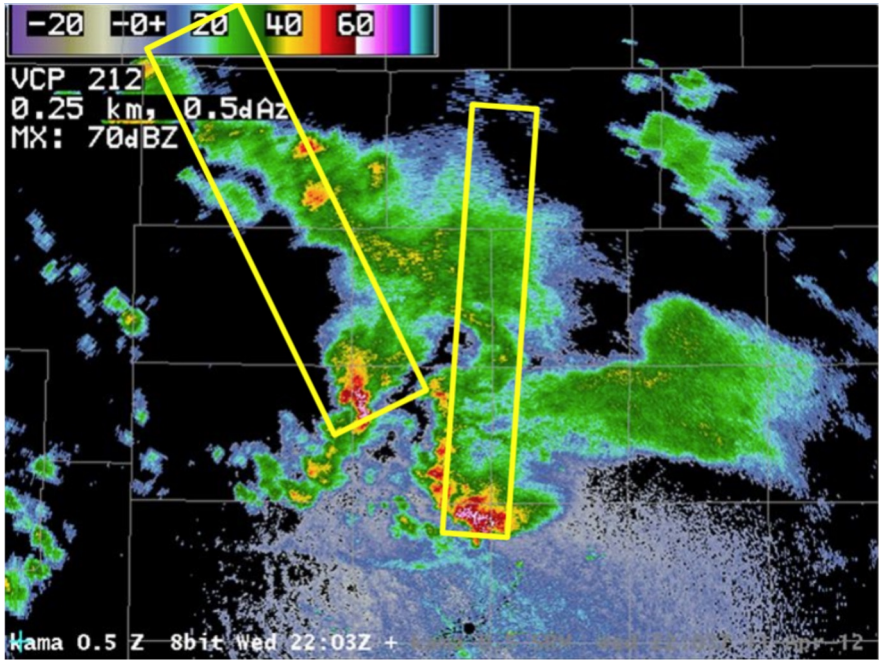
Non-Uniform Beam Filling / Differential Attenuation

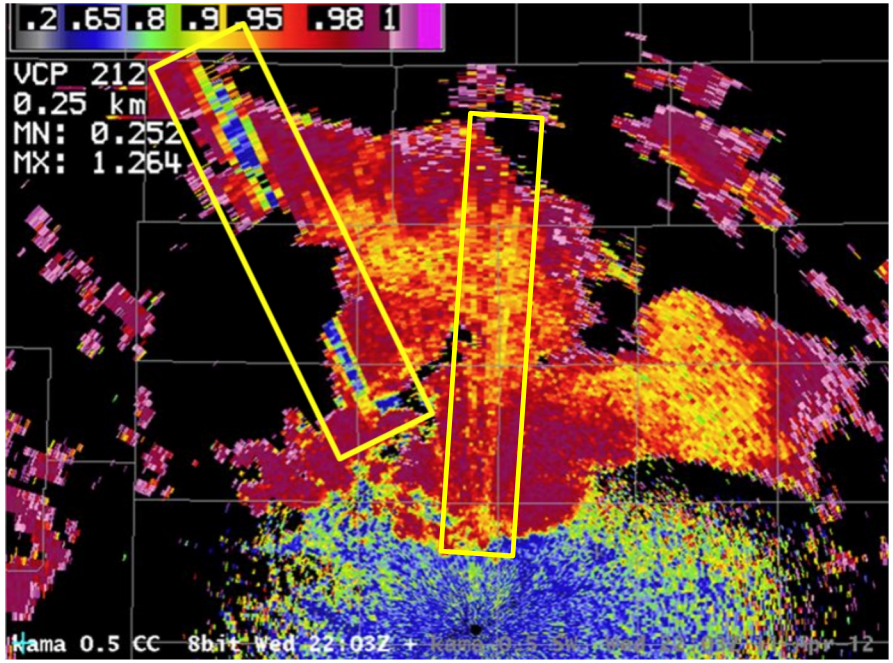


Example of Non-Uniform Beam Filling / Differential Attenuation



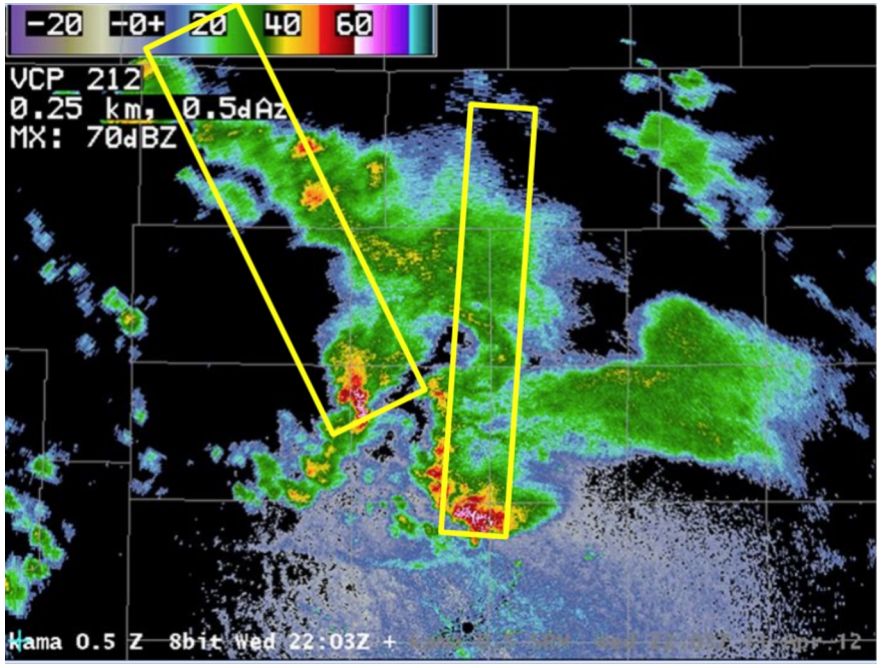
Non-Uniform Beam Filling in Dual-Pol Data

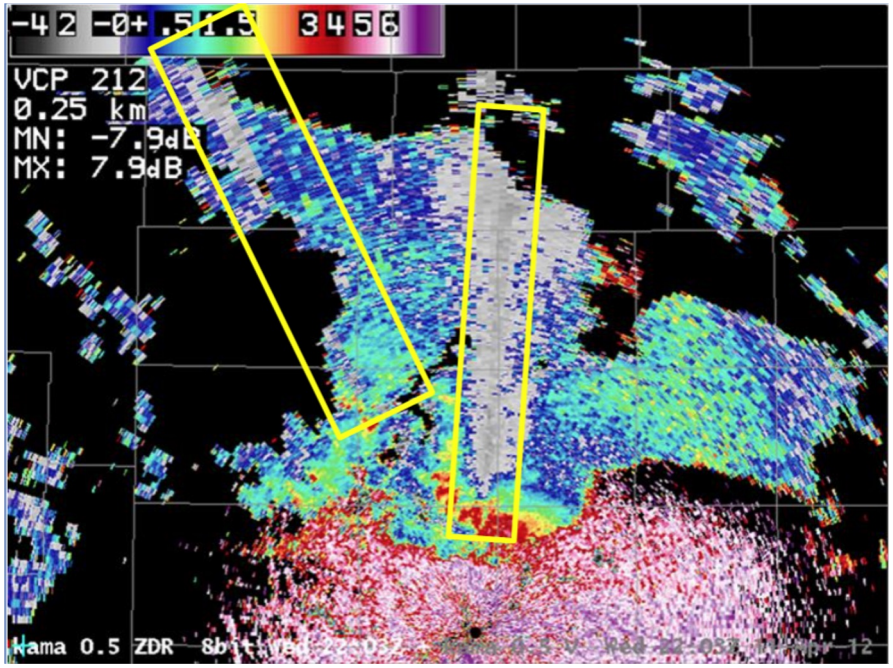




NBF results from PhiDP gradient in beam and lowers CC down radial

Differential Attenuation in Dual-Pol Data





Differential attenuation results from attenuation differences between horizontal and vertical channels affecting ZDR

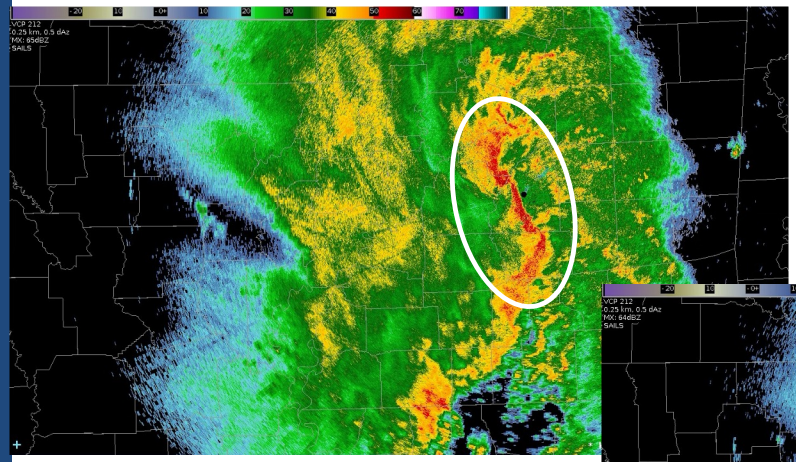
Data Quality

- We've covered non-uniform beam filling and differential attenuation
- Many data quality artifacts also seen in **reflectivity** and **velocity** data
- Some examples are…

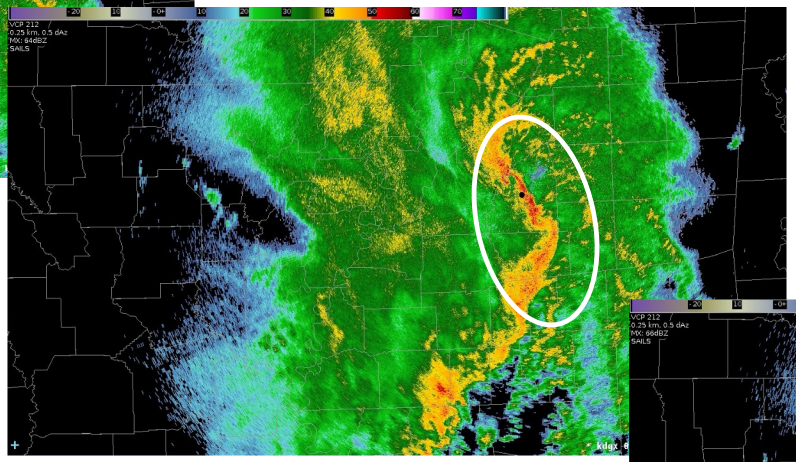
Wet Radome Effect

Biological Returns

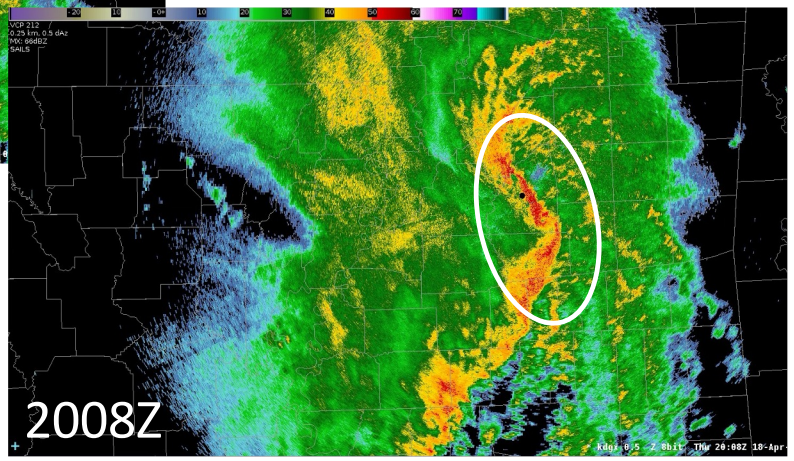
Wet Radome Effect



1959Z

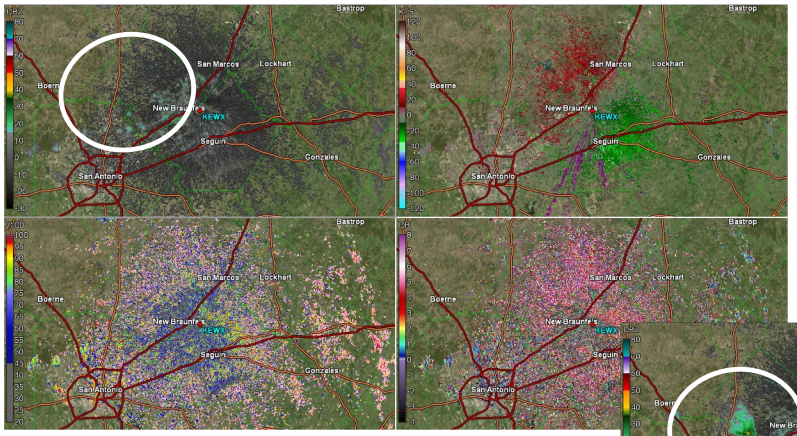


2006Z

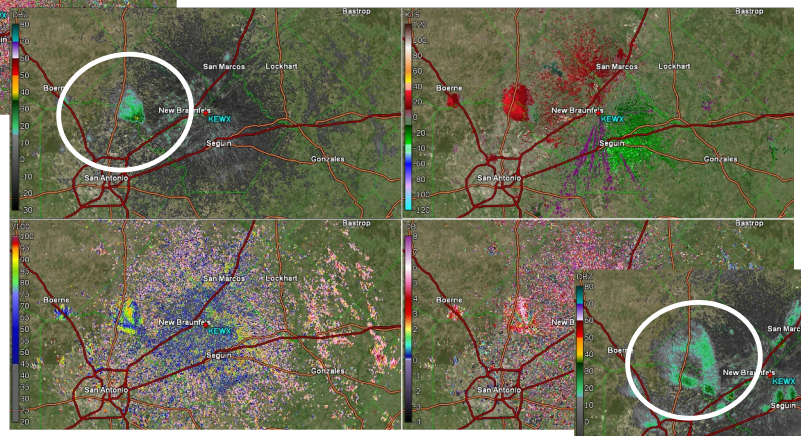


Notice what happens when the line passes over the radar

Biological Returns

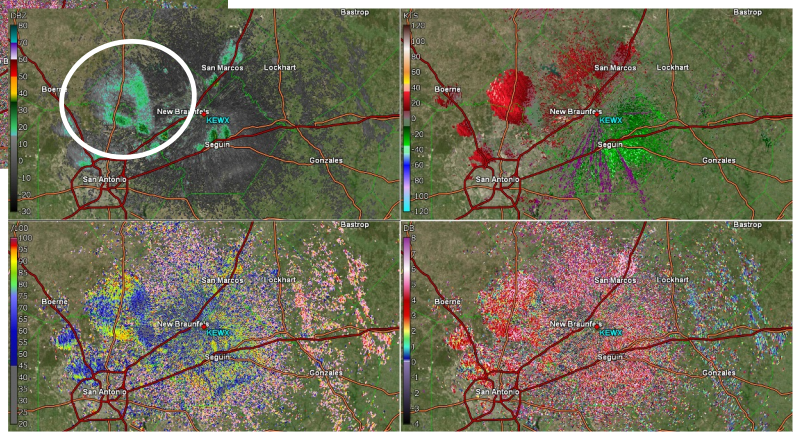


1959Z



2003Z

What could this artifact be from?



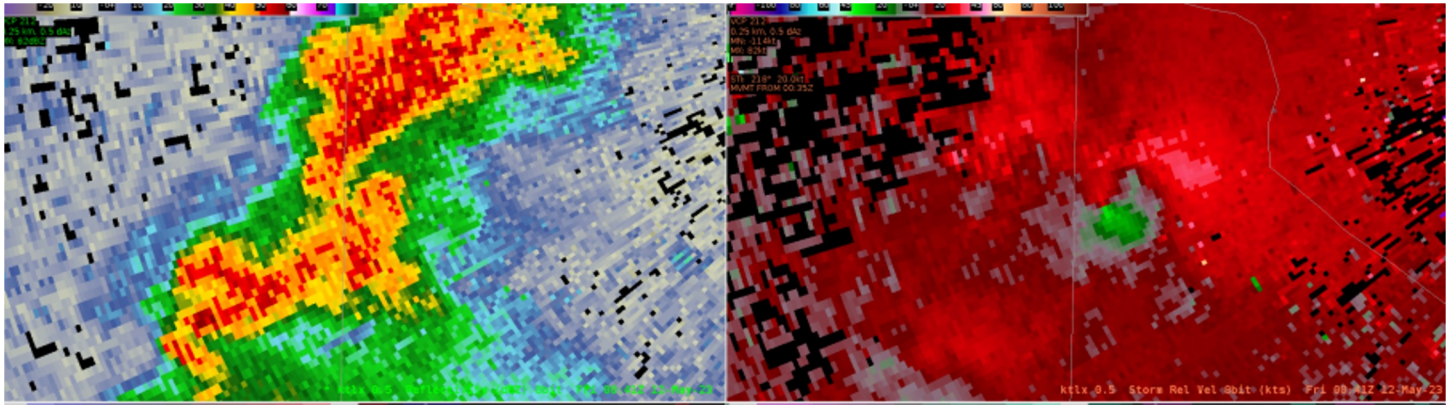
2006Z

Data Application: Using SRM to assess Rotational Velocity (Vrot)

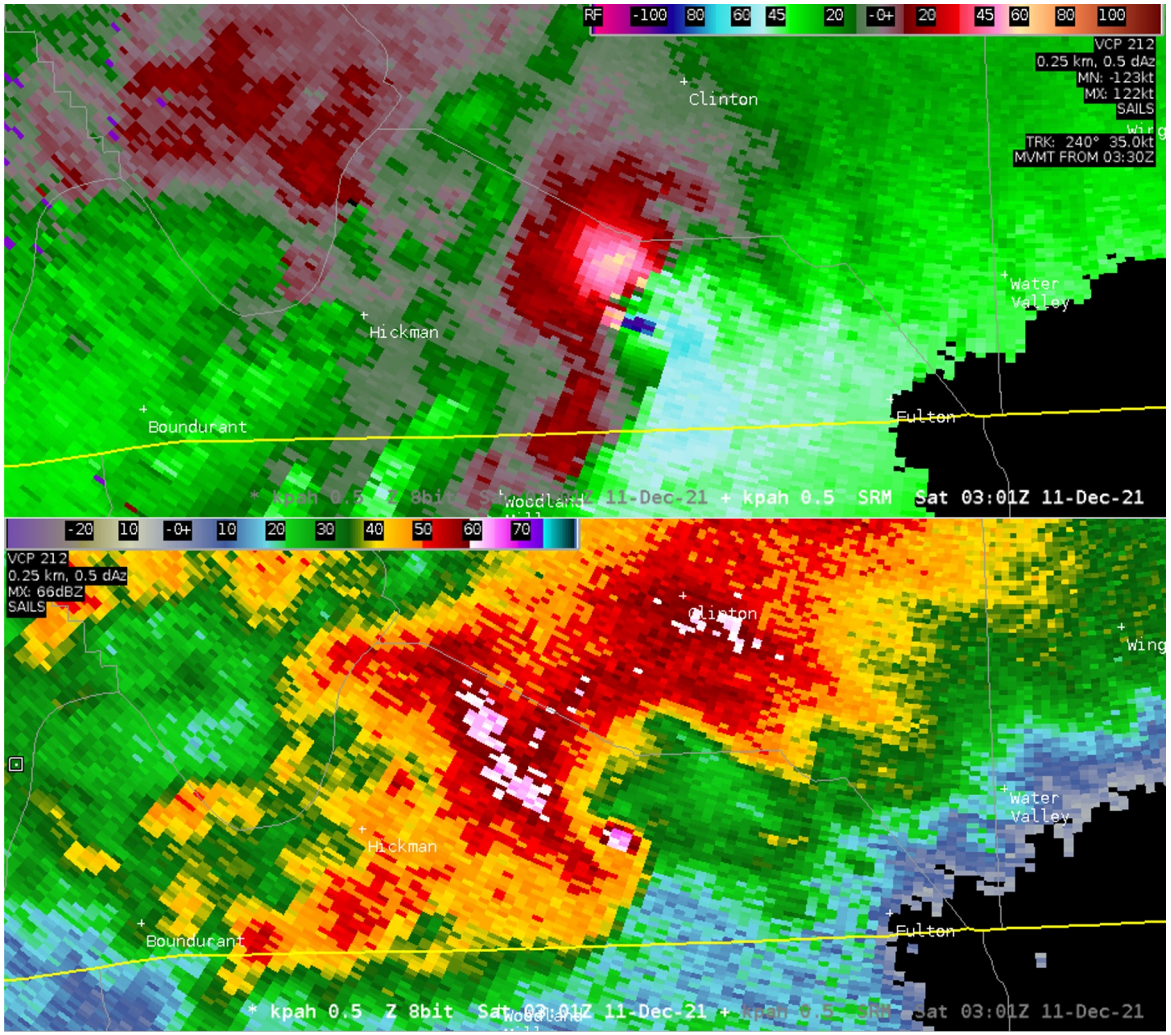
- Research has found a clear link between Vrot and tornado damage ratings (Thompson et al. 2017)

$$V_{rot} = \frac{|V_r max - V_r min|}{2}$$

- Guidelines for calculating Vrot:
  - Max inbound & outbound velocity gates should be co-located with the hook
  - Max inbound & outbound velocity gates should be ~ 1 - 2 nm apart



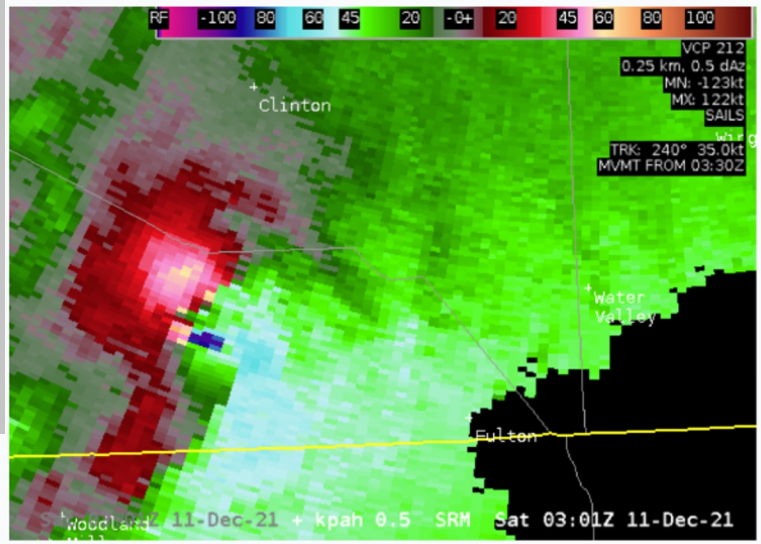
Poll Everywhere Exercise: Calculating Rotational Velocity



Respond at:
https://pollev.com/wdtdrac321

What is the rotational velocity with this supercell?

0



(A) 10 kts - 30 kts

0%

(B) 30 kts - 50 kts

0%

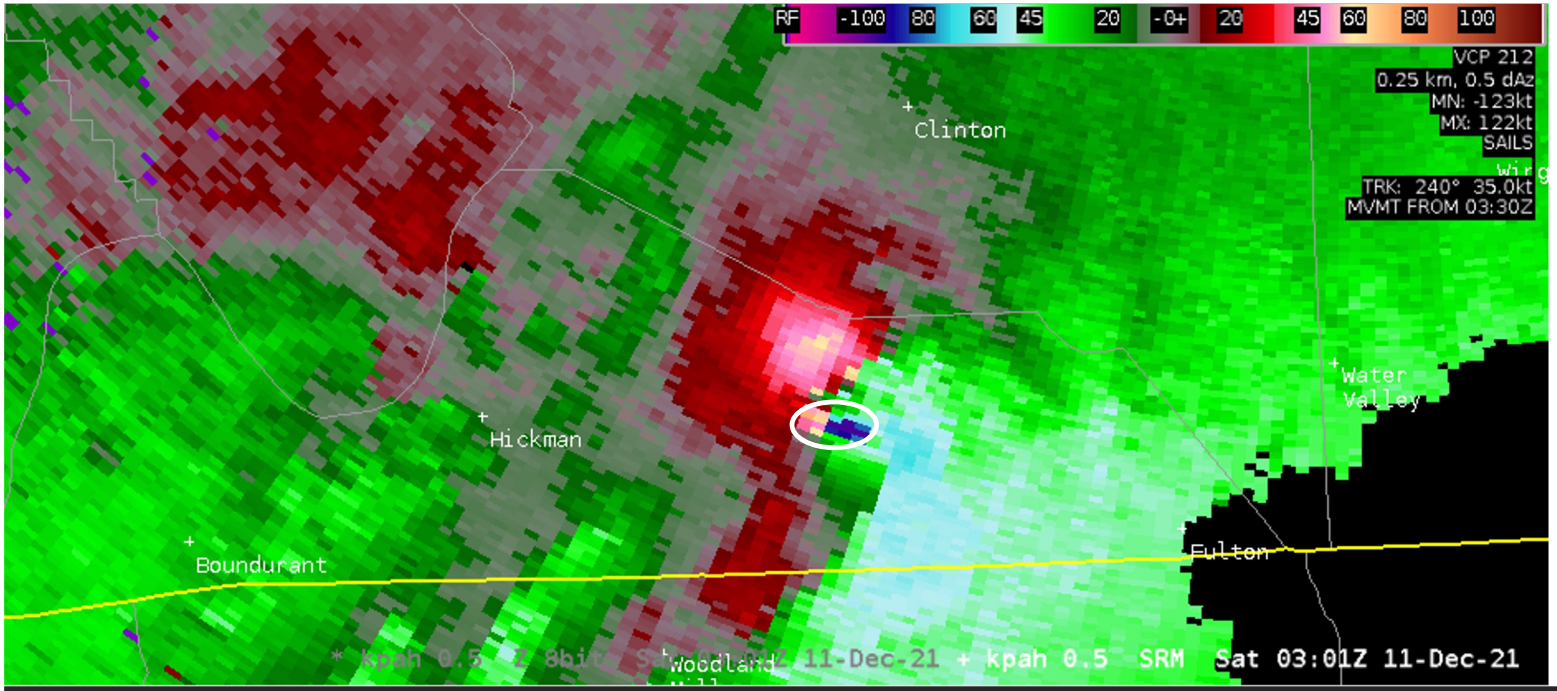
(C) 50 kts - 70 kts

0%

(D) 70 kts - 90 kts

0%

Poll Everywhere Exercise: Calculating Rotational Velocity



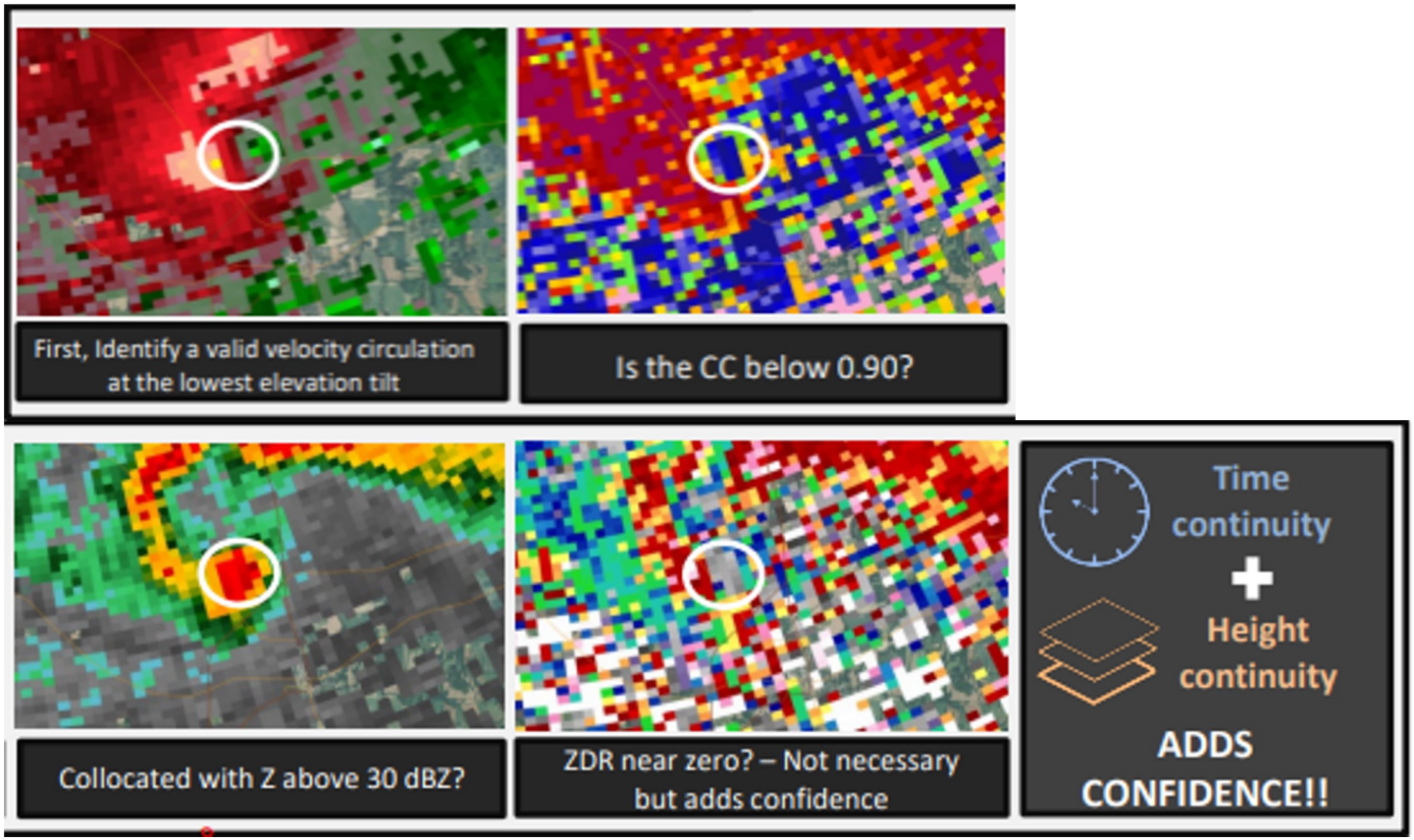
Answer:
~ 84 kts!

Impact-Based Tornado Warning Guidance

30 kt V_{rot}	40* kt V_{rot}	50* kt V_{rot}	70* kt V_{rot}
If STP >0 – Tornado Warning Likely Needed	Considerable Tag With TDS, STP >1	Considerable Tag Without TDS, STP >1	Catastrophic Tag With TDS, STP >6

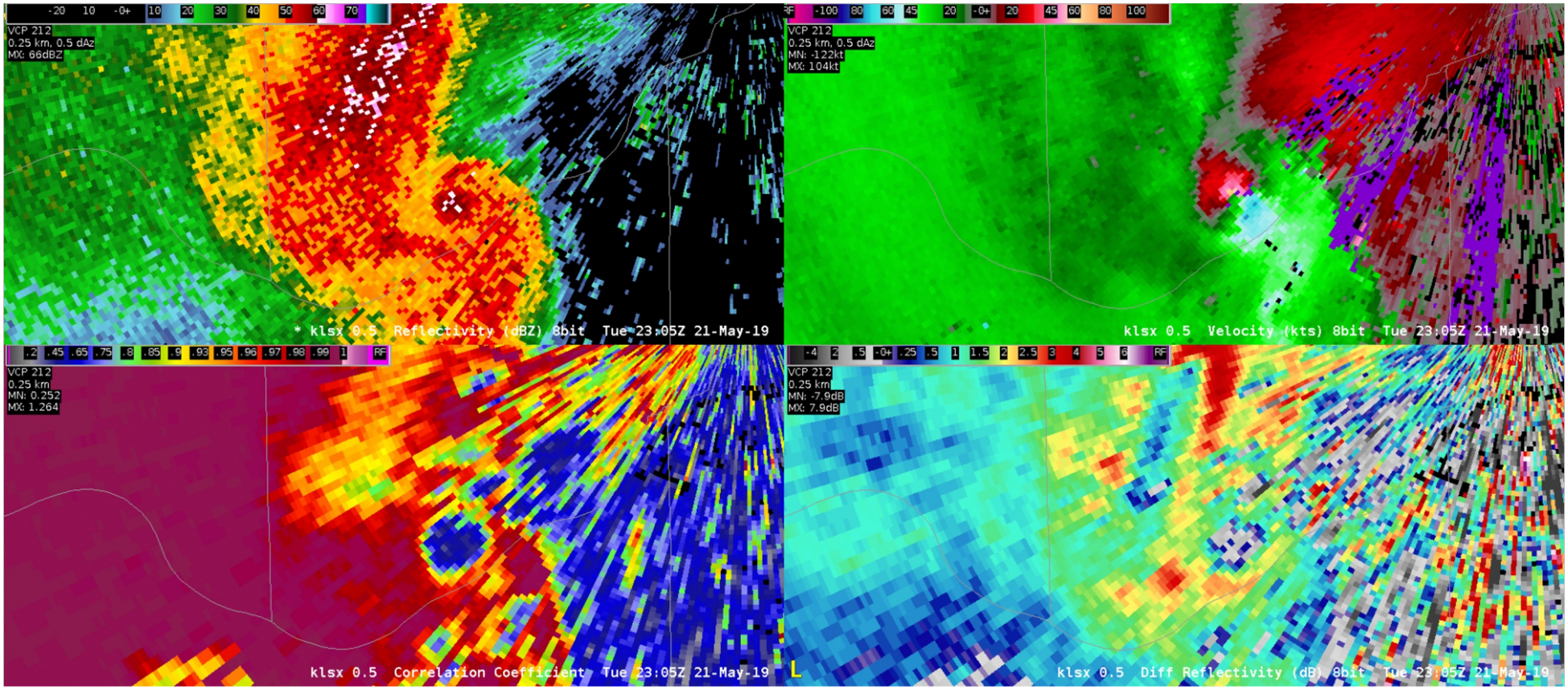
Data Application: Using DP variables to identify tornadic debris

Lofted debris from tornado -> randomly oriented -> very low CC values!



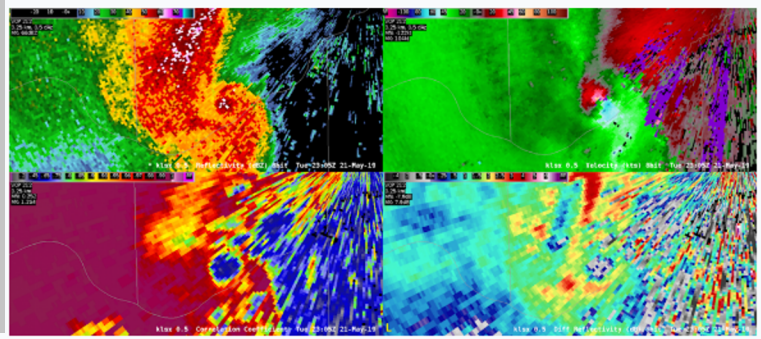
Poll Everywhere Exercise: Identifying a TDS

Respond at: https://pollev.com/wdtdrac321



Is there a tornado debris signature with this supercell?

0



Yes

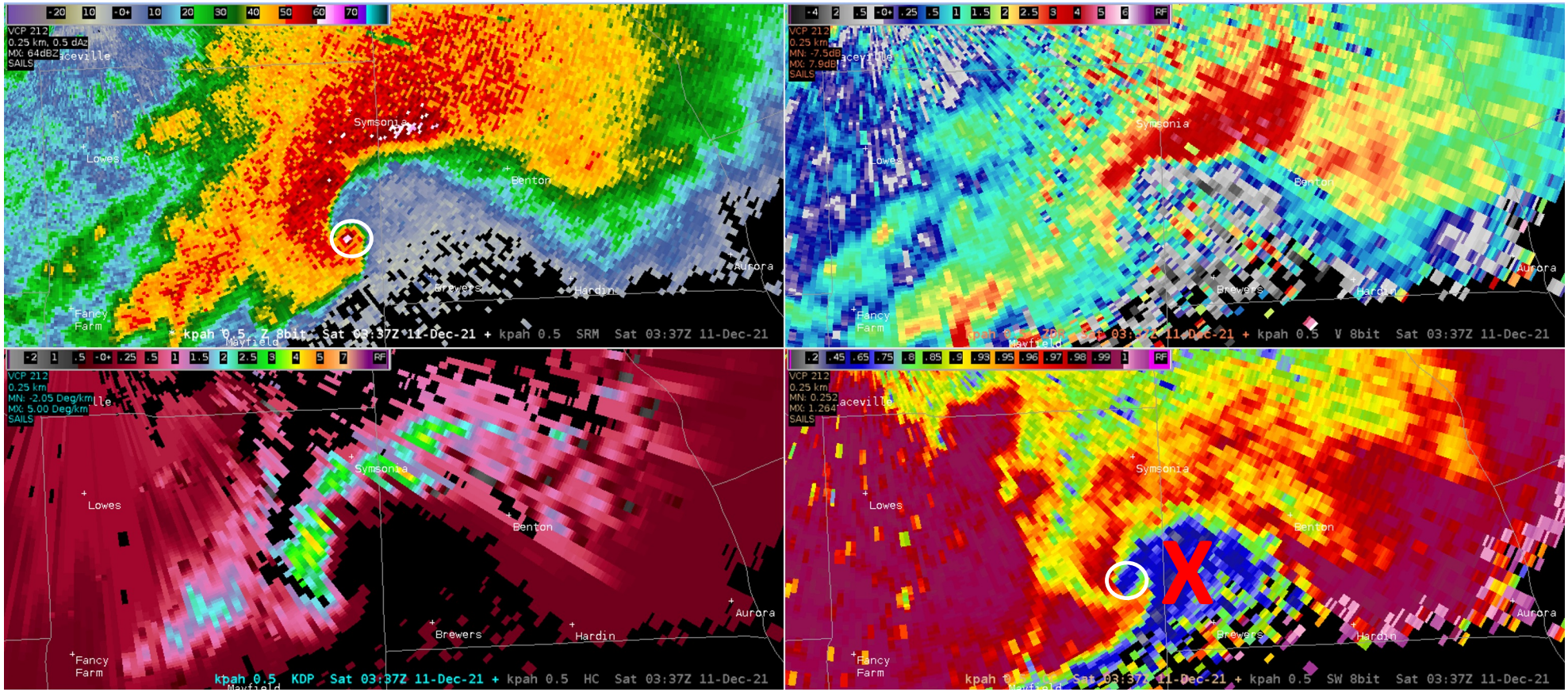
0%

No

0%

Identifying a TDS: Beware of the Inflow!

Beware of low CC from inflow air -> “don’t bite on bugs in the inflow!”



Key Takeaways from Day 1

1. We make a lot of assumptions about what is actually happening that the data doesn't actually show us

1. It's amazing that these systems (and their data) are as good as they are!

End of Day 1

Part 2: Severe Storms Analysis by Radar

- Opening scenario: You make the call
- Focusing on threat assessment - Hail, Wind, Tornadoes
- Scenarios with things to be mindful of to mitigate risk.
- Visual and radar comparisons

Part 2: Severe Storm Detection by the WSR-88D

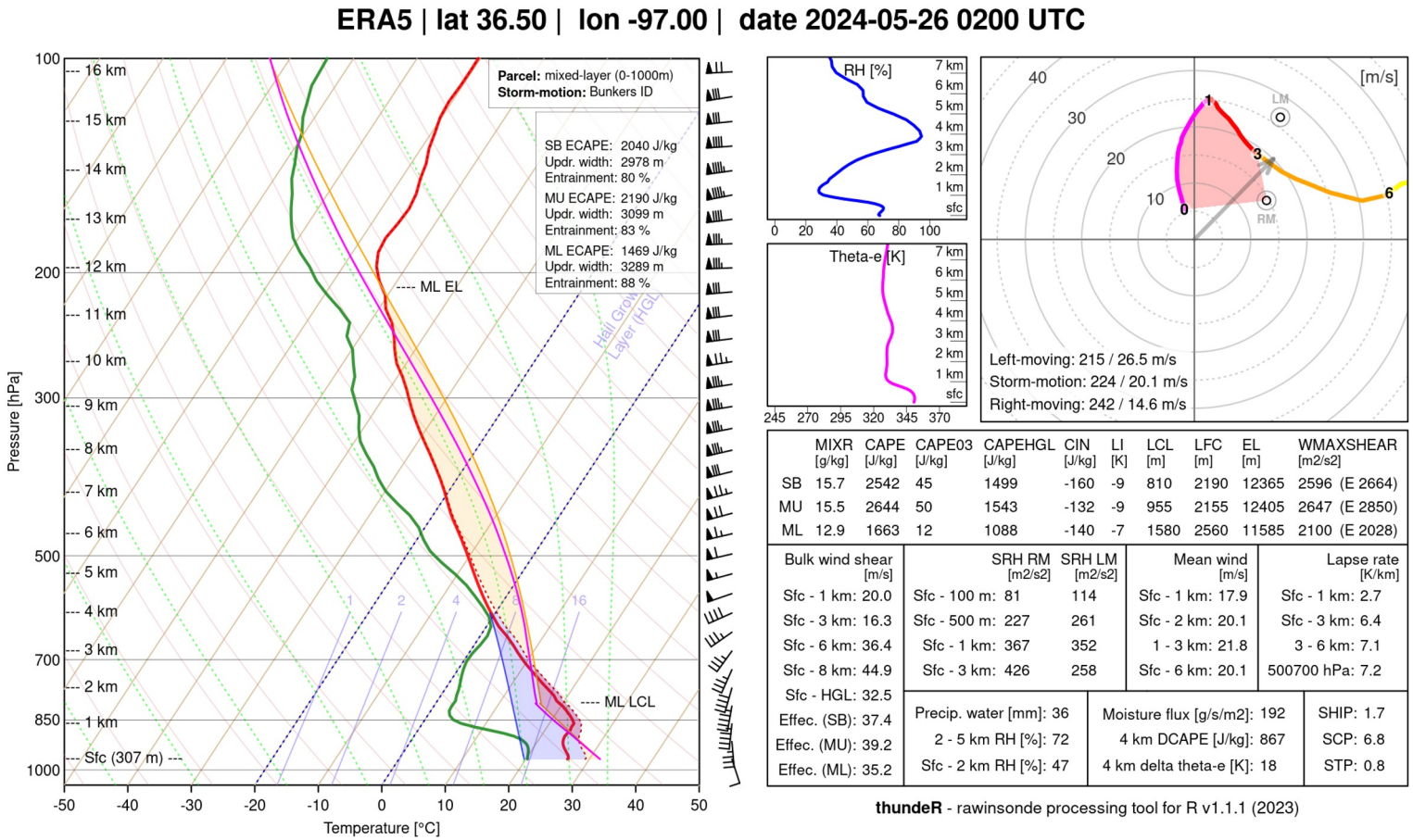
Scenario 1 - 2110 CDT
driving south and there's a cell in the way of home.

Your task is to tell me how large you think the hail is.

I can handle 1.5" but 2" is going to make dents. We need to get home to be ready for school tomorrow morning and still get a good night rest.

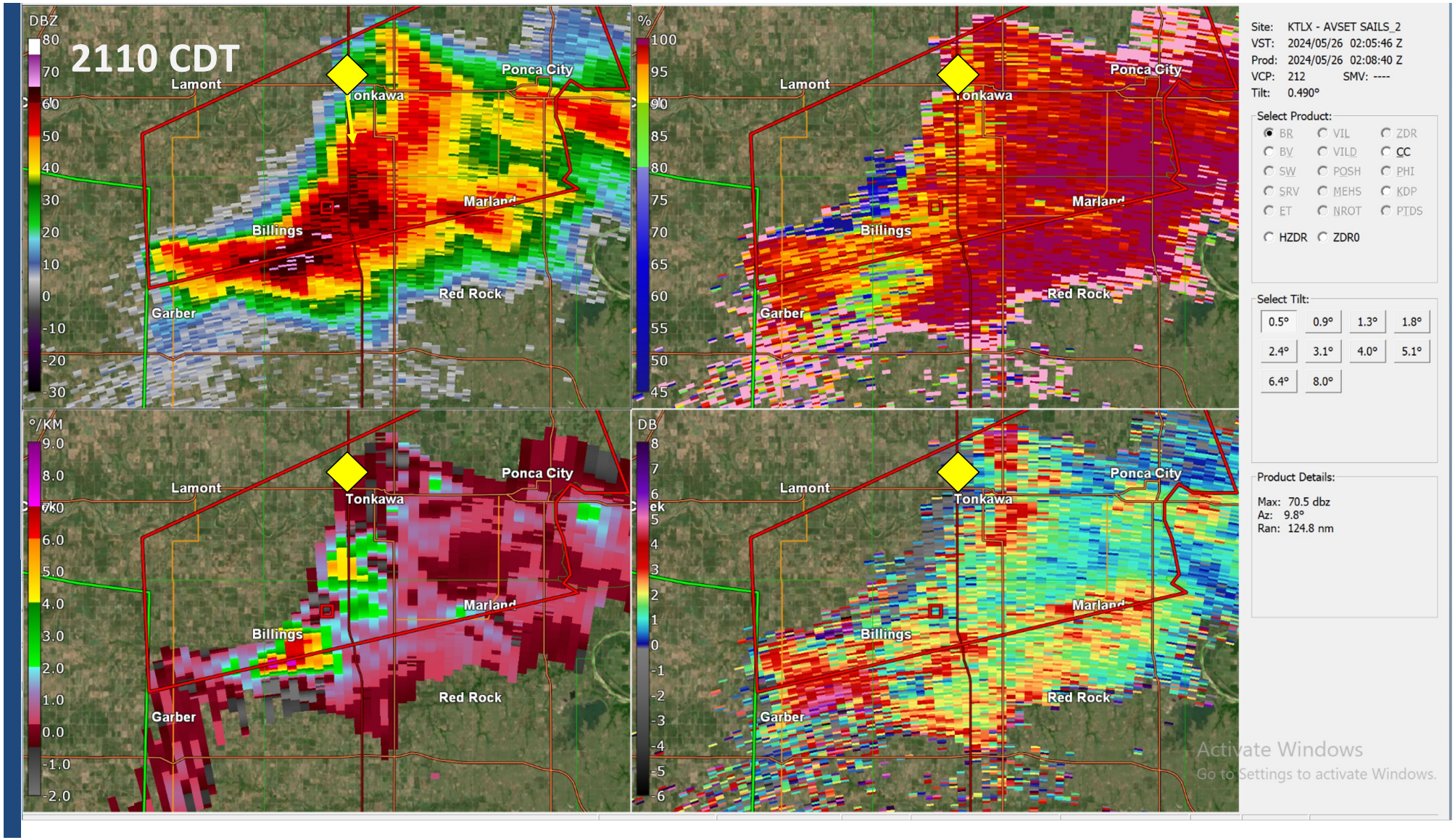
I don't think breaking my windshield is worth getting home early. I certainly don't want to be hit by a tornado.

ERA5 Sounding



2110 Dual Pol Hail Size Guidance

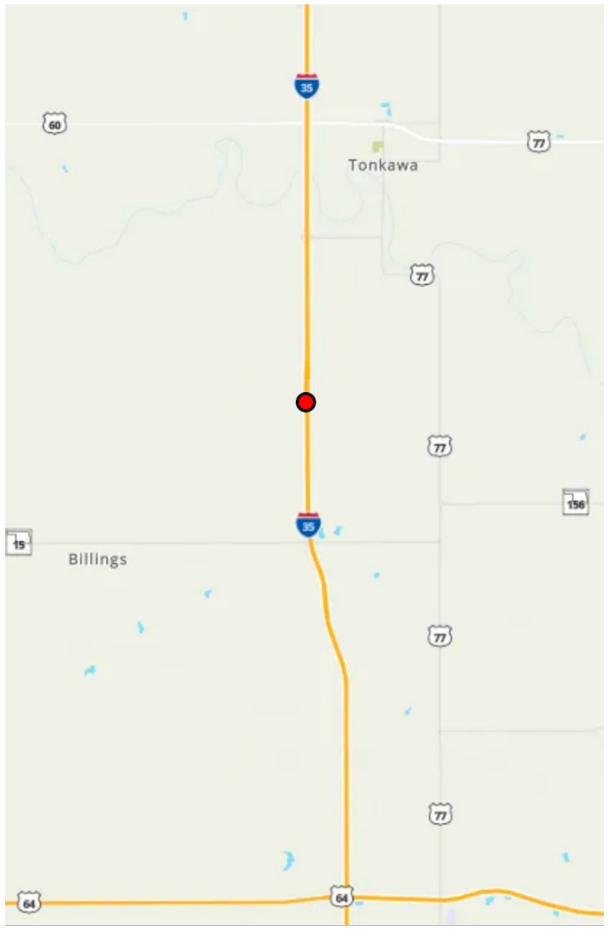
Hydrometeors	Z	ZDR	CC	KDP
Severe rain/hail Mix	>55 dBZ	>1 dB	0.93-0.96	>0.5 ˚C/km
Severe, dry hail	>55 dBZ	<1 dB	0.95-0.97	<1 ˚/km
Significant (≥2”) hail	>55 dBZ	~0 dB or lower	<0.9	No Data

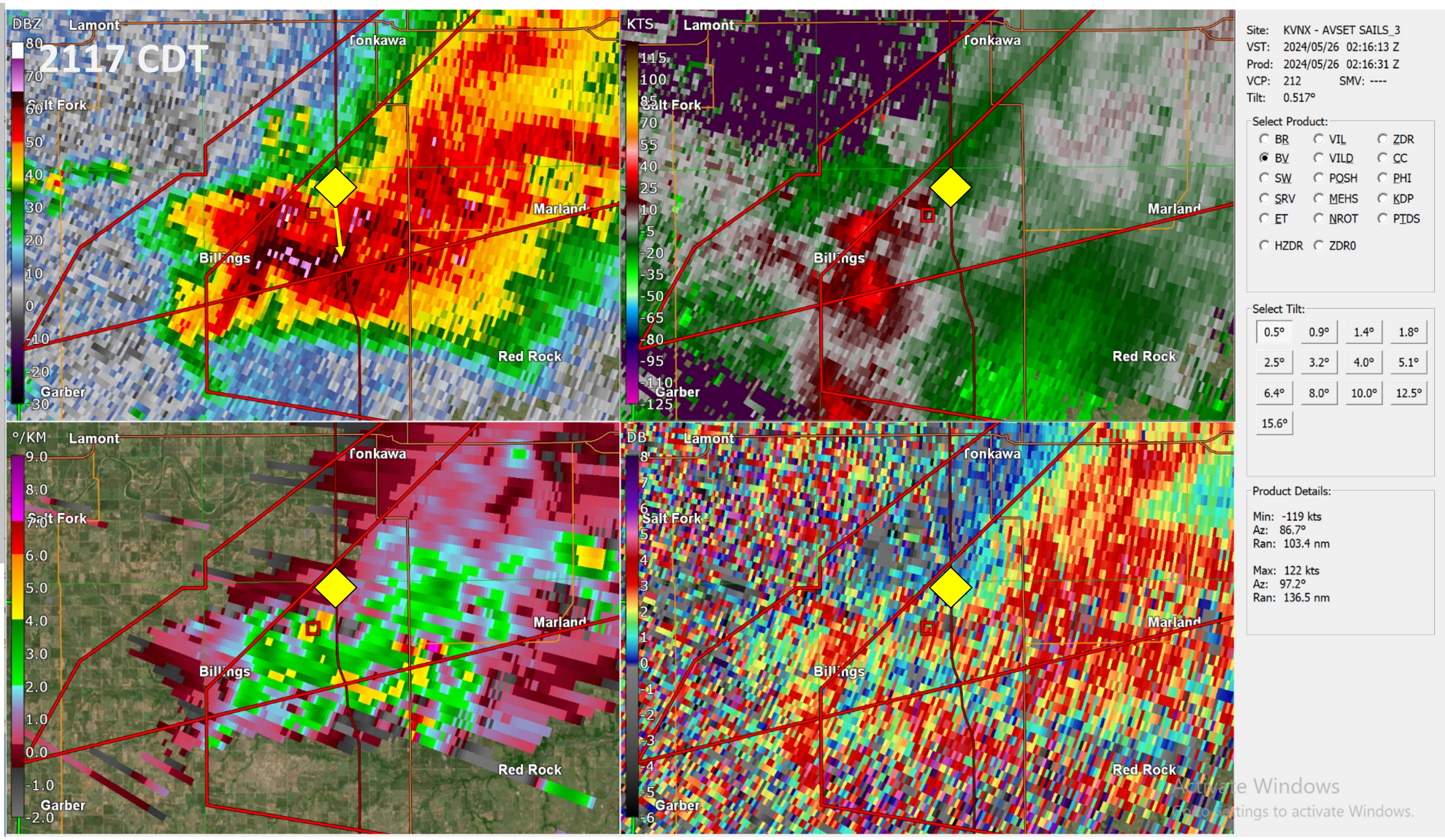

2110 CDT
DBZ
80
70
60
50
40
30
20
10
0
-10
-20
-30
%
100
95
90
85
80
75
70
65
60
55
50
45
°/KM
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
-1.0
-2.0
DB
8
7
6
5
4
3
2
1
0
-1
-2
-3
-4
-5
-6
Lamont
Tonkawa
Ponca City
Marland
Billings
Red Rock
Garber
Site: KTLX - AVSET SAILS_2
VST: 2024/05/26 02:05:46 Z
Prod: 2024/05/26 02:08:40 Z
VCP: 212 SMV: ----
Tilt: 0.490°
Select Product:
BR VIL ZDR
BV VILD CC
SW POSH PHI
SRV MEHS KDP
ET NROT PTDS
HZDR ZDR0
Select Tilt:
0.5° 0.9° 1.3° 1.8°
2.4° 3.1° 4.0° 5.1°
6.4° 8.0°
Product Details:
Max: 70.5 dbz
Az: 9.8°
Ran: 124.8 nm
Activate Windows
Go to Settings to activate Windows.

Poll: 2110 CDT

- What hail size does do you think is falling?
  - <1”, 1 to <2”, 2 -2.5”, 2.75” and larger
- Do I continue or hold back?

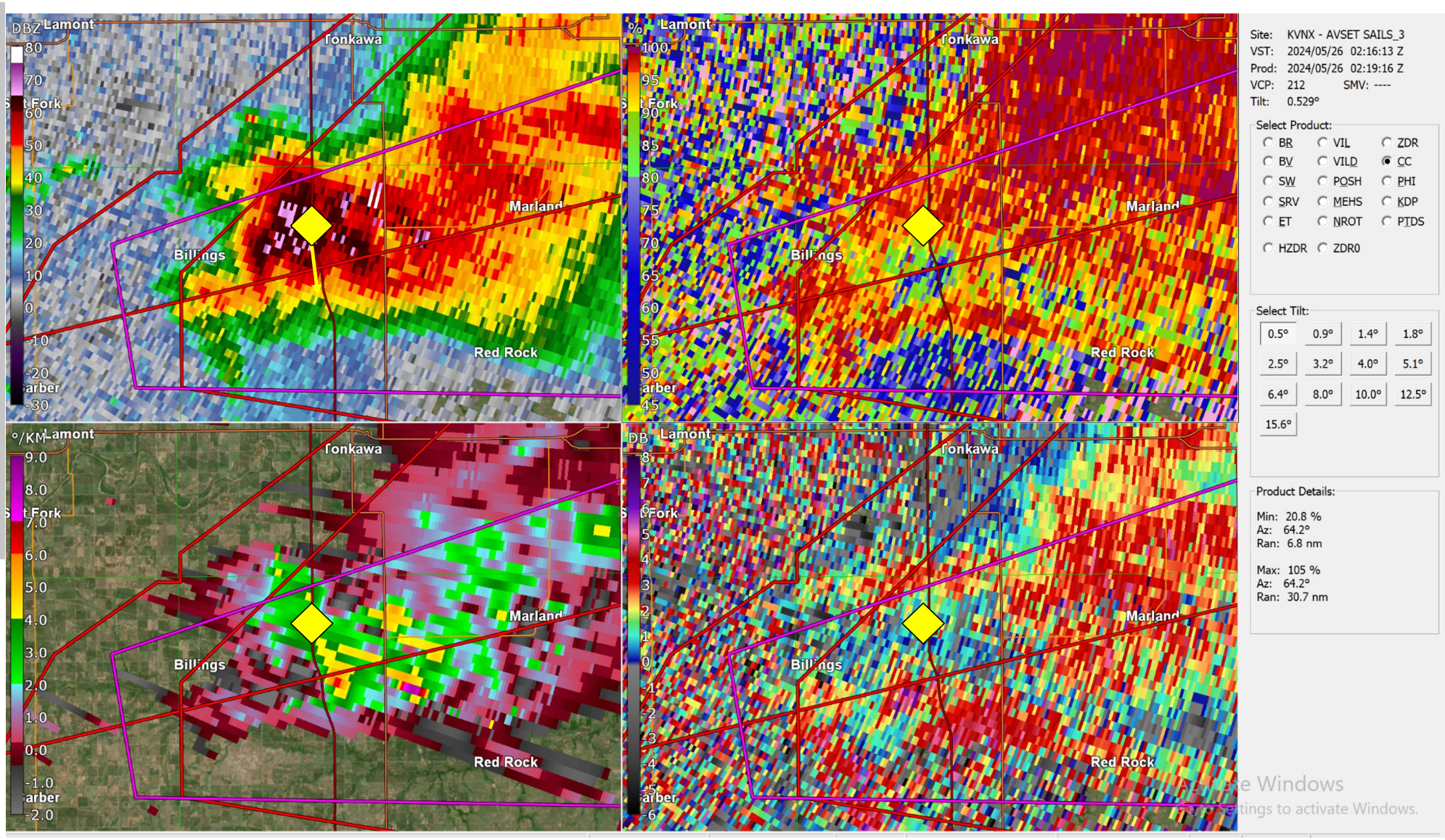
Scenario 1 - 2117 UTC




DBZ
2117 CDT
Lamont
Tonkawa
Salt Fork
Marland
Billings
Red Rock
Garber
KTS
°/KM
DB
Site: KVNX - AVSET SAILS_3
VST: 2024/05/26 02:16:13 Z
Prod: 2024/05/26 02:16:31 Z
VCP: 212 SMV: ----
Tilt: 0.517°
Select Product:
BR VIL ZDR
BV VILD CC
SW POSH PHI
SRV MEHS KDP
ET NROT PTDS
HZDR ZDR0
Select Tilt:
0.5° 0.9° 1.4° 1.8°
2.5° 3.2° 4.0° 5.1°
6.4° 8.0° 10.0° 12.5°
15.6°
Product Details:
Min: -119 kts
Az: 86.7°
Ran: 103.4 nm
Max: 122 kts
Az: 97.2°
Ran: 136.5 nm

Poll: 2117 CDT

- What hail size does do you think is falling?
  - <1”, 1 to <2”, 2 -2.5”, 2.75” and larger
- Do I continue or hold back?


DBZ
Lamont
Tonkawa
Fork
Marland
Billings
Red Rock
%
°/KM
DB
Site: KVNX - AVSET SAILS_3
VST: 2024/05/26 02:16:13 Z
Prod: 2024/05/26 02:19:16 Z
VCP: 212 SMV: ----
Tilt: 0.529°
Select Product:
BR VIL ZDR
BV VILD CC
SW POSH PHI
SRV MEHS KDP
ET NROT PTDS
HZDR ZDR0
Select Tilt:
0.5° 0.9° 1.4° 1.8°
2.5° 3.2° 4.0° 5.1°
6.4° 8.0° 10.0° 12.5°
15.6°
Product Details:
Min: 20.8 %
Az: 64.2°
Ran: 6.8 nm
Max: 105 %
Az: 64.2°
Ran: 30.7 nm