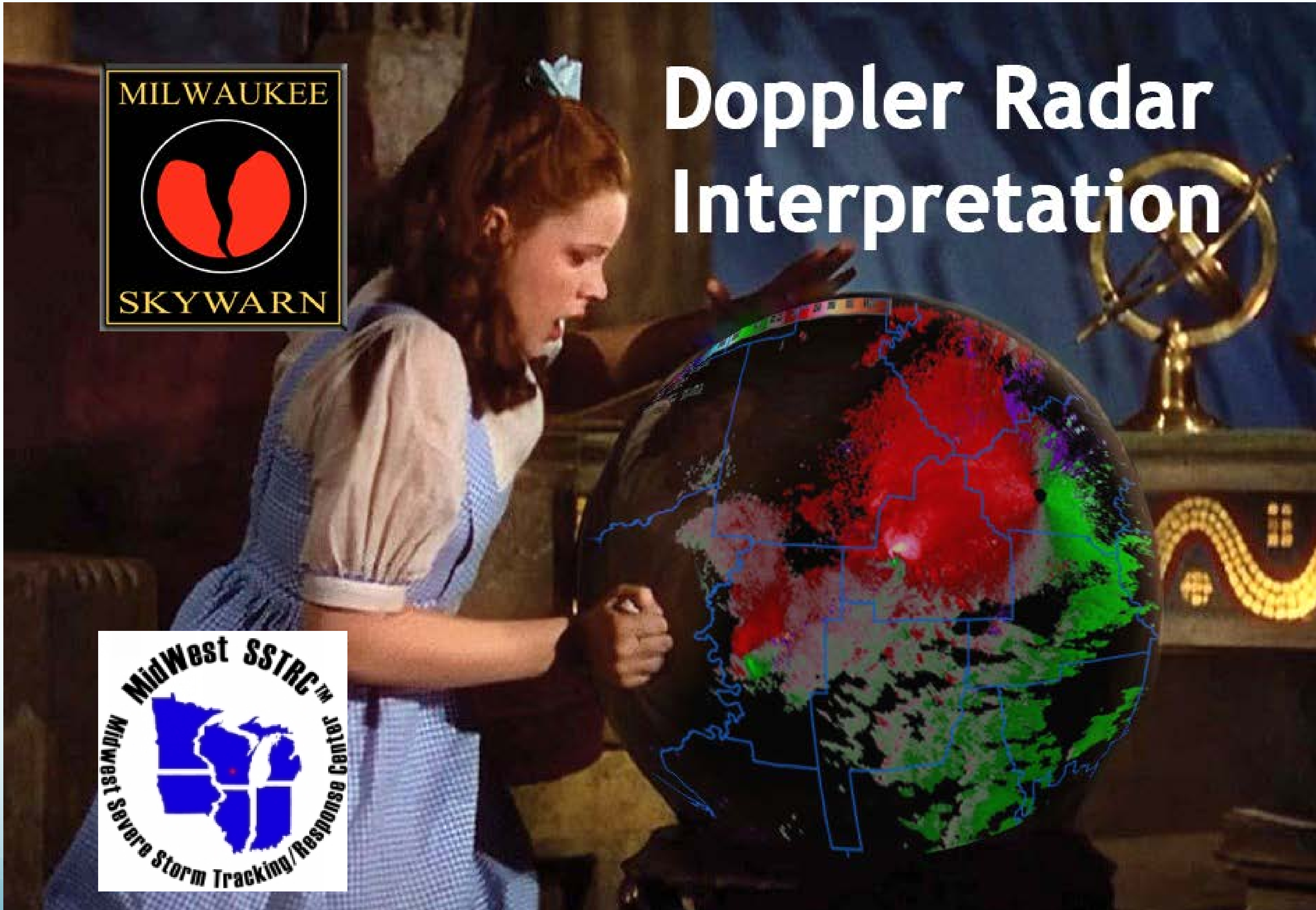
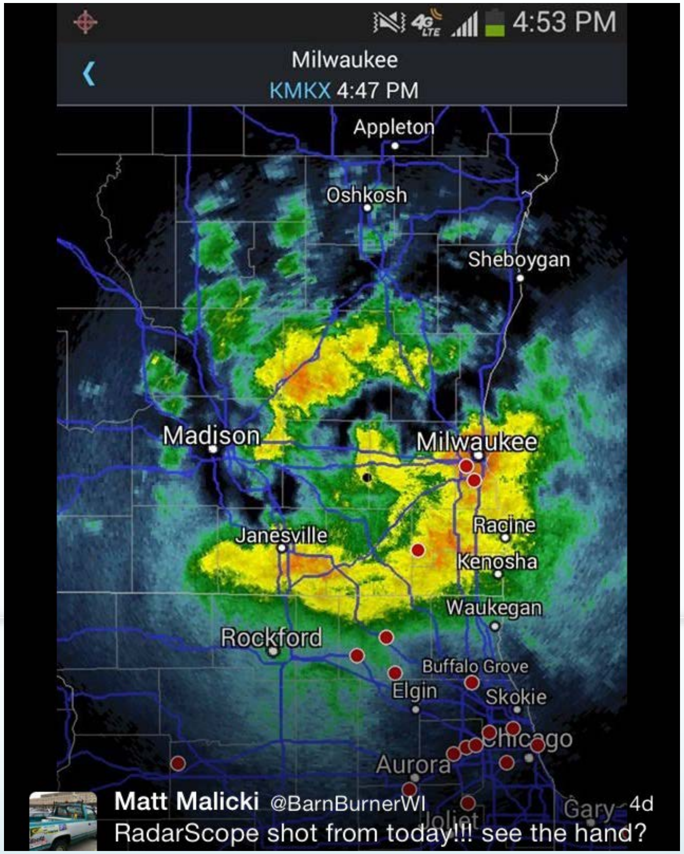
Doppler Radar Interpretation



What Do You See?



Who are MASA & MidWest?

MASA (Milwaukee Area Skywarn Association) & MidWest SSTRC are 501(c)3 Non-Profit Organizations dedication to the early detection and early detection of severe storms, providing critical ground truth information to the NWS and other recognized agencies as requested.

www.mke-skywarn.org
www.midwestsstrc.org

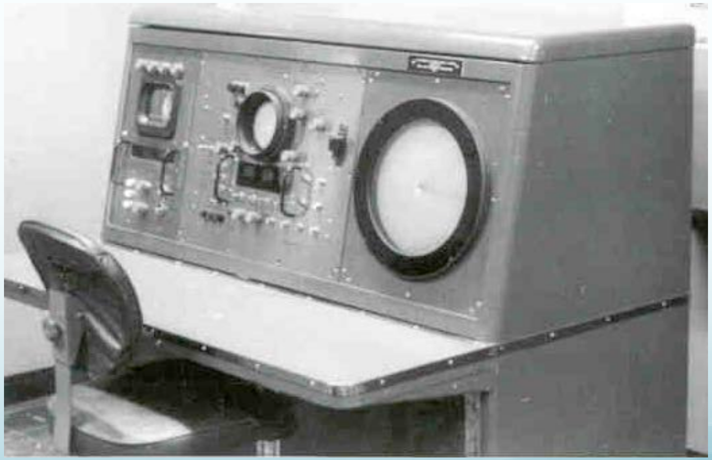
Program Outline

- Radar Overview & History
- Radar Basics & Limitations
- Reflectivity & Velocity signatures
- Downburst Signatures
- Tornado Signatures
- Radarscope Stuff

Radar Observations

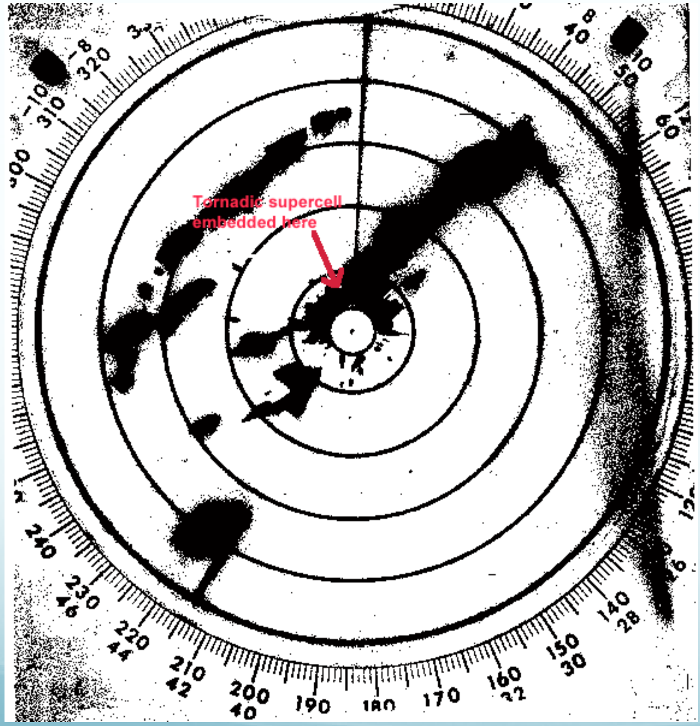
- By-product of World War II
- Acronym **radar** stands for **RA**dio **D**etection **A**nd **R**anging
- Radar initially developed to detect other aircraft
- Precipitation got in the way of detecting other aircraft
- Adopted to civilian use after WWII
- Varity of radar systems in 1950s

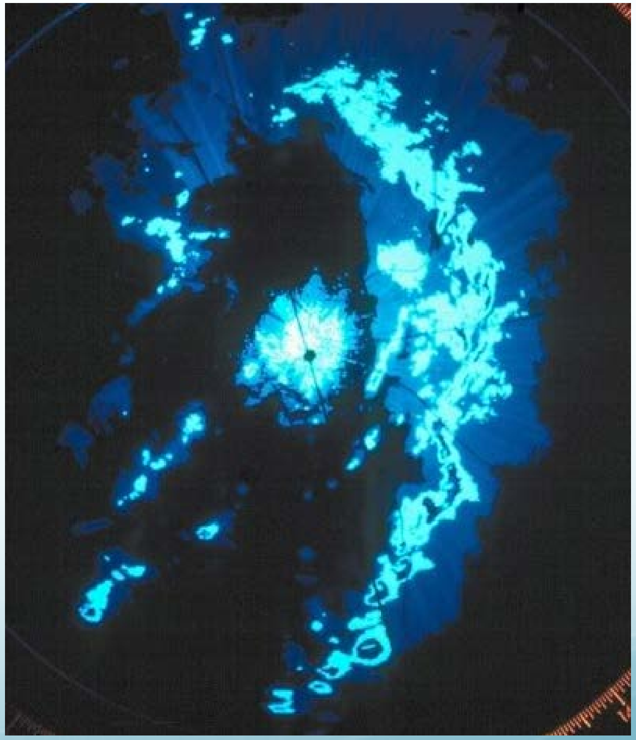
WSR3
Ft. Wayne, IN
mid-1950s



Radar Observations

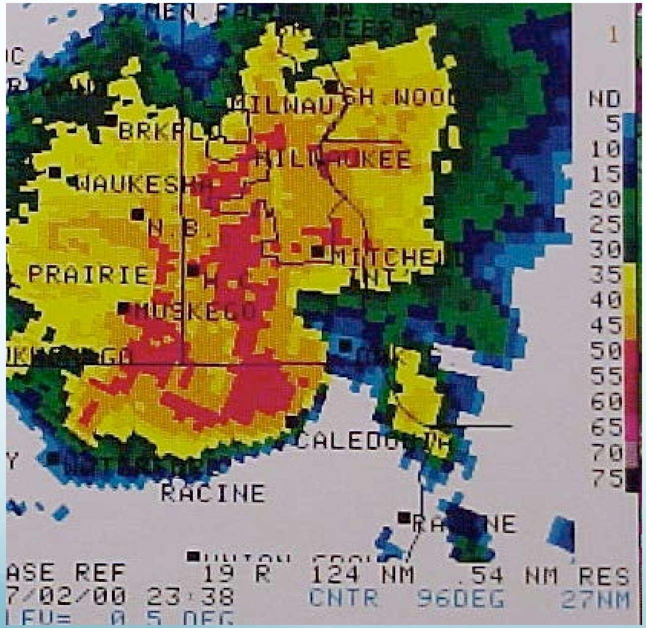
- Technology advances in the 1950s and 1960s resulted in improved radar imagery.
- Initially, just location and movement of precipitation, then intensity became available.





Radar Observations

- From 1990 to 1997, NWS upgraded to WSR 88-D Doppler radar system.
- Greater resolution, velocity information, rainfall estimates.
- WFO Milwaukee/Sullivan upgraded Oct 1993.

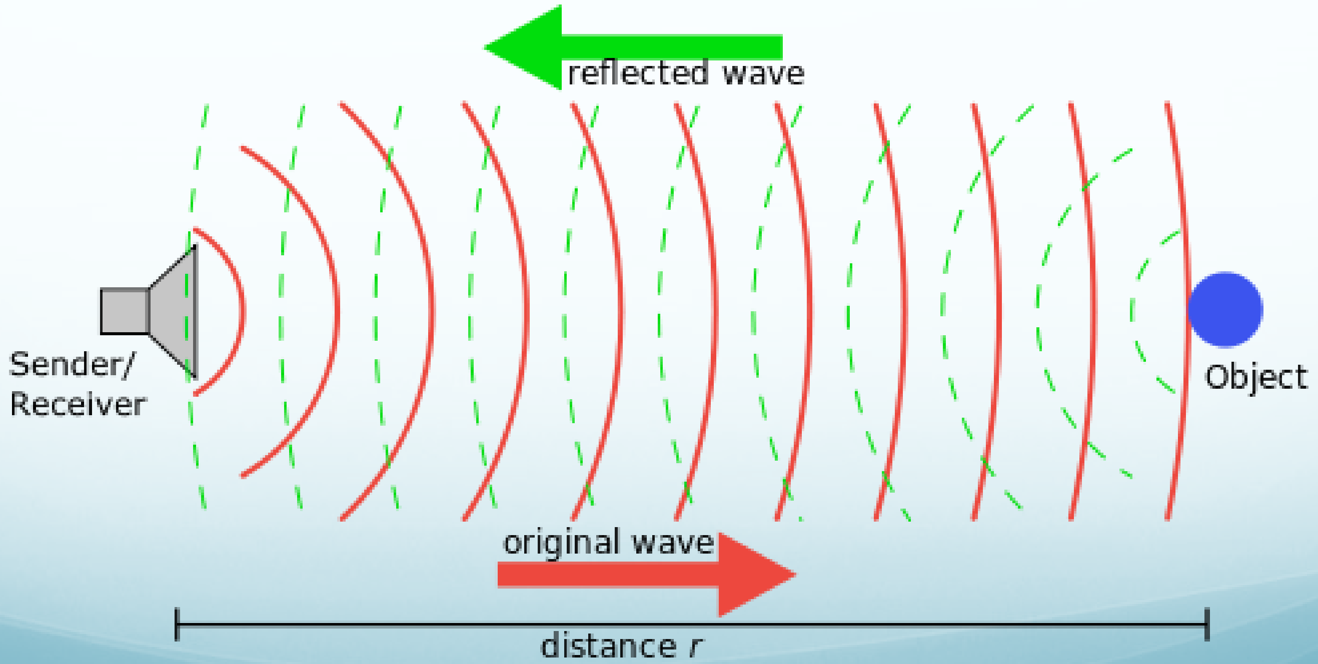


Radar Observations

- Basic radar – provides location/intensity/movement of precipitation & other targets
- Doppler radar – provides…
  a. Better resolution and intensity gradients
  b. Velocity and movement of targets
  c. Rough rainfall estimates
- Dual-Polarization radar – additional benefits…
  a. Resolution of precipitation types
  b. Better rainfall estimates (removal of hail contamination)
  c. Better detection of non-meteorological targets (tornado debris, smoke, birds)

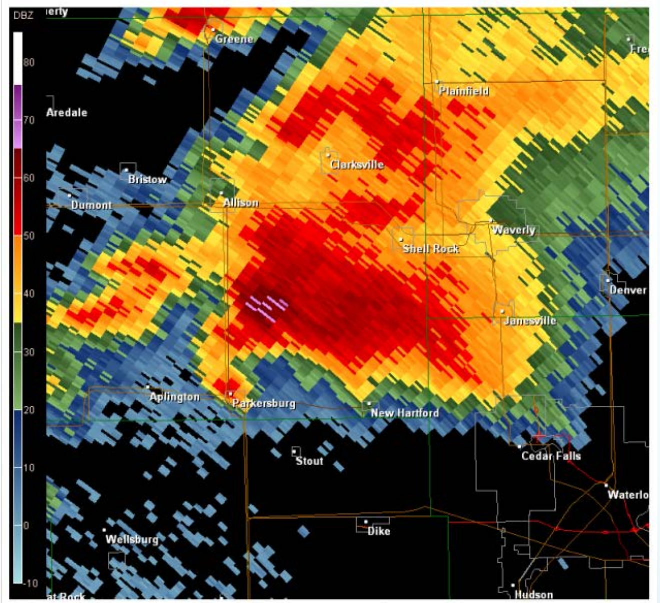
Radar Observations

- Radar energy is a form of electro-magnetic energy…consisting of electric and magnetic fields.
- Part of signal reflects off of targets (reflectivity) & returns to radar site.



Radar Observations

- The amount of reflected energy is directly proportional to the size and density (concentration) of the targets.
- Large, round targets (hail) are ideal reflectors compared to snow or rain drops.
- A high density or concentration of small to medium size targets can reflect as much radar energy as just a few, but large targets.



Radar image of reflectivity over Parkersburg, Iowa from the KDMX WXR-88D taken at 2159 UTC.
Note the obvious debris ball present in the image.
Image 4 of 7

CLOSE ✕

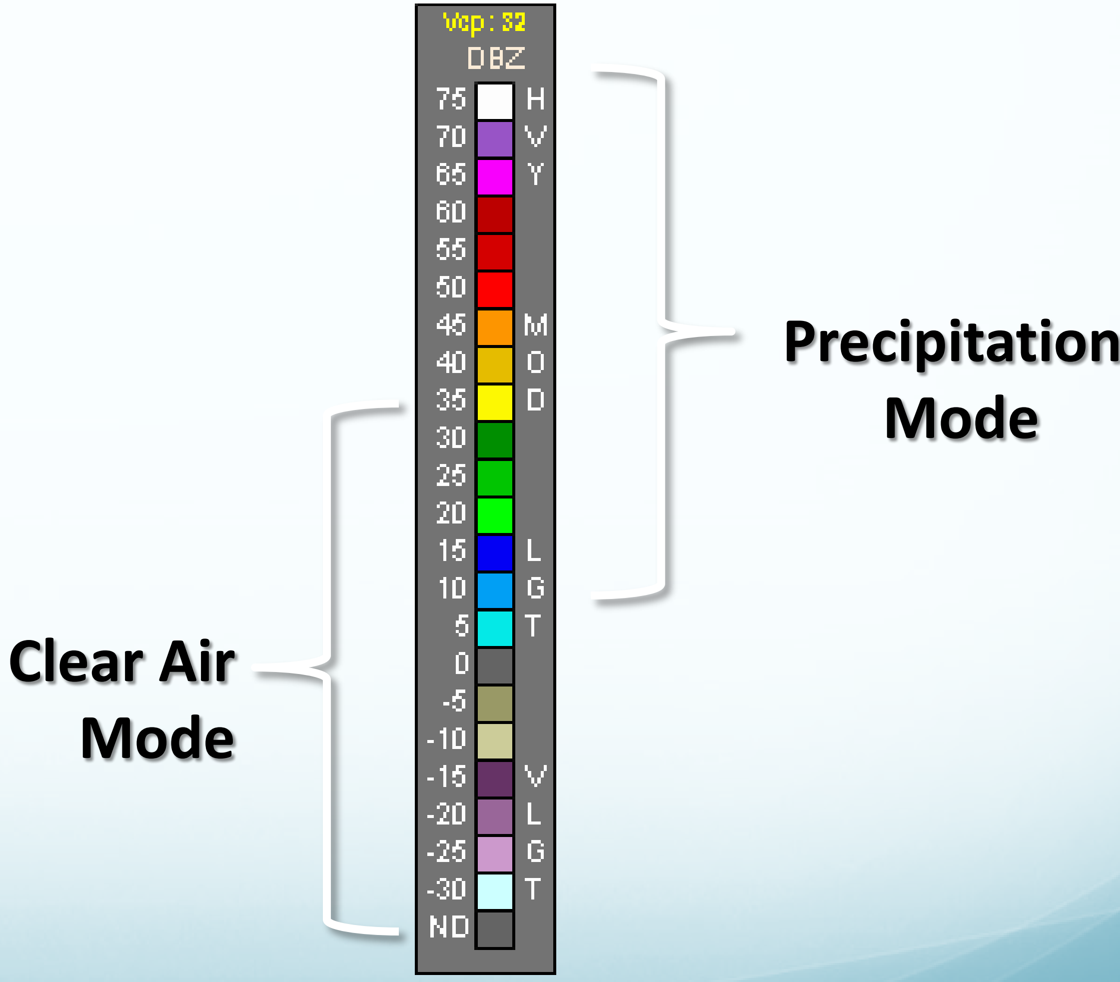
Reflectivity (dBz)

Reflectivity imagery has a variety of colors depicted.

Colors represent variations in the intensity (power) of reflected radar energy.

Intensity variations are plotted on a scale in terms of decibels (dBz)…pronounced **d-b-z**.

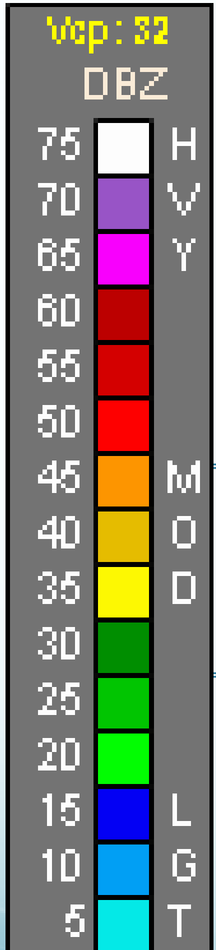
Two operational modes



Doppler Radar

- In 1 hour of operation, it transmits only 5.7 seconds. So it listens 99.843% of the time for reflected energy!
- dBz is converted to a rainfall rate of millimeters per hour (or inches per hour).
- Rain usually reaches the ground at about 15 to 20 dBz.
- dBz values above 55 usually indicate hail is present.

dBz – Rainfall Rates (at ground)



dBZ	R (mm/h)	Rate (in/hr)	Intensity
5	0.07	< 0.01	Hardly Noticeable
10	0.15	< 0.01	Light Mist
15	**0.3**	**0.01**	**Mist**
20	**0.6**	**0.02**	**Very Light**
25	1.3	0.05	Light
30	2.7	0.1	Light to Moderate
35	5.6	0.22	Moderate Rain
40	11.53	0.45	Moderate Rain
45	23.7	0.92	Moderate to Heavy
50	48.6	1.90	Heavy
55	**100**	**4**	**Very Heavy / Small Hail**
60	**205**	**8**	**Extreme / Moderate Hail**
65	**421**	**16.6**	**Extreme / Large Hail**

What is Detected by Doppler Radar?

- Boundaries (lake-breeze, cold front)
- Cloud streets
- Insect swarms
- Smoke plumes
- Cloud bases and tops
- Bird migrations
- Sunrise/sunset “spikes”
- Vehicle convoy movement on freeways
- Chaff (military counter-measure)

Clear-Air Mode

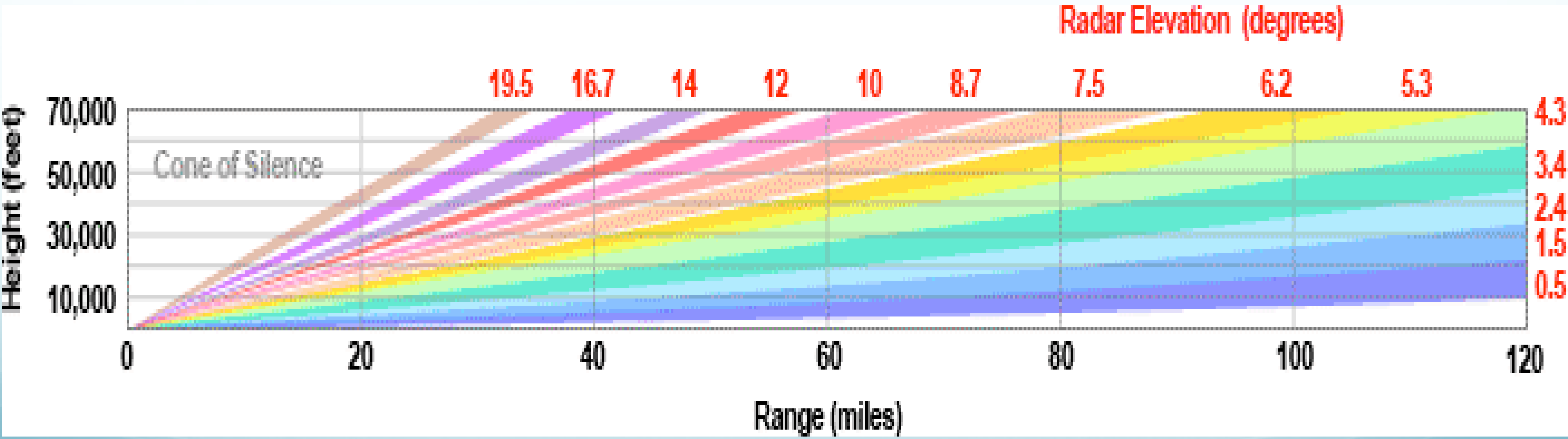
- Rain
- Snow
- Hail
- Tornado debris
- Meso-scale circulations: suggest tornado
- Powerful thunderstorm winds

Precipitation Mode

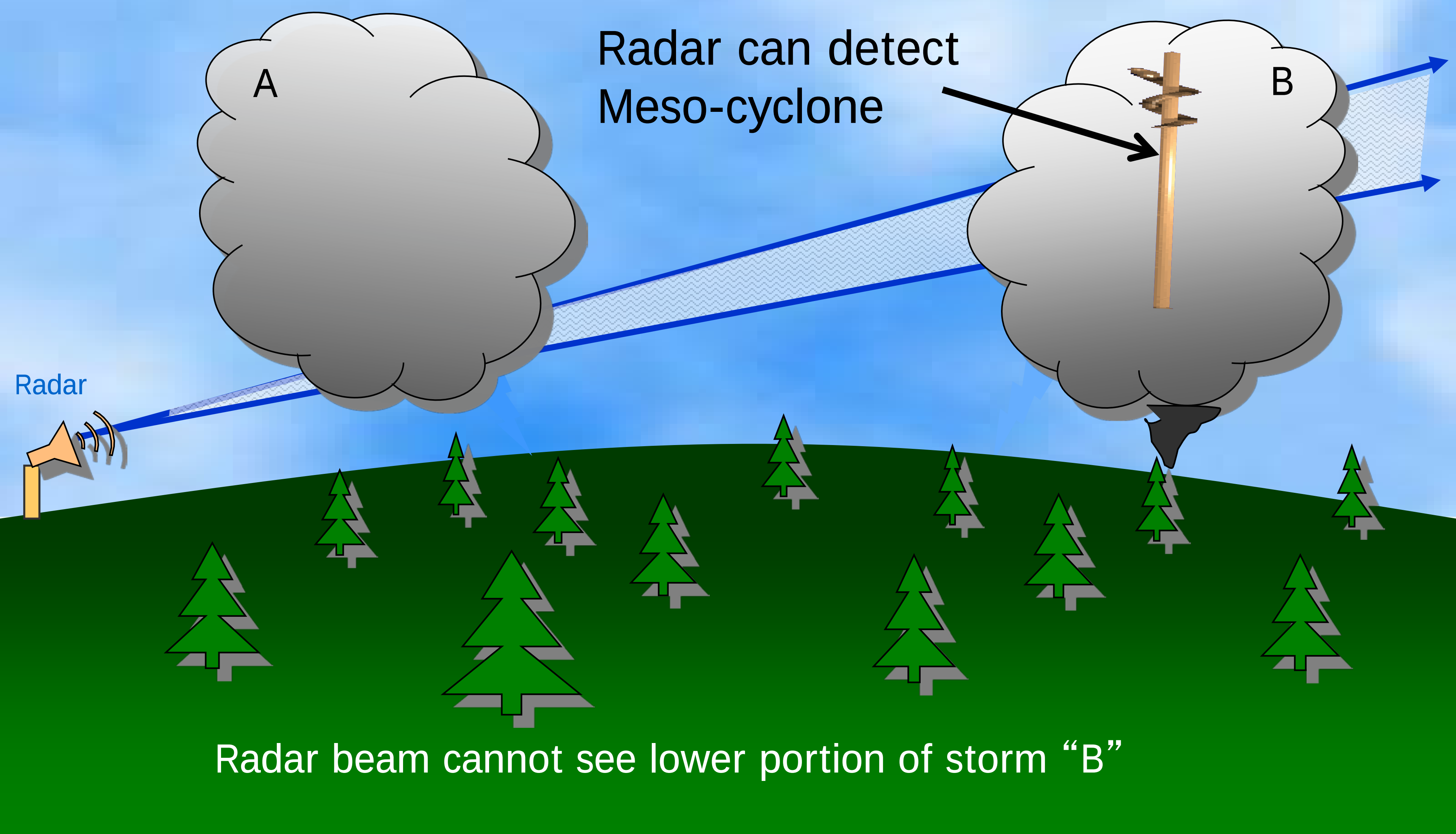
Doppler Radar

Continuous operation going from 0.5 degree to 19.5 degree tilt or slice (one volume scan has 14 elevation slices).

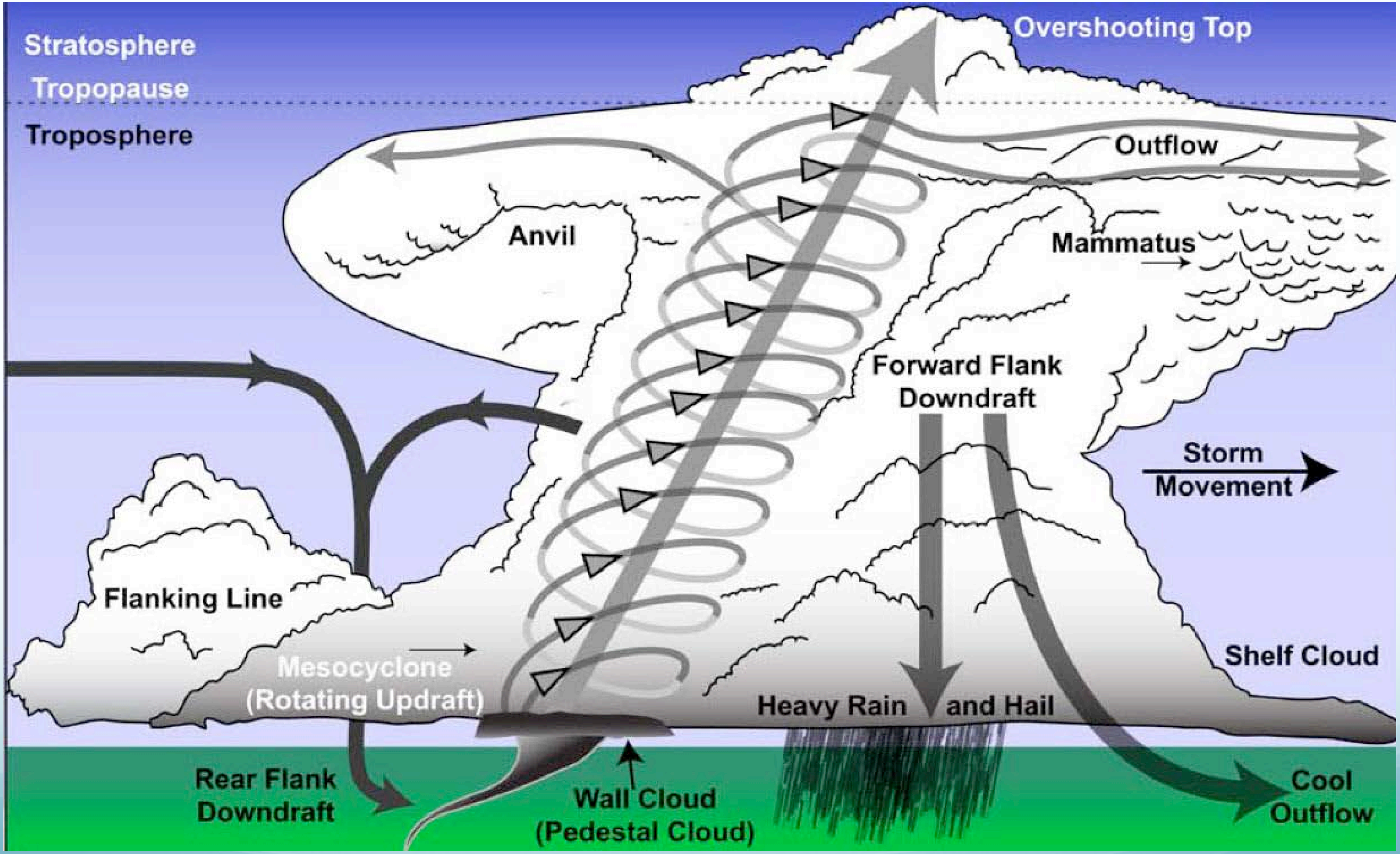
Scan cycle repeats itself.



Radar Limitations

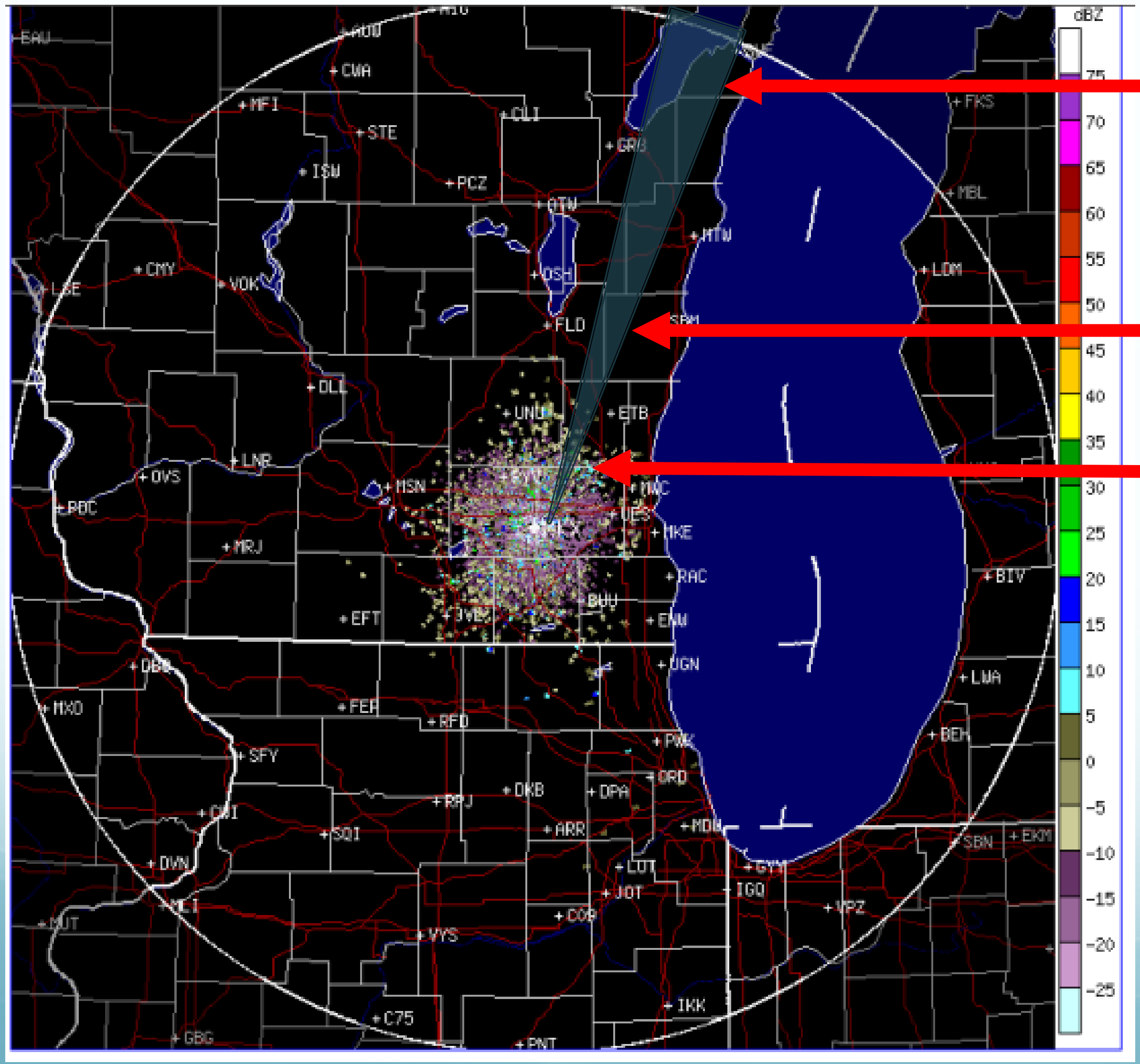


Supercell Structure



www.weatheredge.com

Radar Beam Height Issue

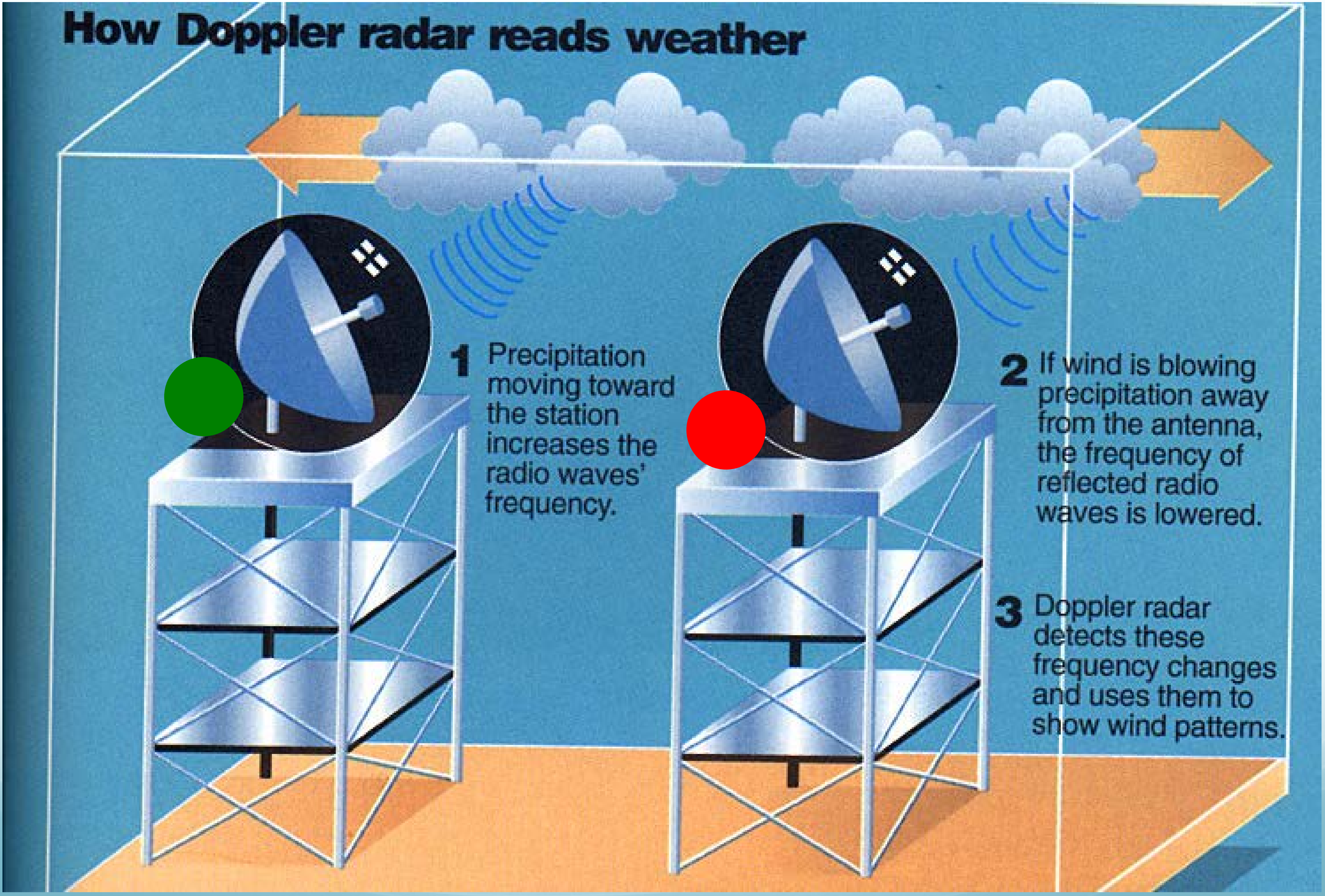


16,000 FT

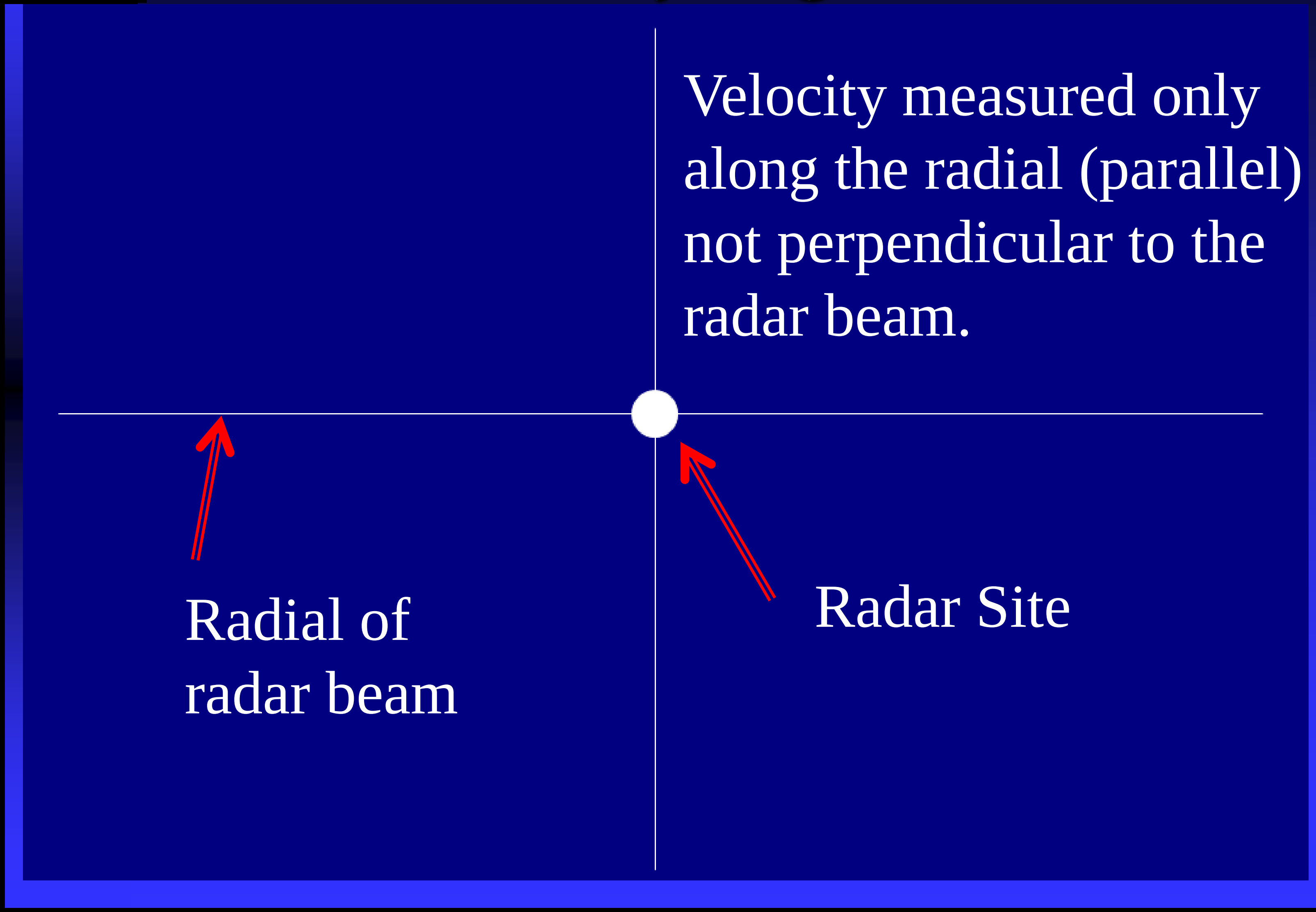
8,000 FT

1,600 FT

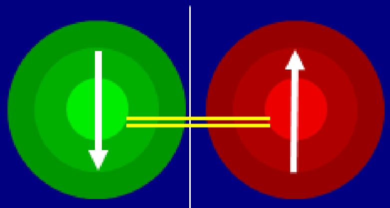
Beam Center Above Ground Level


How Doppler radar reads weather
1 Precipitation moving toward the station increases the radio waves' frequency.
2 If wind is blowing precipitation away from the antenna, the frequency of reflected radio waves is lowered.
3 Doppler radar detects these frequency changes and uses them to show wind patterns.

Radial Velocity Signatures



Radial Velocity Signatures

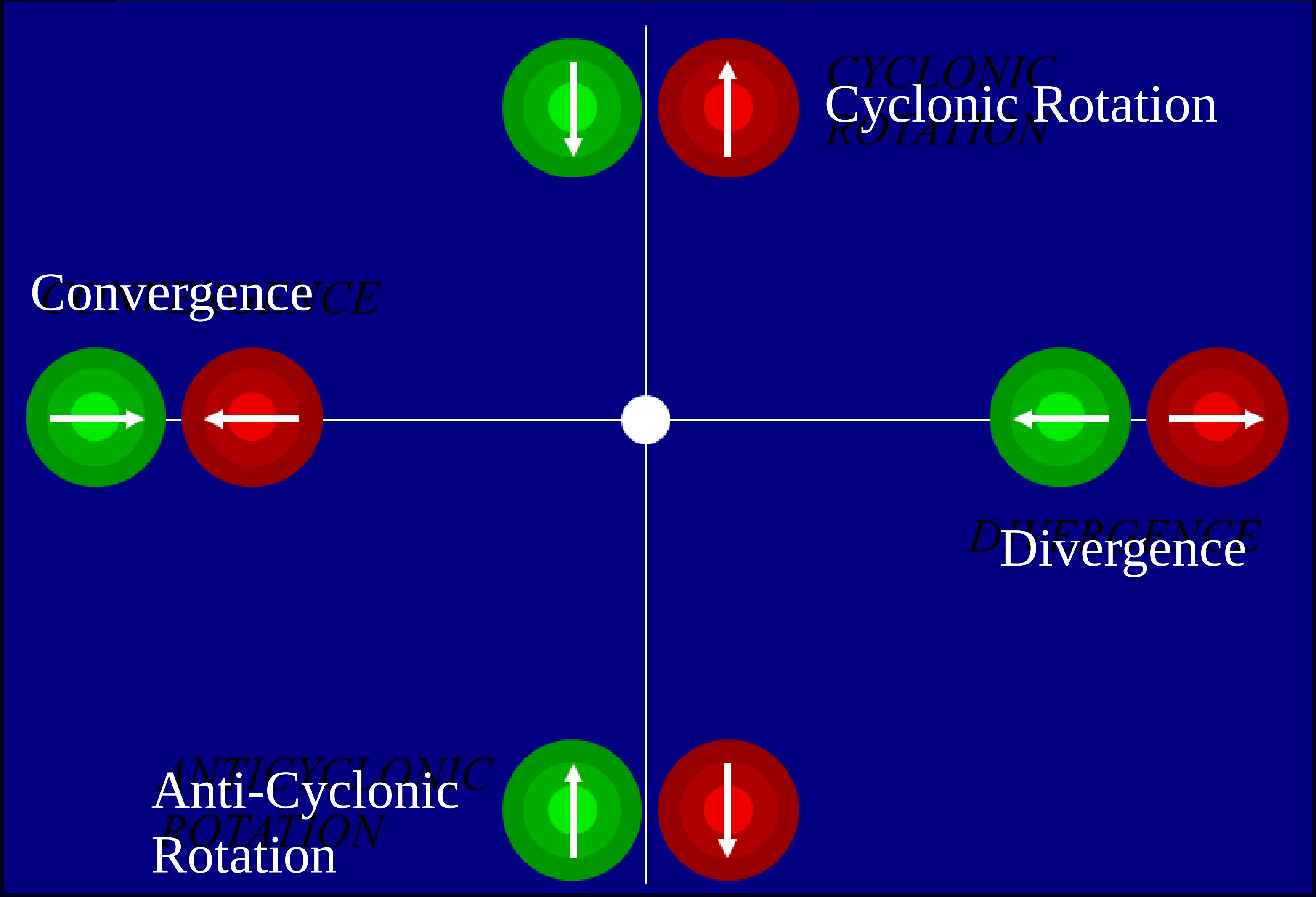


Green – inbound flow
Red – outbound flow

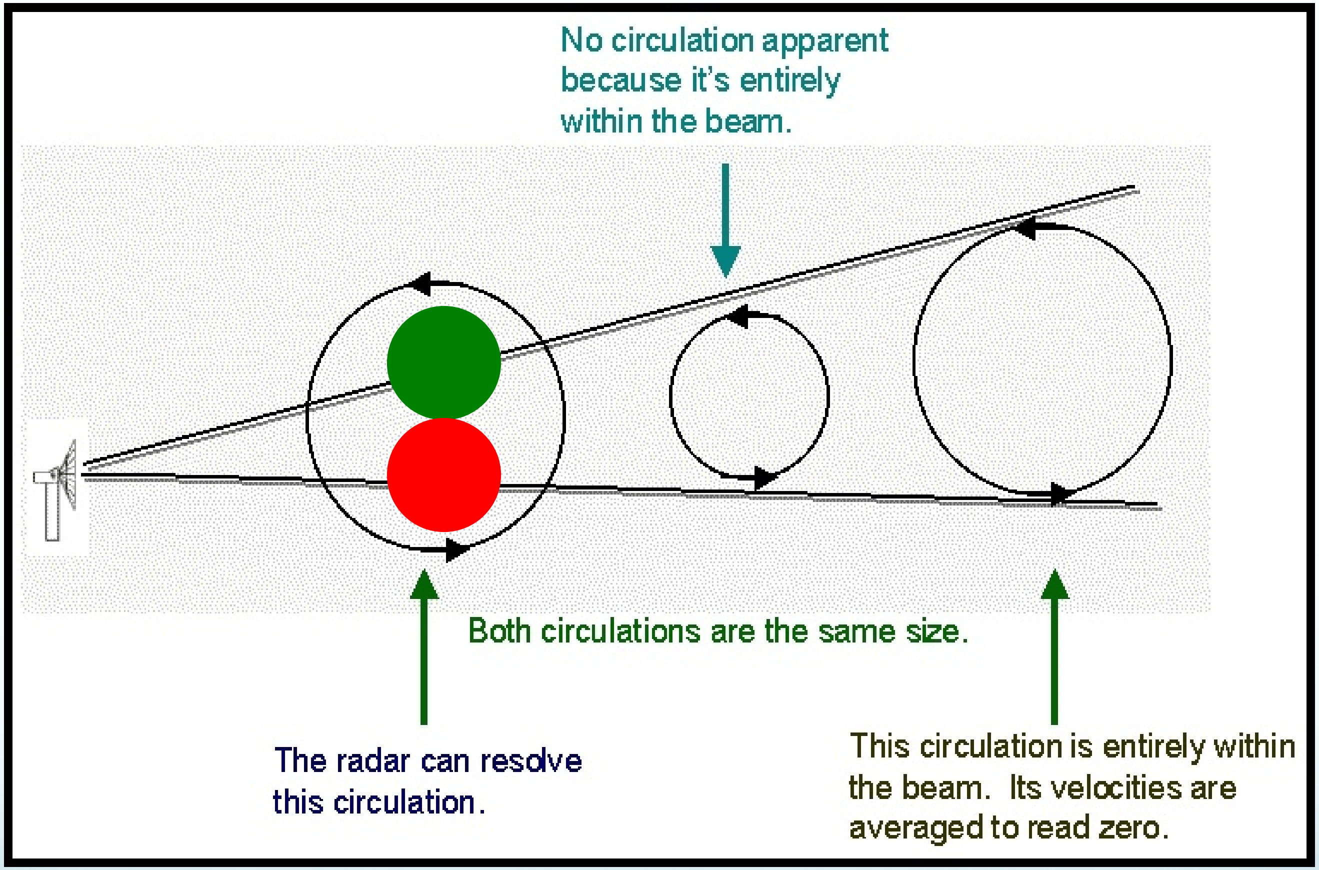
Look for orientation of velocity couplet (line connecting green-red blobs) to be perpendicular to radial.

Put paddle-wheel in middle of this velocity couplet – it will rotate counter-clockwise

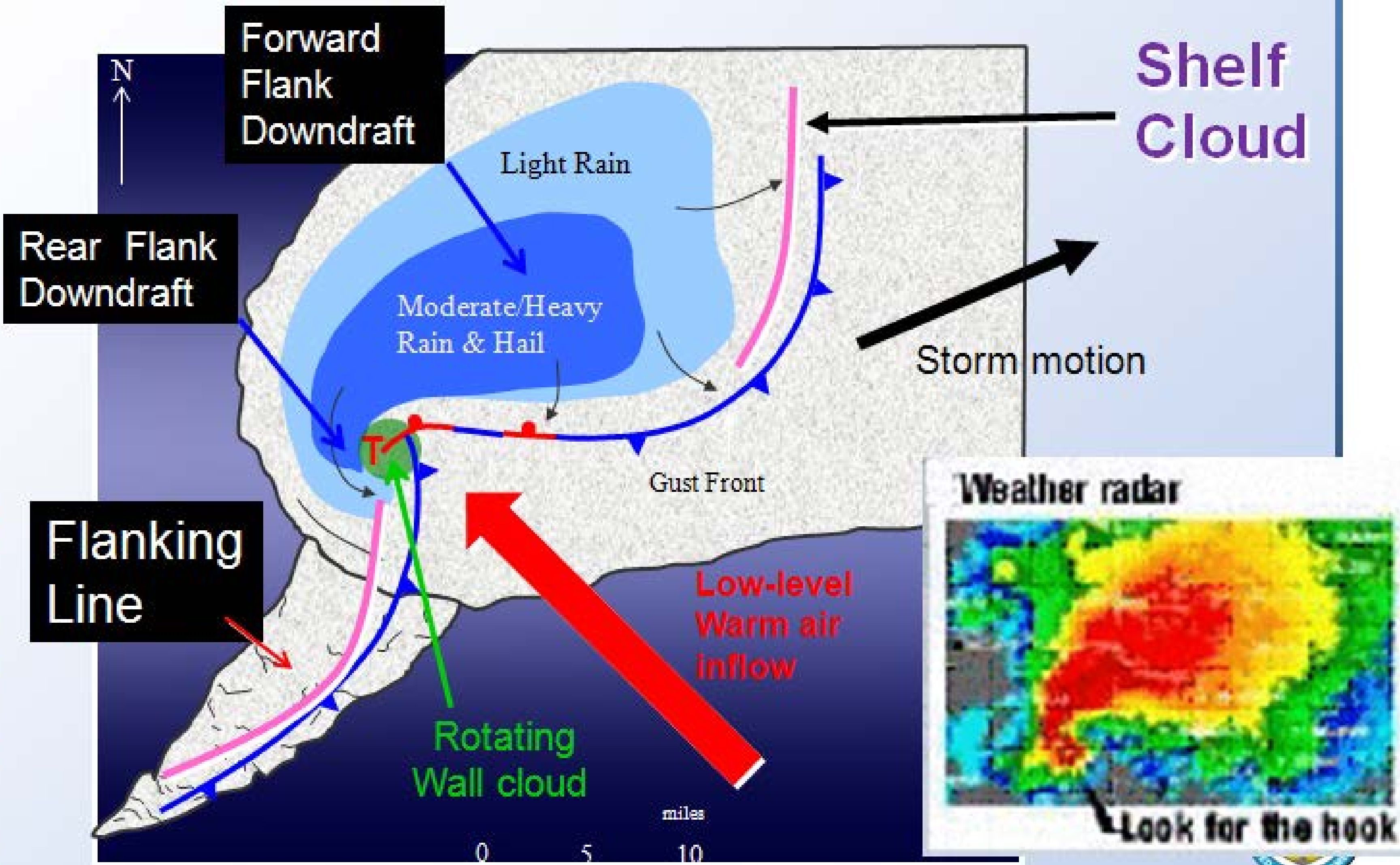
Radial Velocity Signatures



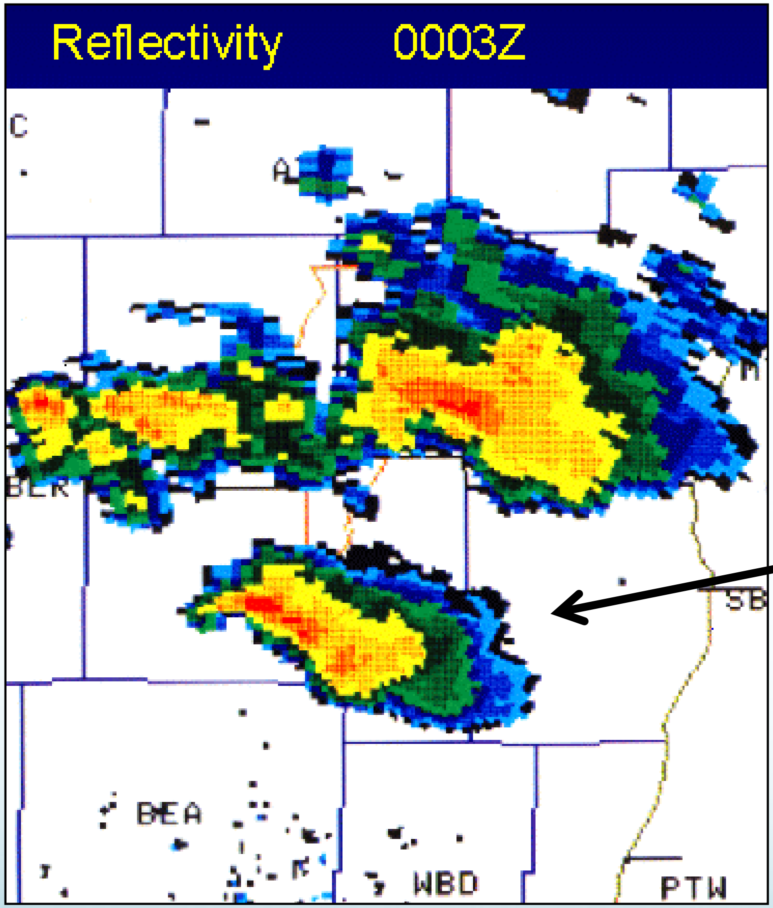
Doppler Radar

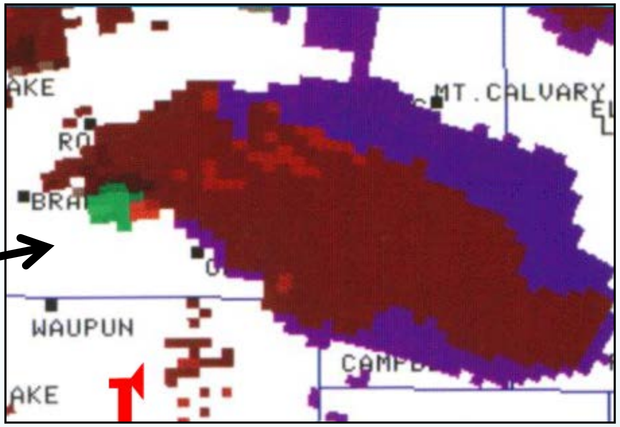


Tornadic Supercell Thunderstorm



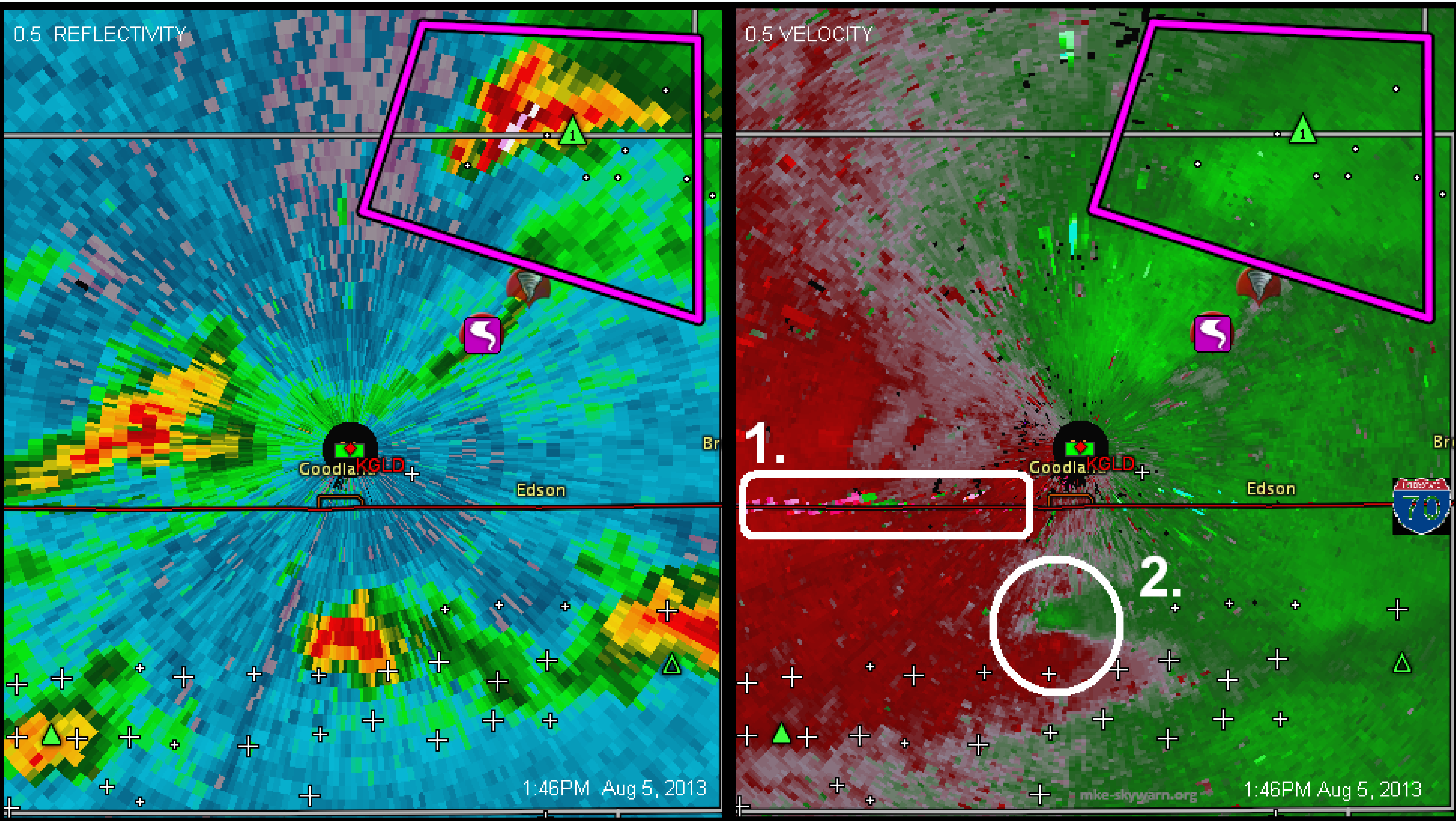
Doppler Radar





Storm Relative Velocity

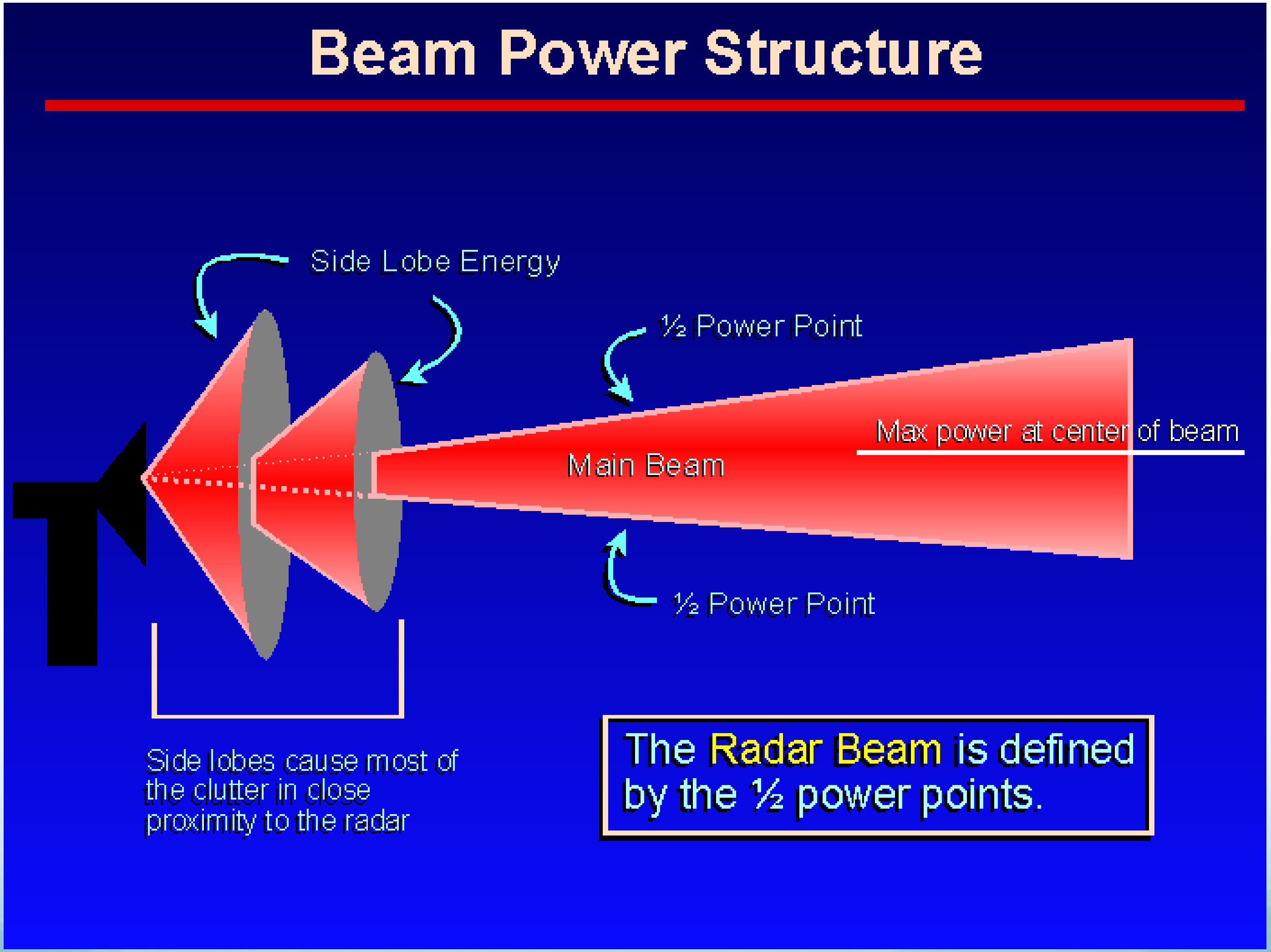
Base Reflectivity (0.5 degree slice/tilt)



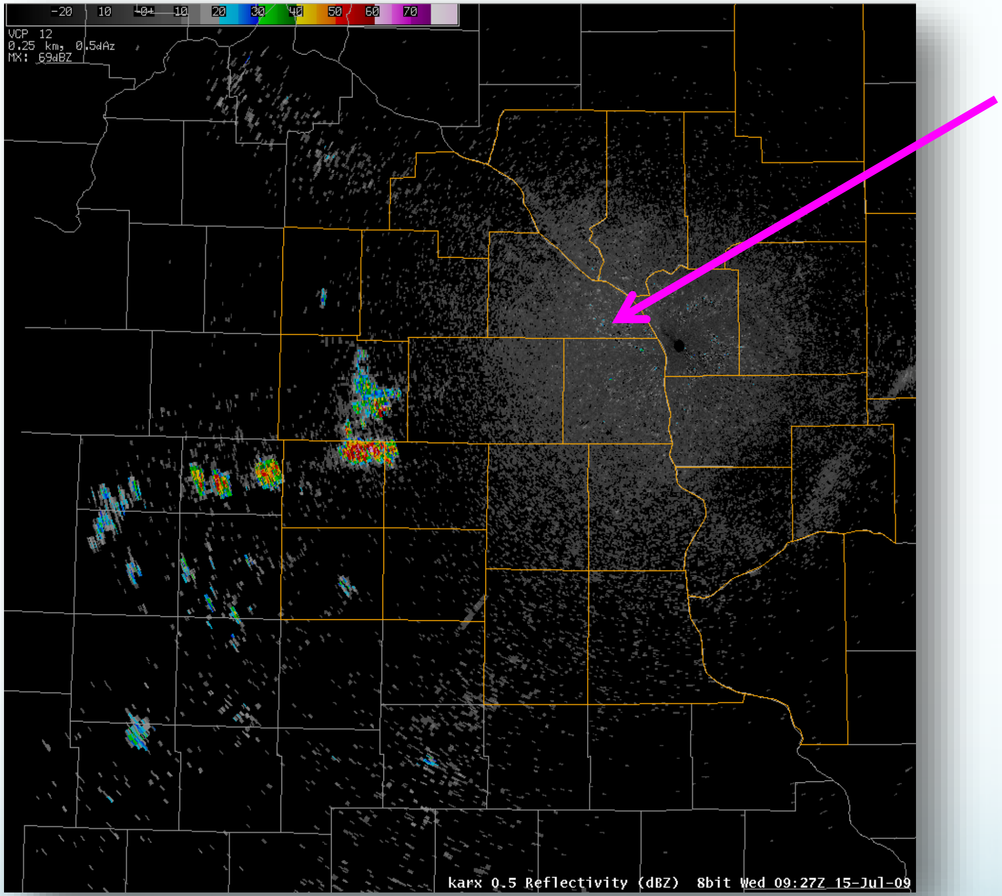
Radar Velocity Quiz:

 # 1 is caused by....
 # 2 is showing what...

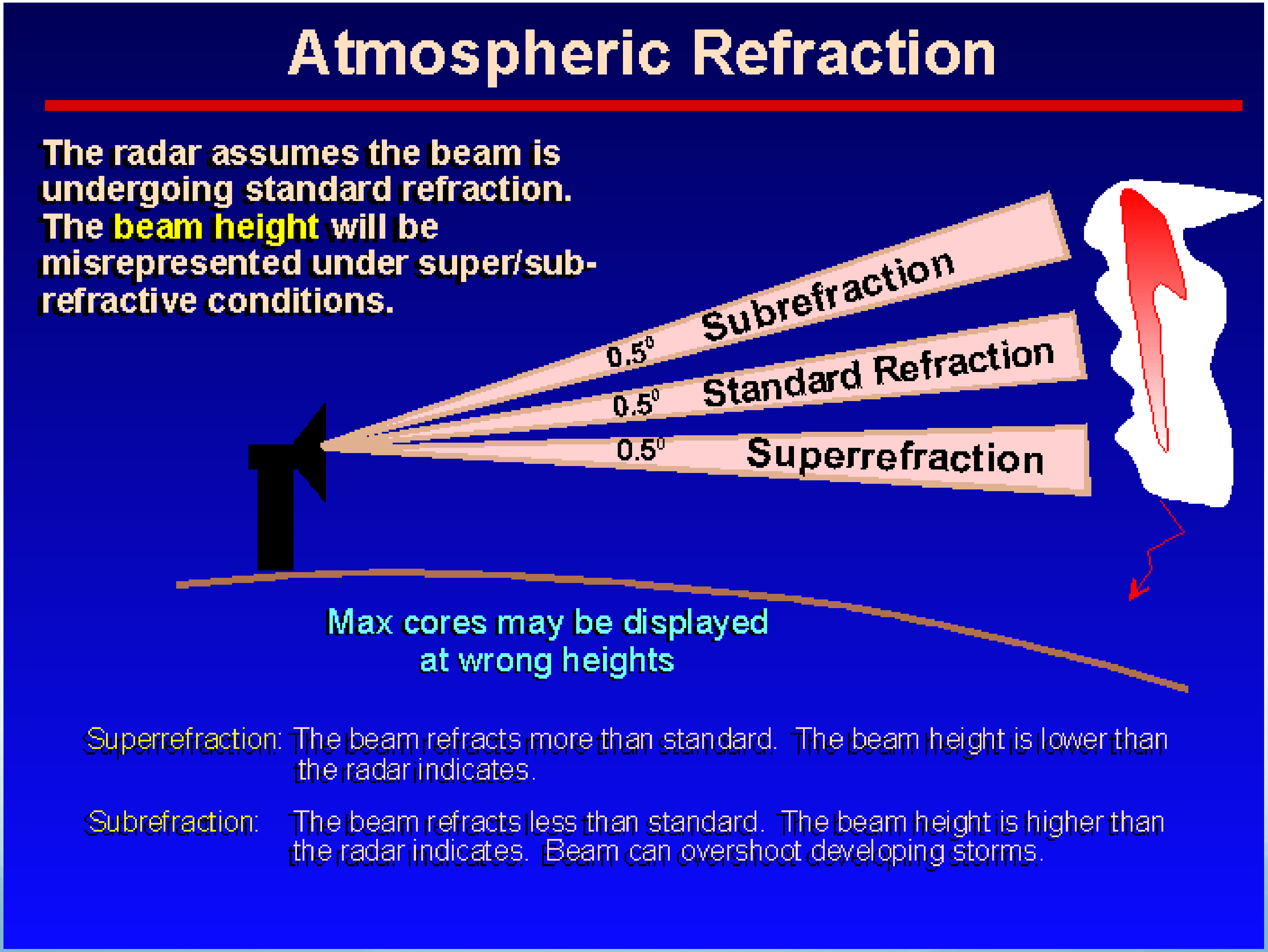
Doppler Radar



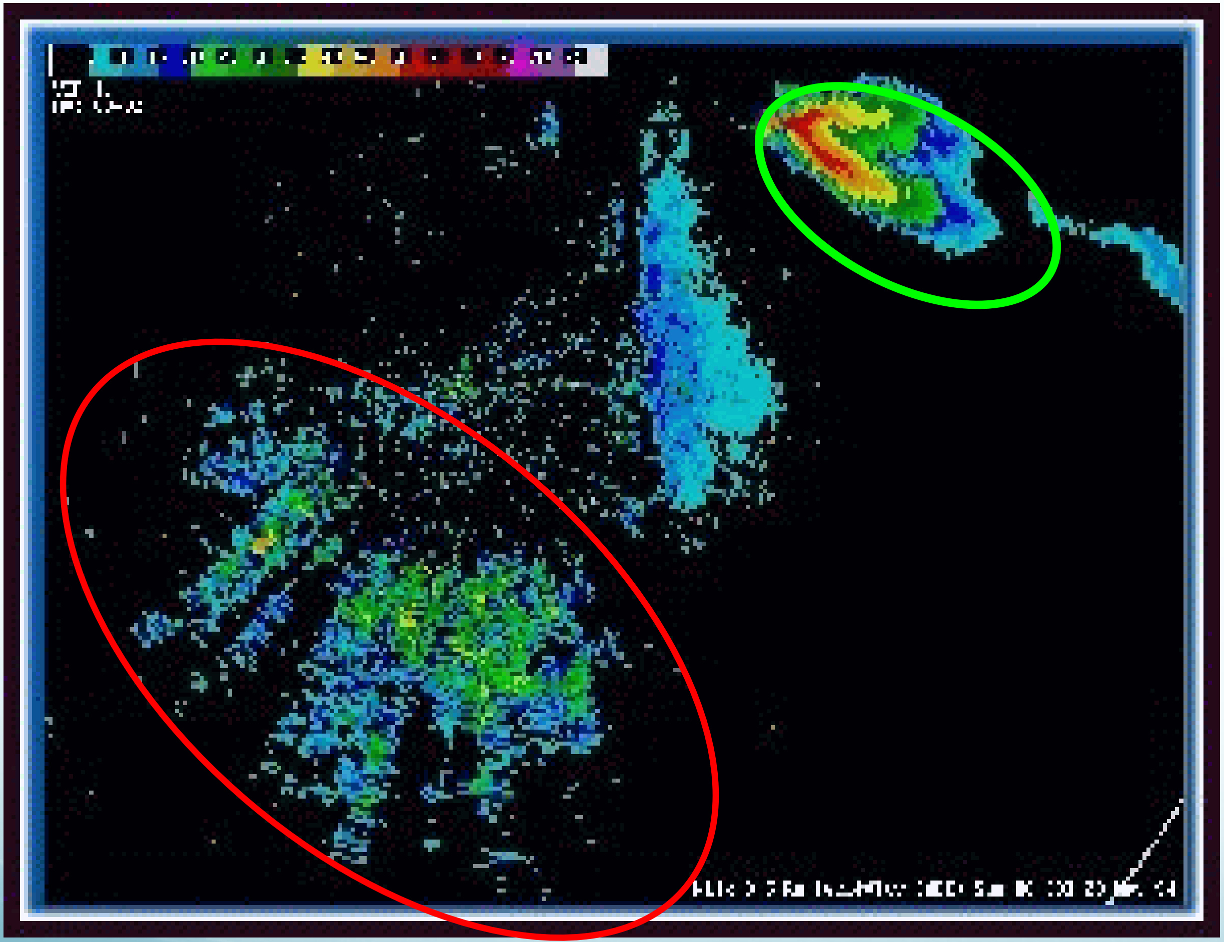
Ground Clutter



Doppler Radar



Anomalous Propagation

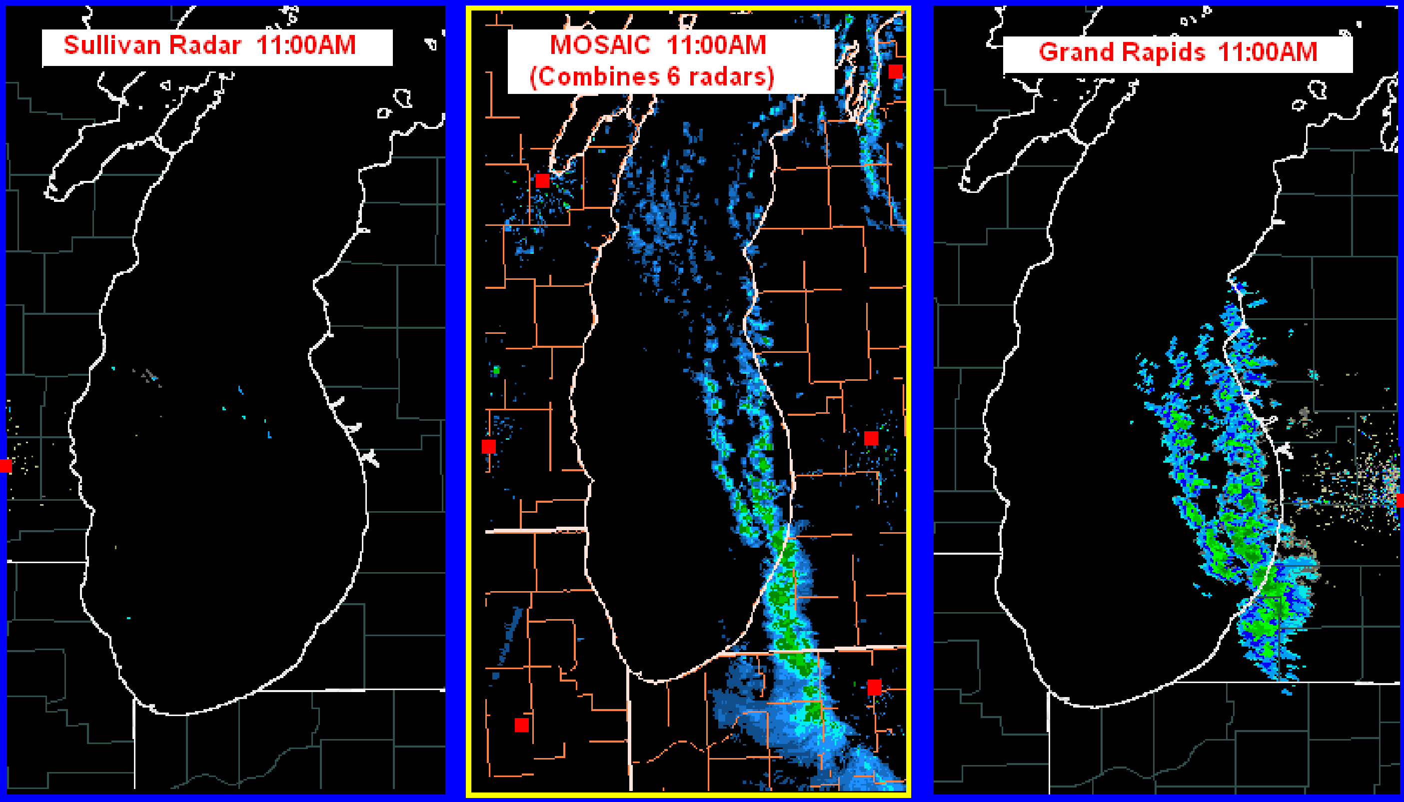


AP refers to false echoes due to trapped radar signal during temperature inversions.
“Super-refraction”

The area circled in red is anomalous propagation. The area circled in green is a tornadic thunderstorm.

AP does not move but disappears when inversion falls apart.

REGIONAL MOSAIC:
6 Radar's 'Composite Reflectivity' images combined

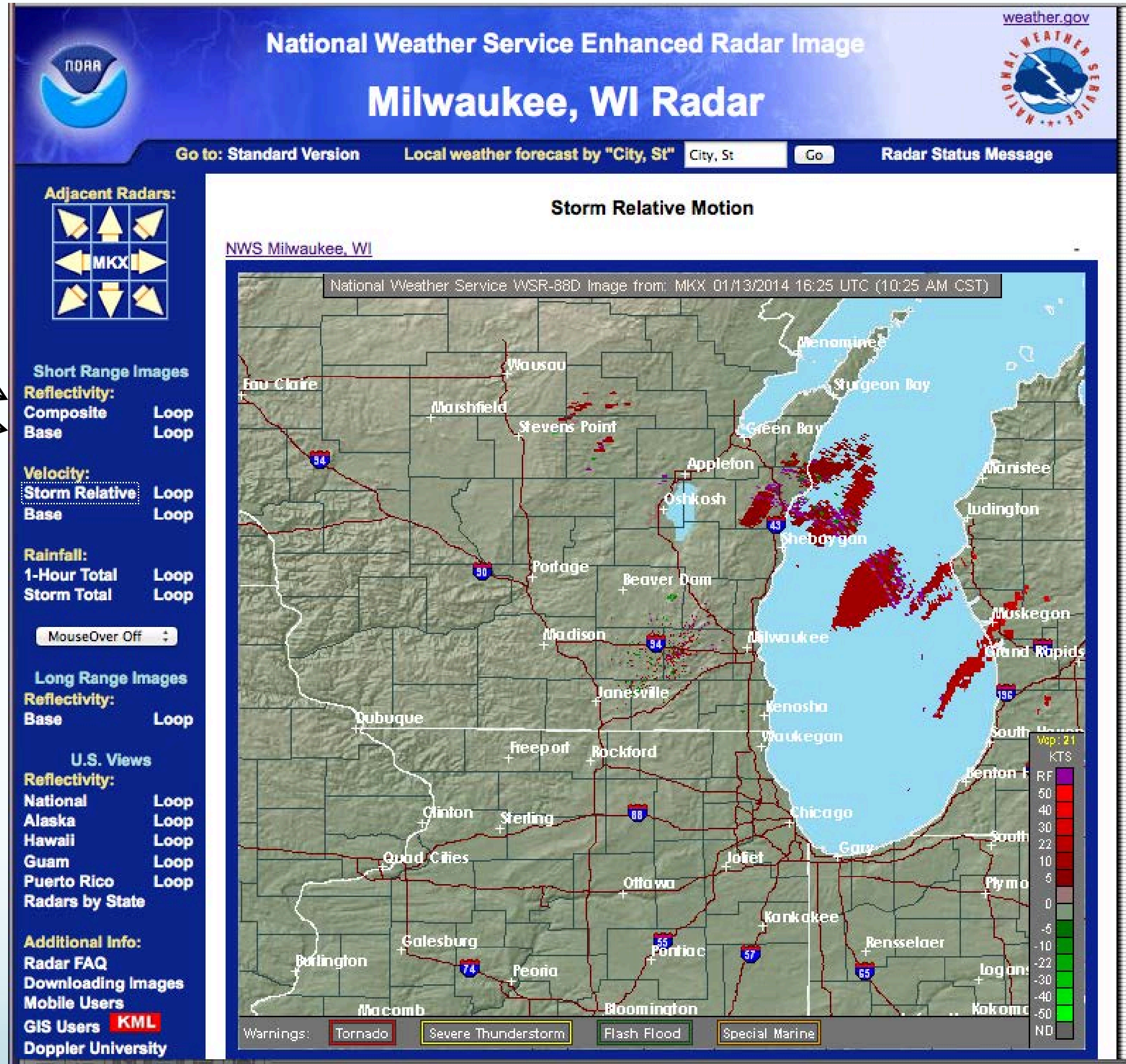


NWS Radar Page

Reflectivity:
* Composite
* Base

Velocity:
* Storm Relative
* Base

www.weather.gov/mkx

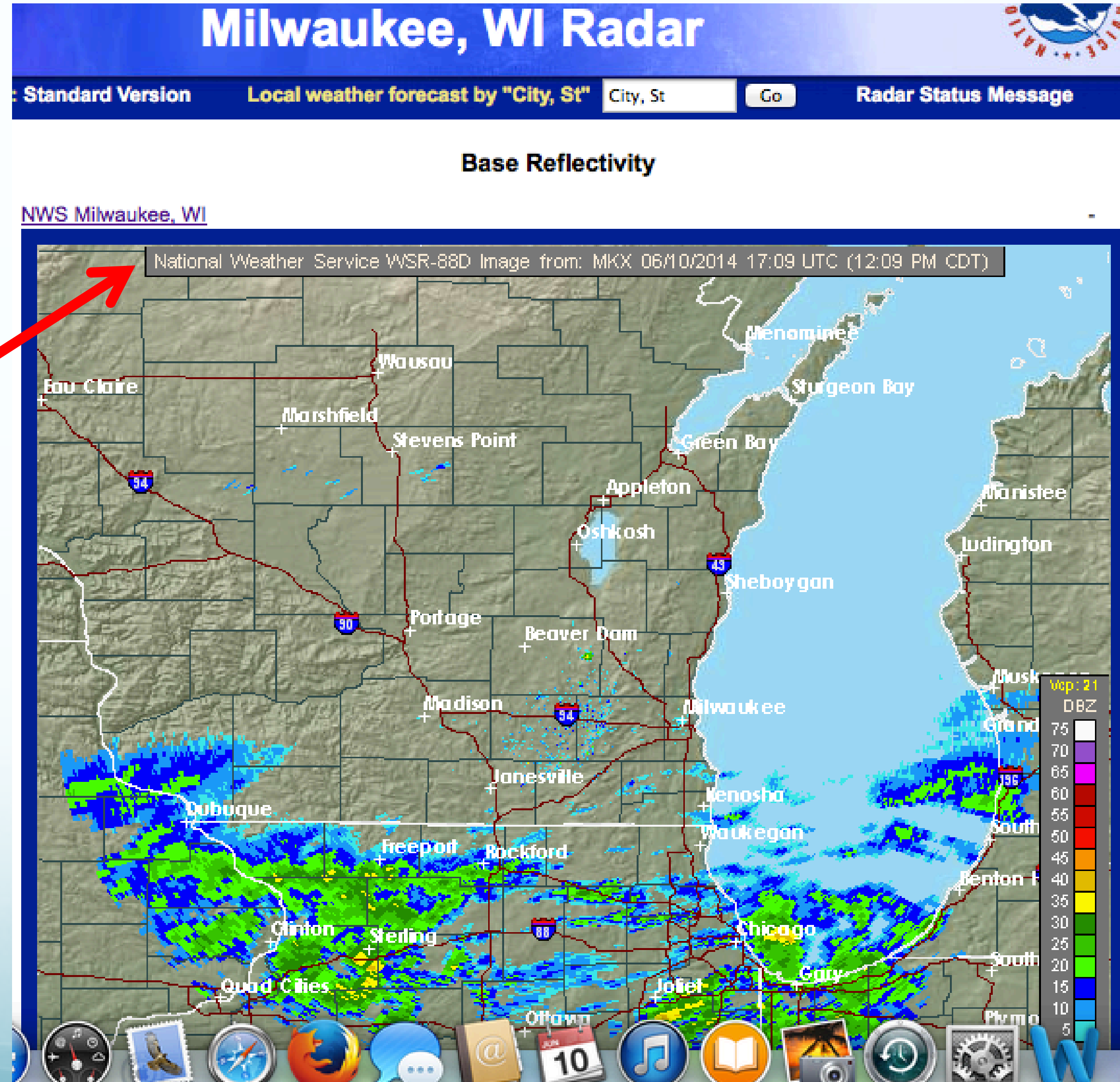


What to Use

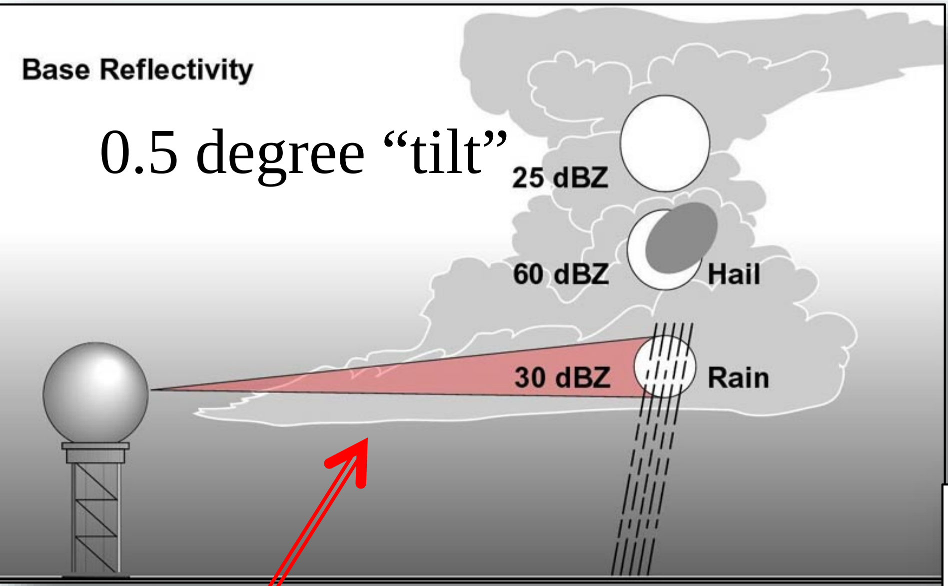
- **Base Reflectivity** – to see reflectivity values at any one of the 14 elevation slices. The 0.5 degree slice is the default image on NWS web sites.
- **Composite** – to see what the maximum dBz value is within the storm over a single geographical point. The storm may have higher dBz values aloft. What goes up must come down!
- **Base Velocity** – to see wind speed values relative to the ground (what you'd feel) at any one of the 14 elevation slices. The 0.5 degree slice is the default image on NWS web sites. Straight-line winds.
- **Storm Relative Velocity** – to see what the rotational wind speeds are within a circulation, as if you were traveling with the storm. Tornadic storms.

NWS Radar Page

Always check the time-stamp, radar system may be down.

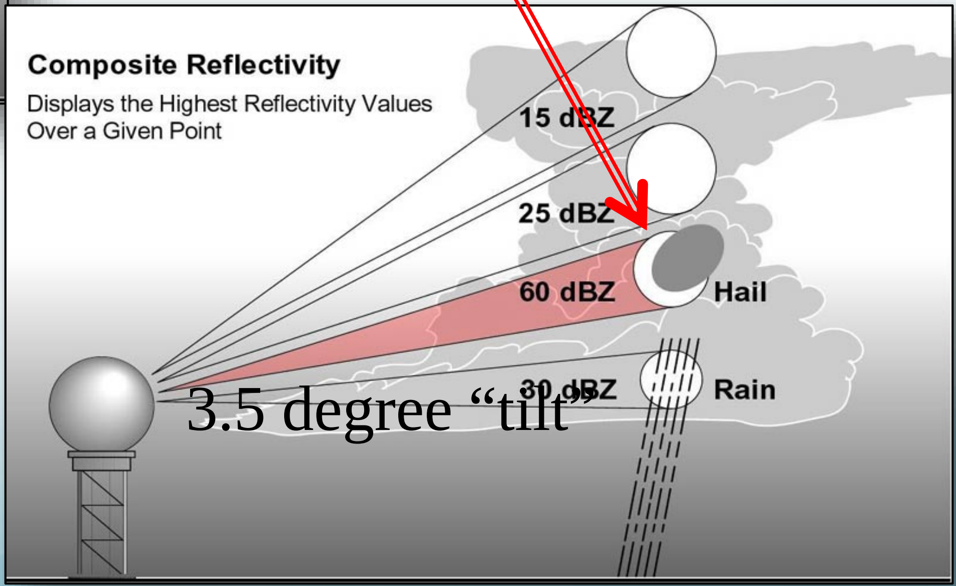


Base Reflectivity Versus Composite Reflectivity

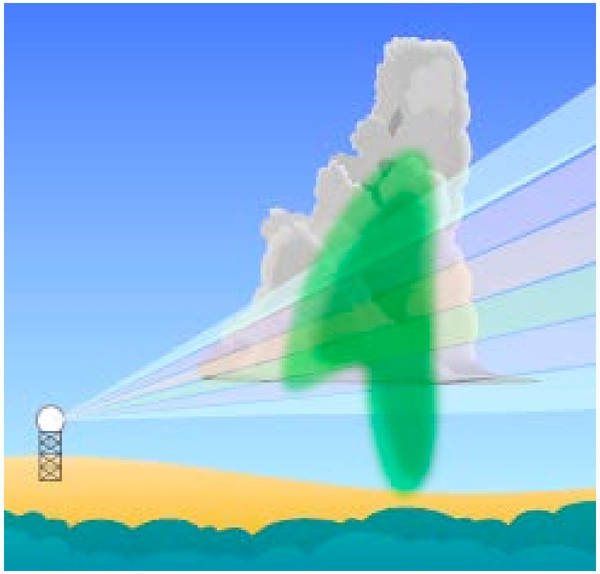


Composite shows you max dBz found in any of the 14 elevation slices.

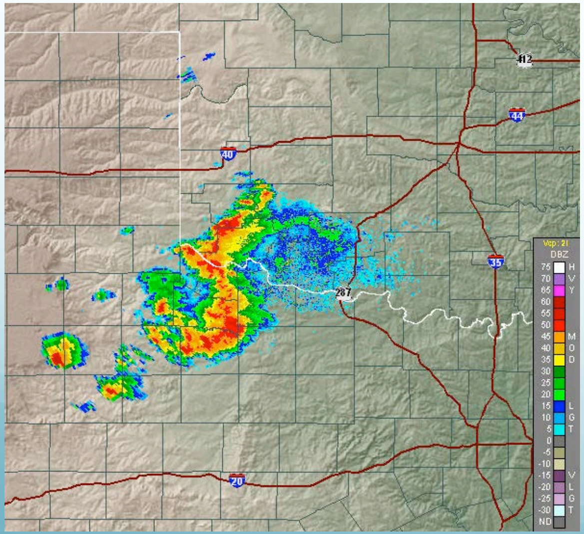
Base shows you dBz in only one of any of the 14 elevation slices



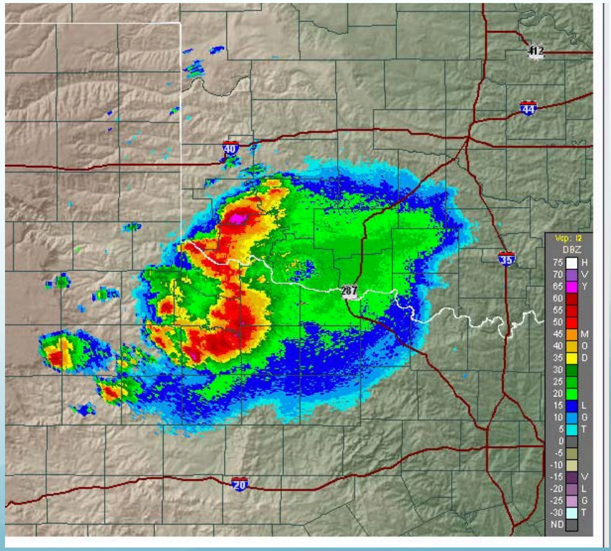
Base Reflectivity Versus Composite Reflectivity



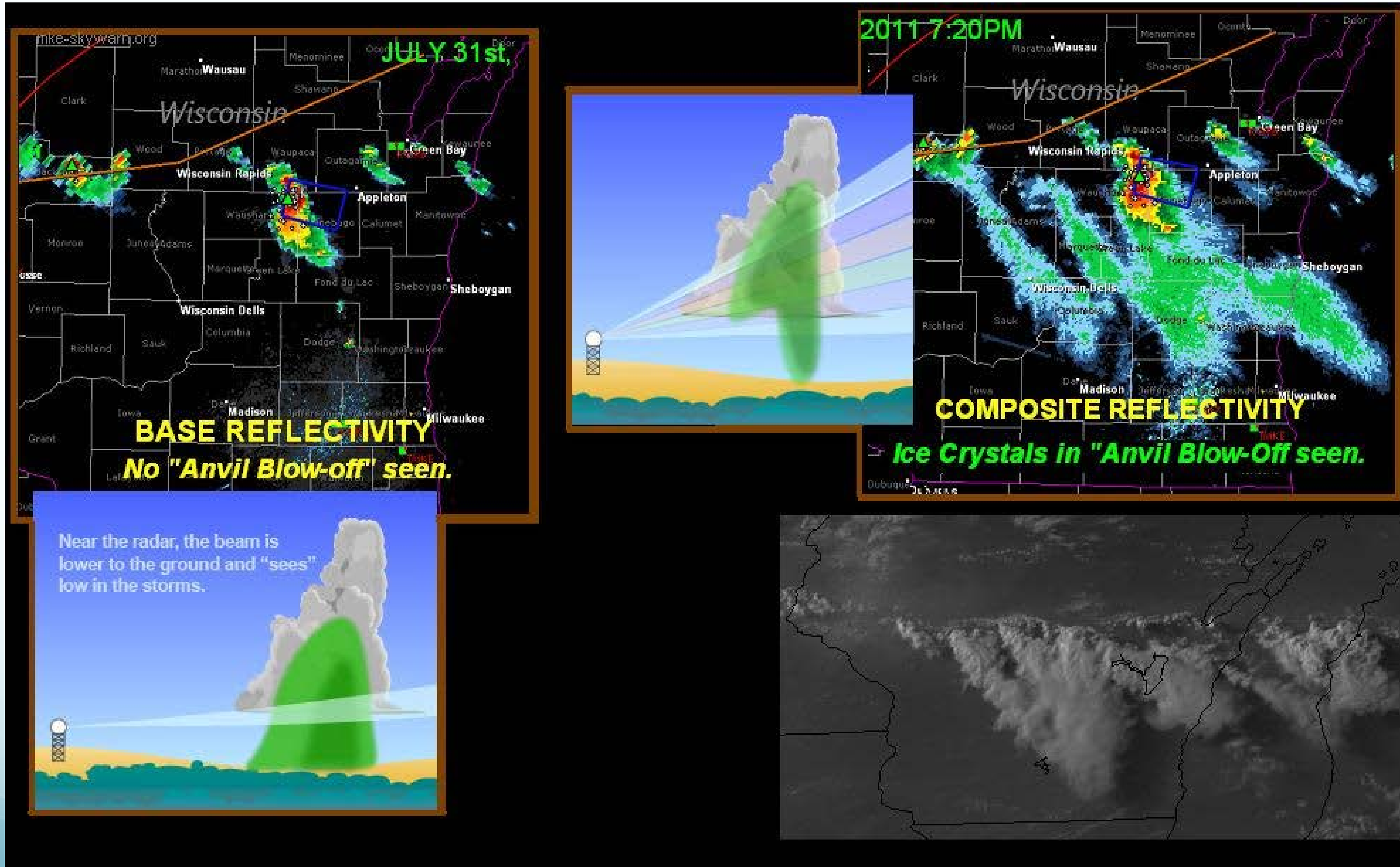
Base Reflectivity



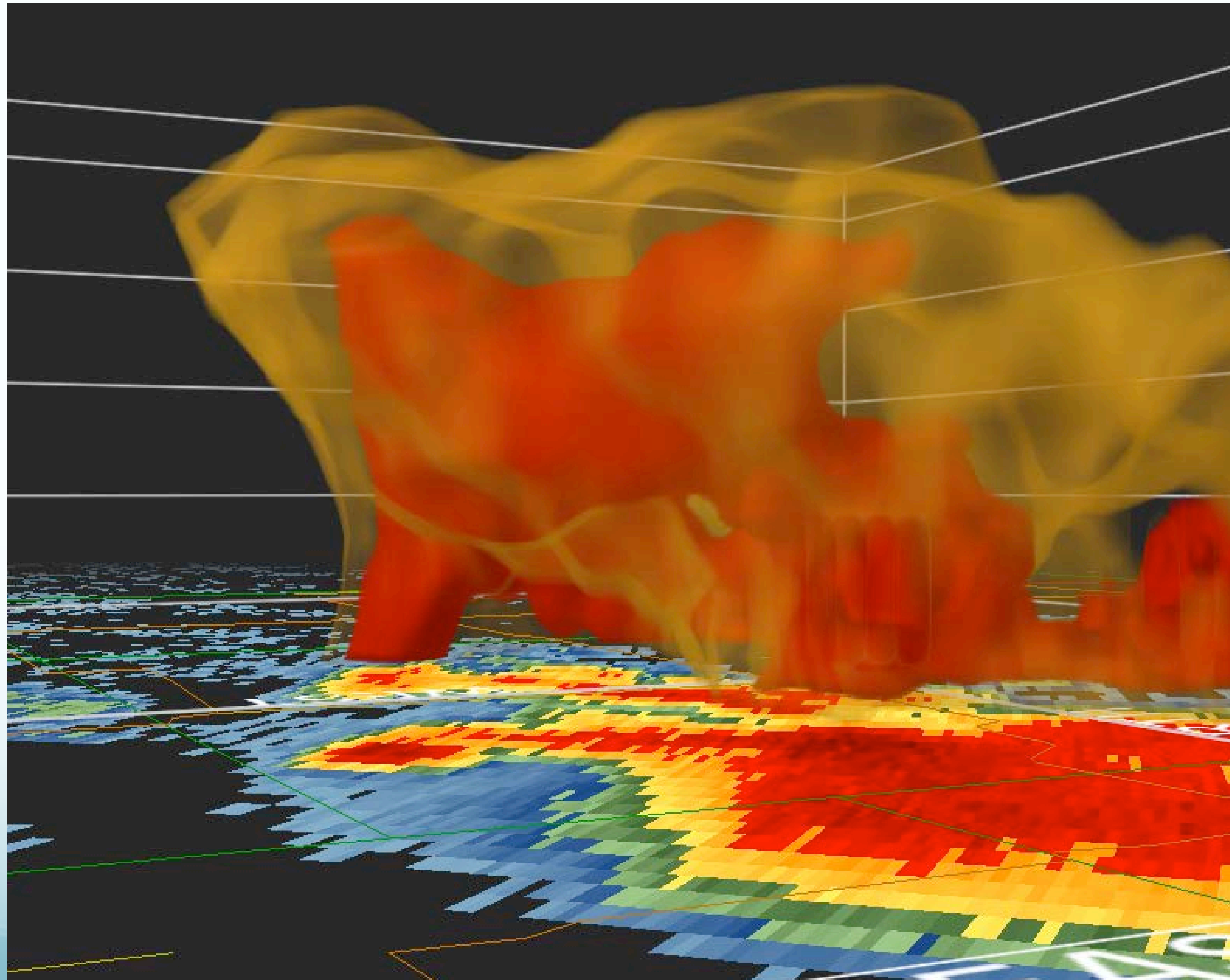
Composite



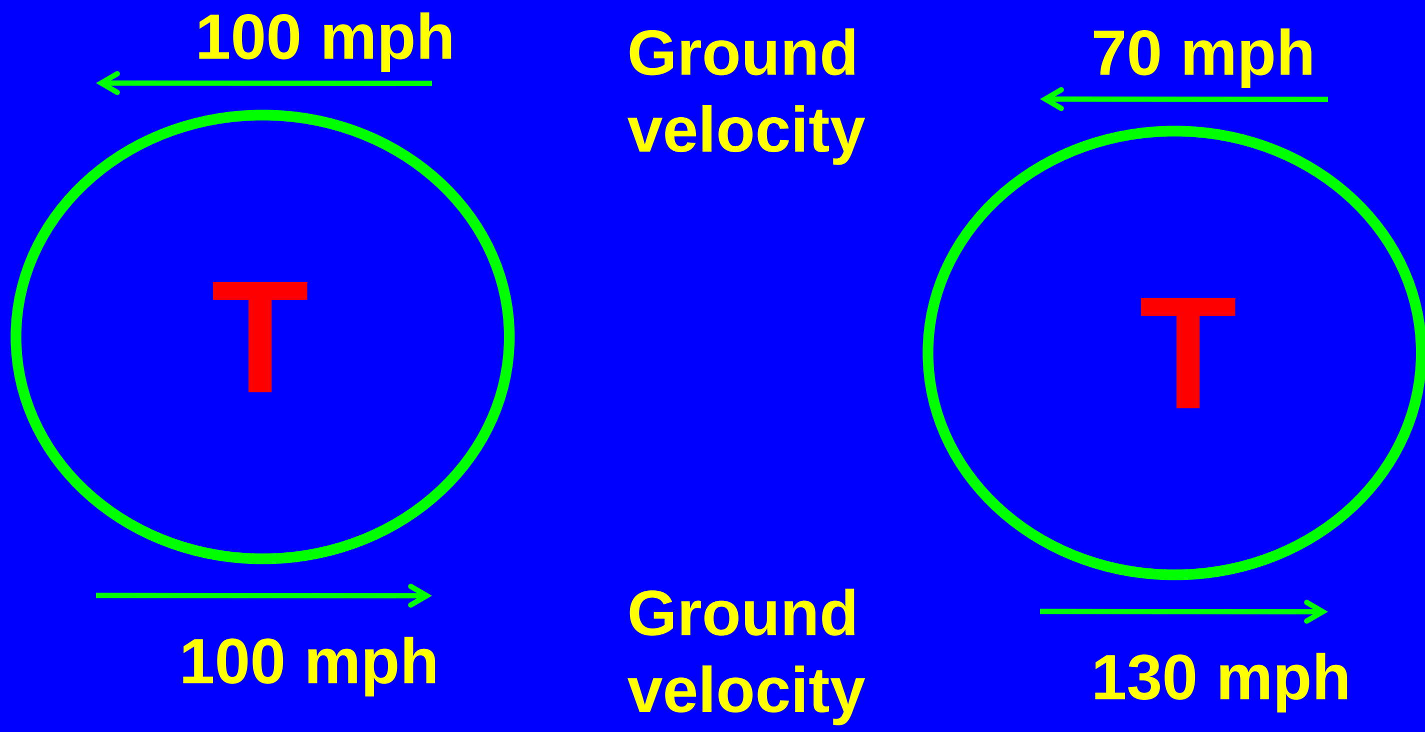
Base Vs Composite Reflectivity



Volumemetric View of Supercell May 25, 2008 Parkersburg, IA



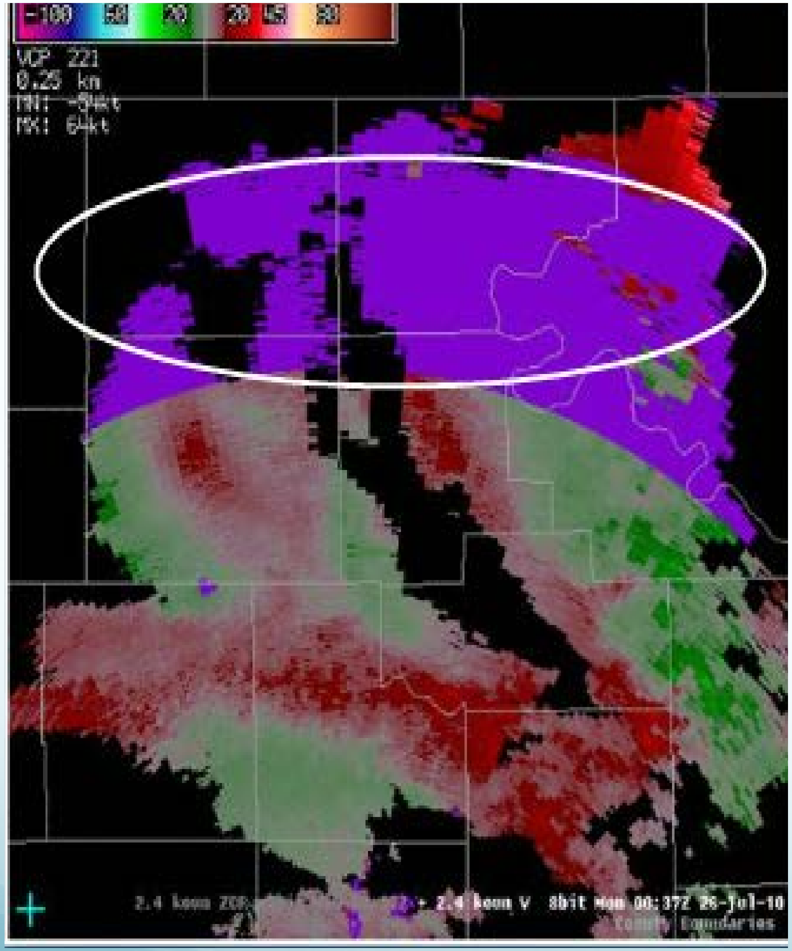
Base Velocity Versus Storm Relative Velocity



Stationary Circulation
"Storm Relative Velocity"

Circulation moving east at 30 mph
"Base velocity".

Range Folding

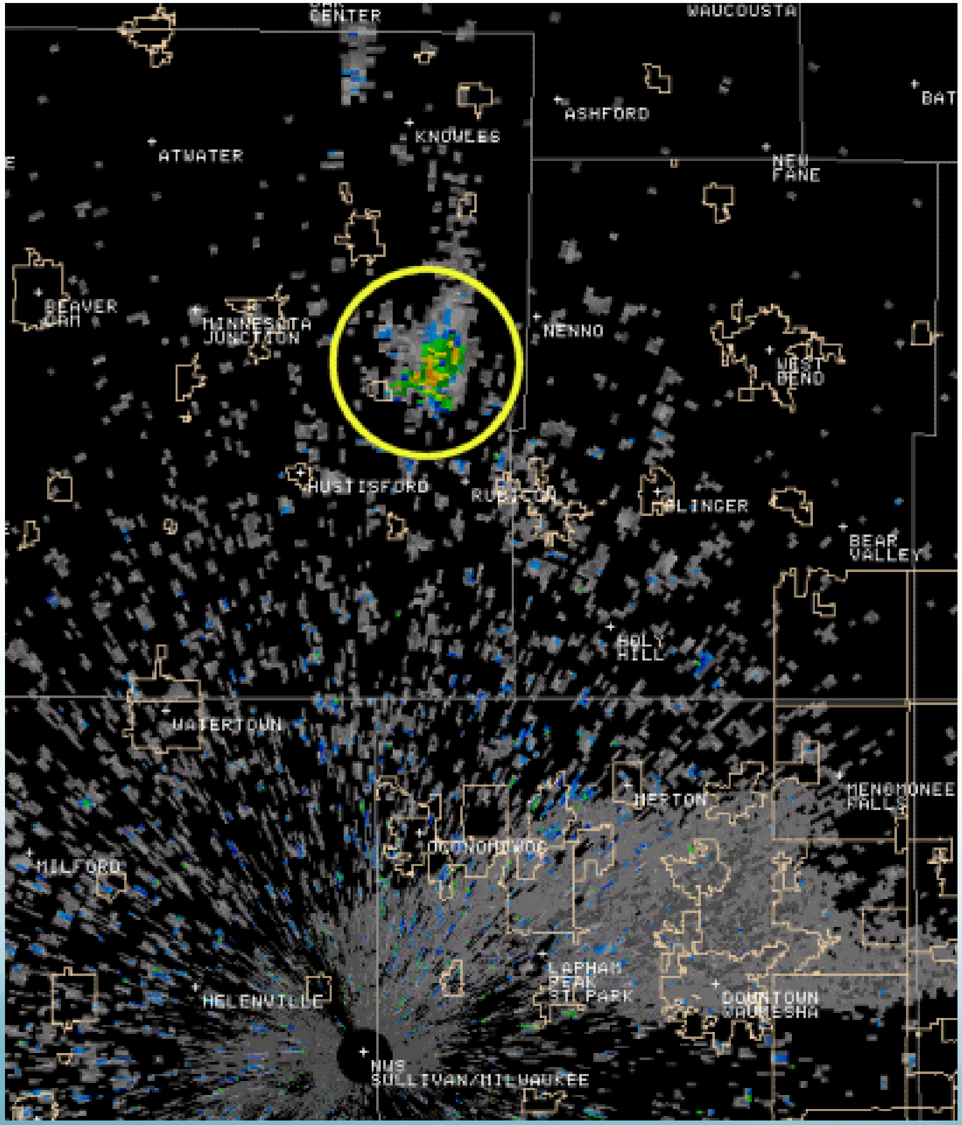


In **Base Velocity** & **Storm Relative Velocity** images.

Purple color: "**Range Folding**"

Radar system has difficulty determining velocity information due to interference from targets at a greater distance.

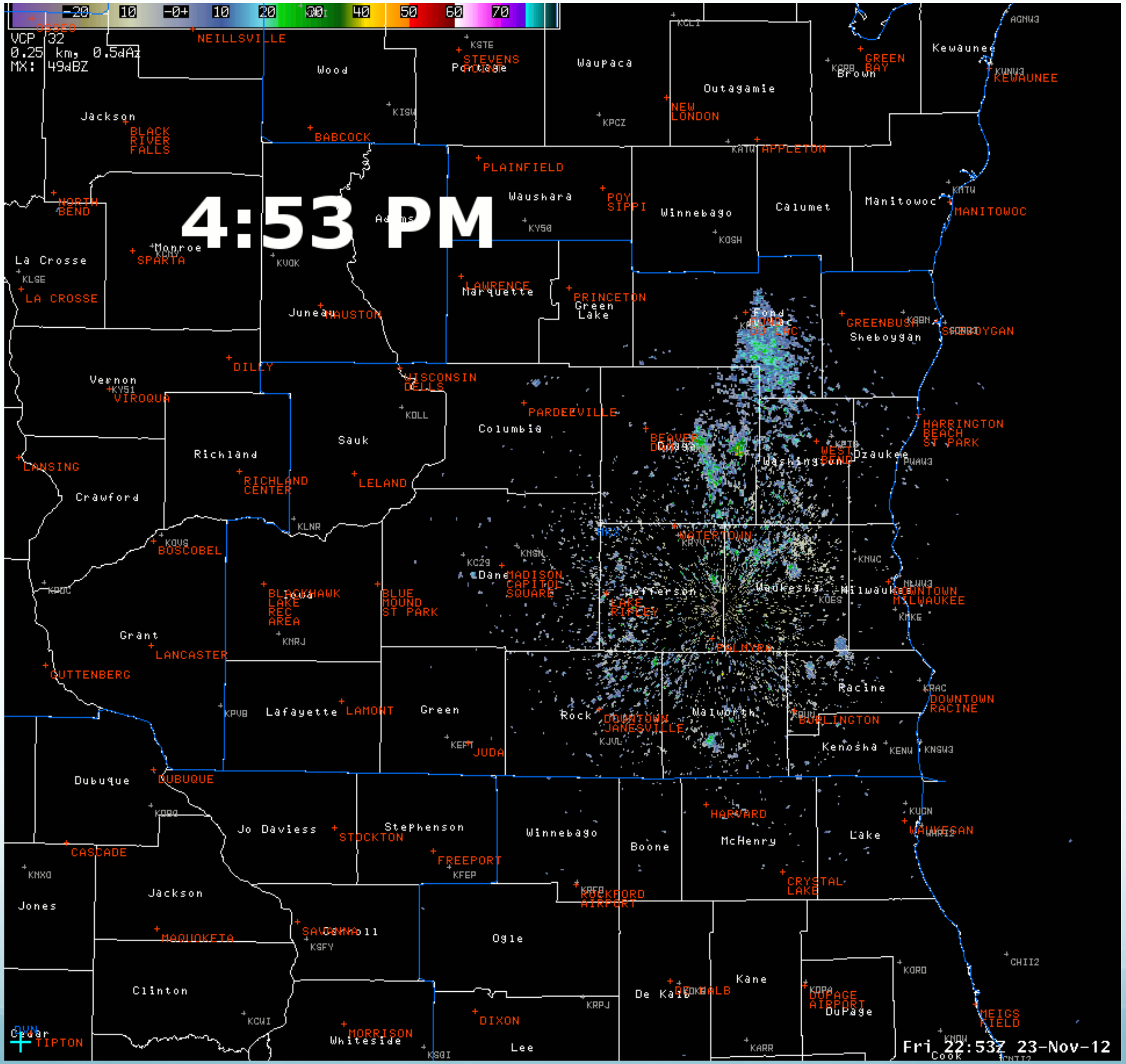
Radar Image – Wind Turbine Farms



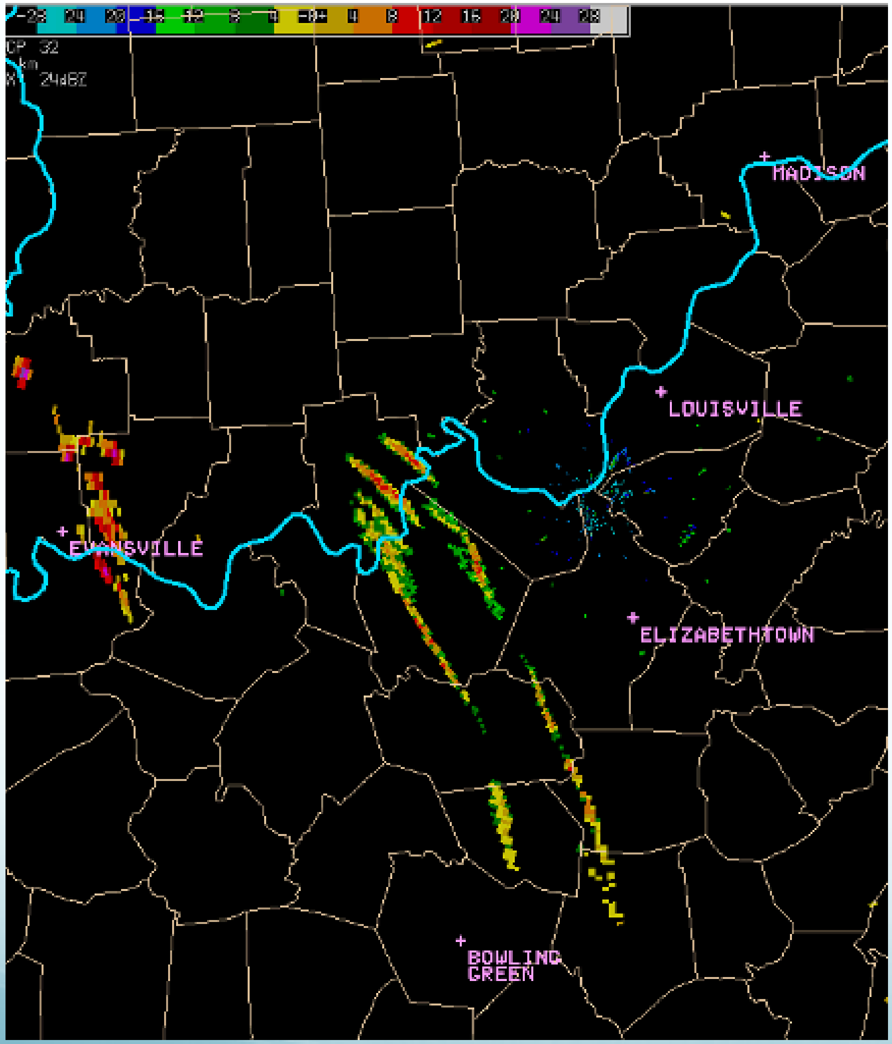
Note the "echo" does not move. There are no clouds or precipitation in the area.

The bottom of the radar beam intersects with the top of the moving turbine blades.

Radar Image – Bird Flocks



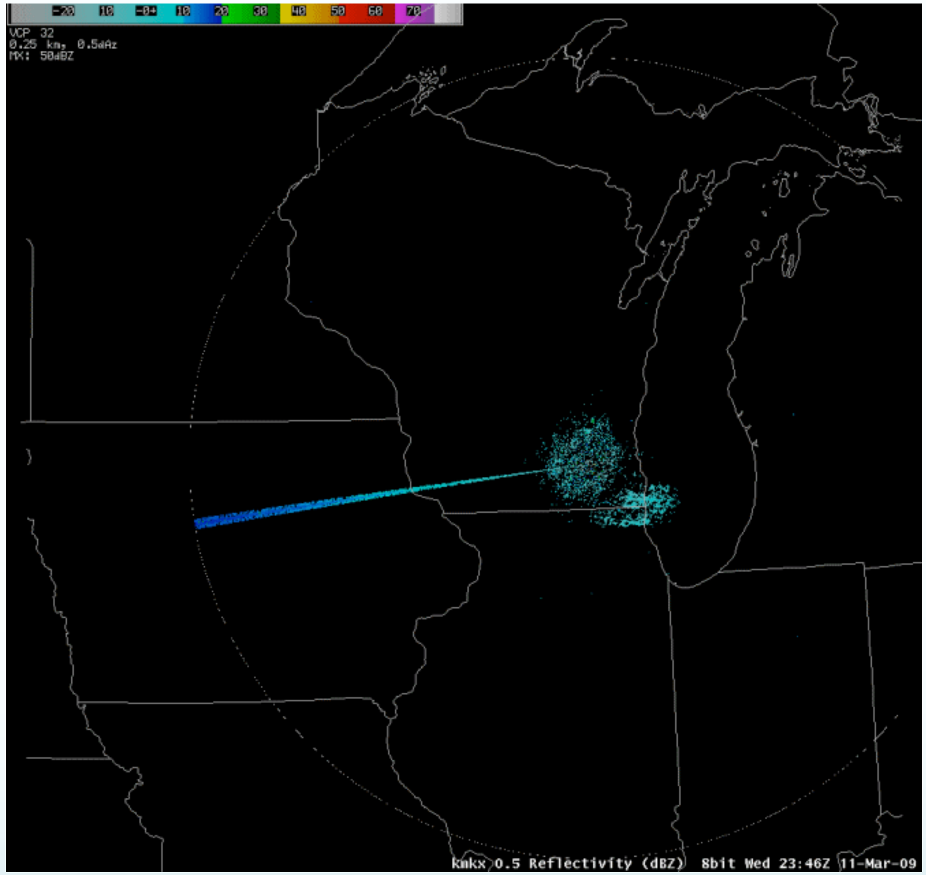
Chaff – Military Countermeasure



Highly reflective material like aluminum which floats slowly downward

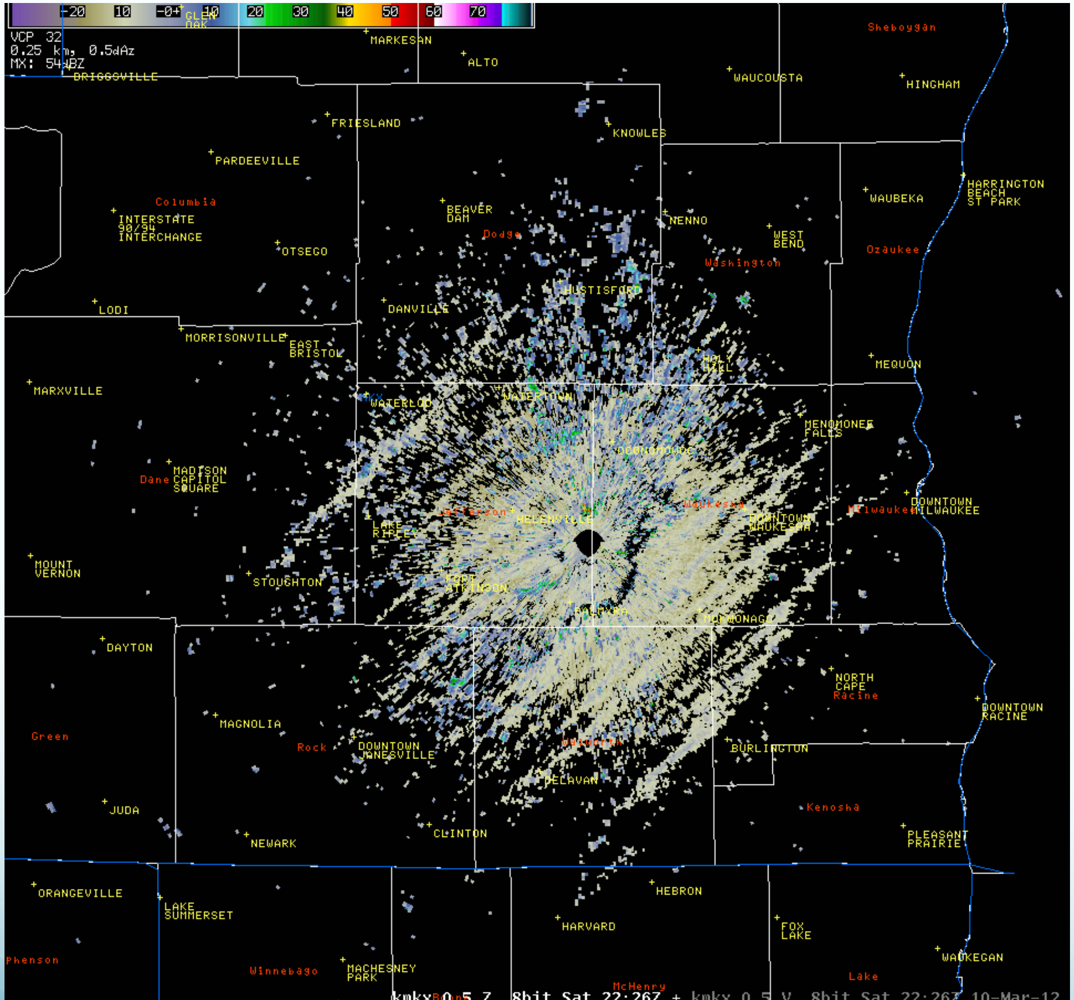
Released by military planes in order to confuse enemy and make it more difficult to detect your planes

Radar Image – Sunset Spike



Interference between Sun's energy with Doppler signal when Sun near horizon (near sunrise or sunset)

Radar Image – Smoke Plume



Note: any moving "target" on radar is being moved/pushed by the wind.

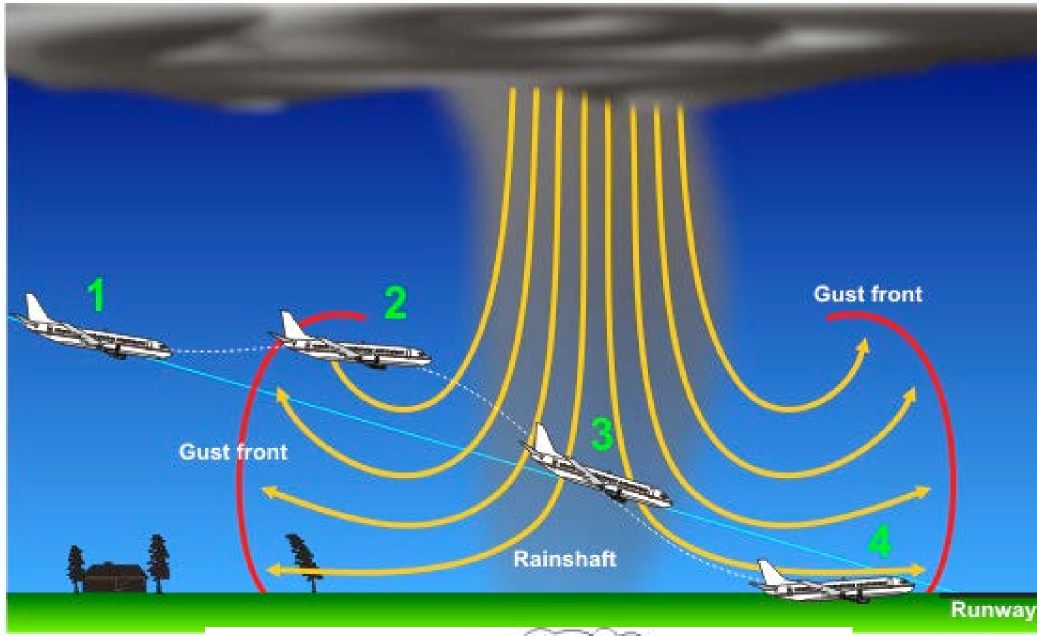
10-min Break

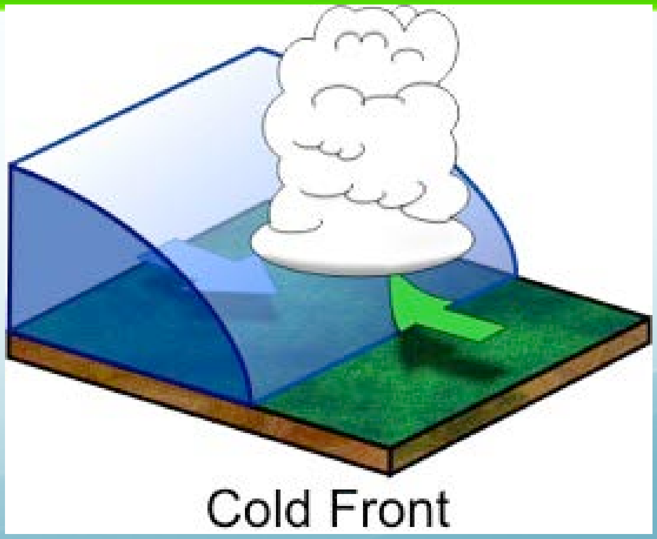
Low-level Boundaries

Rain-cooled air (wind) flowing out of the base of a thunderstorm (downdraft) has a leading edge called "gust front."

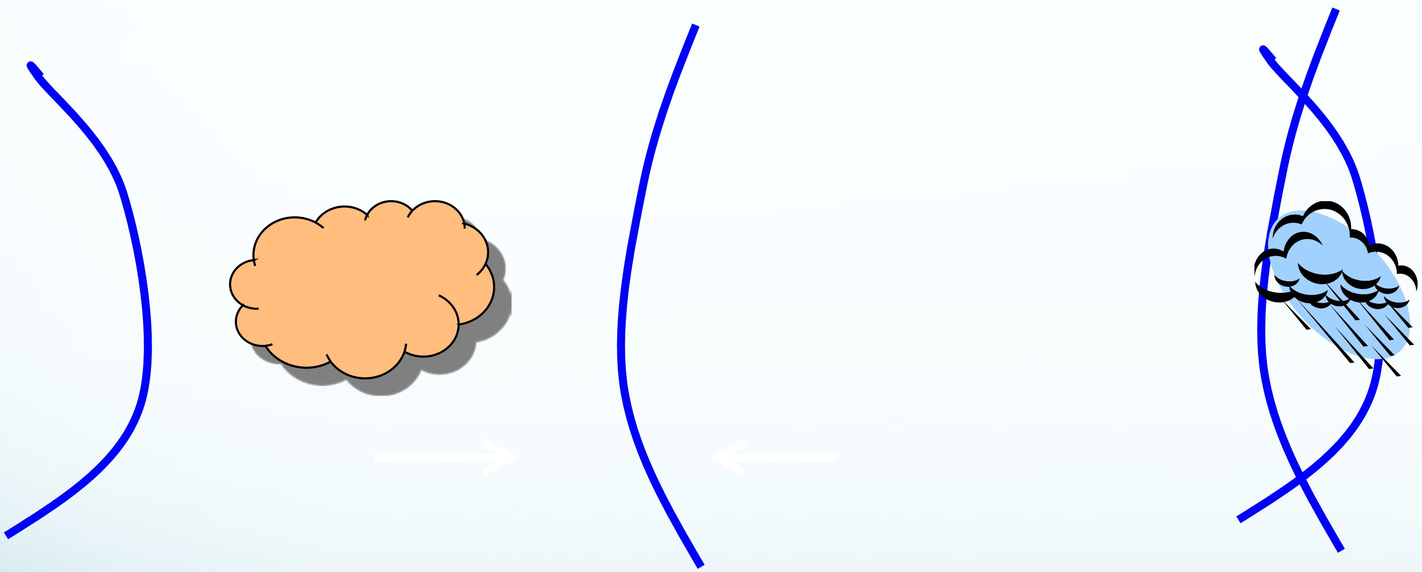
Gust front acts as a mini-cold front and is called a low-level boundary.

It can initiate or enhance showers and storms via "uplift."





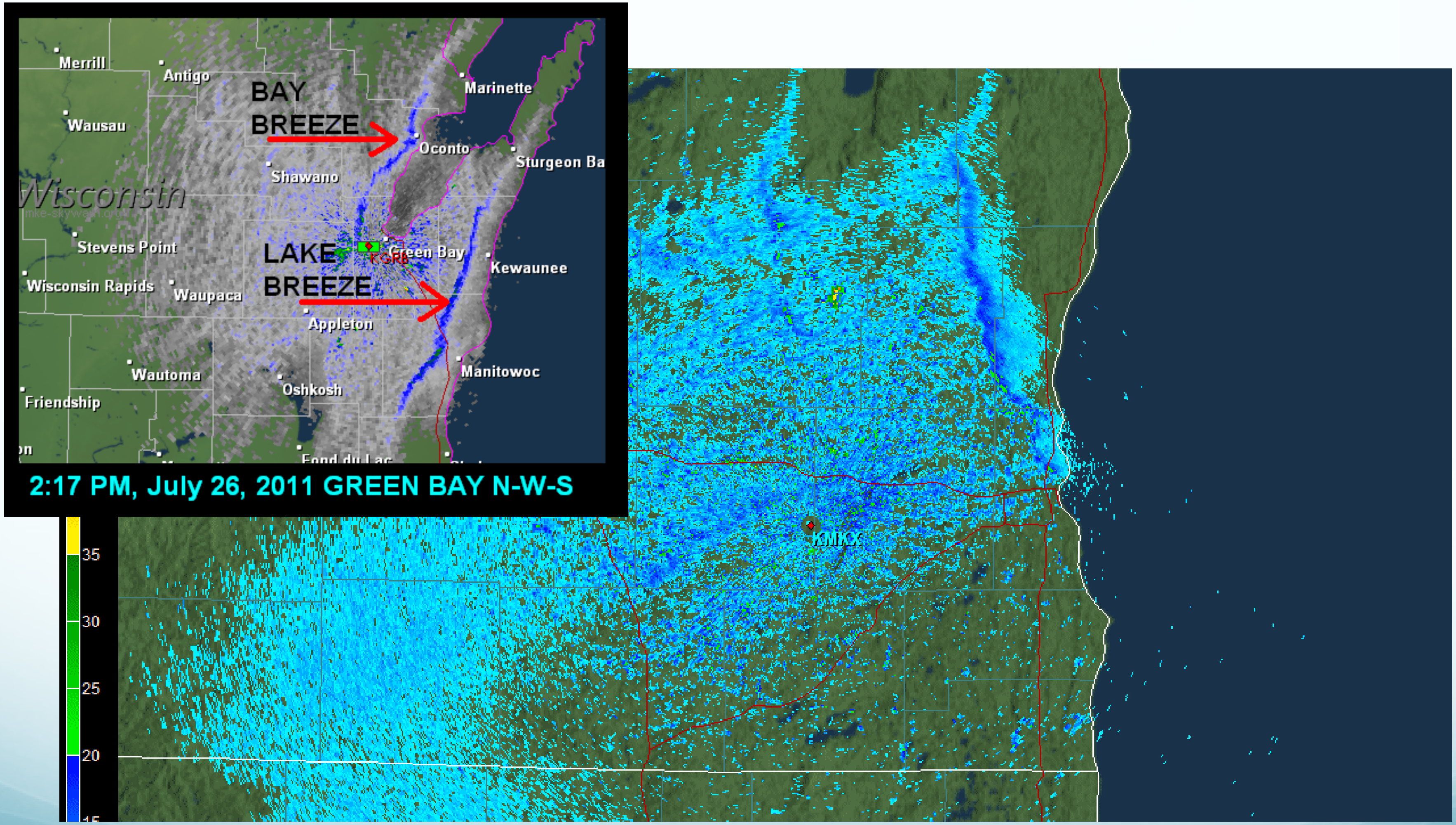
Storm Intensification Intersecting Low-Level Boundaries



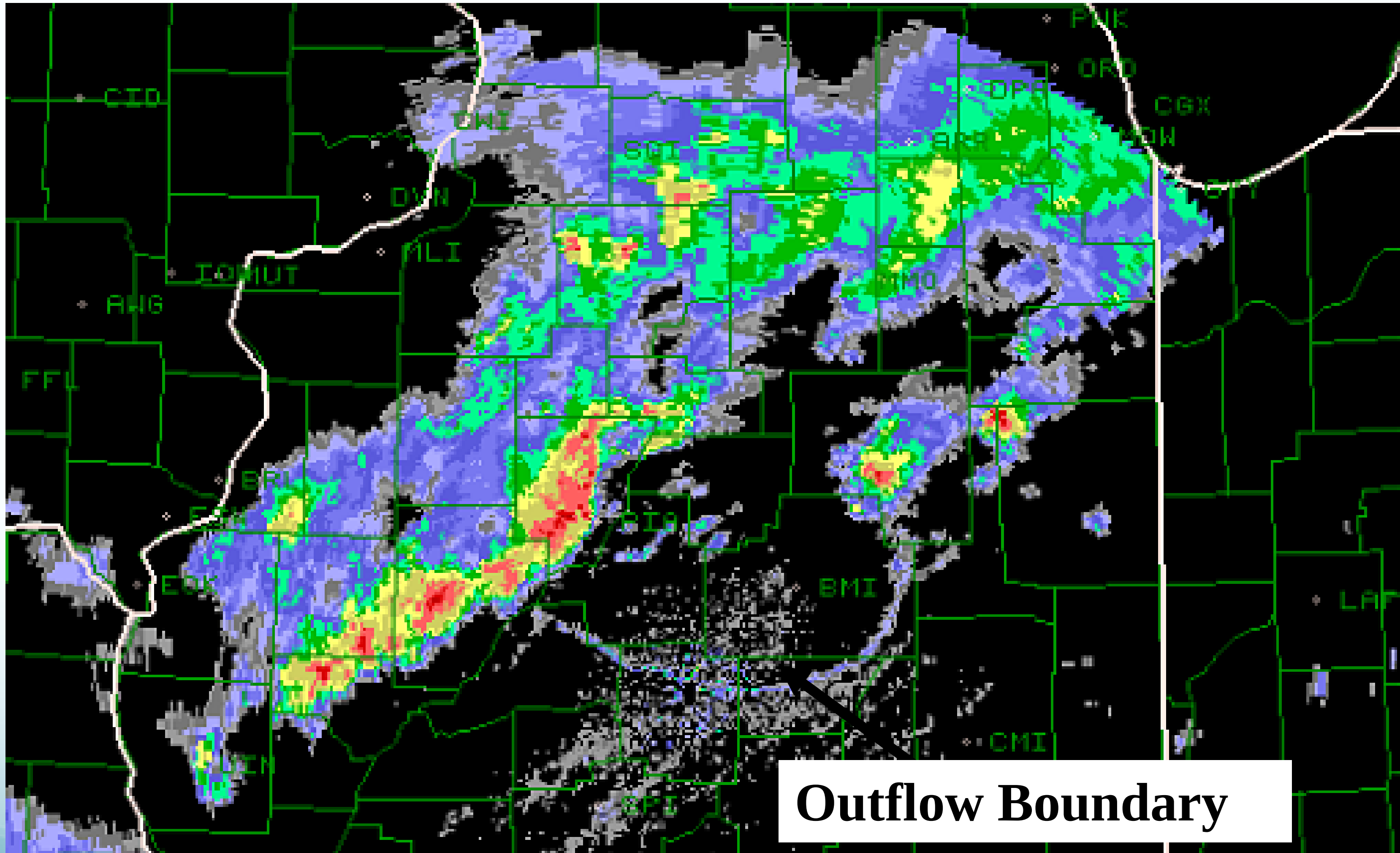
10 minutes ago

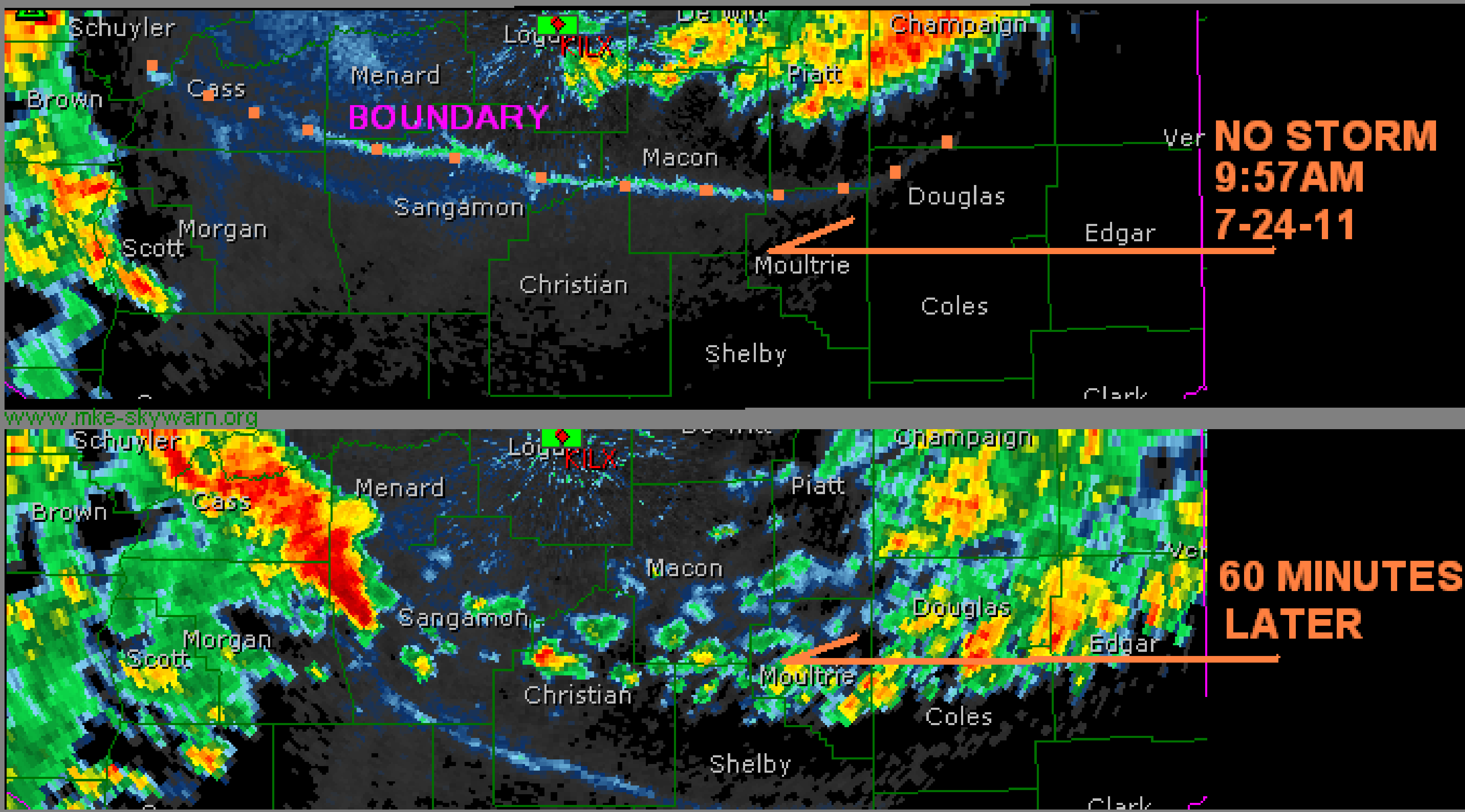
Now

Low-level Boundaries

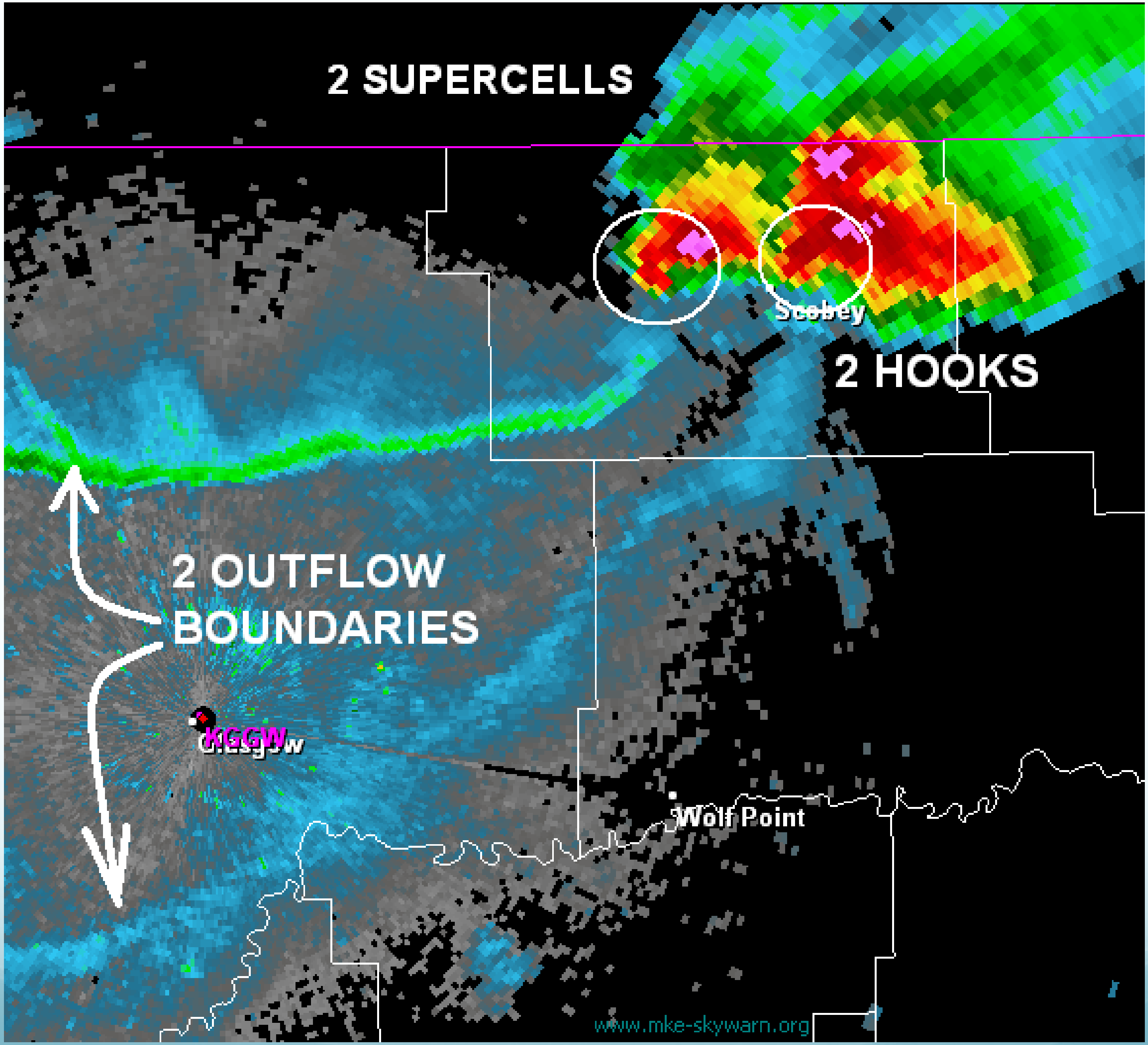


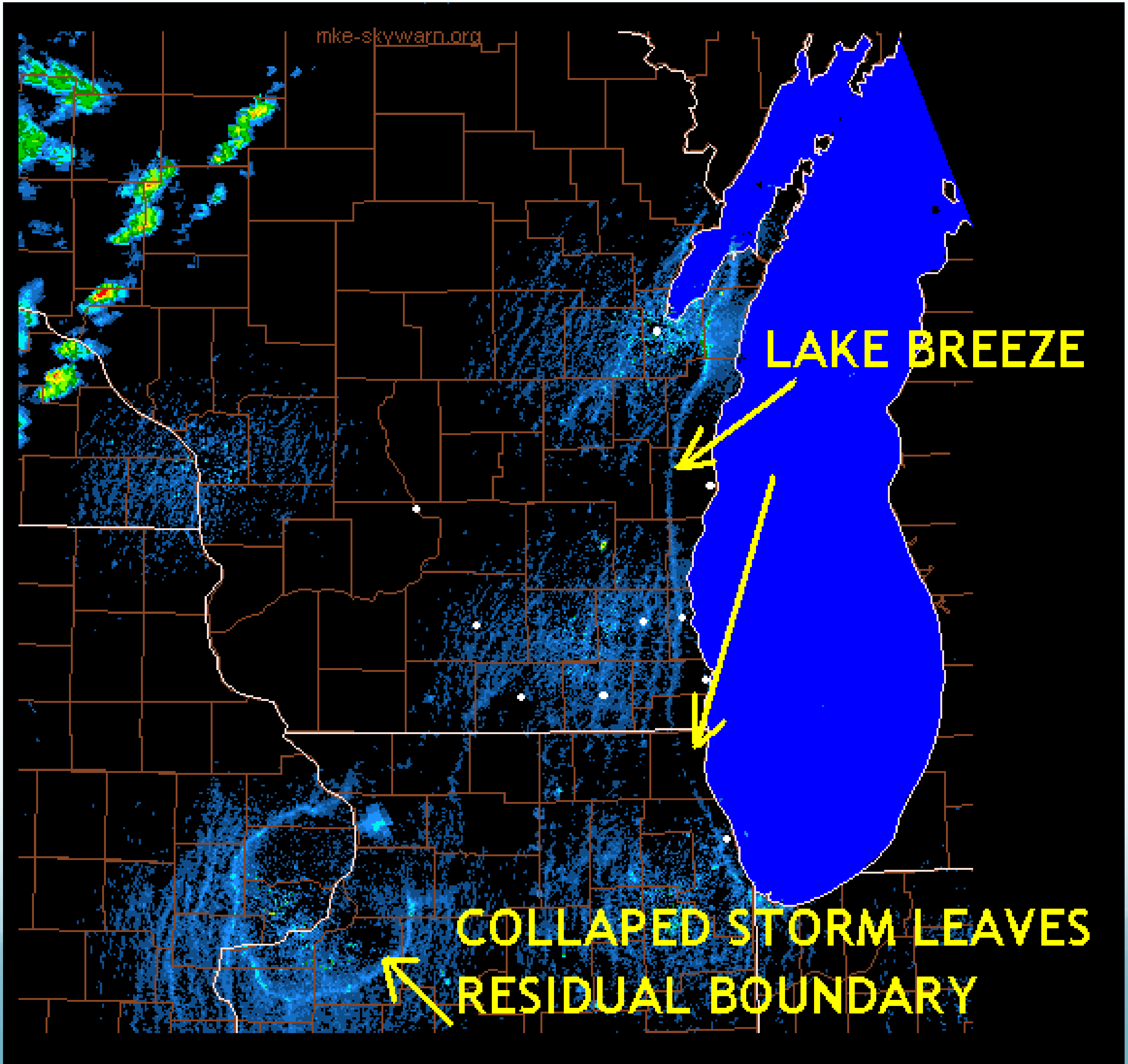
Outflow Boundaries



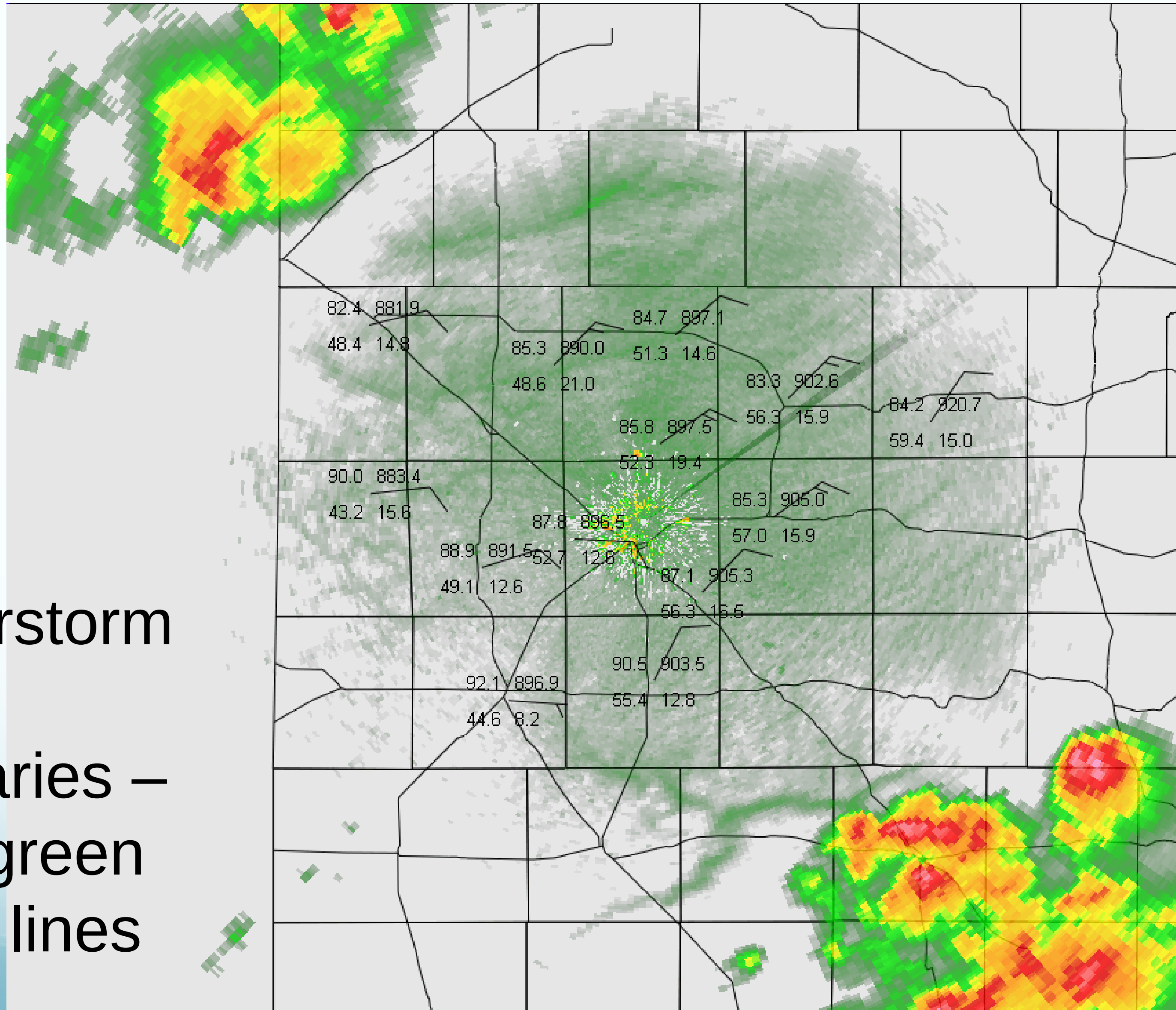


STRONG OUTFLOW BOUNDARY CREATED NEW STORMS WITHIN 60 MINUTES OVER CENTRAL ILLINOIS COUNTIES.

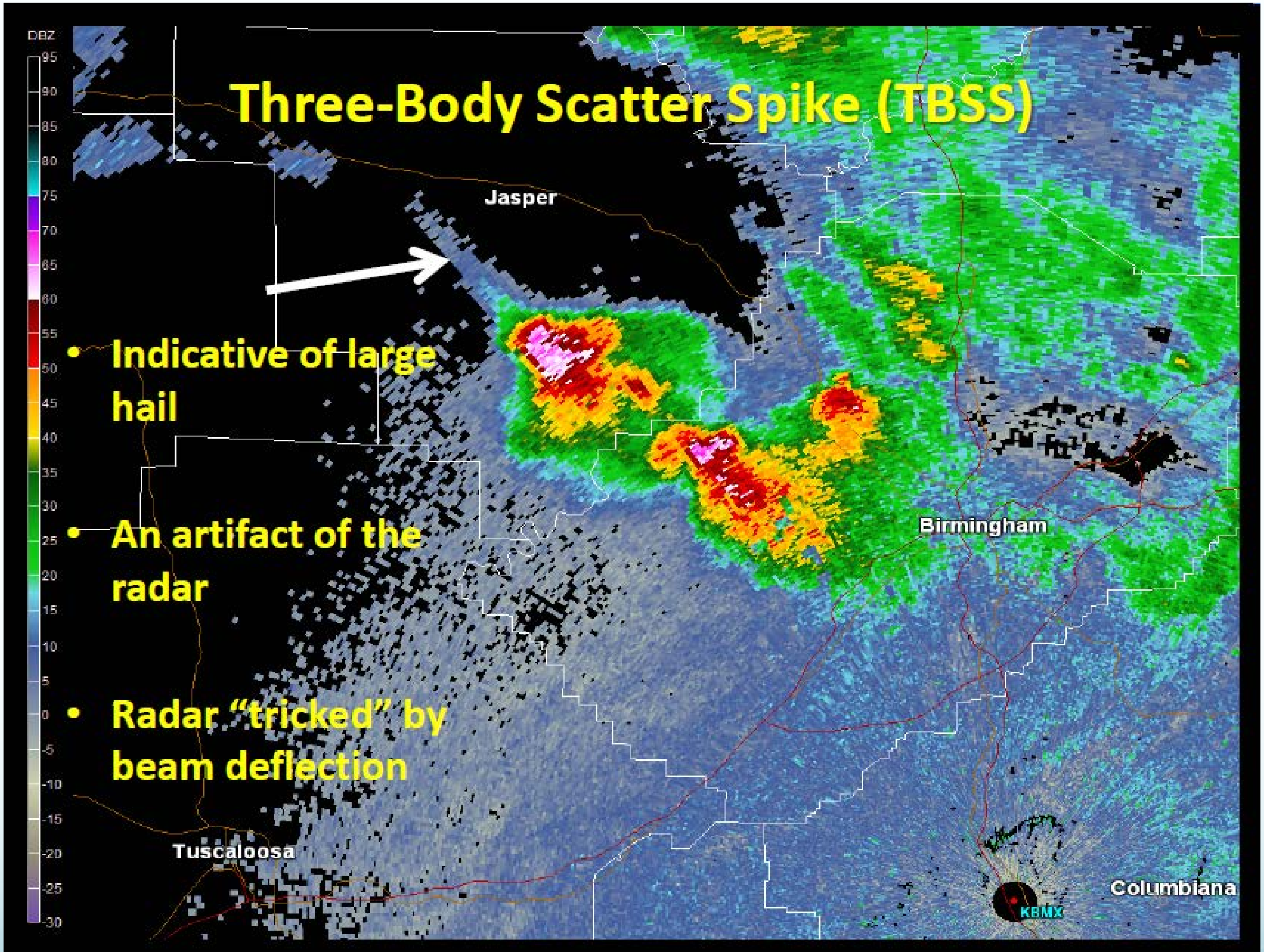

2 SUPERCELLS
2 HOOKS
Scobey
2 OUTFLOW
BOUNDARIES
KGGW
Glasgow
Wolf Point
www.mke-skywarn.org

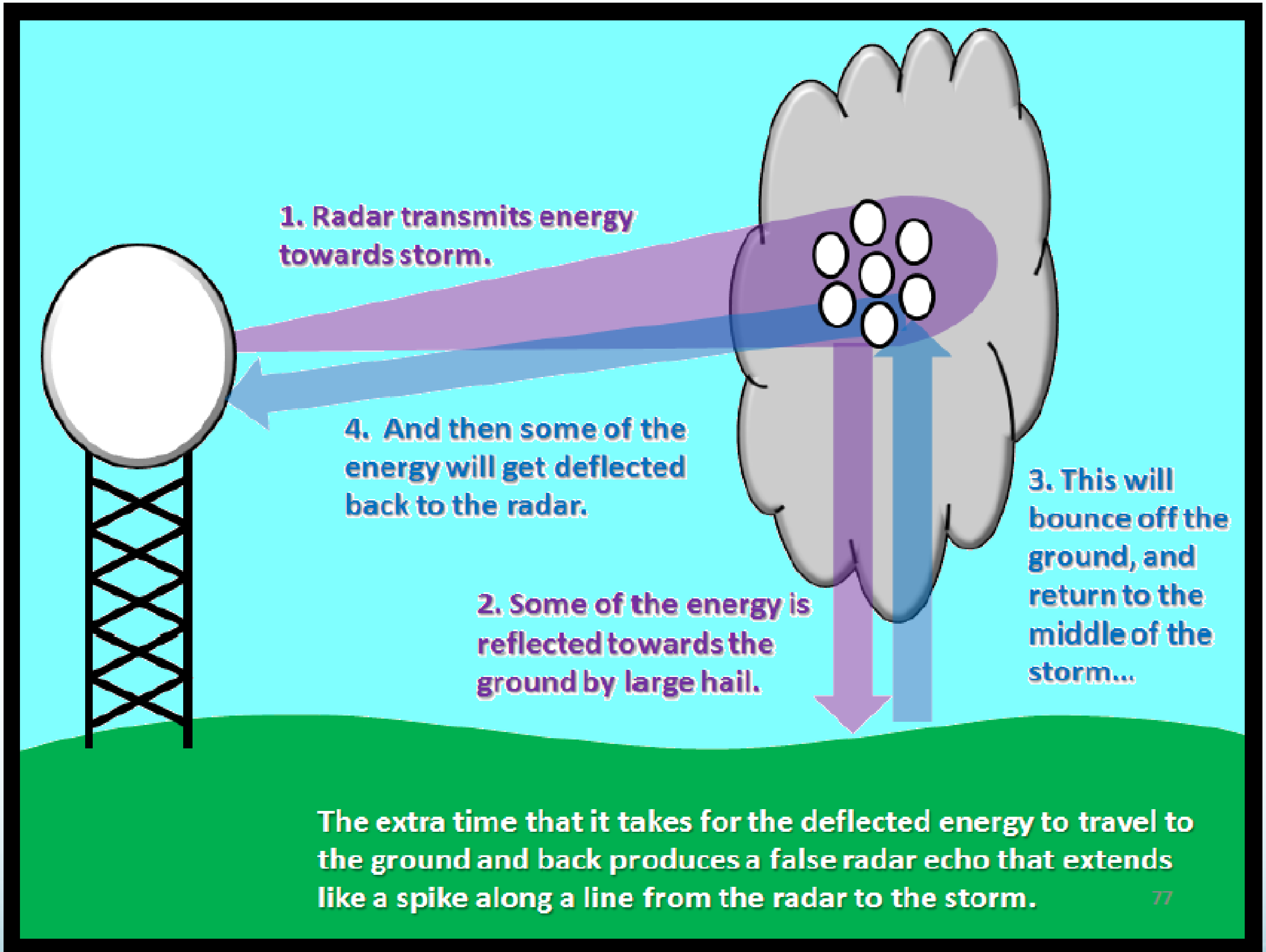

mke-skywarn.org
LAKE BREEZE
COLLAPED STORM LEAVES
RESIDUAL BOUNDARY

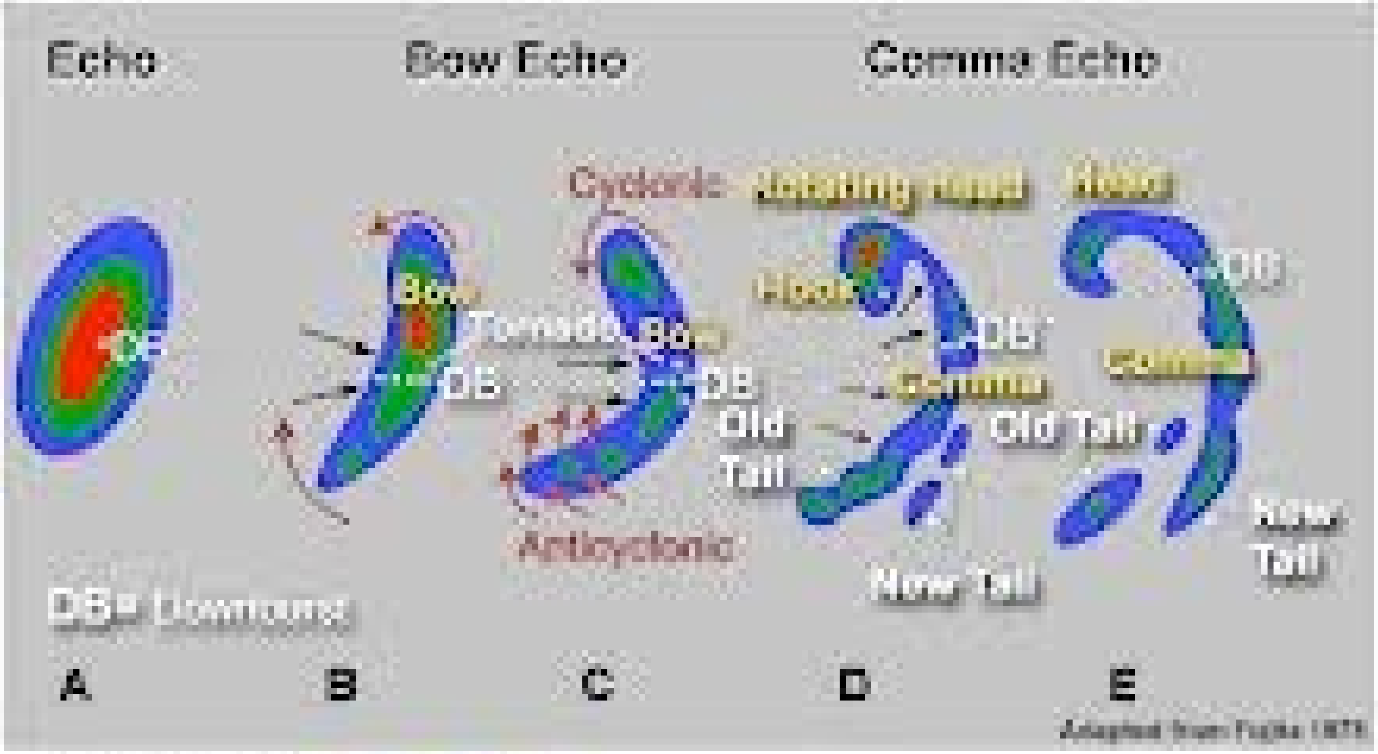
May 30, 2001 Texas Storm

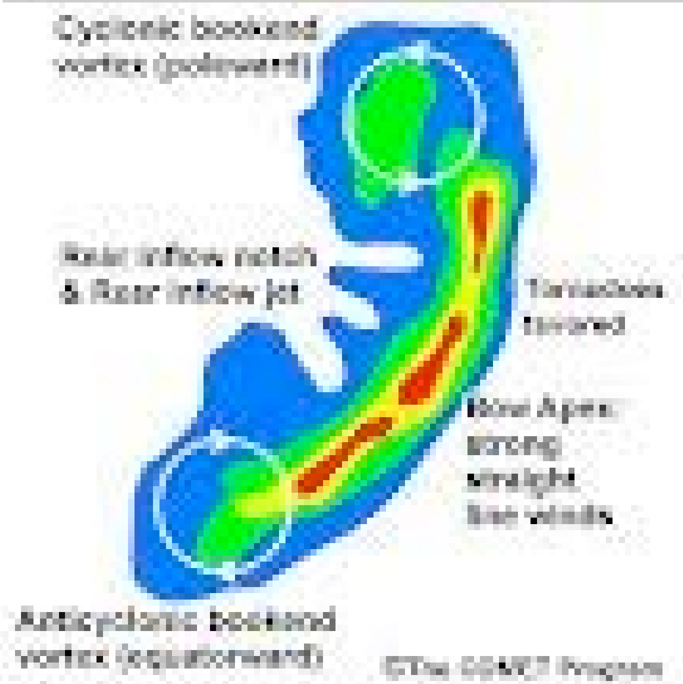


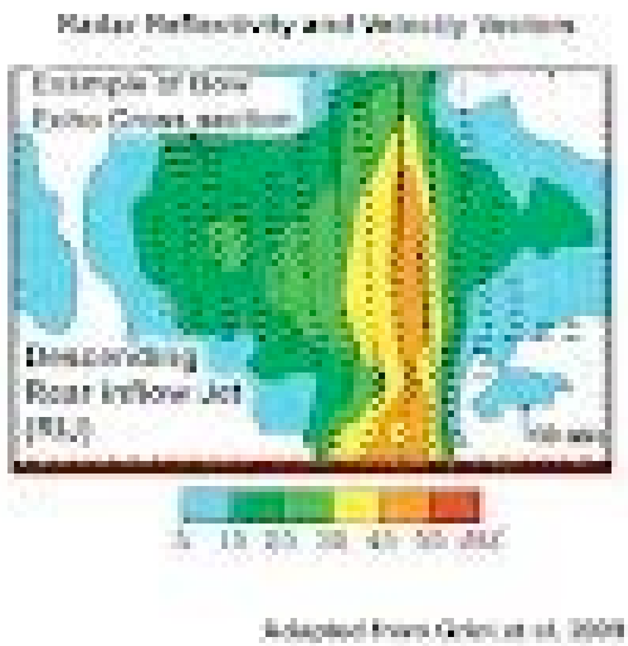
Note thunderstorm outflow boundaries – …thin green or blue lines


Three-Body Scatter Spike (TBSS)
• Indicative of large hail
• An artifact of the radar
• Radar "tricked" by beam deflection
Jasper
Birmingham
Tuscaloosa
Columbiana
KBMX
DBZ

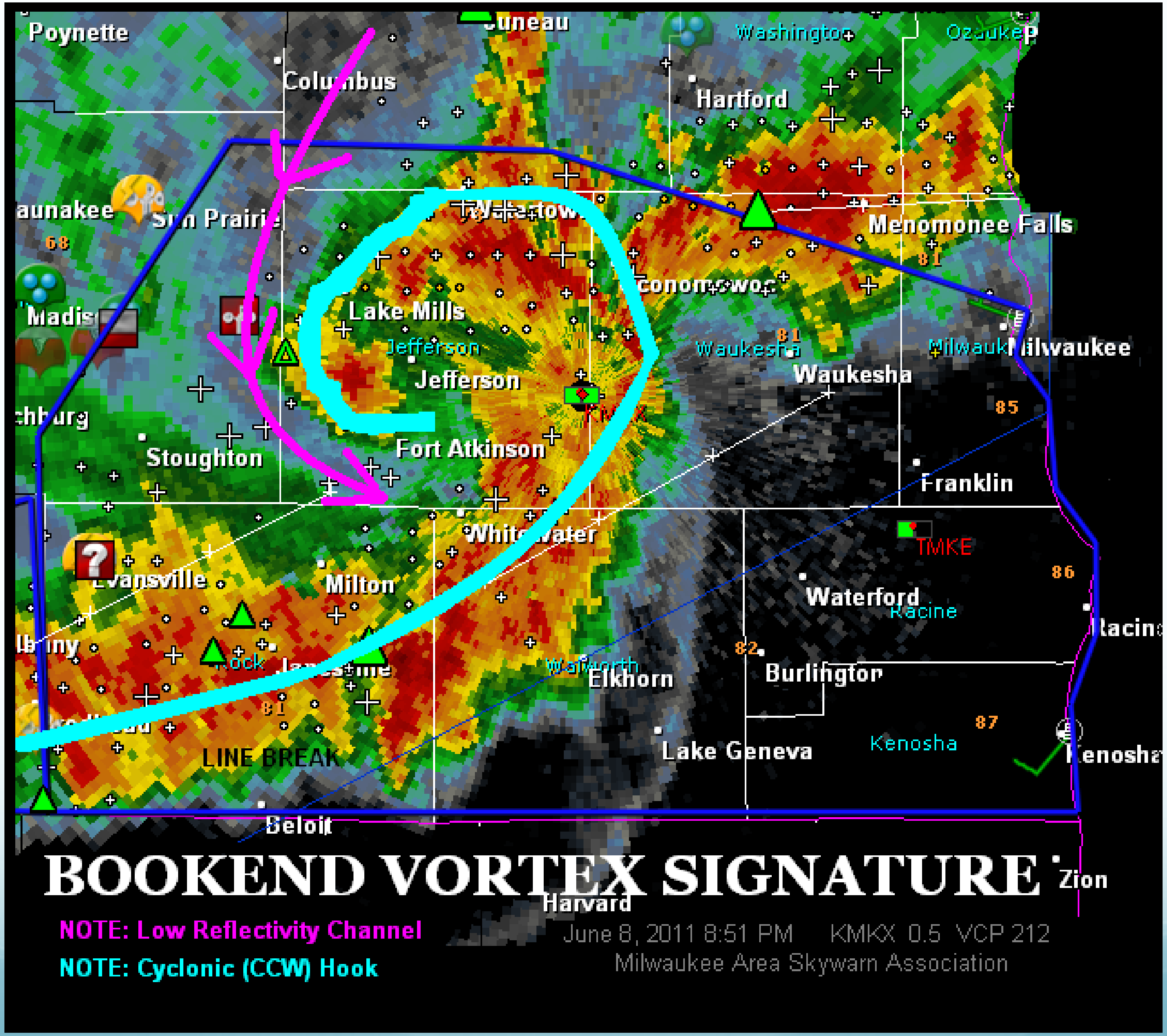

1. Radar transmits energy towards storm.
2. Some of the energy is reflected towards the ground by large hail.
3. This will bounce off the ground, and return to the middle of the storm...
4. And then some of the energy will get deflected back to the radar.
The extra time that it takes for the deflected energy to travel to the ground and back produces a false radar echo that extends like a spike along a line from the radar to the storm.


Echo
Bow Echo
Comma Echo
Cyclonic
Rotating Head
Head
Bow
Tornado
DB
Old Tail
Anticyclonic
Comma
New Tail
A
B
C
D
E

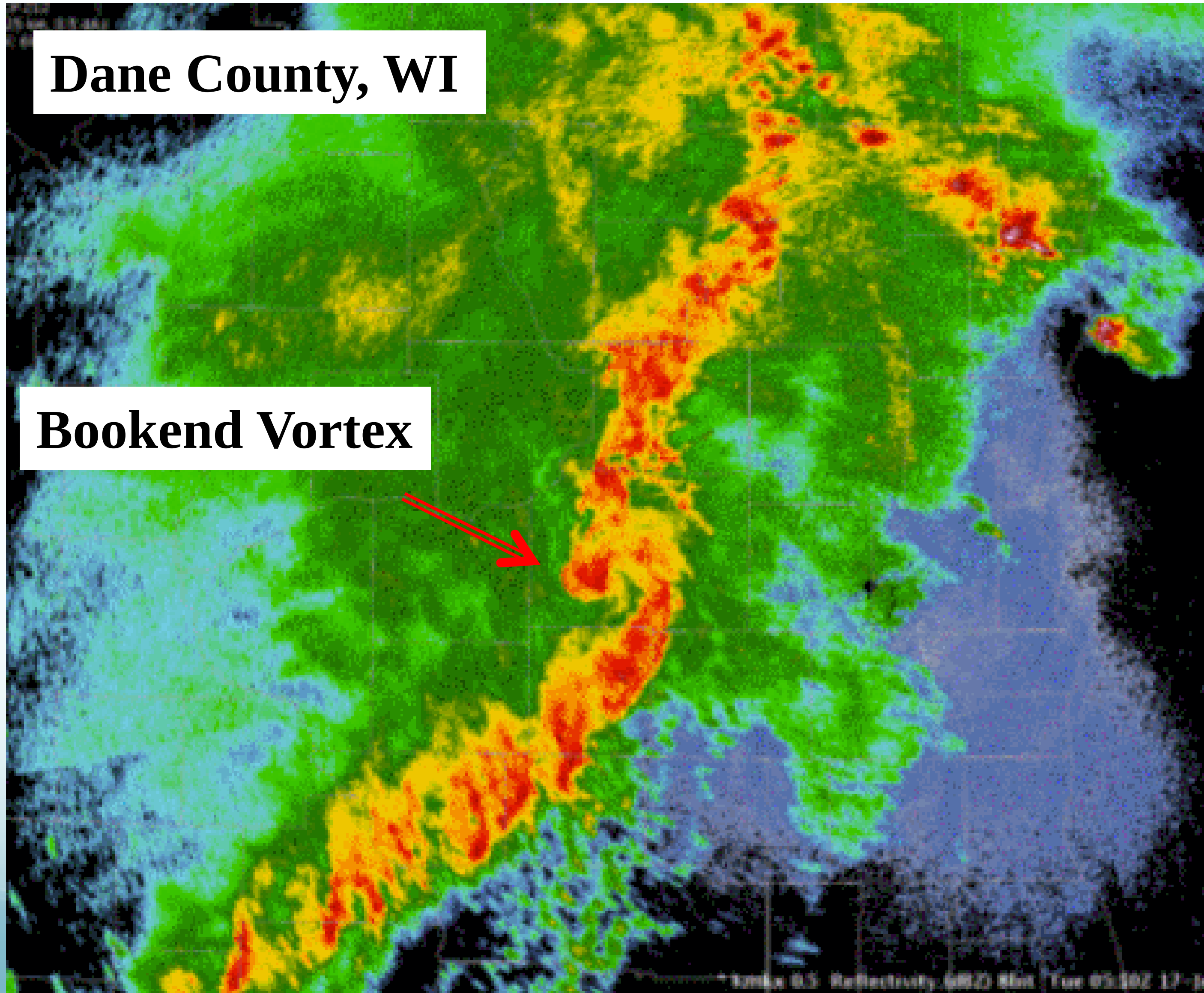

Cyclonic bookend vortex (poleward)
Rear inflow notch & Rear inflow jet
Tornadoes favored
Bow Apex: strong straight line winds
Anticyclonic bookend vortex (equatorward)


Radar Reflectivity and Velocity Vectors
Descending Rear Inflow Jet (RIJ)

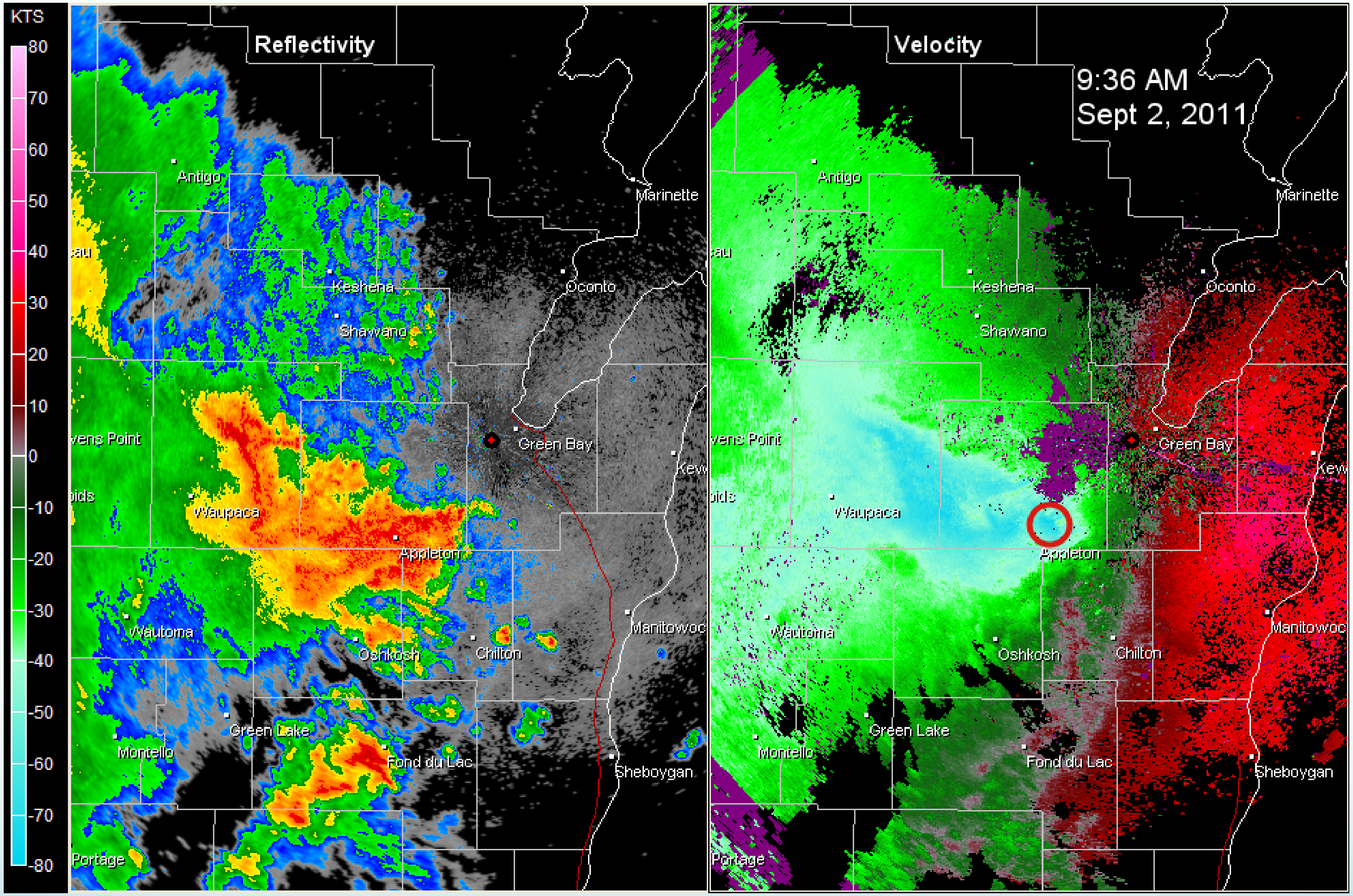
Bow Echo


Poynette
Columbus
Hartford
Washington
Ozaukee
Sun Prairie
Menomonee Falls
Madison
Lake Mills
Jefferson
Jefferson
Waukesha
Waukesha
Milwaukee
Stoughton
Fort Atkinson
Franklin
Whitewater
TMKE
Evansville
Milton
Waterford
Racine
Elkhorn
Burlington
Lake Geneva
Kenosha
LINE BREAK
Beloit
BOOKEND VORTEX SIGNATURE
Zion
Harvard
NOTE: Low Reflectivity Channel
NOTE: Cyclonic (CCW) Hook
June 8, 2011 8:51 PM KMKX 0.5 VCP 212
Milwaukee Area Skywarn Association

June 16, 2014 Tornadoes



Sep 2, 2011 AppletonWI Wind Storm

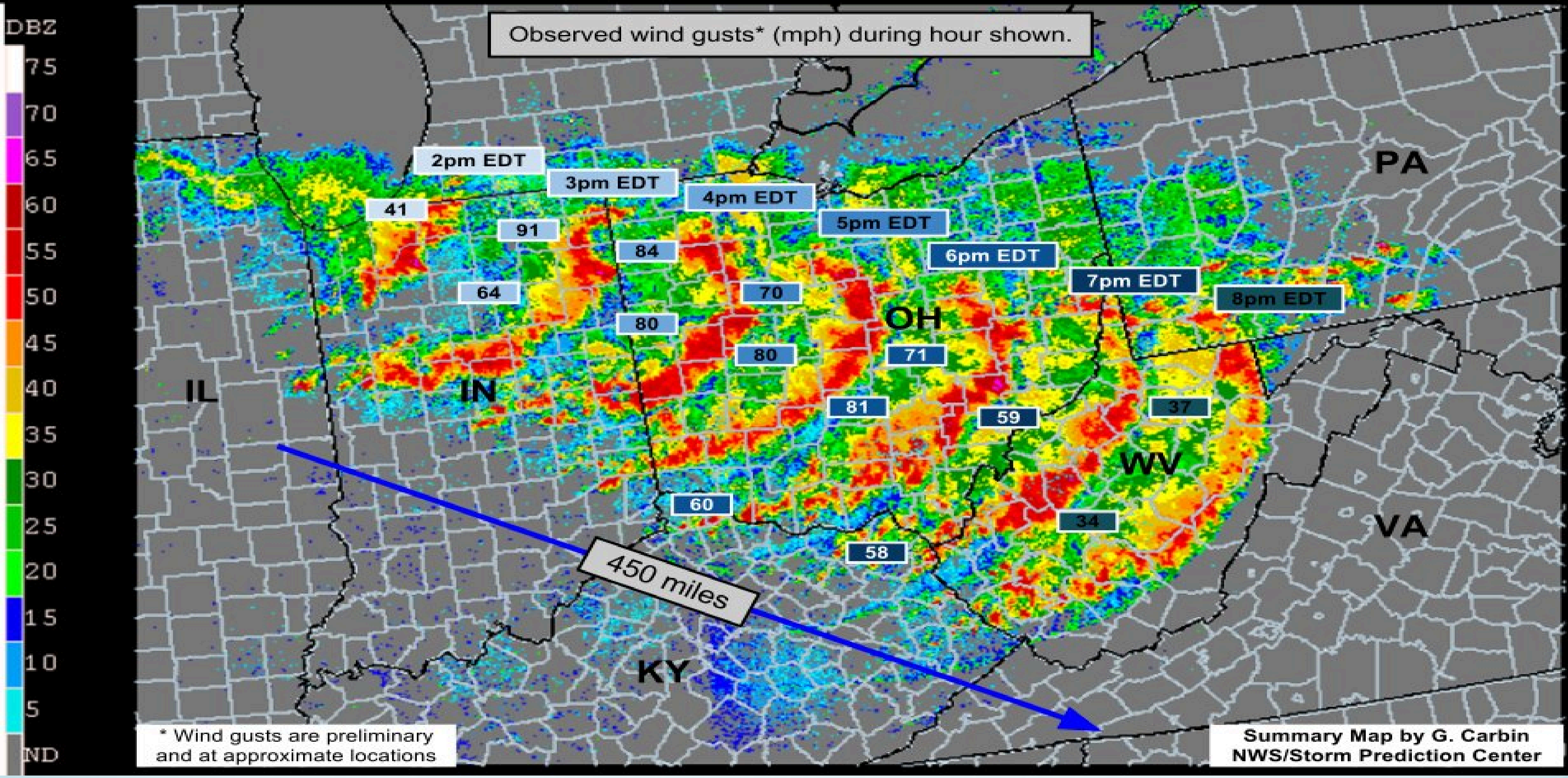


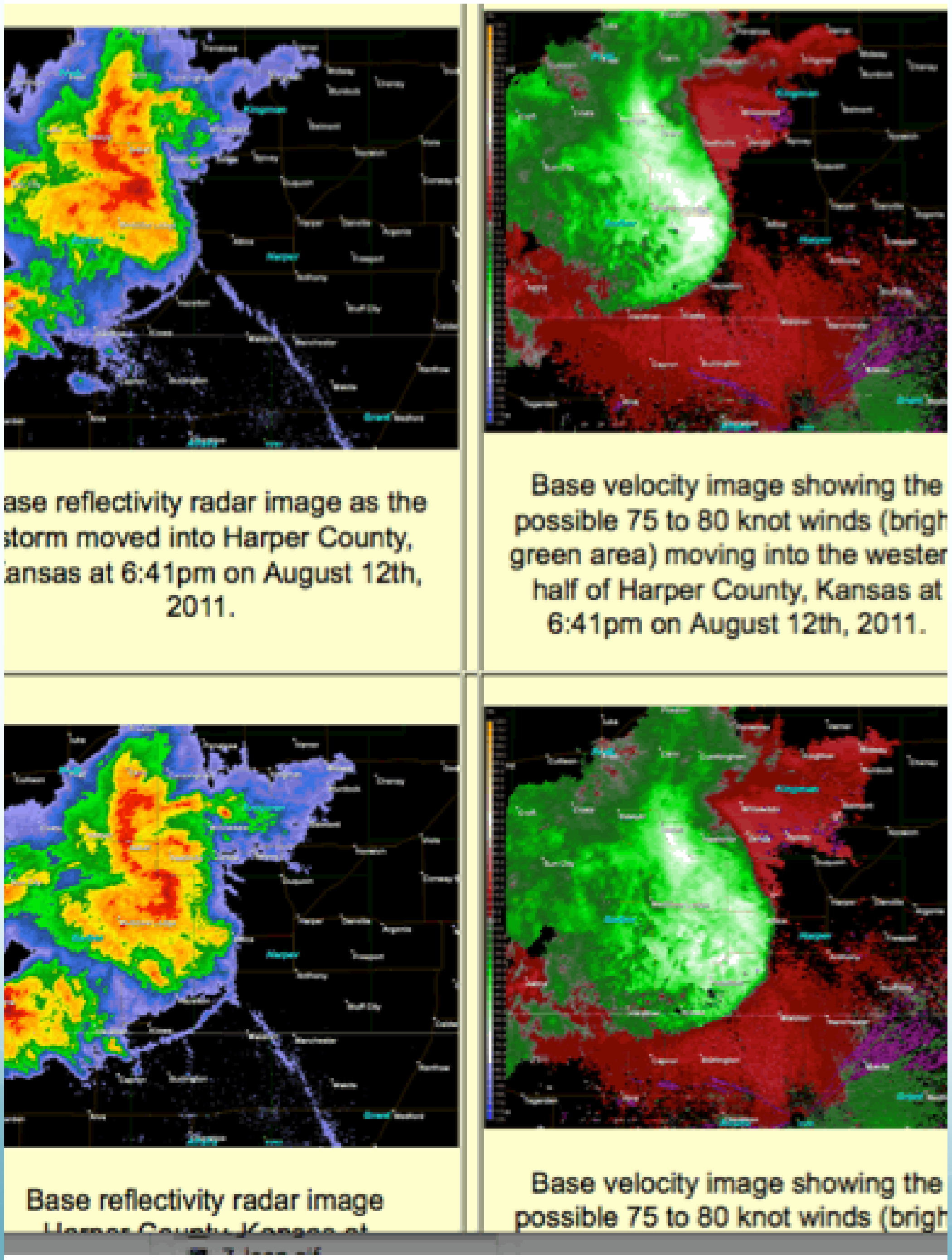
Base Reflectivity

Base Velocity

Look for a large glob of green/blue or red – straight-line winds

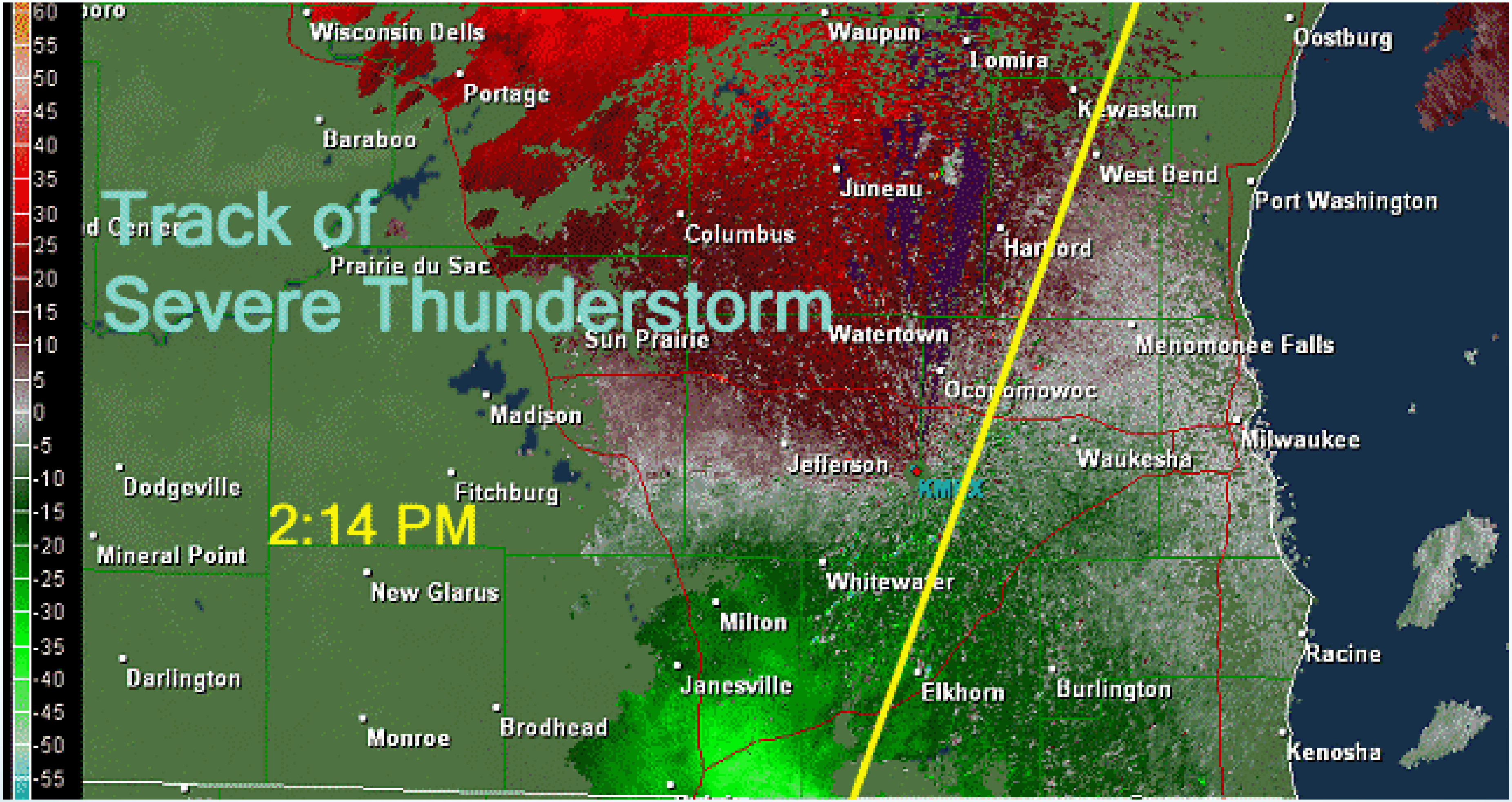
June 29, 2012 Midwest/Ohio Valley Derecho
Radar Imagery Composite Summary 18-00 UTC
~450 miles in 6 hours / Average Speed ~75 mph





Tstm Downburst Winds

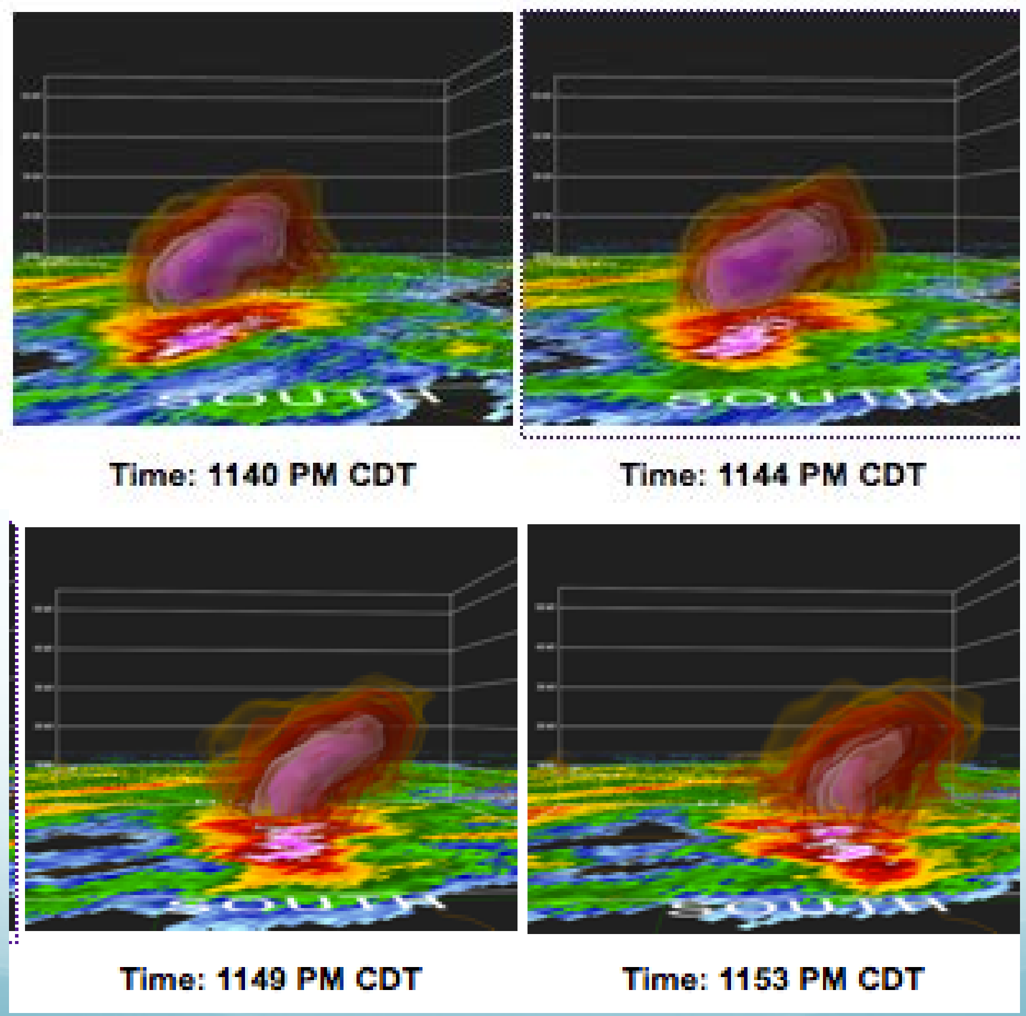
Base Velocity



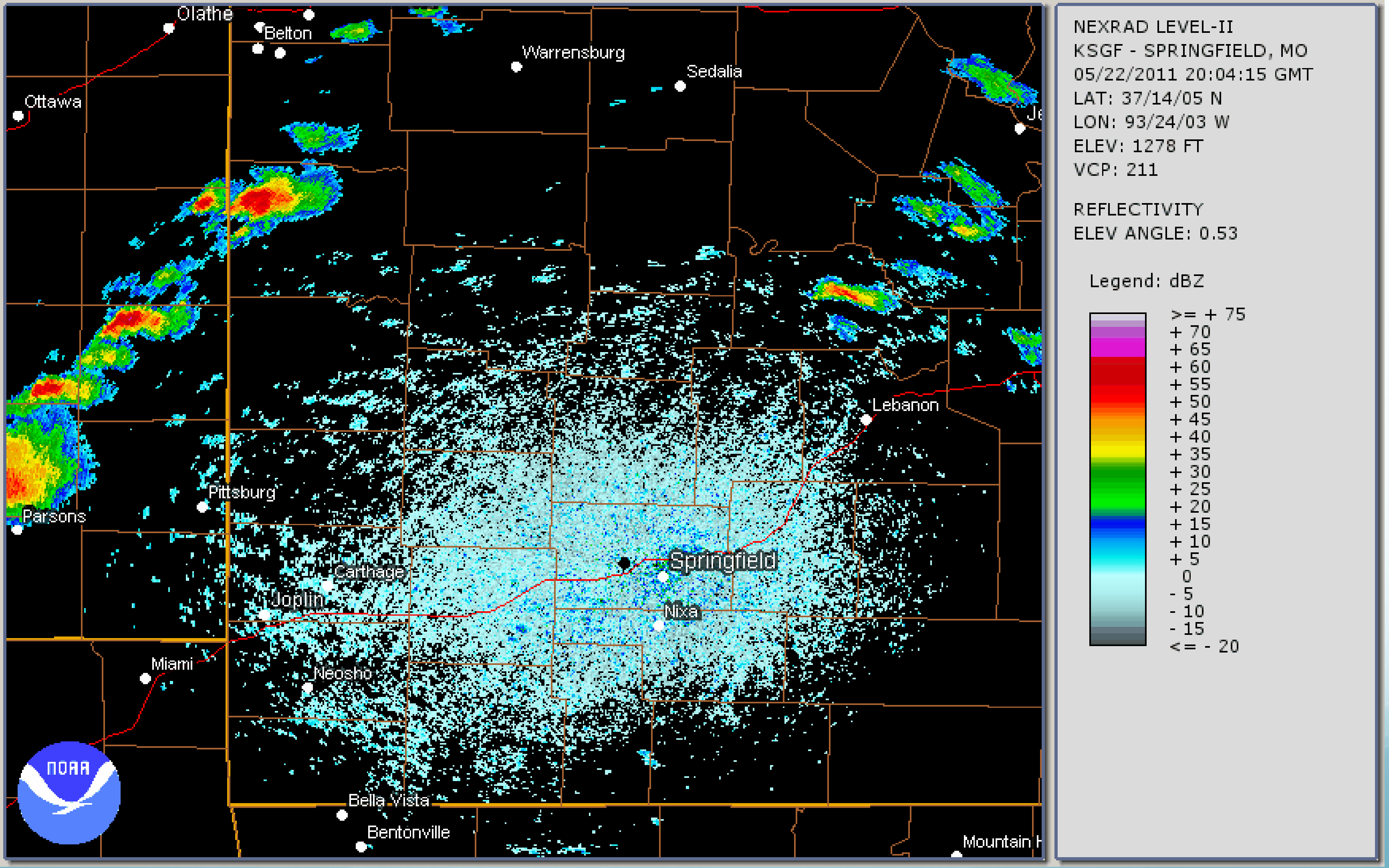
Base Velocity June 21, 2011

Straight-line winds – 80 to 100 mph Waukesha County

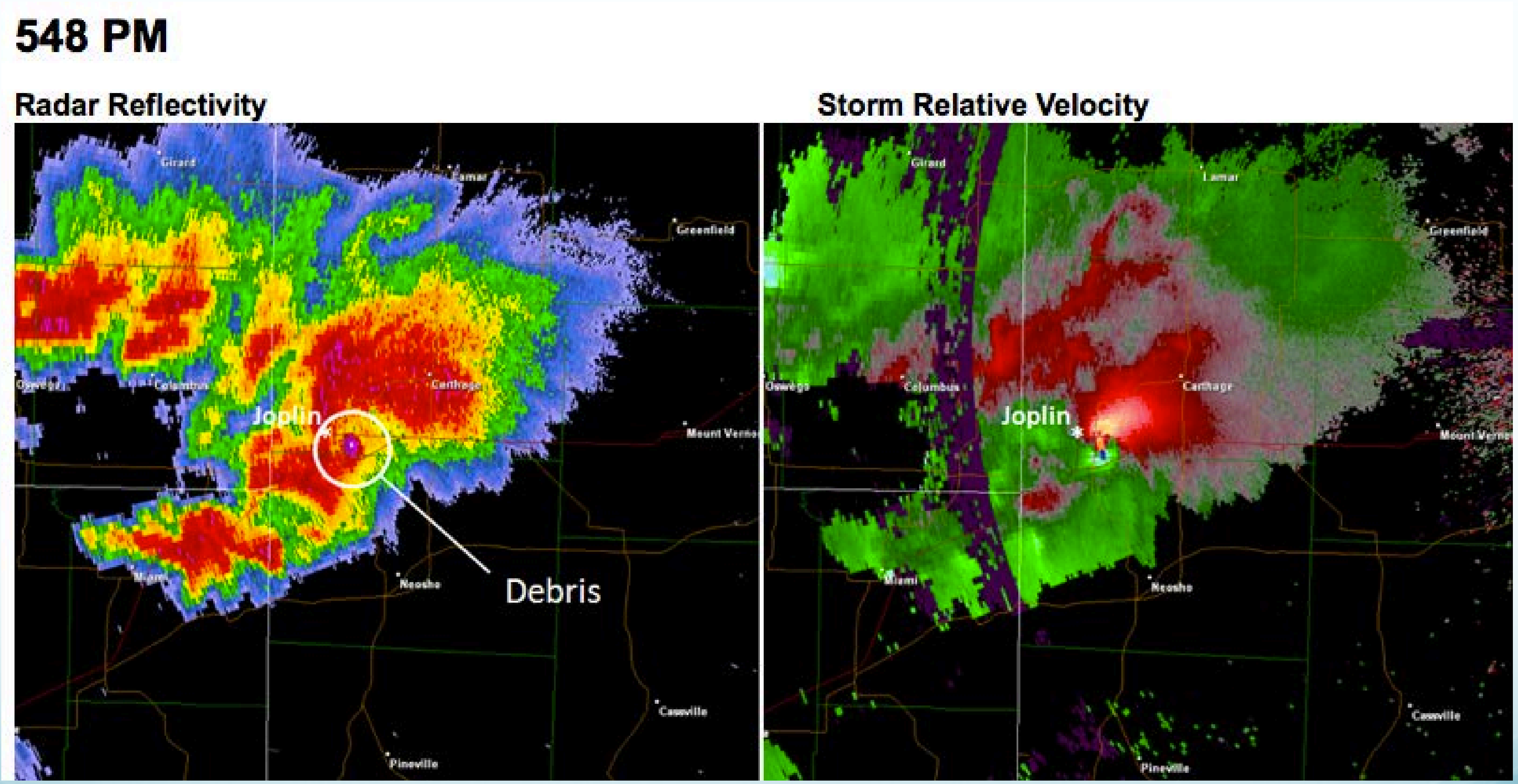
Downburst Winds
Decending Reflectivity Core



Joplin, MO, EF5 Tornado



Joplin, MO, EF5 Tornado



May 31, 2013
Norman Radar Loops

https://www.youtube.com/watch?feature=player_embedded&v=ugdNiW8YSxI

https://www.youtube.com/watch?feature=player_detailpage&v=qGiHqQ2xiNQ

May 20, 2013
Moore, OK EF5 Tornado

https://www.youtube.com/watch?v=HncWemM5fJc

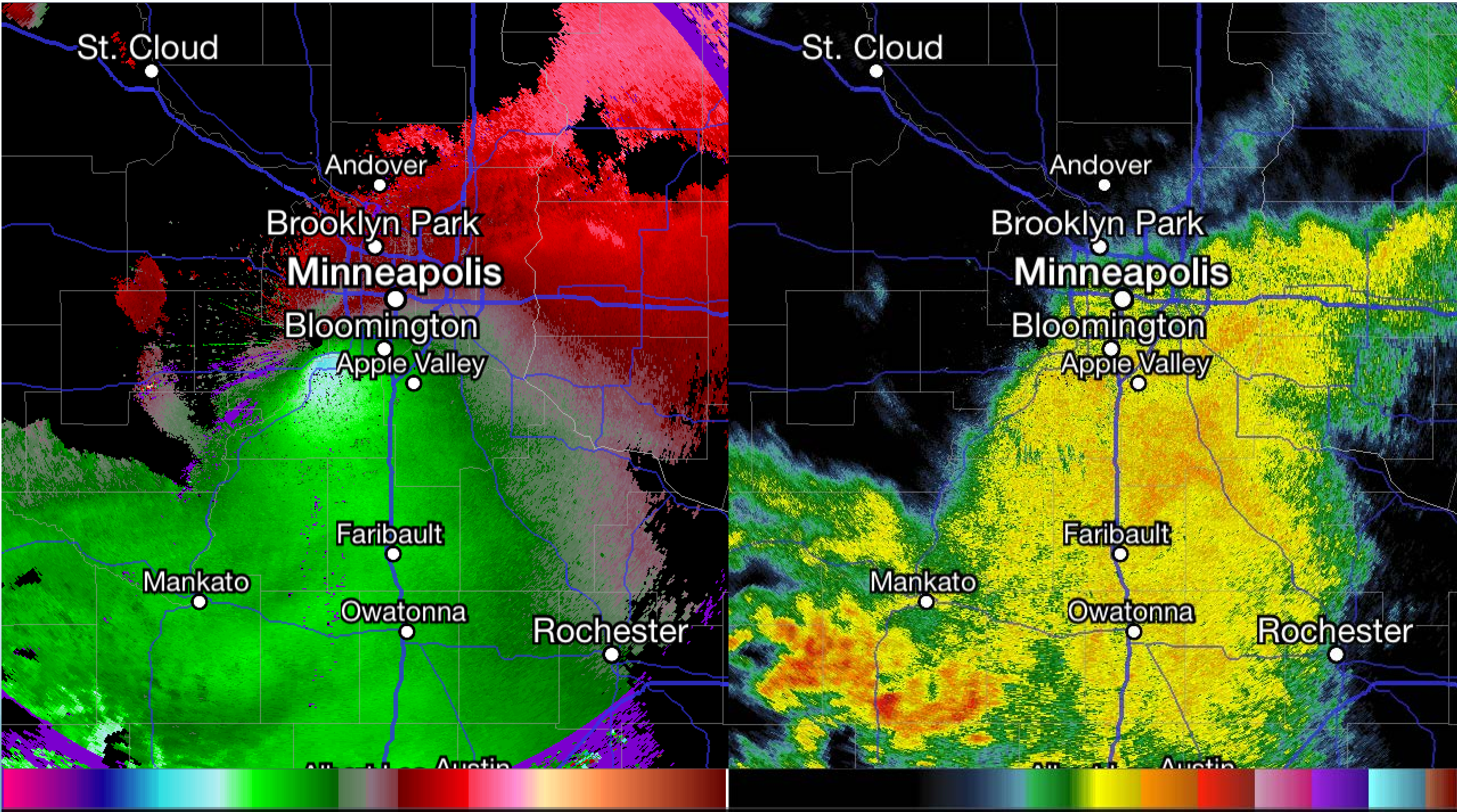
May 19, 2013
Shanee, OK Tornado

https://www.youtube.com/watch?v=uYu1FZ3ieXA

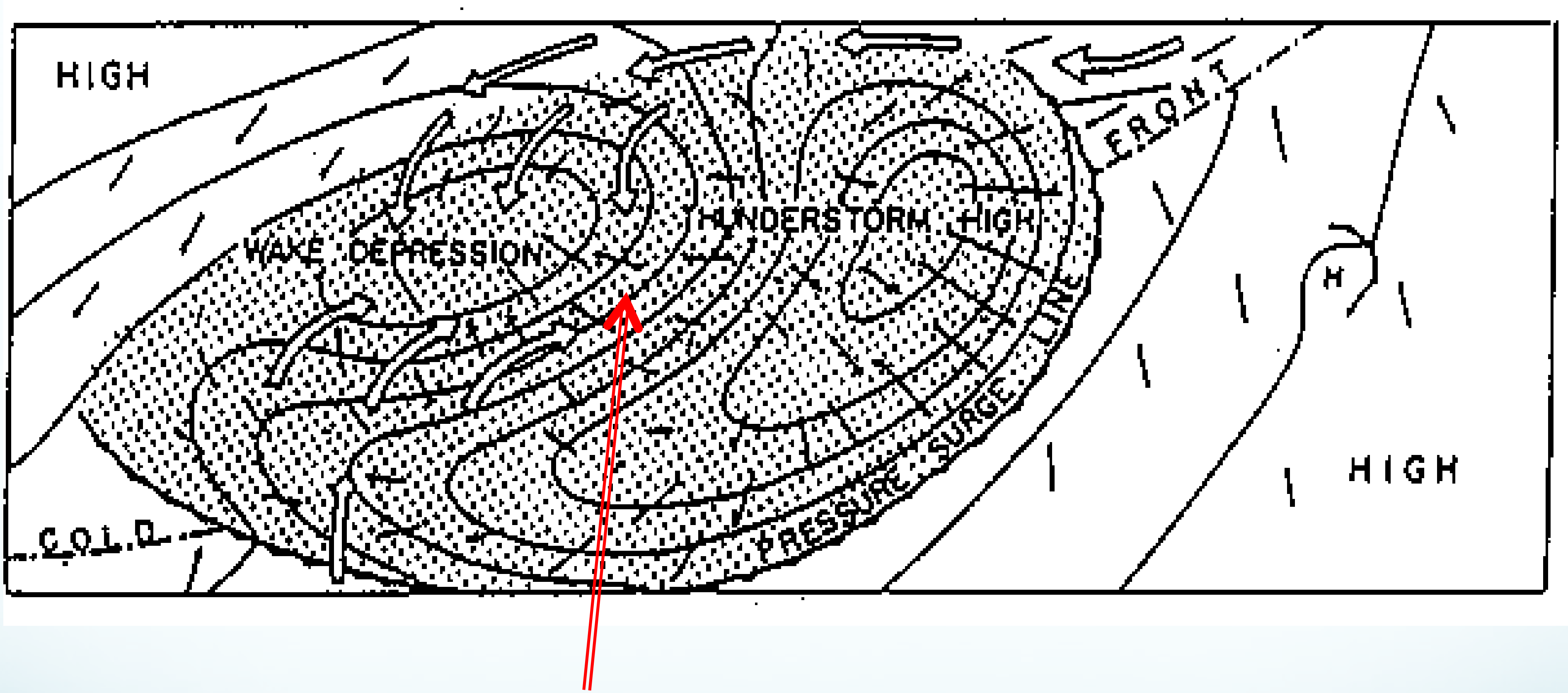
Non-Tstm Severe Winds

- A large area of high winds gusting to 58 mph or higher.
- Showers or storms have ended, leaving behind a gradient of air pressure that forces winds to become stronger.
- Known as a "Wake Low" situation.
- The NWS will issue a "High Wind Warning" for these events.
- Damaging winds may persist for an hour or so.

Non-Tstm Severe Winds



Wake Low



Tight surface pressure gradient on back side of convective complex results in wind speed increase

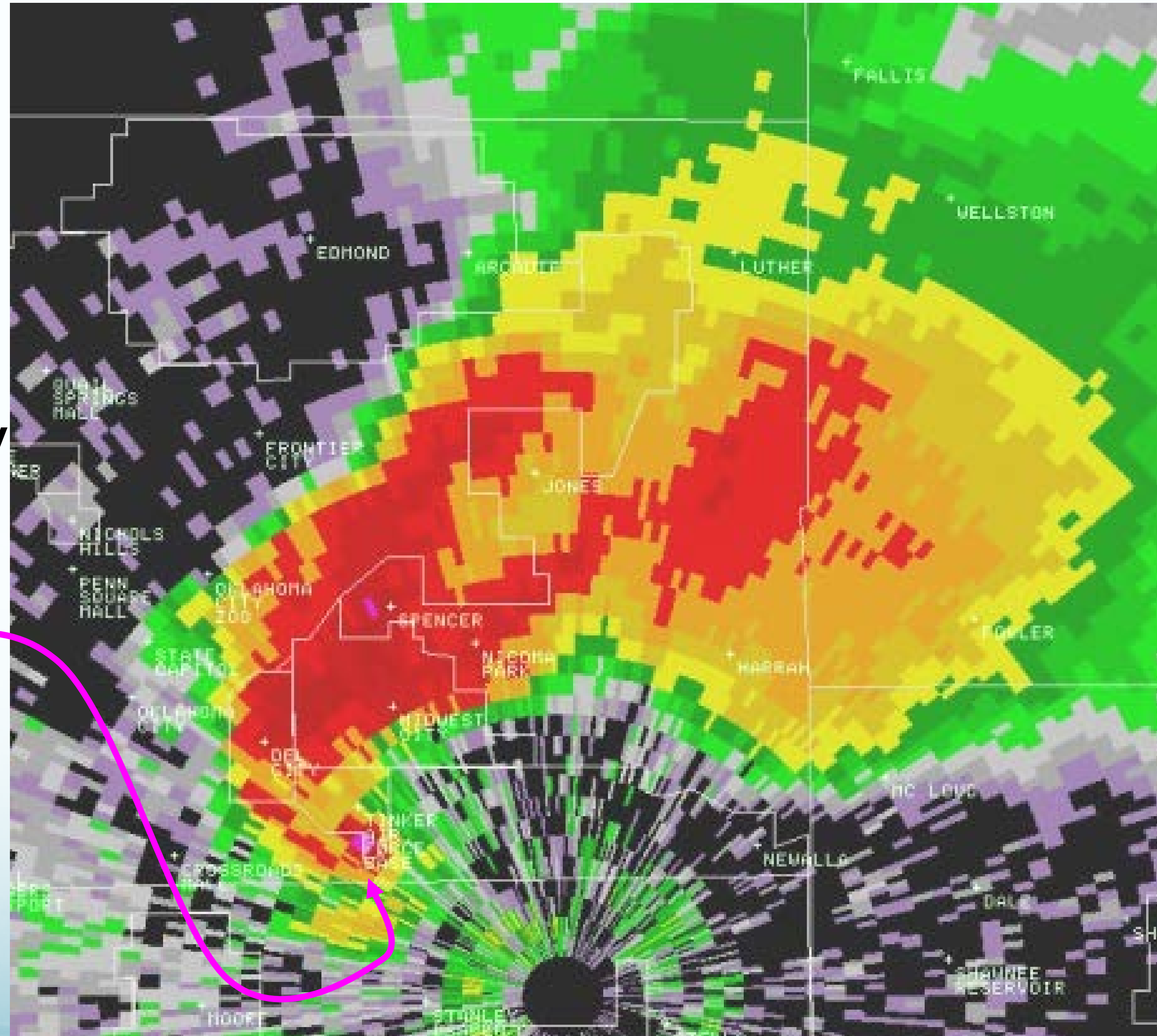
Tornadic Thunderstorm

Storm-scale rotation

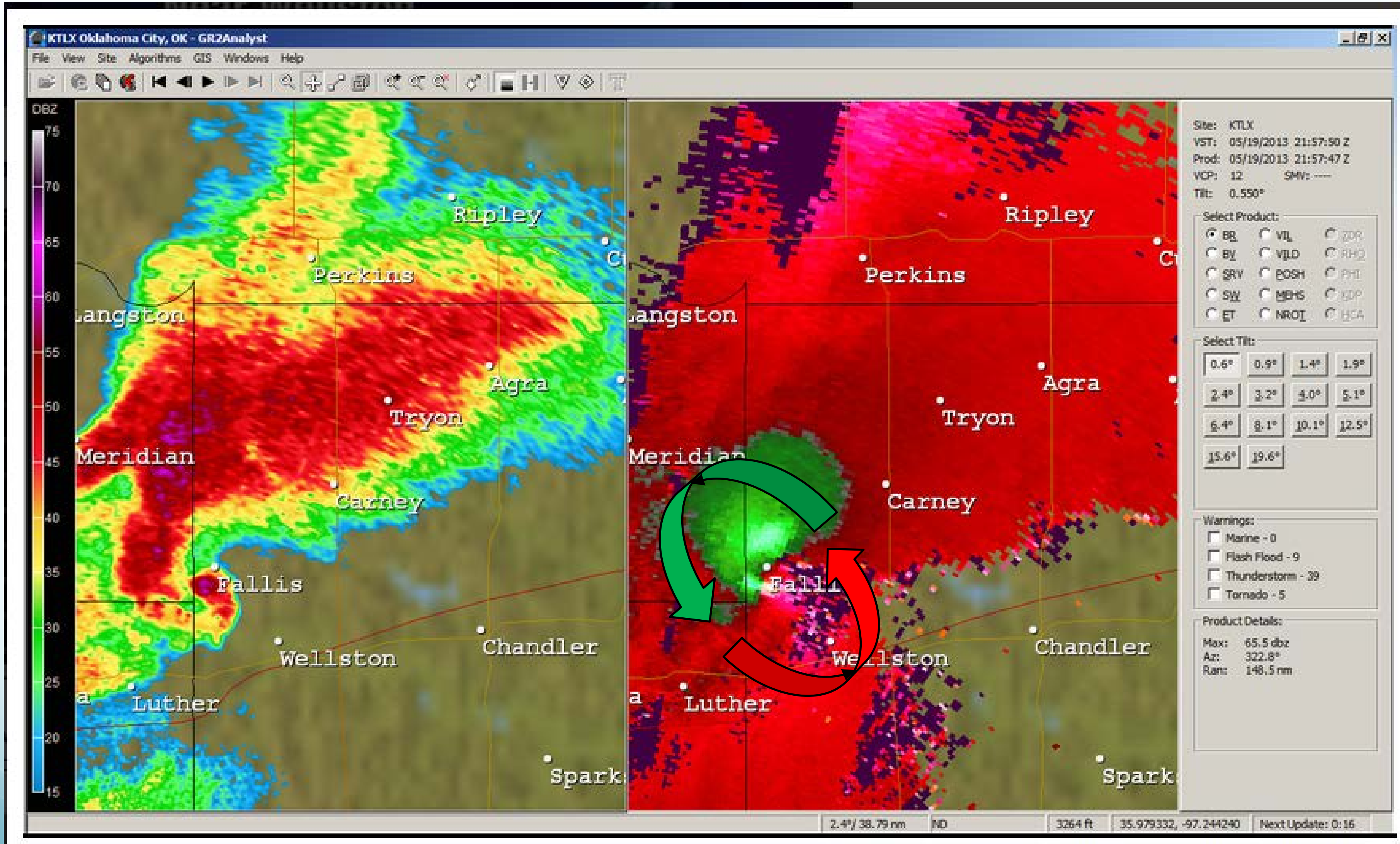
High reflectivity

Hook echo

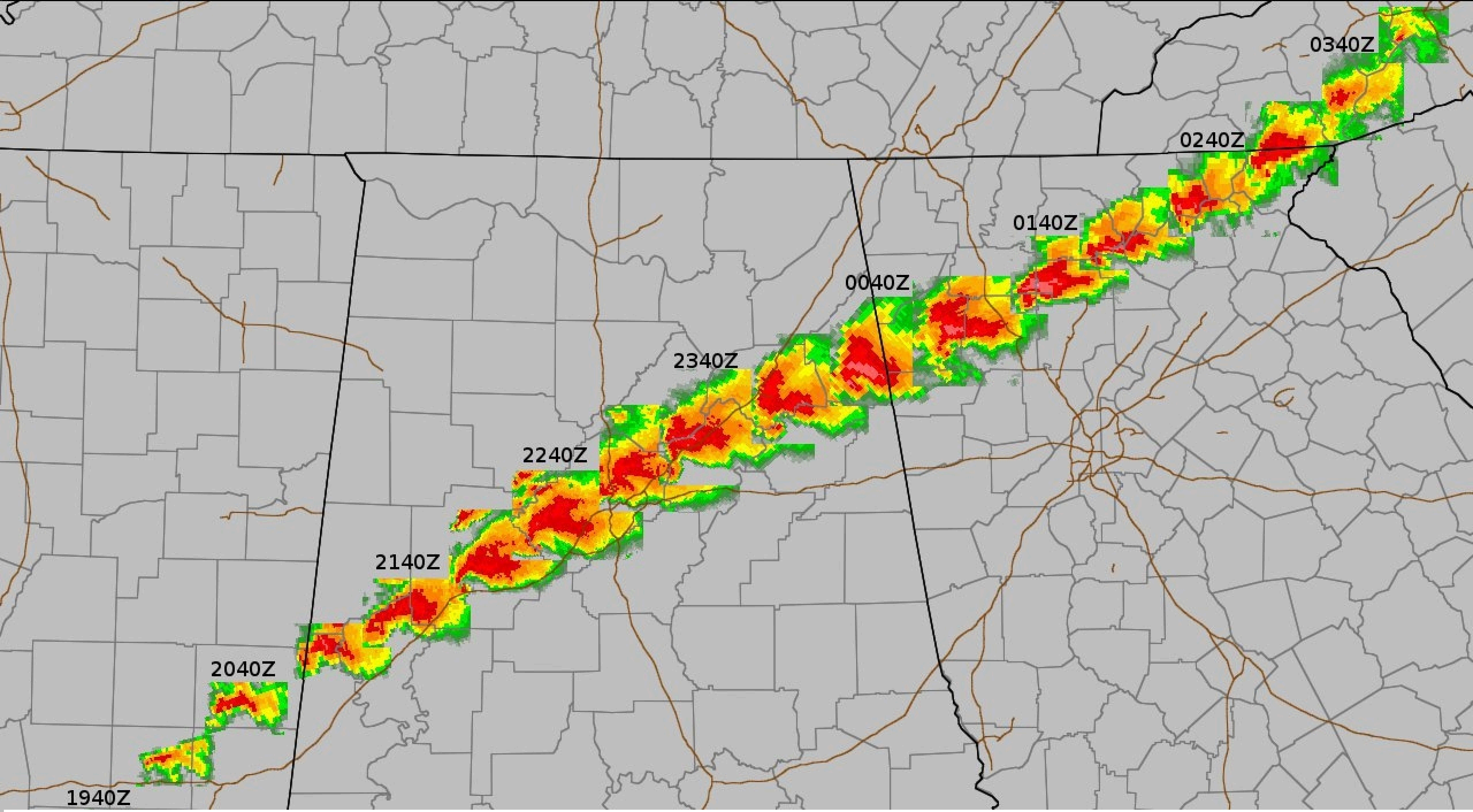
(debris ball at end?)



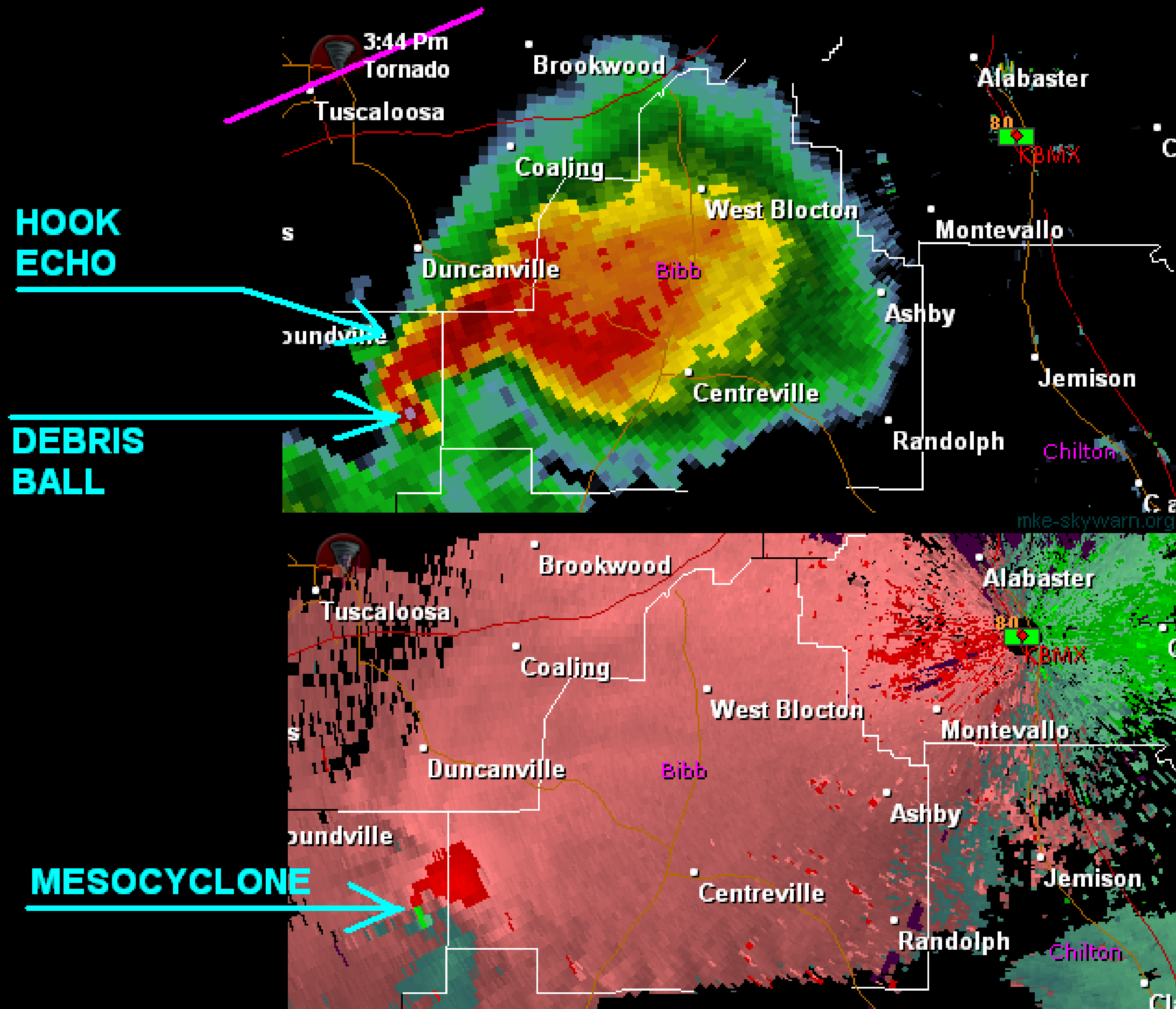
Supercell Structure



Base Reflectivity Storm Relative Velocity

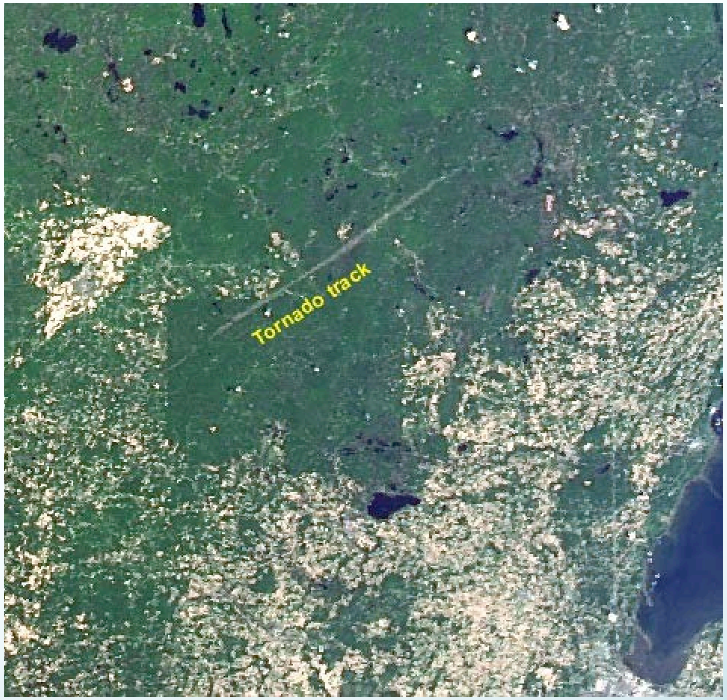


The radar presentation of the supercell that spawned a long-tracked tornado across Alabama on 27 April 2011. It shows a distinct hook echo for most of the time. This is a supercellular tornadic thunderstorm.

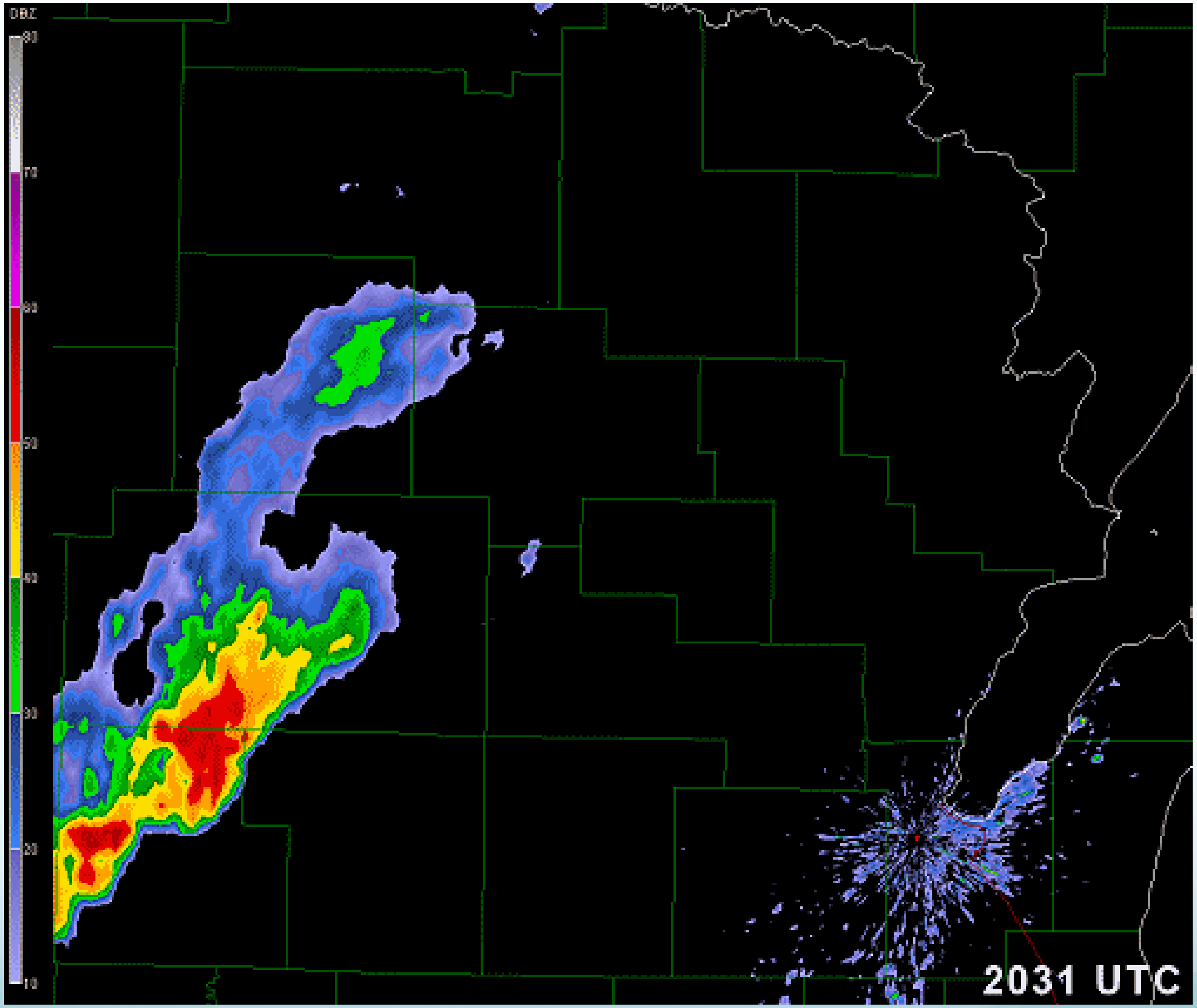


6: 18 PM, APRIL 27, 2011, ALABAMA SUPER OUTBREAK, HIGH RISK.

June 7, 2007 Tornadoes

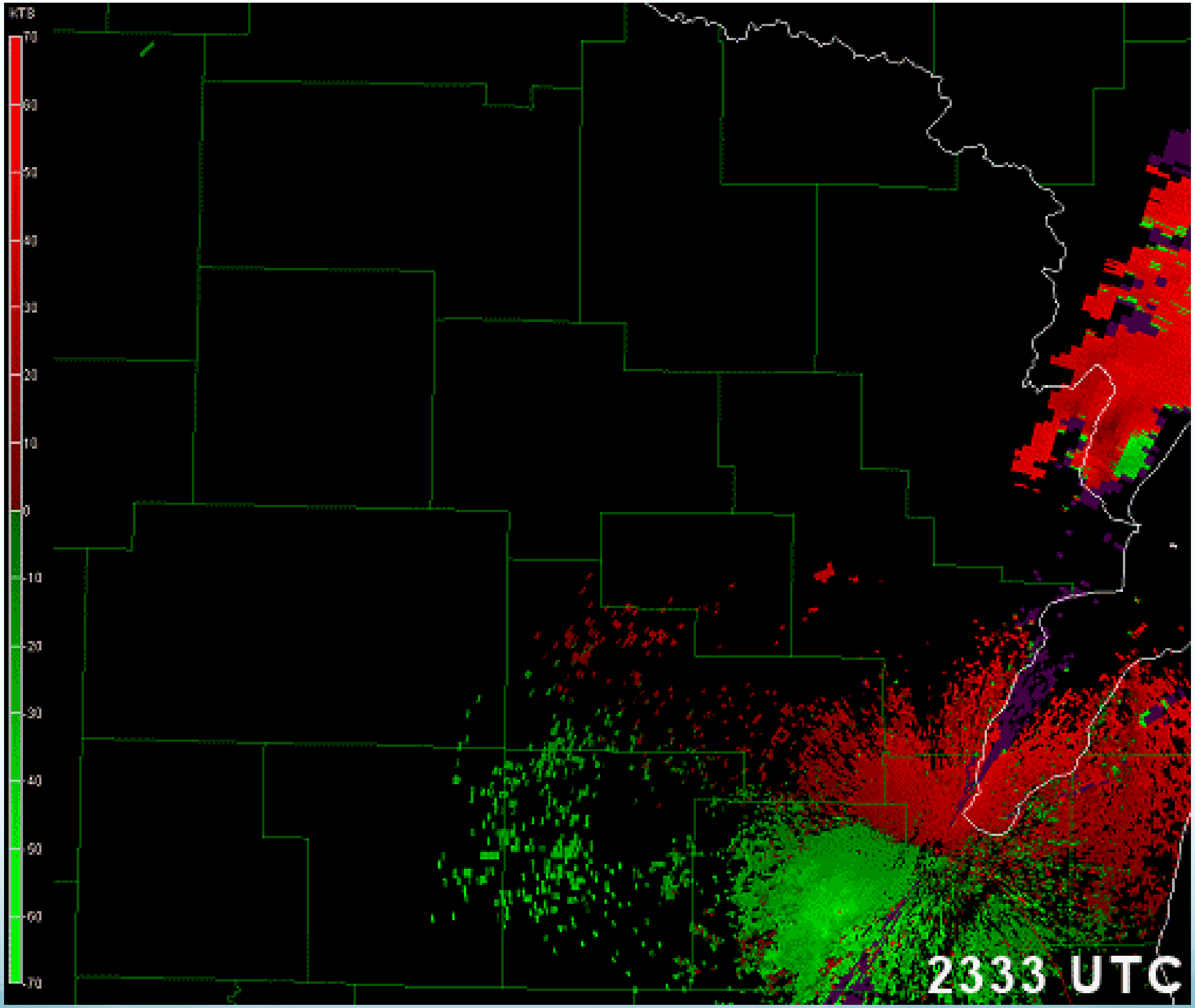


June 7, 2007 Long-Track Tornado



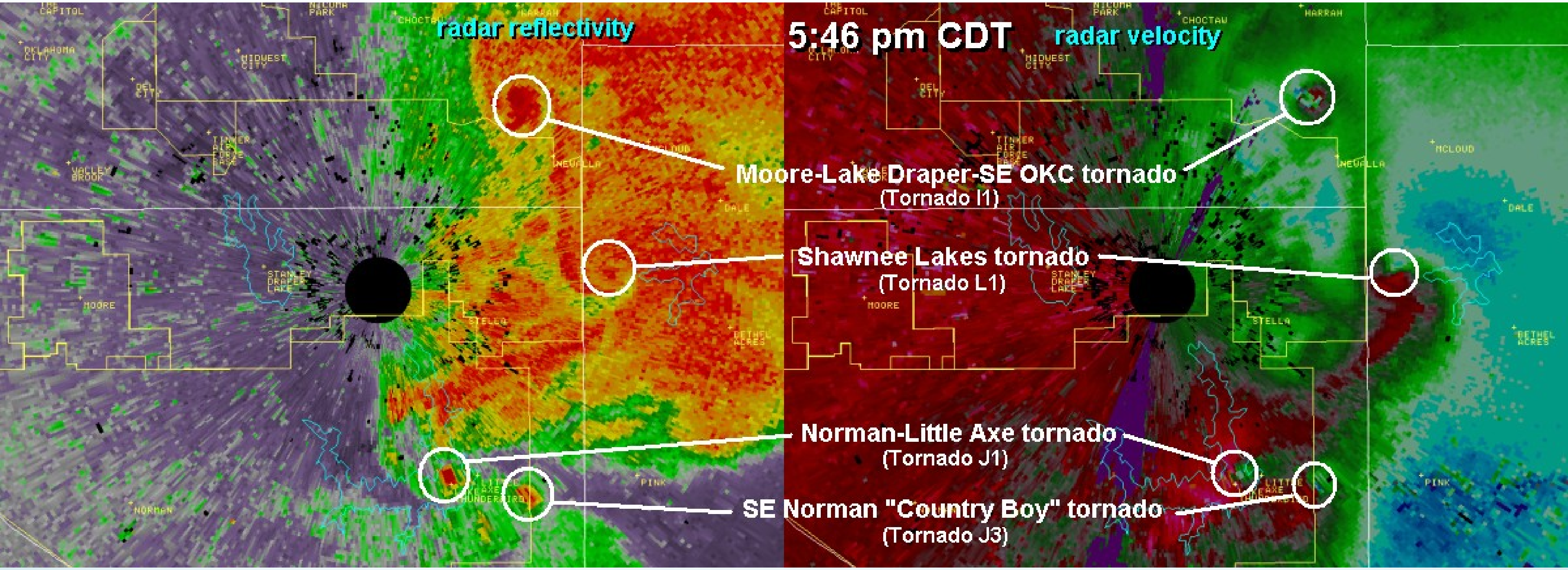
Base Reflectivity

June 7, 2007 Long-Track Tornado



Storm Relative Velocity

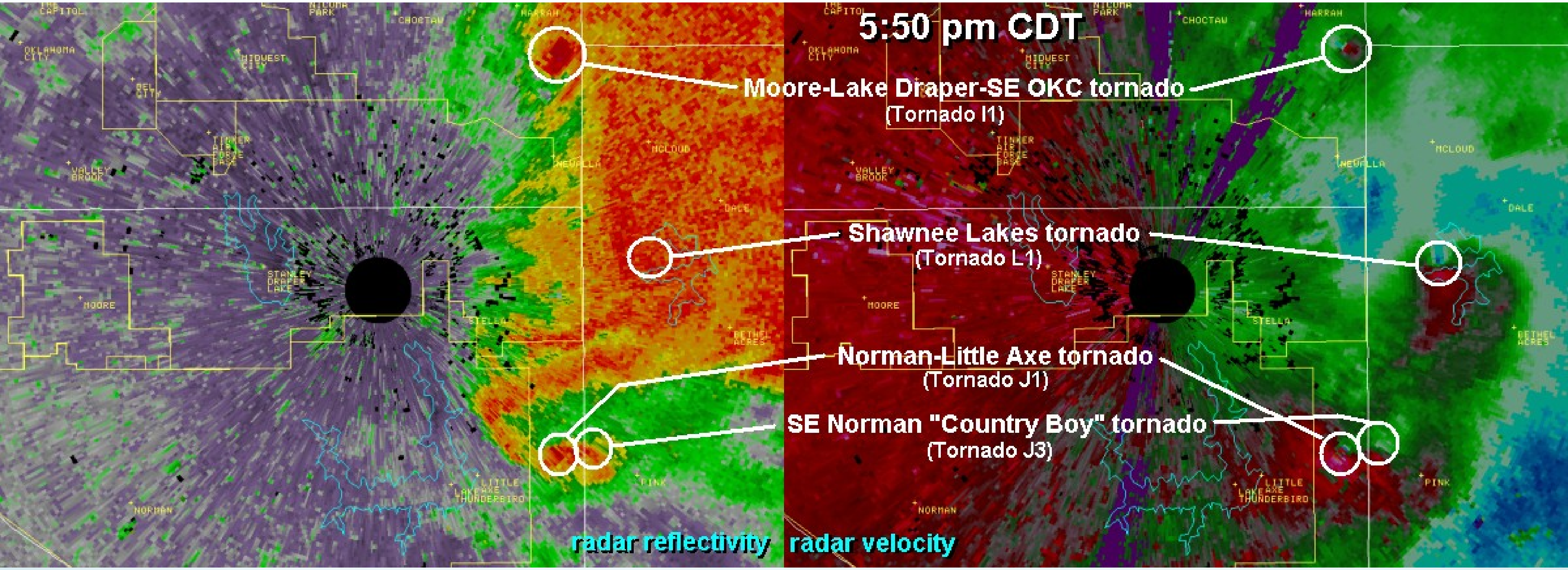
4 in 1



Base Reflectivity

Storm Relative Velocity

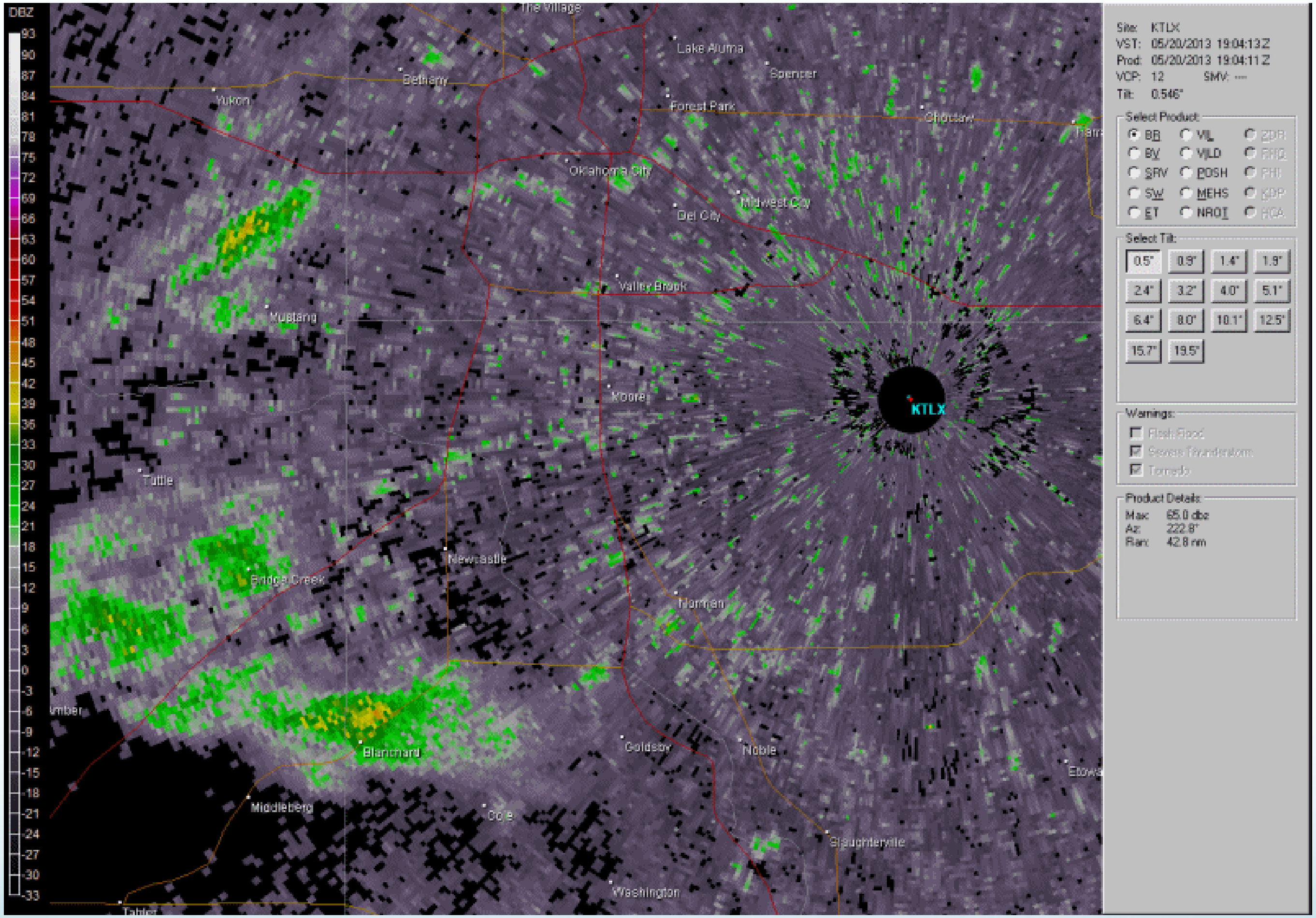
4 in 1



Base Reflectivity

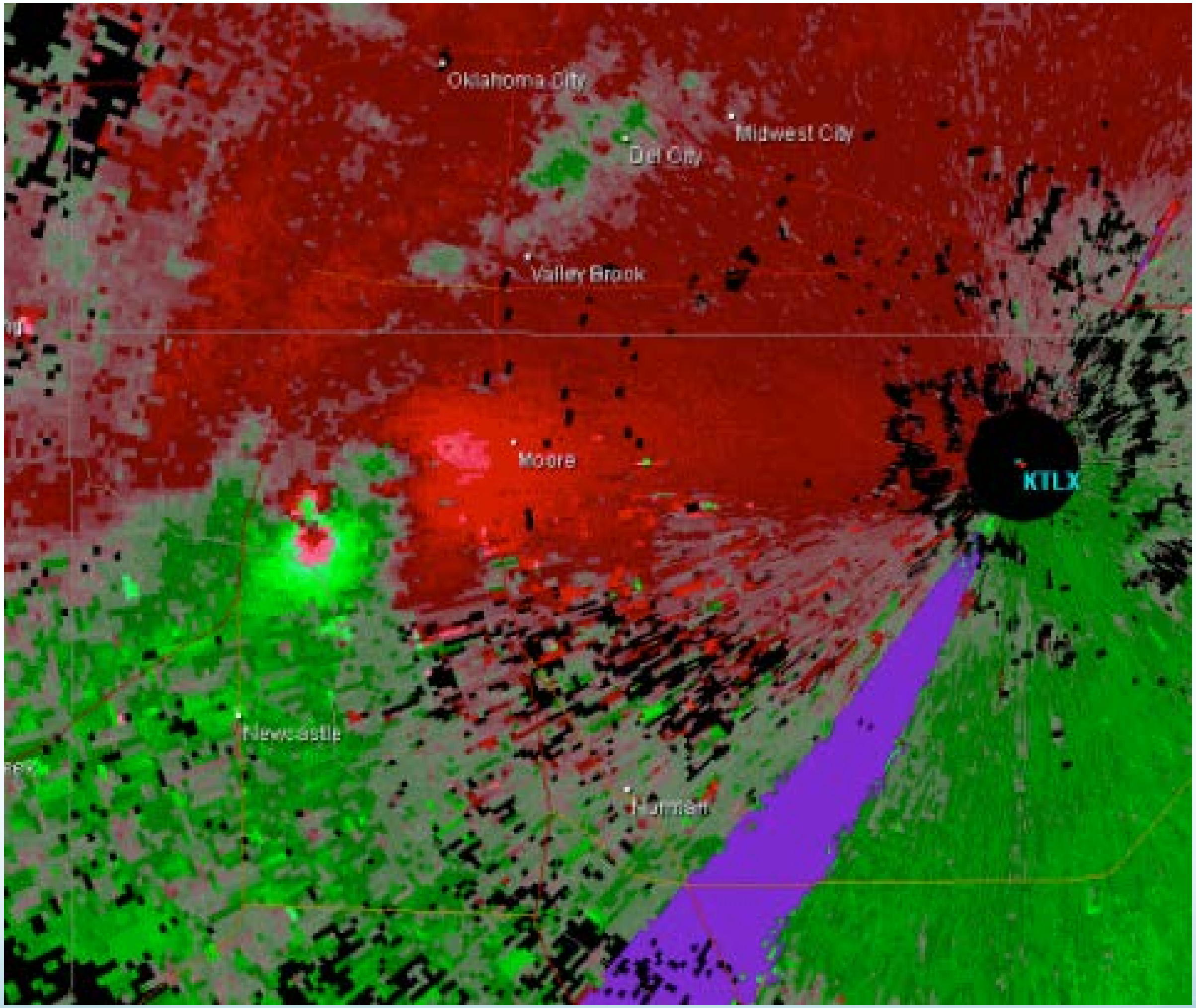
Storm Relative Velocity

May 20, 2013 Moore Tornado



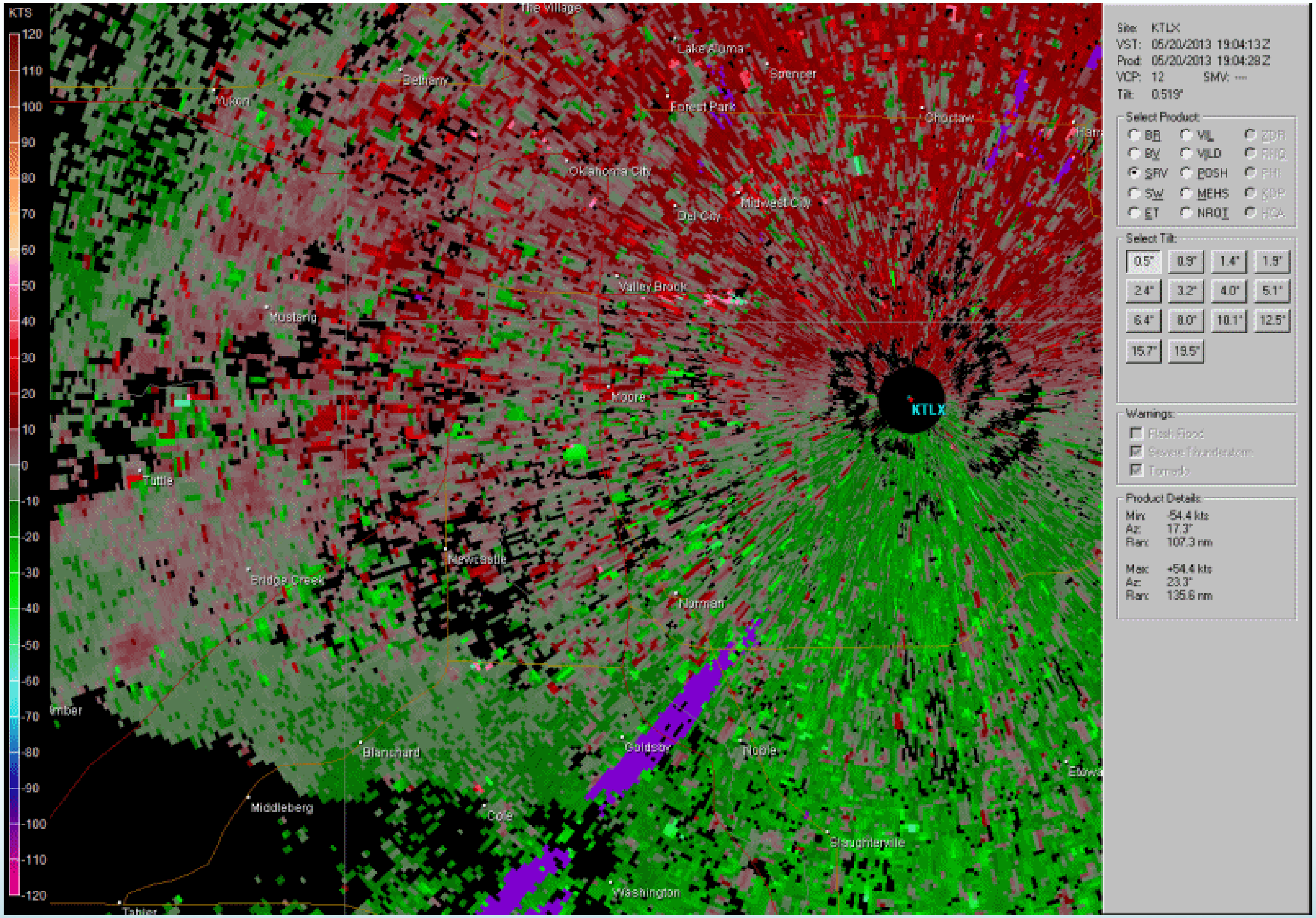
Base Reflectivity

May 20, 2013 Moore Tornado



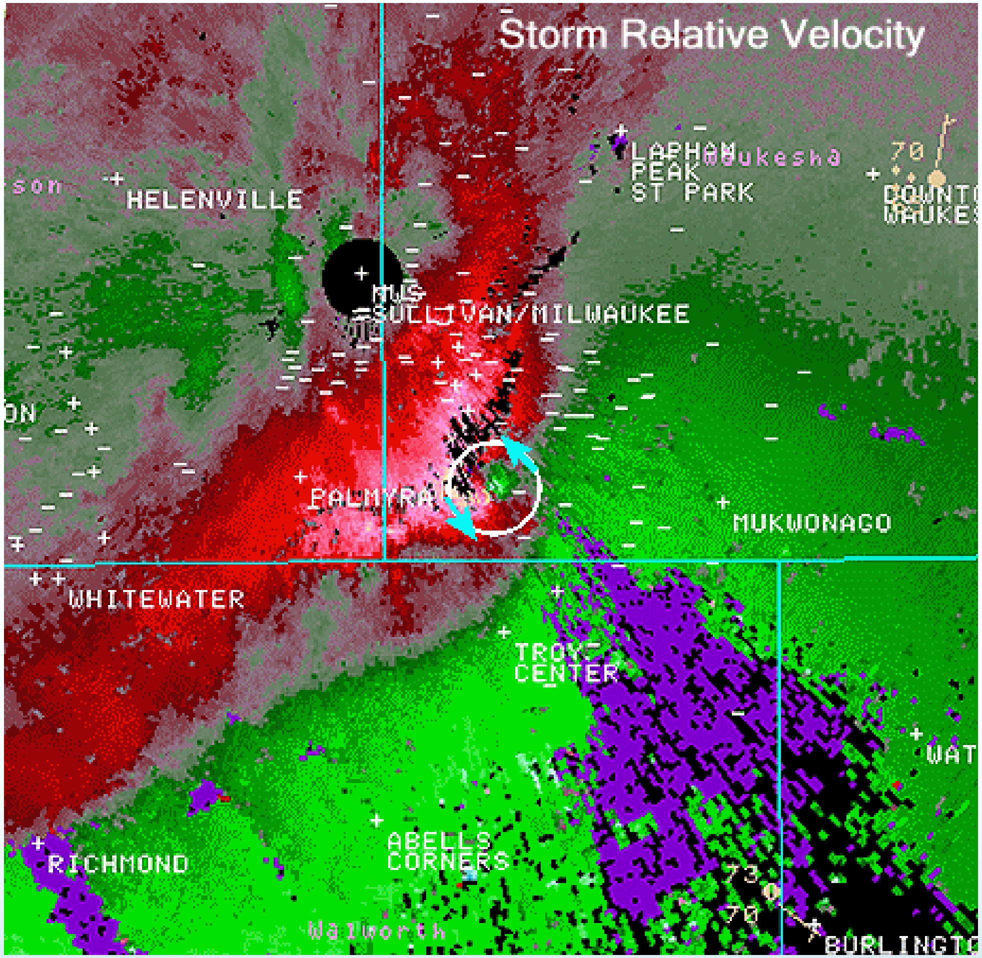
Storm Relative Velocity

May 20, 2013 Moore Tornado

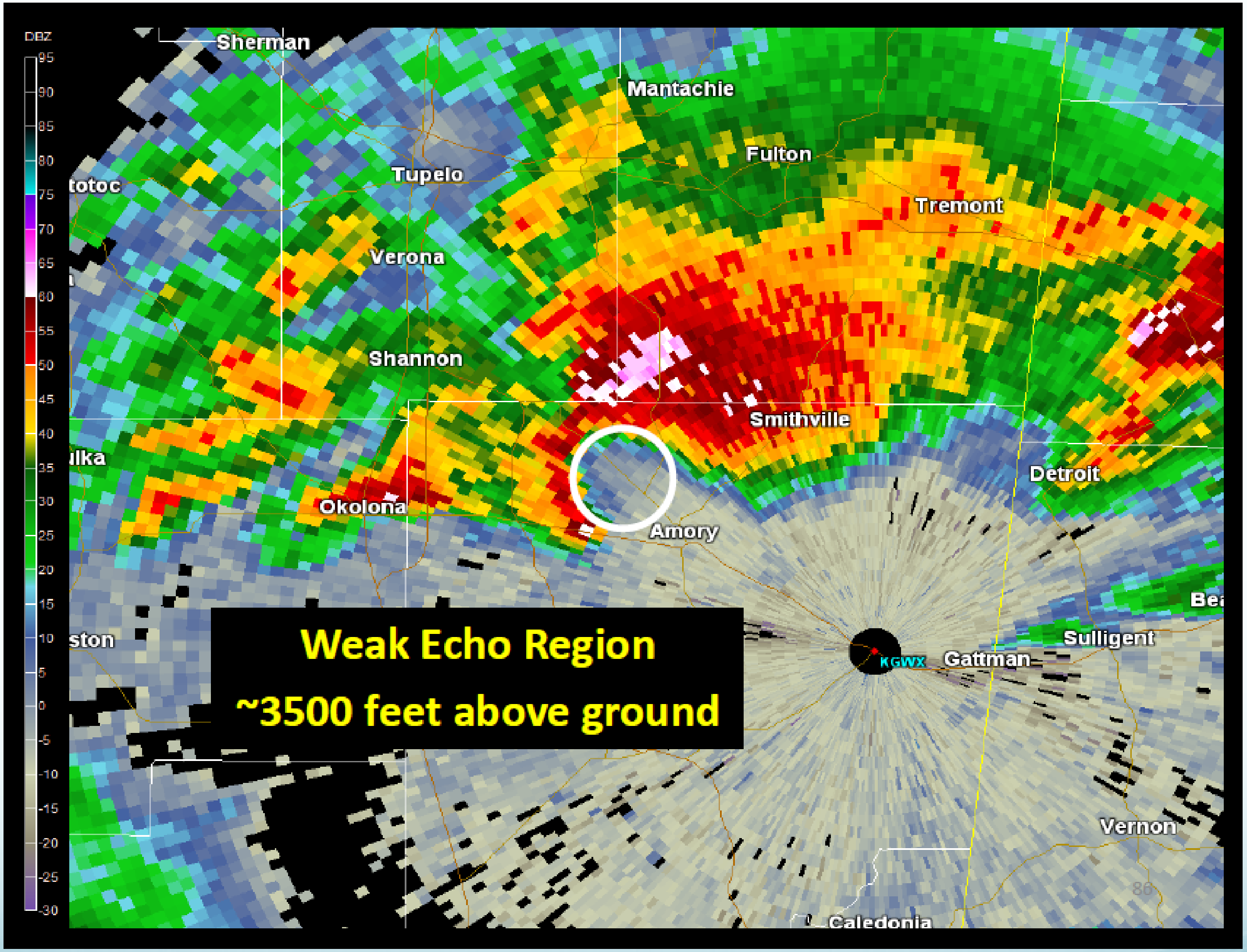


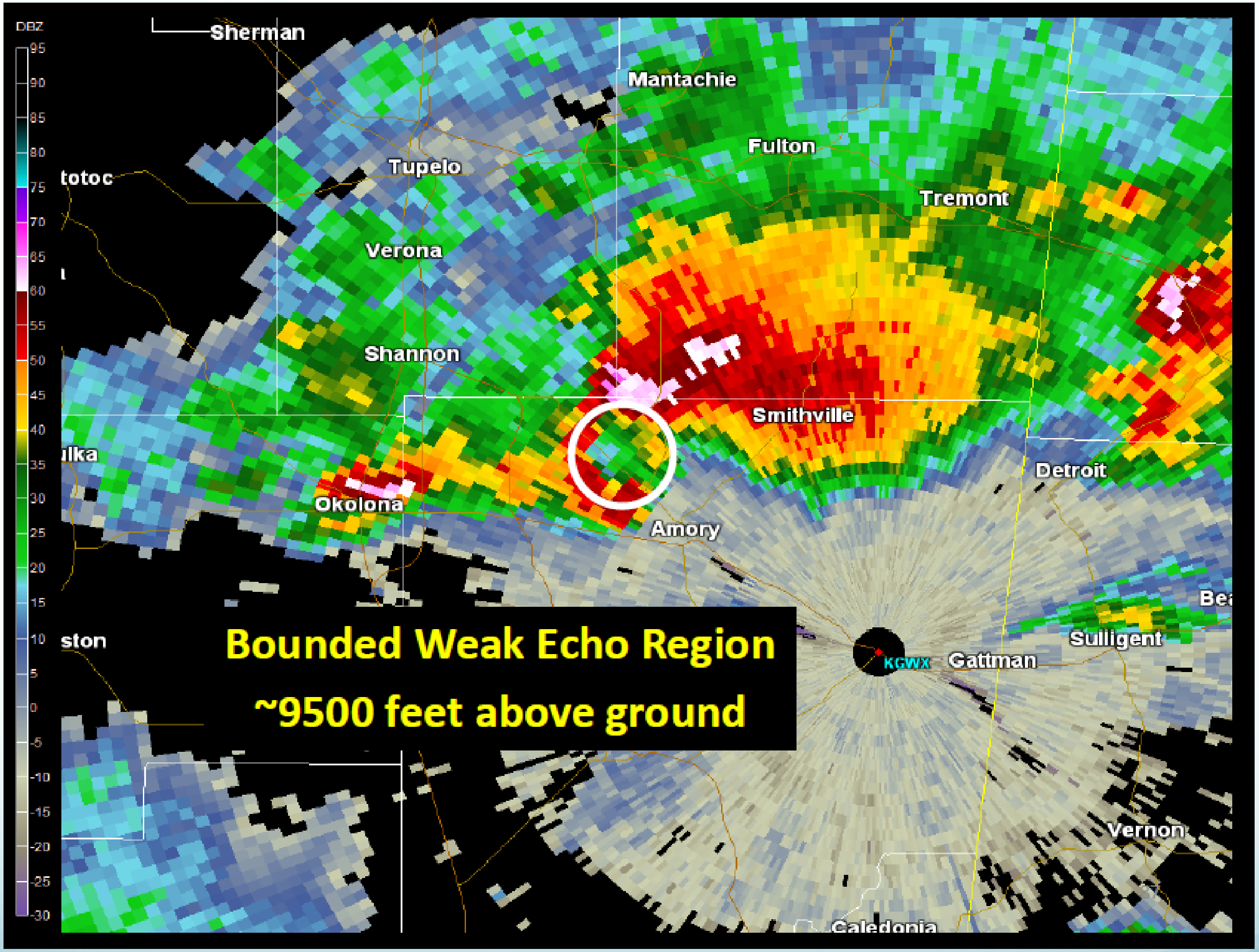
Storm Relative Velocity

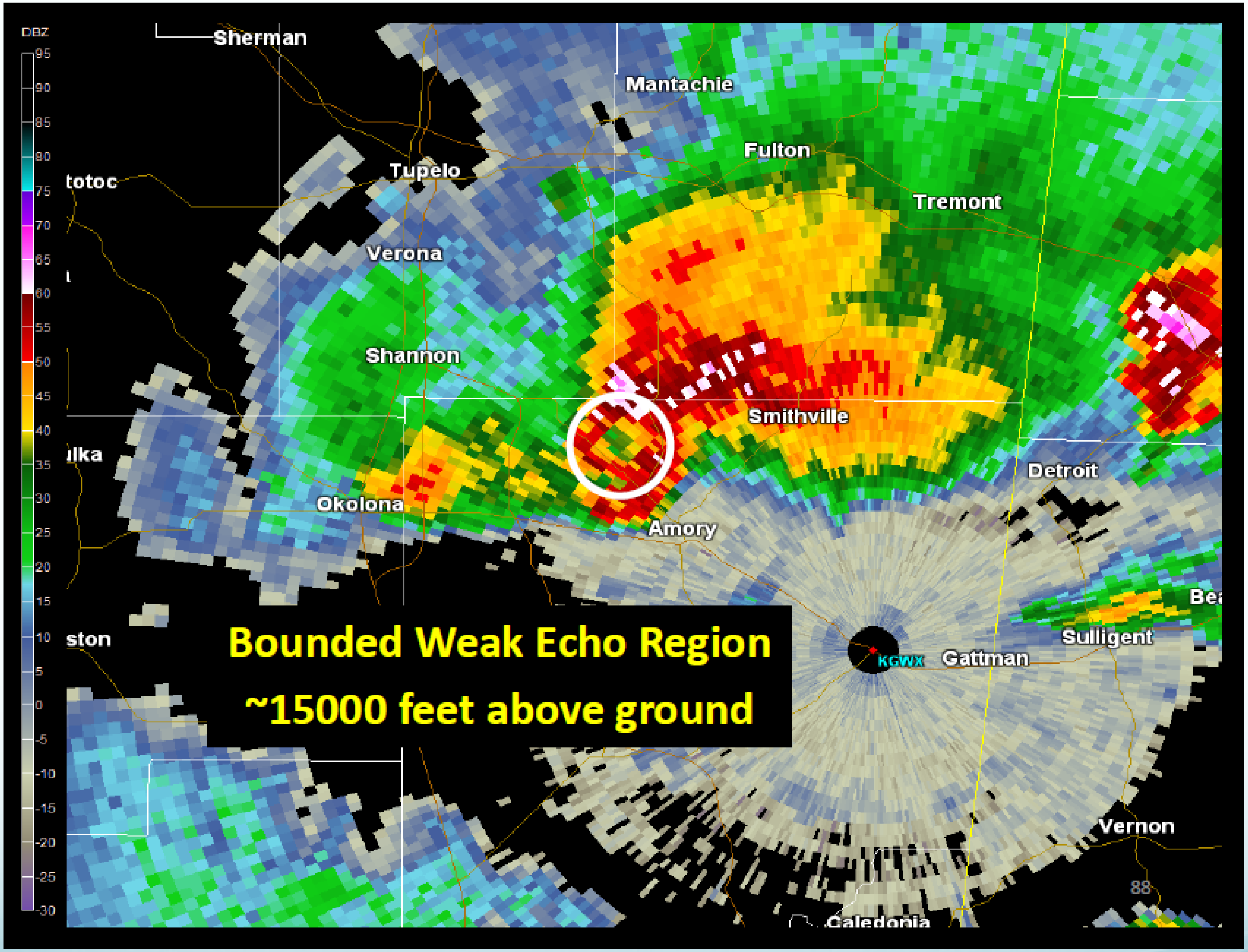
June 21, 2010 EF2 Eagle WI Tornado



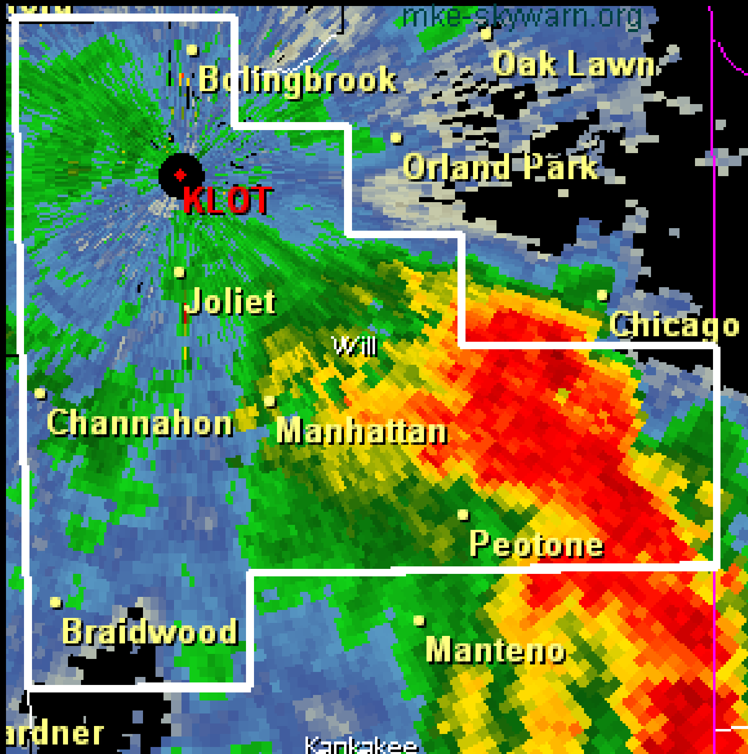
Base Reflectivity Storm Relative Velocity


Weak Echo Region
~3500 feet above ground
DBZ
95
90
85
80
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
-5
-10
-15
-20
-25
-30
Sherman
Mantachie
Fulton
Tupelo
Tremont
Verona
Shannon
Smithville
Detroit
Okolona
Amory
Sulligent
KGWX
Gattman
Vernon
Caledonia

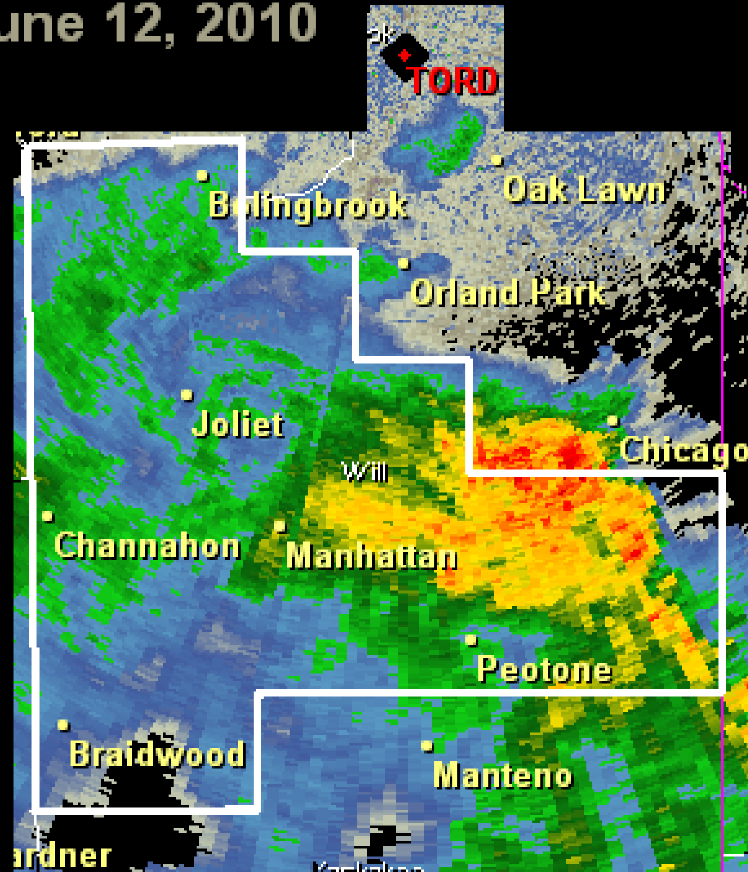

DBZ
Sherman
Mantachie
Fulton
Tupelo
totoc
Tremont
Verona
Shannon
Smithville
ılka
Detroit
Okolona
Amory
Bea
ston
Sulligent
KGWX
Gattman
Vernon
Caledonia
Bounded Weak Echo Region
~9500 feet above ground


DBZ
95
90
85
80
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
-5
-10
-15
-20
-25
-30
Sherman
Mantachie
Fulton
Tupelo
totoc
Tremont
Verona
Shannon
Smithville
ilka
Detroit
Okolona
Amory
Bea
ston
Sulligent
KGWX
Gattman
Vernon
88
Caledonia
Bounded Weak Echo Region
~15000 feet above ground

Will County Illinois June 12, 2010



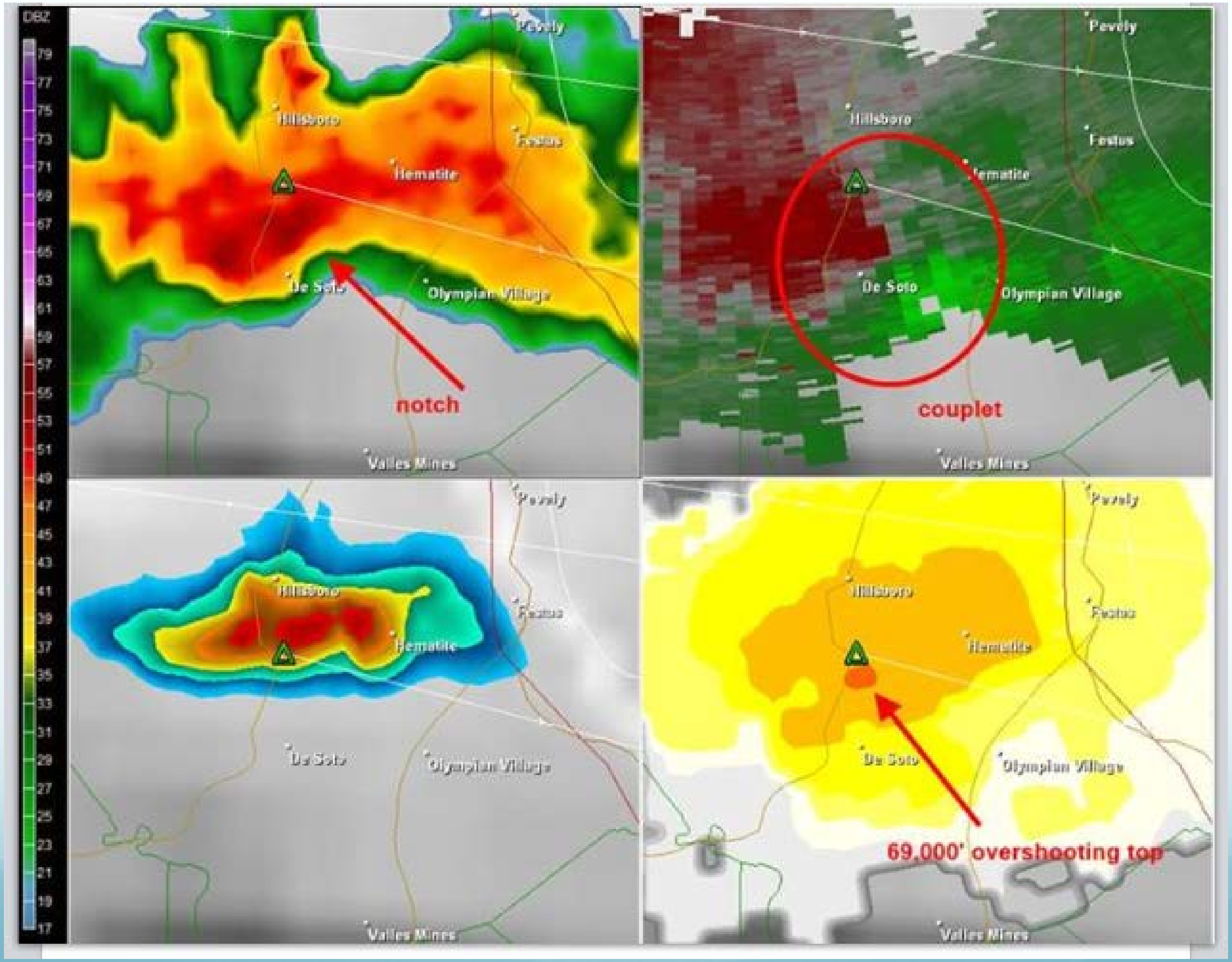
NWS Doppler (10 Centimeter)
2900 Mhz, 750,000 watts



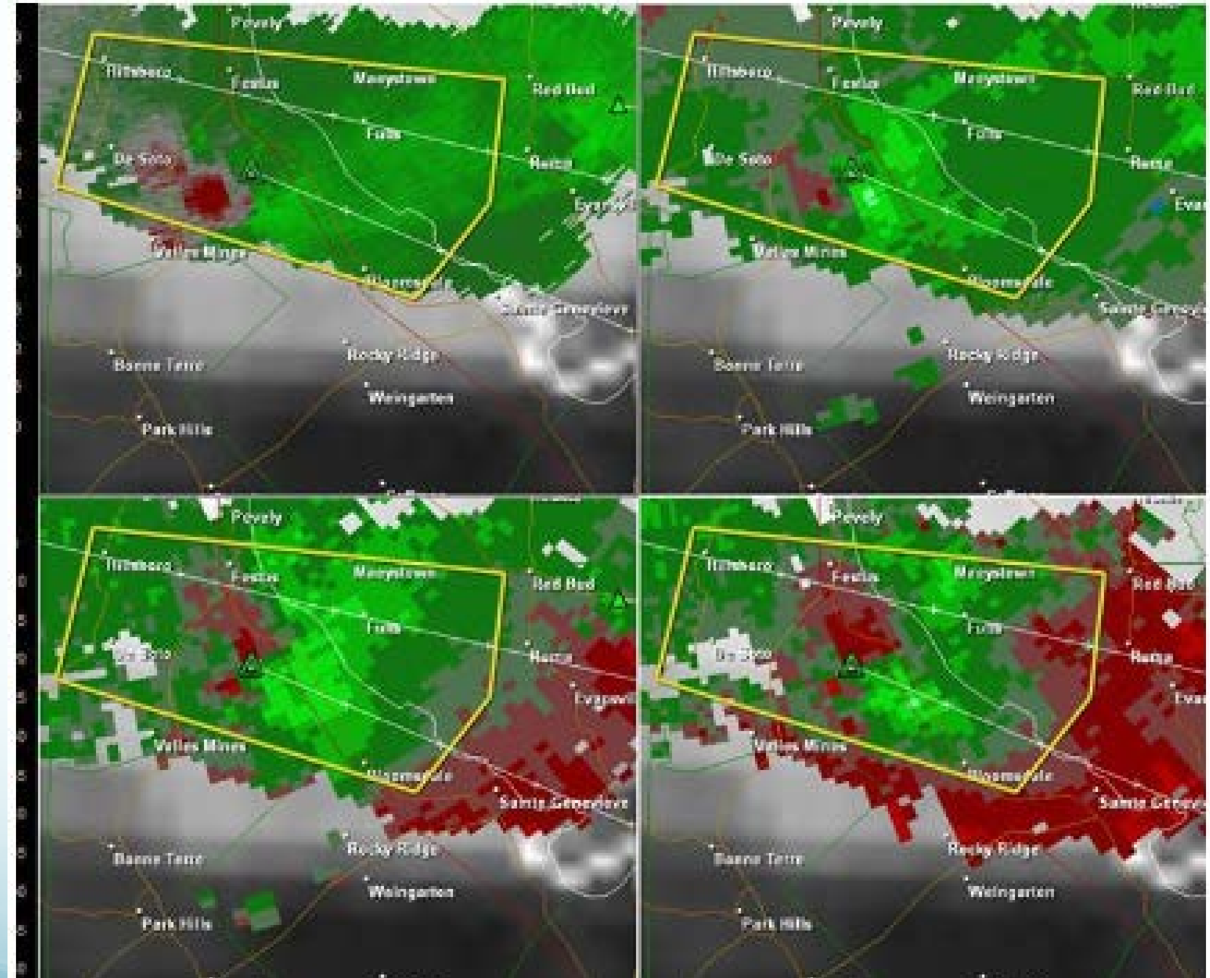
FAA Doppler (5 Centimeter)
5500 Mhz, 250,000 watts
Severe Signal Loss
(attenuation)

SAME STORM-SAME TIME....TWO DIFFERENT RADARS.
Heavy rain/hail caused inaccurate display on FAA site.

Chad Woodward Tweet

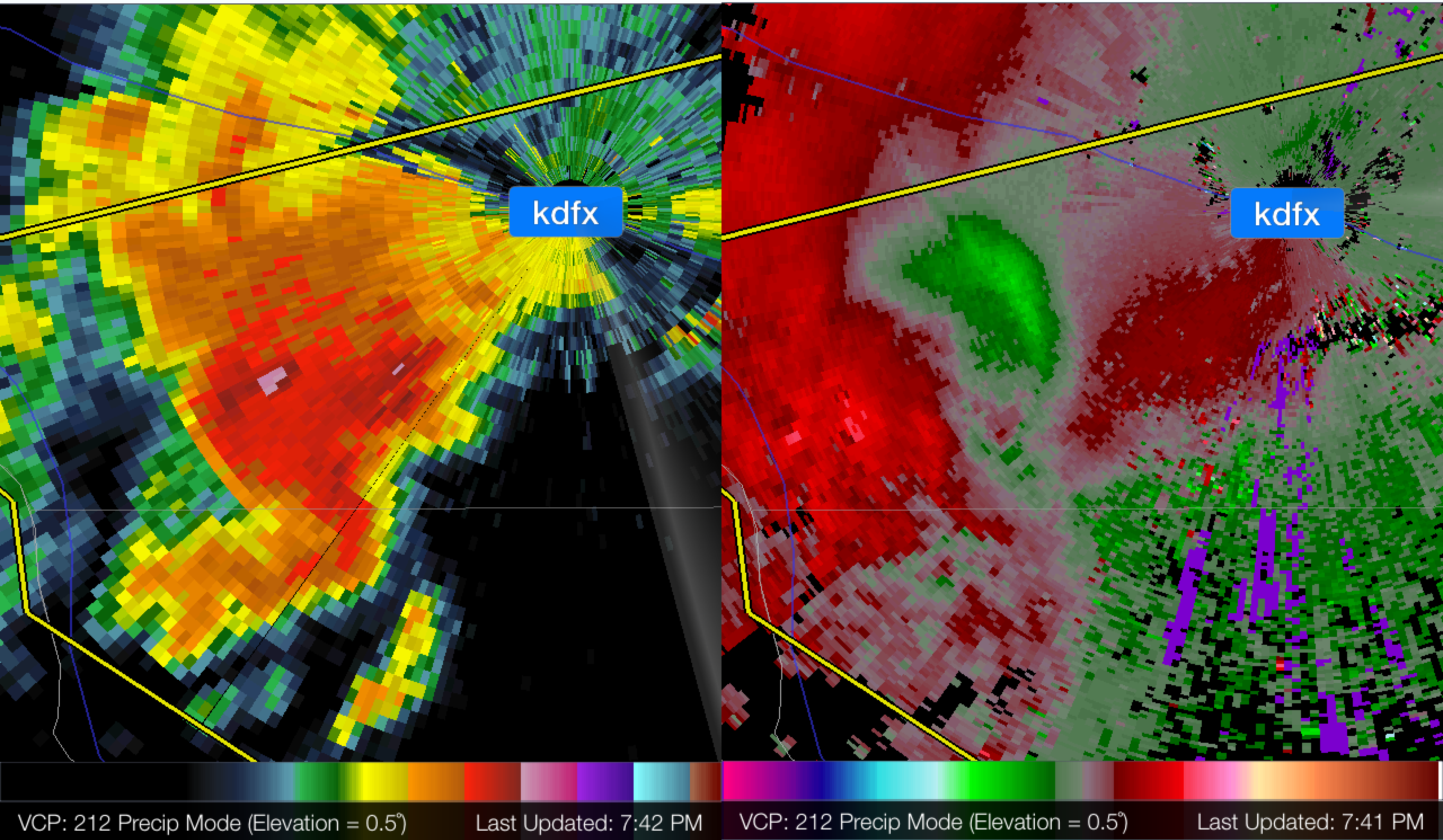


Chad Woodward Tweet



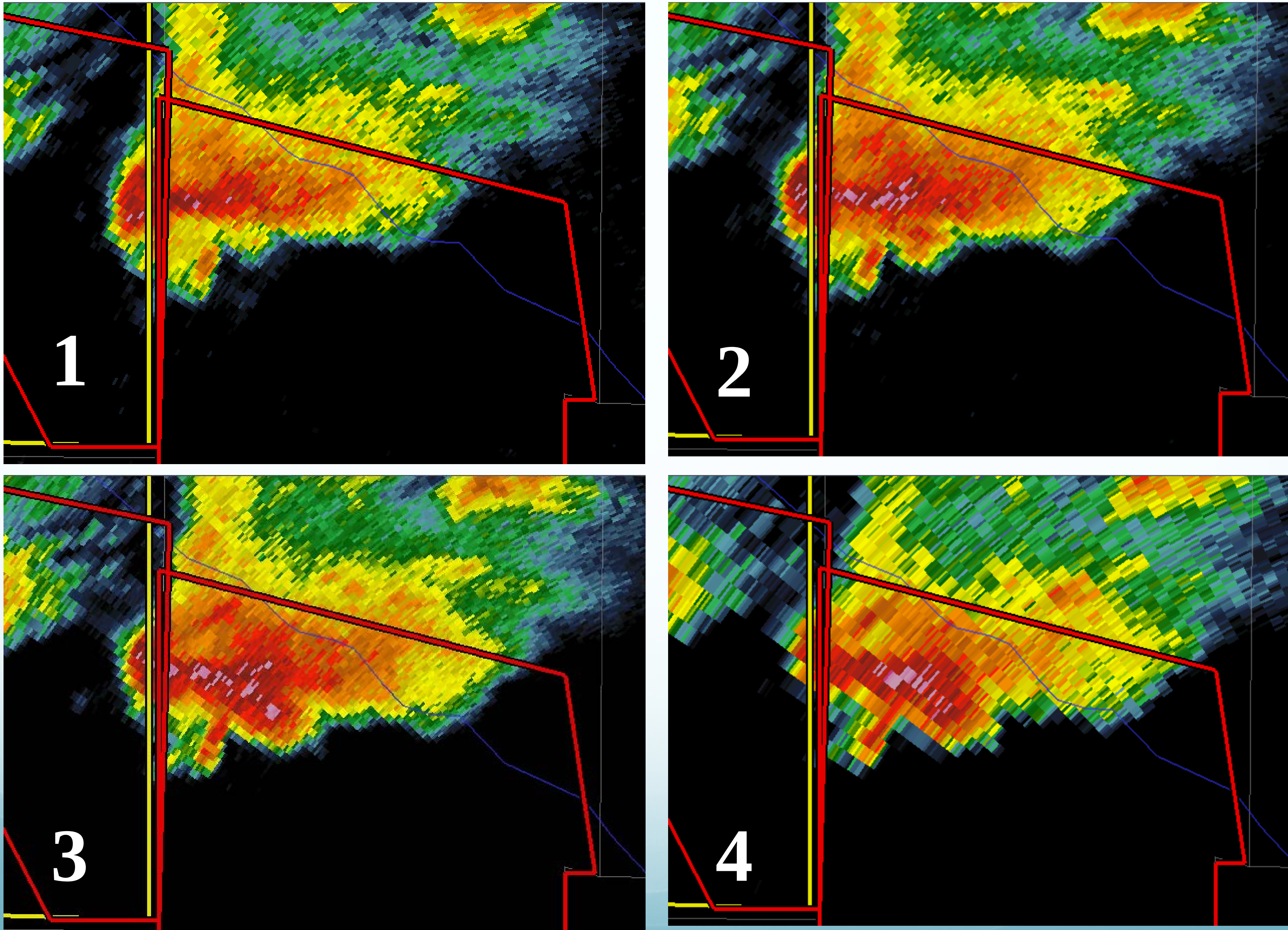
Do You See the Meso-cyclone?

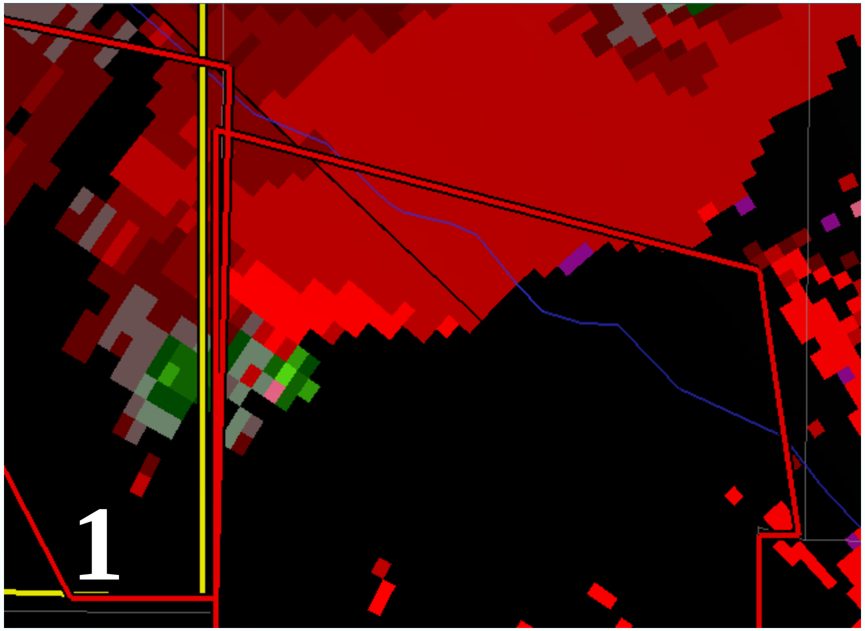
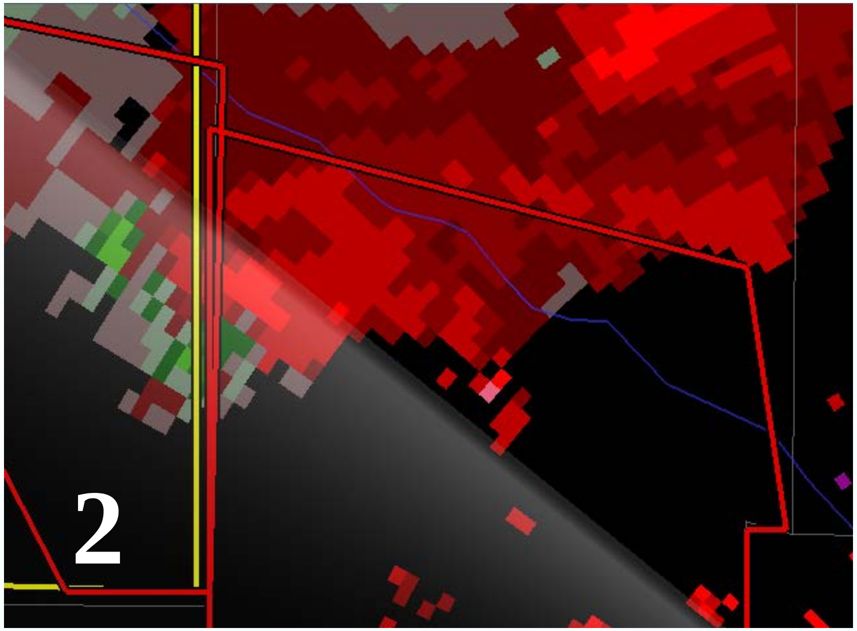
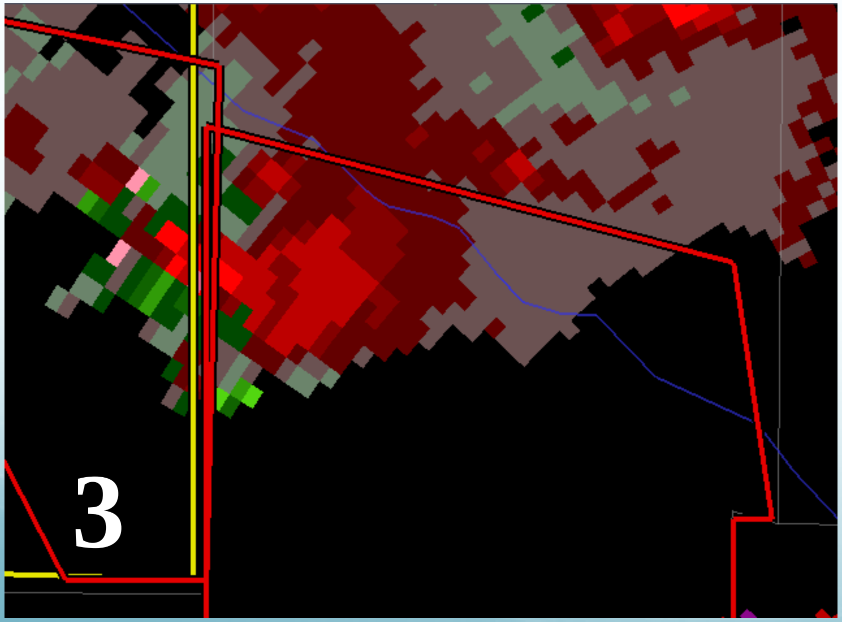
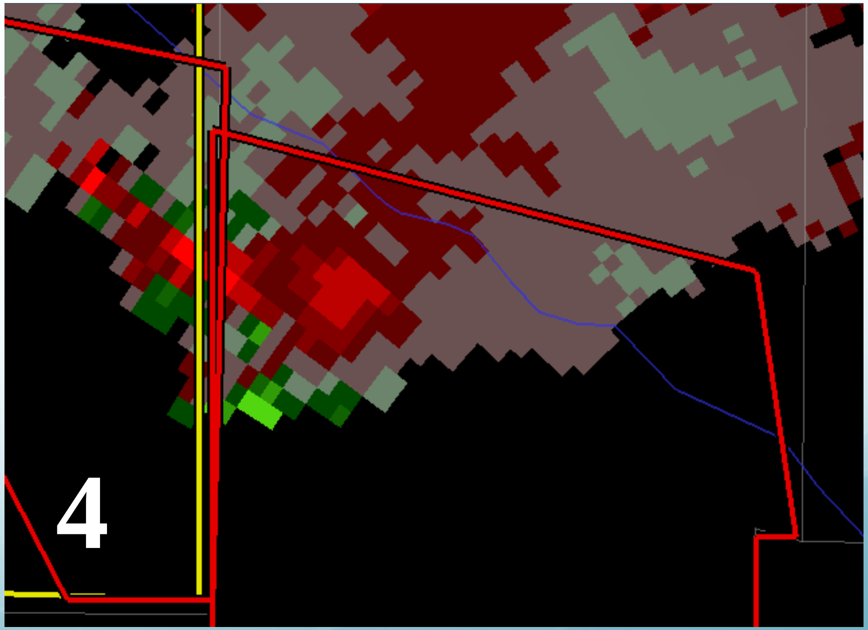
Do You See the Downburst?



Tornado-warned Tstm in Texas

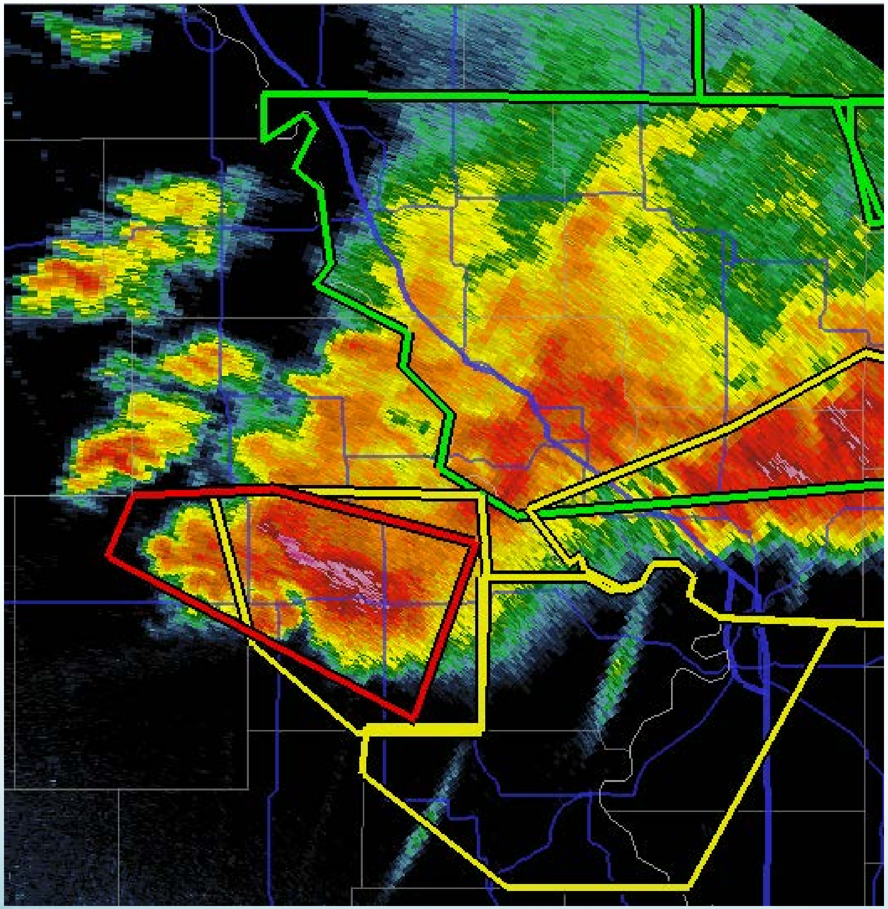
- The next two slides shows a supercell thunderstorm which was tornado-warned.
- The first slide is a 4-panal of SuperRes Reflectivity (Base reflectivity) consisting of the 4 lowest tilts.
- The second slide is a 4-panal of Storm Relative Velocity consisting of the 4 lowest tilts.
- Note how the storm structure changes with height. Circulation gets weaker and less defined with height.

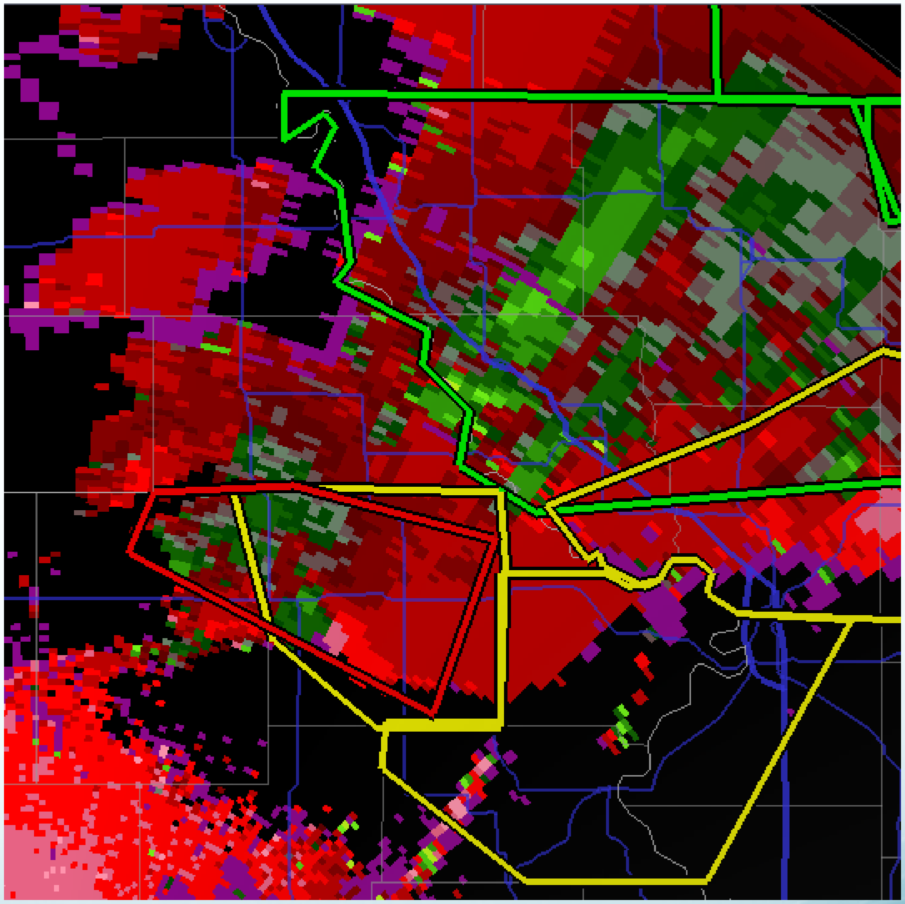

1
2
3
4


1

2

3

4

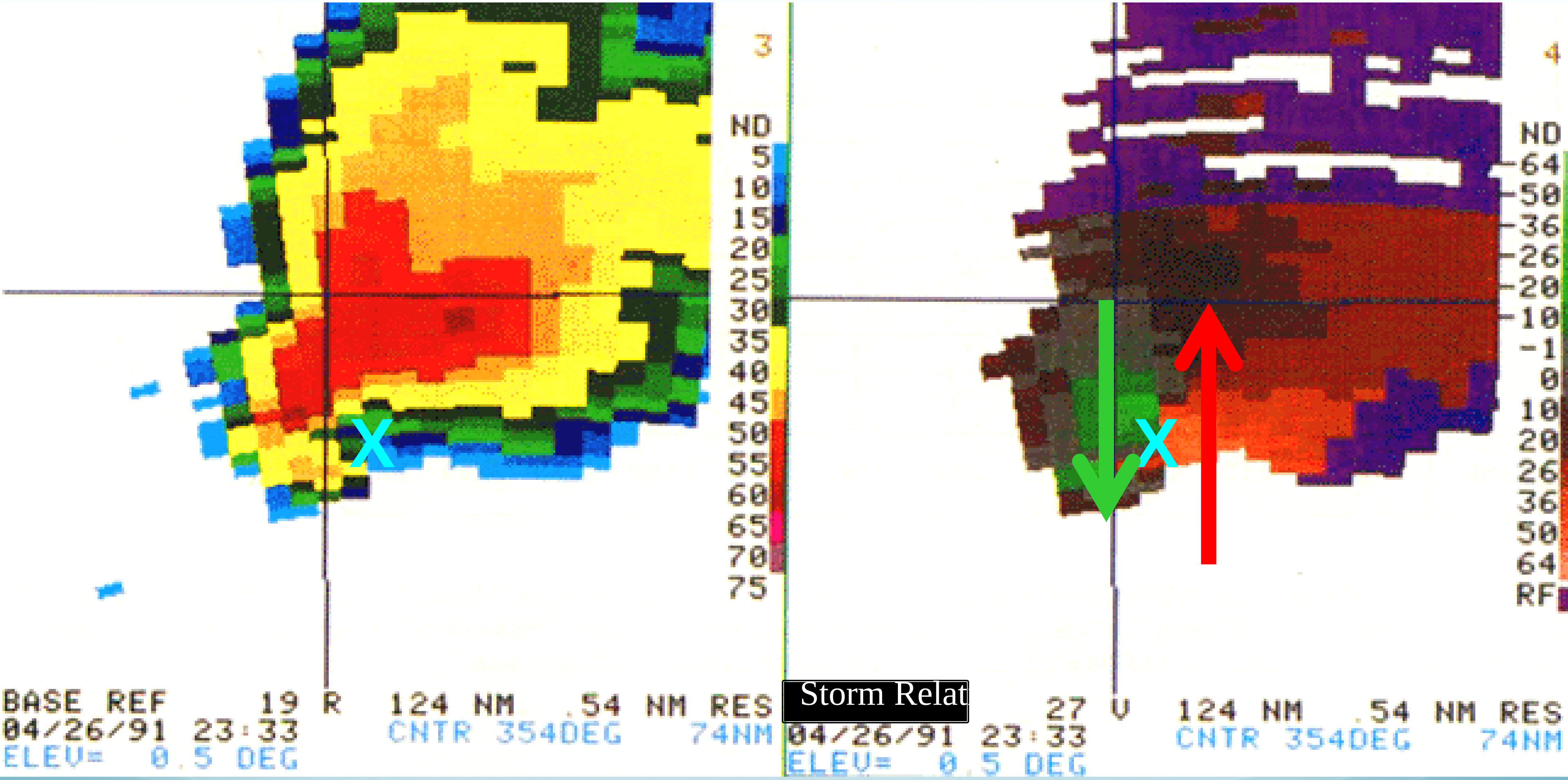
Reed Timmer Tweet

Tornado-warned Supercell





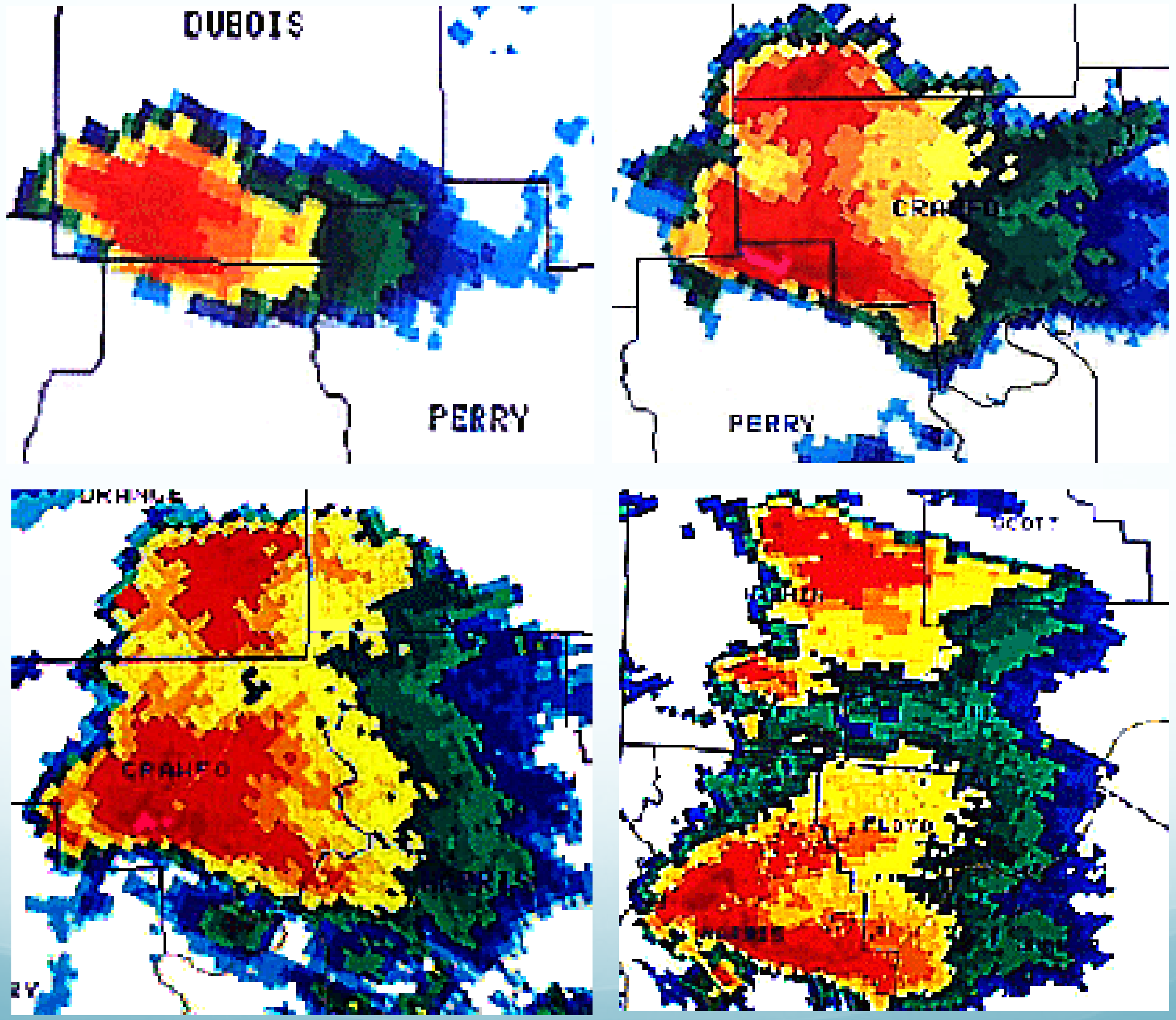
Classic Supercell



Radar site

Radar site

Storm Splitting

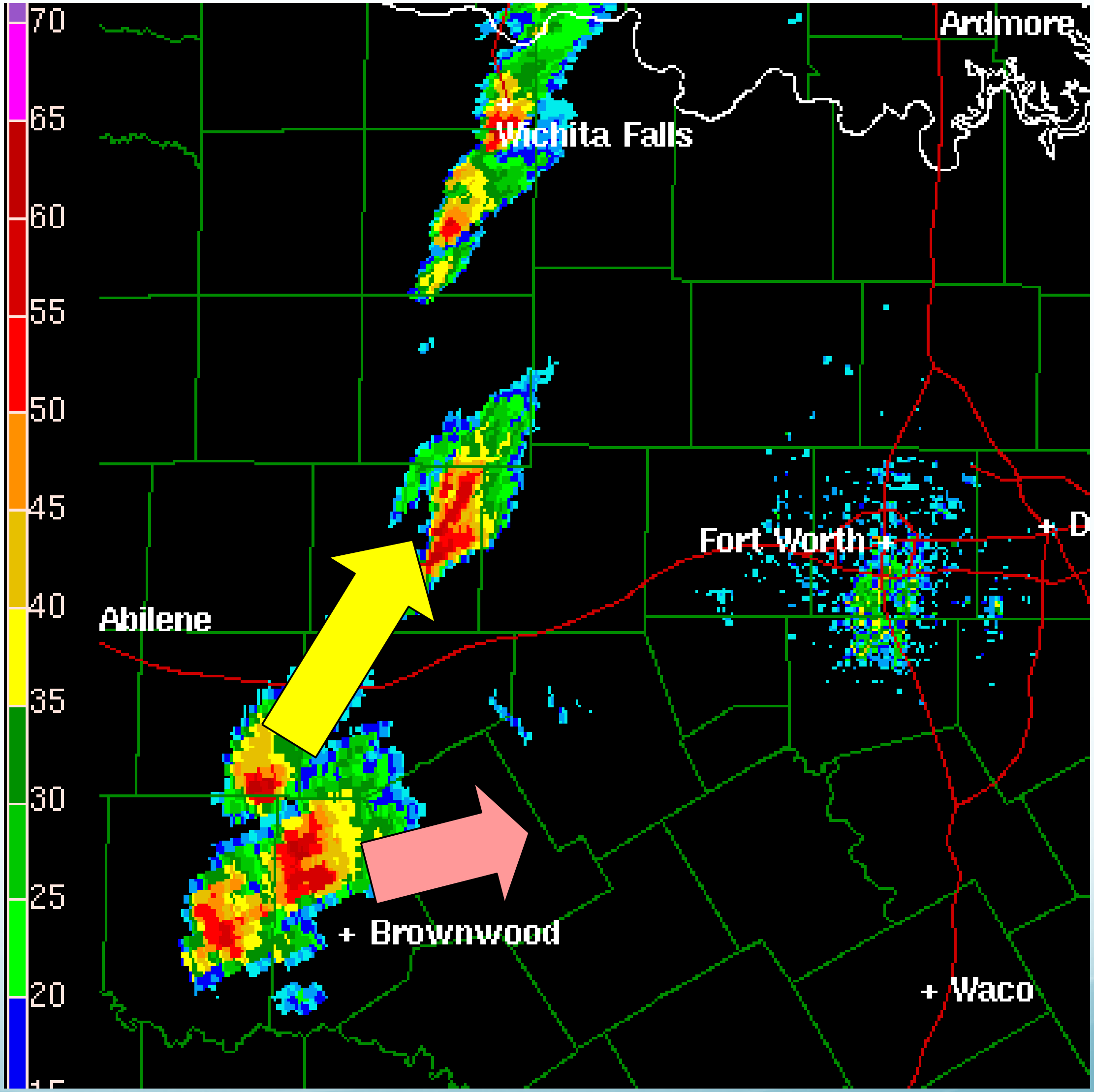


Deviant Storm Motion

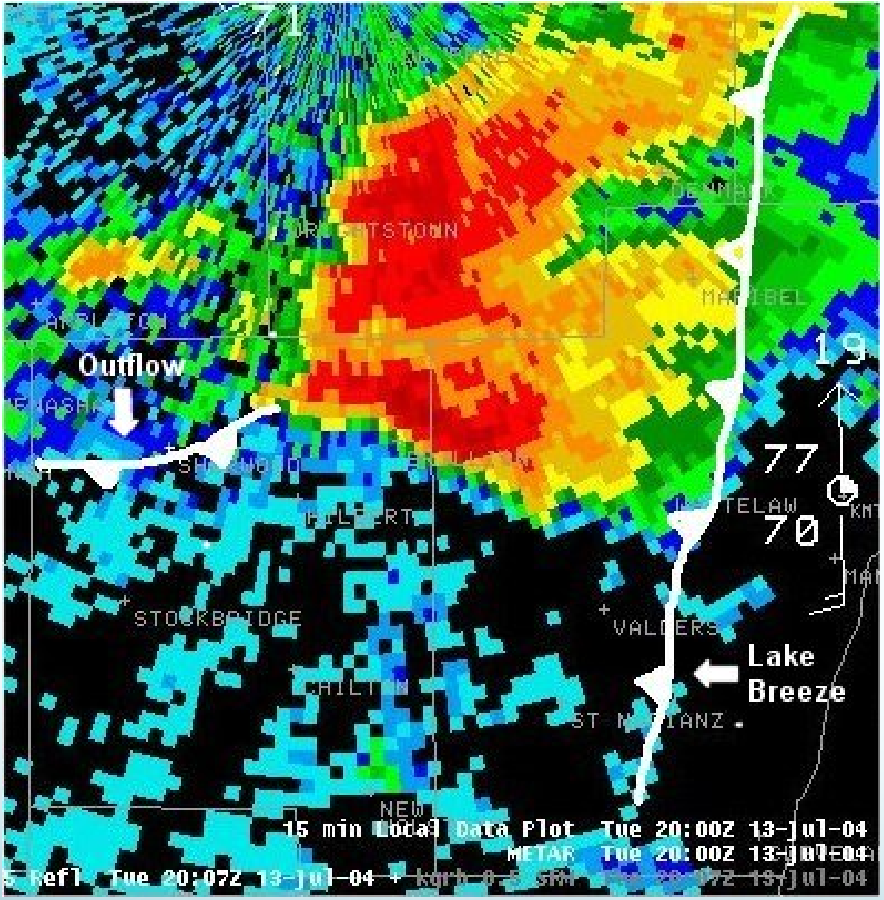
"Average" storm motion NE 30 mph

Faster/left mover – hail/downburst potential

Slower/right mover – suggests storm rotation



Cell Merger


Outflow
Lake
Breeze
STOCKBRIDGE
VALDERS
HILBERT
77
70
15 min Local Data Plot Tue 20:00Z 13-Jul-04

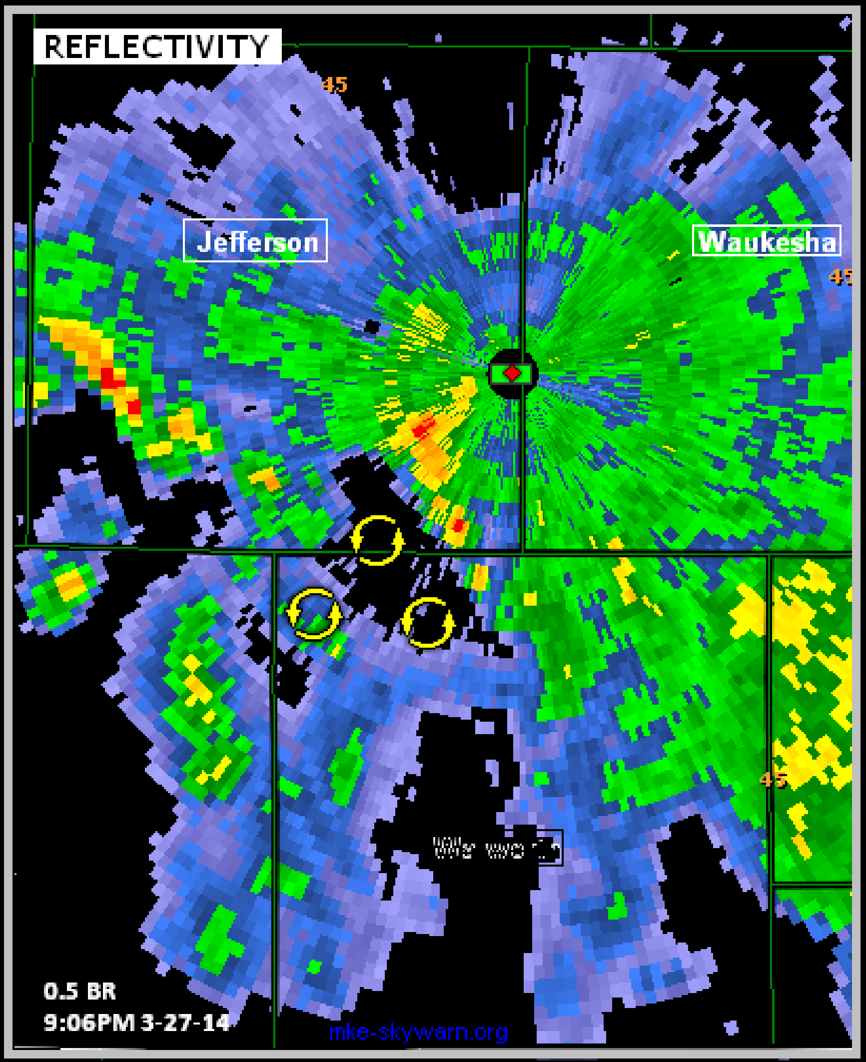

Outflow
Lake
Breeze
VALDERS
HILTON
MARIBEL
72
68
27
15 min Local Data Plot Tue 20:30Z 13-Jul-04
METAR Tue 21:00Z 13-Jul-04

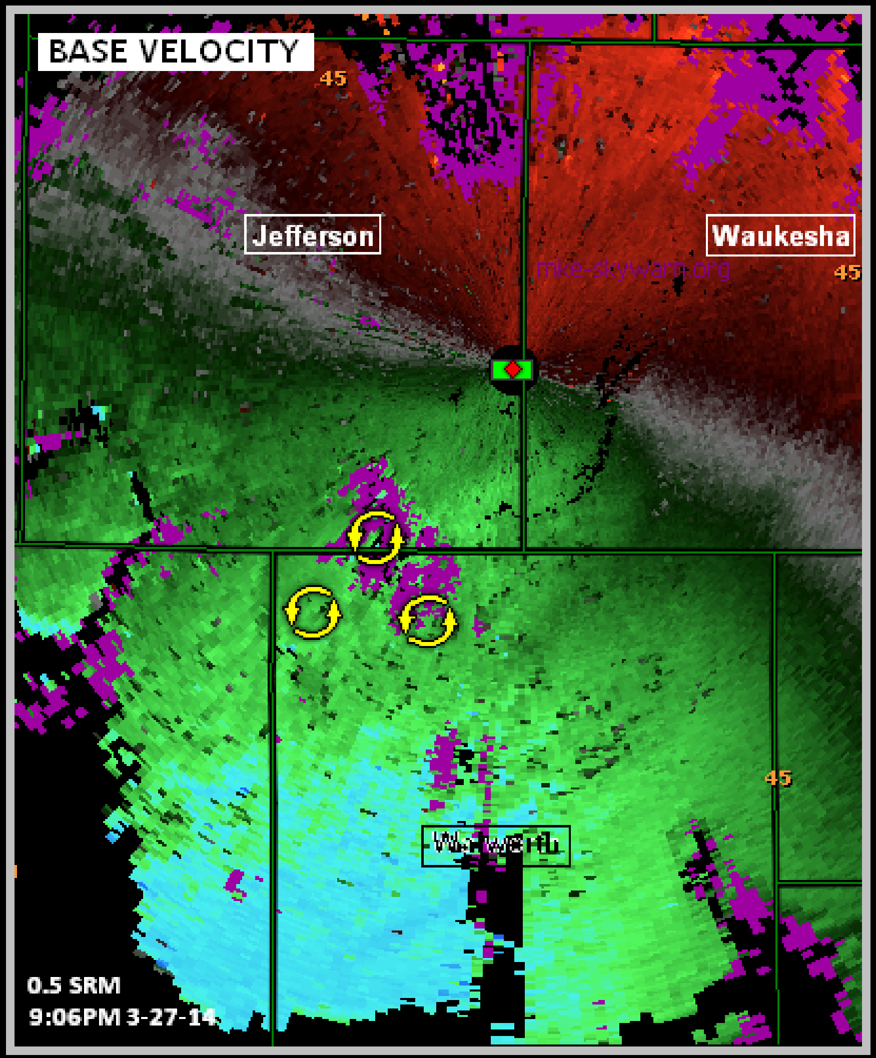
Radar Algorithms:

Computer programs designed to detect rotation, hail, etc.

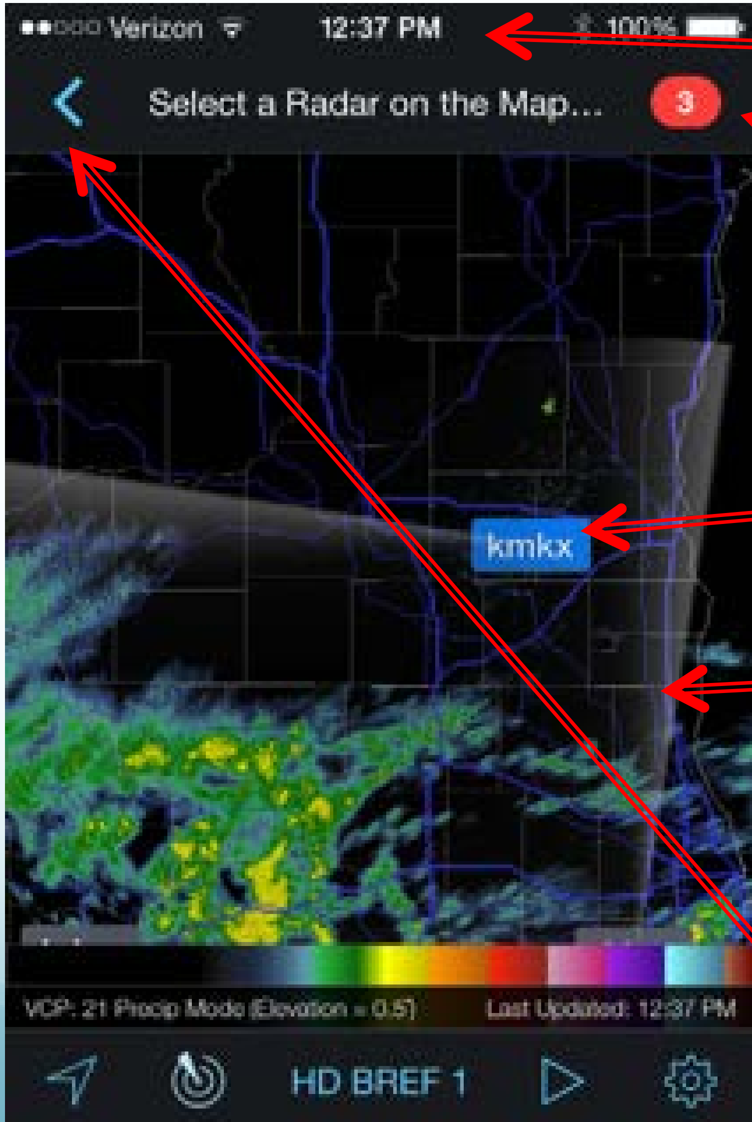
Many do not consider the state of the atmosphere. A simple Yes-No program.

Without other temporal or spatial data consider them as guidance not gospel.





Radarscope "Stuff"



Time Stamp

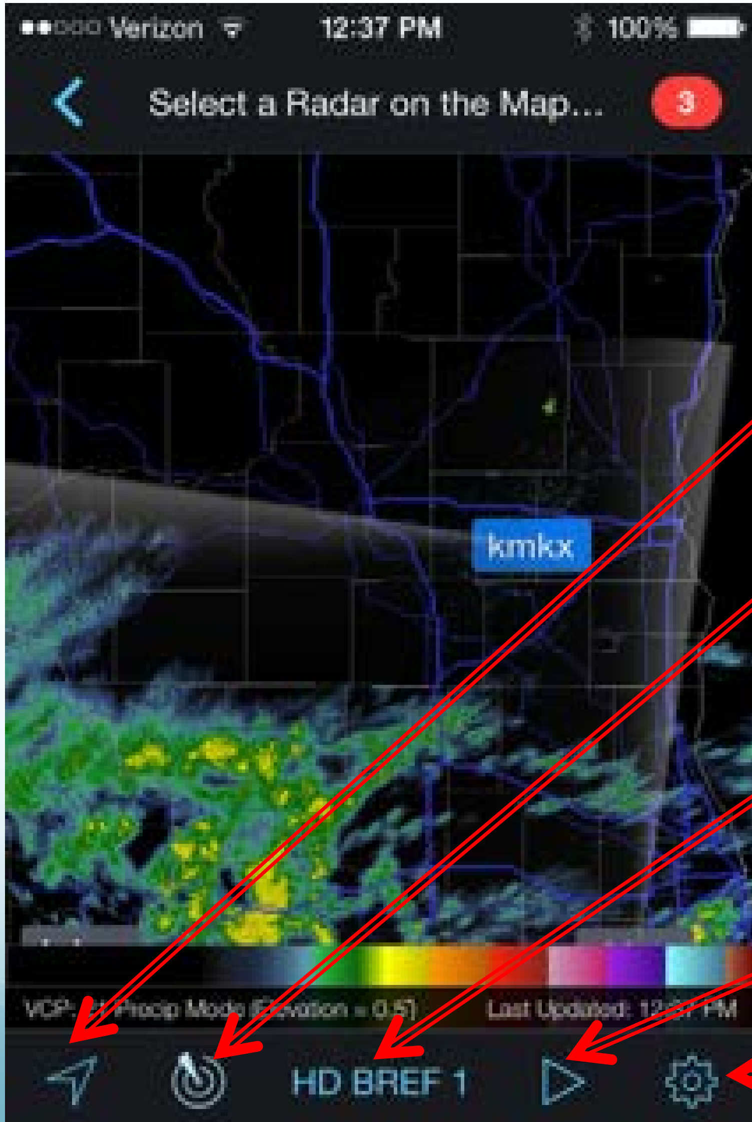
Number of Wrngs in U.S

Radar Site

Radar "sweep"

Open other menu bar

Radarscope “Stuff”



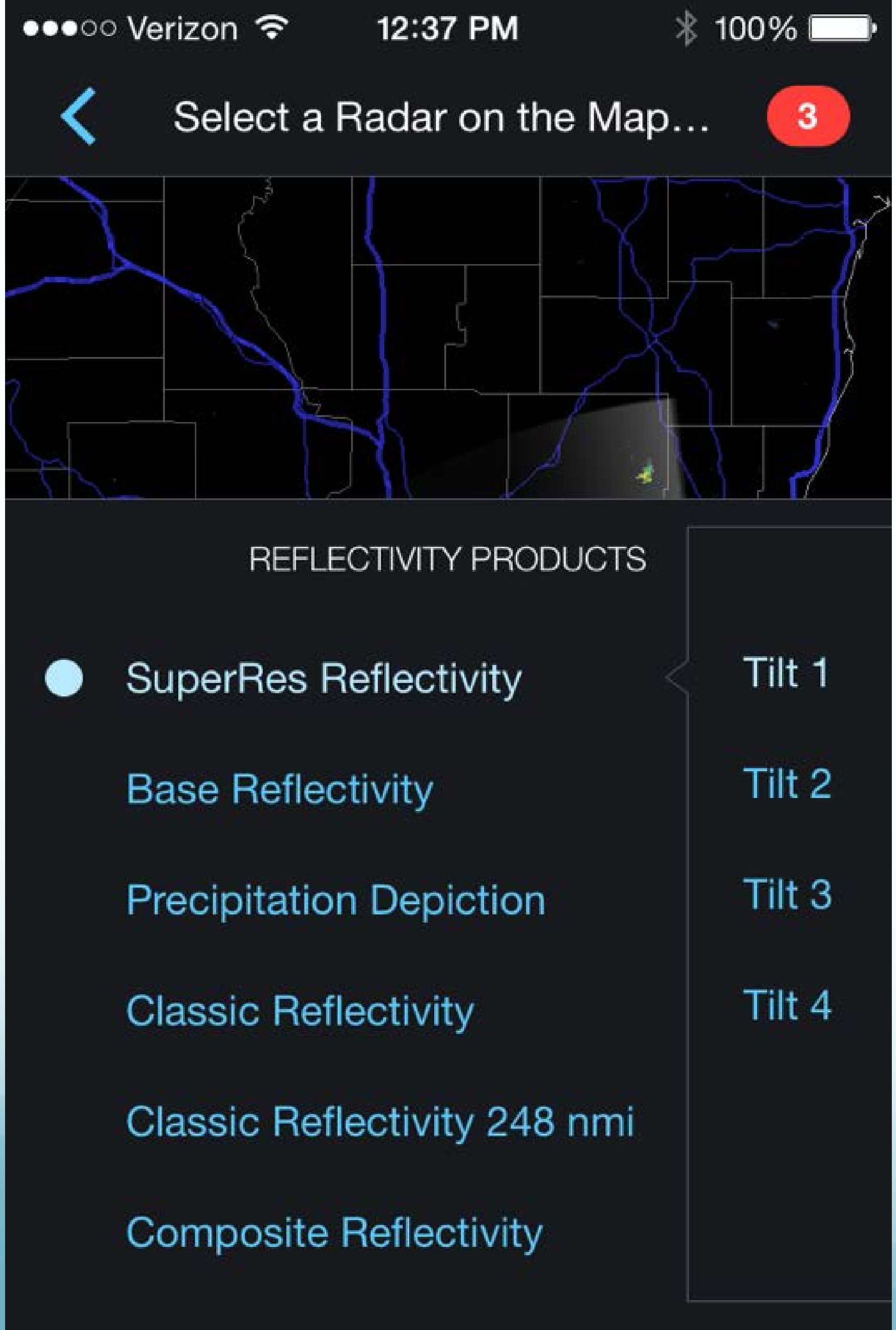
Cell phone location ‘mark”

Map of radar sites

Product (image) Name

Looping

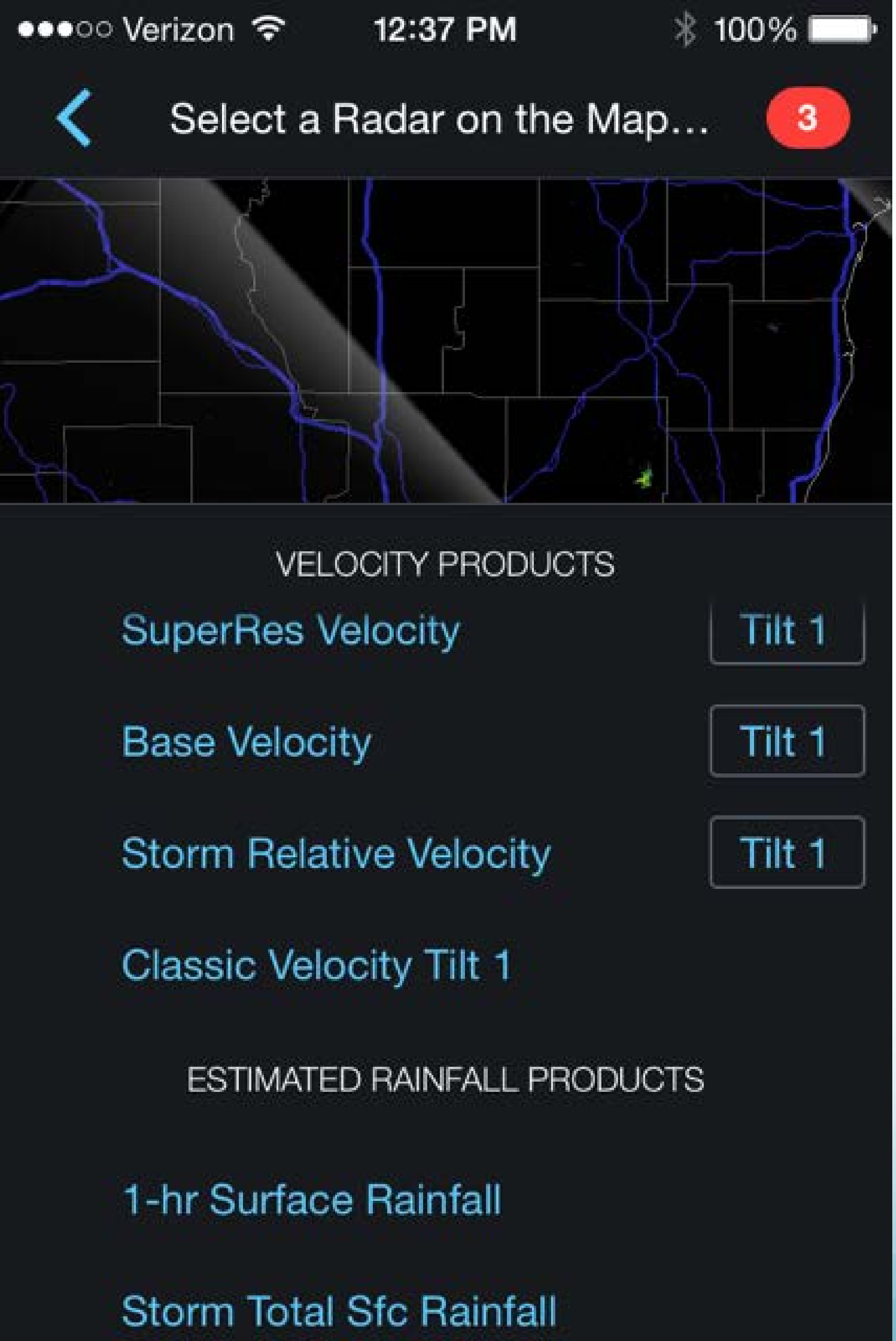
Settings

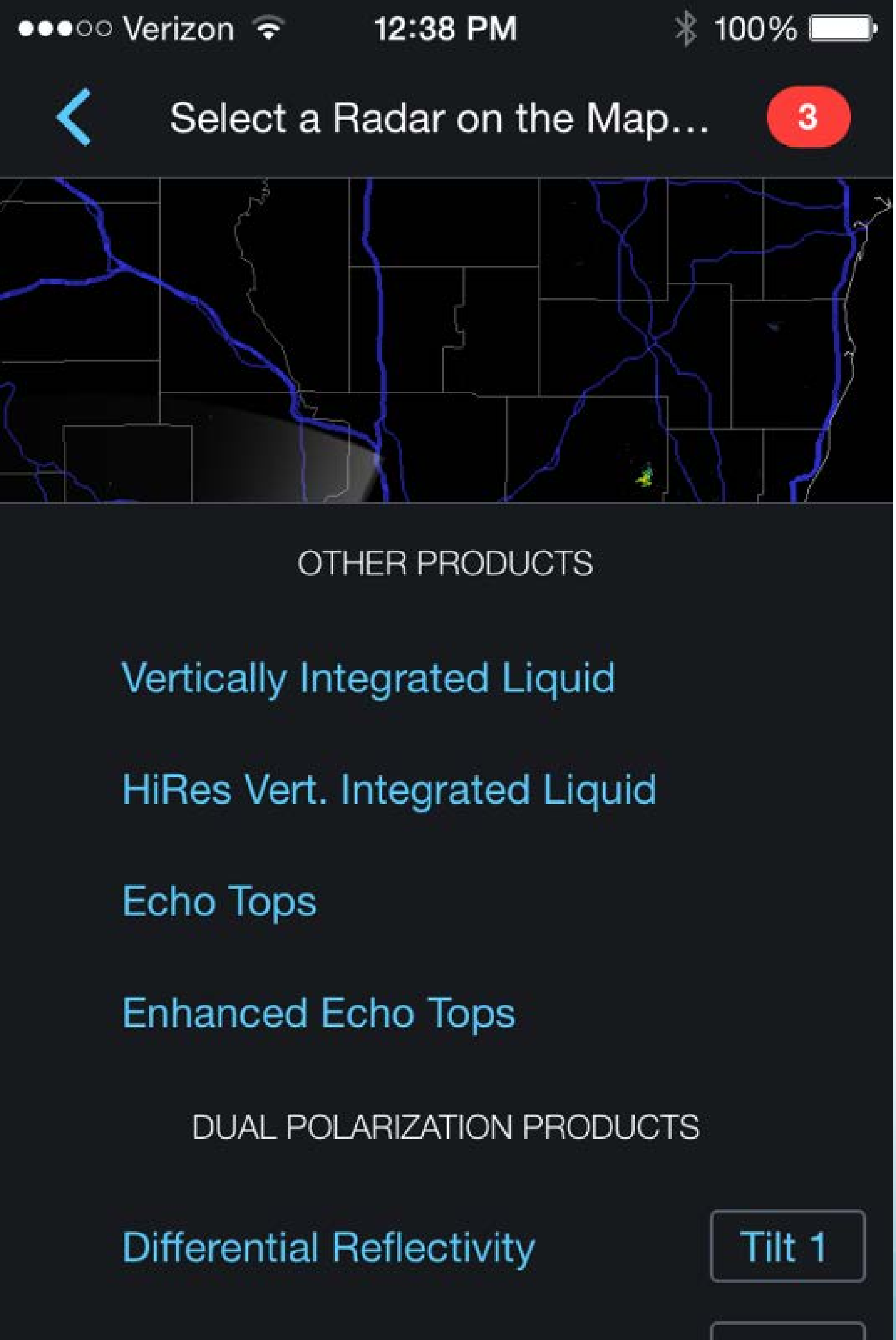


Radarscope Images

When you tap on Tilt 1, a pop-up menu listing the lowest 4 slices appears.

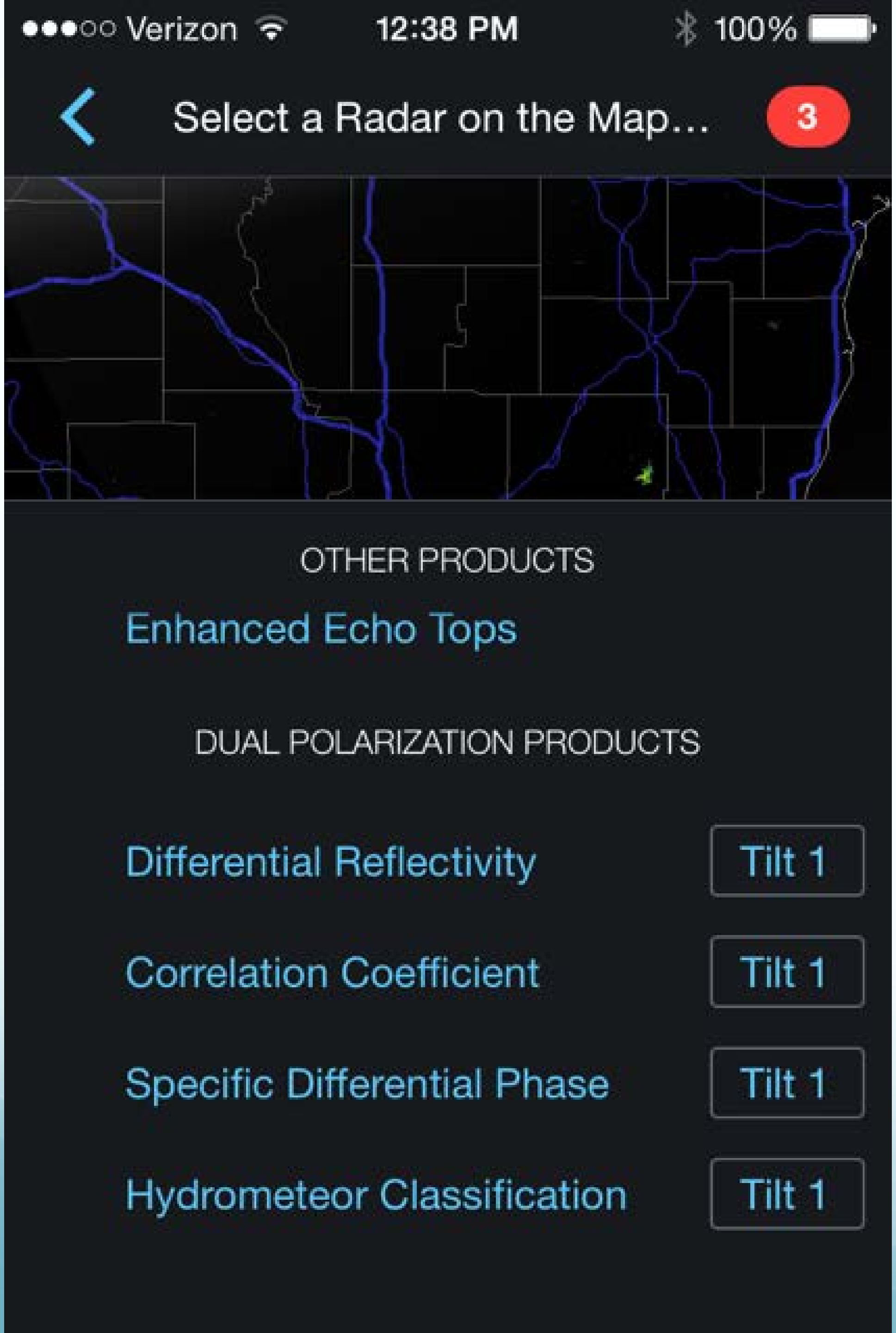
Radarscope Images



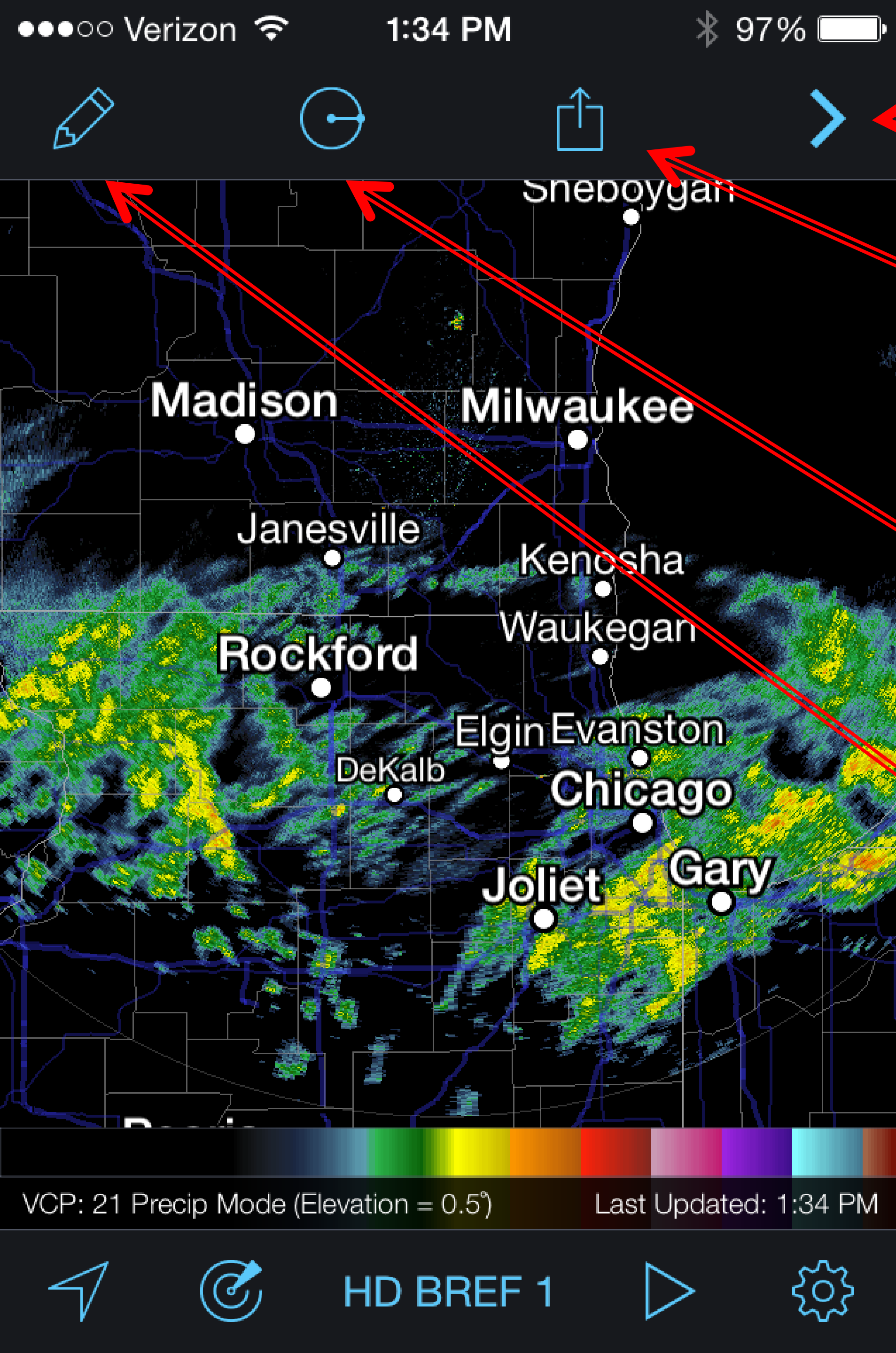


Radarscope Images

Radarscope Images



Radarscope Images



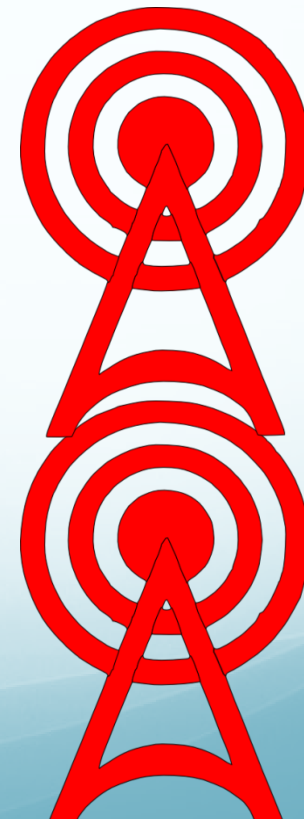
Close this menu line

Addition action – forward image

Marker for radar site

Annotate tool

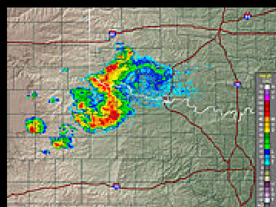
Dual Pol Radar



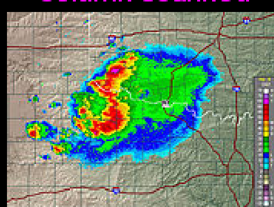
REFLECTIVITY	RADIAL VELOCITY		DUAL POLARIZATION
Base Reflectivity **DBZ** Lowest scan above ground	**Base Velocity** **BV**	**Storm Relative** **SRM**	**Differential Reflectivity** **ZDR** **Correlation Coefficient** **CC** **Spec. Differential Phase** **KDP**
	Always Relative To The Radar's Location		
	Ground Relative Wind speeds	Storm Motion Removed	

REFLECTIVITY

Base Reflectivity
DBZ
Lowest scan above ground



Composite Reflectivity
DBZ
Entire vertical column scanned



- Intensity
- Movement
- Trends
- Aerial Coverage

RADIAL VELOCITY

Base Velocity BV — Ground Relative Wind speeds

Storm Relative SRM — Storm Motion Removed

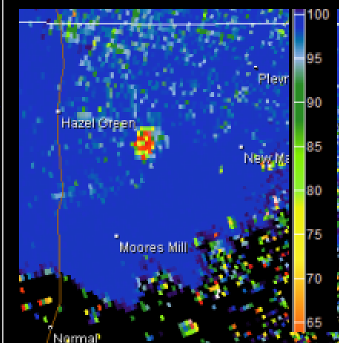
Always Relative To The Radar's Location

- Gust Fronts
- Microbursts
- Straight-Line Winds
- Veering Winds
- Backing Winds
- Diffulence

- Tornado Vortex Signature
- Mesocyclone
- Rotation storms
- Convergence

DUAL POLARIZATION

Differential Reflectivity ZDR
Correlation Coefficient CC
Spec. Differential Phase KDP



- Tornado Debris Signature
- Rain-Snow Areas
- Non-Meteorological's
- Seperate heavy rain-hail
- Rain fall measurements

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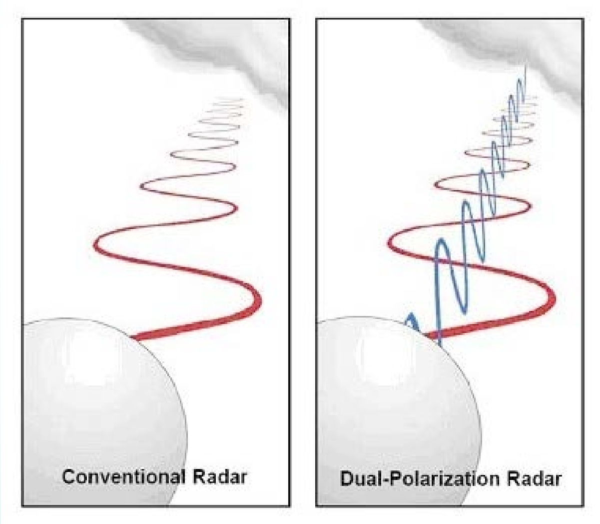
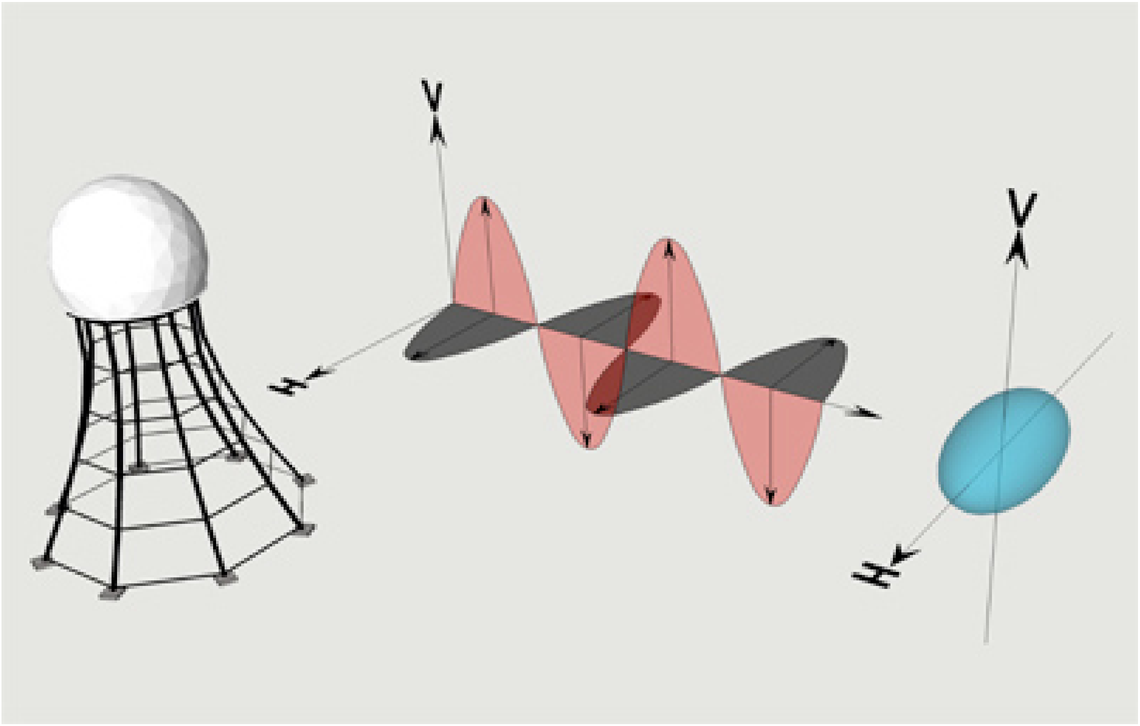
Radar Observations

- Radar energy is a form of electro-magnetic energy…consisting of electric and magnetic fields.
- Weather radars typically transmit/receive in a single electric field (single polarization – usually horizontal).
- Radar pulses – 1000 per second (Pulse Repetition Frequency).
- Part of signal reflects off of targets (reflectivity) & returns to radar site.
- Signal can be attenuated by heavy rains (internal scattering & absorption), leaving less energy to reflect off of targets downstream. This leads to under-estimate of rain intensity & amount.



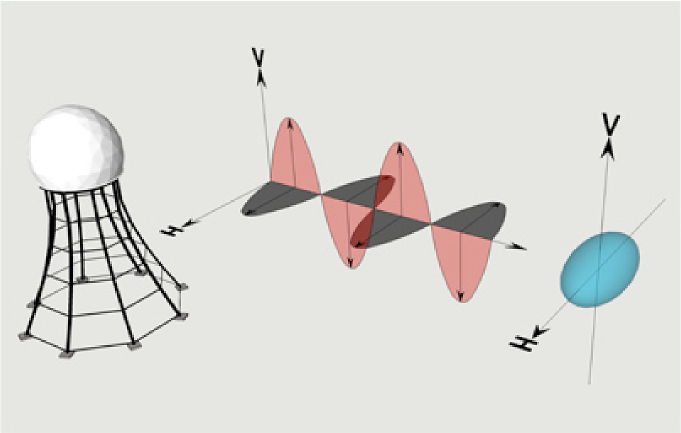
What is Dual Pol?

- Dual–Pol radar signal consists of both a horizontal and vertical component. Legacy Doppler Radar signal consists of only horizontal component.



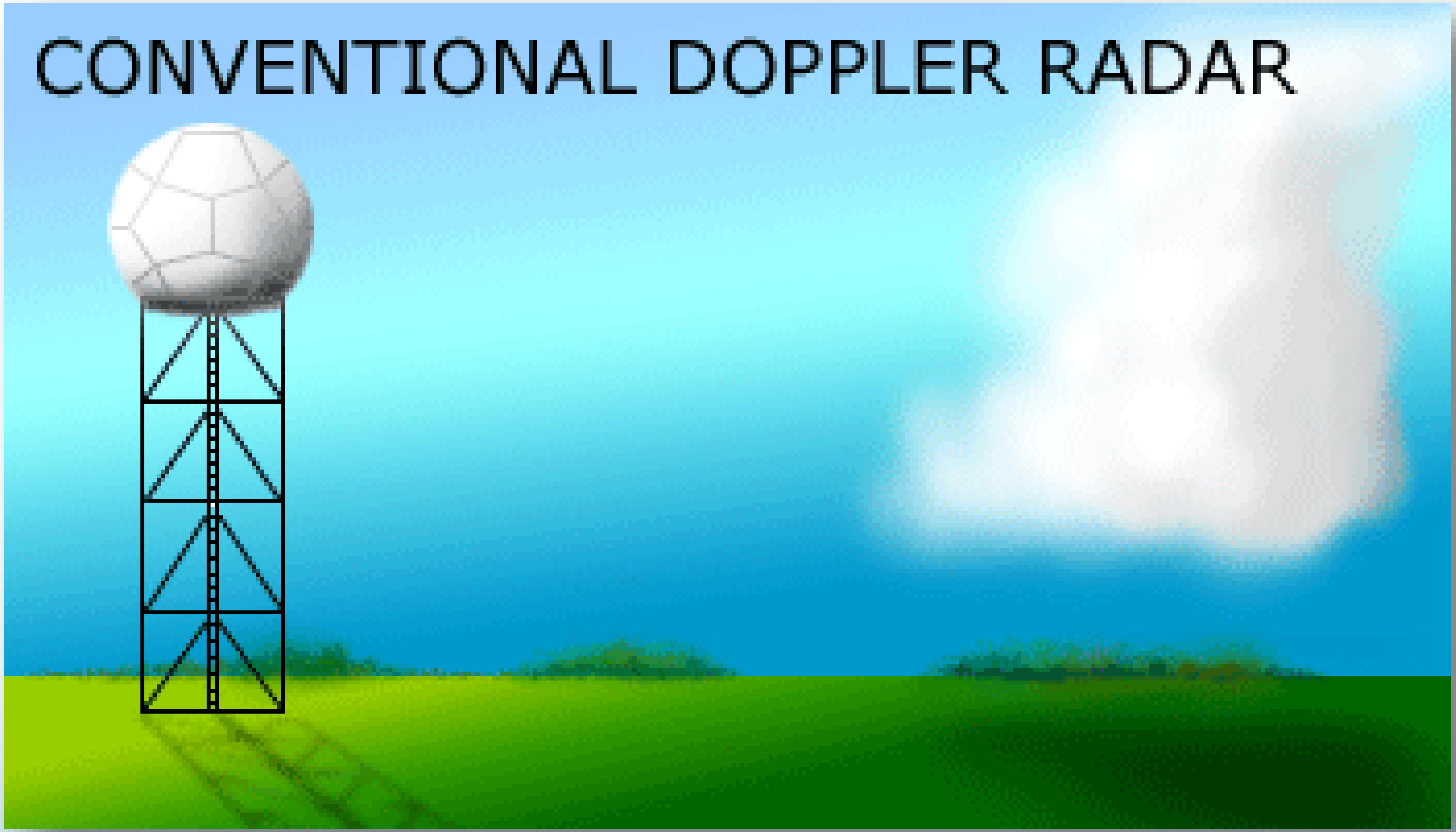
Dual-Polarization Overview

- Radar pulse transmits both horizontal and vertical components – can determine shape and orientation of target.
- Better rainfall estimates since hail contamination is removed.



- Precipitation types are algorithms. Not perfect!
- Can't predict tornado ahead of time!
- Can confirm likelihood of tornado (debris ball).

Dual Polarization Radar

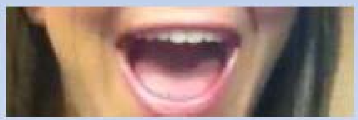


Dual Polarization

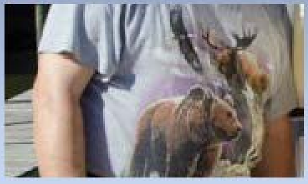
- Better precipitation estimation
- Improved detection / mitigation of non-weather echoes
- Melting-layer identification
- Hydrometeor classification
- Tornado debris ball signature
  - <u>But does not improve lead time of tornado warnings</u>

Horizontal Scanning

- Pink Lipstick
- Blonde, longer hair
- She



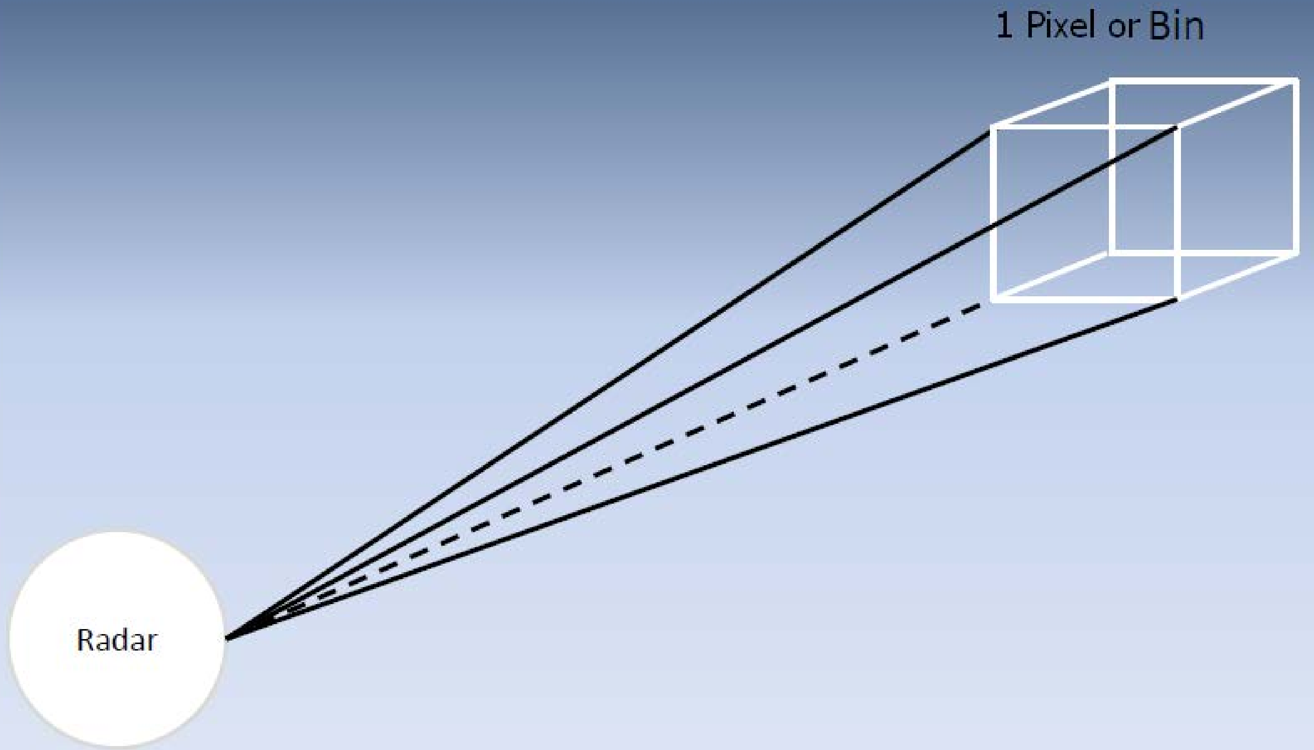
- Shirt, suit
- Tie
- He



- Short Sleeve
- Animal/ Outdoors
- She/He

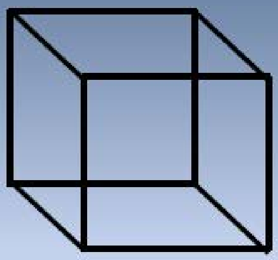
Horizontal and Vertical Scanning

Dual Polarization



Dual Polarization

Bin



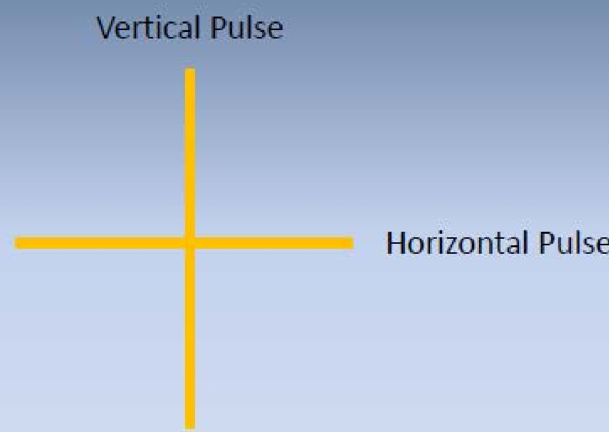
Rain

Hail

Debris

Wood, Insulation, Leaves, Twigs, Paper, etc.

Dual Pol: The Cross Section



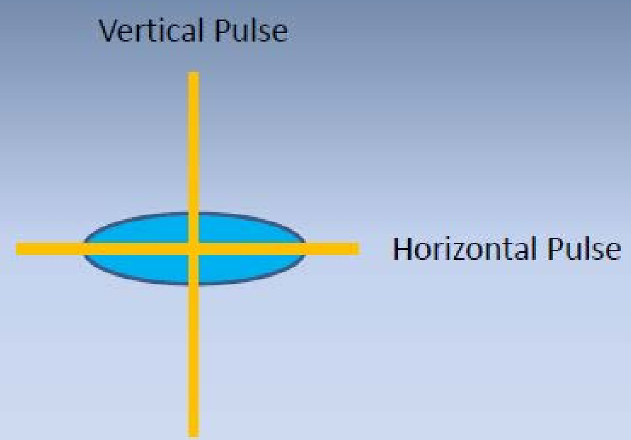
Targets measured in a ratio:

Example: Hail stone of 3 in X 3 in

Ratio: 3 to 3 or 1 to 1

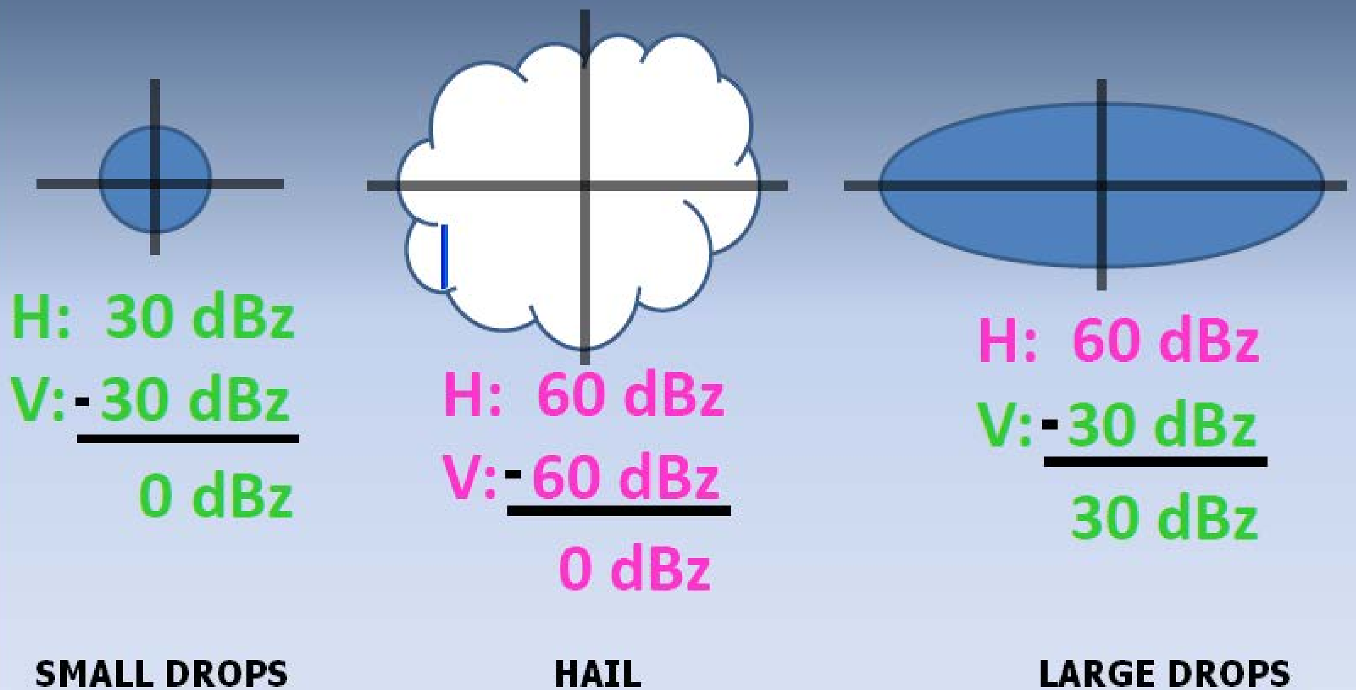
or the target has the same height and width

Dual Pol: The Cross Section



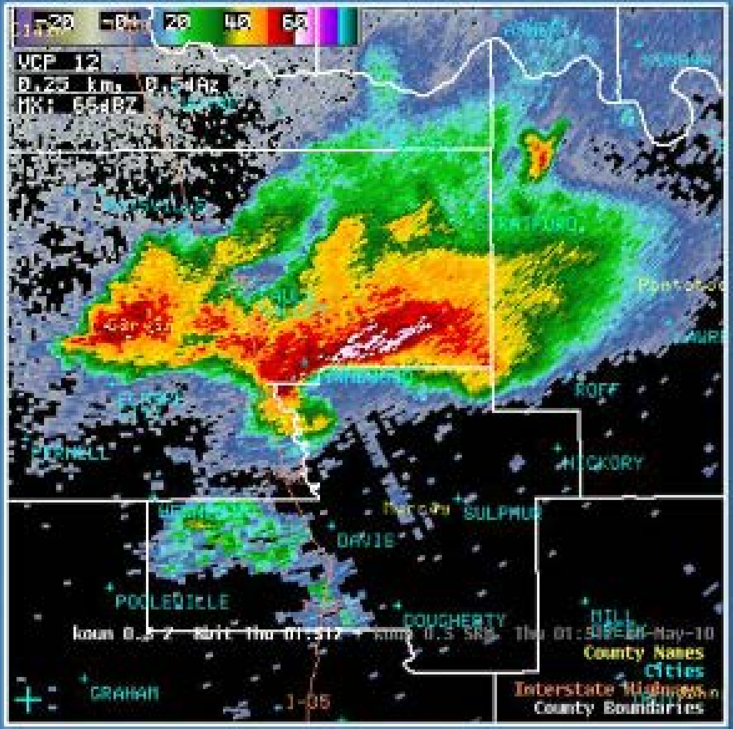
Raindrops are flattened as they fall
Targets measured in a ratio:
Example: width of 3, height of 1 or
a ratio of 3 to 1

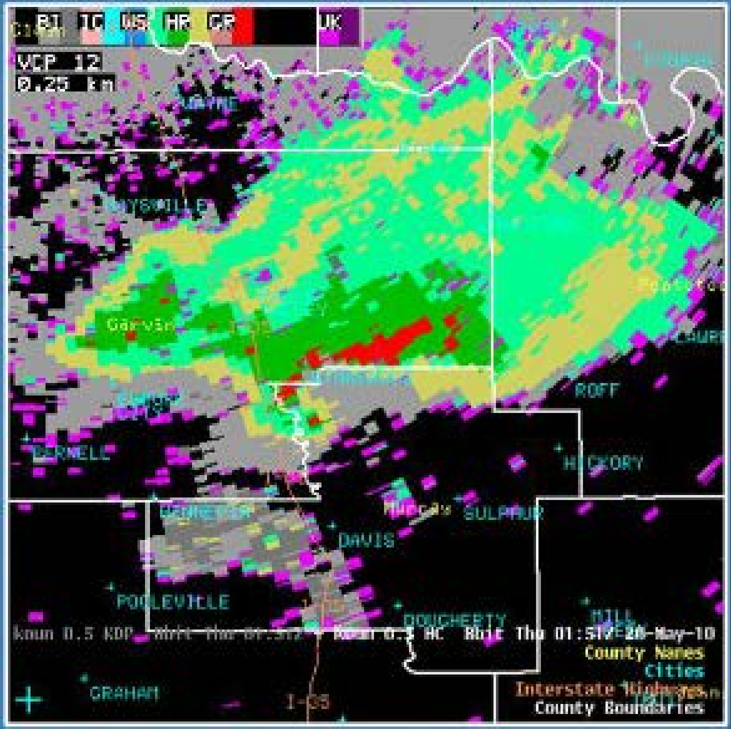
Horizontal and Vertical Scanning



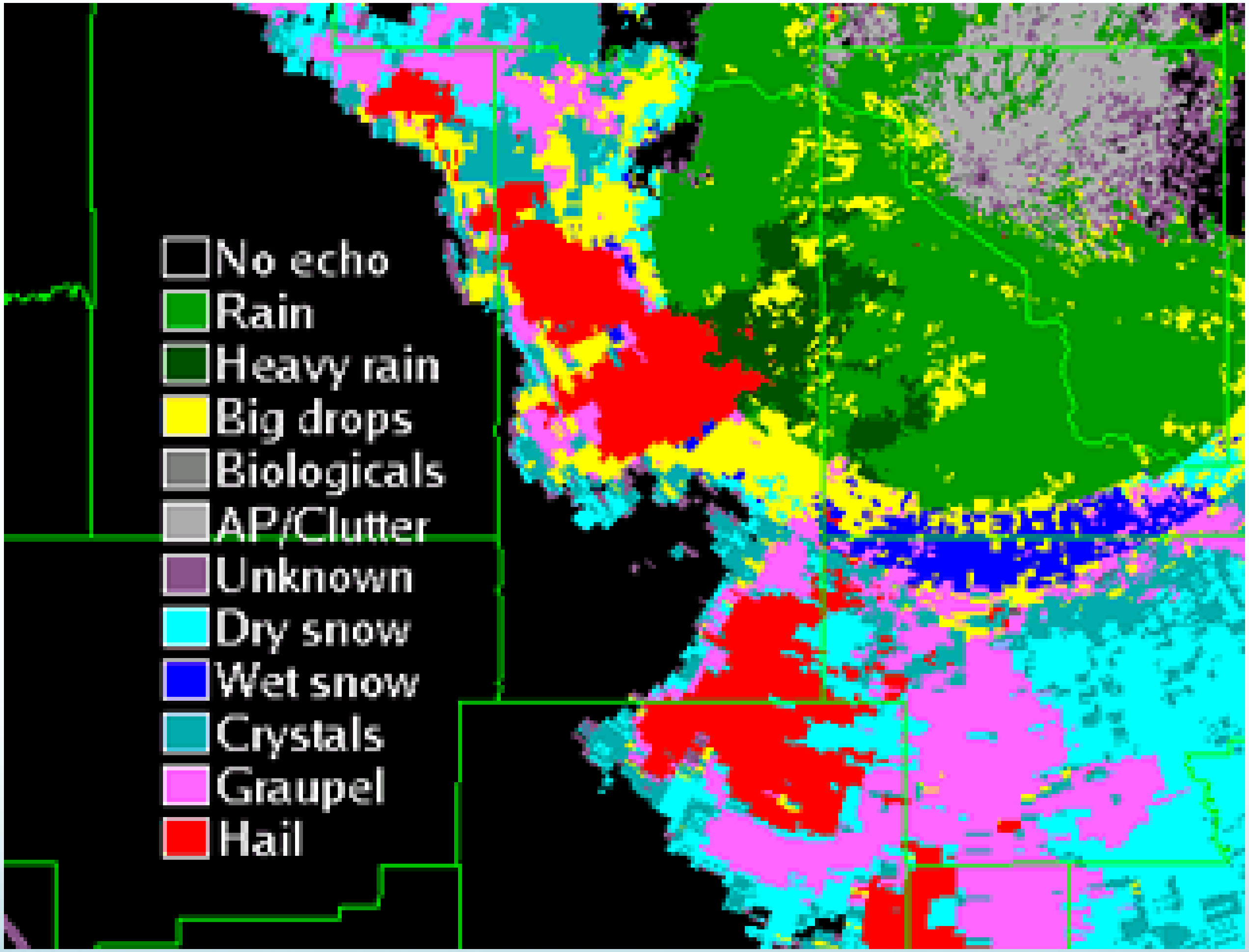
What is the HCA?

- Hydrometeor Classification Algorithm (HCA)
  - Uses dual polarization base products to make a best guess at precipitation type

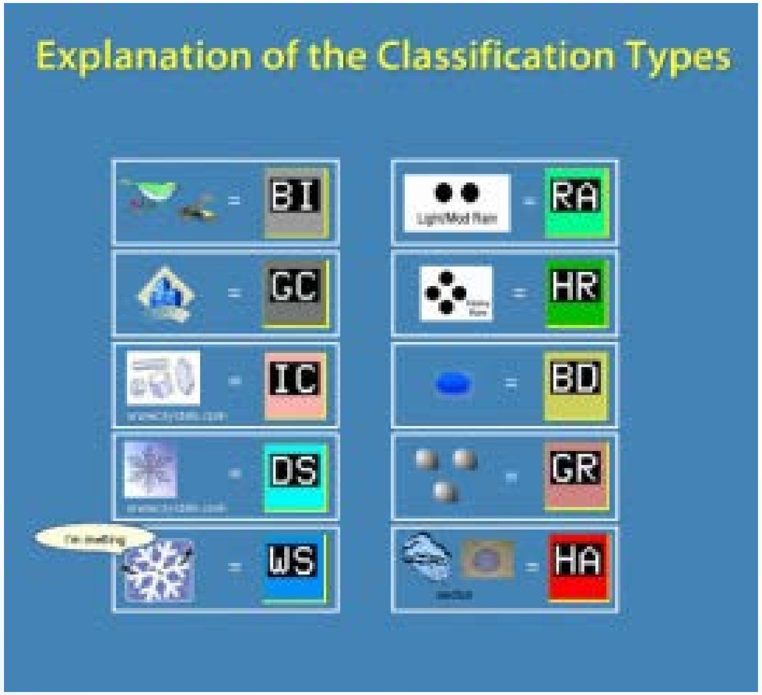


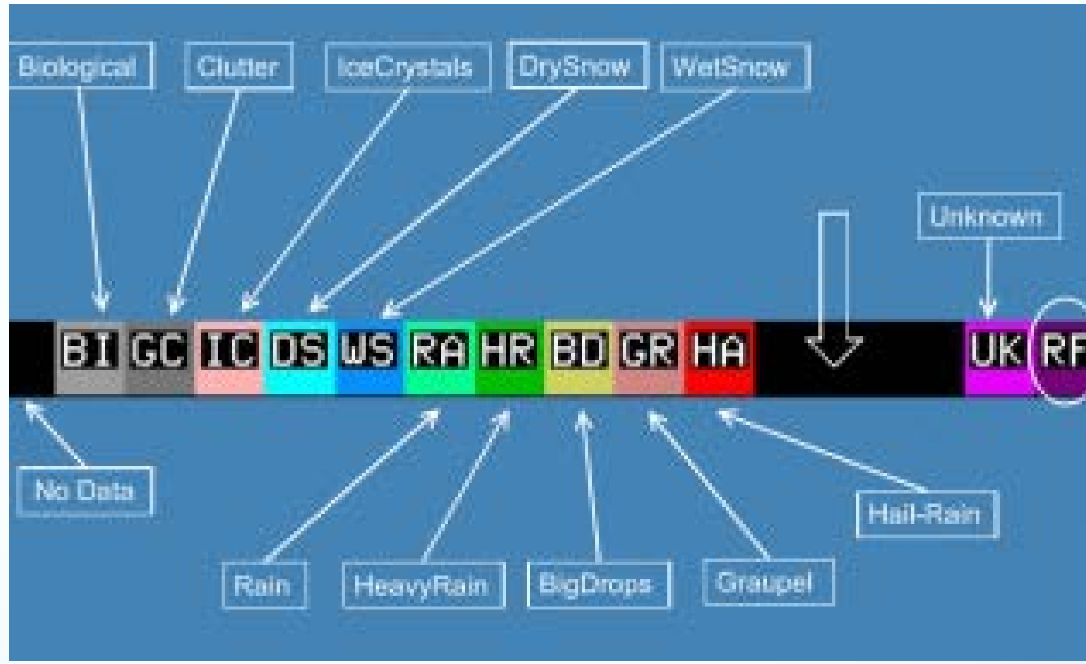


Dual-Polarization Precipitation Types



Precipitation Types

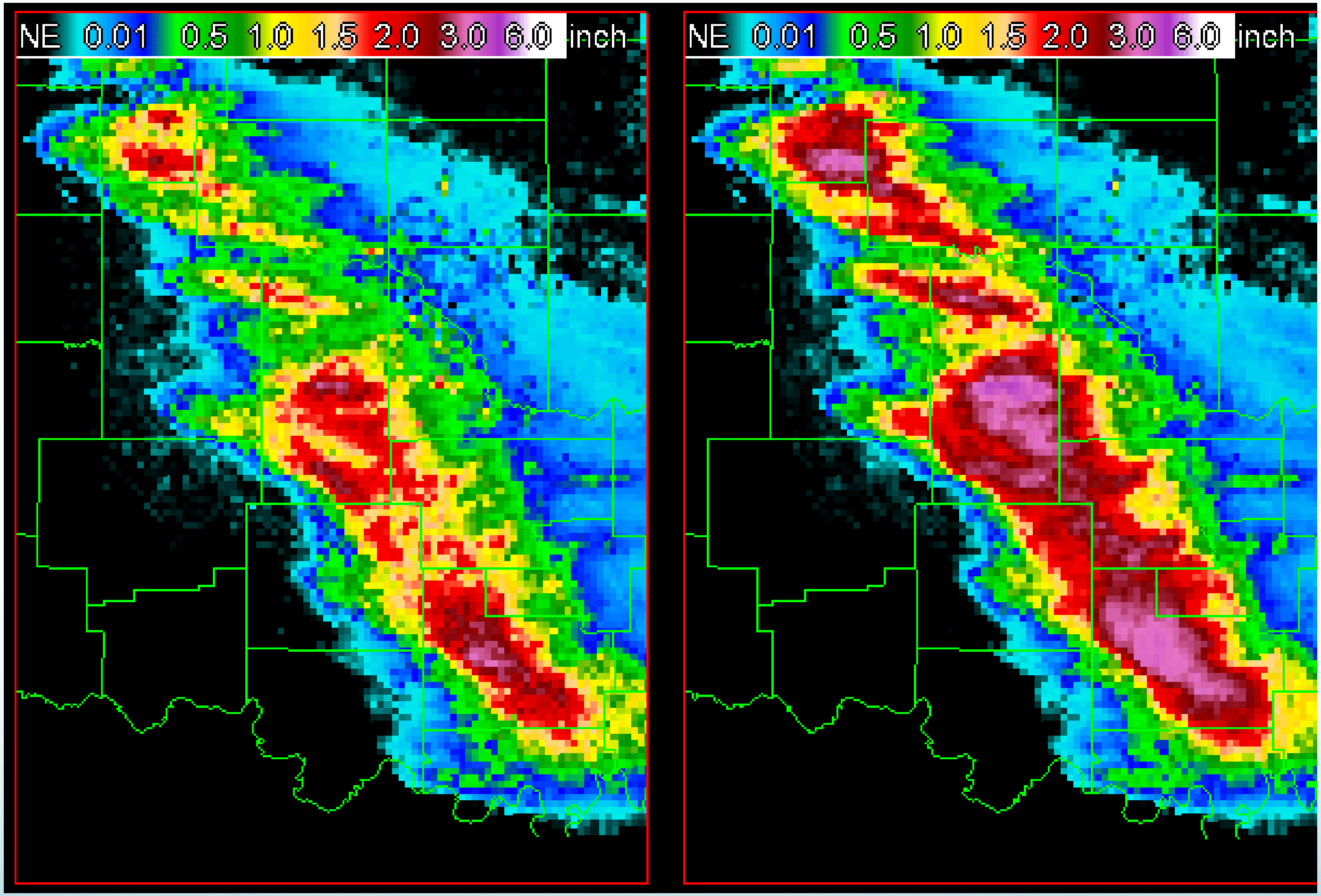




10 “target” classifications

3 additional classifications: no data, unknown, and range-folding

Dual-Polarization Rainfall Estimate



Dual-Polarization Old Doppler Legacy

Dual-Pol Overview

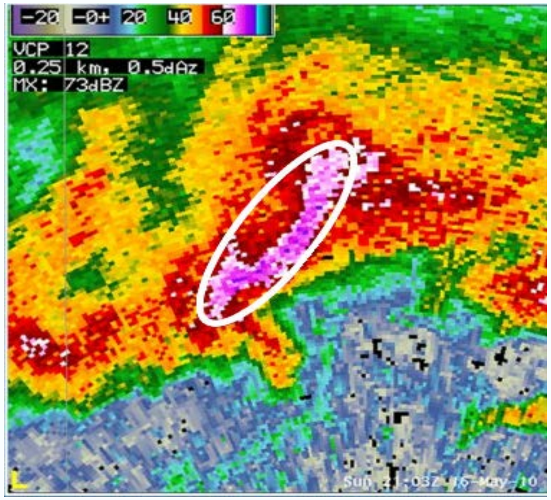
- **Dual-pol product:** Correlation Coefficient (CC)
  - Measure of how similarly the horizontally and vertically polarized pulses are behaving from pulse-to-pulse inside a resolution volume
  - Units: None
- High values = precipitation
- Low values = non-meteorological targets

Correlation Coefficient

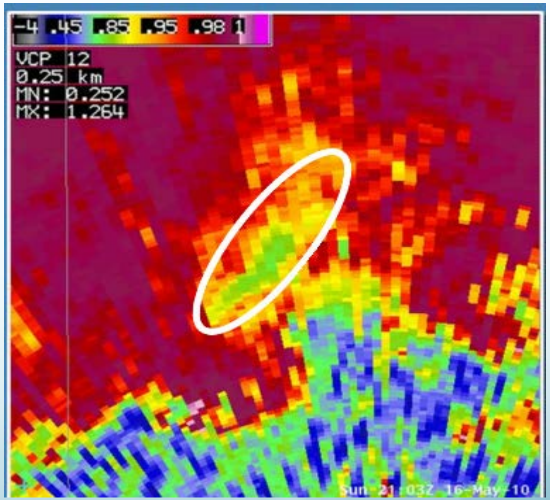
- All of those targets are in the bin and the radar has to distinguish between them
- It calculates the ratios of all those targets
- When you have all different kinds of targets in a bin, and their ratios are not correlated.
  - Correlation Coefficient of that bin is LOWERED

Correlation Coefficient

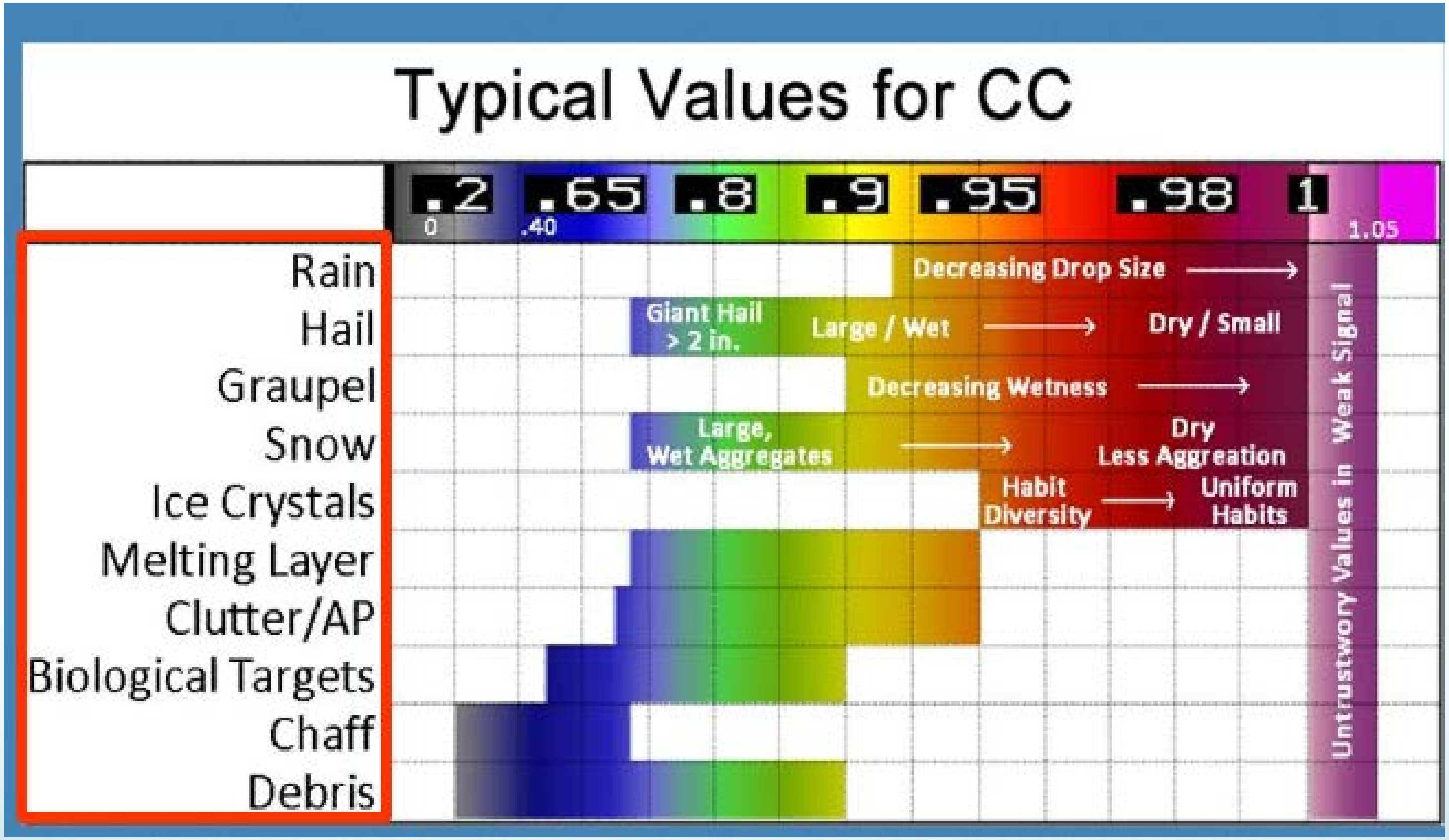
Reflectivity



CC less than 0.85 (golf ball+ hail)



Correlation Coefficient



Dual-Pol Overview

- Dual-pol product: Differential Reflectivity (ZDR)

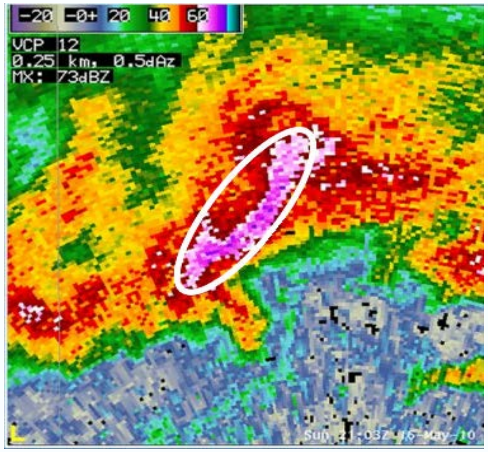
Difference between the horizontal and vertical reflectivity factors

Units: dB

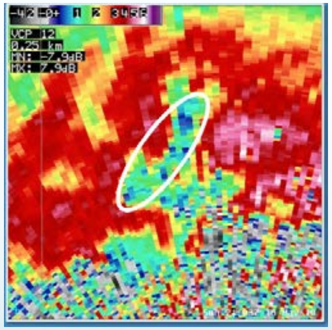
- Higher values = horizontal component larger (rain drops flatten out – oblate – more likely rain)
- Low values = snow/crystals more likely
- Zero value = hail

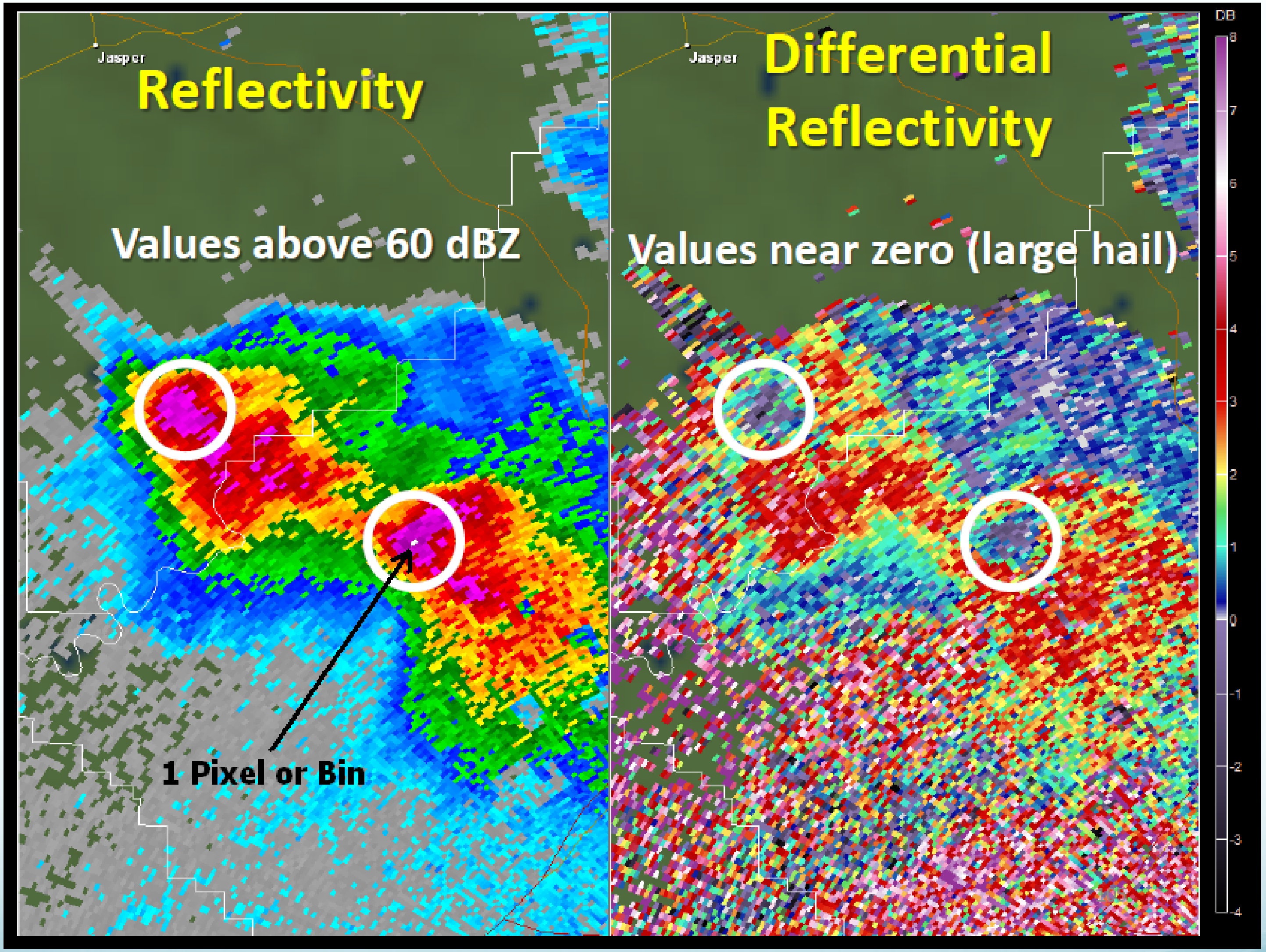
Differential Reflectivity

Reflectivity



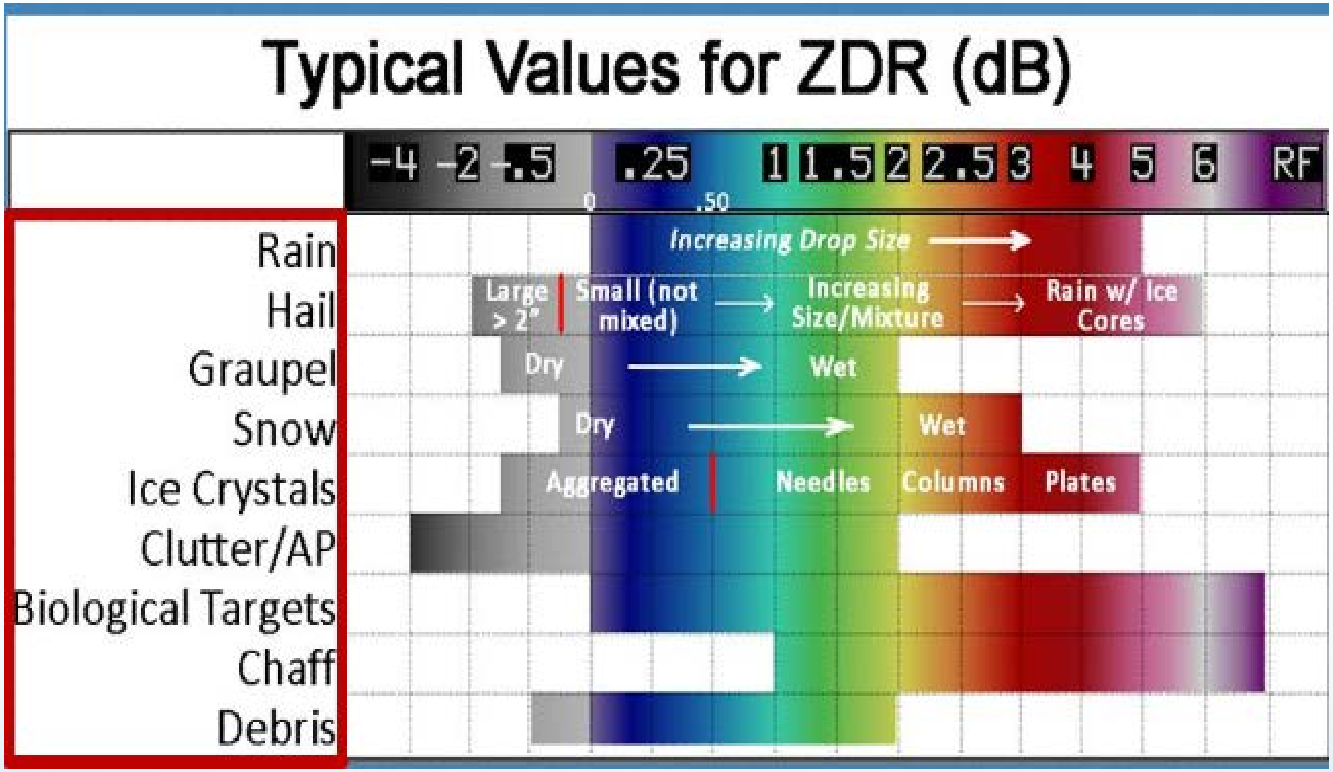
ZDR near zero or slightly neg





Jasper
Reflectivity
Values above 60 dBZ
1 Pixel or Bin
Jasper
Differential Reflectivity
Values near zero (large hail)
DB
8
7
6
5
4
3
2
1
0
-1
-2
-3
-4

Differential Reflectivity



Specific Differential Phase

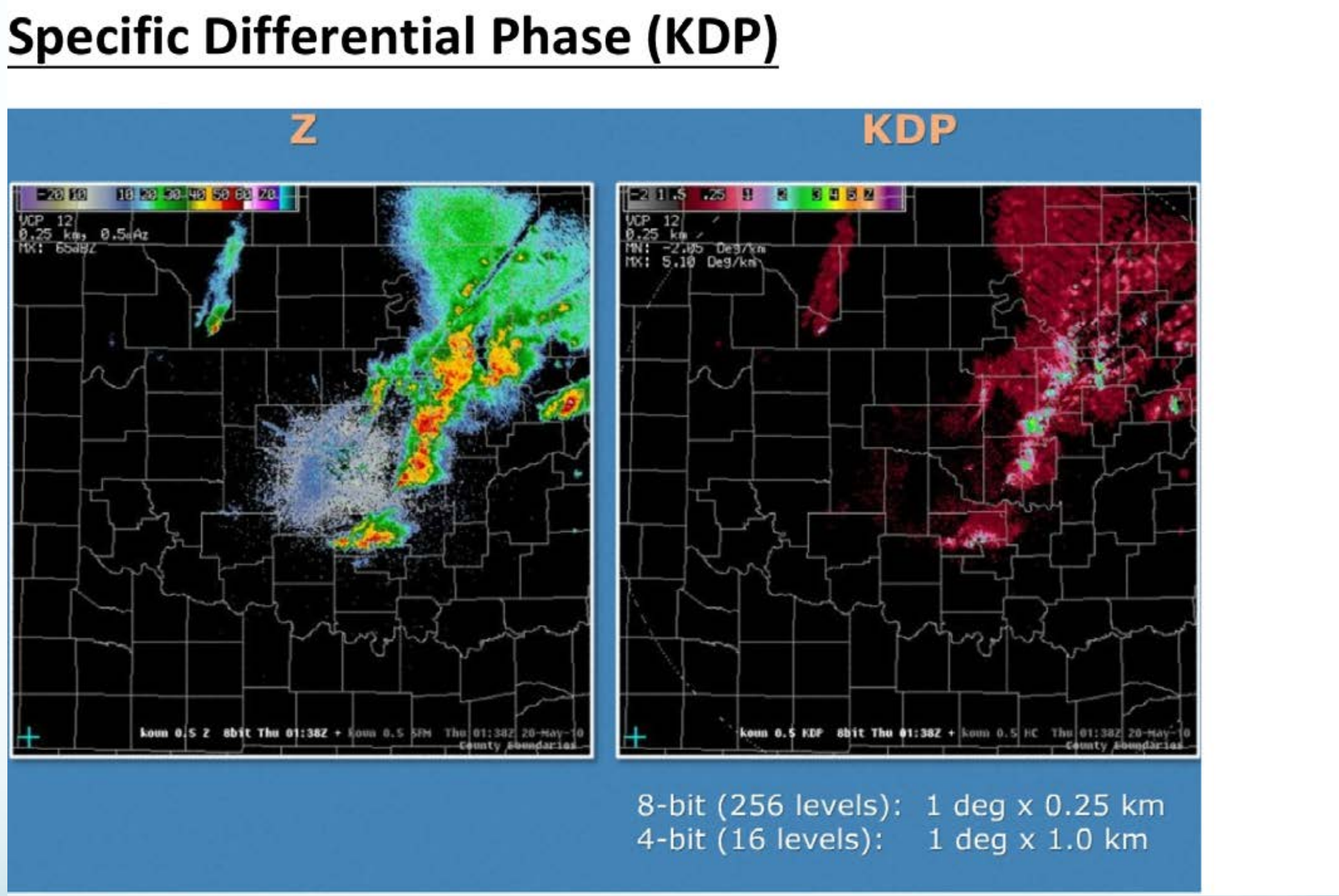
- Dual-pol product: Specific Differential Phase (KDP)

  - Range derivative of the differential phase shift along a radial
  - Units: deg/km

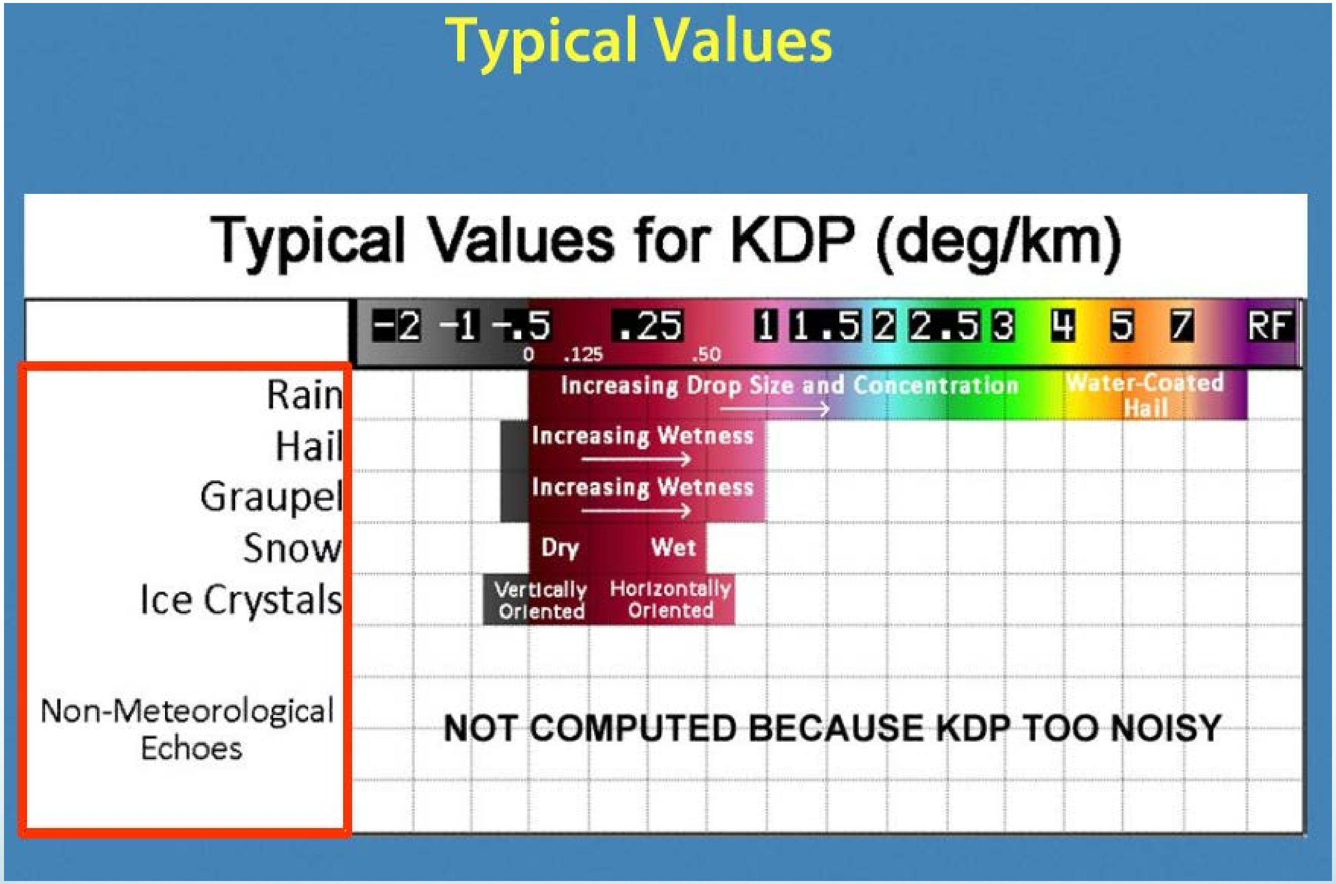
- Higher values = horizontal component larger (rain drops flatten out – oblate – more likely rain, or rain mixed with hail, or rain with melting hail.
- Near zero values = snow/ice/crystals more likely
- KDP not plotted when CC < 0.90

Specific Differential Phase

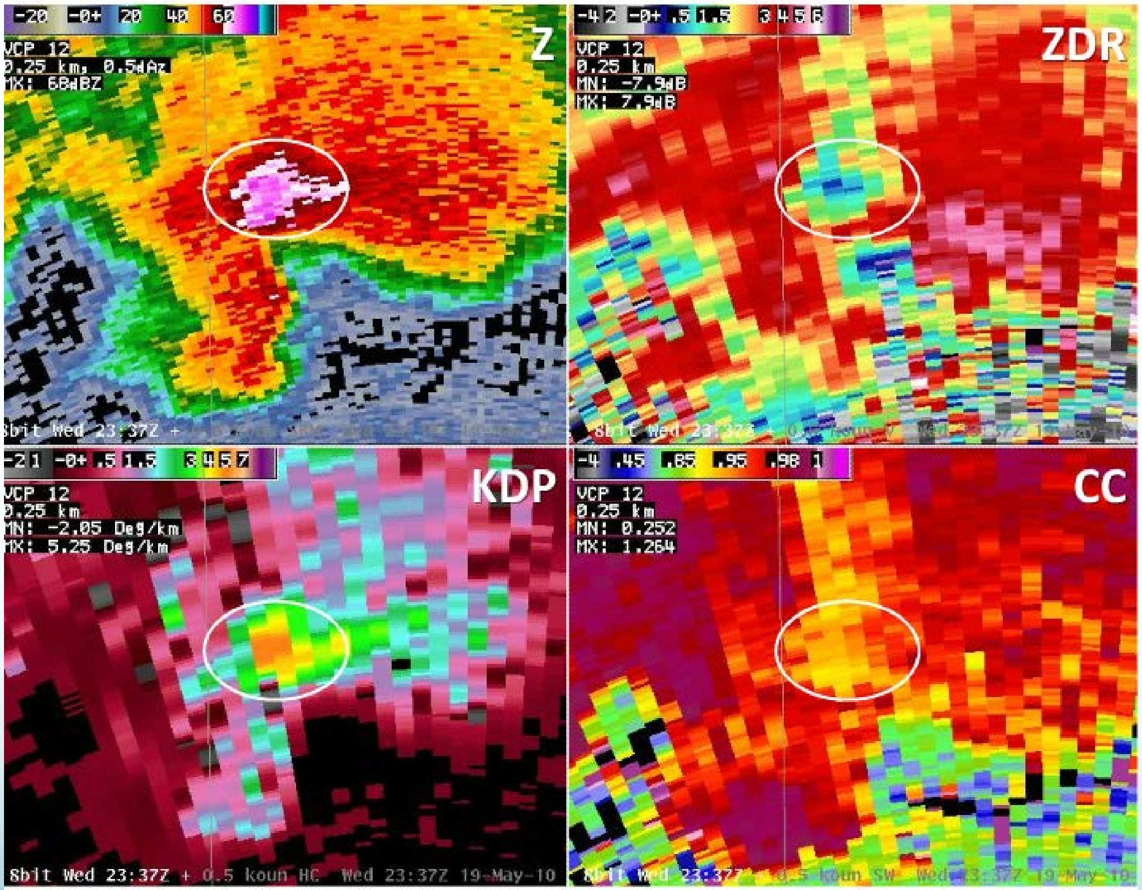
Higher values of KDP where reflectivity is highest suggests very heavy rain, or rain-coated hail which is melting.



Specific Differential Phase



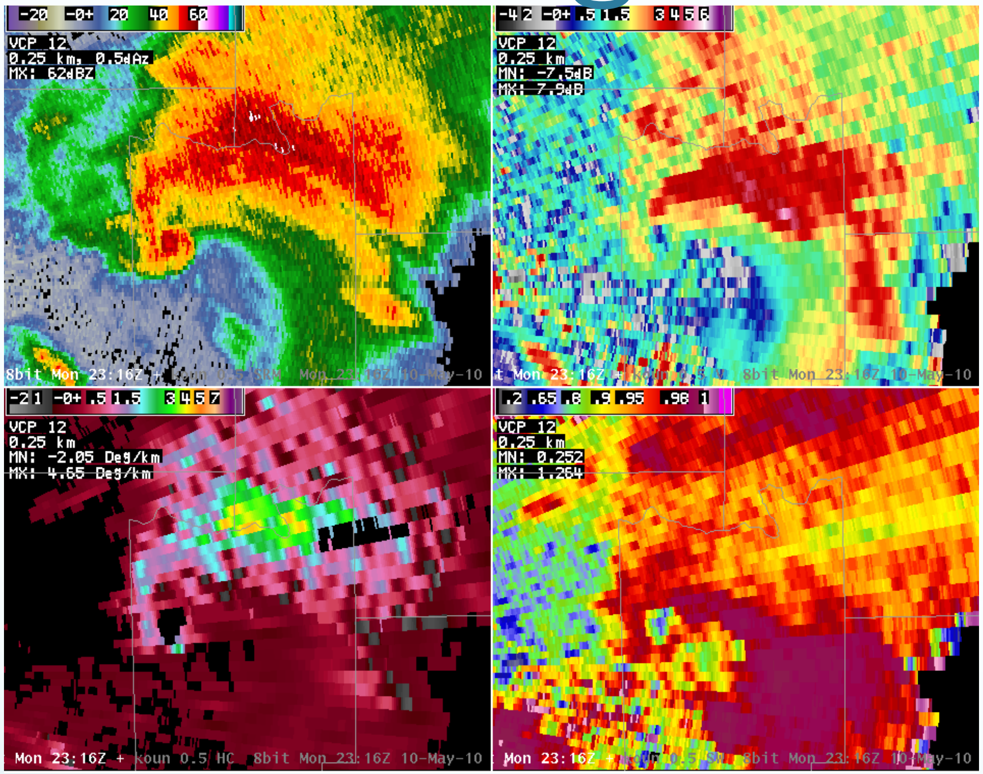
Putting it All Together (1)

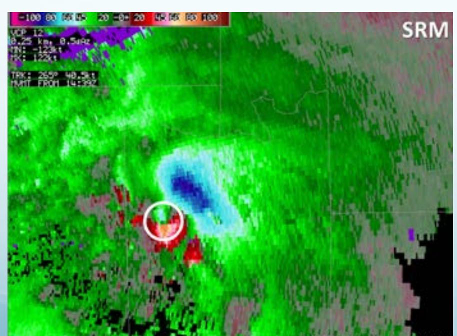


<u>0.5 deg slice</u>

Hi reflect core, ZDR is low…suggests hail Is dominant
Low CC values…0.92 to 0.95…suggest large hail >2 inches…since it is not too low…
KDP is very high in core…suggests this hail is mixed with a large amount of rain…suggesting this hail is melting…but the hail is still big enough to dominate the ZDR signal…we know that cuz ZDR is so low. So, plenty of liquid moisture…rain…and/or melting hail

Putting it All Together (2)





Upper left…Z= high reflect values in ball in hook.
Upper right…ZDR…minimum in ball area.

Lower right…CC = minimum in ball…less than 0.95 by far. In fact it's close of 0.70. The only pcpn that could have a CC so low would be giant hail…and we know giant hail will not be found in middle of a meso.

Lower left picture…"blank" area in KDP…indicating it wasn't calculated…which happens if CC is unreliable (too much variance).

So it has to be a TDS (Tornado Debris Signature).

Note velocity couplet = mesocyclone!