Doppler Radar Basics and Interpretation

for Emergency Managers

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March 2010

Doppler Radar Interpretation

This training presentation is designed for emergency managers that desire basic knowledge of Doppler radar interpretation.

It is hoped that this training will provide you with a better understanding of how the NWS Doppler radar works, basic skills to interpret reflectivity and velocity images, and potential uses of the information.

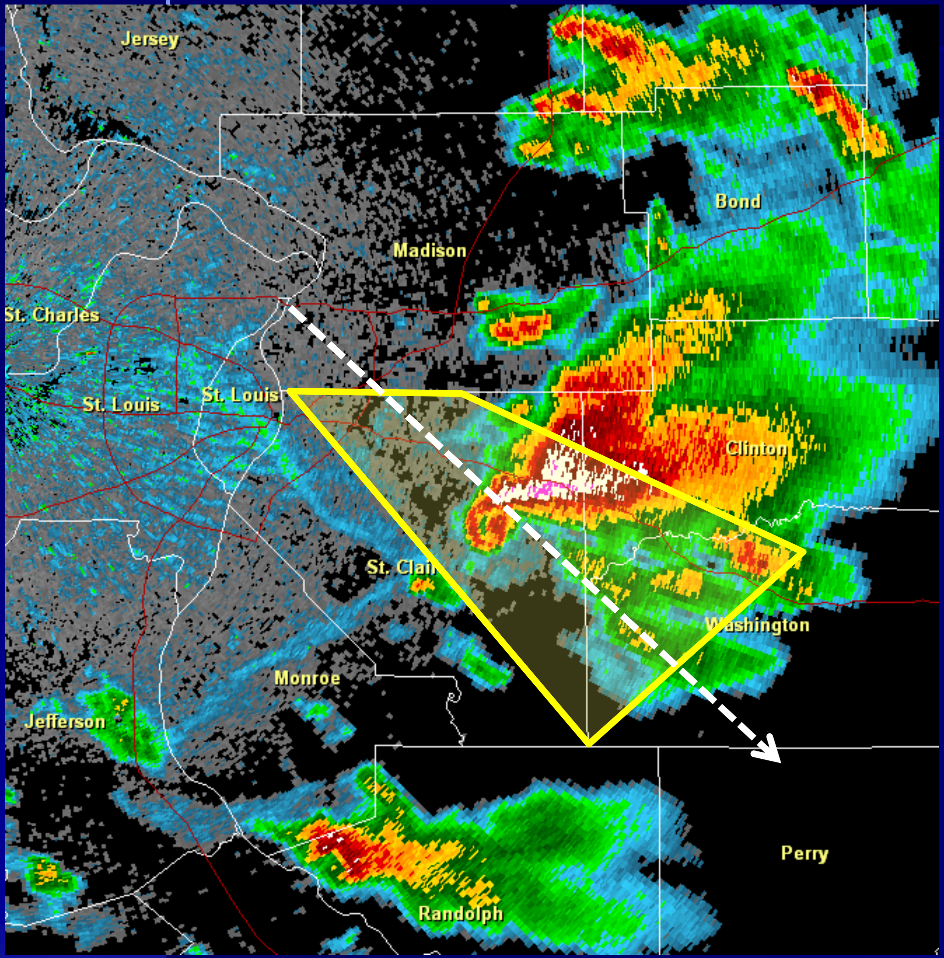
Note: This training is not designed to teach you to issue severe weather warnings

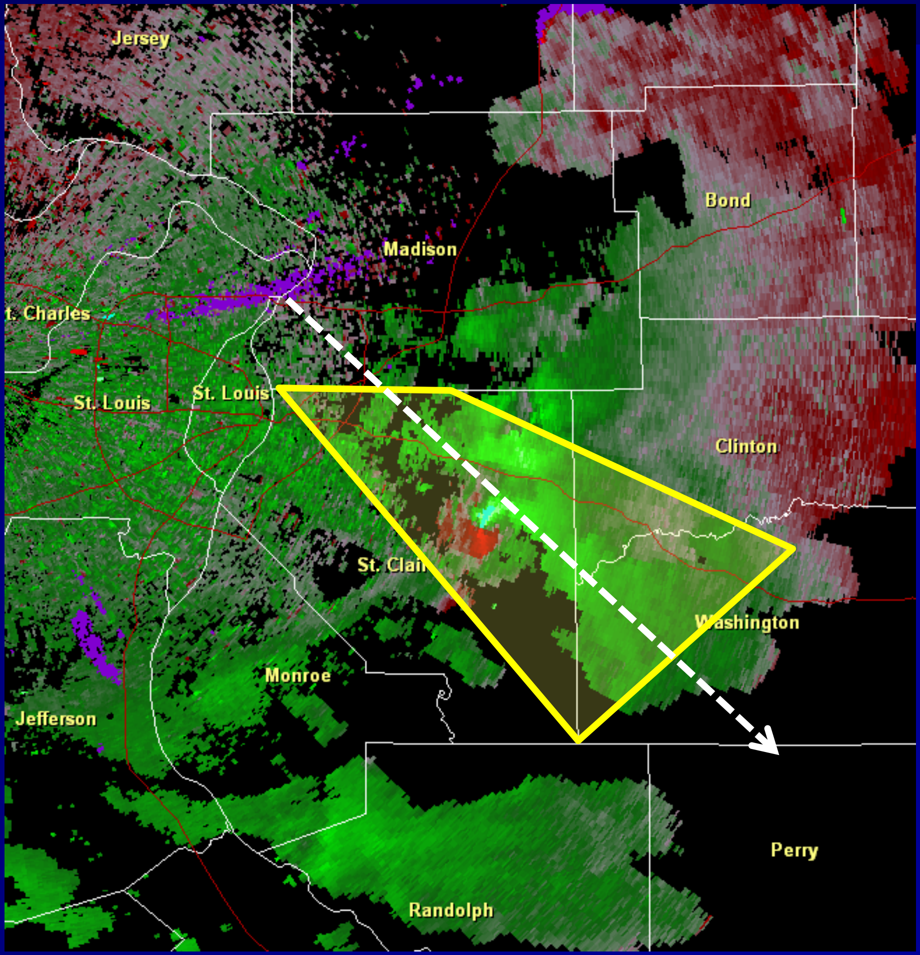
Weather Radar

Can Provide Valuable Input to Decision-Makers

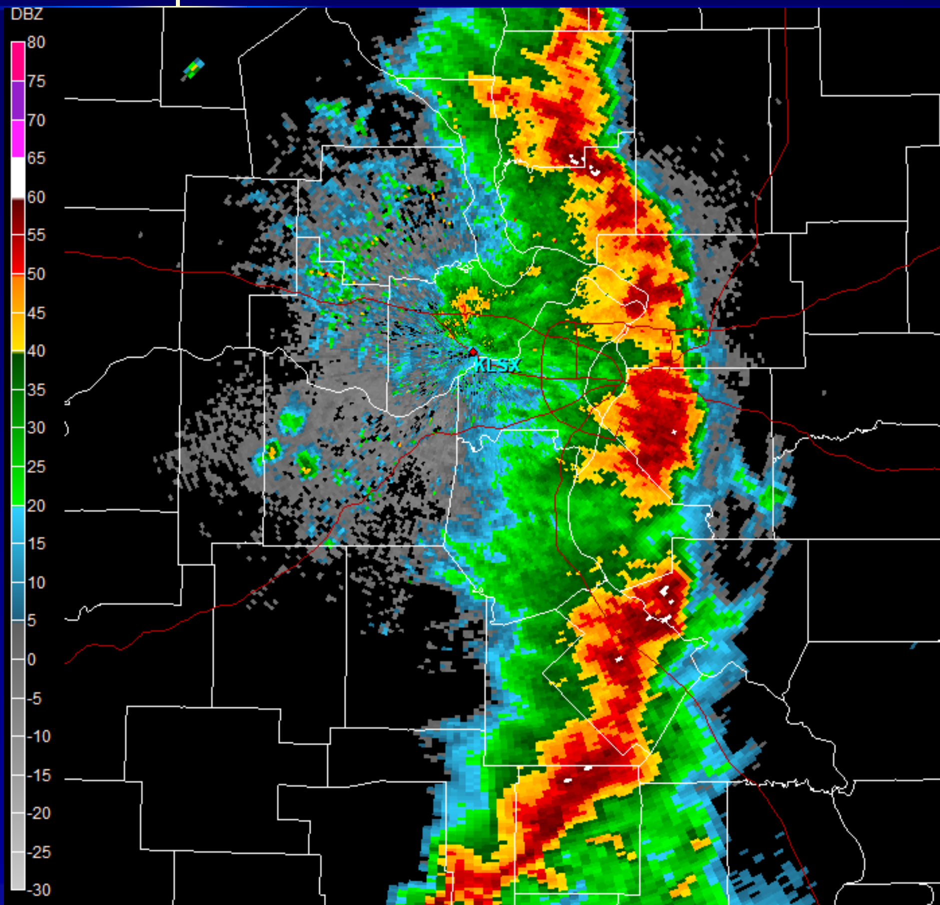
- **Identification of Weather Threats**
  - Location and Evolution
- **Assessment of Weather Impact**
  - Localized versus County or Multi-county Event
- **Deployment of Storm Spotters / Emergency Crews**
  - Location and Timing
- **Assistance in Recovery / Cleanup Efforts**
  - Wind, Heavy Rainfall Hampering Rescue/Recovery
  - Hail, Tornado Threat Compromising Responder Safety

Assess Threat Location

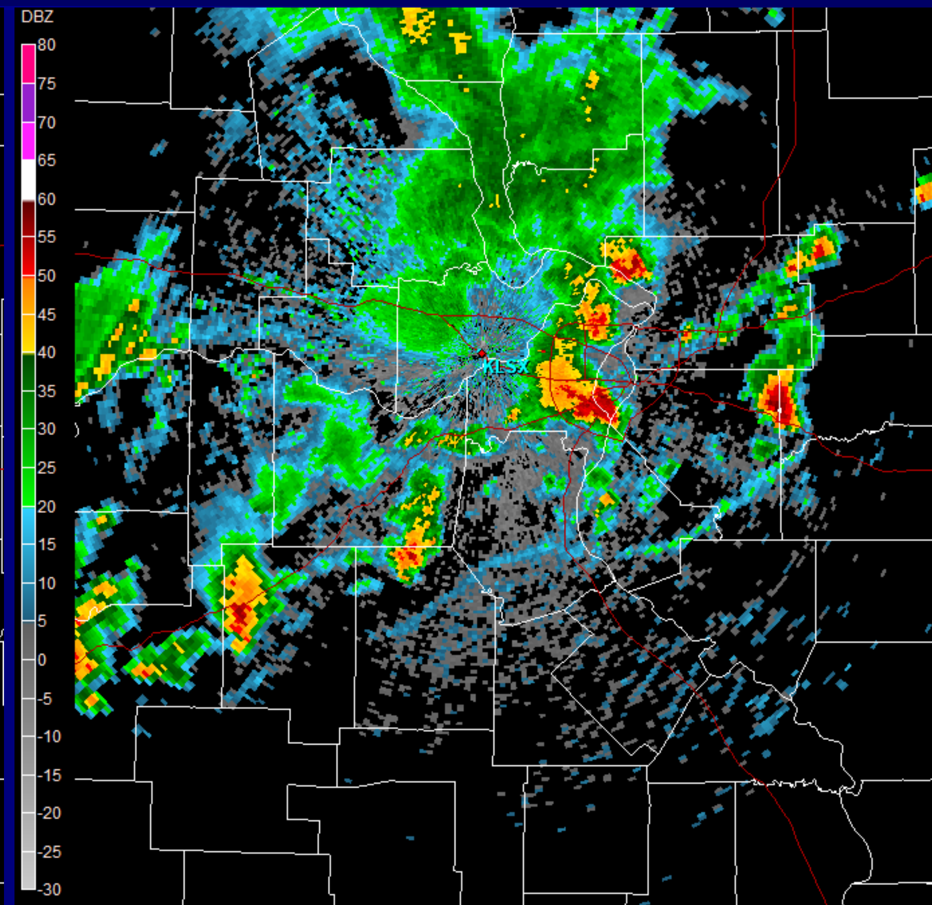




Assess Operational Impact



Widespread



Localized

Topics

Part 1. Radar Concepts

Part 2. Basic Radar Products

Part 3. Other Radar Products

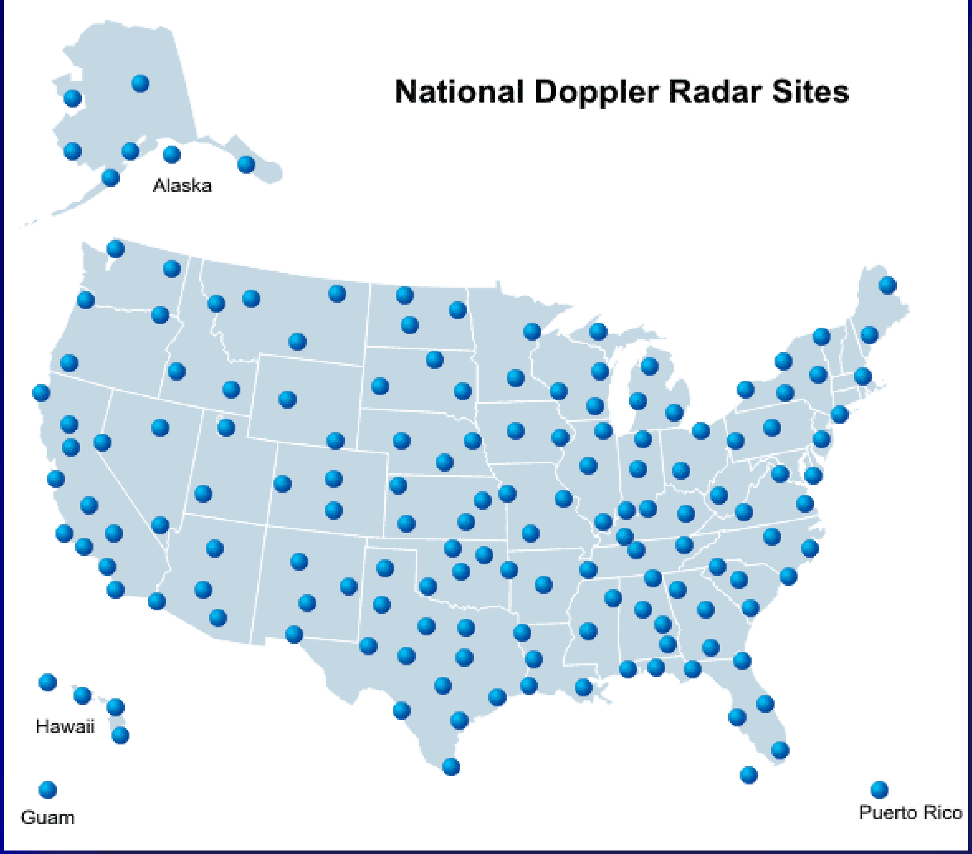
Part 4. Radar Products On the Internet

Part 5. Case Study Examples

Part 1: Radar Concepts

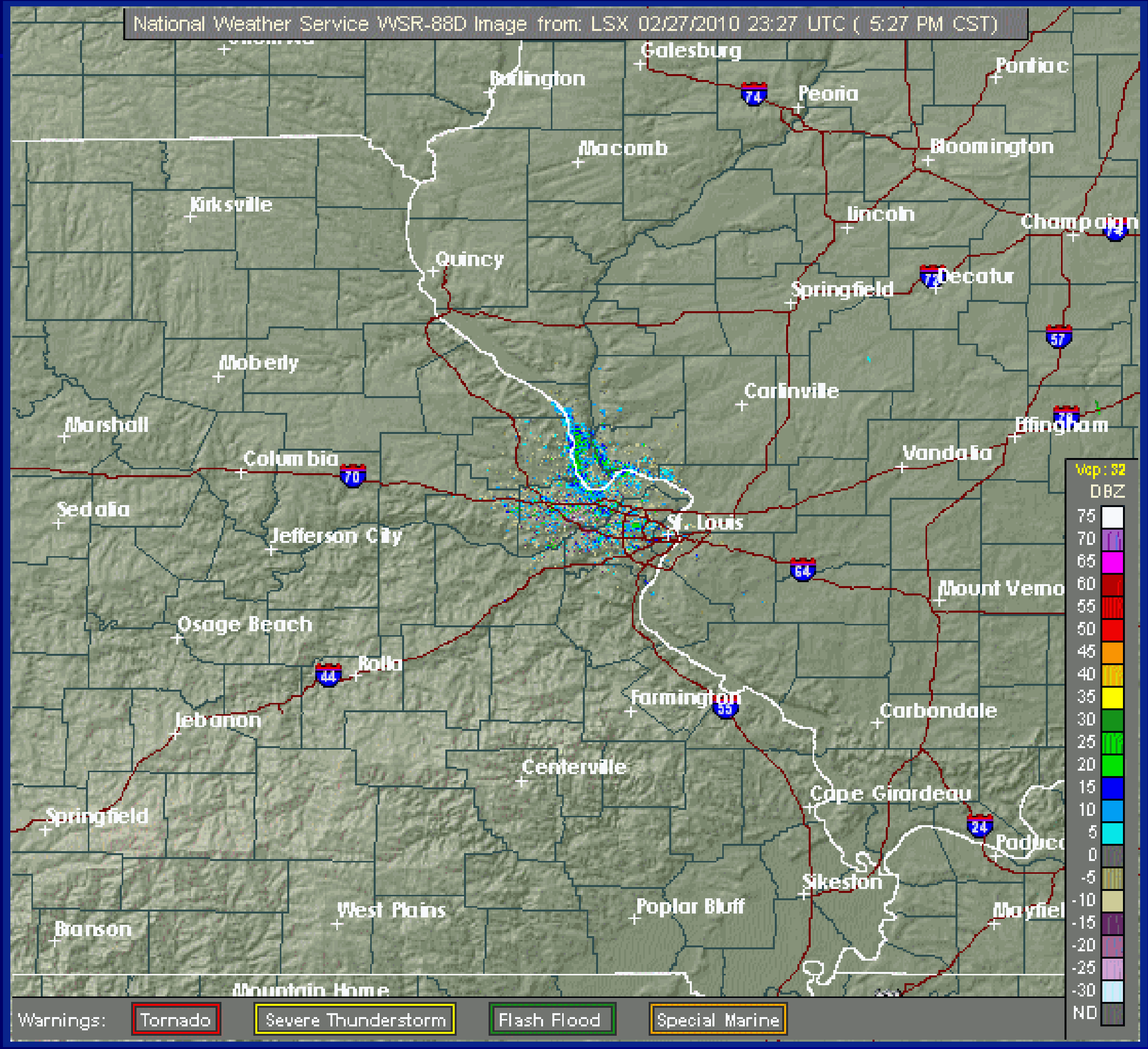
- The NWS WSR-88D
- How Radar Works

NWS WSR-88D Network



The radar used by the National Weather Service is called the WSR-88D – **W**eather **S**urveillance **R**adar-19**88** **D**oppler (the prototype was built in 1988). As its name suggests, the WSR-88D is a Doppler radar, meaning it can detect motion toward or away from the radar as well as the location of precipitation.

KLSX WSR-88D (St. Louis)



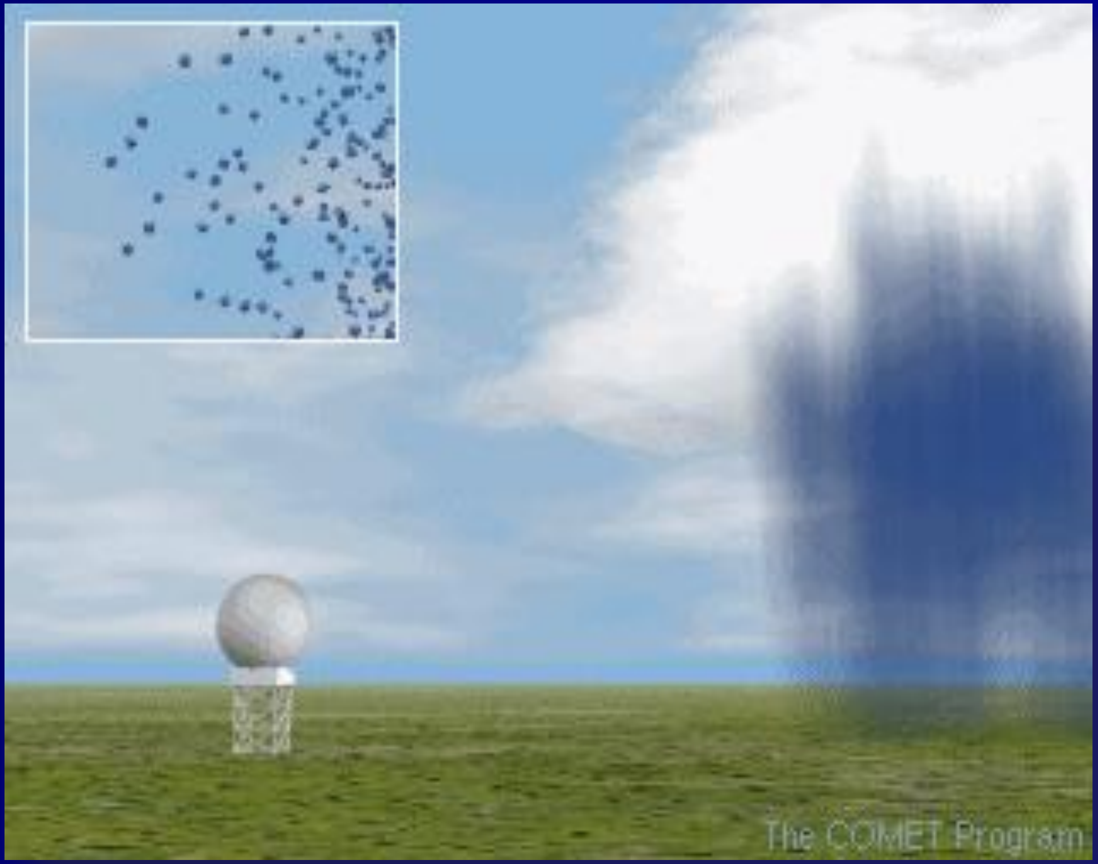
WSR-88D at NWS St. Louis

Facts about the WSR-88D in St. Louis (KLSX)

- Located in Weldon Spring, St. Charles County
- Installed in 1992
- Parabolic dish antenna is 28 ft in diameter
- Enclosed in a fiberglass radome 39 ft in diameter
- Antenna operates 24/7
- S-band, 10 cm
- Peak power: 750 kw

How It Works or Finding Targets

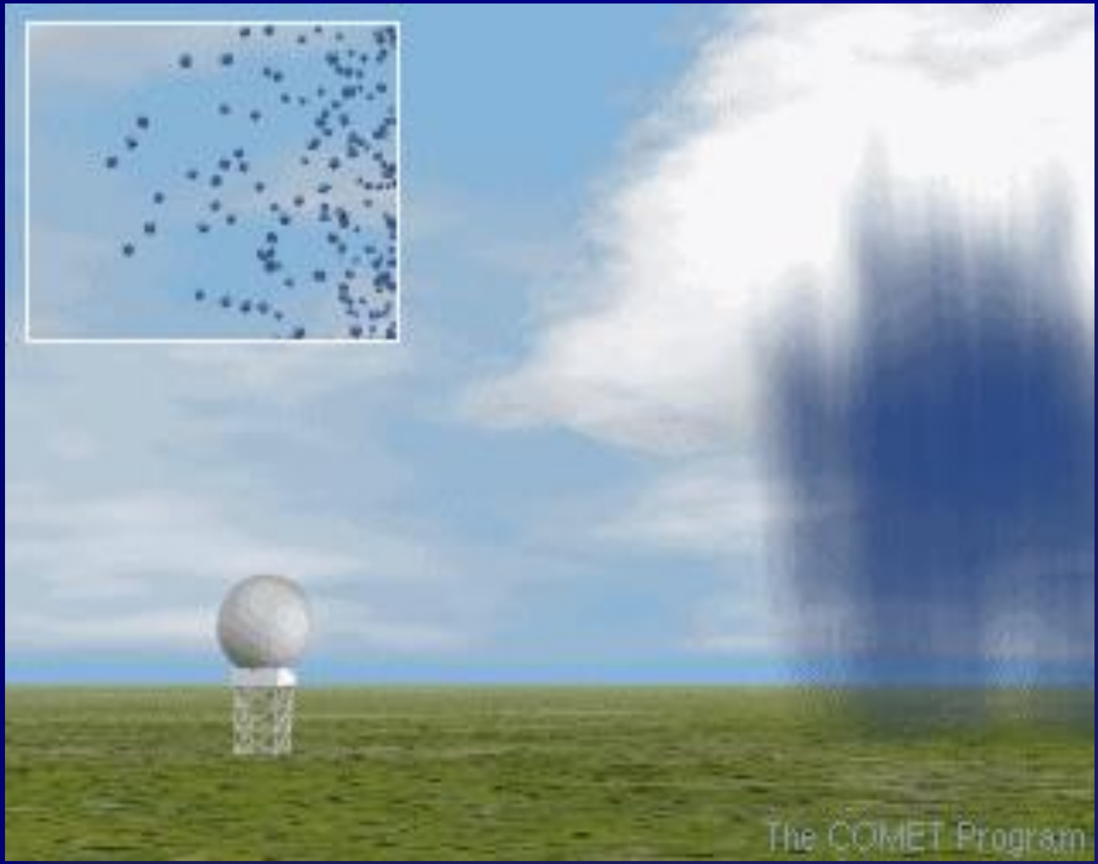
The radar emits short bursts of energy which is reflected off targets in the atmosphere, including hydrometeors (precipitation), animal life (insects, birds), and other phenomena.



Finding Targets

The antenna monitors the atmosphere for the reflected energy.

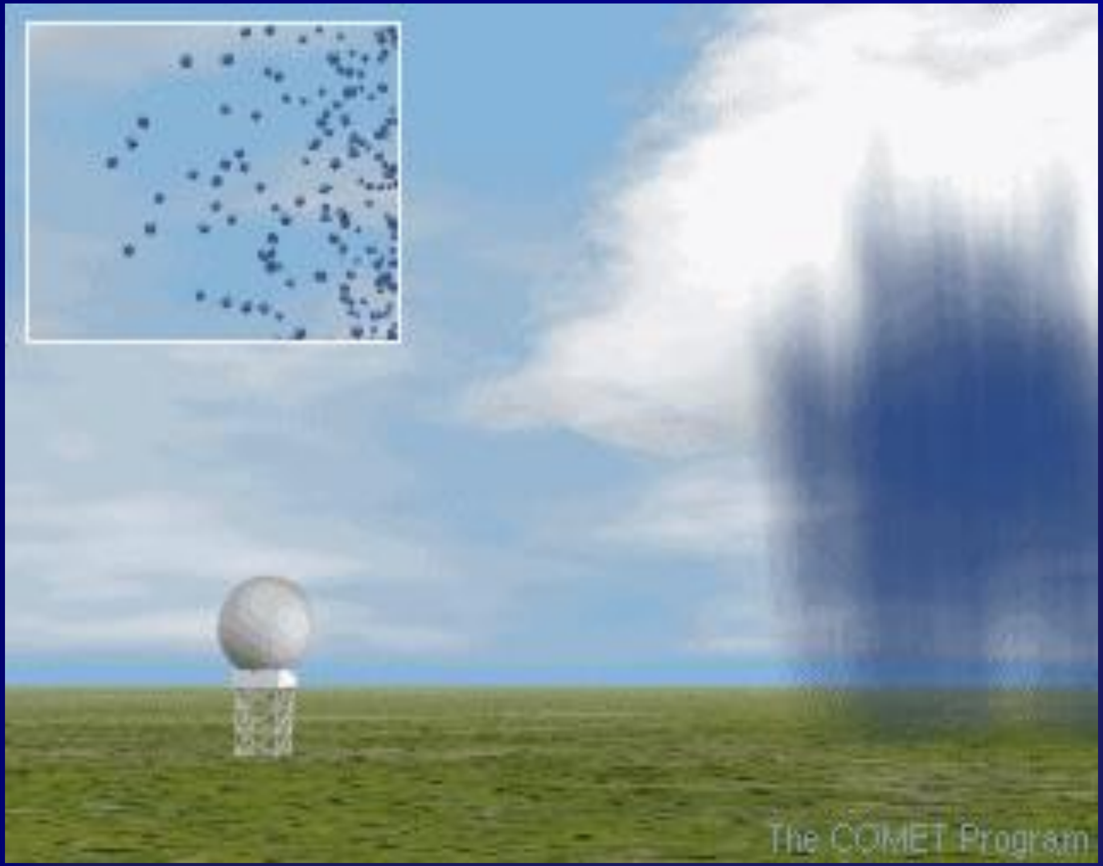
In fact, the radar is only transmitting energy six seconds of every hour (about 0.17% of the time). The radar “listens” the other 99.83% of the time.



Finding Targets

Radar targets include:

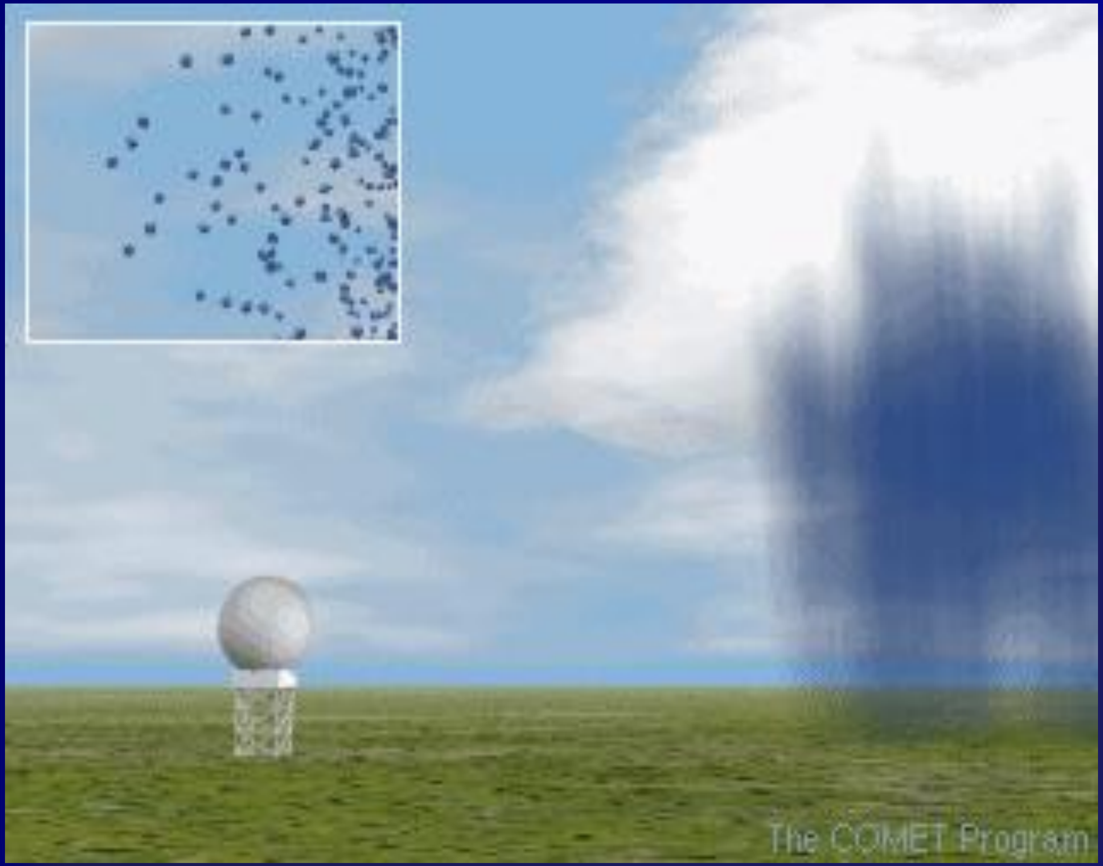
- Rain
- Hail
- Snow
- Drizzle
- Dirt/dust
- Smoke
- Insects
- Birds
- Chaff
- Air density changes



Finding Targets

The amount of energy reflected (scattered) back to the radar antenna is related to:

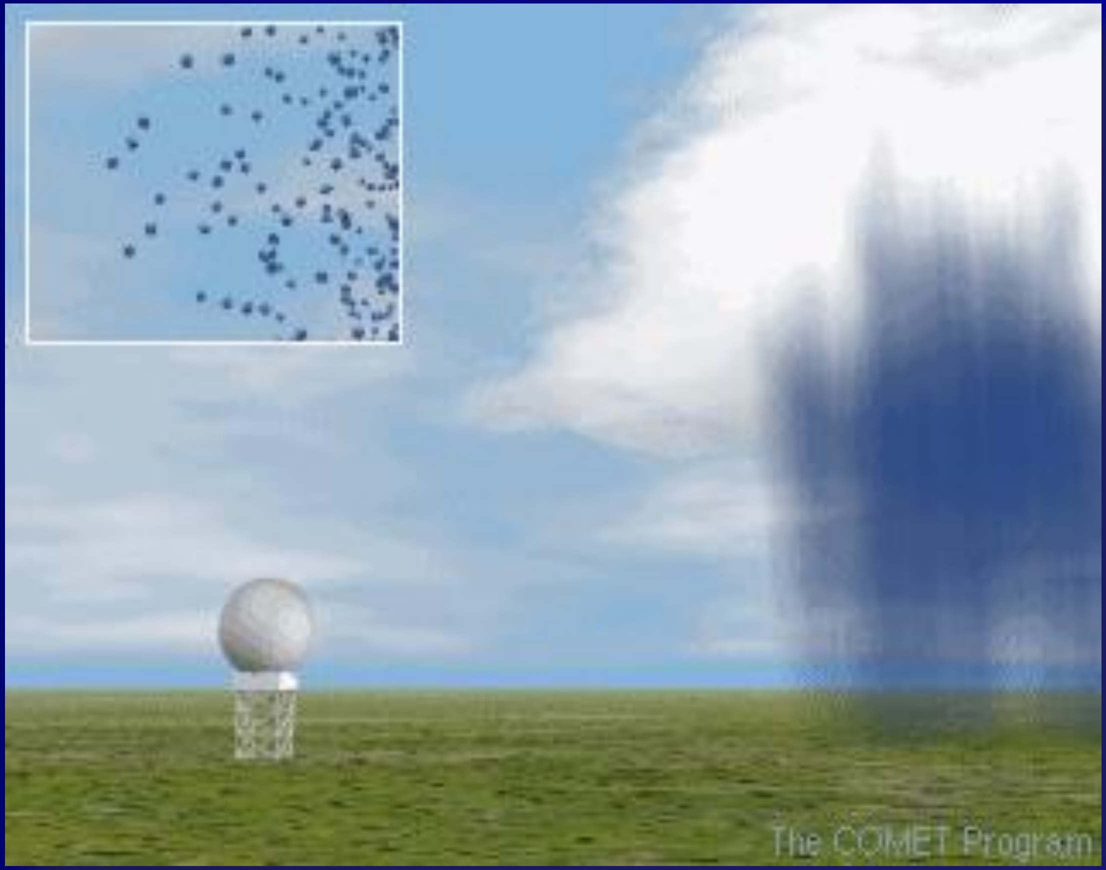
- Size of particles
- Shape of particles
- Number of particles
- State of particles (liquid, ice, snow)



Finding Targets

Larger, more numerous liquid particles (such as big raindrops or wet hail) return the most energy/power.

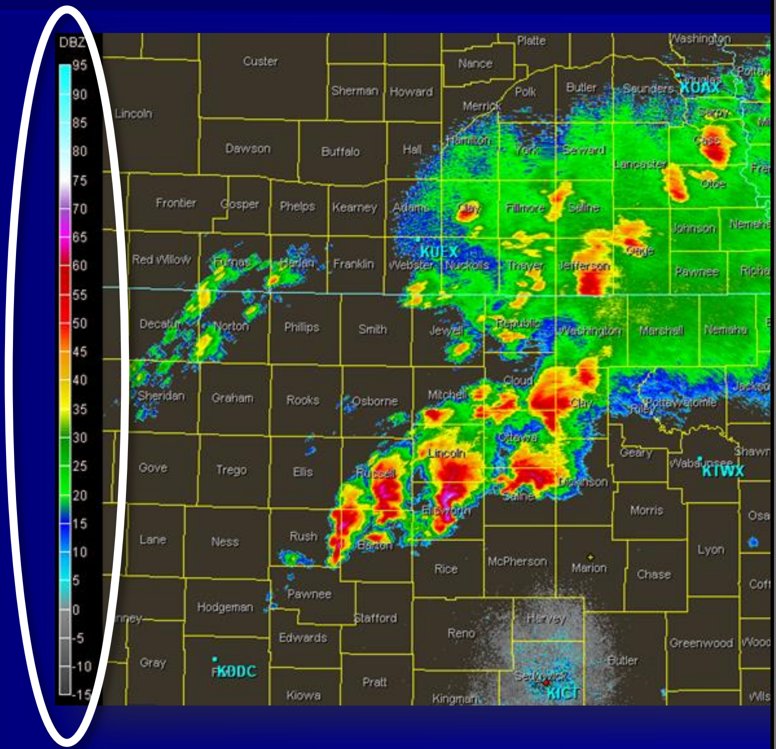
Smaller, fewer ice particles (snow, clouds) or drizzle return the least amount of energy/power.



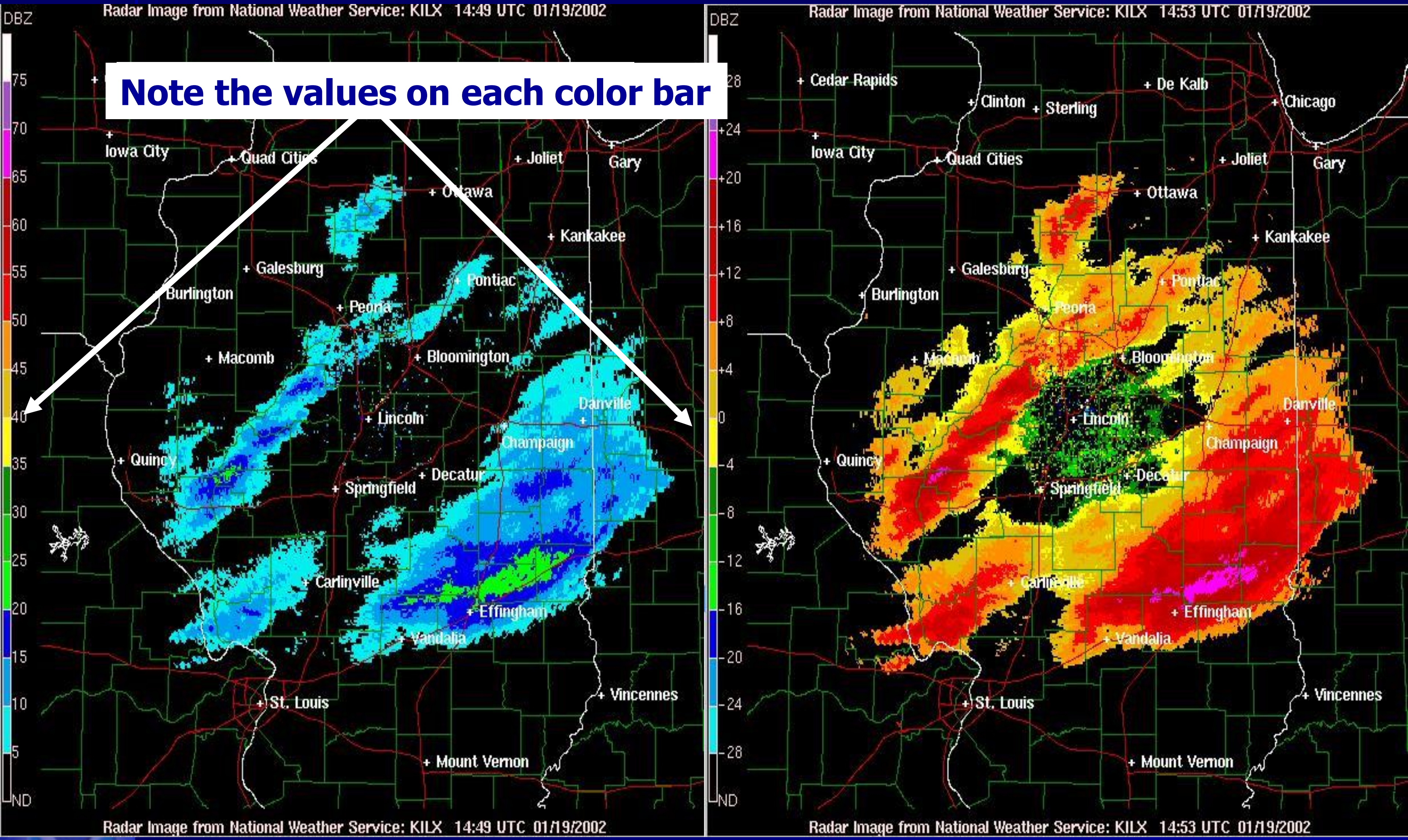
Finding Targets

The color scale seen on radar reflectivity displays is a representation of the power return: The highest values represent the most intense part of the storm or highest precipitation rates.

Not all values are created equal: you may see hail with 55 dBz in January but only heavy rain with the same value in July.

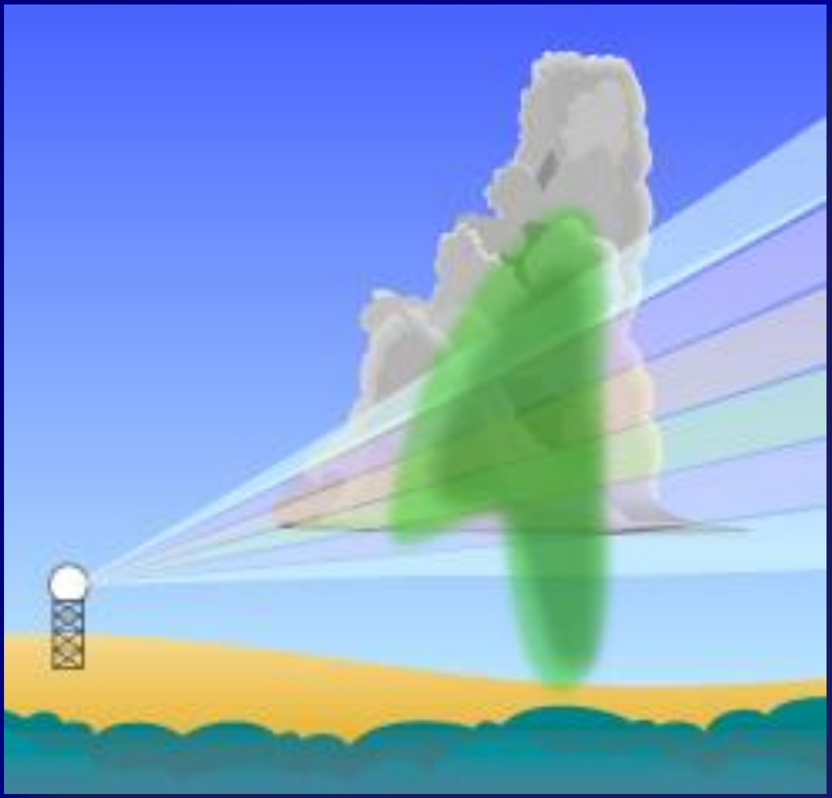


Color scales change



Radar Scanning - Volumetric

The WSR-88D uses "Volume Coverage Patterns" (VCP) to: interrogate the atmosphere:



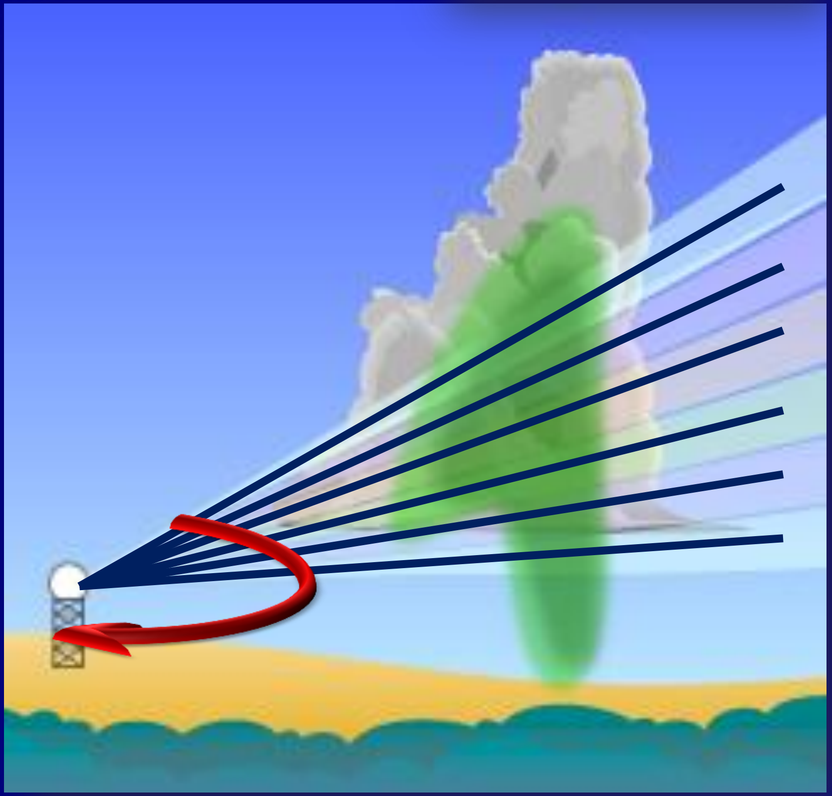
The VCPs:

- Tell the radar which part of the atmosphere to scan
- Allow for 3D views of storms
- Monitor airflow and rotation within storms
- Evaluate storm strength and trends over time

Radar Scanning

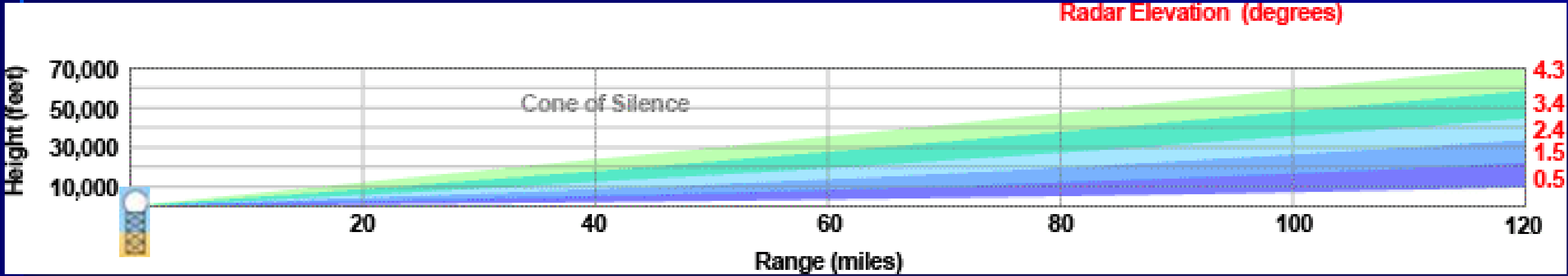
After the radar completes a 360 degree sweep, it goes up to the next elevation.

Once it reaches the "top" of the VCP, it lowers back to 0.5° and begins the process over again.

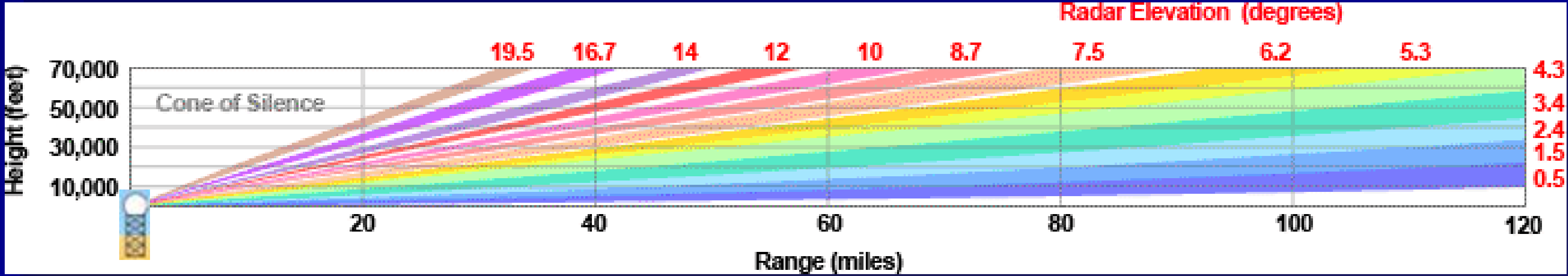


Volume Coverage Patterns

Clear Air Mode (10 minutes)



Precipitation Mode (4-6 minutes)



Volume Coverage Patterns

Clear Air Mode (10 minutes)

VCP 31: 5 angles in 10 minutes (Light or no precip.)
Long pulse for best light precipitation detection
VCP 32: 5 angles in 10 minutes (Light or no precip.)

Precipitation Mode (4-6 minutes)

VCP 11: 14 angles in 5 minutes (Severe weather, t-storms)
VCP 12: 14 angles in 4.5 minutes (Severe weather, t-storms)
VCP 21: 9 angles in 6 minutes (General precip., t-storms)
VCP 121: 9 angles in 5 minutes (High wind events with precip.)
VCP 211, **VCP 212**, **221**: Variations of 11, 12, 21

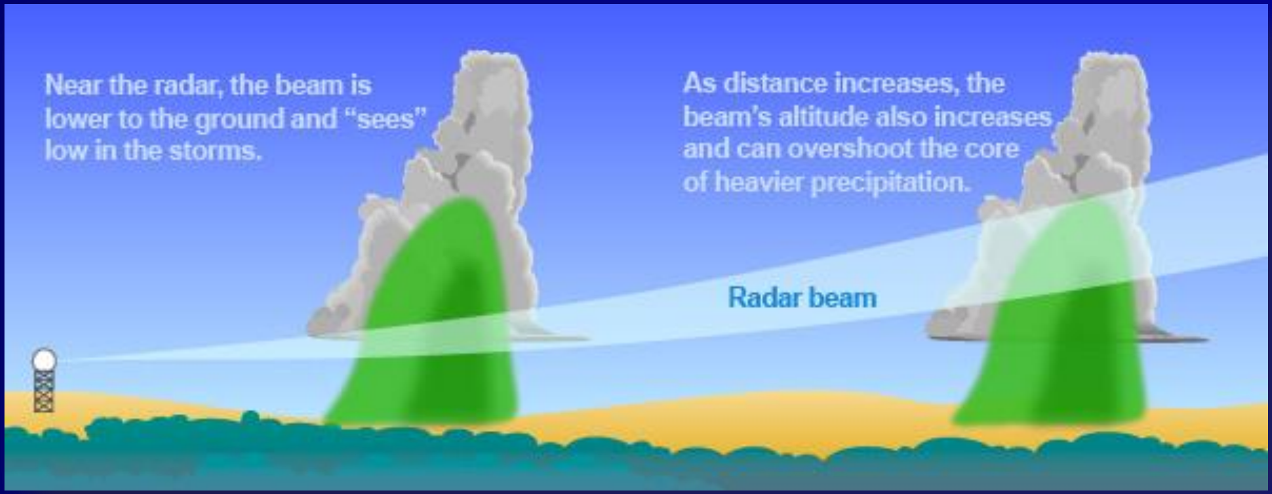
NWS Doppler Radar

Some Questions ...

- How far out does the radar display targets?
  - Answer: 248 nm radius
- How high up does the radar detect targets?
  - Answer: ~ 70,000 ft
- How often will the radar refresh with new information?
  - Answer: 4.5 minutes to 10 minutes (VCP)

The Radar Beam

The beam gains elevation with distance from the radar.



Storms on top of the radar are only sampled at low elevations.

The Radar Beam

The beam also broadens with distance from the radar. This effectively reduces the resolution of the radar. Small features, which can be seen close to the radar, are often obscured when these same feature are located at great distances.

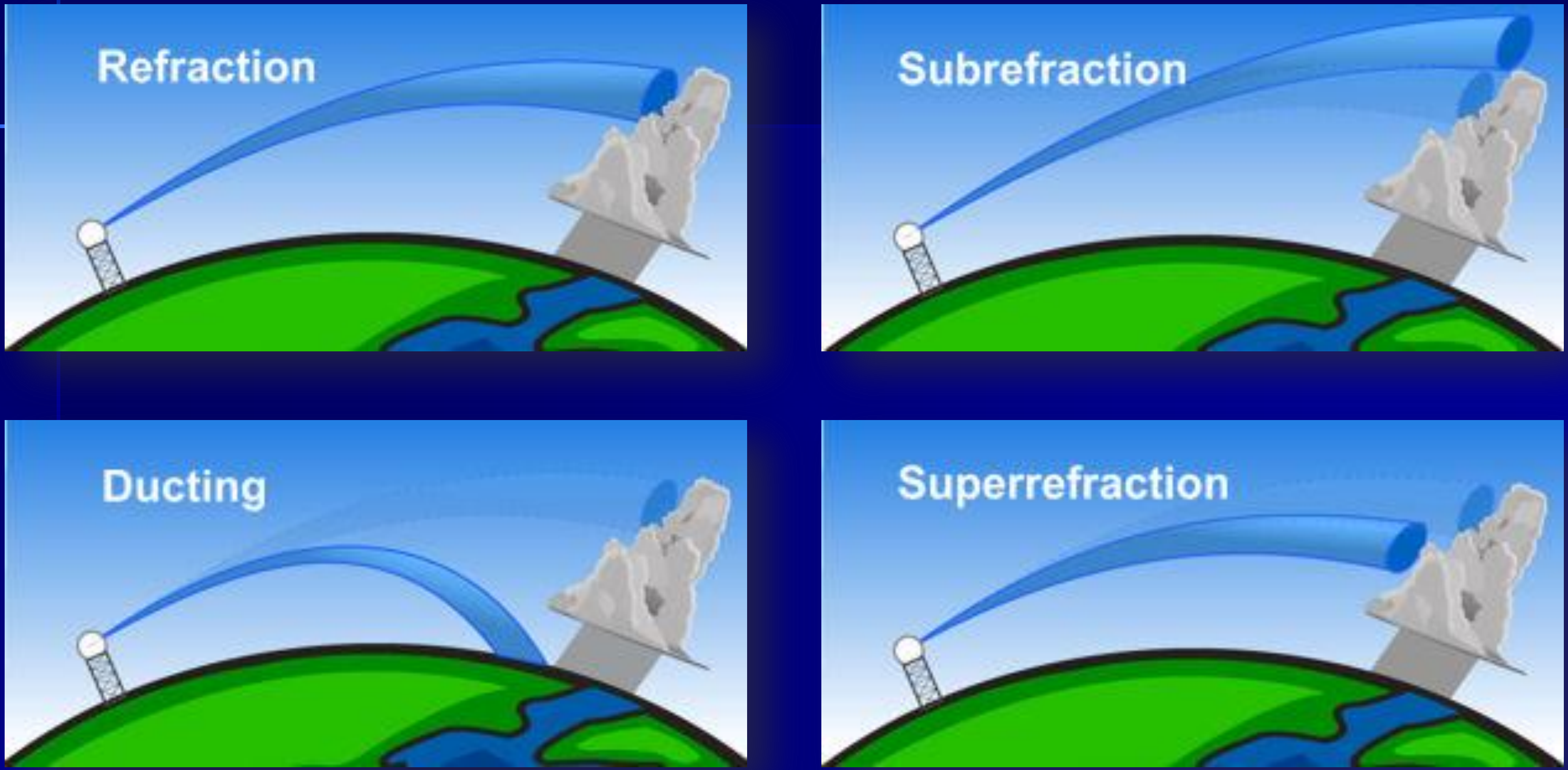
This decrease in resolution, at increasing distances, is often why a solid line of thunderstorms appears to break-up as it approaches the radar. In reality, the line of thunderstorms may have never been solid in the first place; it is just the lack of resolution of the "gaps" that causes the radar to "see" a solid line.

Radar Beam Characteristics

Due to the physical nature of the radar beam and the curvature of the earth, the radar beam gets WIDER *(beam spreading)* and HIGHER the farther it travels.

Range	Beam Diameter	center of 0.5° beam height
10 nm	**1000 feet**	**600 feet**
50 nm	**1 mile**	**4400 feet**
100 nm	**2 miles**	**12500 feet**
150 nm	**3 miles**	**25000 feet**

Atmospheric Effects



In addition to beam spreading, the beam does not travel in a straight line. The beam is bent due to differences in atmospheric density. These density differences affect the speed and direction of the radar beam.

Part 2: Basic Radar Products

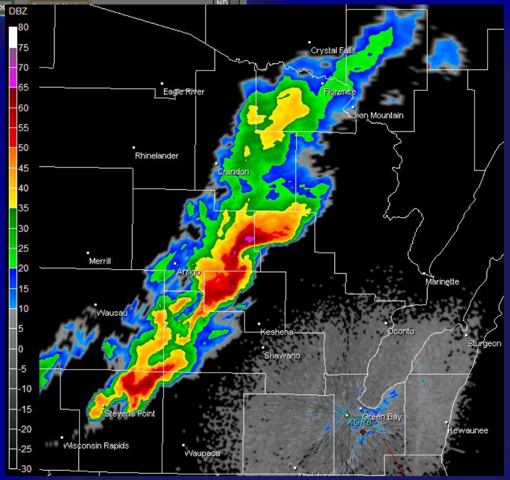
- Reflectivity
- Velocity
- Derived Products

Reflectivity

● Most-used radar product - both the intensity and location of targets are shown.

● Intensity is measured in units of decibels (dBZ), and is proportional to rainfall rate/precipitation rate *(color scale)*.

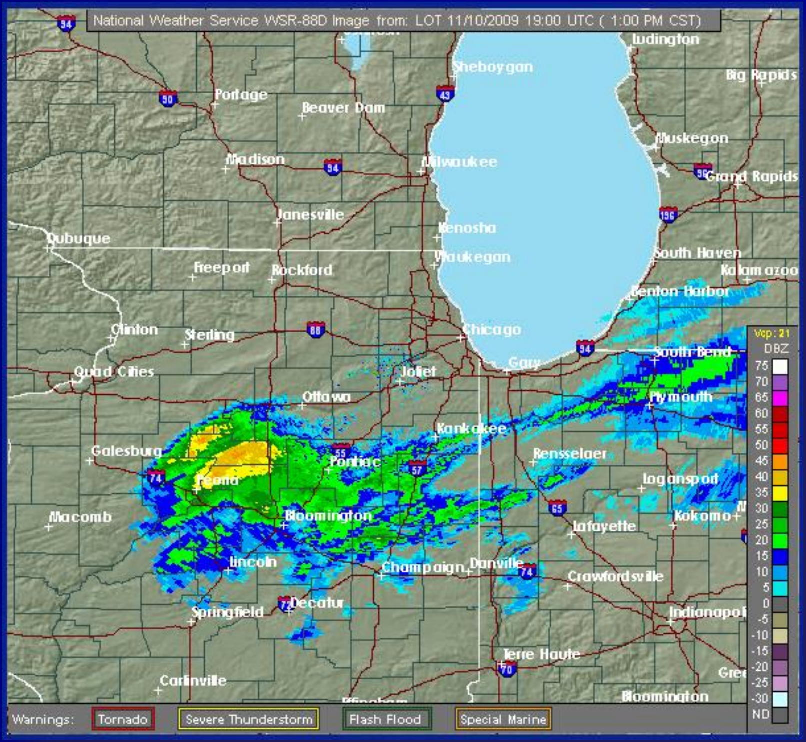
● Reflectivity is available as "base" and "composite."



Base Reflectivity

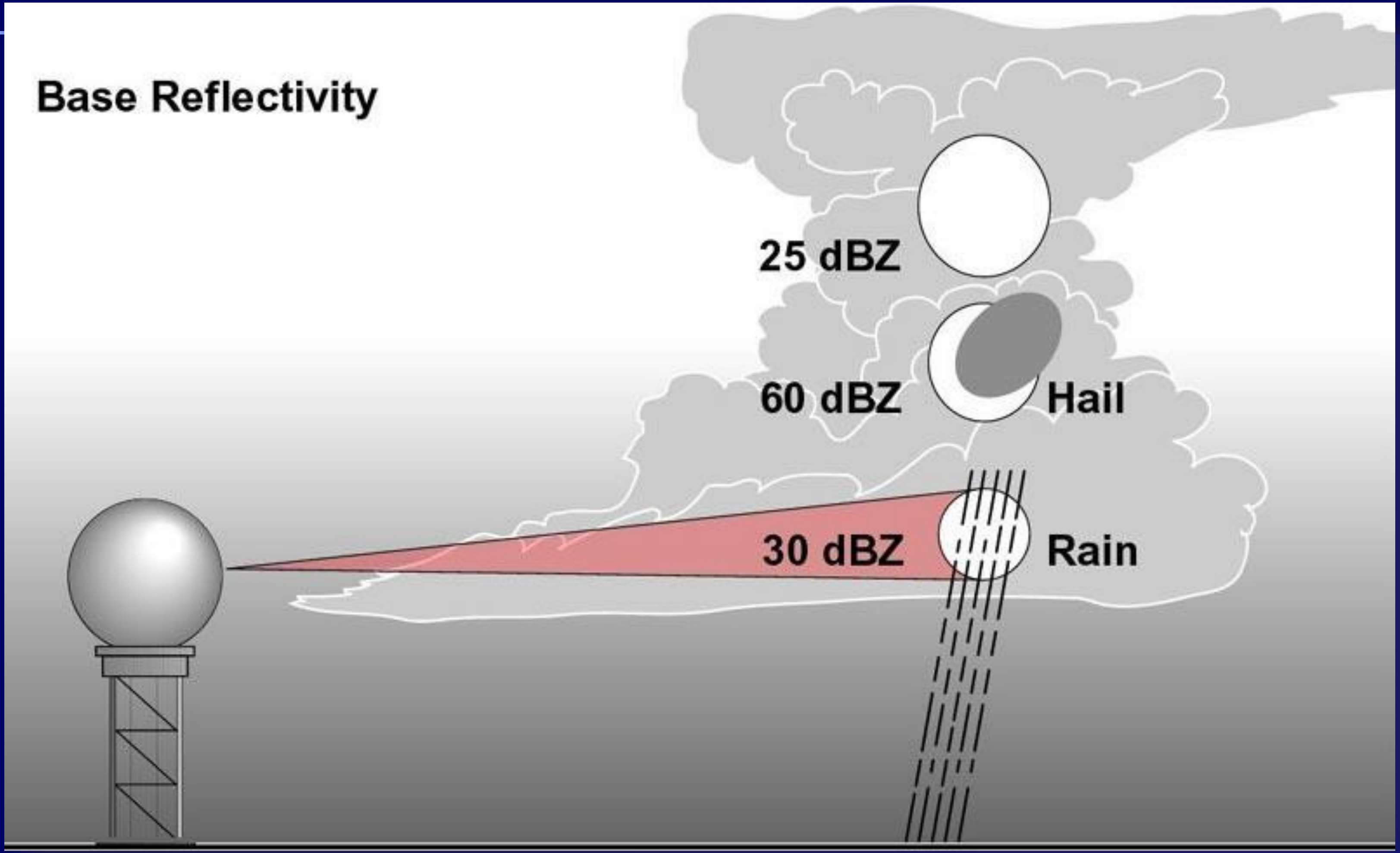
- Base Reflectivity refers to reflectivity from a single elevation slice. NWS websites show the lowest elevation angle only (0.5 degrees).

- There are websites that have other elevation angles available.



0.5 deg Base Reflectivity

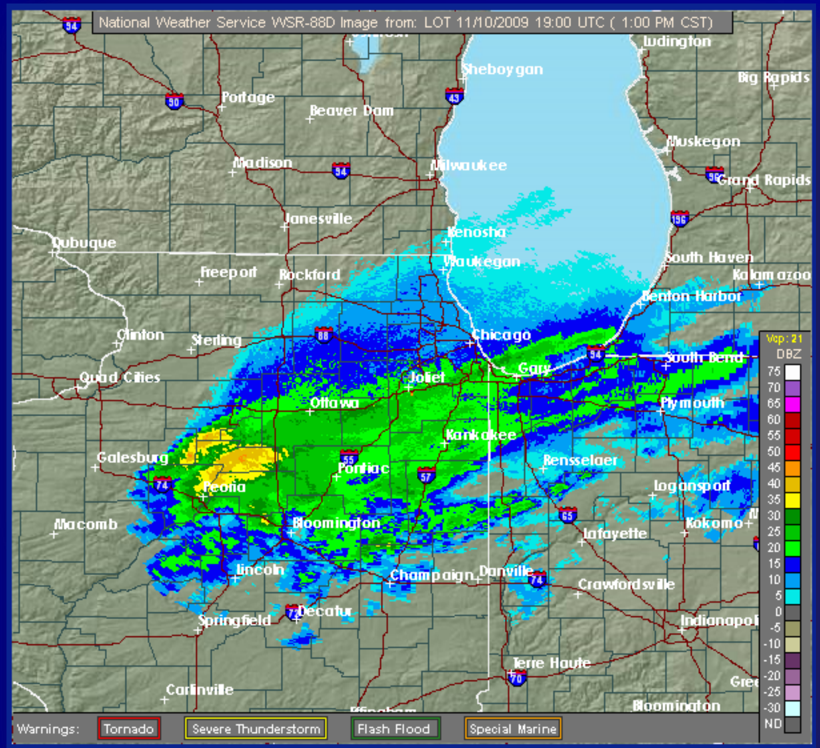
Base Reflectivity



Composite Reflectivity

- Displays the highest intensity reflectivity value detected in a vertical column of the radar volume scan.

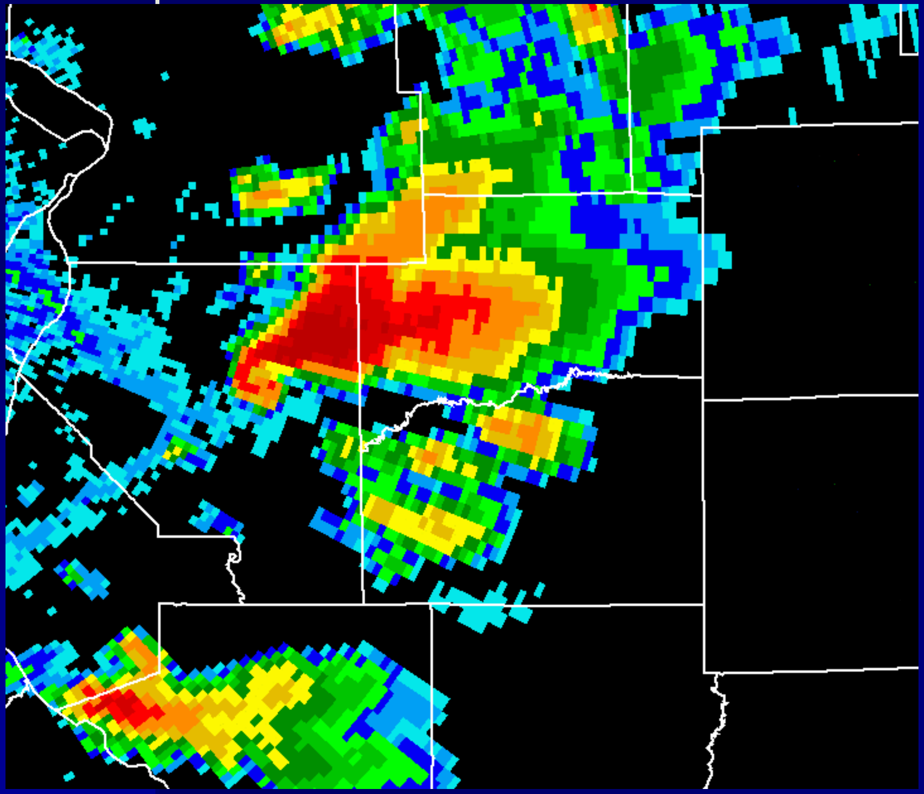
- The image gives a quick overview of where the most intense precipitation is, but does not tell you the altitude of the max reflectivity.



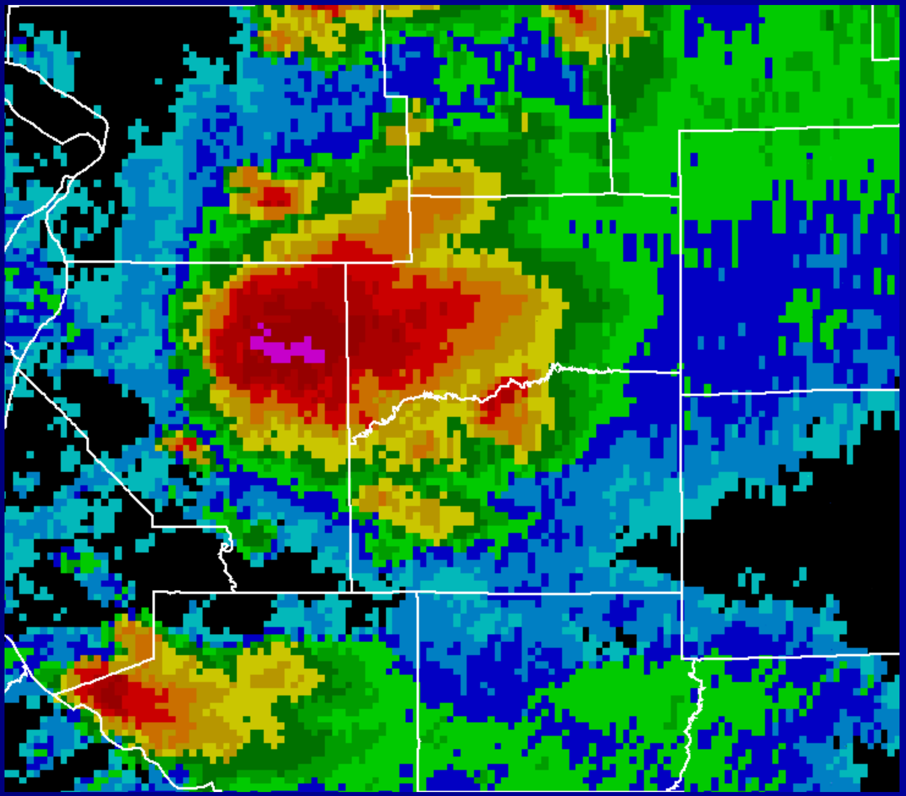
Composite Reflectivity

Comparison

Reflectivity vs. Composite Reflectivity

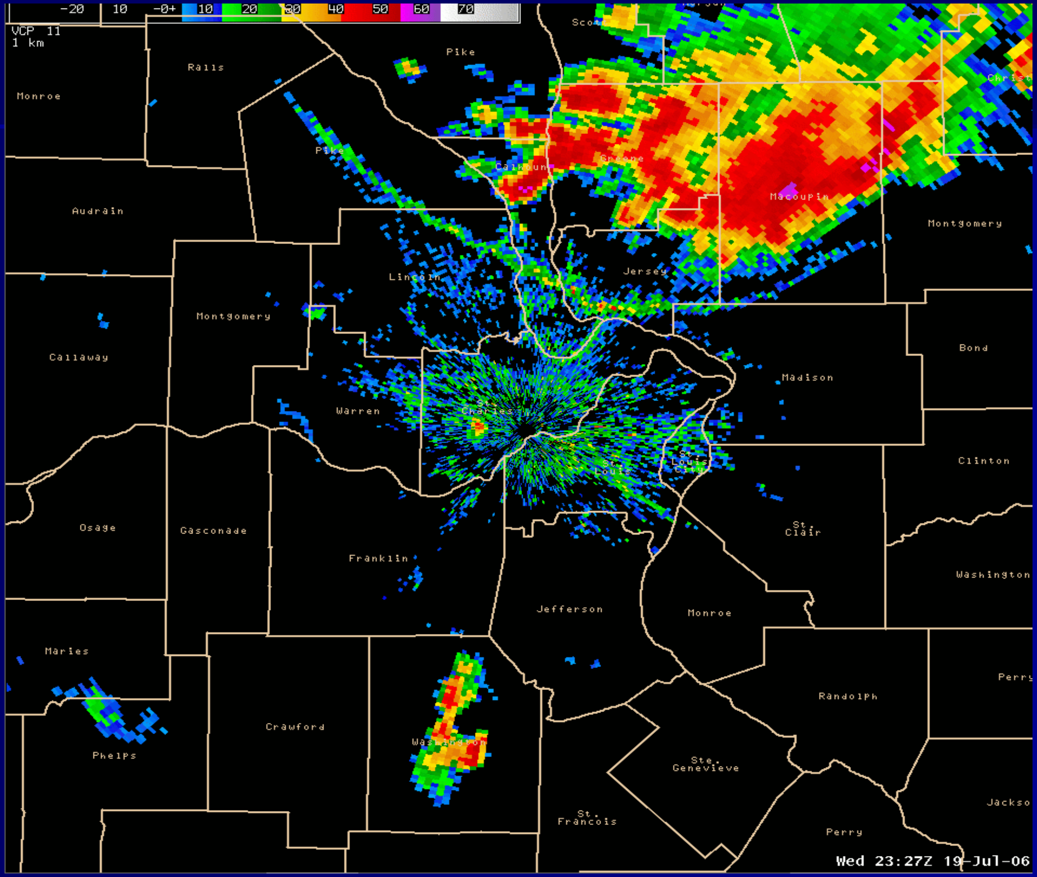


0.5° Base Reflectivity



Composite Reflectivity

Reflectivity Phenomena - Outflow Boundary

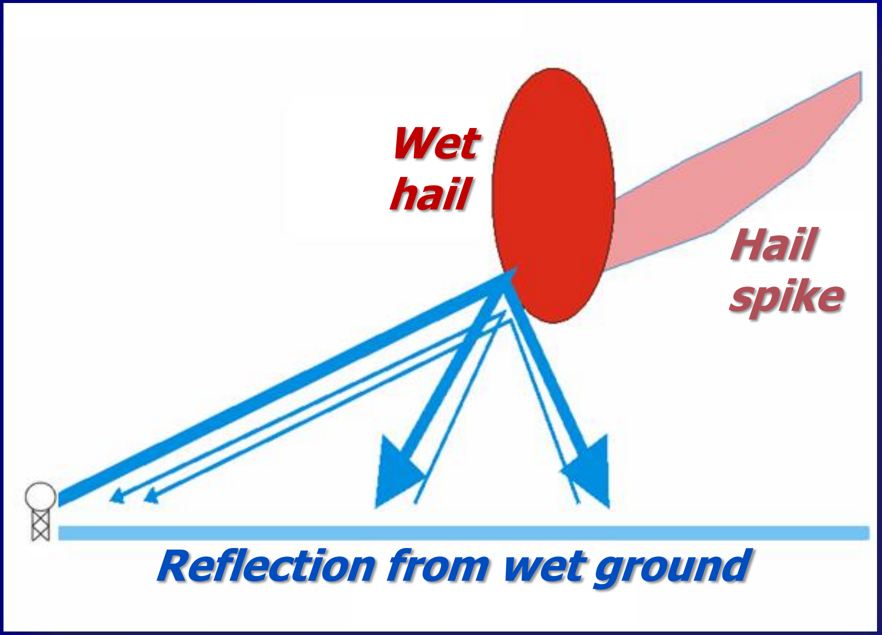


Outflow Boundary – a small scale boundary (front) resulting from the cold air outflow from thunderstorms (a gust front); may be accompanied by a shelf cloud.

Other Reflectivity Phenomena

Three Body Scatter Spike (TBSS)

Also known as **hail spikes**, these are the result of energy from the radar hitting hail and being deflected to the ground, where they reflect back to the hail and then to the radar.



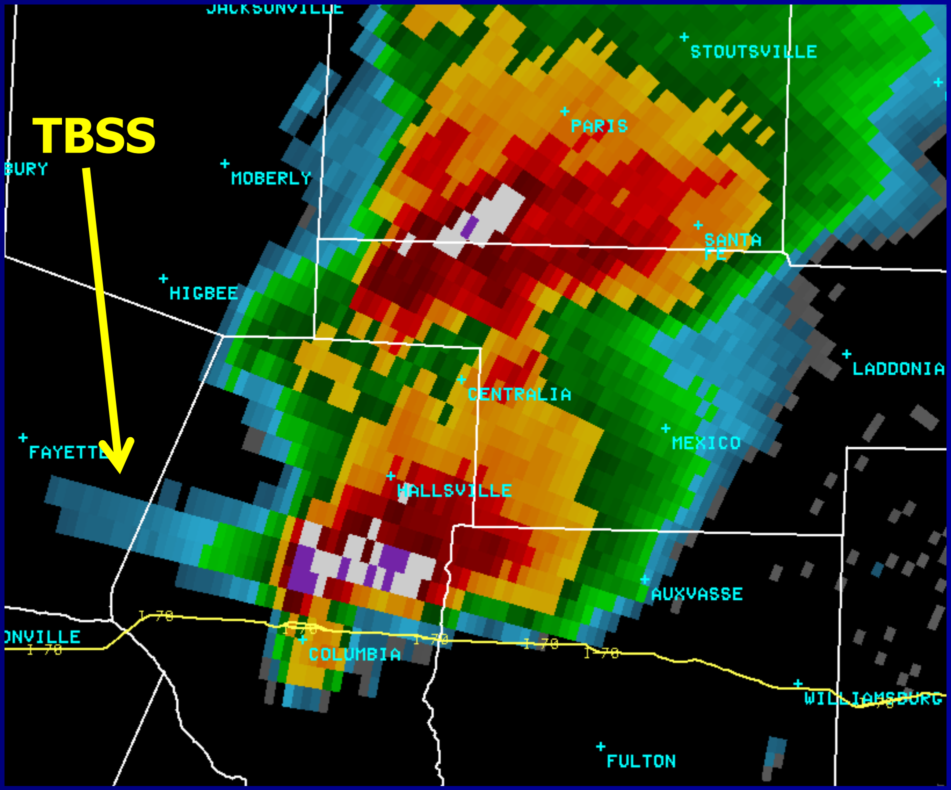
When the radar receives this "delayed" reflected energy, it displays the energy farther away from the radar than its actual location.

Other Reflectivity Phenomena

Three Body Scatter Spike (TBSS)

Hail spikes indicate large hail aloft. When a TBSS is seen, hail can be expected with the storm.

The spike always "points" down radial of (away from) the radar.



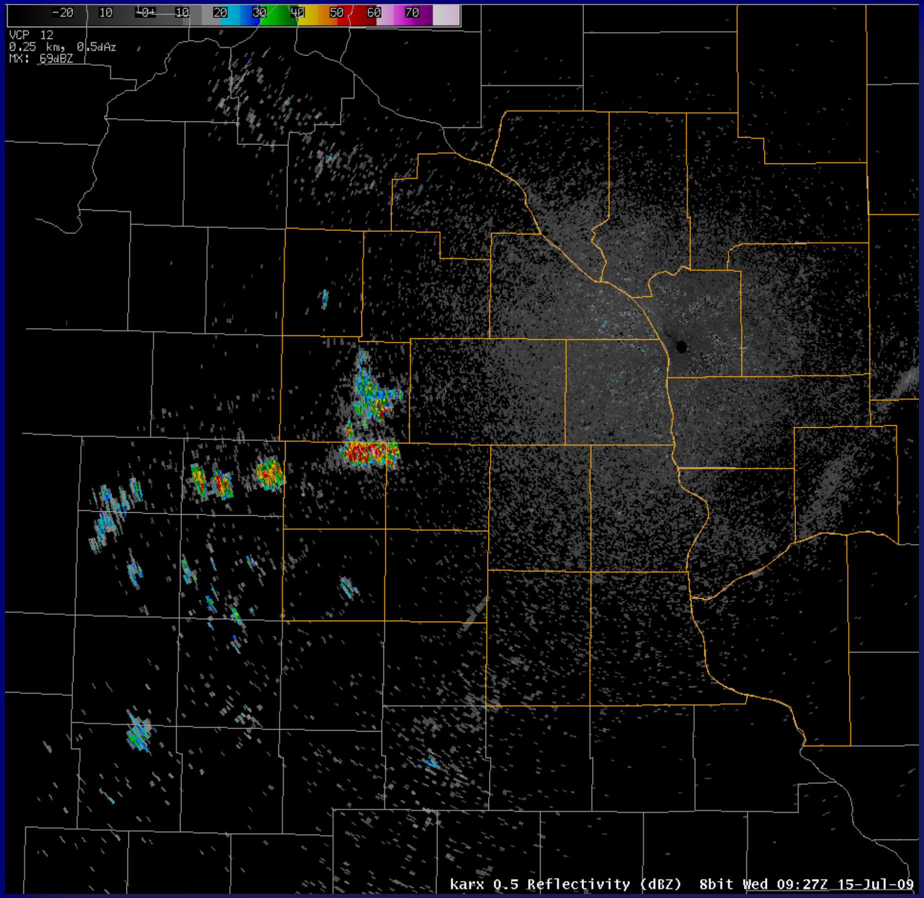
Example of a TBSS. This supercell thunderstorm produced 3" diameter hail in Columbia during the evening of 12 March 2006.

Non-Weather Targets

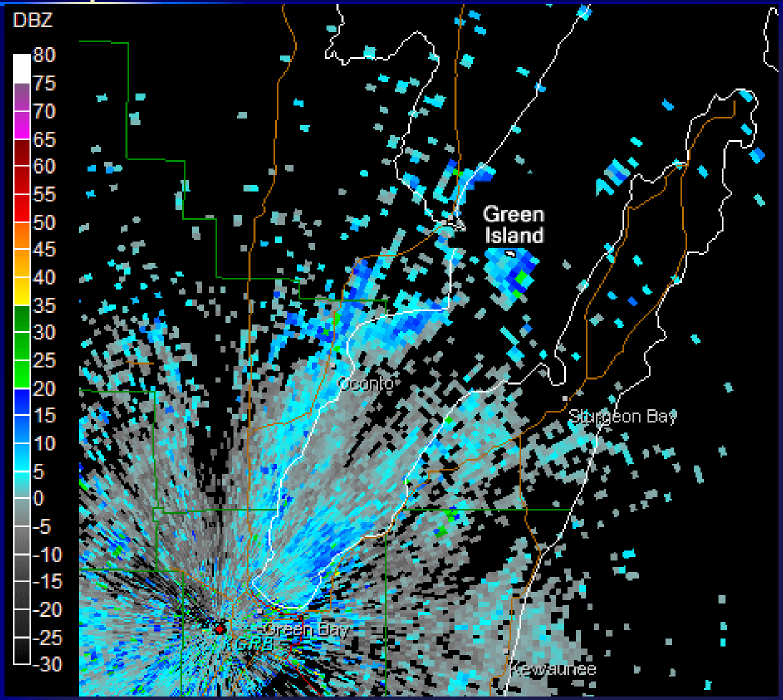
Ground Clutter

Ducting often results in anomalous propagation (AP).

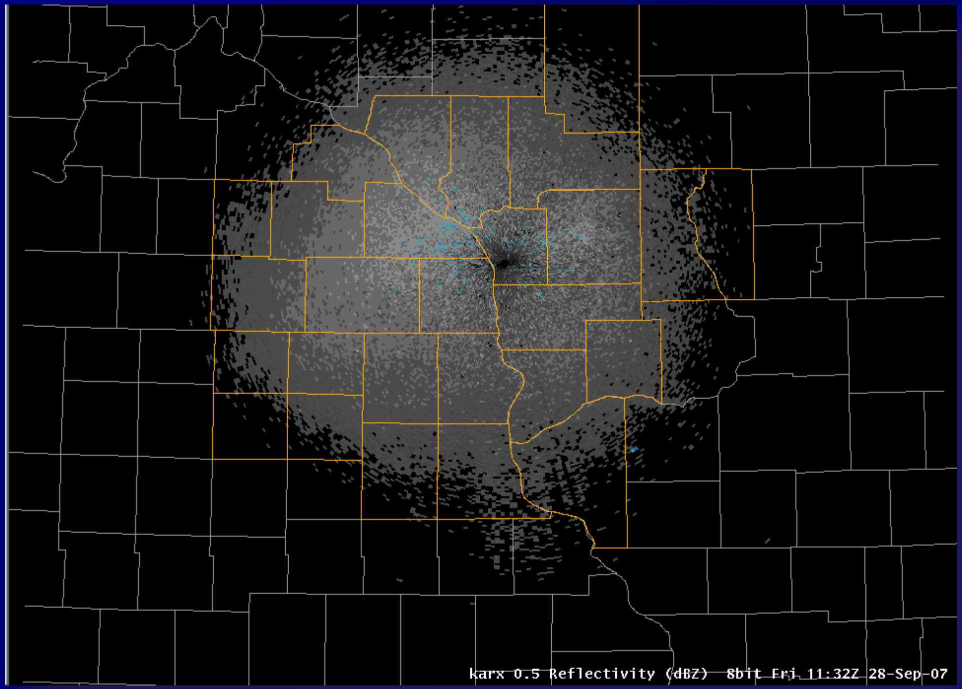
The radar does invoke ground clutter suppression algorithms which usually eliminates most of the AP.



Birds

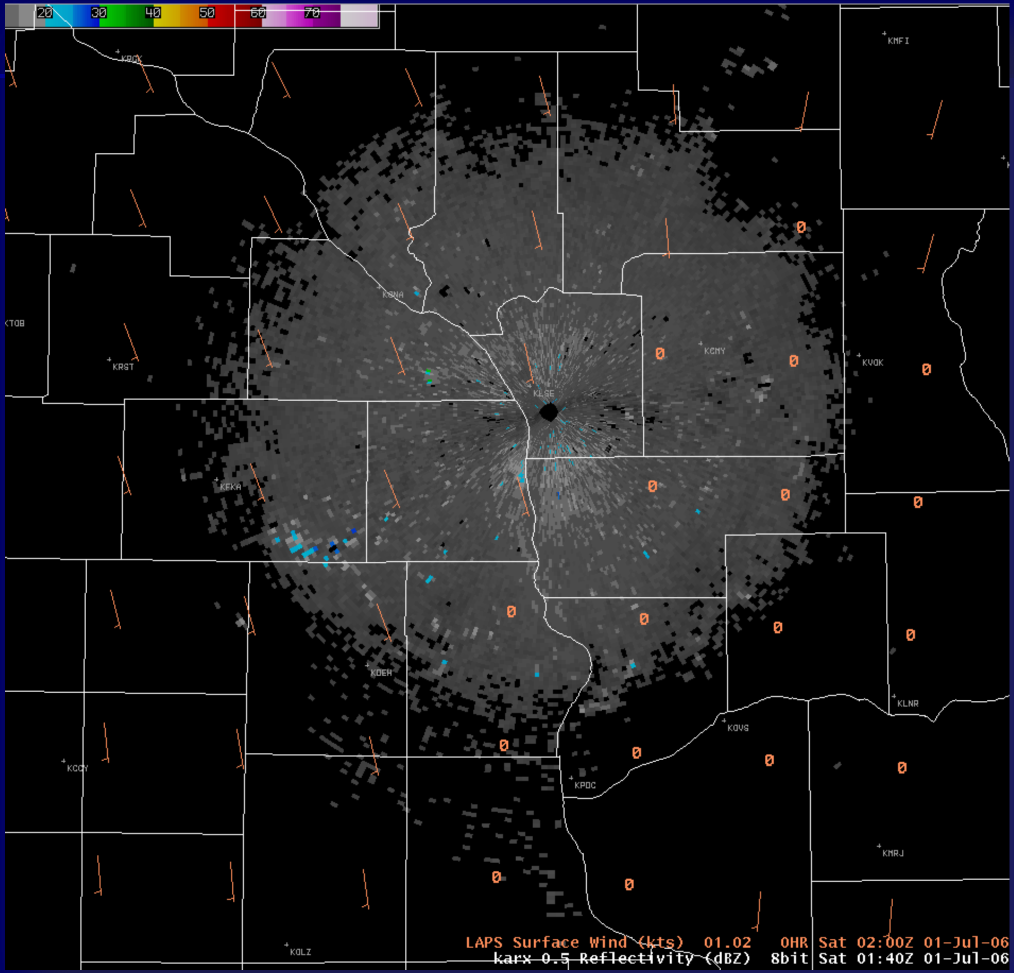


Green Island, Green Bay



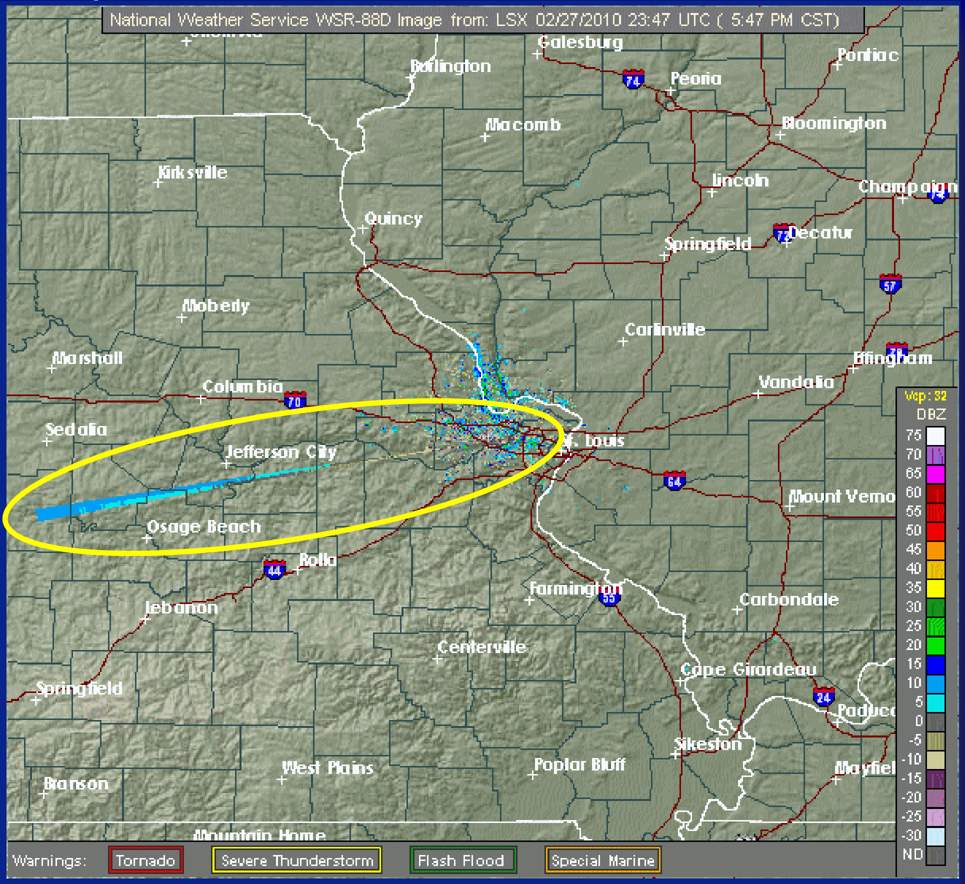
Western Wisconsin

Insects



Mississippi River near La Crosse, WI

Sunrise/Sunset

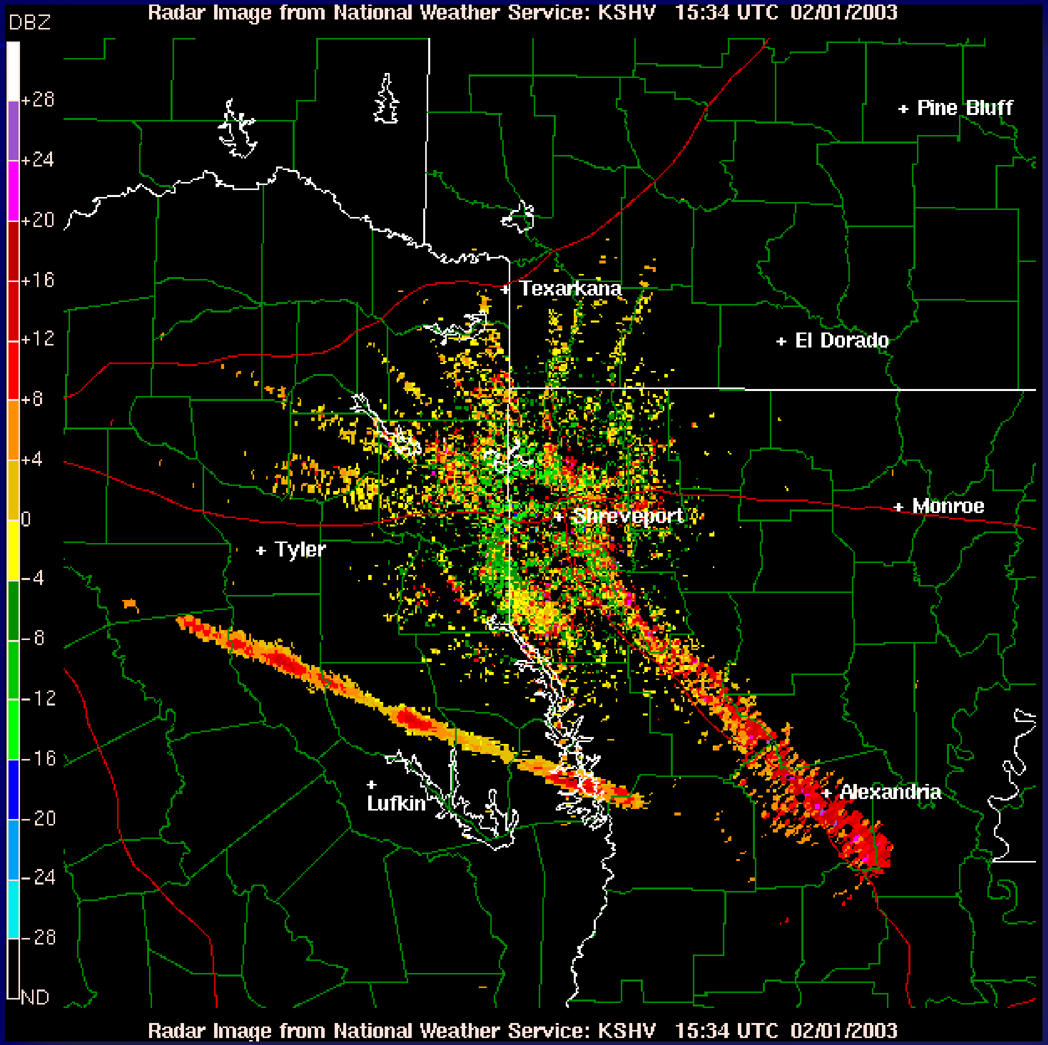


Sunset spike

Twice a day, at sunrise and sunset, the radar experiences interference from the electromagnetic energy emitted by the sun.

There is a point at sunrise and sunset where the radar dish points directly at the sun and is hit with this energy. This is then displayed as a spike of returned energy on our display. It is brief, typically only occurring during one volume scan.

Columbia Space Shuttle

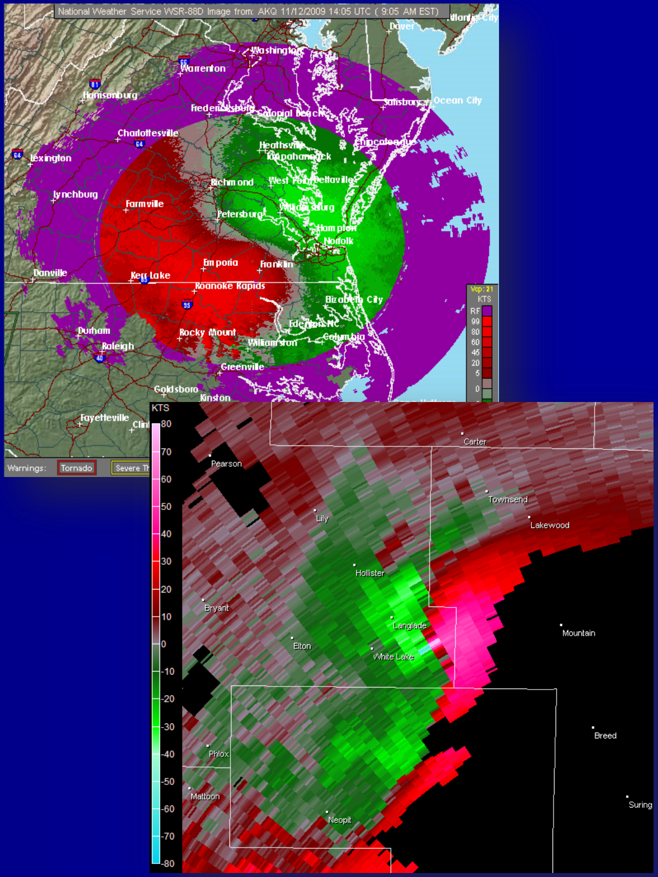


Velocity

- Velocity images allow users to look at a storm system's large- and small-scale wind fields.

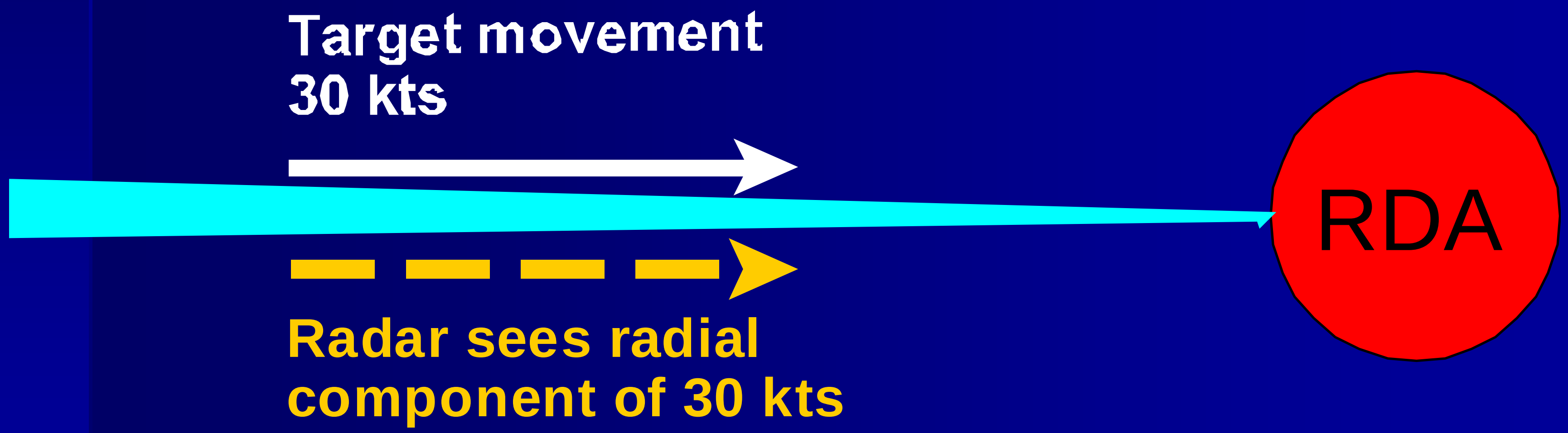
- Velocity is not total velocity, but rather "radial velocity"—that portion of the wind parallel to the radar beam.

- Radar velocity images are available as "base" velocity and "storm-relative."



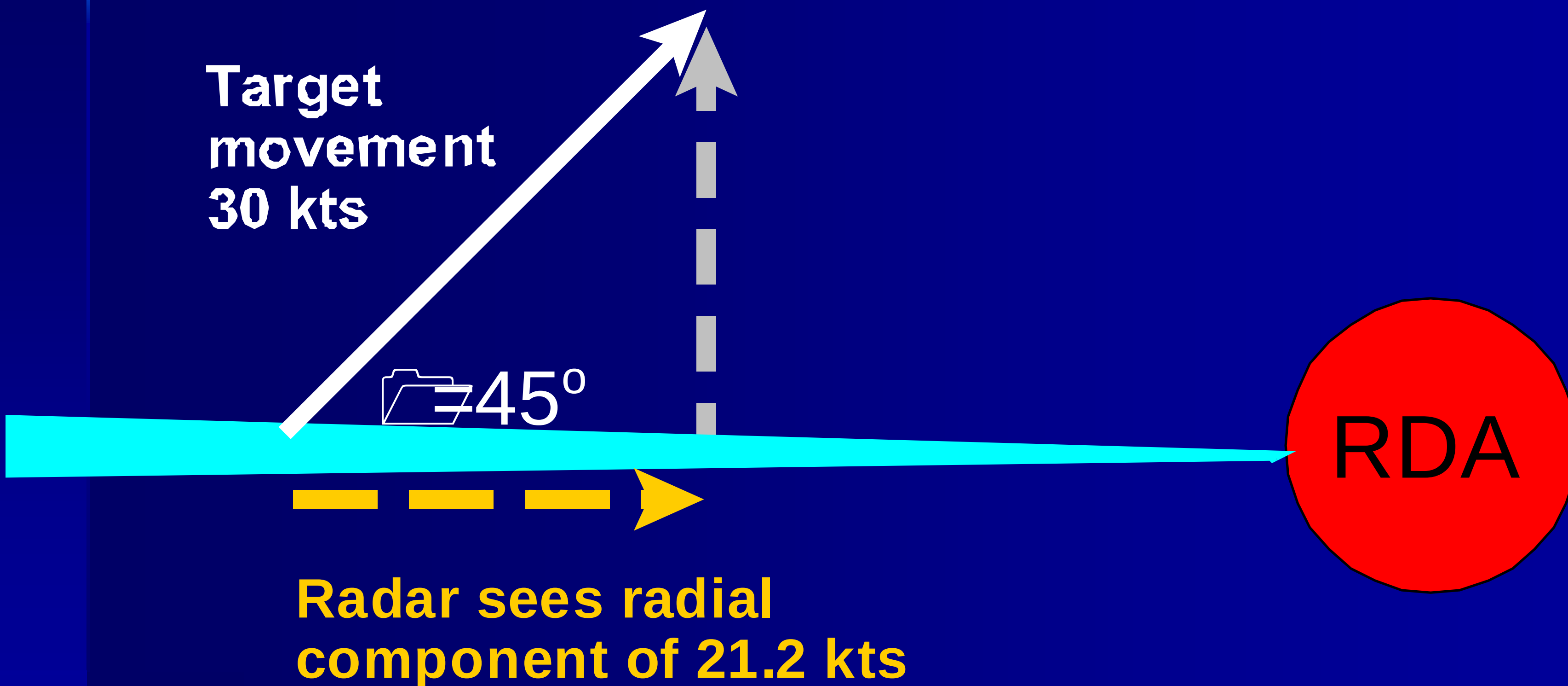
Radar Sees True Velocity

(only when target moves directly toward or away from radar antenna)



Radar Sees Portion of Velocity

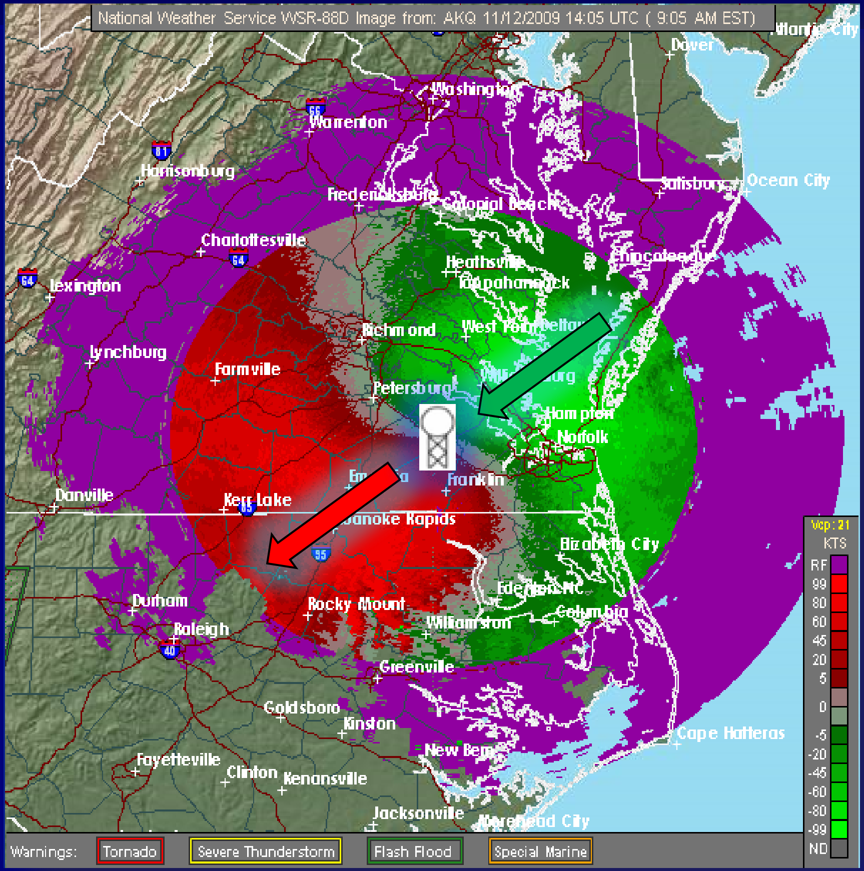
(when target moves at some angle to radar antenna)



Radar Sees Zero Velocity
(when target moves perpendicular to radar antenna)

Velocity Interpretation

- Warm colors (red) / positive values indicate wind moving away from the radar (along a radial).
- Cool colors (green) / negative values indicate wind moving toward the radar.
- Purple indicates "range folding"— where the radar cannot determine the radial velocity.

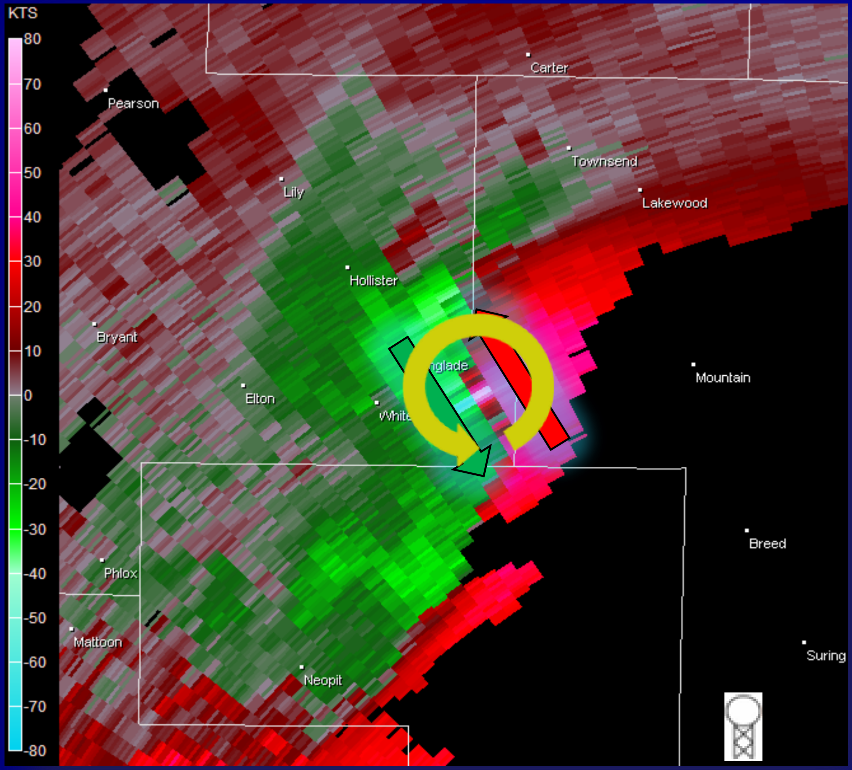


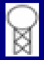
Velocity image of a large-scale weather system.

 *denotes the approx. location of the radar.*

Velocity Interpretation

- An example of a thunderstorm, zoomed in to show the details of the storm.
- Green is air motion towards the radar while red is air motion away from the radar.
- A circulation is evident – a mesocyclone.

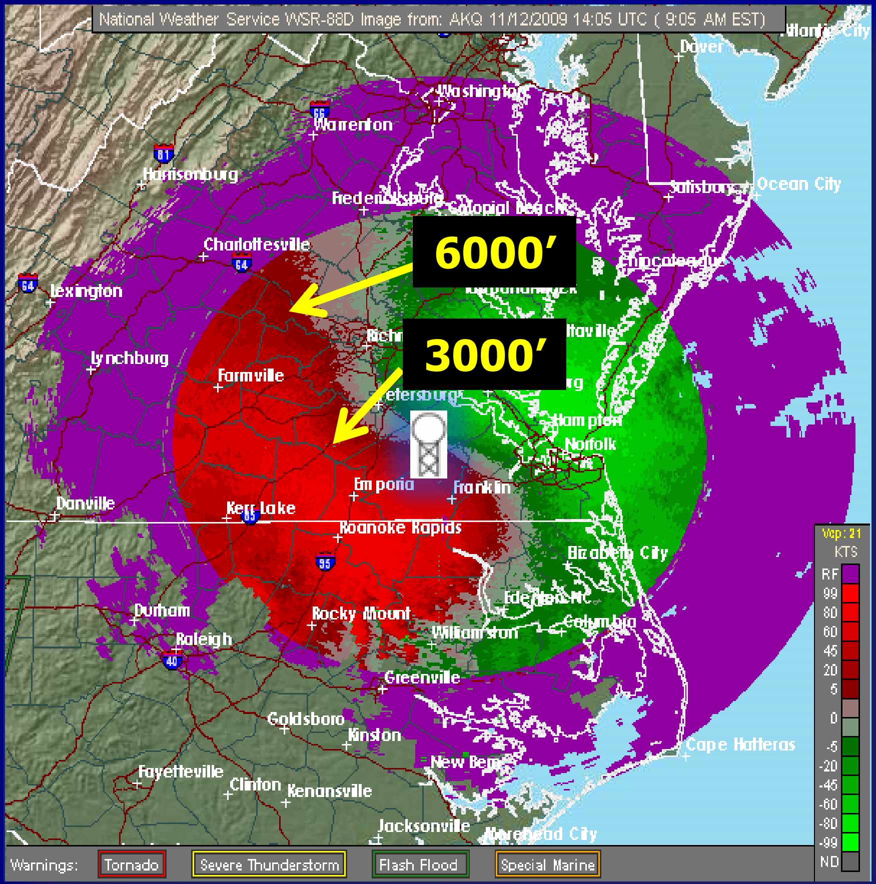


 *denotes the approx. location of the radar.*

More Velocity Interpretation

- Recall: the radar captures data along varying elevations which make up the volume coverage pattern, the radar beam increases in height with distance.

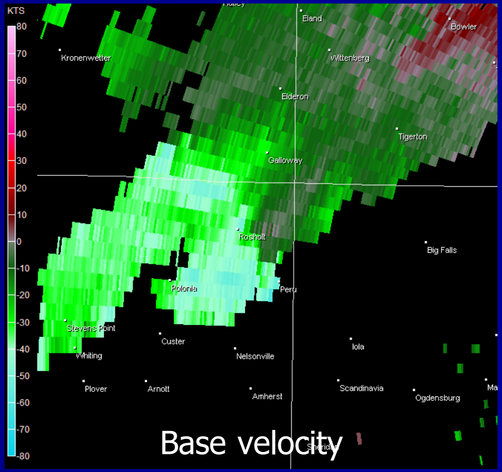
- So, when you look at a radar image at a given elevation angle, you are <u>not</u> looking at data on a constant height above ground.

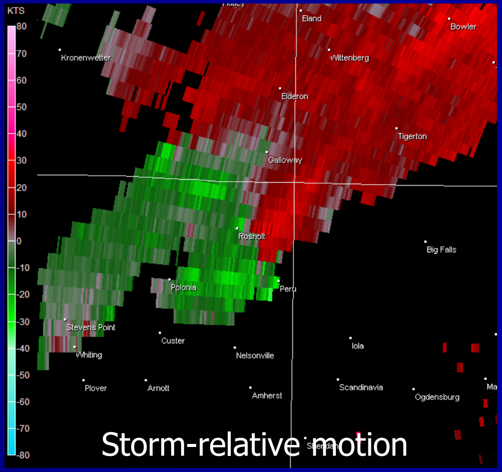


Base vs. Storm Relative Velocity

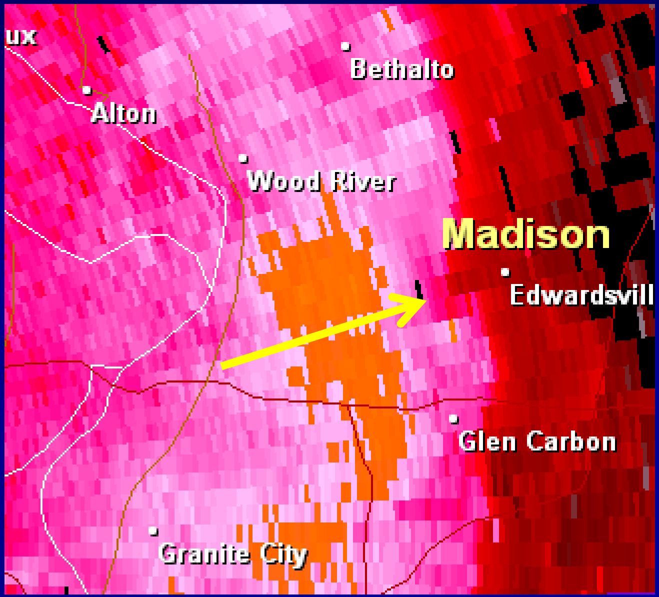
- Storm relative velocity is derived by subtracting the average motion of the storms from the base velocity.

- The storm motion is removed to make the view of the wind relative to the storm. What is left is the wind's motion as if the storms were stationary, making circulations more easily seen.

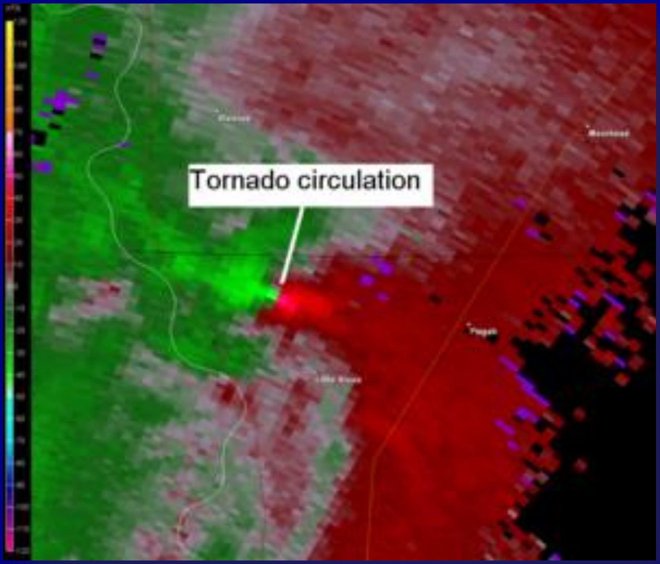




Base vs. Storm Relative Velocity



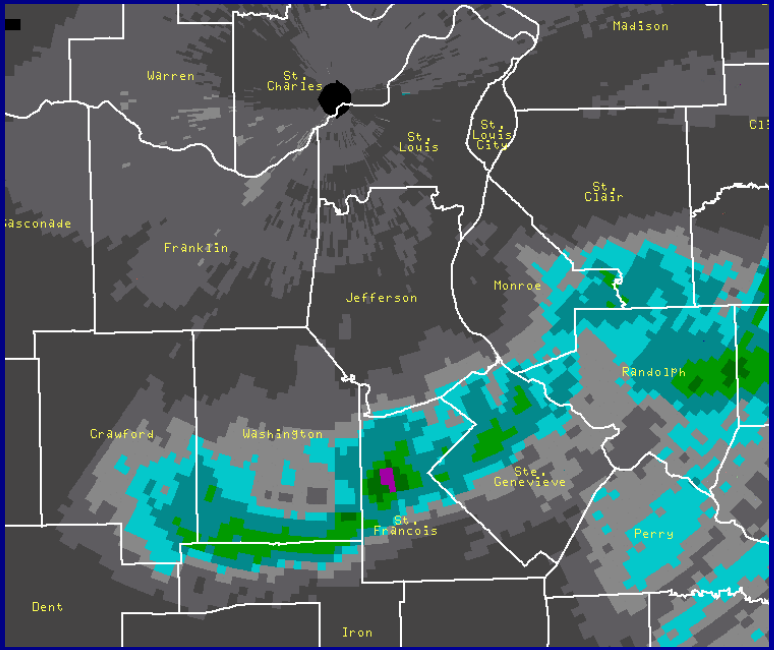
Base velocity is often used to determine potential straight-line wind gusts associated with thunderstorms.



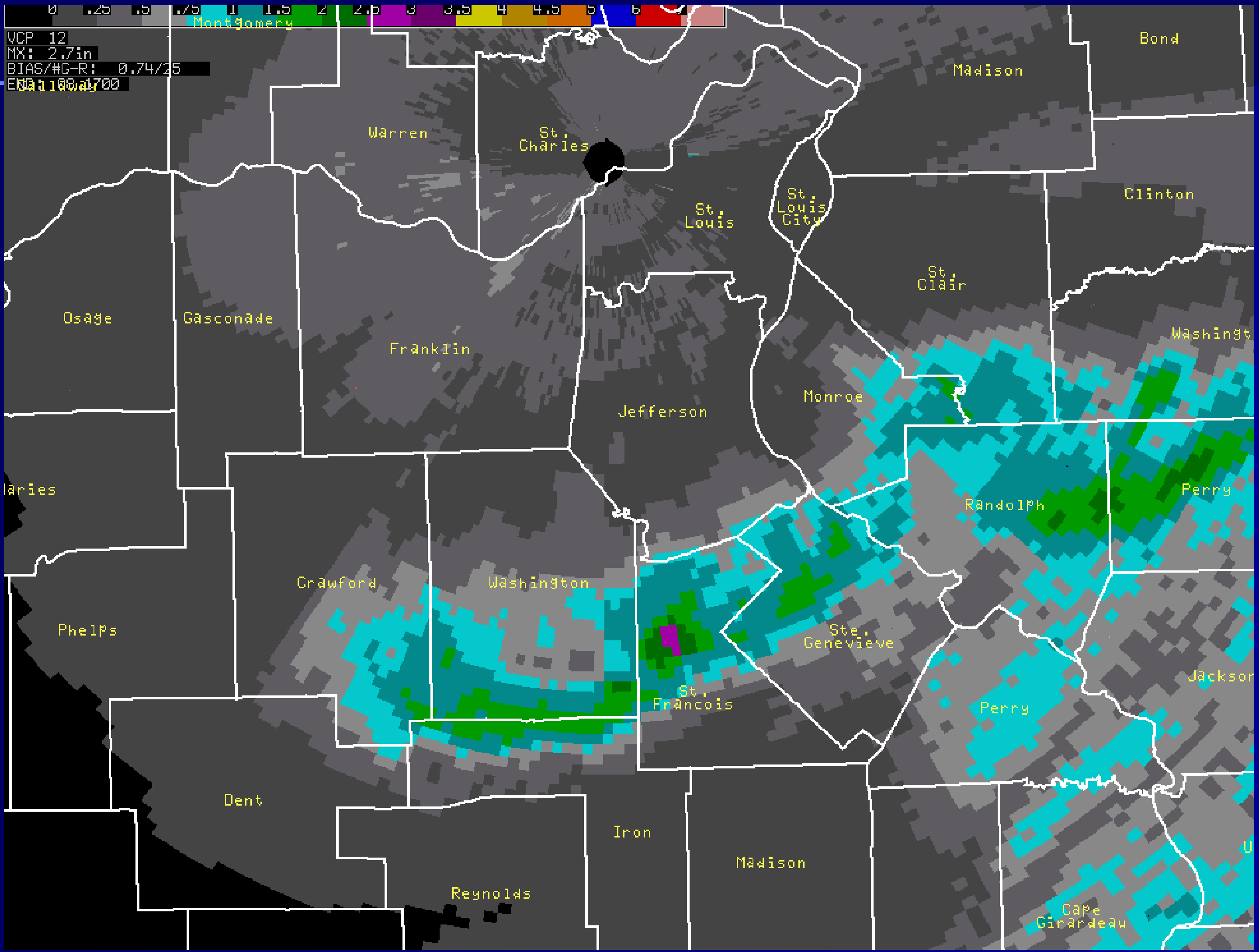
Storm-relative velocity is used to identify circulations within thunderstorms which can be masked by the storm motion.

Precipitation Estimates

- Only an estimate
- Can be very good with amounts, or X times too high *(many caveats)*
- Typically great with location
- Usually amounts too high if storm has hail or ice (cool months)
- Used primarily for flash flood detection
- 1-hour / Storm Total Products



May 8, 2009



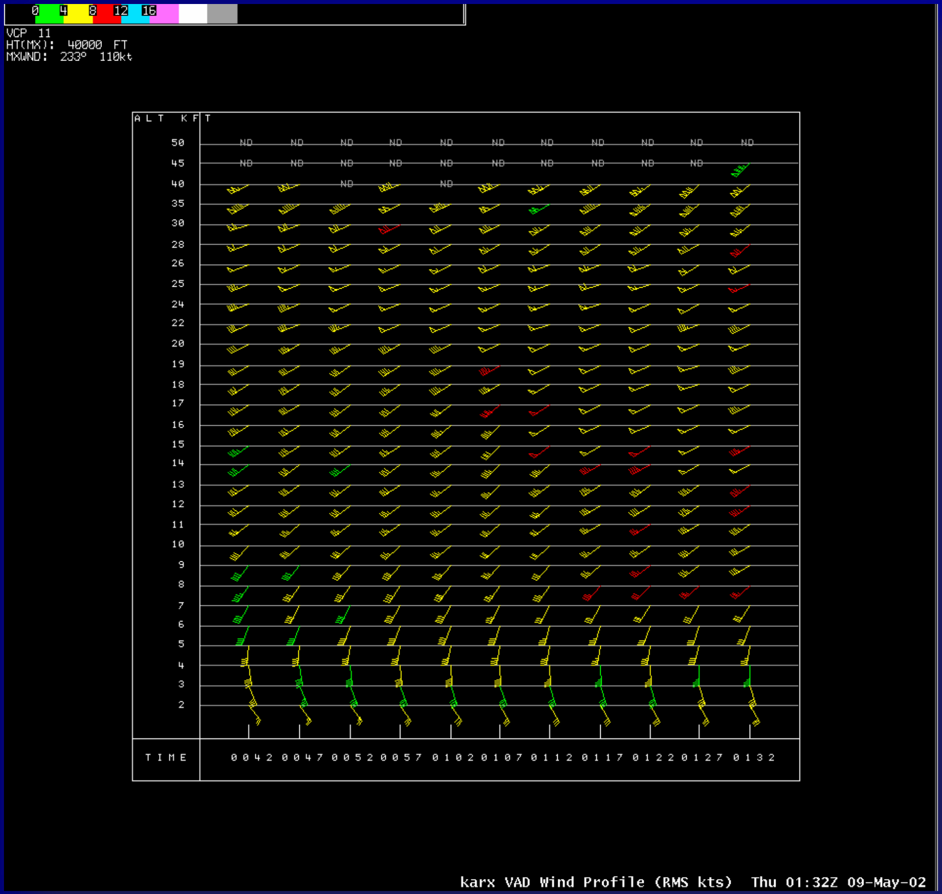
0 .25 .5 .75 1 1.5 2 2.5 3 3.5 4 4.5 5 6
VCP 12
MX: 2.7in
BIAS/#G-R: 0.74/25
Montgomery
Warren
St. Charles
St. Louis
St. Louis City
Madison
Bond
Clinton
St. Clair
Osage
Gasconade
Franklin
Jefferson
Monroe
Washington
Randolph
Perry
Crawford
Washington
Ste. Genevieve
St. Francois
Jackson
Phelps
Perry
Dent
Iron
Madison
Reynolds
Cape Girardeau

Part 3: Other Radar Products
(from algorithms)*

- VAD Wind Proflile
- Vertically Integrated Liquid (VIL)
- Hail
- Mesocyclone
- Tornadic Vortex Signature
- Storm Track

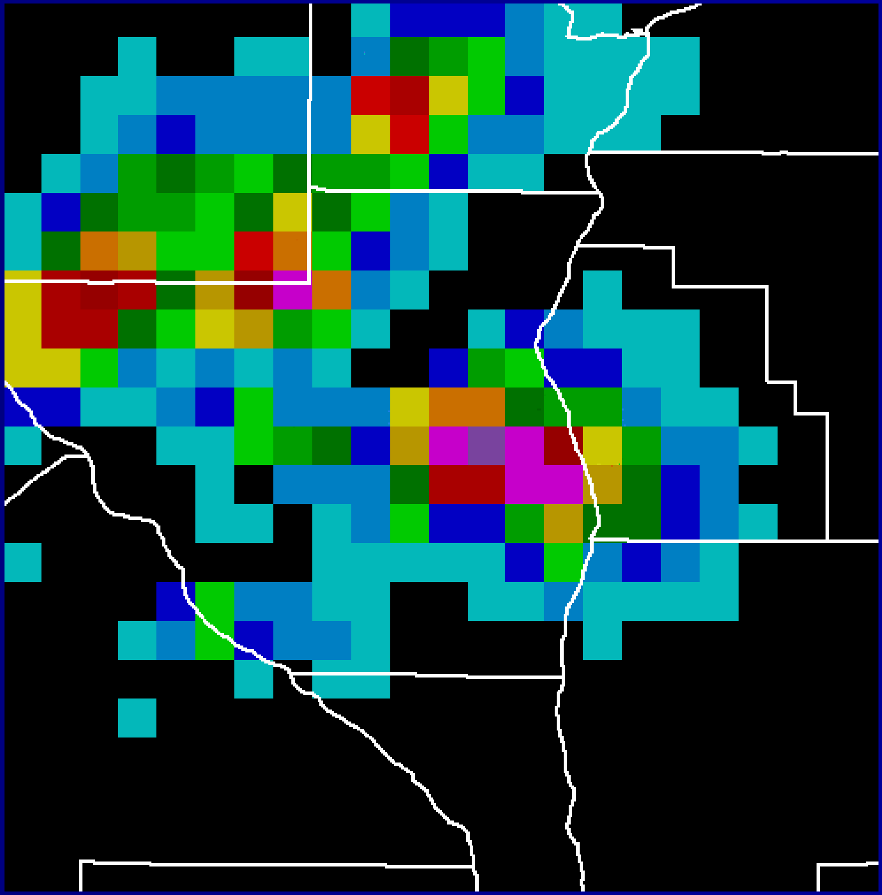
VAD Wind Profile

- Vertical wind profile – change in wind direction and speed with height *(shear)*
- Wind changes over past hour
- Needs clouds, precipitation, or lots of other scatterers



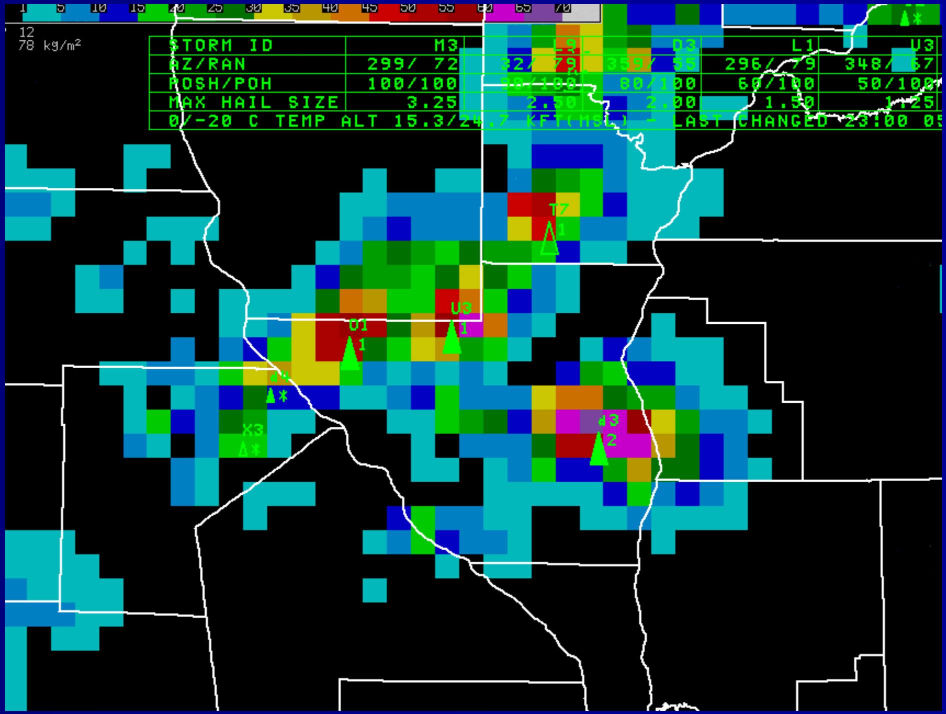
Vertically Integrated Liquid (VIL)

- Reflectivity converted to liquid values
- Pin-points most intense storms
- Correlates very well with hail or heavy rain
- High values indicate the most intense area but not necessarily hail

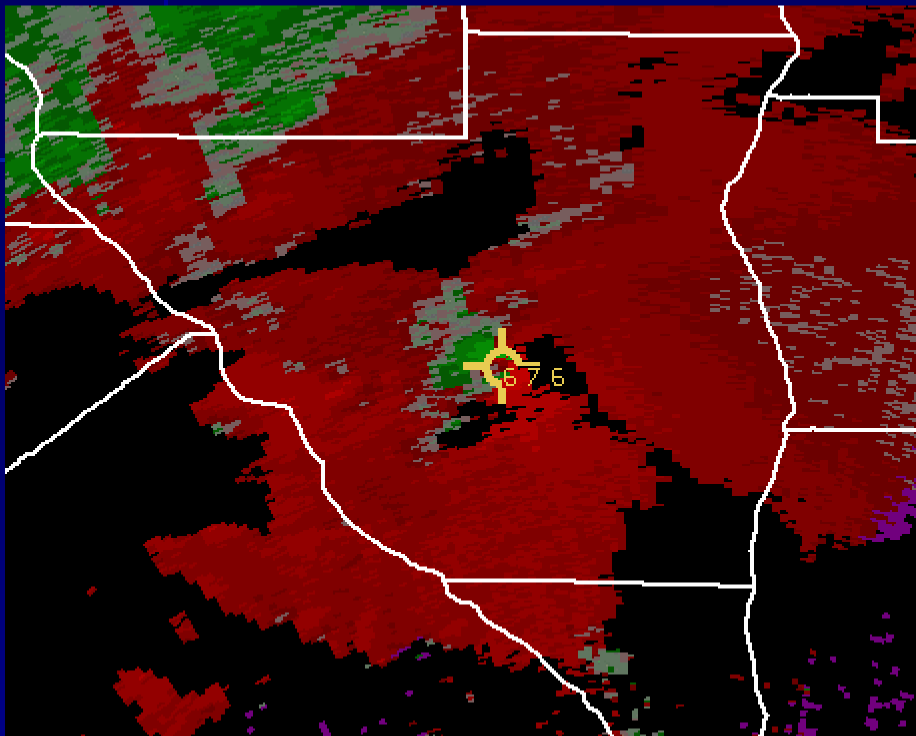


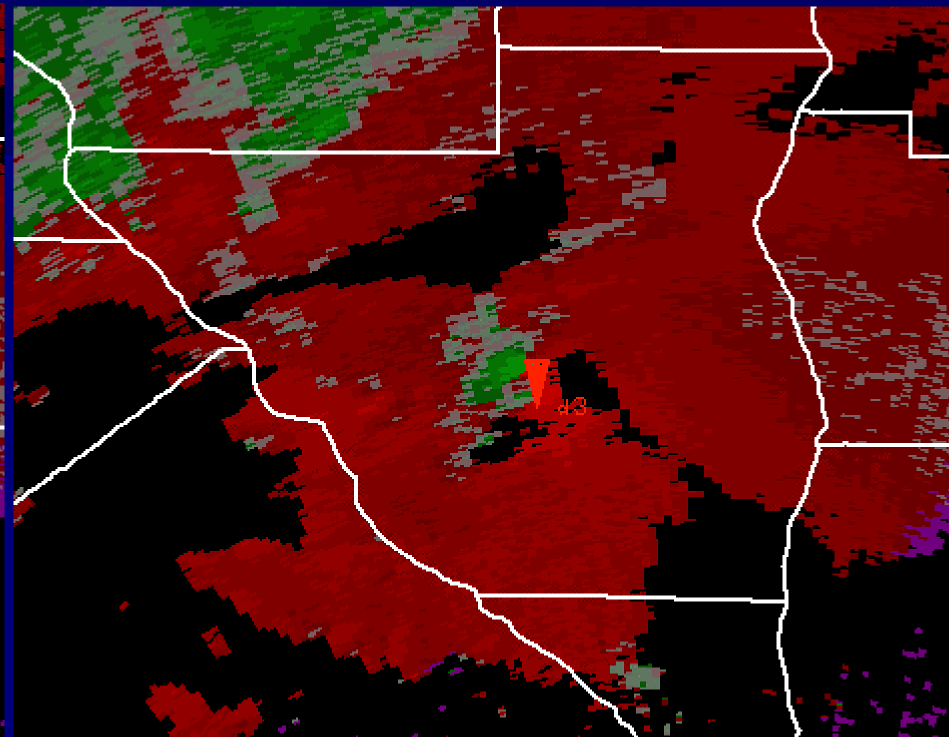
Hail Algorithm

- Provides an estimate of maximum expected hail stone in the storm and location
- Typically overestimates



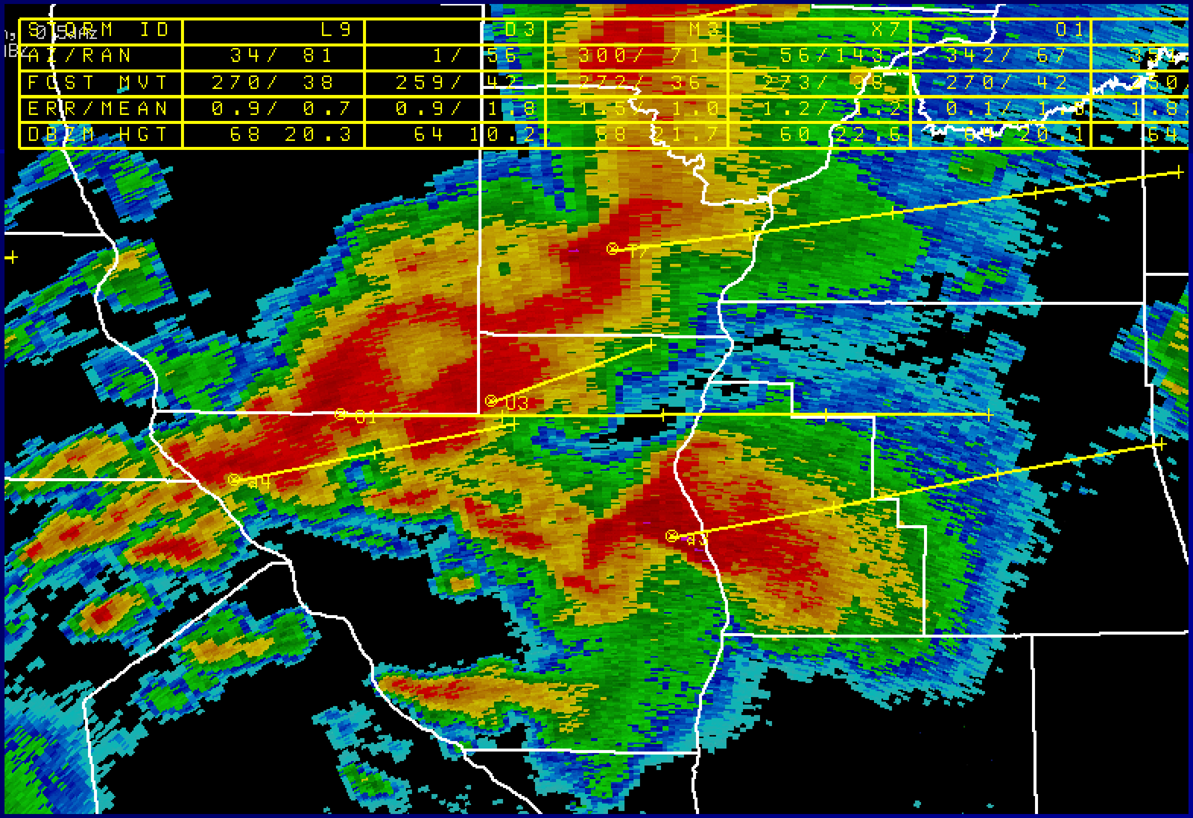
Mesocyclone / Tornado Vortex Signature (TVS)





- Identify areas of rotation, scales of rotation, and strength
- Accuracy is subject to quality of the base velocity data
- Failures are not uncommon (bad data or range issues)
- Also does not identify all significant circulations
- A small percentage of mesocyclones actually produce tornadoes (10-20%)

Storm Track



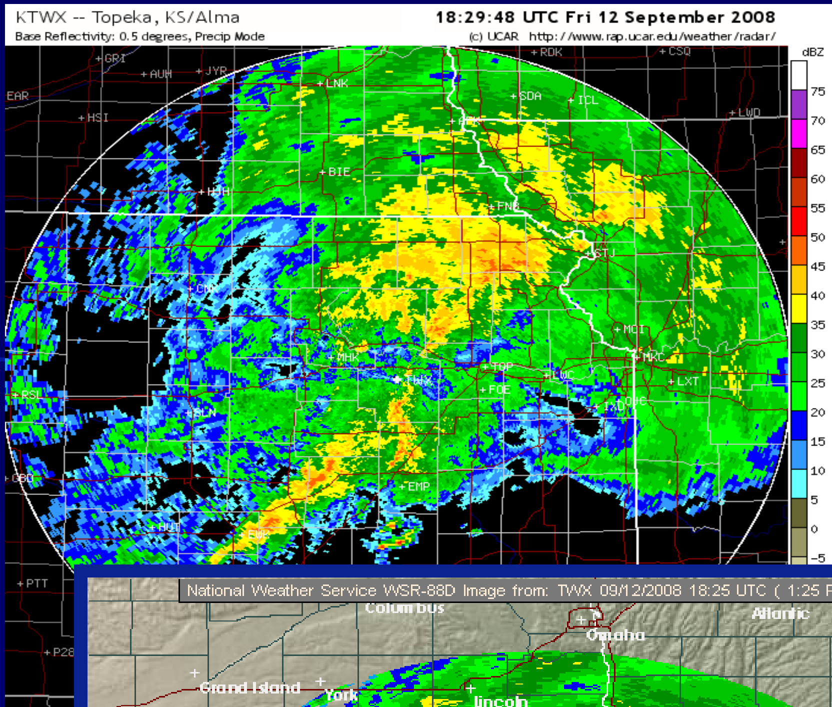
- Provides an estimate of storm motion
- Best for isolated storms
- Tracks can jump around when there is difficulty locating the storm center

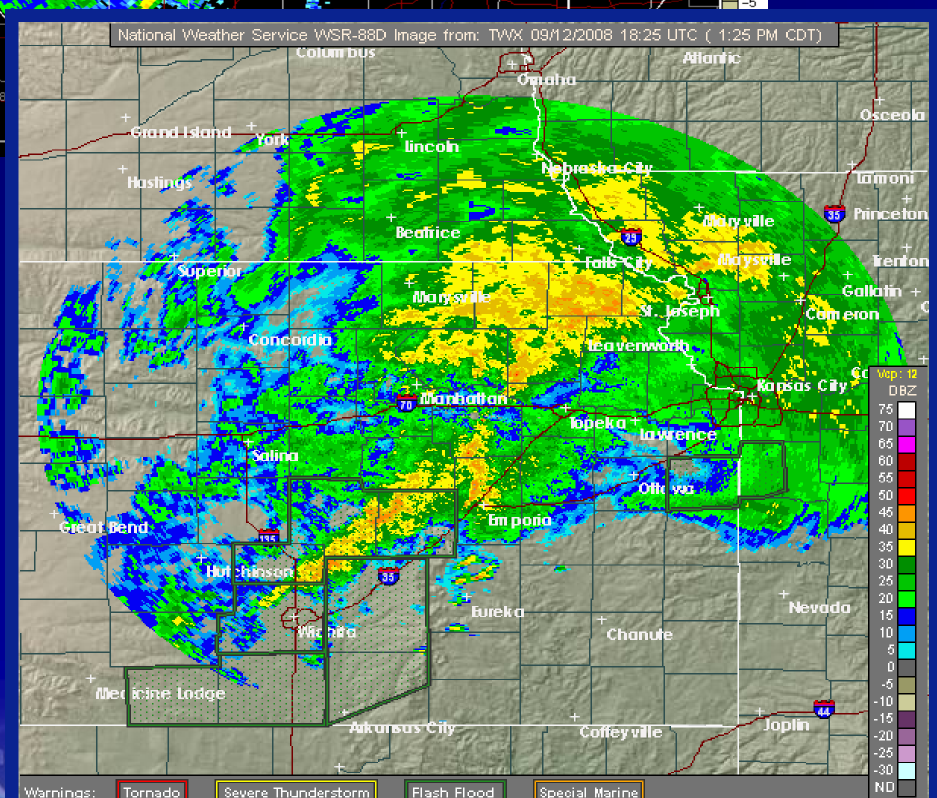
Part 5: Radar Data On The Internet

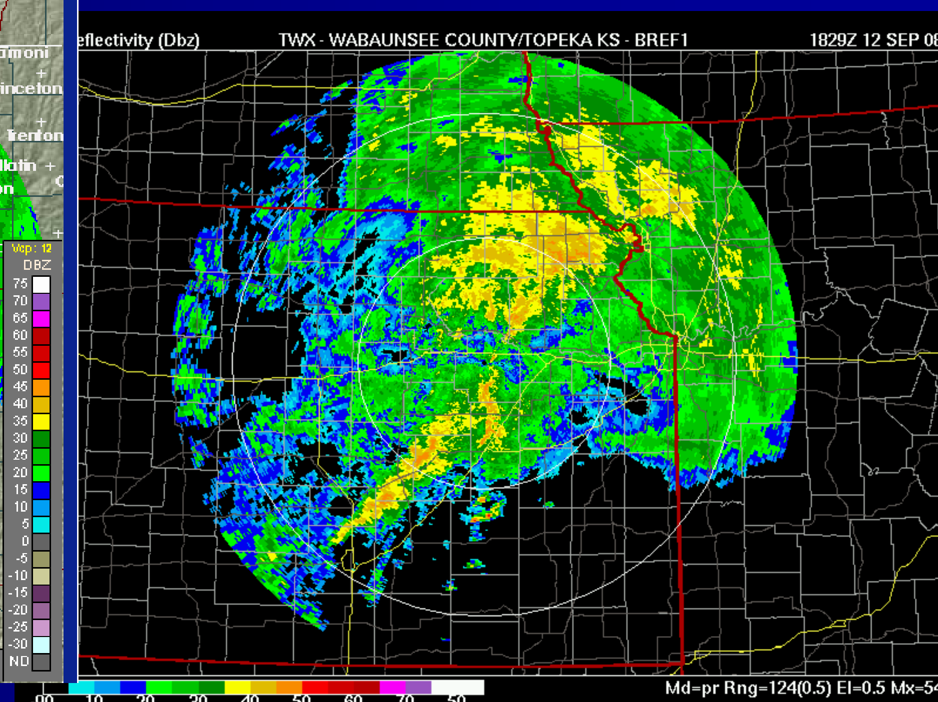
- Base Reflectivity
- Composite Reflectivity
- Base Velocity
- Storm-Relative Velocity
- Precipitation/Rainfall Estimates
- Others (VIL, ET, VWP, storm tracks, meso,TVS, hail, additional elevations)

Internet Single Site Displays:

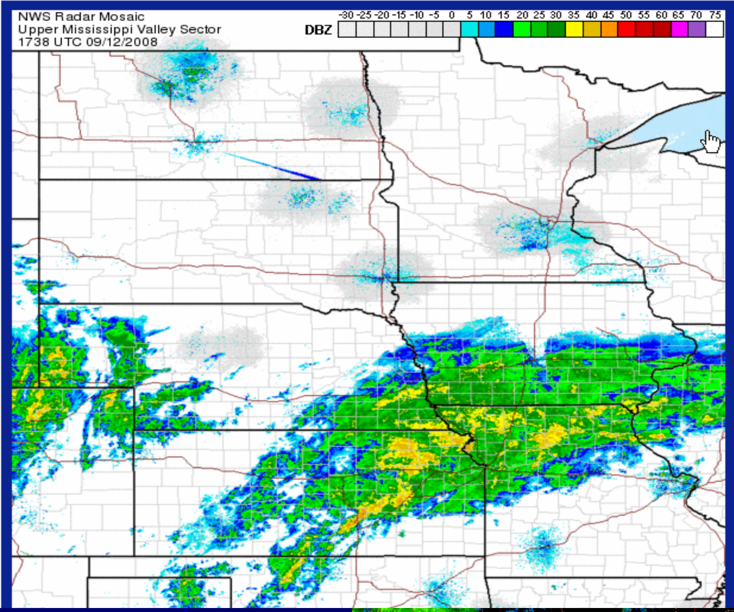
Same Data Source, Different Packaging

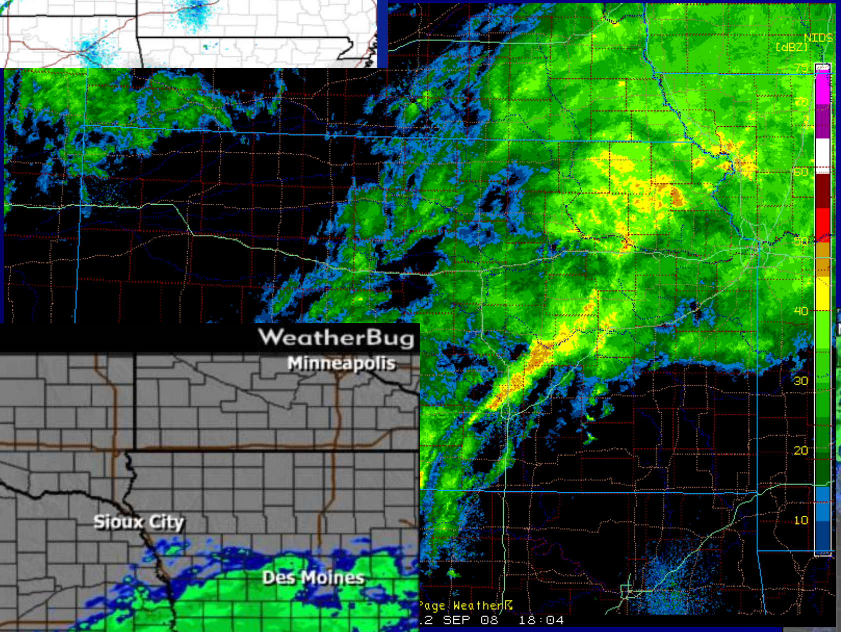


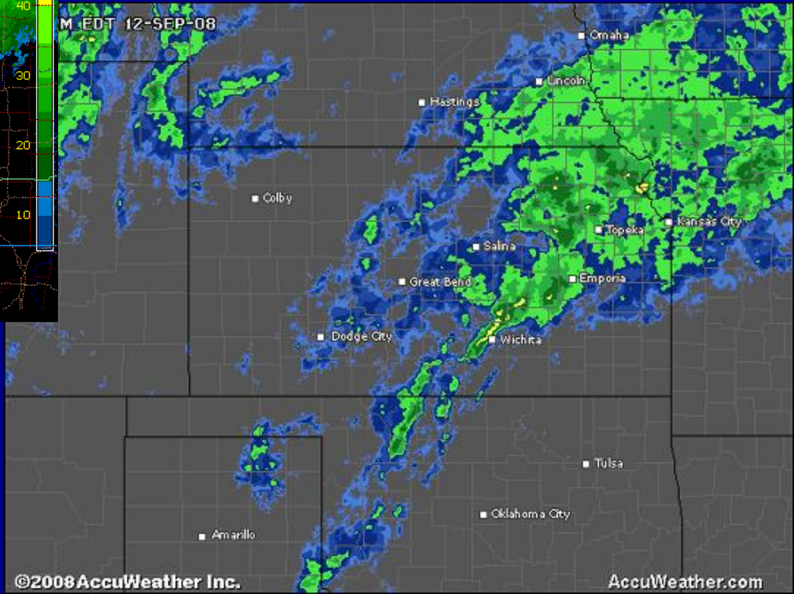




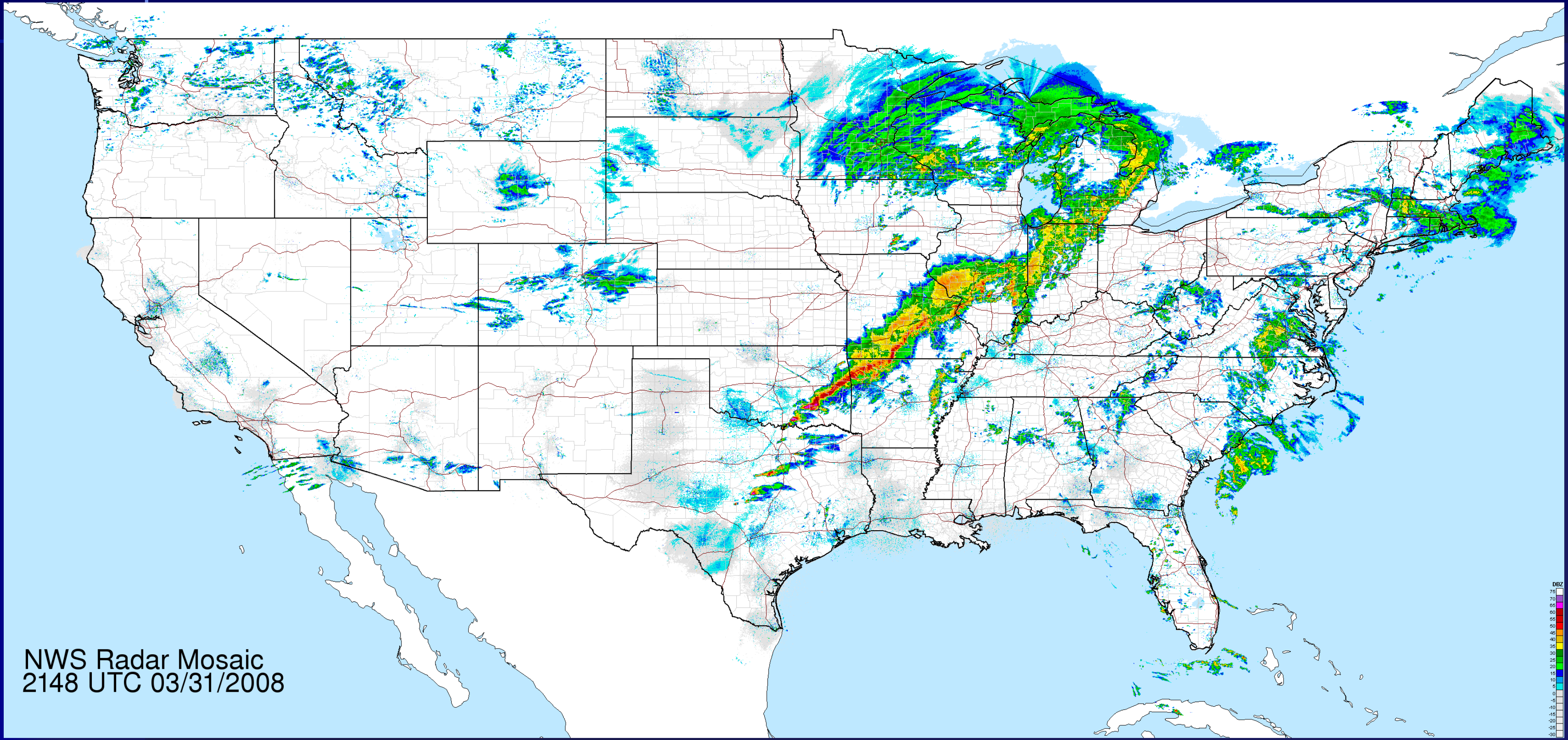
Internet Mosaic Displays: Multiple Radar Sites Combined in One Image



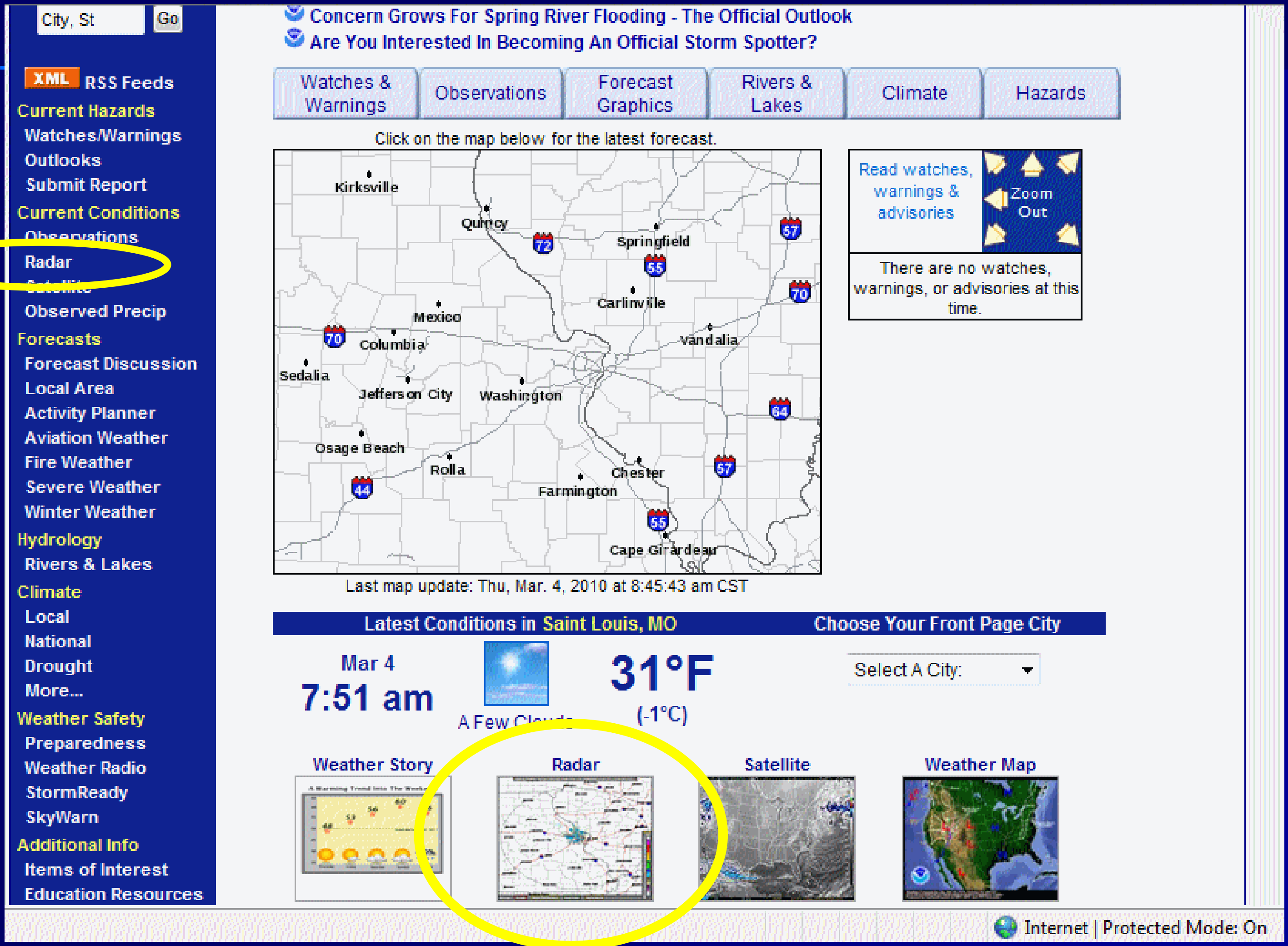




National Mosaic Base Reflectivity

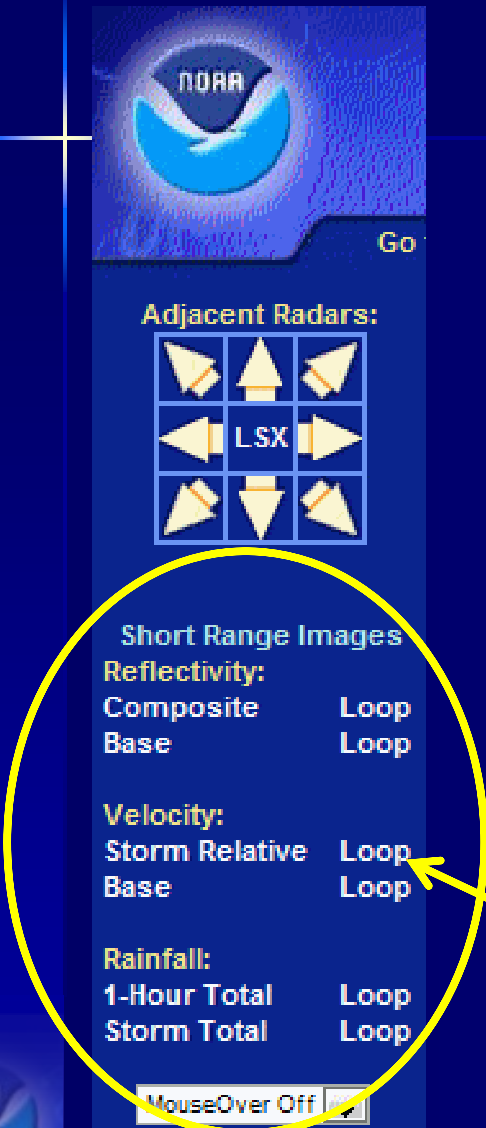


NWS St. Louis Web Page
weather.gov/lsx



NWS St. Louis Radar Web Page

NWS St. Louis Radar Web Page



Radar Products Available

- ✔ 0.5° Base Reflectivity
- ✔ Composite Reflectivity
- ✔ 0.5° Base Velocity
- ✔ 0.5° Storm Relative Velocity
- ✔ 1 Hour Rainfall Accumulation
- ✔ Storm Total Rainfall Accum.

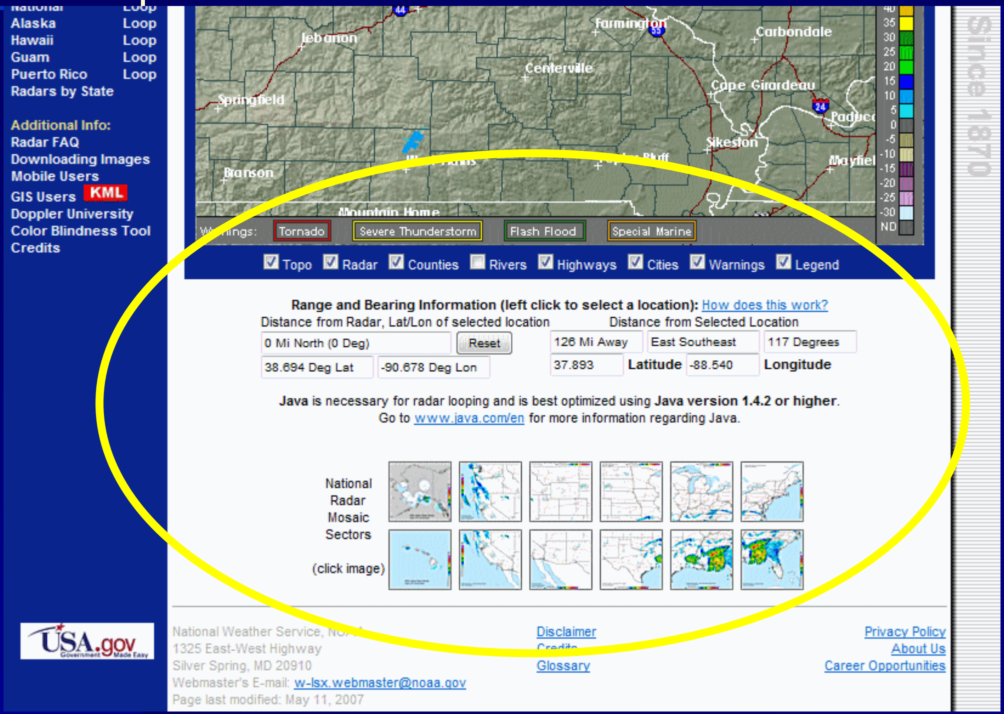
Animation/looping capabilities

NWS St. Louis Radar Web Page

To access radar data from adjacent radars:

- Click on one of the arrows located in the upper left portion of the display.
- The arrows point in the general direction where adjacent radars are located.

NWS St. Louis Radar Web Page



The Bottom Portion:

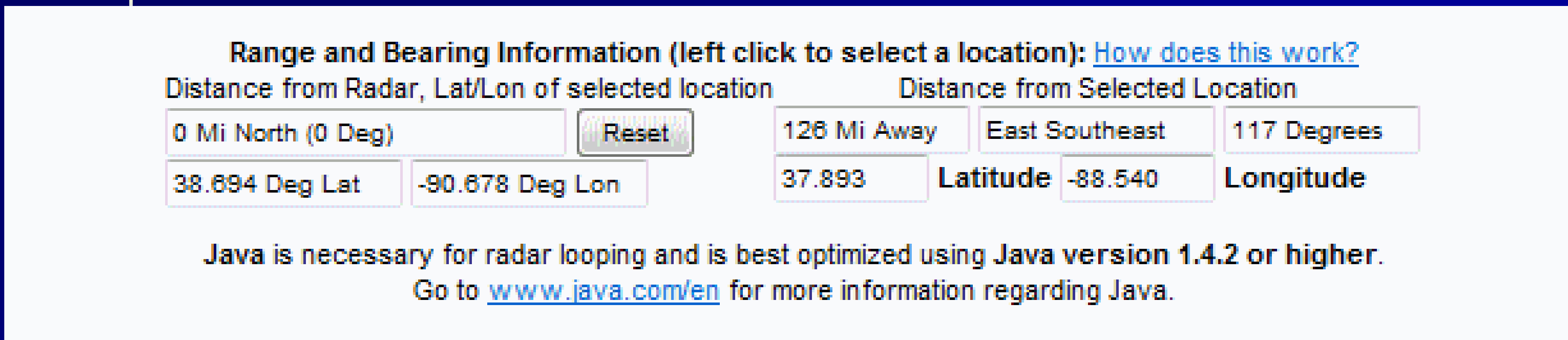
- Overlays
- Range and Bearing Info
- Regional Mosaics

NWS St. Louis Radar Web Page

The Bottom Portion:

- **Overlays**

NWS St. Louis Radar Web Page



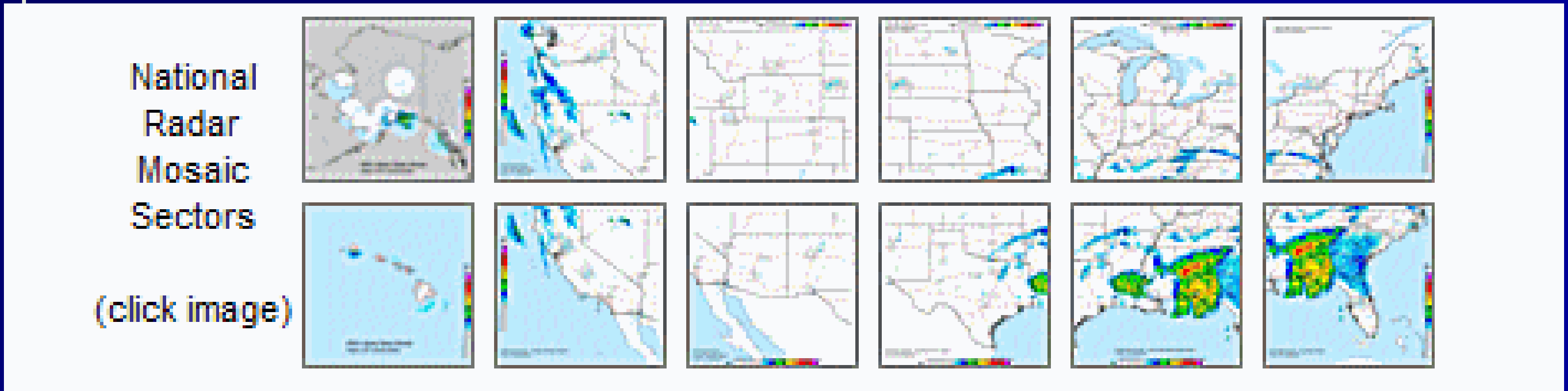
1. Click on the radar map to set the reference point

2. Distance from the Selected Location is the distance from the mouse pointer and the selected reference point

The Bottom Portion:

- **Range and Bearing Info**

NWS St. Louis Radar Web Page



The Bottom Portion:

- Regional Mosaics

NWS St. Louis Web Page
weather.gov/lsx

Other Radar Imagery Websites

(The National Weather Service does not endorse any of these sites)

- Plymouth State University:

  vortex.plymouth.edu/lnids_conus.html?
- College of DuPage:

  weather.cod.edu/analysis/analysis.radar.html
- Weather Underground

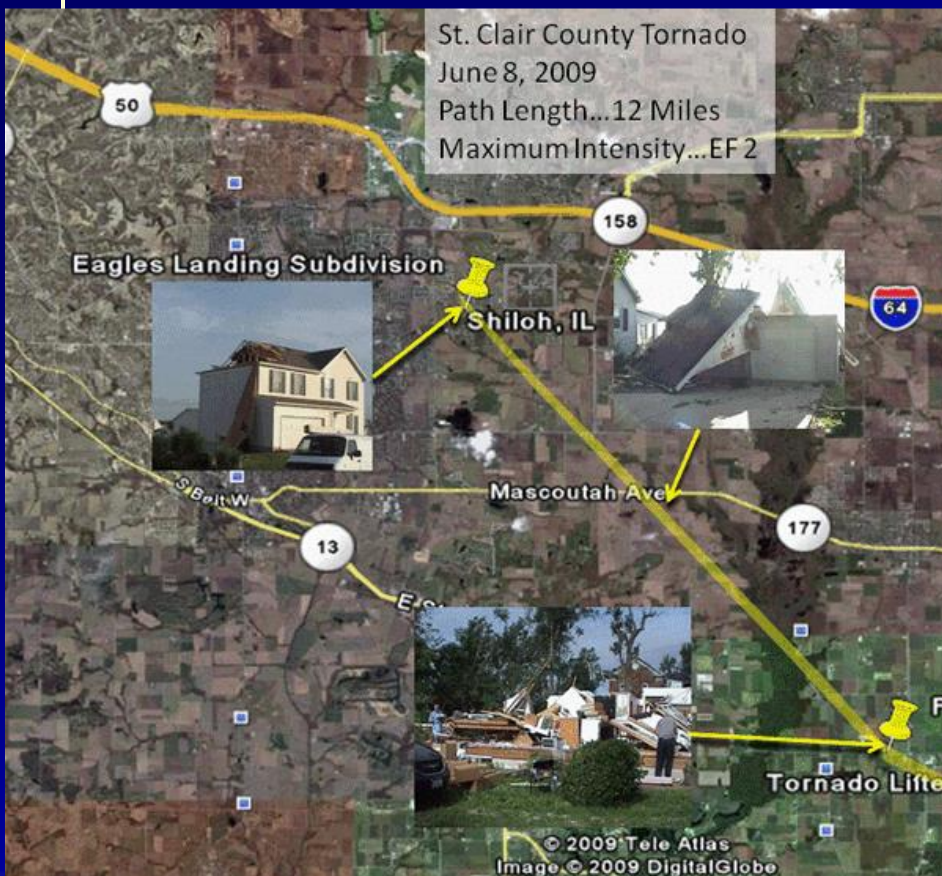
  www.wunderground.com/radar/map.asp

Part 5: Case Study Examples

- June 8, 2009 Supercell
- August 5, 2009 Bow Echo
- August 5, 2009 Line of Storms
- May 25, 2008 Flash Flooding

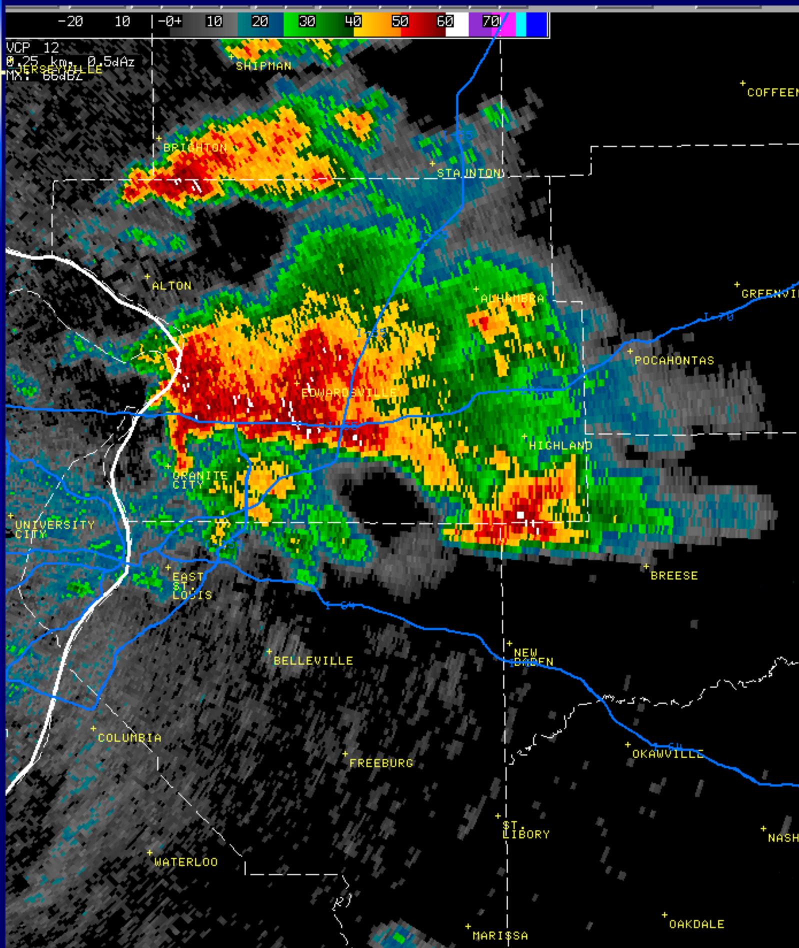
Supercell

St. Clair County, IL --June 8, 2009

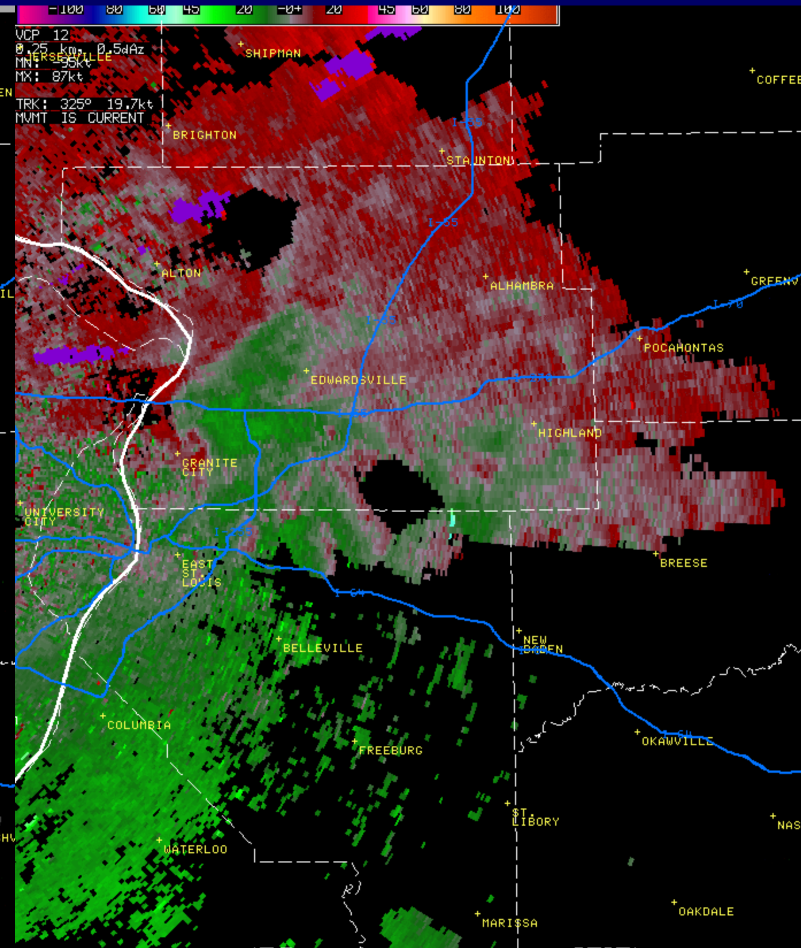


Supercell

June 8, 2009 (445 pm)



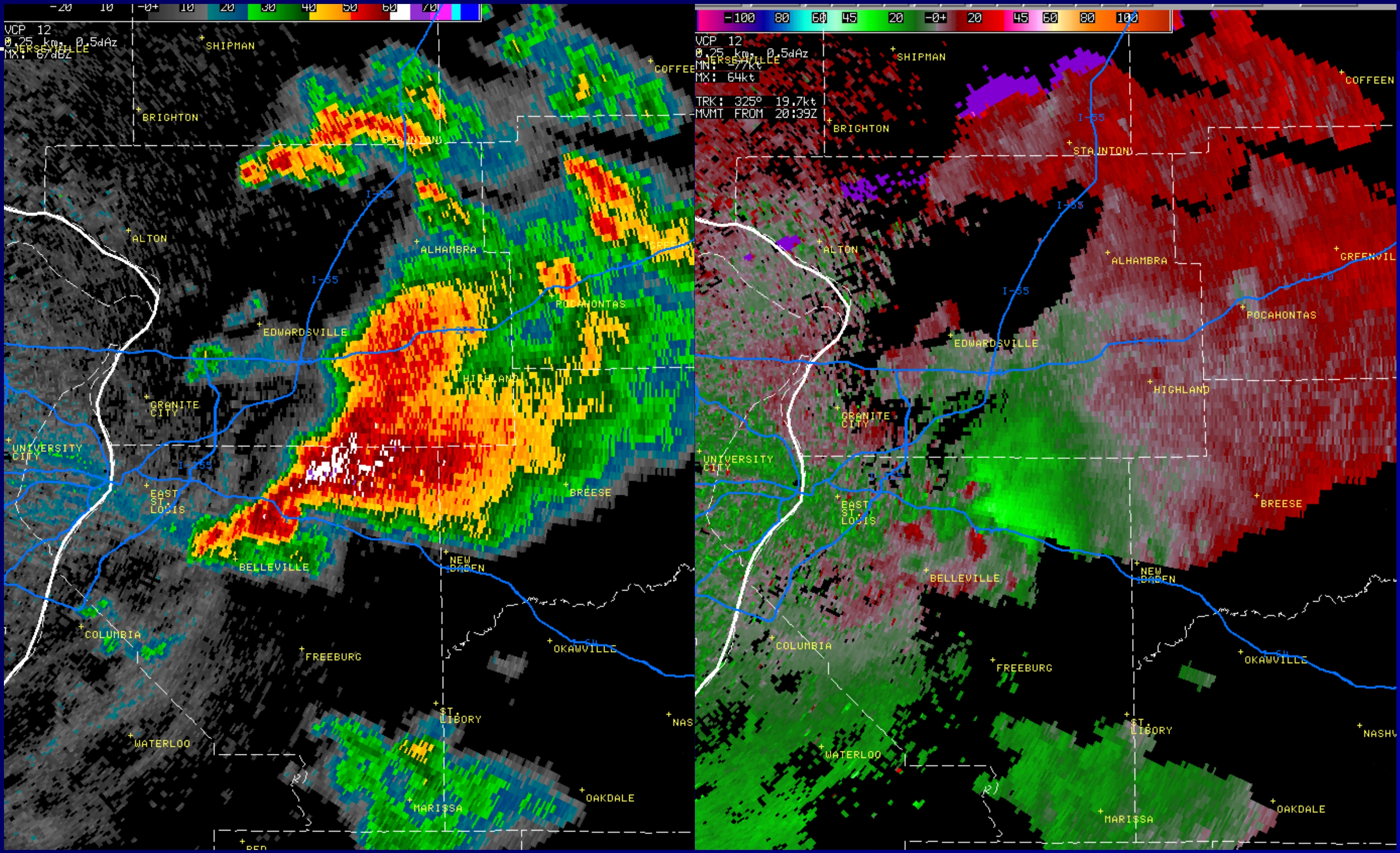
Base Reflectivity



Storm Relative Motion (SRM)

Supercell

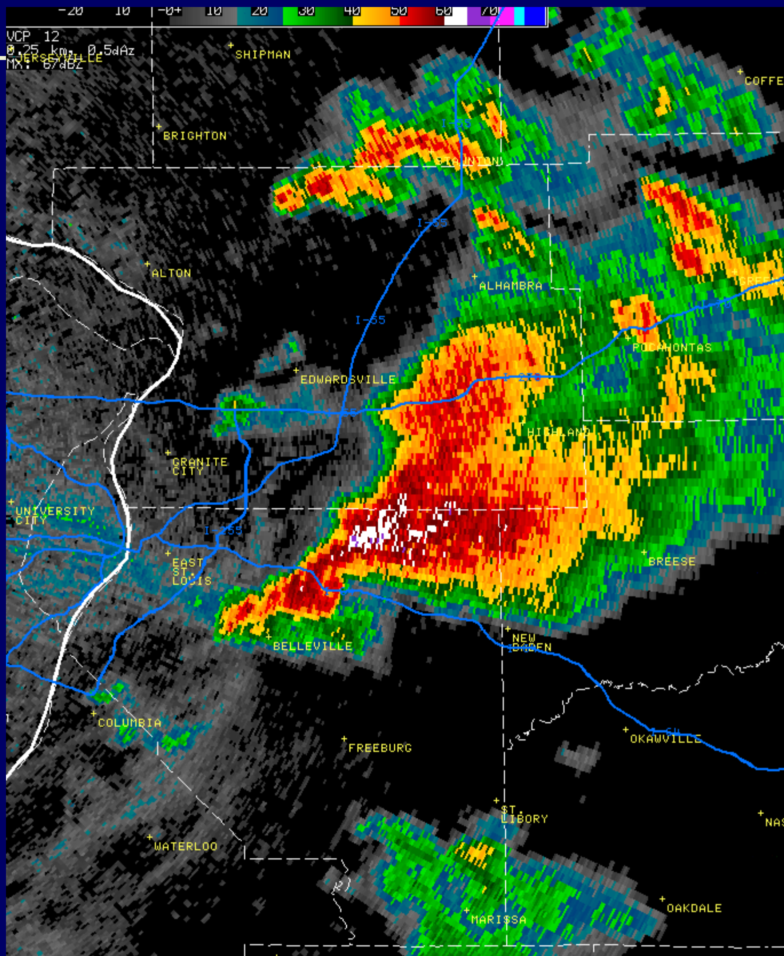
June 8, 2009 (519 pm)



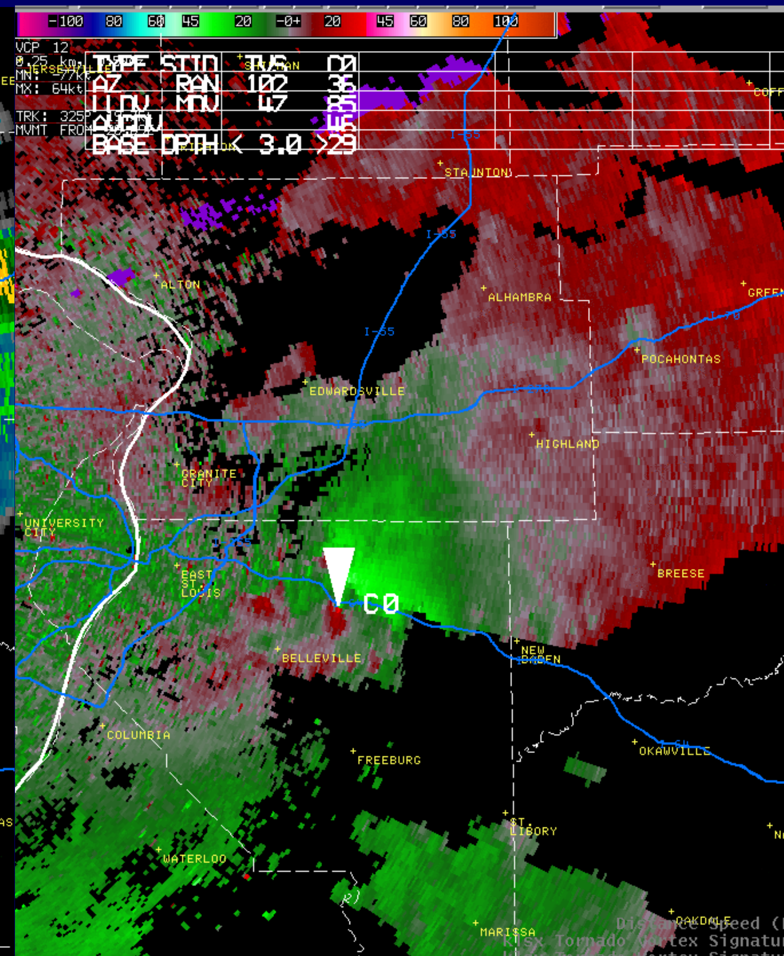
Base Reflectivity | **Storm Relative Motion (SRM)**

Supercell

June 8, 2009 (519 pm)



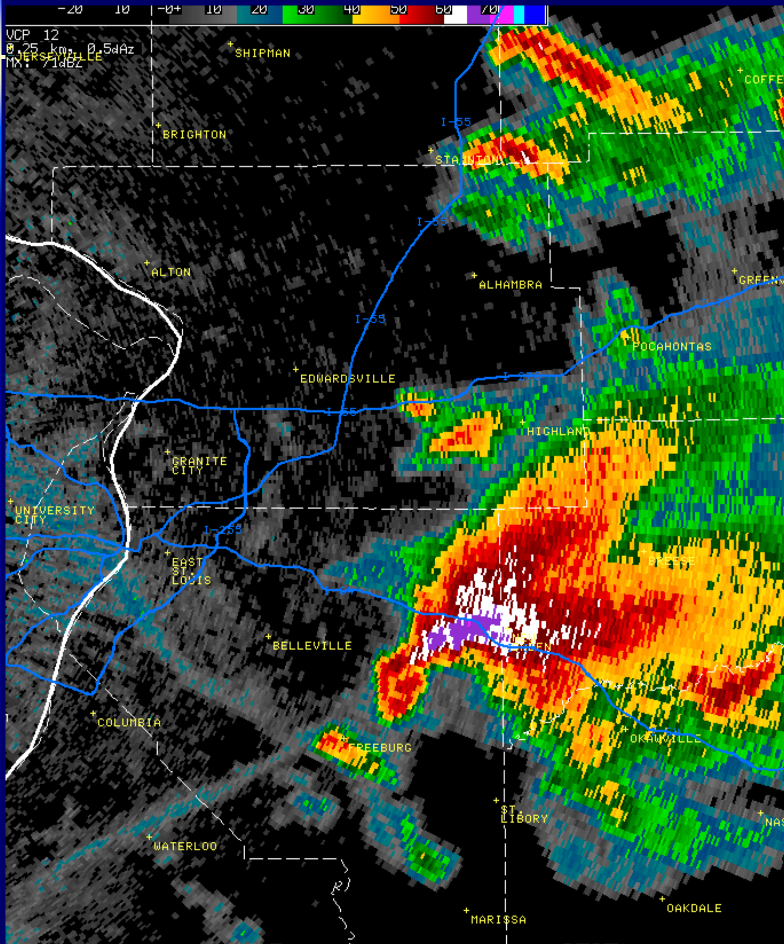
Base Reflectivity



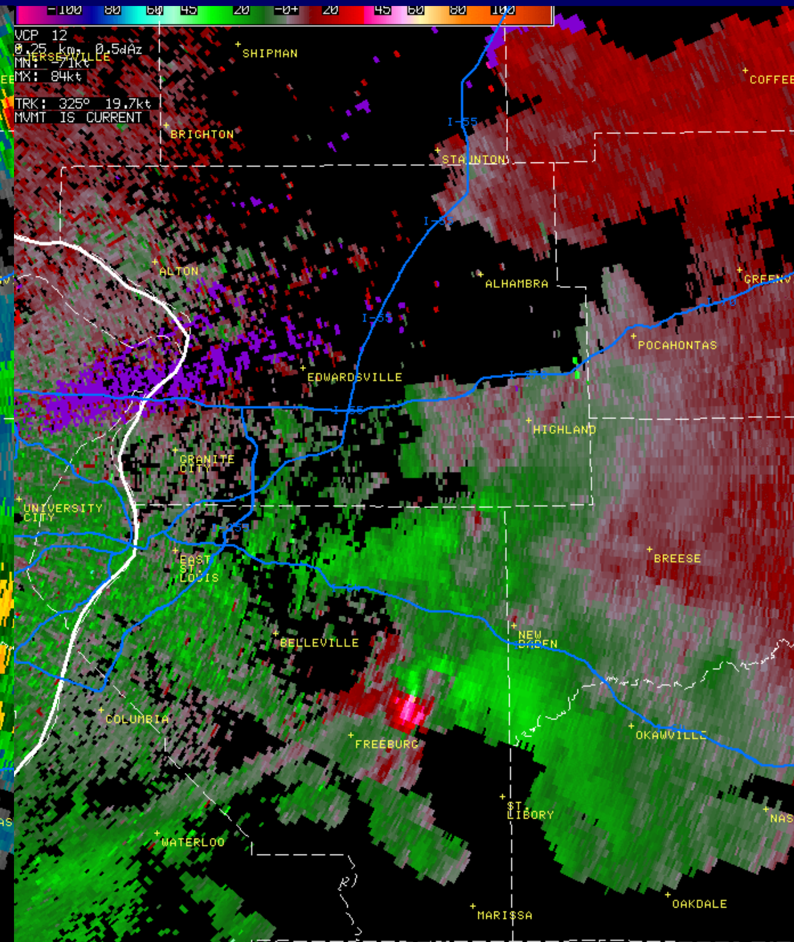
Storm Relative Motion (SRM) + Tornado Vortex Signature (TVS)

Supercell

June 8, 2009 – 545 pm



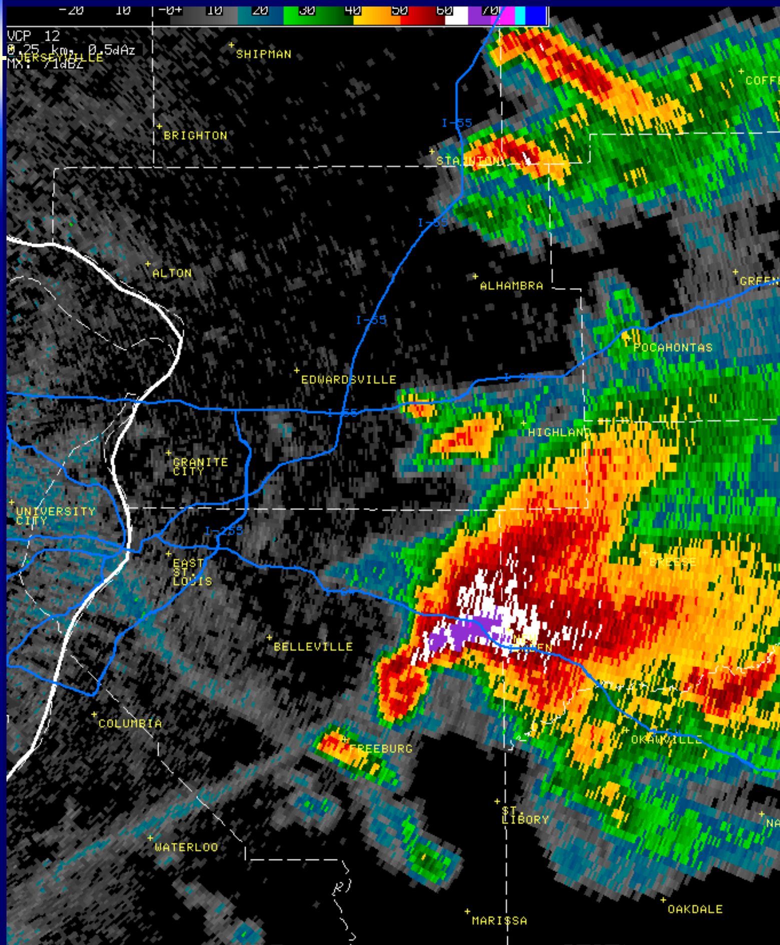
Base Reflectivity



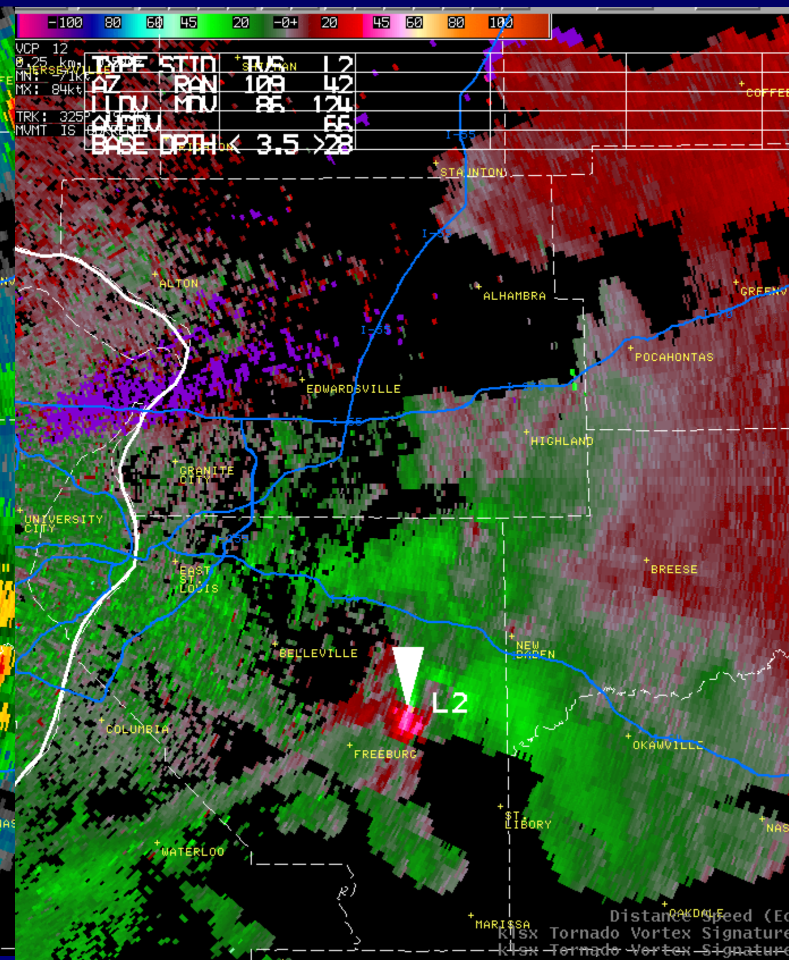
Storm Relative Motion (SRM)

Supercell

June 8, 2009 (545 pm)



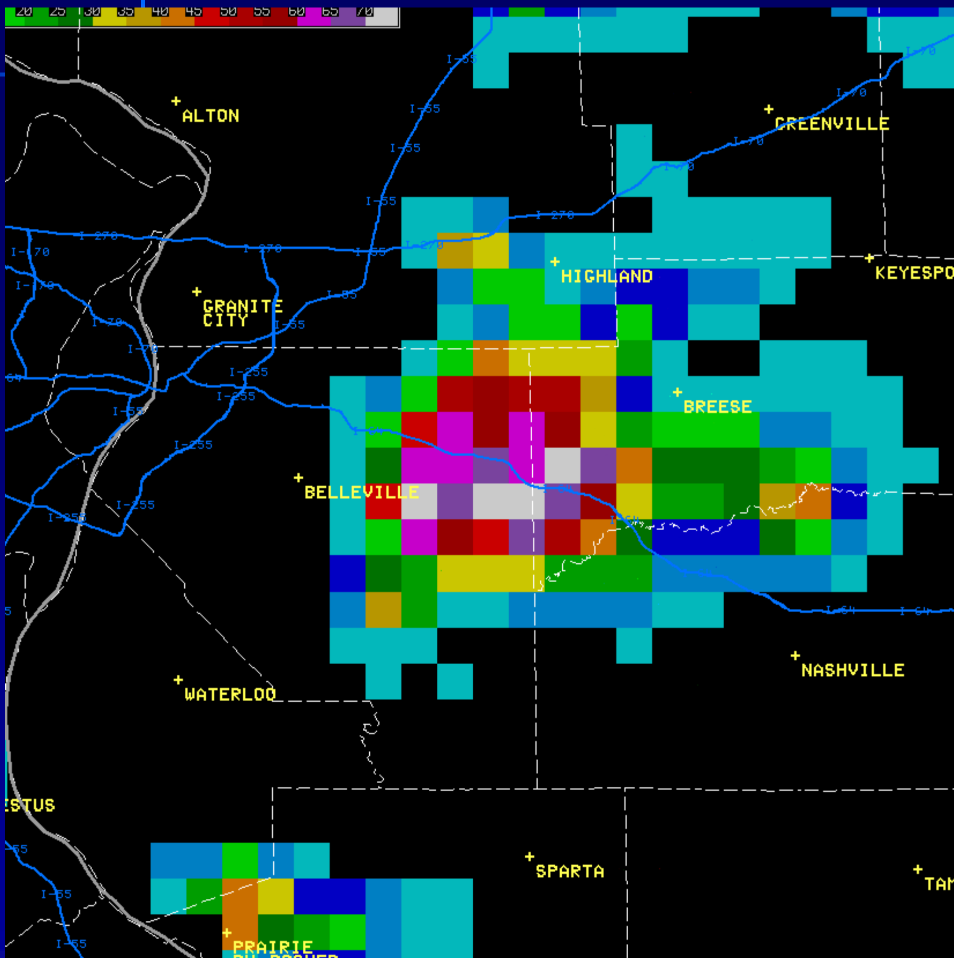
Base Reflectivity



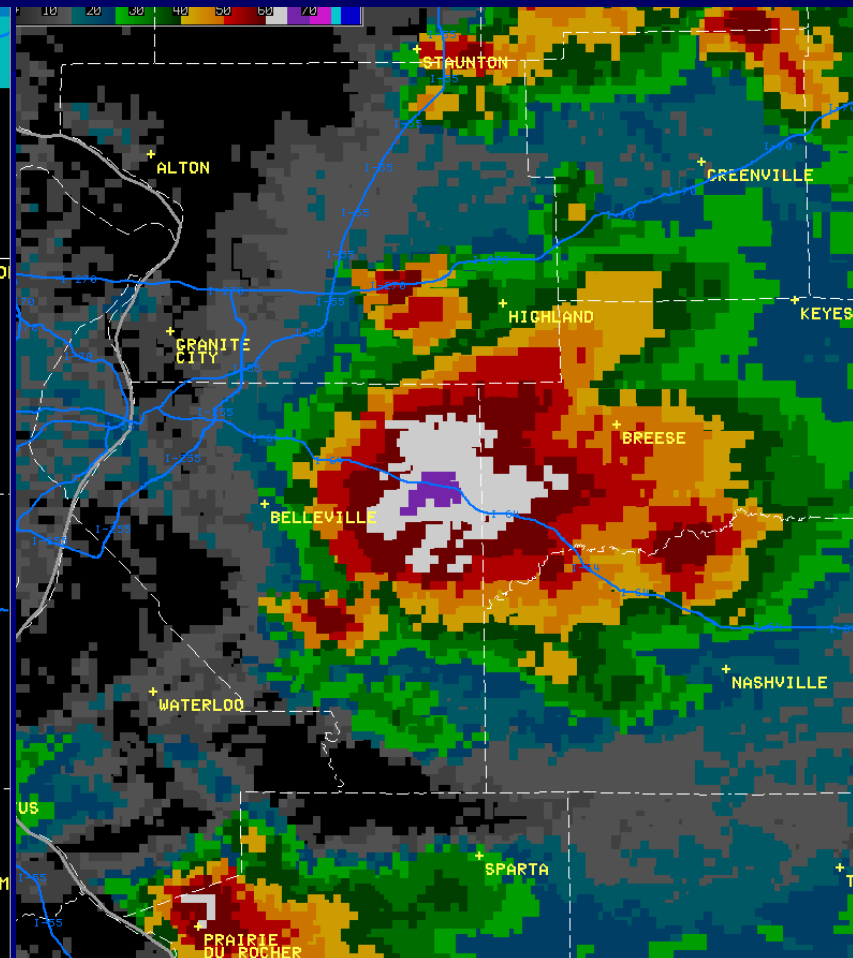
Storm Relative Motion (SRM) +
Tornado Vortex Signature (TVS)

Supercell

June 8, 2009 (545 pm)



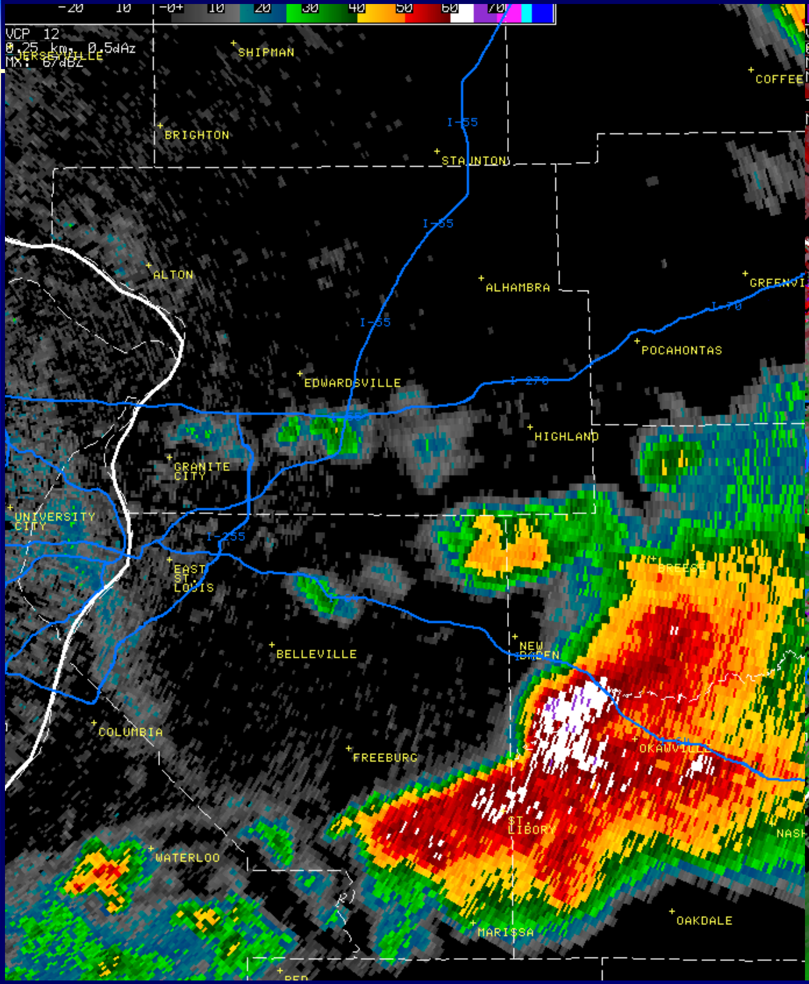
Vertically Integrated Liquid (VIL)



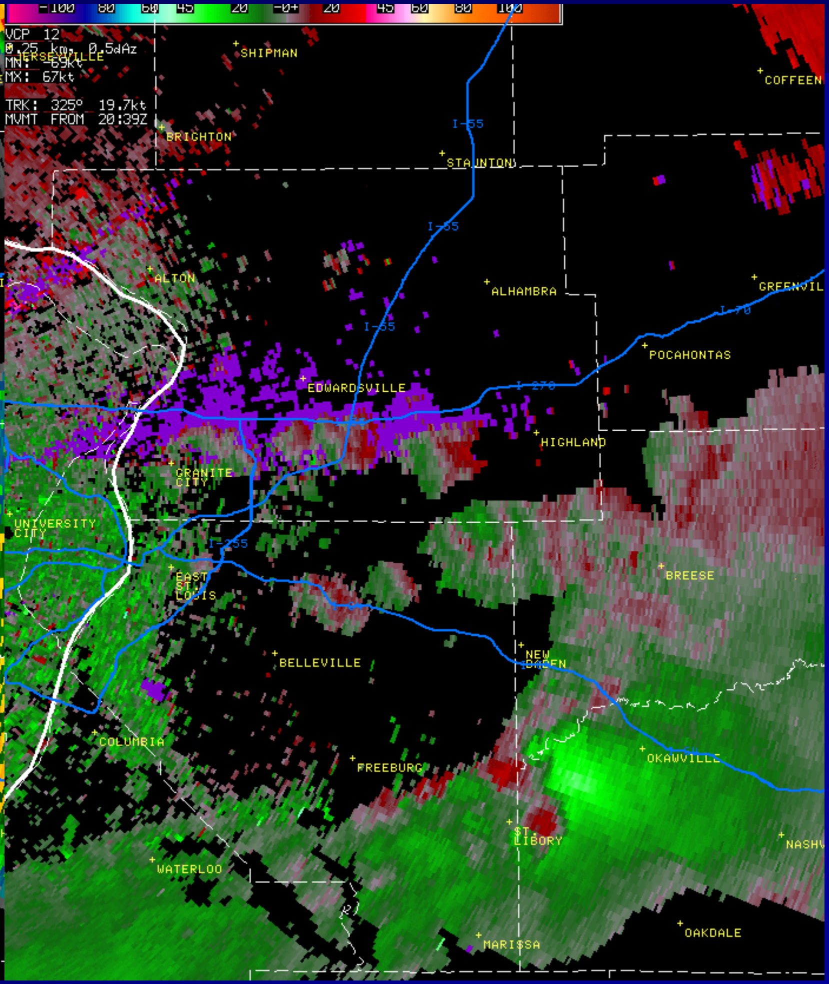
Composite Reflectivity (CR)

Supercell

June 8, 2009 (615 pm)



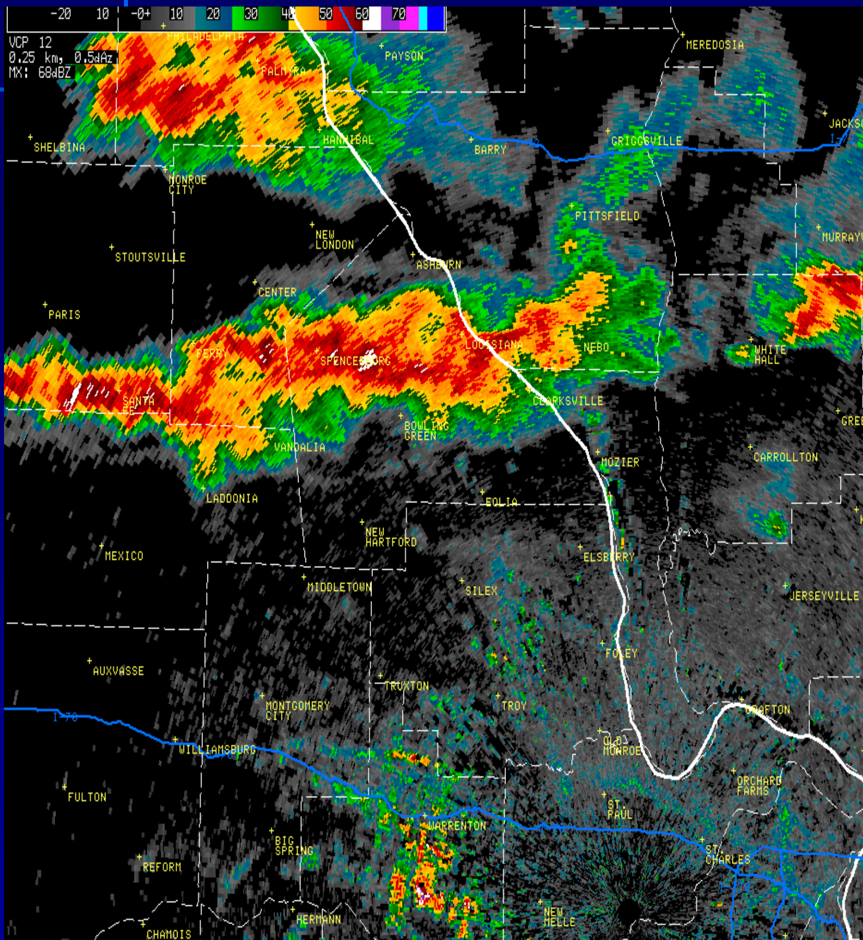
Base Reflectivity

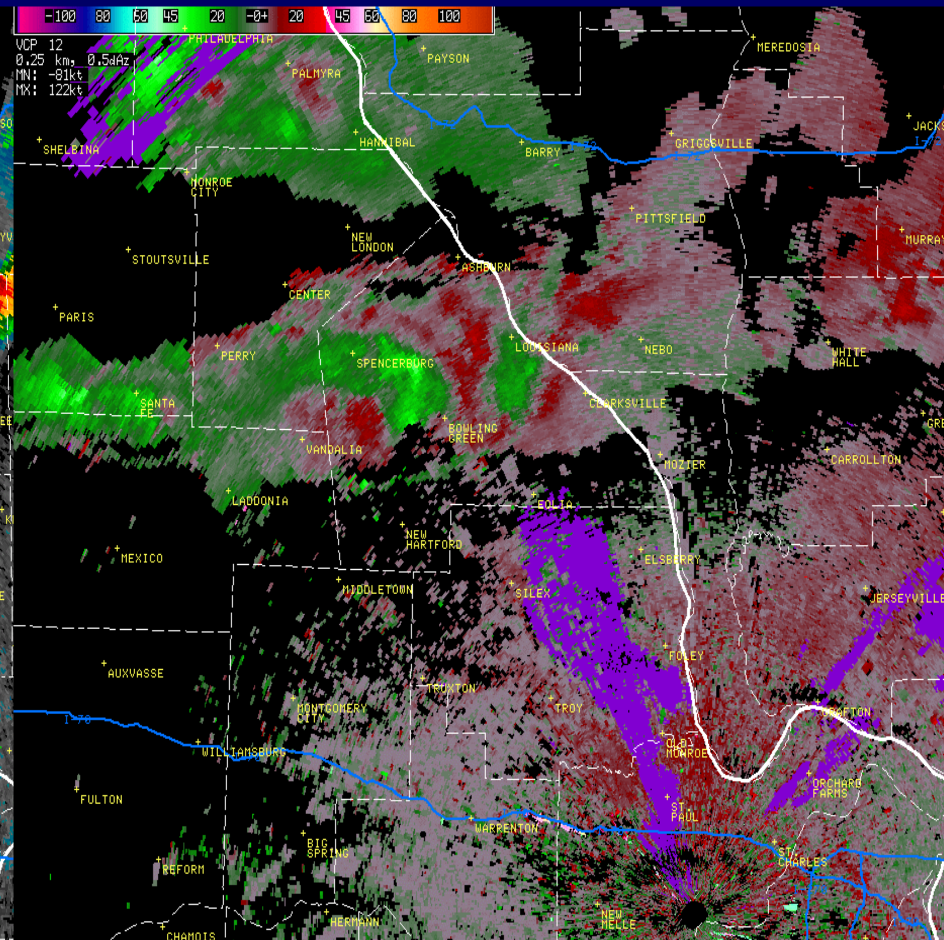


Storm Relative Motion (SRM)

Bow Echo

August 5, 2009 (430 - 627 pm)



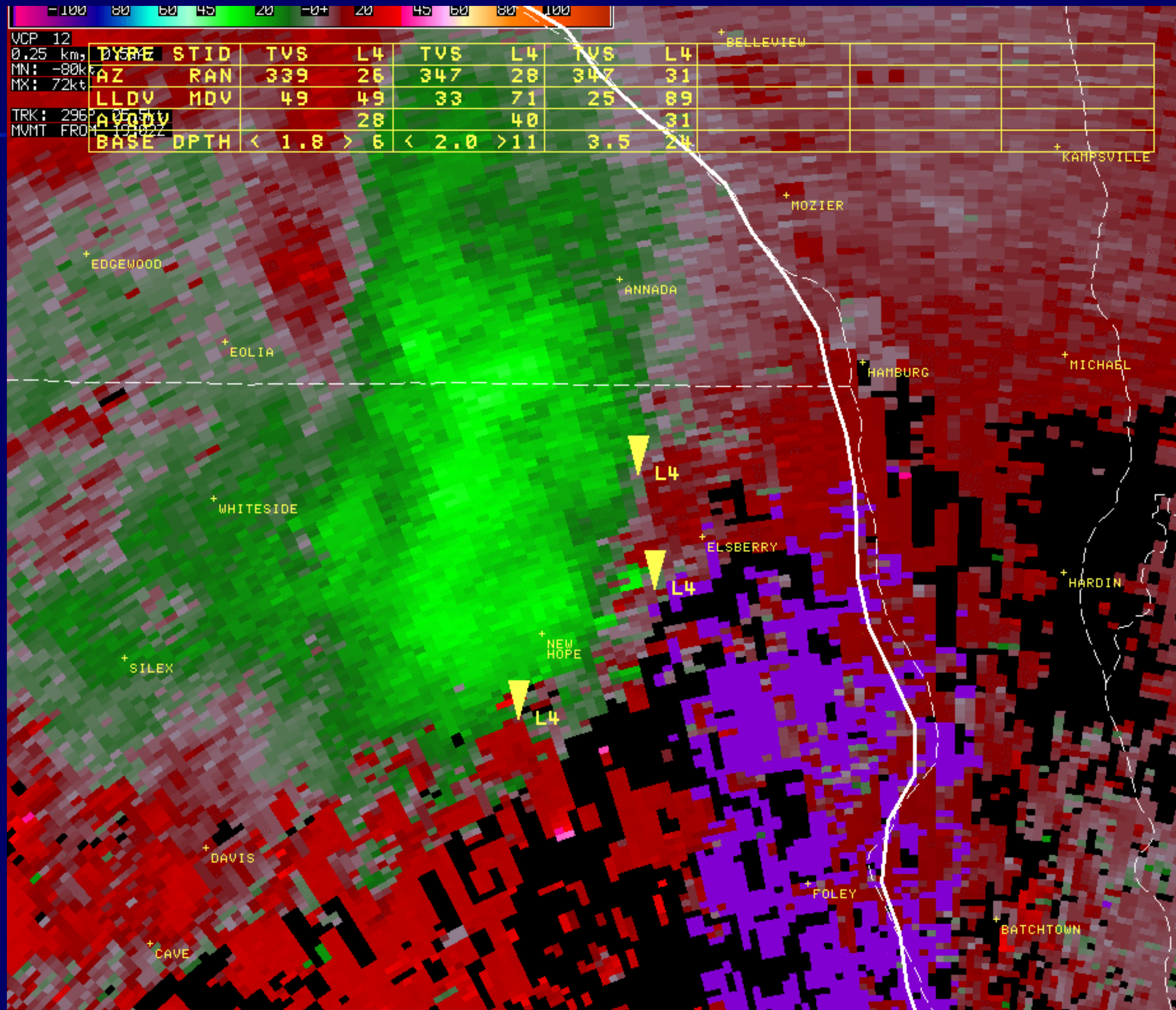


Base Reflectivity Loop

Base Velocity Loop

Bow Echo

August 5, 2009 (521 pm)



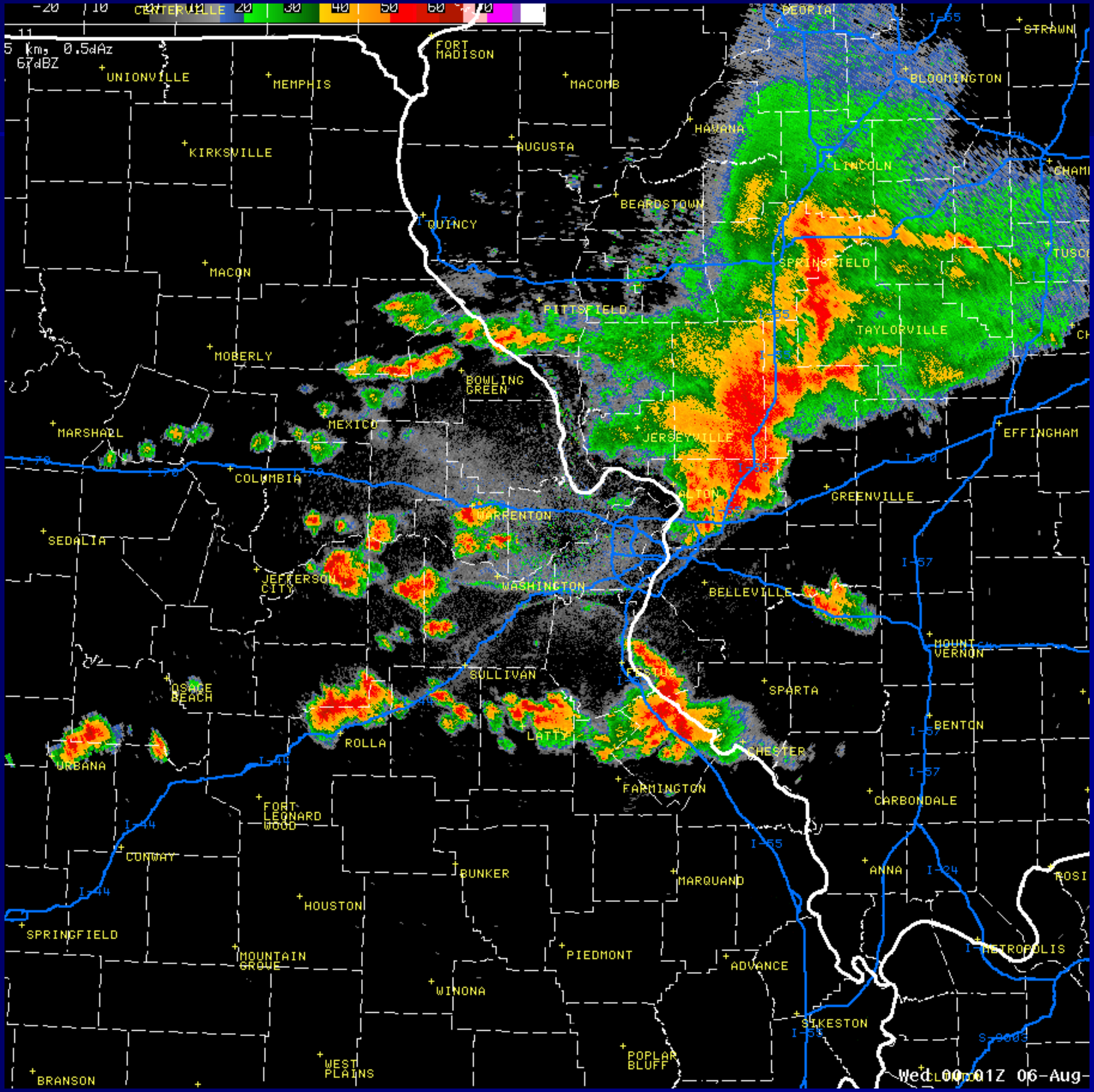
Storm Relative Velocity (SRM) + Tornado Vortex Signature (TVS)

Line of Storms

Eastern MO and Southwest IL -- August 5, 2009

Line of Storms

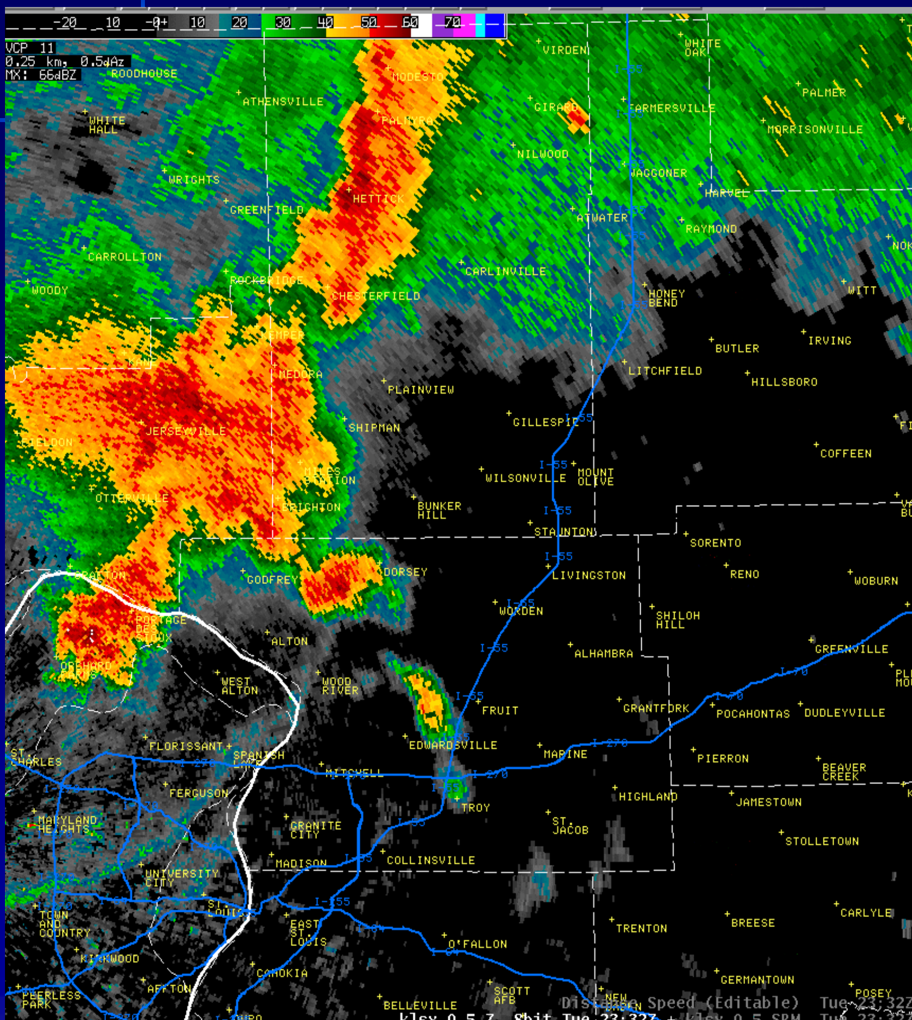
August 5, 2008 (701 pm)

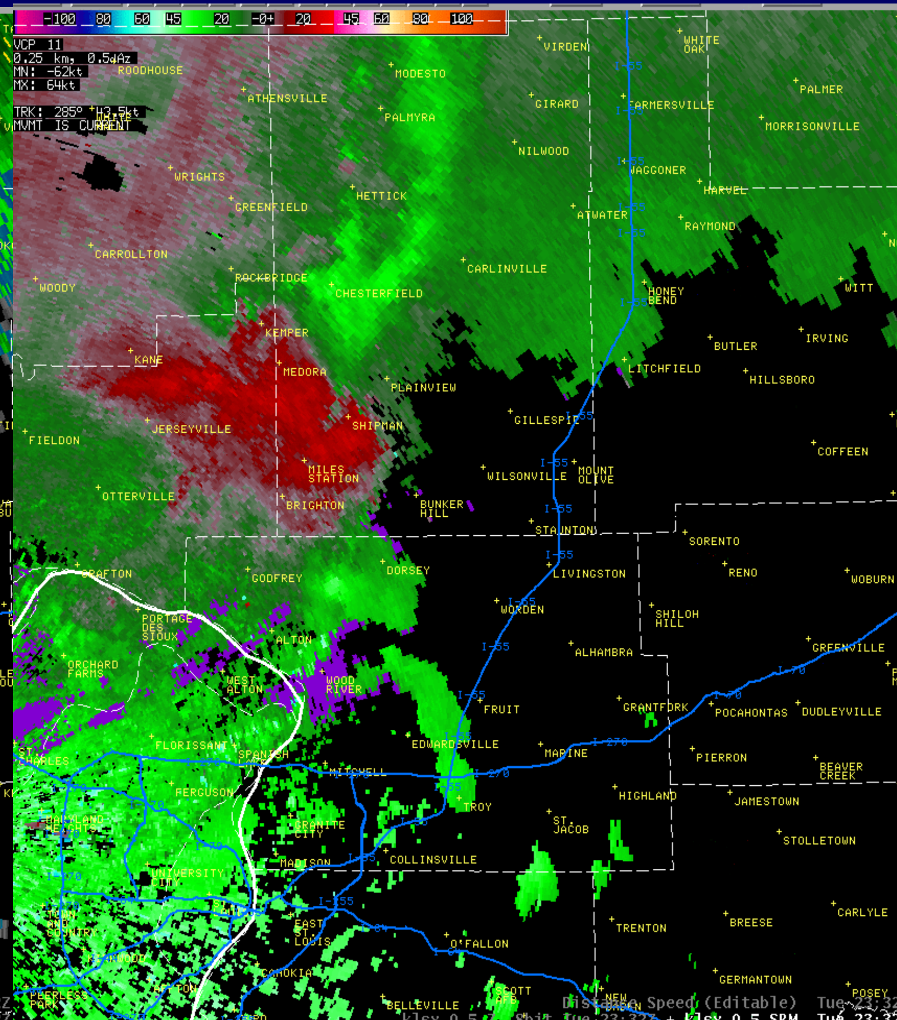


Base Reflectivity

Line of Storms

August 5, 2009 (632 pm)



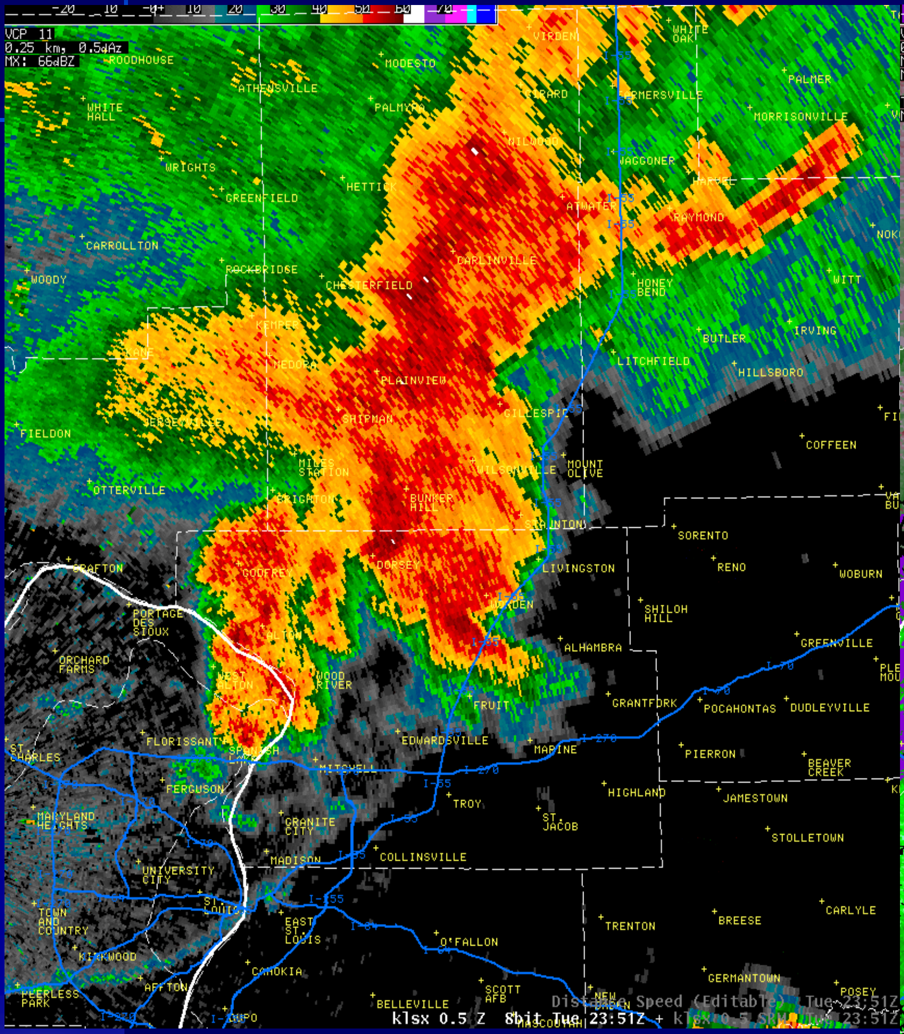


Base Reflectivity

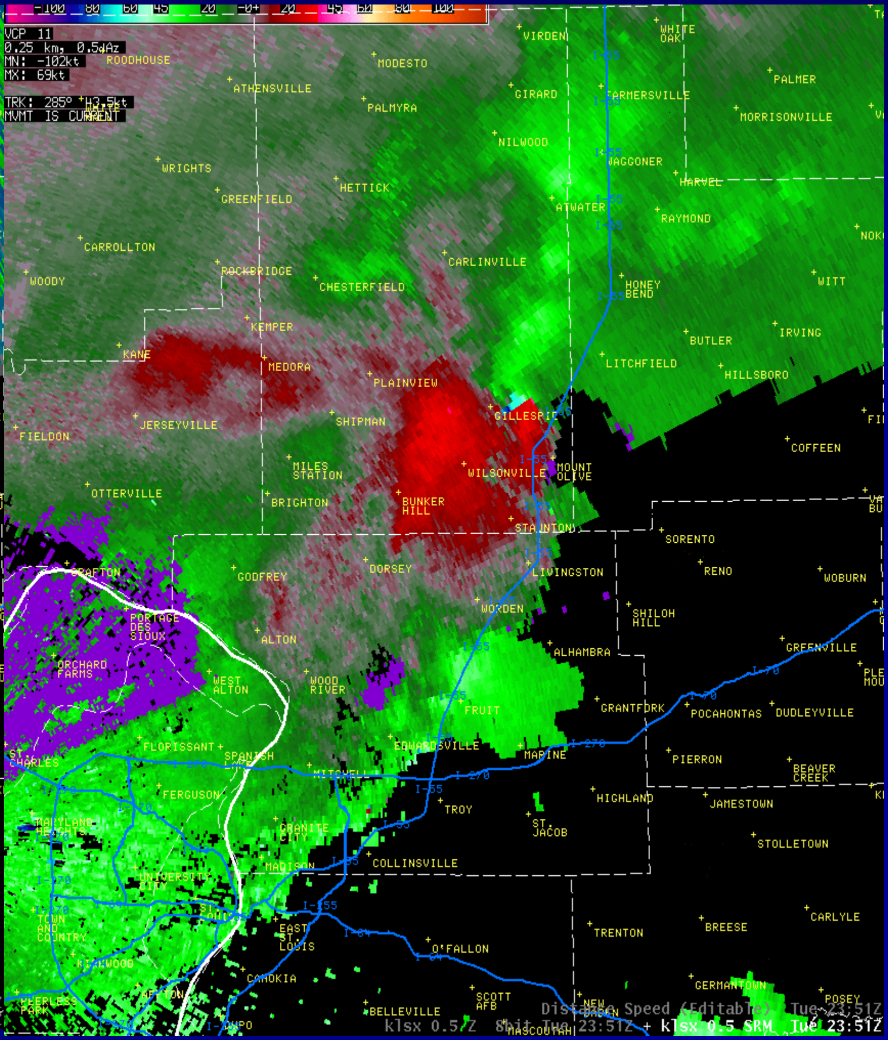
Storm Relative Motion (SRM)

Line of Storms

August 5, 2009 (651 pm)



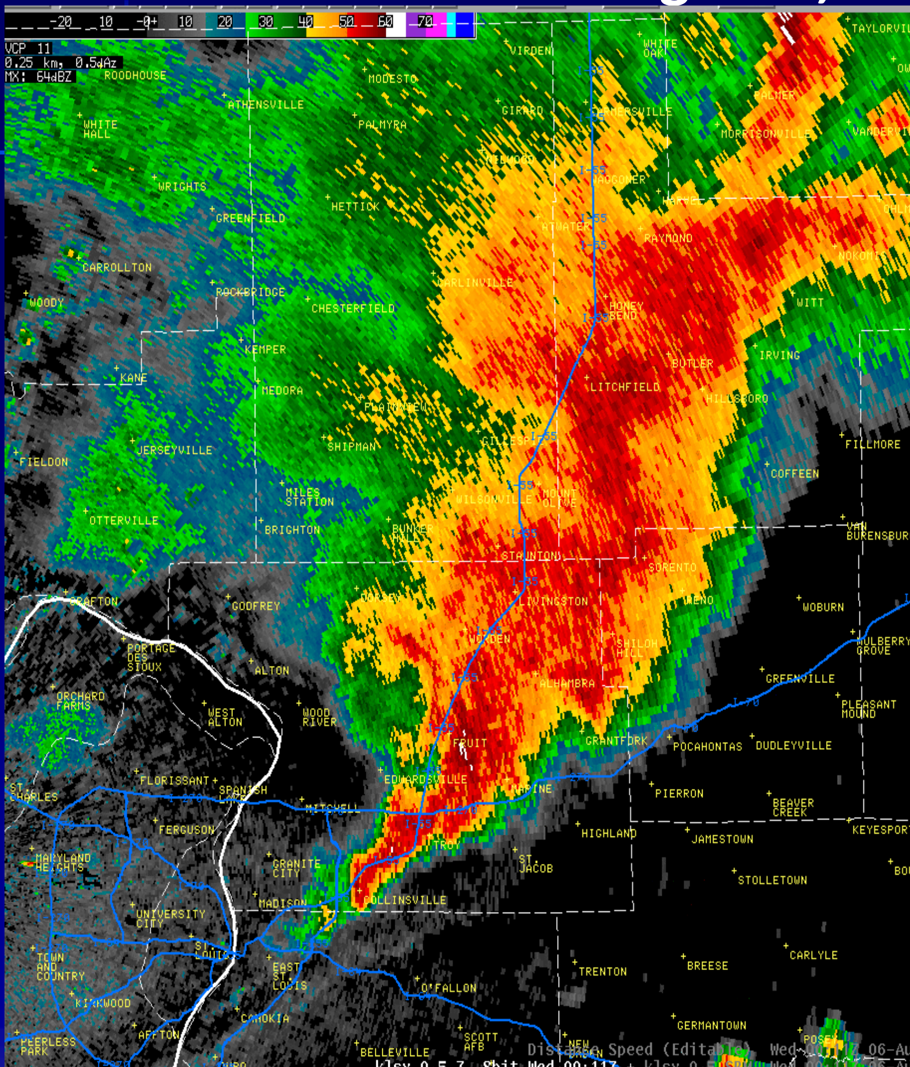
Base Reflectivity



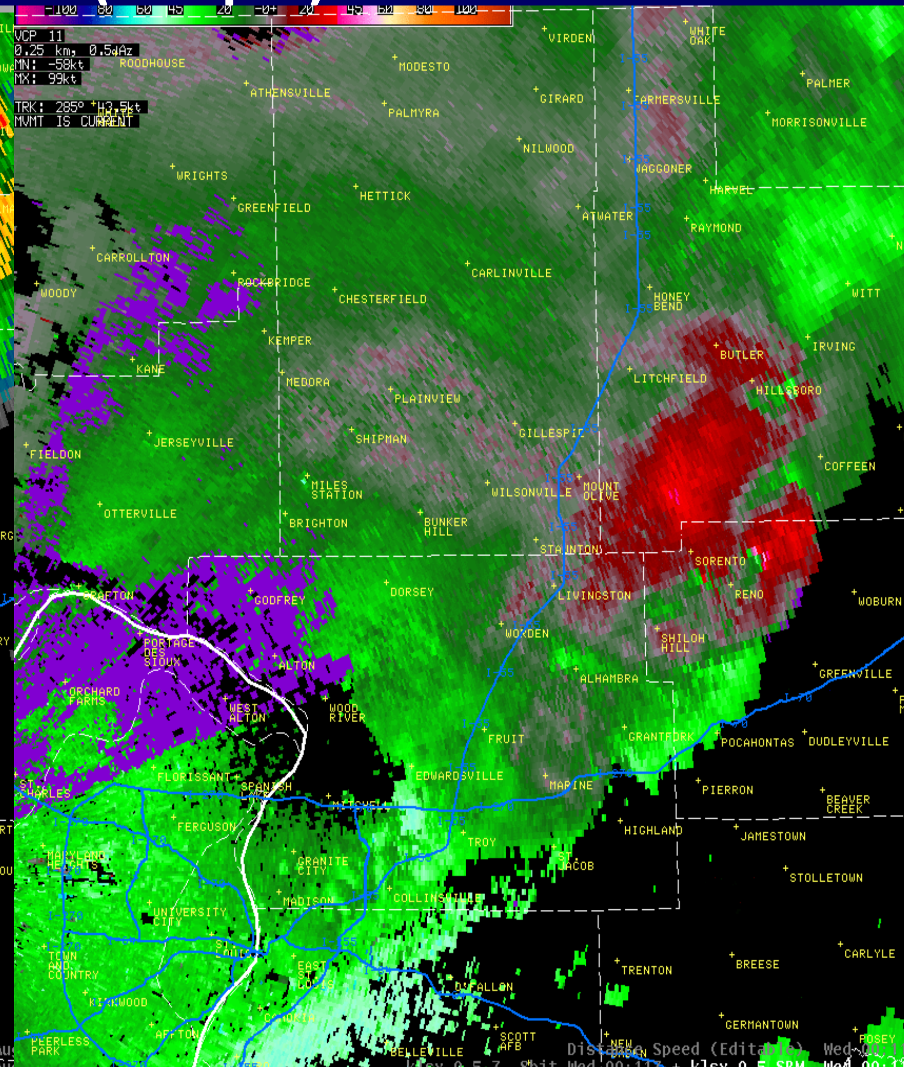
Storm Relative Motion (SRM)

Line of Storms

August 5, 2009 (711 pm)



Base Reflectivity



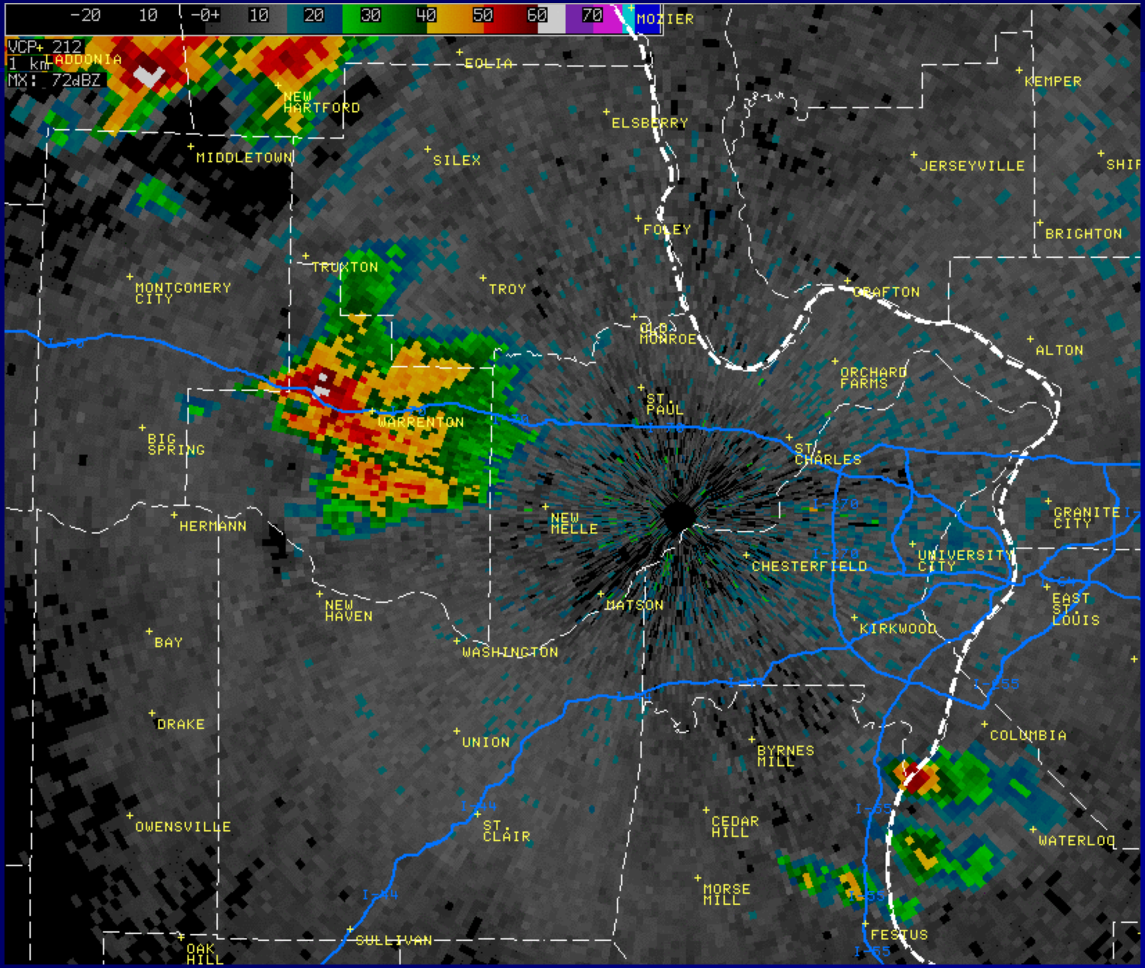
Storm Relative Motion (SRM)

Flash Flooding

St. Charles County, MO -- May 25, 2008

Flash Flooding

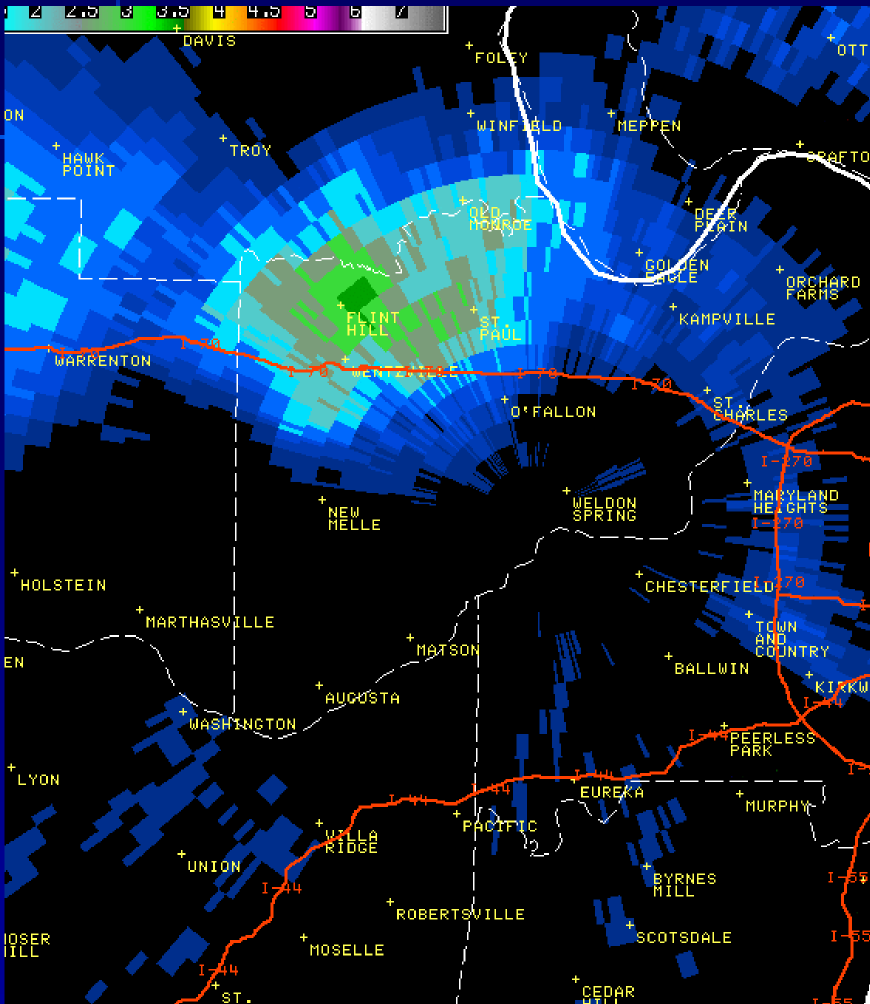
May 25, 2008 (630 – 1100 pm)



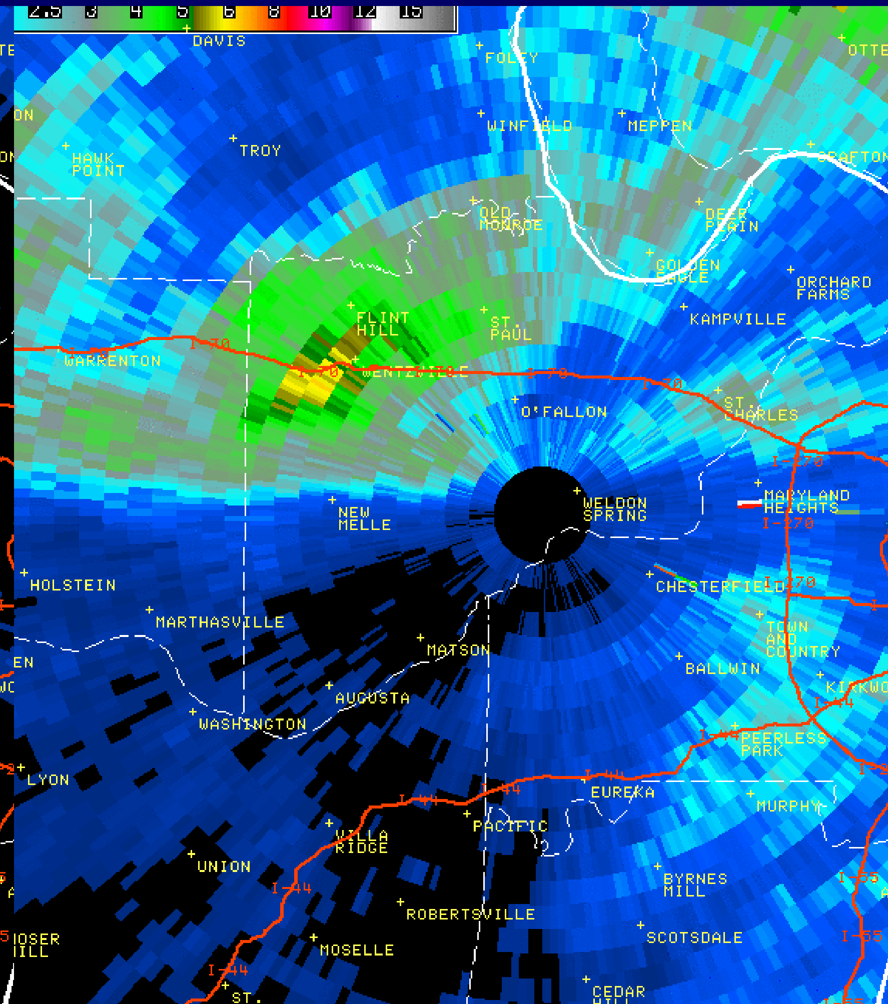
Base Reflectivity Loop

Flash Flooding

May 25, 2008 (615 pm)



One Hour Precipitation
830 – 930 pm



Storm Total Precipitation
Ending at 1130 pm

Questions or Comments?

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Mark.Britt@noaa.gov