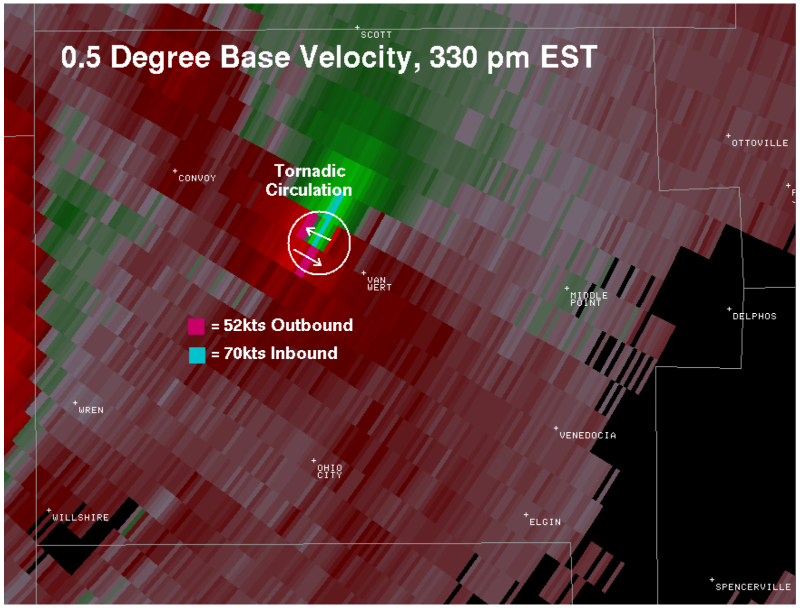
Technology and Storm Spotting

Doppler Radar:

The most effective tool to detect precipitation is radar. Radar, which stands for RAdio Detection And Ranging, has been utilized to detect precipitation, and especially thunderstorms, since the 1940's. Radar enhancements have enabled NWS forecasters to examine storms with more precision.

The radars used by the National Weather Service utilize Doppler weather radar principles. All weather radars, including Doppler, electronically convert reflected radio waves into pictures showing the location and intensity of precipitation. However, Doppler radars can also measure the frequency change in returning radio waves which allows Meteorologists to display motions toward or away from the radar.

This ability to detect motion has greatly improved the meteorologist's ability to peer inside thunderstorms and determine if there is rotation in the cloud, often a precursor to the development of tornadoes.



Doppler Velocity Wind Data showing a tornadic circulation near Van wert, Ohio on November 10th 2002.

Doppler Weather Radar Images

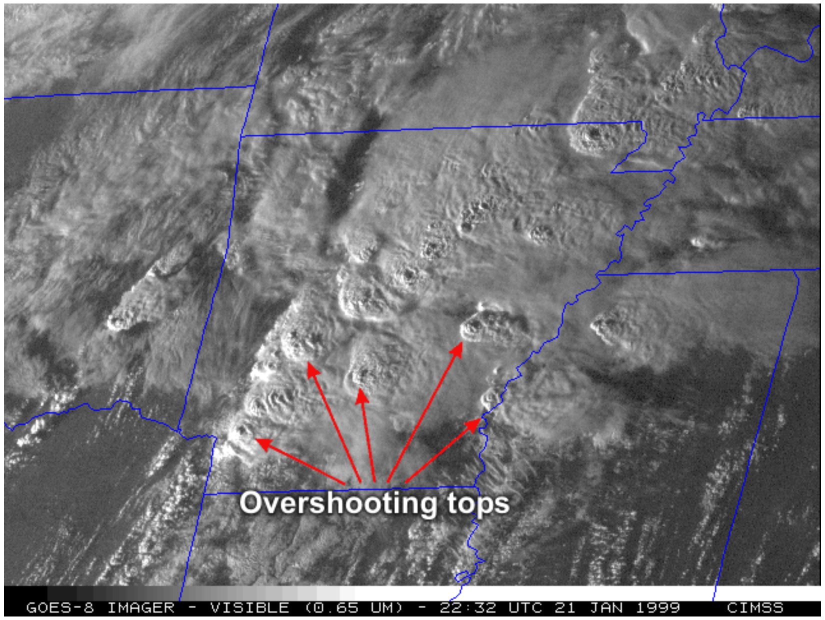
Reflectivity is the amount of transmitted power returned to the radar receiver after hitting precipitation. It is measured in decibels (dBZ). **Composite Reflectivity** utilizes all radar elevation scans to create an image and displays the maximum reflectivity vertically at any point. **Precipitation** images (One Hour and Storm Total) are created by applying computer algorithms to reflectivity imagery to estimate rainfall.

Velocity imagery is a sample of wind data using Doppler principles. Red color is outbound wind speed and green is inbound wind speed in knots relative to the radar. **Storm Relative Velocity (SRM)** subtracts the storm motion from the overall wind to reveal winds relative to the storm. This image is useful in displaying small scale circulations within thunderstorms.

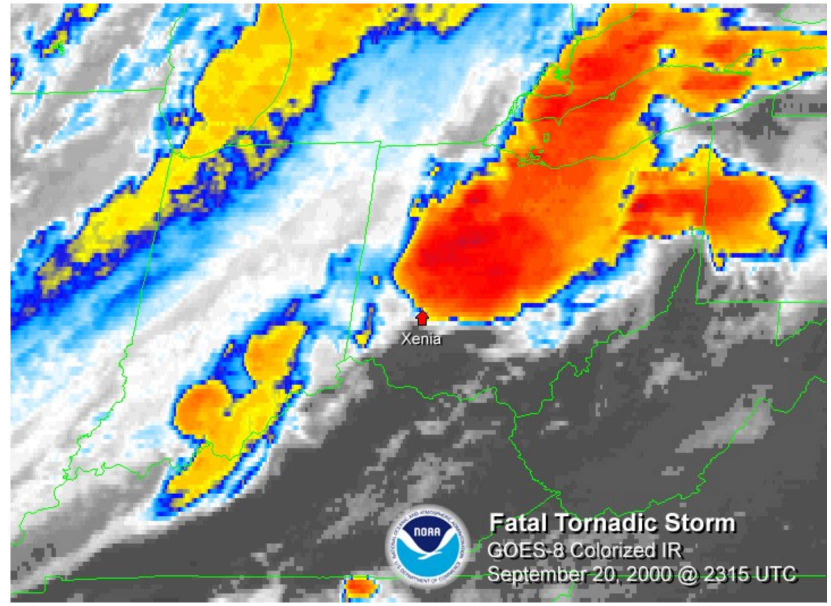
Satellite Imagery:

National Weather Service satellites are capable of producing information on clouds and moisture in three primary forms (Visible, Infrared (IR) and Water Vapor)

Visible imagery is an image of the earth in visible light. This is a similar manner to that of a person taking a picture with a camera. The satellite detects sunlight reflected from objects within the viewfinder. In the case of the satellite, the objects are the upper surfaces of clouds. Thick clouds do a much better job of reflecting light and therefore appear brighter in visible photos.



Visible Satellite image showing overshooting thunderstorm tops in Arkansas on January 21st 1999



Infrared(IR) picture of a thunderstorm that produced a tornado near Xenia Ohio on September 20th, 2000

The obvious problem with visible imagery is that it is only available during the day. To combat this problem, the infrared (IR) sensor was devised. It senses radiant (heat) energy given off by the clouds. Warmer (lower in the atmosphere) clouds give off more energy than cold (higher) clouds. The IR sensor measures the heat and produces several images based upon different wavelengths in the IR range of the electromagnetic spectrum.

Water vapor imagery is unique in that it can detect water vapor (water in a gas state) in addition to clouds. This type of image shows water vapor in the top one-third of the troposphere. Energy from moisture in the lower levels of the atmosphere is absorbed by the atmosphere and hidden from the satellite sensor. Upper level moist and dry areas are plainly observable and can show prominent air currents. Moist areas show as white, while dry areas show as black.

Types of Satellites

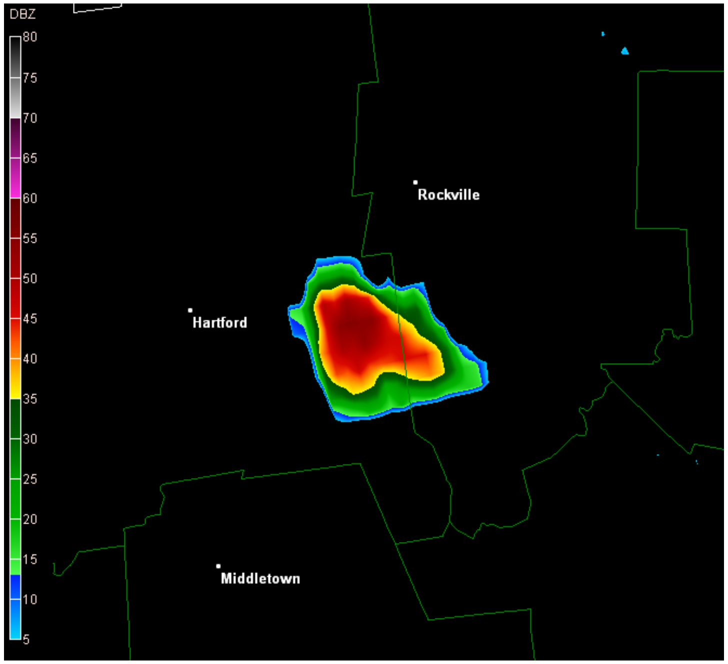
Geostationary Operational Environmental Satellite's (GOES) path around the earth at an altitude of 22,236 miles. At this distance the satellite completes one orbit of the earth in 24 hours. The net result is the satellite appears stationary, relative to the earth. This allows them to hover continuously over one position on the surface. Because they stay above a fixed spot on the surface, they provide a constant vigil for the atmospheric severe weather conditions. The United States operates two meteorological satellites in geostationary orbit, one over the equator at 75 deg W with a view of the East Coast and the other over the equator at 135deg W for the West Coast view.

Polar Orbiting Satellites (POES) offer the advantage of daily global coverage, by making nearly polar orbits roughly 14.1 times daily. Since the number of orbits per day is not an integer, the orbital tracks do not repeat on a daily basis. Currently in orbit we have morning and afternoon satellites, which provide global coverage four times daily.

Common Storm Types on Radar

Single Cell Thunderstorm

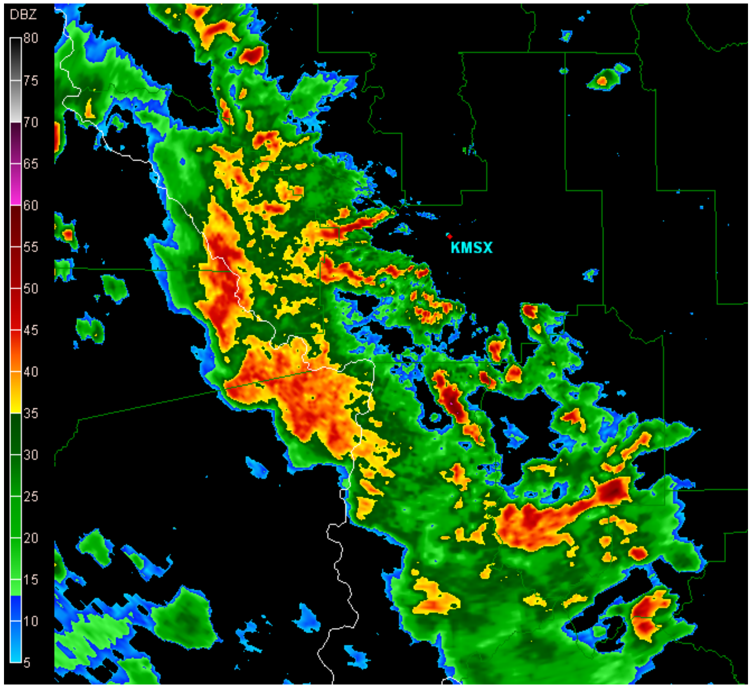
This type of thunderstorm develops in weak vertical wind shear environments characterized by a single updraft core and a single downdraft that descends into the same area as the updraft. The downdraft and its outflow boundary then cut off the thunderstorm inflow. This causes the updraft and the thunderstorm to dissipate. Single cell thunderstorms are short-lived. They only last about 1/2 hour to an hour. These thunderstorms will occasionally become severe (3/4 inch hail, wind gusts in the excess of 58 miles an hour, or a tornado), but only briefly. In this case, they are called Pulse Severe Thunderstorms.



Single cell thunderstorm viewed by Boston Radar on June 9th, 2008.

Multi-cell Thunderstorm

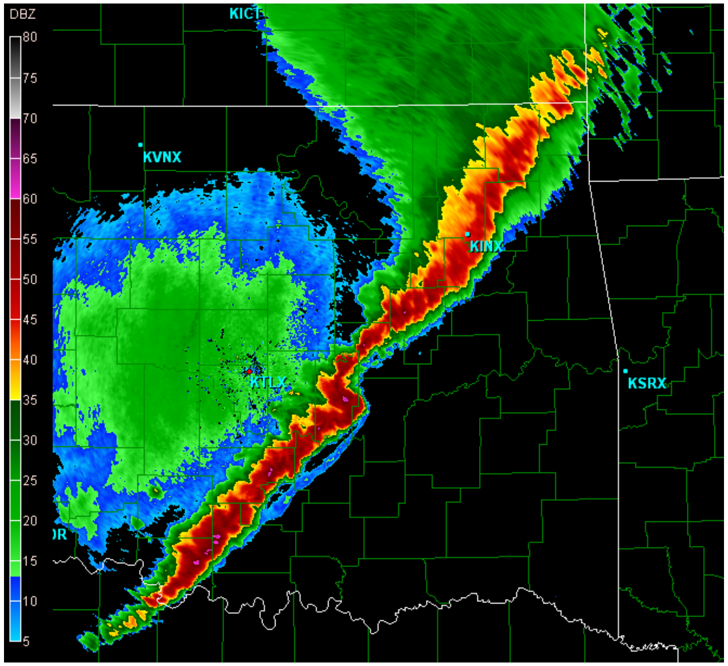
These thunderstorms are organized in clusters of at least 2-4 short-lived cells. Each cell generates a cold air outflow and these individual outflows combine to form a large gust front. Convergence along the gust front causes new cells to develop every 5 to 15 minutes. The cells move roughly with the mean wind. However, the area (storm) motion usually deviates significantly from the mean wind due to discrete propagation (new cell development) along the gust front. The multi-cellular nature of the storm is usually apparent on radar with multiple reflectivity cores and maximum tops.



This Multi-cell cluster of storms produced 60 mph wind gusts from several of the storms that broke large tree branches in western Montana near Missoula, MT. Image is from the Missoula Doppler Radar on June 4th, 2007..

Multi-cell Line

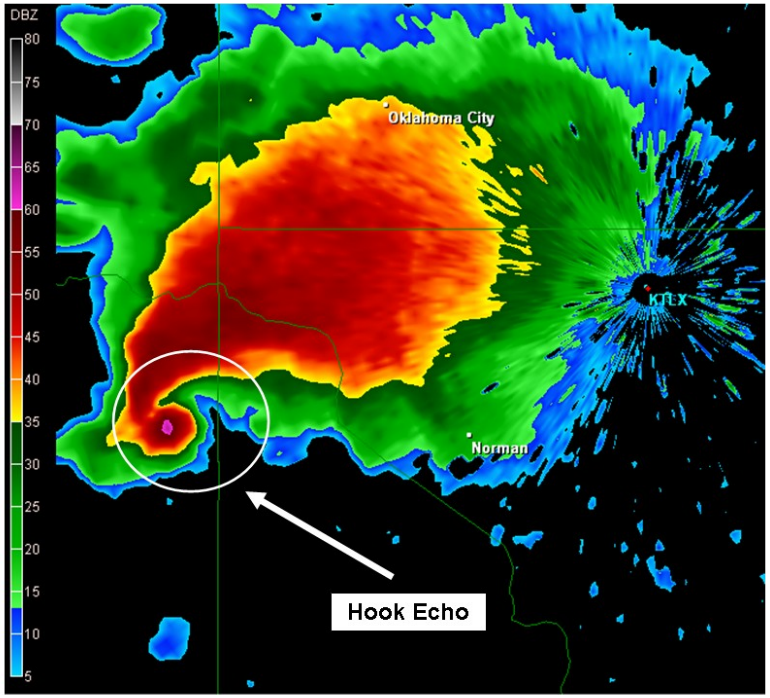
A line of active thunderstorms, with or without breaks, including contiguous precipitation areas resulting from the existence of the thunderstorms.



Multi-cell thunderstorm line without breaks, as viewed by Oklahoma City Radar on September 7th, 2001. A Bow Echo is evident in the center of the line (southeast of KTLX), with a gust front leading the line south of the bow. Near the bow echo, wind speeds of 60 knots were observed. Hail 1.75 inches in diameter was reported on the south end of the thunderstorm line in Oklahoma.

Supercell Thunderstorm

Potentially the most dangerous of the convective storm types. Storms possessing this structure have been observed to generate the vast majority of long-lived strong and violent (F2-F5) tornadoes, as well as downburst damage and large hail. It is defined as a thunderstorm consisting of one quasi-steady to rotating updraft which may exist for several hours. Radar will observe one long-lived cell, but small perturbations to the cell structure may be evident. The stronger the updraft, the better the chance that the supercell will produce severe weather (hail greater than 3/4 inch in diameter, wind gusts greater than 58 miles an hour, and possibly a tornado)

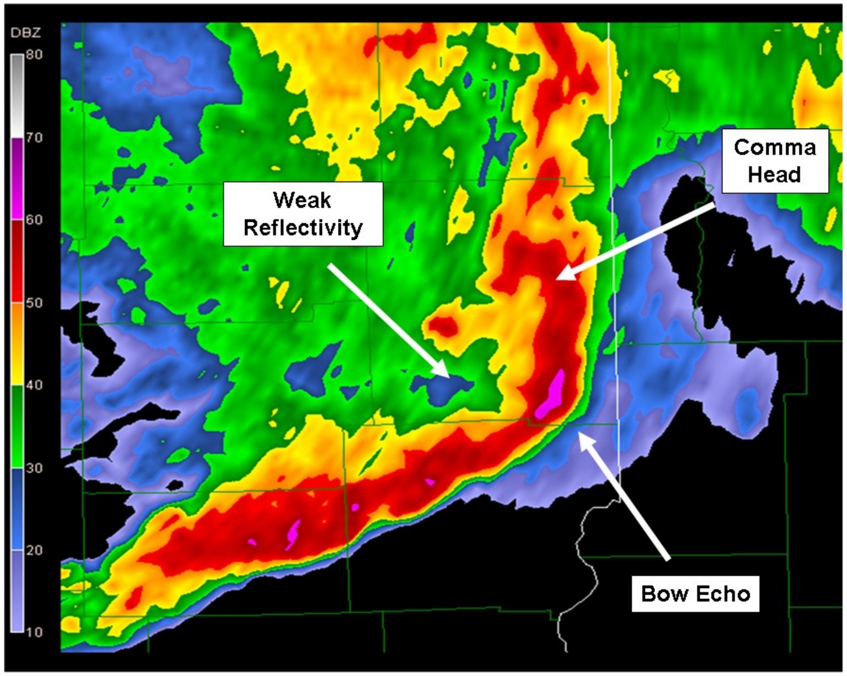


Supercell thunderstorm with a "hook echo" viewed by Oklahoma Radar on May 3rd, 1999. This storm produced a F5 tornado that moved through Bridge Creek, Moore, and Oklahoma City with storm damage reported in a path up to one mile wide.

Severe Weather Radar Signatures:

A **hook echo** is a radar reflectivity pattern that forms a hook shape, usually in the trailing portion of a Supercell storm. This hook shape forms when precipitation gets wrapped around the storm mesocyclone and is a favorable region for tornado development.

A **bow echo** occurs when a portion of a line of thunderstorms accelerates ahead of the rest of the line. This produces a bend, or bow, in the line. This acceleration of the radar echo is a reflection of strong localized "straight-line" winds at or near the surface.



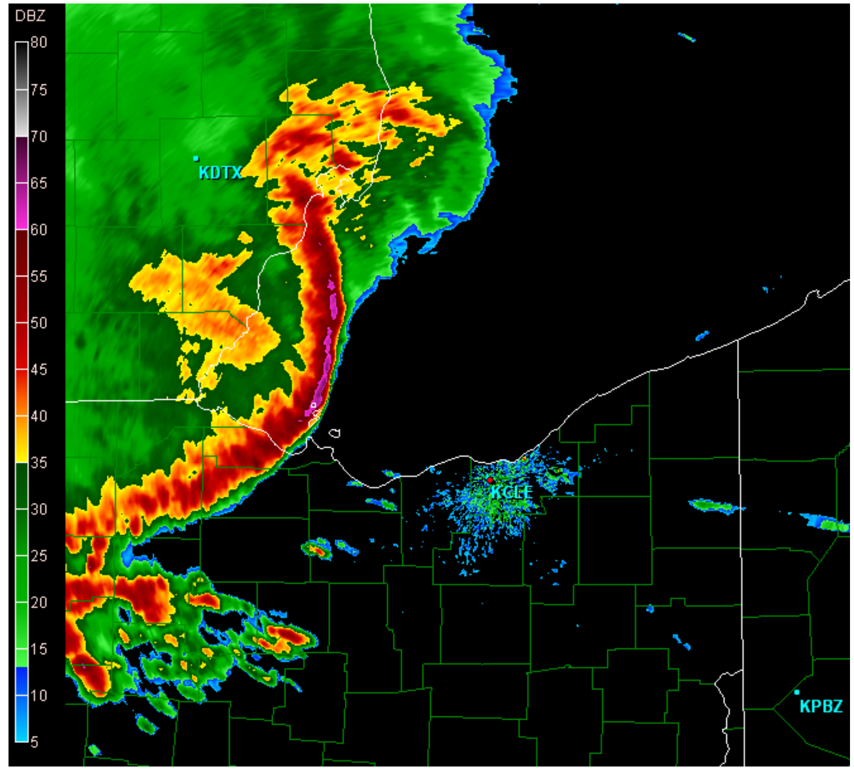
Radar features of a Bow Echo in southeast Illinois June 3rd 2008

Observations and post-storm analysis show that the greatest threat for straight- line wind damage is typically found near the leading edge (near the apex) of the bow.

Another radar characteristic of mature bow echoes is the region of weak reflectivity trailing immediately behind the bowing line of strong thunderstorms. This weakness in the reflectivity is caused by a descending flow of air from mid-levels of the atmosphere.

Sometimes significant wind damage and even weak tornadoes can also occur on the northern end of the bowing line segment within the cyclonically (counter-clockwise) rotating **comma head** region.

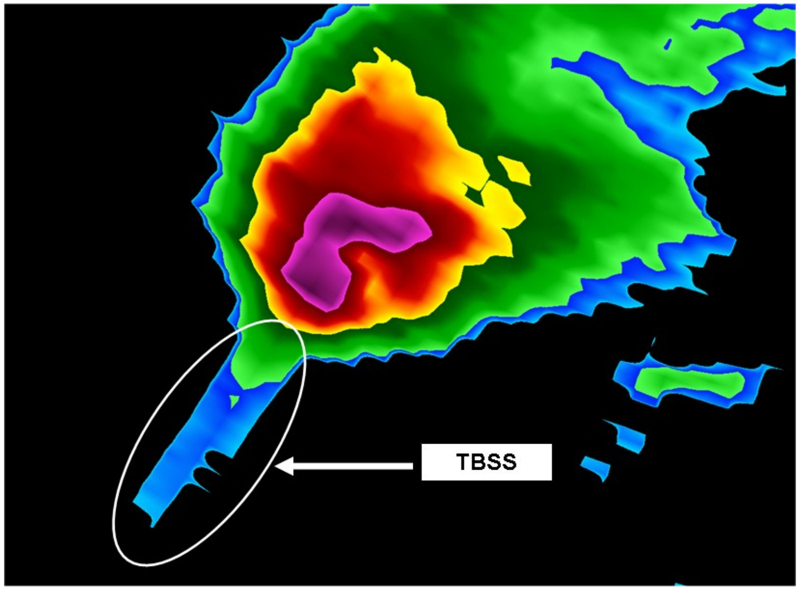
Large, organized and very long-lived bow echoes can develop and move across several states producing long swaths of wind damage. This type of convective system is often referred to as a **derecho**.



A severe squall line called a Derecho in Northwest Ohio May 21st 2004

In a severe thunderstorm, large water-coated hail stones suspended aloft in the storm will reflect the radar energy in a complex way that causes a narrow spike of reflectivity to protrude from the intense reflectivity core on the image. This feature is referred to as a **three-body scatter spike.** The "spike" is along a radial; that is, the spike is along the radar beam at that particular azimuth. In basic terms, this is caused by the radar beam hitting the large water-coated hail, scattering the energy to the ground below, then scattering the energy back upward, and finally scattering the energy once again by the hail aloft.

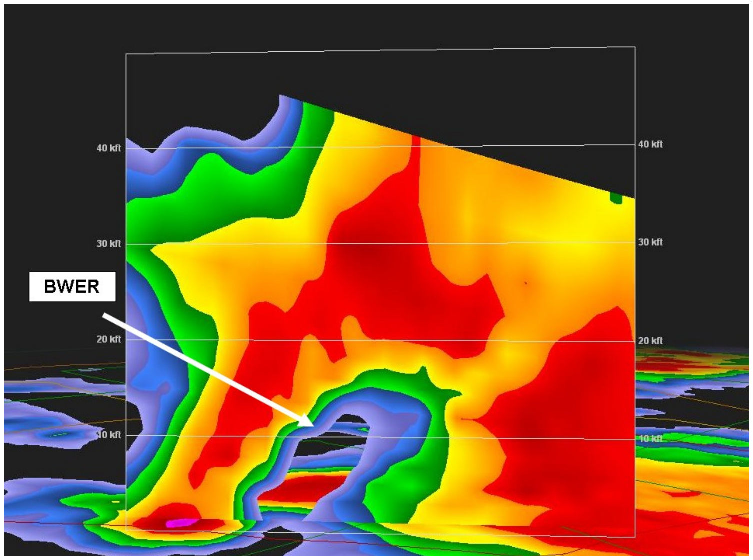
The three scatterings illustrate the triple reflection, thus the term "three-body scatter spike." The presence of a hail spike is a very reliable indicator that severe hail (greater than 3/4 inch in diameter) exists in the storm.



Three Body Scatter Spike (TBSS on June 6th, 2005 as seen by the Cannon Air Force Base, NM radar.

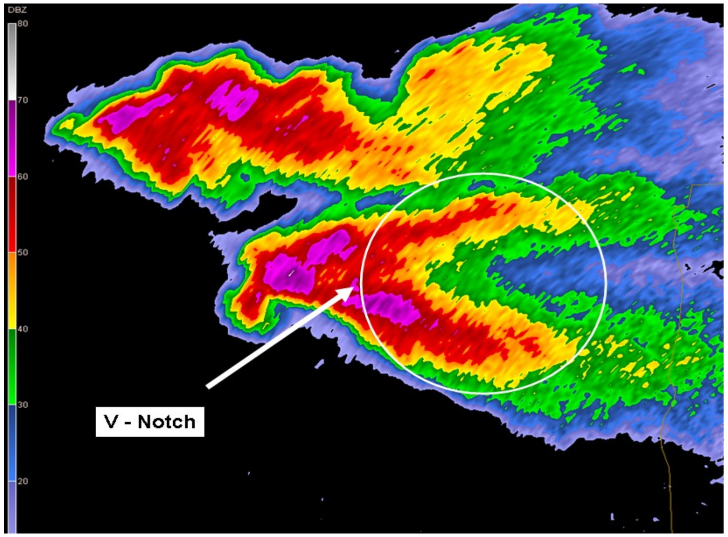
The **bounded weak echo region** (BWER) is a nearly vertical channel of weak reflectivity echoes surrounded on all sides and on top by higher radar reflectivities. The weak reflectivity core is a result of strong storm updrafts carrying hydrometeors upward so quickly they do not grow to radar detectable size until at high storm levels. The BWER is associated with very strong storm updraft speeds and is typically found 3-10 km above the ground.

The strong updraft speeds associated with the supercells suspend the hail above the updraft until the hail grows large enough that the updraft winds can no longer support it. At this time, the hail falls down to the ground. The largest hail falls next to the updraft area of the supercell, generally from the west through north side of the mesocyclone.



The Bounded Weak Echo Region (BWER) shown in a reflectivity cross-section of the May 3rd 1999 Okalahoma City Tornado

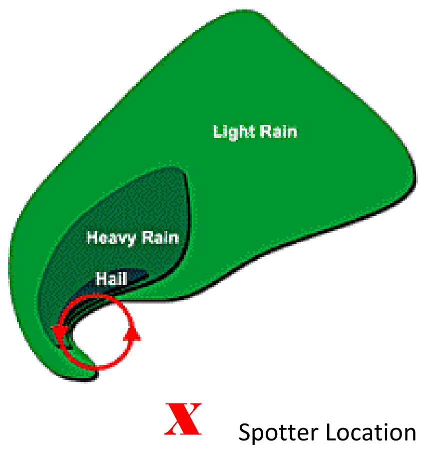
A V-notch is a radar reflectivity pattern that forms a V- shape in the downwind part of a supercell thunderstorm echo. This V-notch is a sign of diverging flow around the very strong storm updraft.



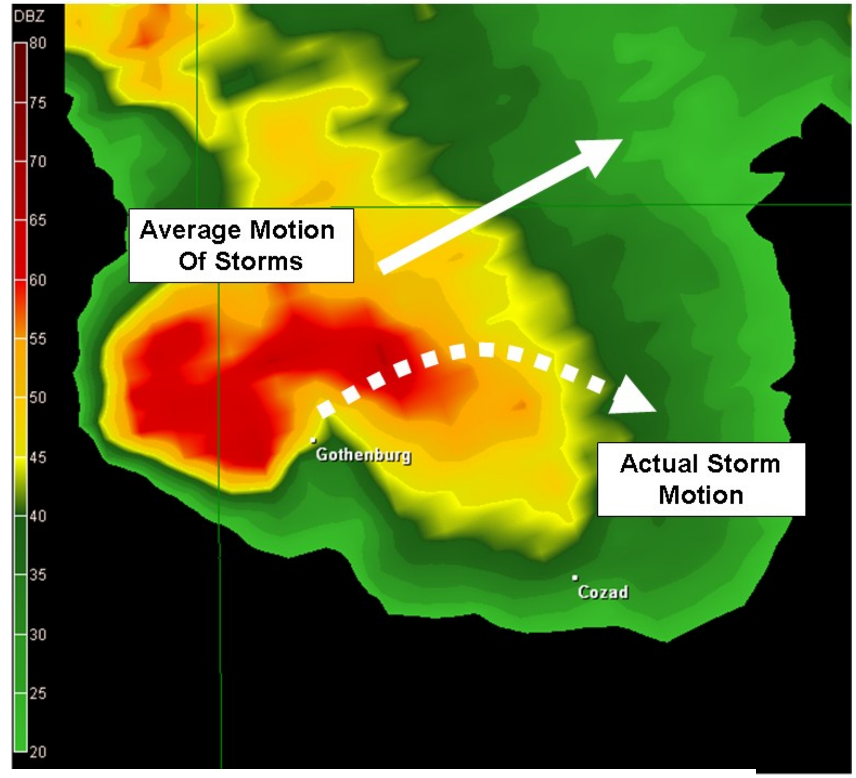
V-notch on a supercell storm on 24 June 2008 from the KLNX radar.

Storm Movement and Spotter Location:

The best location for storm spotters to view the approaching storms would be from the southeast. From this direction, the spotter can get a clear view of the rain-free updraft region of the storm. This is where the wall clouds and associated tornadoes may form. In any other direction, rain and hail may block the view of the updraft region of the storm.



The direction of the mid-level atmospheric winds will generally be the direction of movement of most storms. However, supercell storms that move to the right of the main steering winds and of other storms typically have a higher potential of being severe. Storm spotters must anticipate and recognize this change in motion in order to understand the potential of the storm and to remain in a safe location.



Supercell storms frequently have a deviant motion and may move to the right or left of the prevailing storms This propagation can be dangerous to unsuspecting spotters.