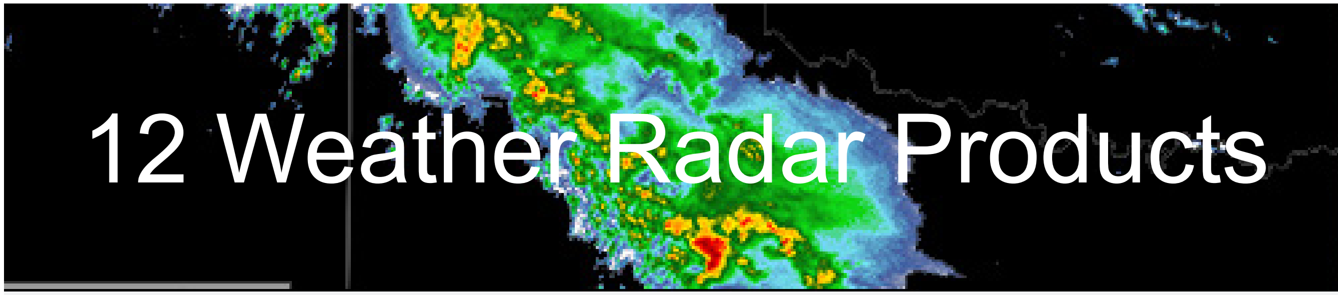
12 Weather Radar Products



In 1946 the Weather Bureau obtained several surplus military radars. Refined by 1959 the first network of Weather Surveillance Radar-1957 (WSR-57) marked the beginning of a U.S. weather radar warning system. Sixty-six WSR-57s were in place by the early 1970s. The network covered most of the central and eastern U.S., with a few units in the west. (The right side of the banner shows a WSR-57 display console.) Western states' coverage was supplemented by Air Route Traffic Control Center (ARTCC) radars. An updated version, the WSR-74, supplemented and began replacing older units in 1977. By the 1990s the NEXRAD (NEXt generation RADar) WSR-88D Doppler radar system was completed. NEXRAD provides, with a few exceptions, radar coverage in the contiguous United States, Hawaii, the Caribbean, and portions of Alaska.

To assist pilots avoid thunderstorm hazards airborne weather radar units were introduced in the late 1950s. Early radars had technical problems, but by the beginning of the 1960s most airliners were equipped with weather radar. Airborne units have seen significant improvements over the years.

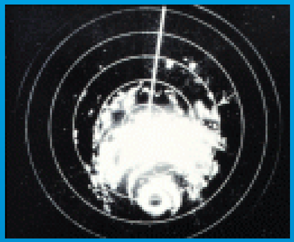
Access to preflight and inflight weather radar has increased dramatically over the last decades. Many twin, and more and more single, engine aircraft are being equipped with airborne weather radar or lightening detection systems, and several vendors supply data link ground-based radar directly to the aircraft. Automatic Dependent Surveillance-Broadcast (ADS-B) "In" includes NEXRAD weather radar images.

Radar Basics

Radar works on the transmission and detection of electromagnetic energy. The radar return is referred to as *reflectivity*, *backscatter*, or *echoes*.

Oversimplification

> Most often we hear about reflected radar energy. This isn't quite true for precipitation. Although a small amount of energy is reflected, the radar emission causes an oscillation of the electrical charge in the precipitation particle. This causes the particle to generate energy, while much of the radar's transmitted energy passes through the target. This is why distant precipitation can be detected behind other precipitation targets. However, from an operational perspective, and for simplicity, we'll refer to this phenomenon as reflected or "backscatter" energy.



WSR-57 PPI display.

The transmitter sends out a pulse. As the energy strikes a target, some energy returns to the antenna. The bearing to the target can be determined as the antenna scans through the atmosphere. Since the pulse moves at the speed of light, time between the transmitted and received pulse determines range. This information is displayed to the operator/pilot on a *plan position indicator* (PPI). It's important to understand that the PPI presentation does not depict the vertical extent of the storm; it only represents a small cross section, based on antenna elevation.

Although a generalization, radar displays an image dependent on returned energy. Intensity depends on several factors: particle or droplet size, shape, composition, and quantity. Additional factors include radar frequency, power output, antenna type and size, and radome. These factors affect airborne radars to a greater degree than ground units.

radar mosaic—An image consisting of multiple single-site radars combined to produce a regional or national scale display.

Ground based NEXRAD radars can display both precipitation and cloud size particles. However, Radar mosaic products only display precipitation size returns. A precipitation free area does not translate into a cloud-free sky.

Liquid precipitation is a good radar reflector, while frozen precipitation is not. Rain is the best reflector, although wet hail and wet snow—because of their liquid water coating—are also good radar reflectors. Dry hail and dry snow are poor reflectors; with water vapor and small dry hail—due of their small size and ice crystals providing essentially no radar return. Although moderate and heavy snow is generally displayed, light snow returns too little energy to appear in the image.

The Radar Beam

While it's not necessary to be an engineer, a basic understanding of radar will help in the recognition of radar's uses and limitations.

Radars transmit signals in brief bursts called *pulses* measured in microseconds (μ sec). Pulses range from a fraction of a microsecond to several microseconds. As pulse length increases, the strength of the signal increases. A long pulse will detect weaker targets than a short pulse. However, the shorter the pulse, the greater the accuracy of the range. The emission of pulses is timed so that, within the normal range of the radar, the echo from one pulse is returned to the antenna before the next pulse is transmitted.

The size and shape of the radar beam is determined by the size and shape of the antenna and its *wavelength*. The purpose and physical location of the antenna is governed by its size and design. Ground based units have virtually no limit on size or shape. Airborne units, especially for smaller aircraft, have major design constraints.

Resolution is to the ability of the radar to detect individual targets. *Range resolution* refers to the ability of the radar to distinguish between two or more targets at the same azimuth, but at different ranges. For example, range accuracy with a pulse length of one μ sec permits targets separated by as little as one-tenth of a mile to be resolved as separate echoes. A pulse length of five μ sec would decrease accuracy to a separation of about one-half mile.

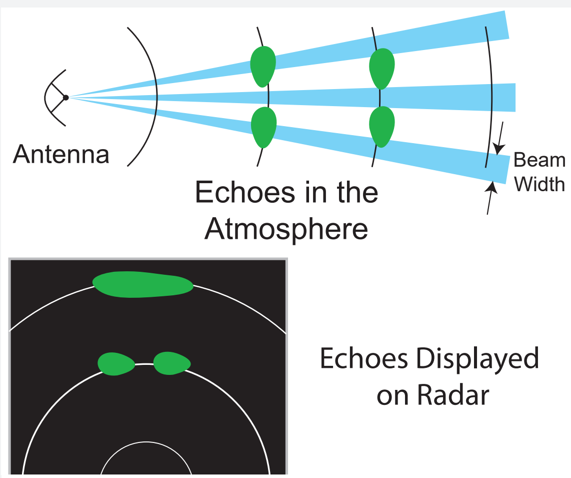


Fig. 12-1. *Beam resolution refers to the ability of the radar to distinguish between targets at the same range, but at different* azimuths.

Beam resolution describes the ability of the radar to distinguish between targets at the same range, but at different azimuths. Further from the antenna, the focused radar beam becomes wider with distance as illustrated in Fig. 12-1. When a target is within any portion of the beam, and gives sufficient backscatter,

NWS NEXRAD antenna Norman, Oklahoma.

In the early days of radar meteorology, forecasters were puzzled by the appearance of a solid line of echoes in the distance, which routinely broke into individual cells as the system approached the radar; then grew back into a solid line as echoes moved off into the distance.

the radar detector interprets this as filling the whole beam. To obtain beam resolution two targets must be separated by at least one beam width. Because of increasing beam width with distance, beam resolution decreases with range. In Fig. 12-1 the more distant target appears larger and solid, even though it's two separate, smaller targets. Thus, a narrow beam will be more representative of distant targets.

Attenuation is any process that reduces power density within the beam. Range attenuation is the loss of power density due to distance from the antenna as illustrated in Fig. 12-2. Power density in the radar beam decreases with range. In Fig. 12-2 the energy of the radar return is less with the distant target. A *sensitivity time control* (STC) circuit compensates for range attenuation. With STC displayed signal strength is independent of range. However, because of relatively low power and greater beam width, airborne units will indicate weaker intensities from storms at the radar's maximum range. Effective range is usually limited to 60 to 80 nautical miles (nm). Within the normal range of the radar targets at various ranges are displayed in relation to their actual intensity. (This is why more distant targets may appear to grow in intensity as the aircraft approaches a storm.)

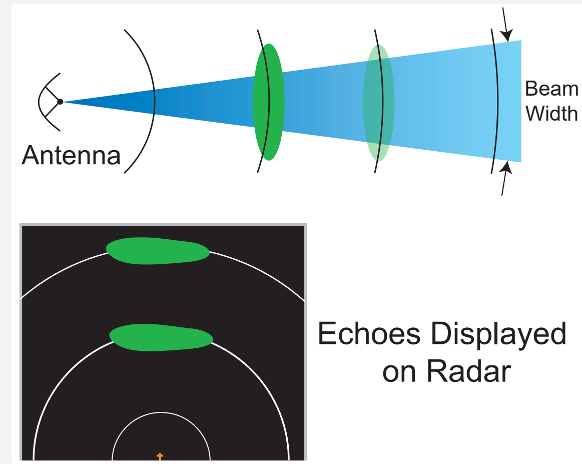
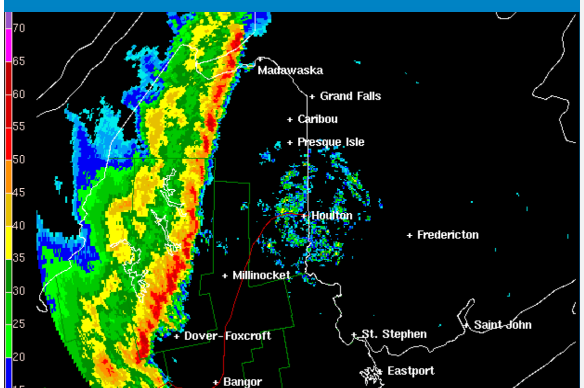


Fig. 12-2. *Range attenuation is the loss of power density due to distance from the antenna.*



Significant attenuation can result from heavy rainfall and steep precipitation gradients.

Precipitation attenuation may distort displayed intensity within the normal range of the radar. A target or obstruction close to the antenna may absorb and scatter so much energy that little passes to more distant targets. Significant attenuation can result from heavy rainfall and steep precipitation gradients—often a result of severe weather. Precipitation attenuation is related to wavelength. Precipitation attenuation is not significant with high power 10 centimeter (cm) ground based units. However, it can be a serious problem with relatively low power five- and three-cm wavelength airborne units.

Figure 12-3 illustrates the effects of precipitation attenuation. It shows how a heavy

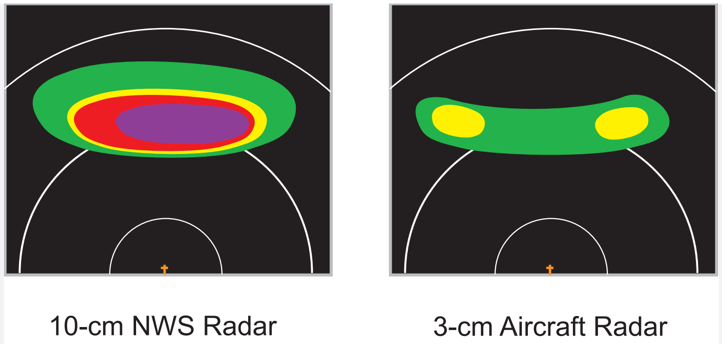


Fig. 12-3. *Precipitation attenuation, can be a serious problem with low-power, short-wavelength sets.*

precipitation pattern with a strong gradient might appear on an NWS 10-cm radar, compared with the same precipitation as seen on a three-cm aircraft unit. A pilot seeing the pattern on a three-cm unit might elect to penetrate the weather at what appears to be its weakest point only to find the most severe part of the storm or find additional severe weather where the radar indicated a precipitation free area.

Case Study

According to the National Transportation Safety Board, precipitation attenuation was a contributing factor in the crashes of a Southern Airways DC-9 in 1977 and an Air Wisconsin Metroliner in 1980.

The NTSB recommends: "...in the terminal area, comparison of ground returns to weather echoes is a useful technique to identify when attenuation is occurring. Tilt the antenna down and observe ground returns around the radar echo. With very heavy intervening rain, ground returns behind the echo will not be present. This area lacking ground returns is referred to as a shadow and may indicate a larger area of precipitation than is shown on the indicator. Areas of shadowing should be avoided."

Warning

When using airborne weather radar or commercial Data Link mosaics it's imperative to understand the unit, its operational characteristics, and *limitations*.

Just reading through the brochure that comes with the equipment is not enough to prepare a pilot to translate the complex symbology presented on the display into reliable data. A training course with appropriate instructors and simulators is mandatory for safe and efficient operation of the equipment.

Radar Intensity Levels

Prior to the commissioning of the NEXRAD network, weather radar intensity was described as Video Integrator and Processor (VIP) levels based on intensity. This system divided radar returns into six levels. NEXRAD displays reflectivity as energy returned in decibels. (A decibel is a unit that describes the change of power emitted versus power received.)

Table 12-1 describes radar intensity levels. "Intensity" represents the verbal or spoken description of observed echoes. Decibels (dBZ) shows the associated intensity range for each category. "NEXRAD Color" pictorially represents intensities used on many derived products: green to red—lowest to highest intensity. (These levels are not necessarily those used on airborne radar displays.) "Associated Convective Weather" describes typical *convective phenomena* produced at various dBZ levels.

Table 12-1. *Radar Intensity Levels*

Intensity	dBZ	NEXRAD Color	Associated Convective Weather
Light	<30		Light to Moderate Turbulence Possible Lightning
Moderate	30 - 40		
Heavy	>40 - 50		Severe Turbulence Lightning
Extreme	>50		Severe Trublence Lightning Wind Gust Hail

Caution

With convective weather, even a green return represents potential danger when associated with moderate or greater convective echoes. This can be seen in the associated convective weather portion of Table 12-1. Therefore, determining the character of a weather system—convective or non-convective—is important in estimating potential hazards.

So, how can we determine if a weather system will result in convective weather—thunderstorms? Stability, the third factor in the Weather Equation, is the answer.

Unstable air mass precipitation characteristics:

- Echoes tend to form as lines or cells.
- Steep gradients.
- Intensities generally vary from moderate to extreme.
- Occasionally intensities can be light.
- Echo patterns change rapidly when “looping” the image.

Stable air mass precipitation characteristics:

- Widespread areal coverage.
- Weak gradients.
- Intensities generally light to moderate (39 dBZ or less).
- Occasionally intensities can be stronger.
- Echo patterns change slowly when “looping” the image.

Note

Non-convective storms may display HEAVY intensity but not contain severe turbulence or lightning. Non-convective storms rarely, if ever, produce EXTREME intensity echoes.

Radar Limitations

Radar displays precipitation, not turbulence or other associated thunderstorm hazards. However, a direct relationship exists between echo intensity and turbulence. And, although some airborne weather radars have turbulence detection modes, they only detect turbulence within areas of precipitation. They cannot detect clear air turbulence (CAT), which is often associated with convective weather. Hail is another significant airborne hazard. Dry hail is a poor reflector of radar energy.

Probability is often used in aviation weather. For example, let’s take a 50% probability of turbulence. A pilot flying through an infinite number of events can expect to encounter turbulence one-half of the time. However, since penetrating an infinite number of events is impossible, pilots may spend their entire career and never encounter any turbulence. On the other hand, an "unlucky" pilot might encounter a greater number of events than the probability indicates; but, on average the probability holds.

Figure 12-4 shows the probability of turbulence associated with echo intensity.

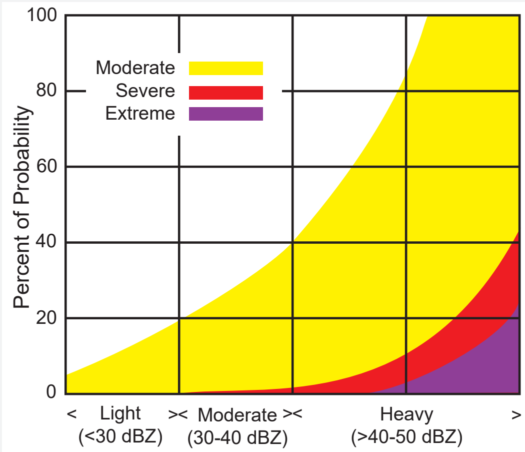


Fig. 12-4. *Even though the probability of significant turbulence is small, never assume penetrating a MODERATE cell is without risk.*

Although not directly depicted in Fig. 12-4, expect an almost 100% probability of light turbulence in any area of convective rain. An area of LIGHT echoes, not associated with higher intensity levels, has almost no chance of producing severe or extreme turbulence. However, LIGHT intensity echoes produce a 5% to 20% probability of moderate turbulence.

As with LIGHT, MODERATE intensity echoes have almost no probability of extreme turbulence. However, the probability of moderate turbulence increases to 20% to 40%; severe turbulence is low, up to about 5%.

Figure 12-4 shows a high probability of moderate turbulence for HEAVY intensity echoes, increasing form 40% to 85% to 100%. The probability of severe turbulence has increased to between 5% and 10%; with a slight chance of extreme turbulence—although less than about 2%. With HEAVY intensity echoes above 45 dBZs the chance of severe turbulence increases to between 10% and 50%; extreme turbulence probability increases from slightly greater than about 2% to 25%.

Case Study

> *(ASRS) While cruising at FL330 the aircraft encountered severe turbulence and lost several hundred feet of altitude. There were injuries to two flight at-*

tendants and one passenger.

We were deviating around weather on a route suggested by ATC and our own flight dispatcher. We also agreed with their suggestions, as we had a good picture on our airborne radar. Approximately 10 minutes prior to the encounter, we had been visual, but at the actual time of the encounter we were IFR in cirrus type clouds. At the time of the encounter we were approximately 25 miles from the nearest contouring cell as depicted on our radar. Since we were in clouds and radar showed us to be on a clear path, we can only assume we encountered a wind shear situation or flew into a rapidly developing buildup that did not contain enough moisture to give a return on our radar.

During a Callback conversation the reporter restated the fact that the turbulence was totally unexpected. The pilot stated that the color radar that was on board did not paint the smaller cells and that might have had a bearing on the incident.

Research indicates damaging hail to aircraft to be on the order of 3/4 inch or greater in diameter. Three-quarter inch hail is the threshold for aviation severe thunderstorms. Hail is reported in METAR as GR; hail size appears in remarks.

Figure 12-5 shows hail size probability. The probability of damaging hail begins with HEAVY intensity echoes and increases with intensity. Expect hail in any MODERATE convective echo and the chance of damaging hail in any HEAVY or greater echo.

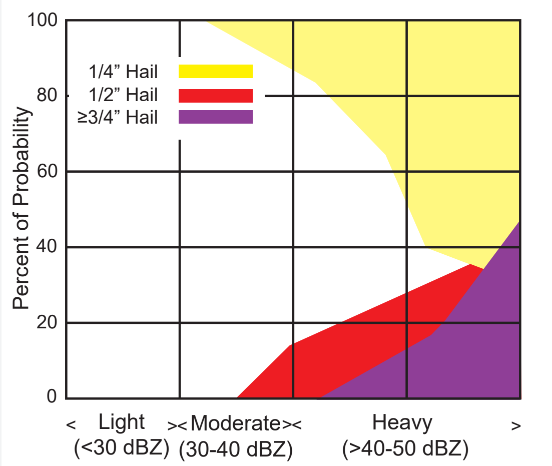


Fig. 12-5. *Damaging hail probability begins at the lower end of HEAVY intensity echoes.*

The largest hail stone reported in U.S. occurred in south-central Nebraska on June 22, 2003. The hailstone measured seven inches in diameter, with a circumference of almost 19 inches!

Case Study

We were on an IFR flight in a Cessna 172 from Lancaster's Fox Field in California's Mojave Desert to Van Nuys. We flew into a big, black, ugly looking cloud. In the cloud turbulence was briefly moderate and the sound of hail hitting the windscreen was deafening! I thought I would be buying a new windscreen, but it turned out there was no damage. Based on the turbulence and hail probability charts this was a growing LIGHT intensity cell—not yet a thunderstorm. I don't do silly things like this anymore!

Hazardous areas of turbulence and hail are not necessarily associated with areas of maximum radar intensity. The probabilities of turbulence apply to the entire storm. Severe turbulence and hail may be encountered in clear air surrounding a thunderstorm. What does this mean? Avoid any intensity level associated with the moderate storm echo and the surrounding area. The violent nature of thunderstorms causes gust fronts, strong up and downdrafts, and wind shear in clear air adjacent to the storm out to 20 miles. Precipitation, which is detected by radar, generally occurs in the downdraft, while updrafts remain relatively precipitation free. Clear air or the lack of radar echoes does not guarantee a smooth or safe flight in the vicinity of thunderstorms.

Case Study

> MSY UUA /OV NEW 150020/TM 2015/FLDURD/TP C550/TB SEV/RM OCCURED IN AREA WHERE ACFT RADAR DID NOT INDICATE PCPN. BOTH CREW INJURED.

This incident occurred over New Orleans, Louisiana in thunderstorm weather. Both crew of a Cessna Citation were injured when the aircraft encountered severe turbulence in an area where their airborne weather radar indicated no precipitation.

The bottom line: Although penetrating a MODERATE intensity cell may appear to be an acceptable risk, it's NOT! Ground based radars display MODERATE echoes as yellow; airborne radar shows this intensity as red. Whenever radar shows a MODERATE or greater convective storm, the entire storm cell should be considered extremely hazardous and be avoided! This includes LIGHT echoes associated with MODERATE or greater returns. Remember, radar is a storm avoidance, NOT a penetration, tool.

Precipitation may be occurring but not depicted. The absence of echoes does not necessarily mean clear skies. Echo tops are not cloud tops. We can expect to find holes in what the radar portrays as "solid," especially with isolated and scattered precipitation. Targets farther from the antenna might be smaller than depicted.

National Weather Service Radars

National Weather Service NEXRAD Doppler radars, with a narrow linearly polarized beam, are ideal for detecting precipitation-size particles and the relative motion of precipitation within a storm. *Dual Polarization* improves the ability to evaluate shape and composition of precipitation. This increases the accuracy of severe weather warnings and has the capability of detecting wind shear.

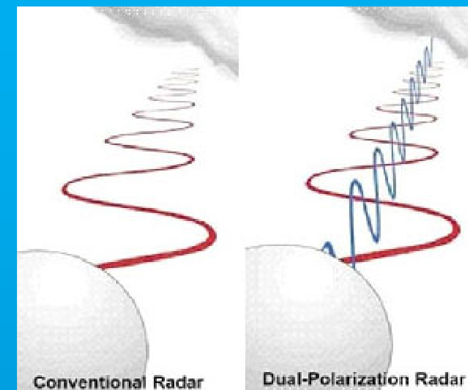
NWS radars can detect most precipitation within about 80 nm of the radar and intense rain or snow within about 140 nm. Light rain, light snow, or drizzle from shallow weather systems are not normally detected.

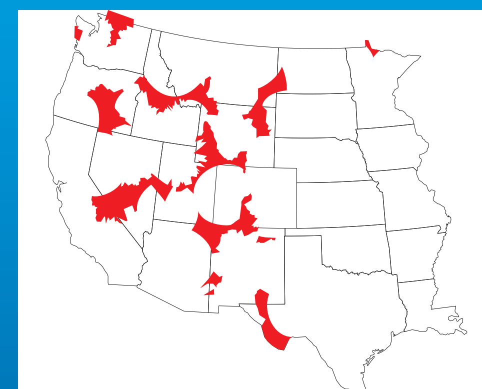
NEXRAD Doppler radars provides hazardous and routine weather radar data typically above 6000 ft east of the Rockies. Because the radar beam is "line of sight" it may overshoot some areas of precipitation. This is especially true in the western U.S. where sites are located on mountain tops, thus restricting coverage to above about 10,000 ft (callout). As a result, valley surface observations may report precipitation, not detected on the radar. However, this precipitation is usually light and not the result of convective weather.

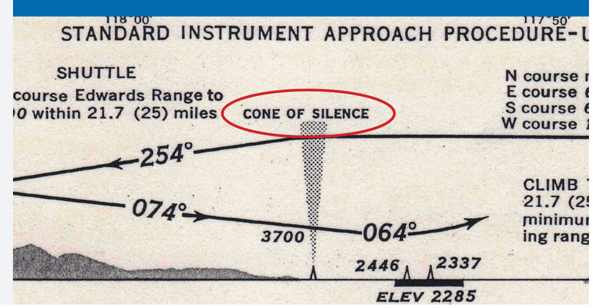
The radar scan begins at an elevation of 0.5° above the horizon. The elevation angle increases to a maximum of 19.5°. The *scan volume* consists of a 360° rotation at each elevation angle. Typically, images are updated every five to 10 minutes. Updates are based on the operational mode of the radar. Because of the radar's inability to scan at higher angles, coverage is limited close to the radar site. This area is commonly referred to as the "cone of silence." To determine activity directly over a site select an adjacent radar image or mosaic.

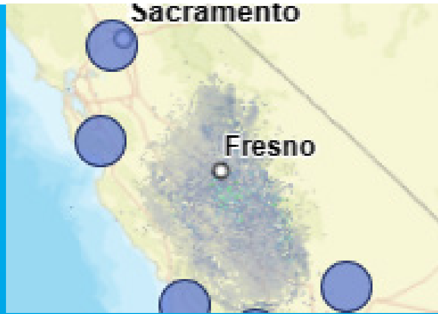
Trivia

> The "cone of silence" originally referred to a signal dead zone above a Four Course Low-Frequency Radio Range which identified station passage (callout). This was shown in the movie *Airport 1954* (aka: *The High and the Mighty)*.









Ground Clutter

Echoes from surface targets appear in most radar images. Within an area of about a 20 nm radius *ground clutter* generally appears as a roughly circular region with echoes that show little spatial continuity. They result from energy reflected back to the radar from outside the central radar beam—from the Earth's surface or buildings. Certain sites situated at low elevations on coastlines regularly detect sea returns, a phenomenon like ground clutter—except that the echoes come from ocean waves.

Note

> Traditional cathode ray tube (CRT) radar displays use a black background. This convention carried over to electronically generated displays—as seen in many of the examples. The background color was changed from black to white for accessibility. Black is "less friendly" to those with colorblindness. In fact, the black background with green and red data is impossible to see by some users. A white background complies with governmental accessibility requirements.

Special automated error checking generally removes most surface returns from the radar image. Mosaics typically remove most non-precipitation features. Since surface returns do not move with the normal pattern of precipitation, they are usually easy to detect. Even with limited experience, pilots can differentiate precipitation from these echoes.

Under highly stable atmospheric conditions (typically on calm, clear nights), the radar beam can be refracted almost directly into the ground at some distance from the radar. This results in an area of intense looking echoes. Known as *anomalous propagation* (AP), this phenomenon is much less common than ground clutter. AP typically appears as speckled or blotchy, high reflectivity echoes. When "looping" images, AP tends to bloom up and dissipate and has no continuity of motion. Unlike AP, precipitation echoes move with a smooth, continuous motion.

Returns from aerial targets are rather common. Echoes from migrating birds regularly appear during nighttime hours between late February and late May, and again from August through early November. Returns from insects sometimes appear during July and August. The apparent intensity and aerial coverage of these features are partly dependent on conditions but usually appear within 30 nm of the radar site and produce reflectivity less than 30 dBZ.

Of the NEXRAD radar products, *Base Reflectivity* and *Composite Reflectivity* are the most useful. The availability of a "loop" has additional advantages. The loop can determine echo movement—direction and speed, echo intensity trend—increasing or decreasing, and help detect non-precipitation echoes—ground clutter, surface returns, and anomalous propagation.

Base reflectivity images are available at several elevation angles (tilts) and detect precipitation, evaluate storm structures, locate atmospheric boundaries, and determine hail potential. The base reflectivity image is normally the 0.5° elevation angle.

The maximum range of the base reflectivity product is 124 nm. This view will not display more distant echoes, even though precipitation may be occurring.

Composite reflectivity displays maximum echo intensity from the scan volume. It reveals the highest reflectivity within a storm. When compared with base reflectivity, composite reflectivity often reveals important storm structure features and intensity trends. The maximum range of the composite reflectivity product is 248 nm. The blocky appearance is due to its lower resolution.

Although composite reflectivity displays maximum echo intensities out to 248 nm, the beam at this distance is at a very high altitude. Thus, only the most intense convective storms and tropical systems are detected. Special care must be taken interpreting this product. While the radar image may not indicate precipitation it's quite possible that the radar beam is overshooting precipitation at lower levels, especially at greater distances.

Note

> Under certain conditions maximum returns may be quite high. Pilots may be able to "fly under" areas of extensive echoes. In a "dry environment" the weather system may only produce VIRGA. Conversely, pilots flying at high altitudes may be able to top any low level echoes.

To determine precipitation occurring at greater distances an adjacent radar site or a mosaic should be used.

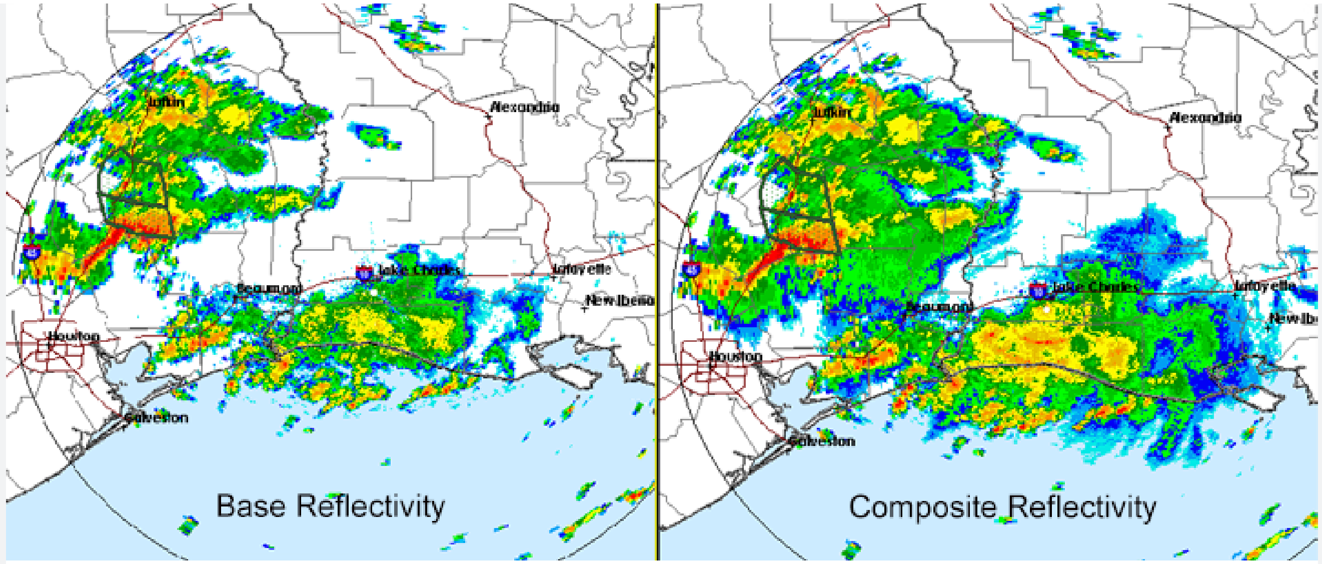


Fig. 12-6. *Composite reflectivity should be used to determine maximum storm intensity.*

Figure 12-6 illustrates the difference between base and composite reflectivity.

Radar products are available in *clear air* and *precipitation* modes. In clear air mode the radar is in its most sensitive operation. Clear air mode has the slowest antenna rotation rate which permits the radar more time to sample a given volume of the atmosphere. This increases the radar's sensitivity and ability to detect smaller objects. Precipitation mode is designed primarily to detect precipitation. Precipitation and clear air modes are most often clearly distinguishable. The key is the dBZ scale. In precipitation mode the scale goes from +5 to +75 dBZ; in the clear air mode the scale goes from –28 to +28 dBZ.

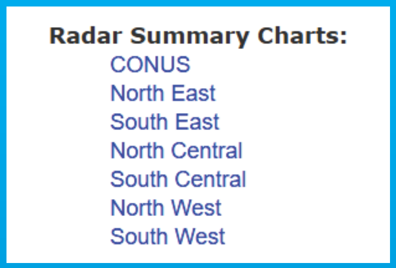
Never assume that in clear air mode there are no precipitation echoes. However, most often these returns will not be precipitation, but the high end (above about 16 dBZ) may result from light rain or snow. Therefore, clear air mode is occasionally used to detect light snow. In the winter dBZ values between 4 and 16 (yellow) would represent light snow. Snow flurries will appear as a 4 dBZ value. Snow characteristics—fine, large, wet or dry—all play a role in the intensity displayed. An area of dry, large snowflakes may only appear between 8 and 12 dBZ.

Product Availability

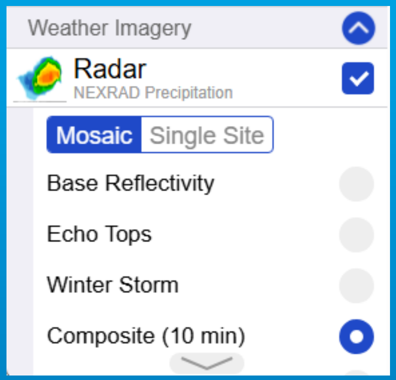
Chapter 11, Graphical Observational Products described initial product accessibility from Leidos Flight Service and the Aviation Weather Center. We'll continue that discussion for Weather Radar Products.

Leidos Flight Service

Access Leidos Flight Service radar products from the website "Home Page" top menu (Fig. 11-1). On the "Wx Charts" page access radar products from the **Radar Summary Charts** menu (Fig. 11-2). Options include CONUS or one of six regions (callout). These products do NOT have "Loop" or "Zoom" capabilities.

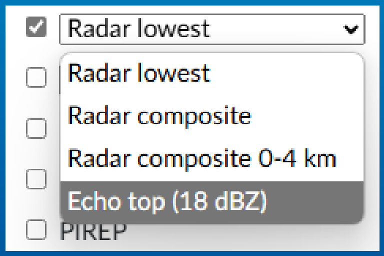


From the "Map" page Layers Controls panel (Fig. 11-3) "Click" Weather Imagery, Radar option dropdown box (callout). Selections include Mosaic/Single Site, Base Reflectivity, Echo Tops, Winter Storm, and Composite options. (Unlike the Echo Tops display from the "Wx Charts," **Radar Summary Charts** menu, Echo Tops on the "Map" page use the same display as AWC products presented later in this chapter.) The Winter Storm layer emphasizes areas of potentially hazardous surface weather—snow and ice. (Additional explanation and application are provided in ch16, Enroute Forecast Products.) The "Map" page (Fig. 11-3) provides "loop" and "zoom" capabilities.

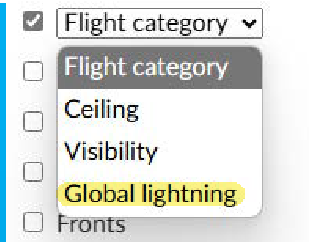


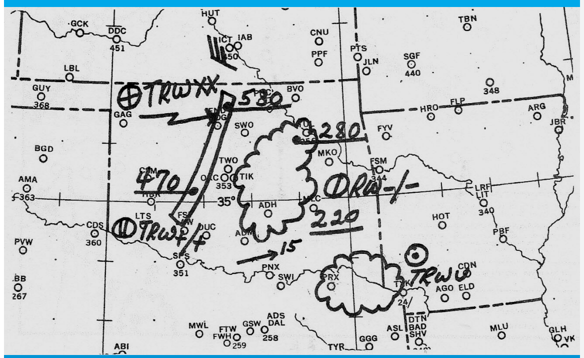
Aviation Weather Center

AWC Weather Radar Products are available on the Aviation Weather Center's website. On the AWC's "Home Page" (Fig. 11-3), from the "Weather" dropdown menu, select *Observations*. To view products "Click" the Layers Selector icon in the Options Panel (inset Fig. 11-4). The Layers Selector menu is shown in the callout consisting of *Radar lowest, Radar composite, Radar composite 0-4 km*, and *Echo top (18 dBZ)*.

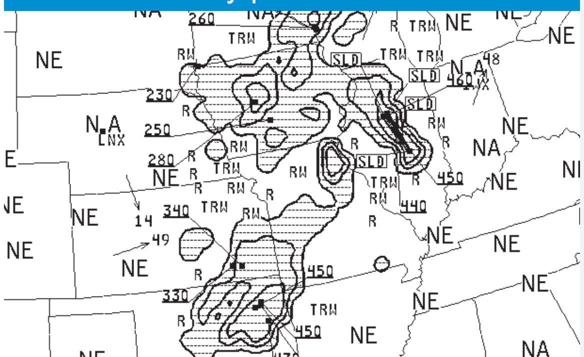


Radar lowest (Base Reflectivity) is the lowest scan at each grid point. *Radar composite* (Composite Reflectivity) is the strongest echo return for each elevation. *Radar Composite 0-4 km* is the strongest radar echo return for each elevation level up to four kilometers (~13,000 ft) combined into one image. This image gives a better view of all





Manually plotted RAREP.



The “legacy” radar summary chart was a computer analysis of RAREP digital data.

precipitation for low altitude aviation operations. *Echo top (18 dBz)* represents the threshold used to compute the value of echo tops. From ch11, Graphical Observation Products, select *Global lightning* from the *Observations*, Layers Options panel Flight category menu (callout).

Radar Products

With the deployment of the WSR-57 network textual Radar Reports (RAREPs) were prepared and disseminated on teletype weather circuits and via facsimile (callout). Some facilities were provided with local remote radar displays. In the western U.S. a few locations received locally drawn facsimile depictions of FAA Air Route Traffic Control Center (ARTCC) radar data.

The “Legacy” Radar Summary Chart evolved in the late 1960s and 1970s. The chart contained a summation of computer analyzed data based on hourly radar observations. (An example of the “Legacy” Radar Summary Chart is shown in the callout.) The chart graphically displayed precipitation type, intensity, configuration, coverage, tops, and movement. Latency was a serious problem, with some charts over an hour old. The National Weather Service ceased producing and disseminating this product in June 2013.

Computer graphics and electronic transmission of radar data began in the late 1980s and early 1990s. Automated Flight Service Stations (AFSS) were provided with commercial weather graphics, with almost “real time” displays and “loop” capability.

Radar data is observed, collected, and processed by the National Weather Service (NWS) and made available to the government and commercial vendors. Radar composite/mosaic images are available for preflight and inflight distribution on Leidos Flight Service and Aviation Weather Center websites, and through Data Link. Commercial vendors provide an assortment of products based on NWS data.

Warning

> Radar products are always old by the time they’re compiled and distributed—latency. Their use is limited to general flight (strategic) planning and cannot be substituted for “real time” (tactical) weather radar information.

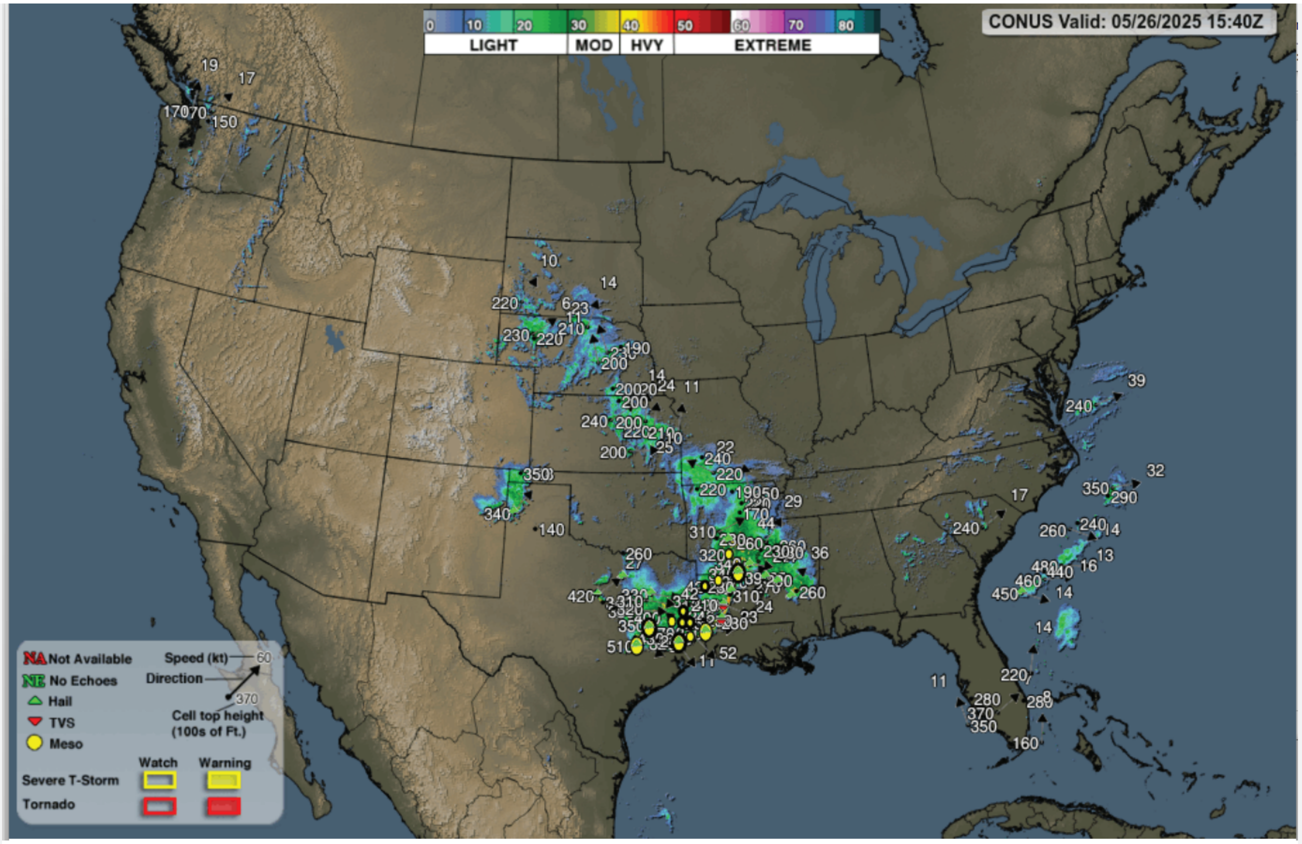


Fig. 12-7. *The Leidos Flight Service radar mosaic suffers from "clutter," and the lack of "loop"* and "zoom" capability.

Leidos Flight Service radar mosaic for the CONUS is shown in Fig. 12-7. (The time of observation, upper right corner, is the same as in the AWC graphic Fig. 12-8). The Leidos Flight Service radar mosaic incorporates cell movement and echo tops, and additional data.

Most symbols are self-explanatory. A Tornado Vortex Signature (TVS) indicates the possible location of a tornado. Meso (mesocyclone) represents a small area of low pressure where tornadoes tend to develop. Severe convective *Watch* and *Warning* areas are dispicted. What's the difference between a National Weather Service "Watch" and a "Warning?" Both products are *Public* forecasts issued for severe convective activity.

WATCH: Conditions are favorable for the development of severe events. They serve as a “heads-up;” be prepared and monitor the situation. They cover large areas, the size of states, usually valid for 8 to 12 hours.

WARNING: Severe weather is imminent or occurring; take immediate action. They cover small areas, the size of cities or counties, usually valid for an hour or less.

Additional details on NWS “Watch” and “Warning” products are presented in ch 15, Weather Advisories.

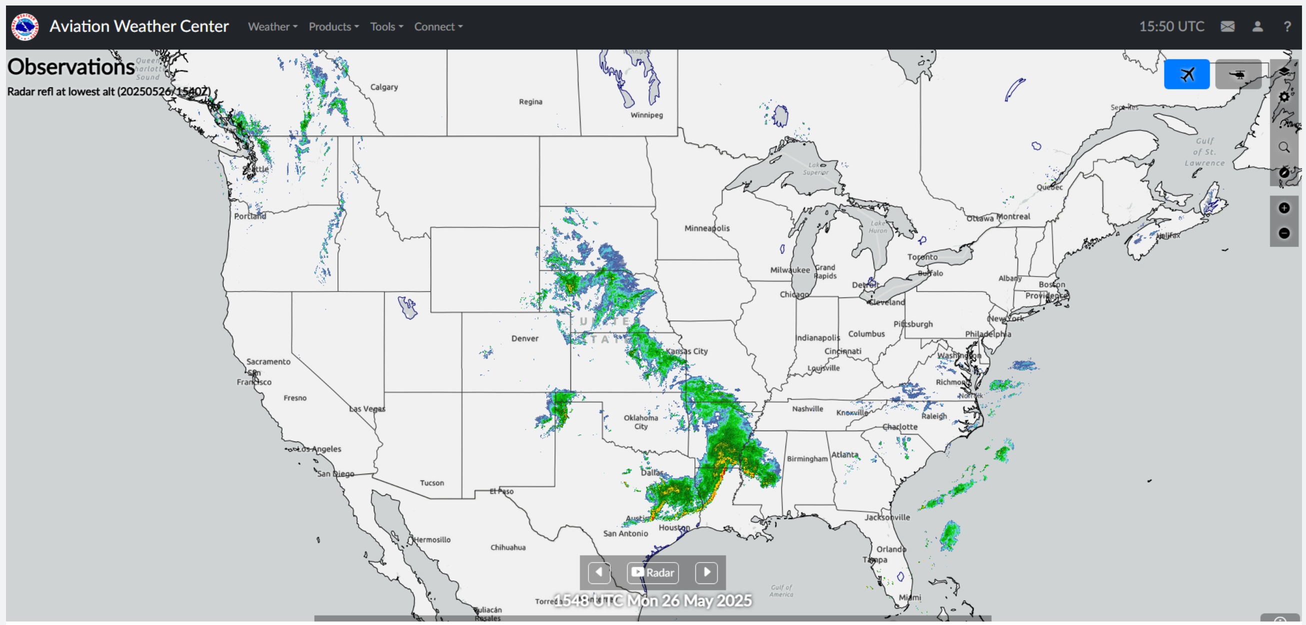


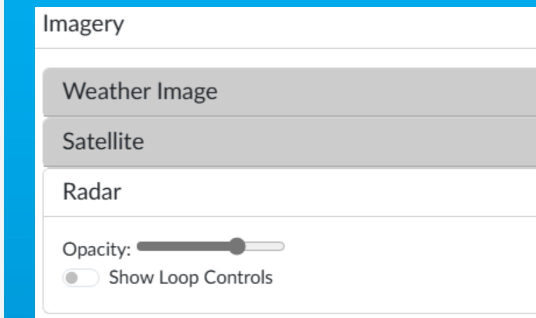
Fig. 12-8. *The AWC mosaic combines “loop” and “zoom” capabilities.*

Figure 12-8 contains an example of an AWC National Weather Service Radar Mosaic. The mosaic combines multiple radar images to display a national view. Images, in the contiguous U.S., are typically no older than 15 minutes. Post-processing removes some ground clutter and anomalous propagation (AP). Radar limitations such as blockage by mountains, lack of overlap, and over-processing of clutter and AP can result in the elimination of some precipitation.

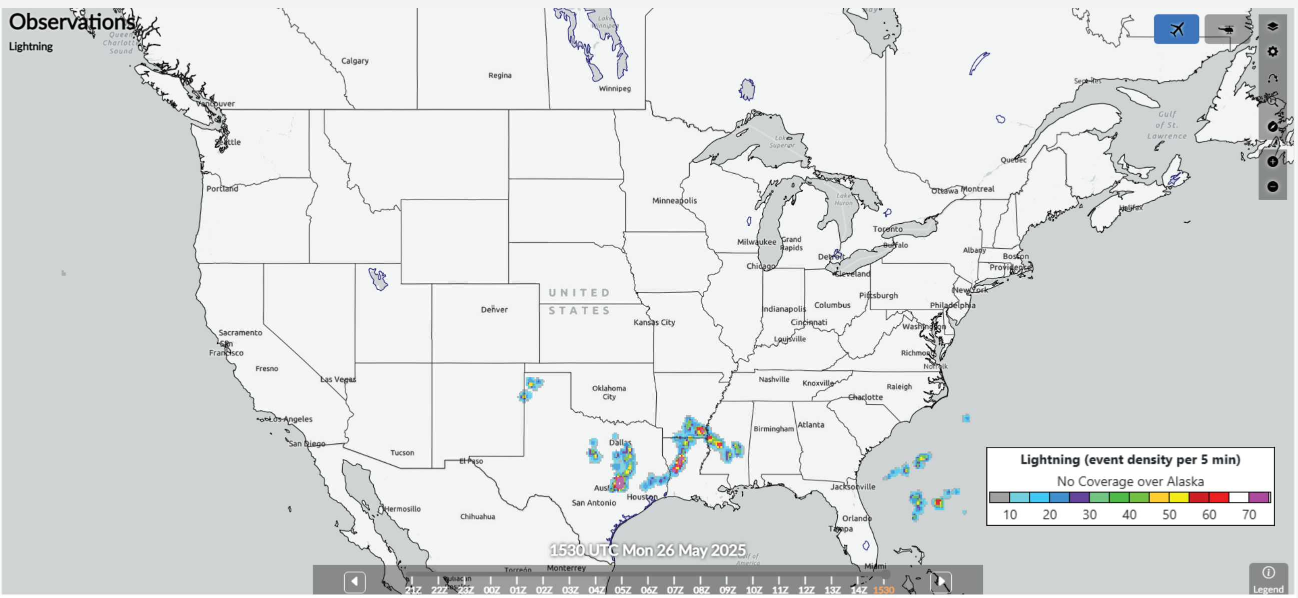
Note

Why are some mosaic images squashed? The image appears elongated due to the display of information. For data to be ingested—their word, not mine—the information uses an UN-projected format. This means the depiction, intended for a spherical Earth, becomes distorted on a flat surface.

Radar image valid time is displayed in the top left corner of the display (Observation time: 20250526/1540Z). The "Imagery" menu (callout) selects layer "Opacity" and "Loop" controls. When selected the radar loop control panel appears at the bottom of the Observations panel (Fig. 12-8). The loop provides the latest five images ending in the time shown on the time slider. Move the time slider to show a trend. Adjust magnification using the "Zoom" function. Display severe convective *Warning* areas by selecting "NWS Warnings" from the Layers Selector, Options Panel.



The Aviation Weather Center offers a Global lightning display option (Fig. 12-9). The Flight Categories dropdown menu on the Option Panel, Layers Selector, Flight Category menu (callout) allows the selection of the Global lightning layer.



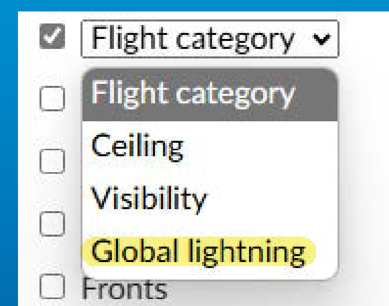
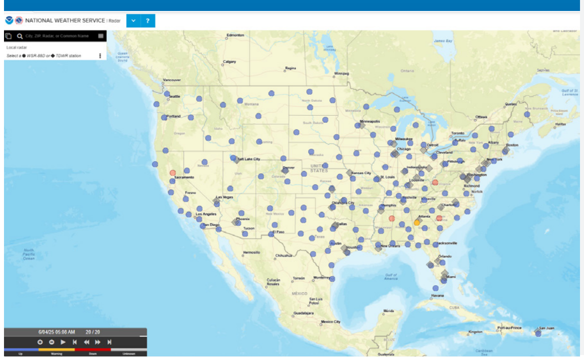


Fig. 12-9. *The absence of lightning does NOT indicate the absence of thunderstorms.*

Refer to ch23, Thunderstorm Avoidance for additional details on the use and limitations of lightning data.



Gridded data from the Geostationary Operational Environmental Satellite (GOES) Geostationary Lightning Mapper (GLM) provides enhanced visualization of convection beyond the extent of ground-based observations. The observation was made at 1530Z on May 26, 2025, the same time frame as the previous radar mosaics. (The Global lightning Legend is shown in Fig. 12-9.)

A comparison of Fig. 12-7 and Fig. 12-8, with Fig. 12-9 confirms thunderstorm activity in the Texas and Oklahoma panhandles. Other activity for most of Missouri northwest into southern South Dakota has not produced thunderstorms (lightning) as of the time of observation. Lightning data infers thunderstorms; the lack of lightning data does NOT necessarily indicate the absence of thunderstorms.

Access local radar displays from individual WFO websites or the NWS' National Radar Network. WSR-88D weather Radar in the CONUS is available at:

www.radar.weather.gov

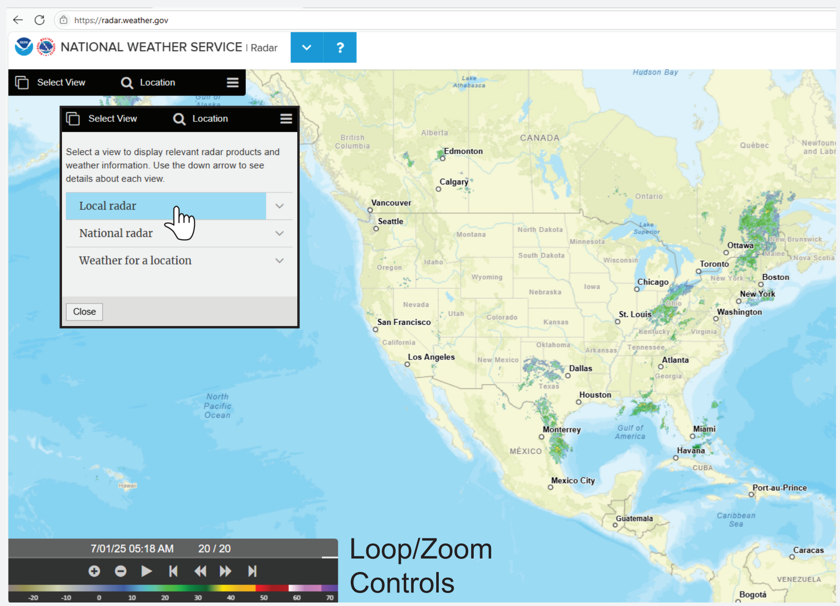


Fig. 12-10. *Individual radars are available from the National Weather Service Radar website.*

Figure 12-10 shows the NWS radar "Home Page." "Loop" and "Zoom" controls, and "Legend" are in the lower left corner of the page.

Access individual radar sites from the top, left menu, "Click" *Select View*, the Local Radar option menu appears in the inset Fig. 12-10. The callout shows the Local Radar page. Gray circles indicate locations. "Click" on a station to select a location. Red circles indicate radars that are temporarily out of service.

Leidos Flight Service links to this site from the “Map” page, *Layer Control*, RADAR dropdown menu. The *Single Site* option is shown in Fig. 11-3.

The type of precipitation is often an indicator of atmospheric stability. Stable and unstable precipitation types were presented in previous chapters. Sources include observation products (ch9, Surface Observations and ch11, Graphical Observational Products) and forecast products (ch15, Weather Advisories and ch16, Enroute Forecast Products).

Intensities are described using NEXRAD dBZ levels, as shown in previous sections and Table 12-1. Coverage is graphically depicted.

Echo configuration consists of cell, area, or line. A single isolated area of precipitation, clearly distinguishable from surrounding echoes, constitutes a *cell*. An *area* consists of a group of echoes of similar type that appear to be associated. A *line* defines precipitation in a line—straight, curved, or irregular—at least 60 miles long, with at least 40% coverage. Cell movement indicates short-term motion of cells within an area or line—not necessarily the movement of the area or line itself—which can be considerably different.

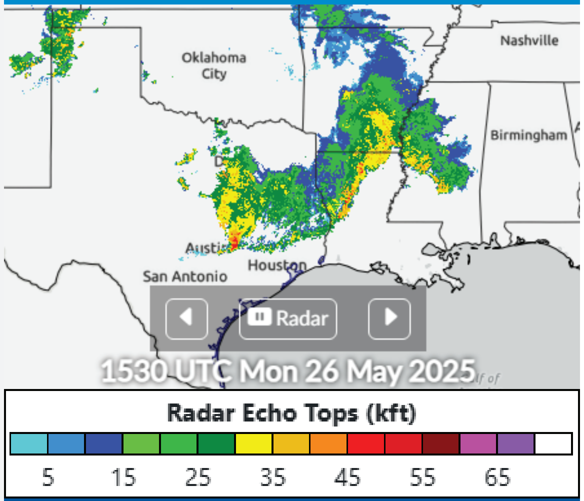
The Leidos Flight Service product (Fig. 12-7) depicts centroid movement (cell movement). A wind barb shows direction and speed in knots. On the AWC product (Fig. 12-8) use the “loop” function to determine general movement.

The Leidos Flight Service product (Fig. 12-7) includes observed maximum *cell tops*. An Echo Top (18 dBZ) option is available on the AWC’s Observations layer *Options Panel*, Radar dropdown menu. View echo tops as a separate layer (callout). The Legend decodes height in 1000s of ft MSL.

Thunderstorm cloud tops typically extend to between 26,000 and 33,000 ft. Use the Clouds layer and select the Cloud Cover option, Cloud Tops for forecast cloud tops. (This product is addressed in ch16, Enroute Forecast Products.)

A detailed description of convective coverage, intensity, configuration, movement, and tops is available in Convective SIGMETS (WST) and convective Center Weather

Severe weather echo “signatures” are depicted in the following section.



This depiction of Echo Tops is the same time frame as that illustrated in Fig. 12-8.

Advisories (CWA). Both products provide observational and forecast data and are presented in ch15, Weather Advisories.

Radar products are observations. Flight decisions can never be based solely on radar products. However, they do provide a “big picture” of precipitation coverage, intensity, movement, and infer atmospheric stability.

Severe Weather Echoes

Severe weather produces damaging surface winds, severe or extreme turbulence, large hail, and tornadoes. Radar signatures of these patterns are most often seen on individual NEXRAD sites, but may appear on composites, mosaics, and airborne displays. Maximum turbulence occurs in areas that contain the most abrupt changes in rain intensity—gradient. The steeper the gradient, the greater the turbulence. Severe weather is most often located in the southwest quadrant of the storm. Growing shapes indicate rapid motion within the cloud. Avoid any target with changing shapes. The most common erratic motions are right turning echoes, splitting echoes, and merging echoes. Significant turbulence will almost always occur under these conditions. Hail can occur above a severe storm and often falls outside and downwind of the parent cell. Figure 12-11 depicts echo patterns that indicate the potential for severe weather. Avoid these areas by at least 20 nm!

Probably the most familiar—certainly the most mentioned—radar signature is the hook echo. Hooks are typically located at the right rear side of the thunderstorm’s direction of movement. The hook is a small scale low pressure area, sometimes referred to as a mesocyclone or mesolow. (MESO may appear on some radar charts to indicate this signature.) They typically range from about three to 10 miles in diameter. Tornadoes form in the low near the hook. Research indicates almost 60% of all observed hook echoes spawn tornadoes. However, a hook echo does not always generate a tornado.

Warning

Severe storms created by wind shear aloft tend to tilt through their vertical extent. This results in multicell/supercell thunderstorms, often severe. They are identified by uneven or non-concentric echo shapes.

Supercells produce maximum average hail over 2 inches in diameter, with hail swaths over 12 miles—60% produce funnel clouds or tornadoes.

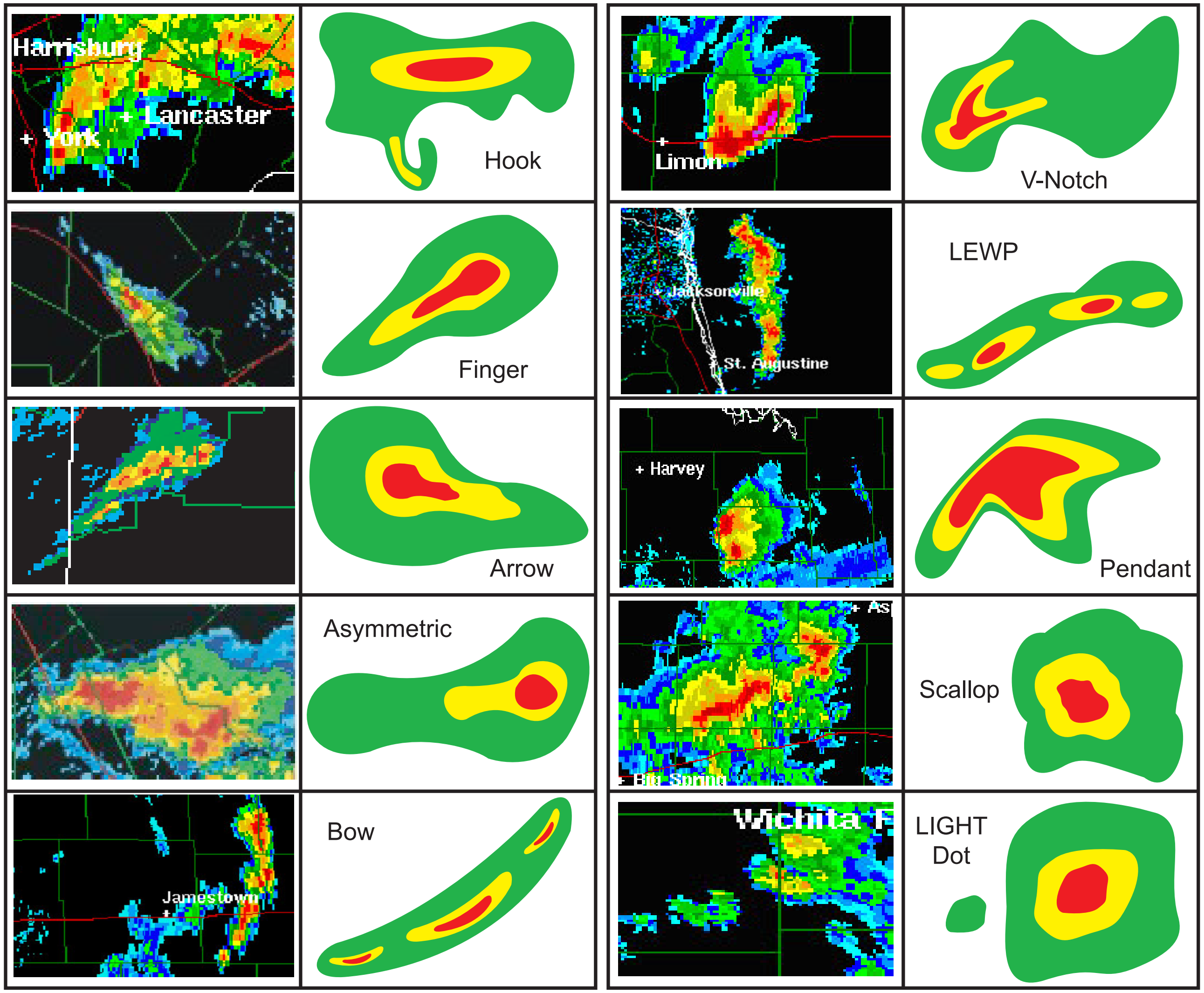


Fig. 12-11. *Severe weather echo signatures signal severe thunderstorms (wind and hail) and tornadoes; avoid these areas by at least 20 nm!*

Finger echoes represent a strong probability of severe weather. Like fingers, avoid any target with an arrow shape. This is indicative of a storm with. Similar to the arrow shape, any asymmetric echo indicates a tilted storm, with its associated severe weather.

Bow echoes are typically associated with fast moving, broken or solid lines of thunderstorms. Severe weather will most likely develop along the bulge and at the northern end of the echo pattern.

Large, isolated echoes will sometimes have the configuration of a V or U shape—a V-Notch—often accompanied by severe weather. However, severe weather does not necessarily accompany a V-notch. Severe thunderstorms have dry air mixing in the middle altitudes which can create an intrusion. Avoid any target with a dry intrusion (dryer air being sucked into the storm) giving it a V or U shape. Hail rising and descending in a thunderstorm would also appear as a missing area or cutout in the storm.

Line Echo Wave Patterns (LEWP) indicate severe weather. They form when a segment of a line of thunderstorms surges forward at an accelerated rate, causing a wavelike configuration. LEWPs form solid or nearly solid lines. Typically, the most severe weather occurs in the trough of the wave. Additional areas of severe weather are associated with the advancing edge of the line—to the east or southeast.

A pendant represents one of the most severe storms—a supercell. A pendant radar signature is generally similar to a hook, except that the hook shape is not as well defined.

Scalloped echoes indicate turbulent motion within the cloud. There is a significant probability of hail within and adjacent to the storm associated with these echoes. Targets with scalloped edges indicate severe weather.

Since hail is a poor radar reflector, this may be indicated as an isolated LIGHT dot not attached to a convective storm. Avoid storms with a few LIGHT intensity “dots” nearby. Winds at altitude will typically indicate on which side of the storm hail will fall.