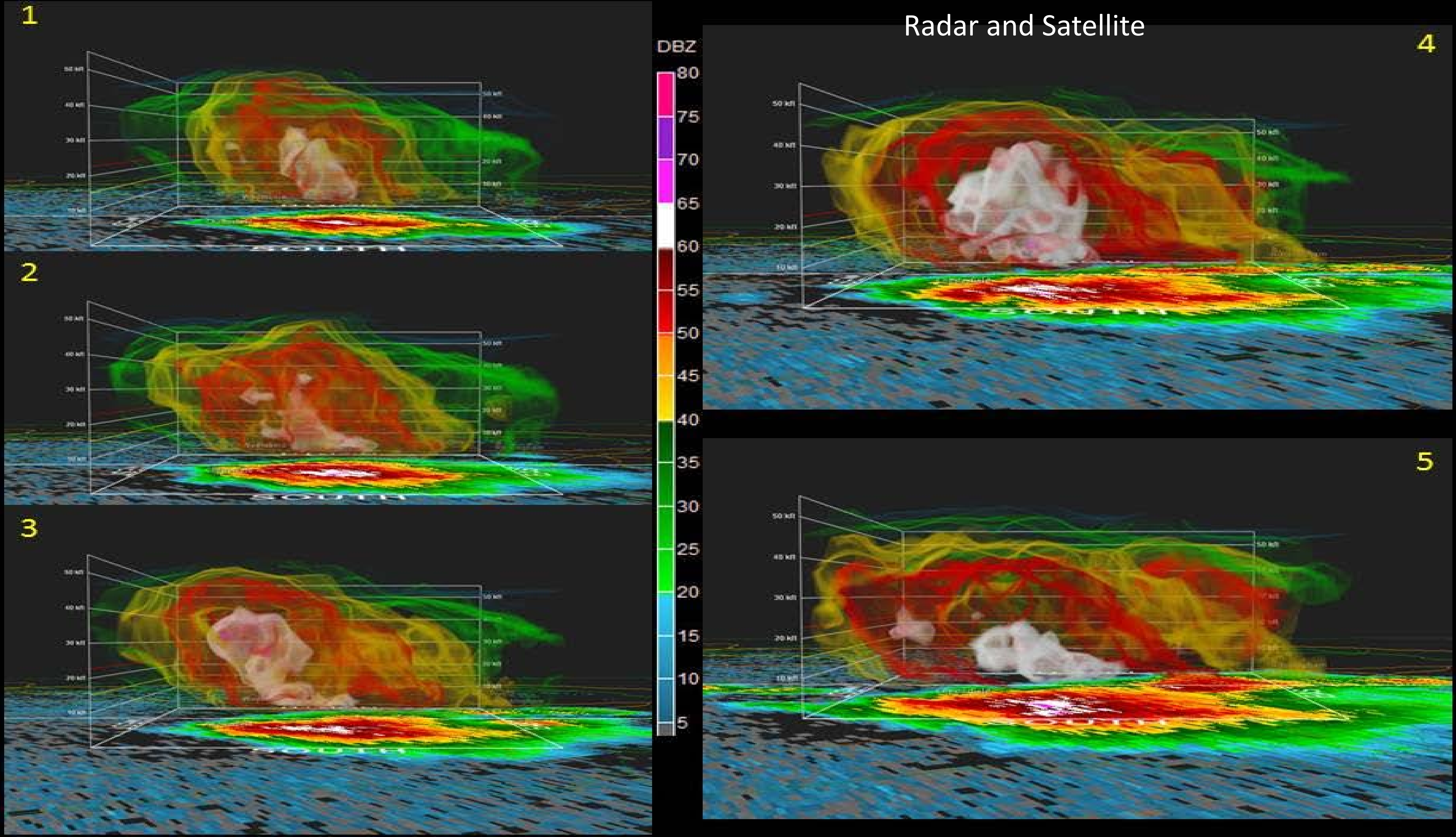
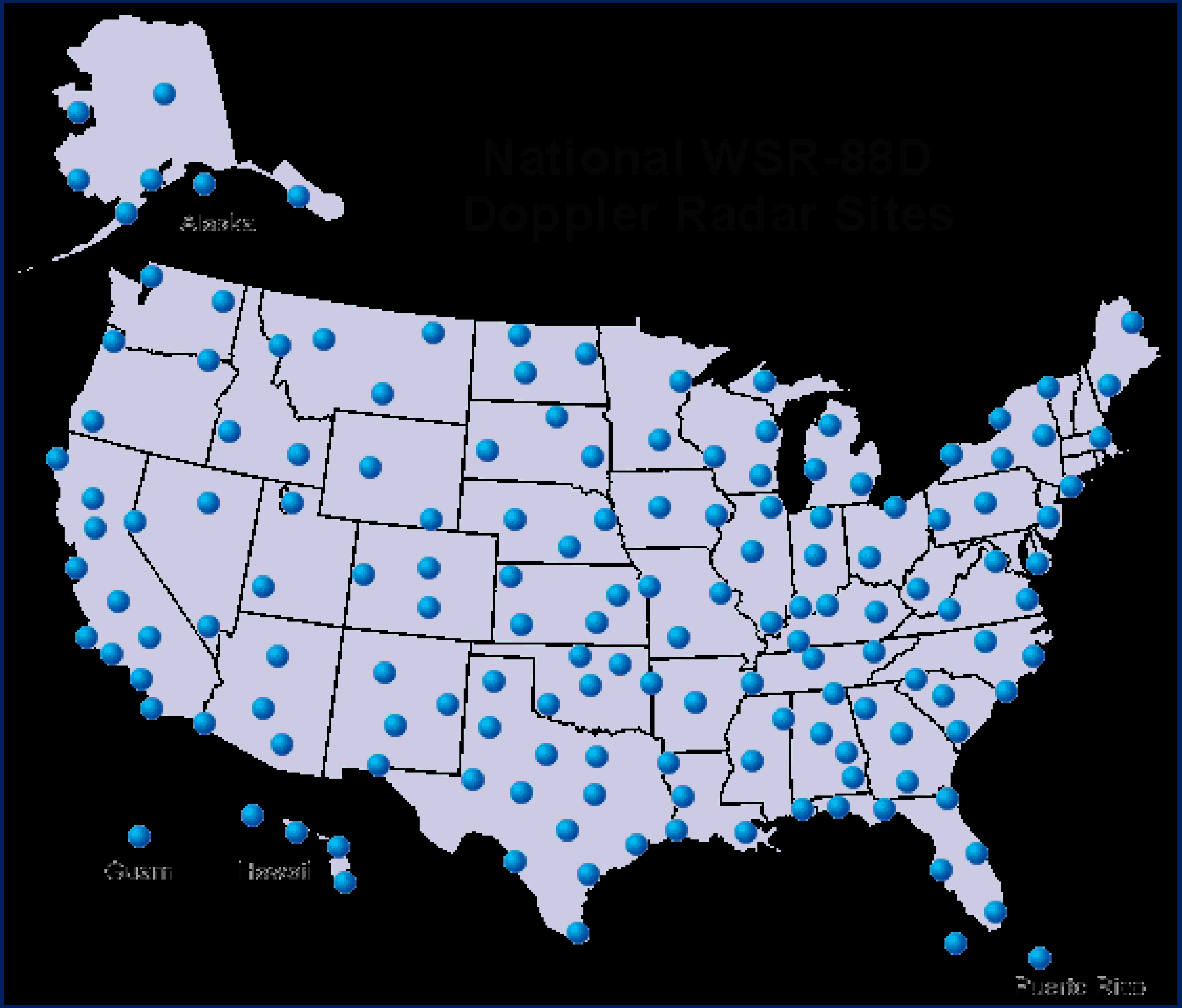
Radar and Satellite



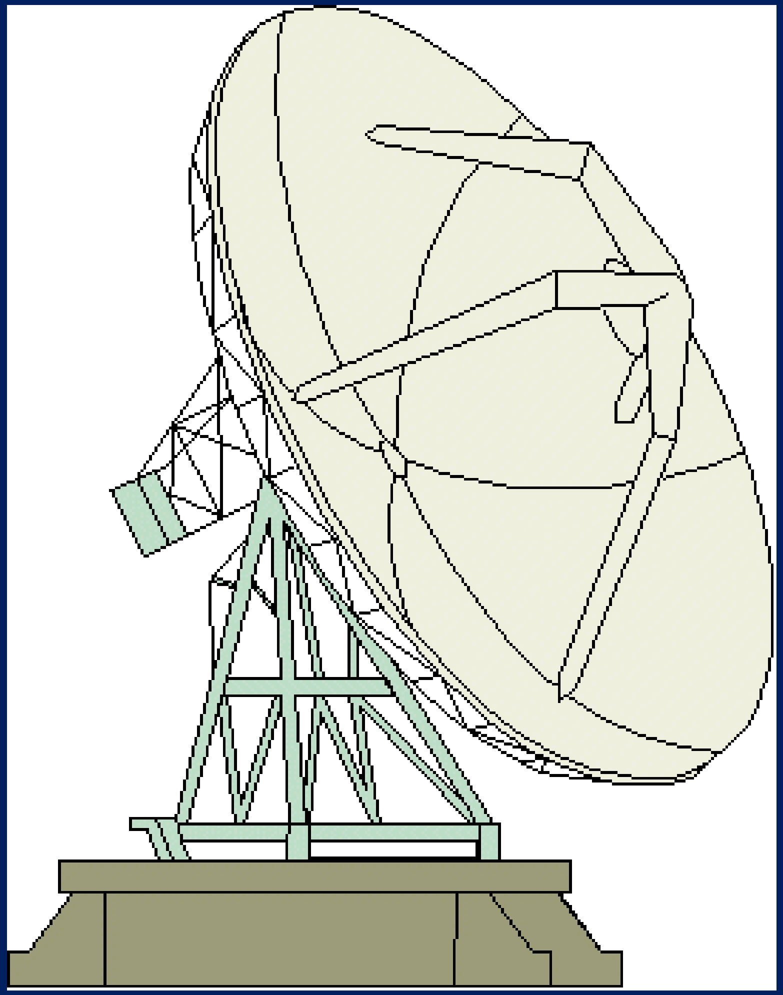
Principles of Weather Radar. The most effective tool to detect precipitation is radar. Radar, which stands for Radio Detection and Ranging, has been utilized to detect precipitation since the 1940s. Radar enhancements have enabled more precision in detecting and displaying precipitation.

The radar used by the National Weather Service (NWS) is called the Weather Surveillance Radar-1988 Doppler (WSR-88D). The prototype radar was built in 1988.

It is essential to understand some principles of weather radar. This will allow you to correctly interpret WSR-88D images. This section will also include a comparison between some WSR-88D principles and aircraft radar principles. These comparisons will help explain the strengths and limitations of the WSR-88D and aircraft radar.

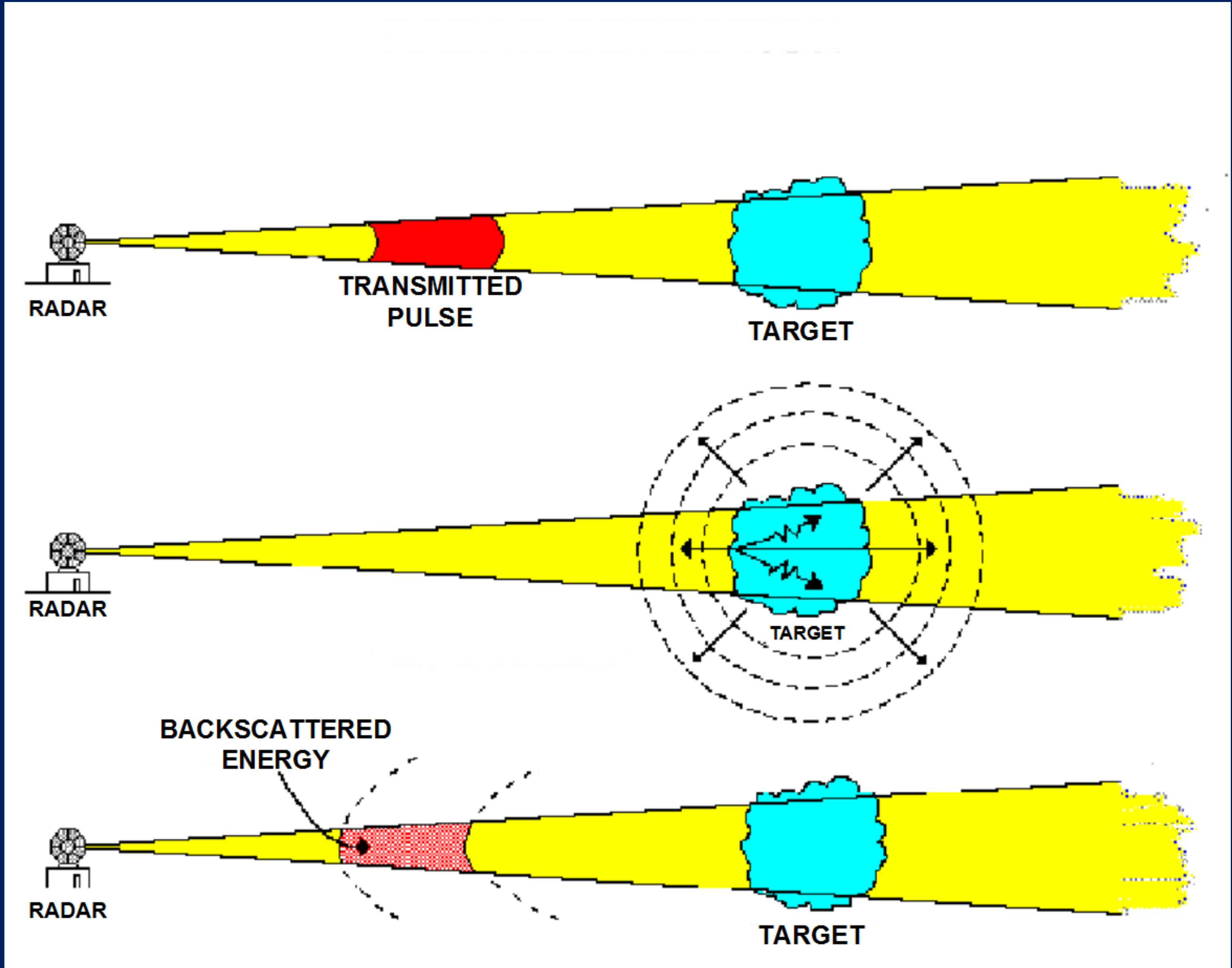


The antenna alternately emits and receives radio waves into the atmosphere. Pulses of energy from the radio waves may strike a target. If it does, part of that energy will return to the antenna.

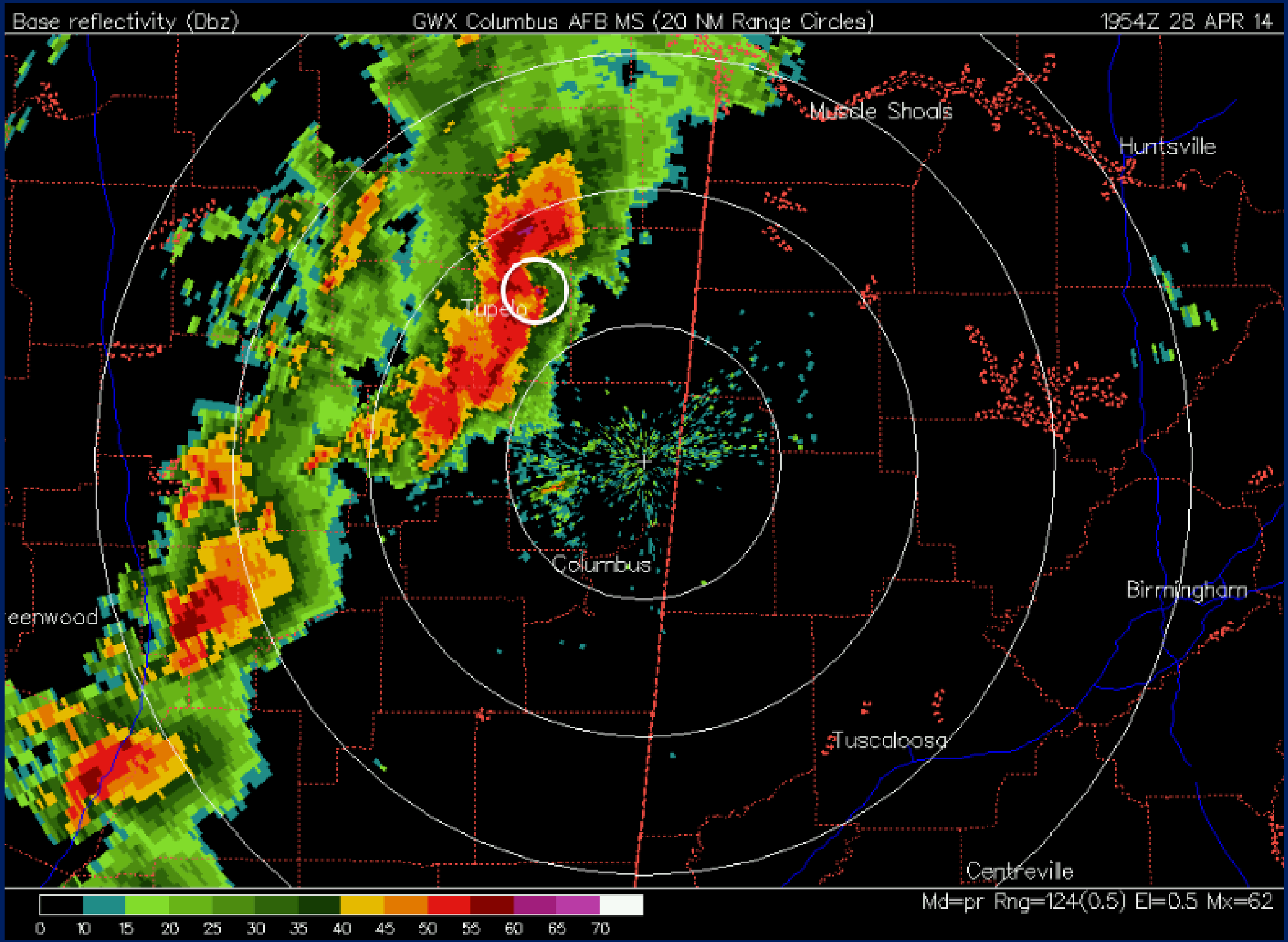


The shape of an antenna determines the shape of a beam. The WSR-88D has a parabolic-shaped antenna. This focuses the radio waves into a narrow, coned-shaped beam. The antenna can be tilted to scan many altitudes of the atmosphere.

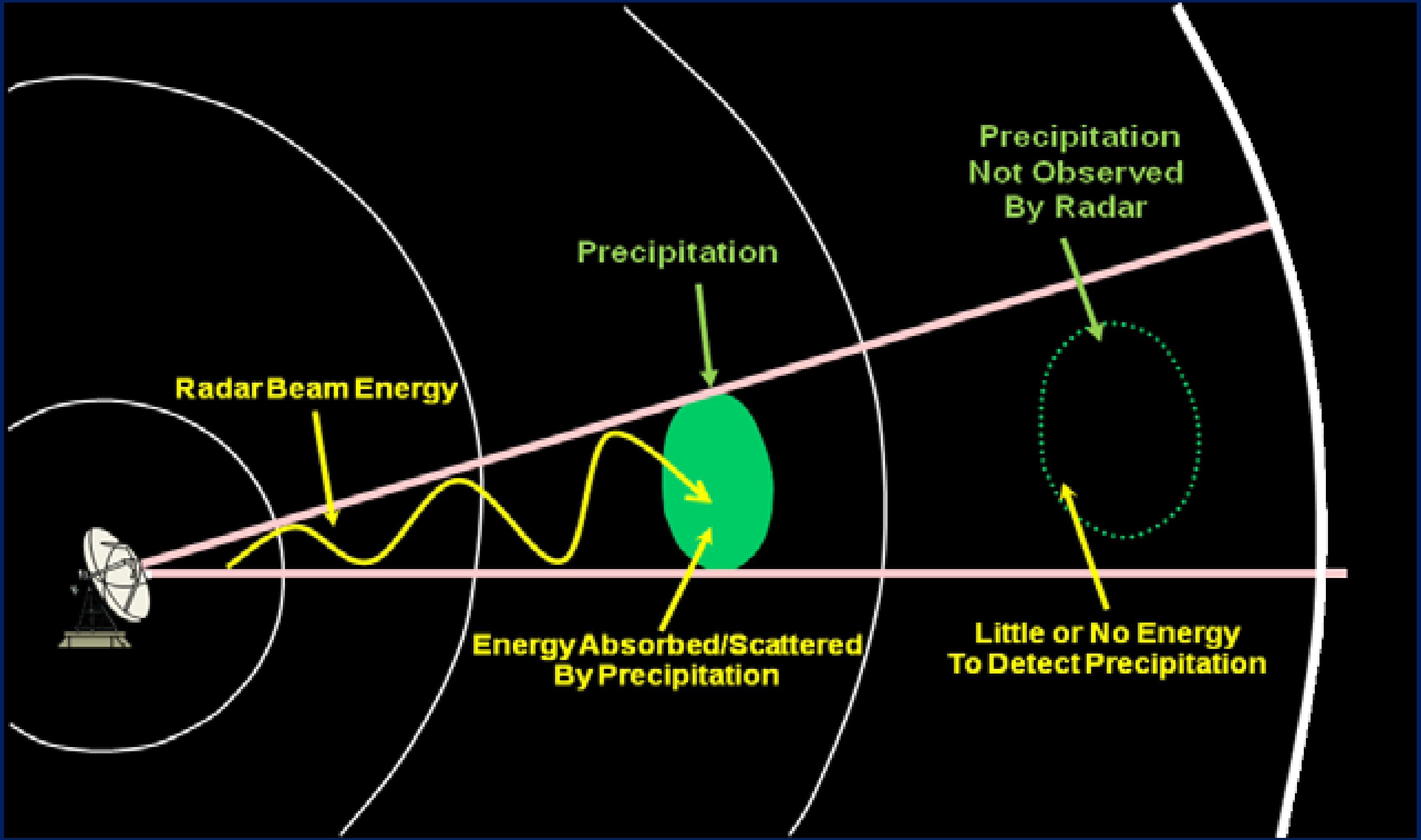
The amount of energy returned directly back to the radar after striking a target is called backscattered energy



Targets may include precipitation, clouds, dust, birds, insects, buildings, air mass boundaries, terrain features, etc. Reflectivity is a measurement of the amount of backscattered energy. An echo is the appearance, on a radar display, of the backscattered energy



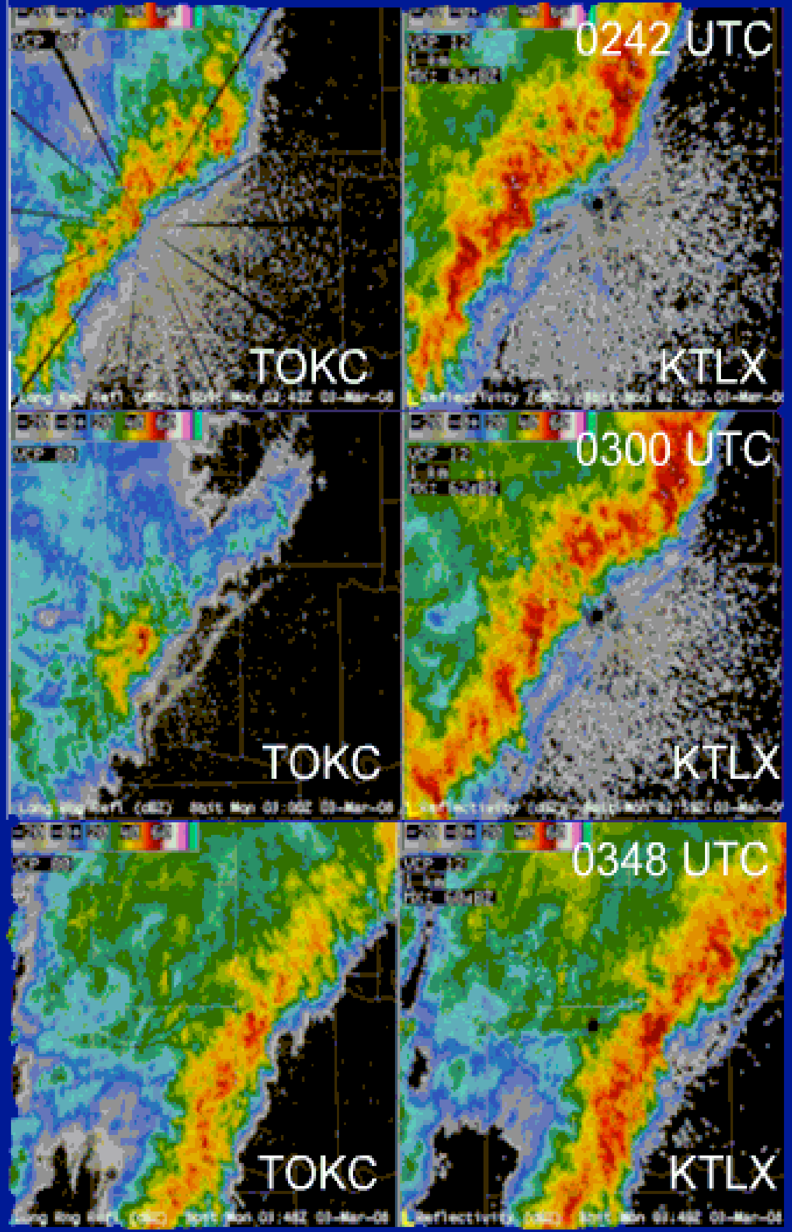
Precipitation attenuation is the decrease of the intensity of energy within the radar beam due to absorption or scattering of the energy from precipitation particles.



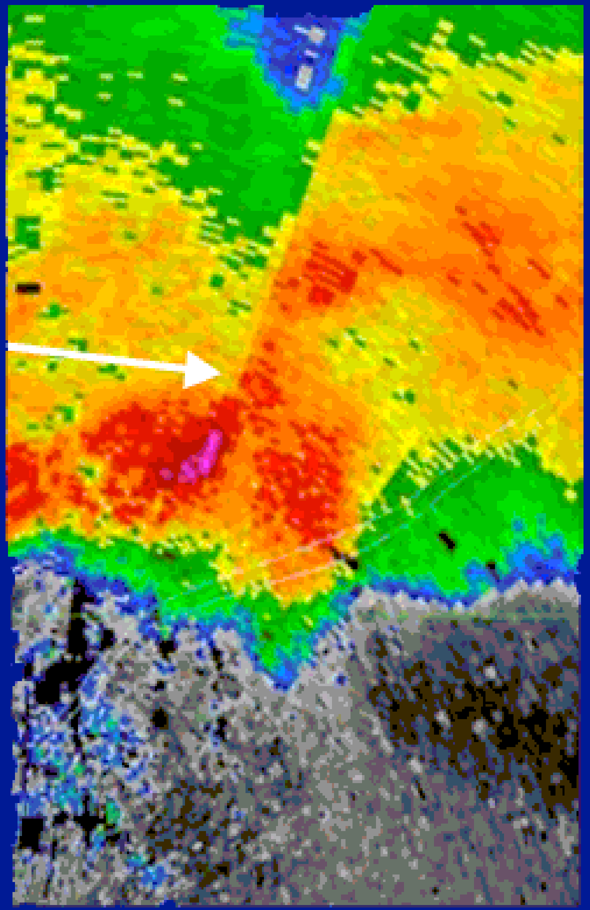
Precipitation close to the radar absorbs and scatters energy within the radar beam. Therefore, very little, if any, energy will reach targets beyond the initial area of precipitation. Because of precipitation attenuation, distant targets (i.e., precipitation) may not be displayed on a radar image.

Attenuation from a squall line

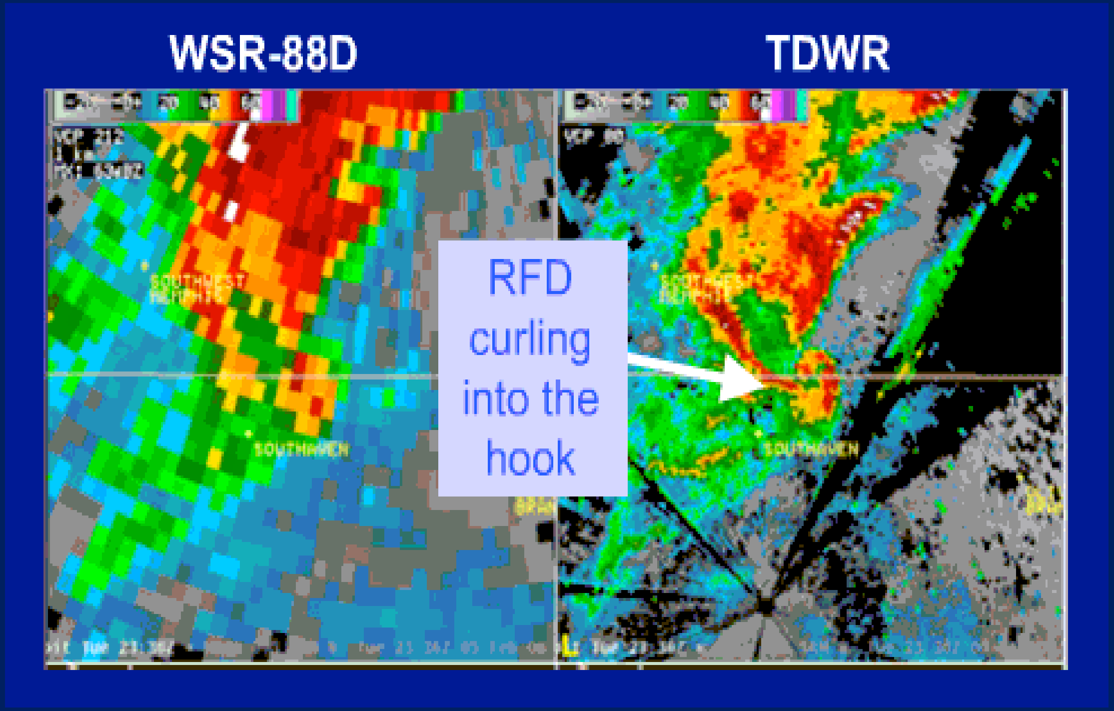
New TDWR | Old NEXRAD

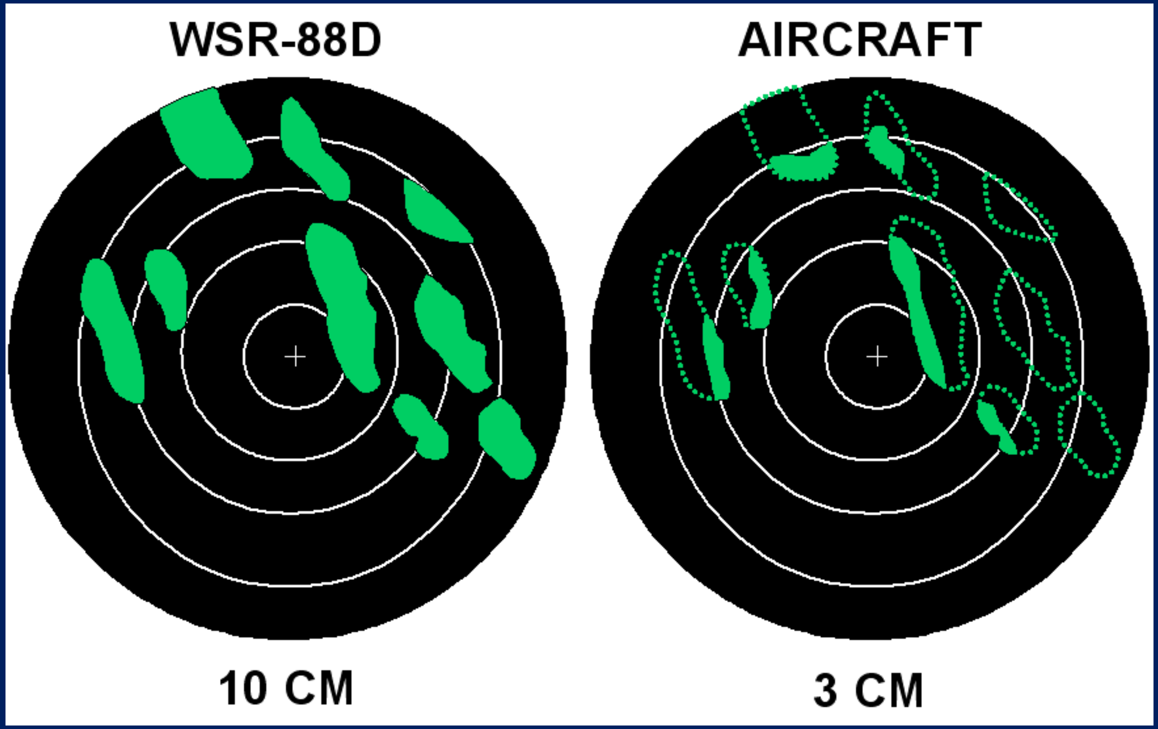


Attenuation behind a cell with hail



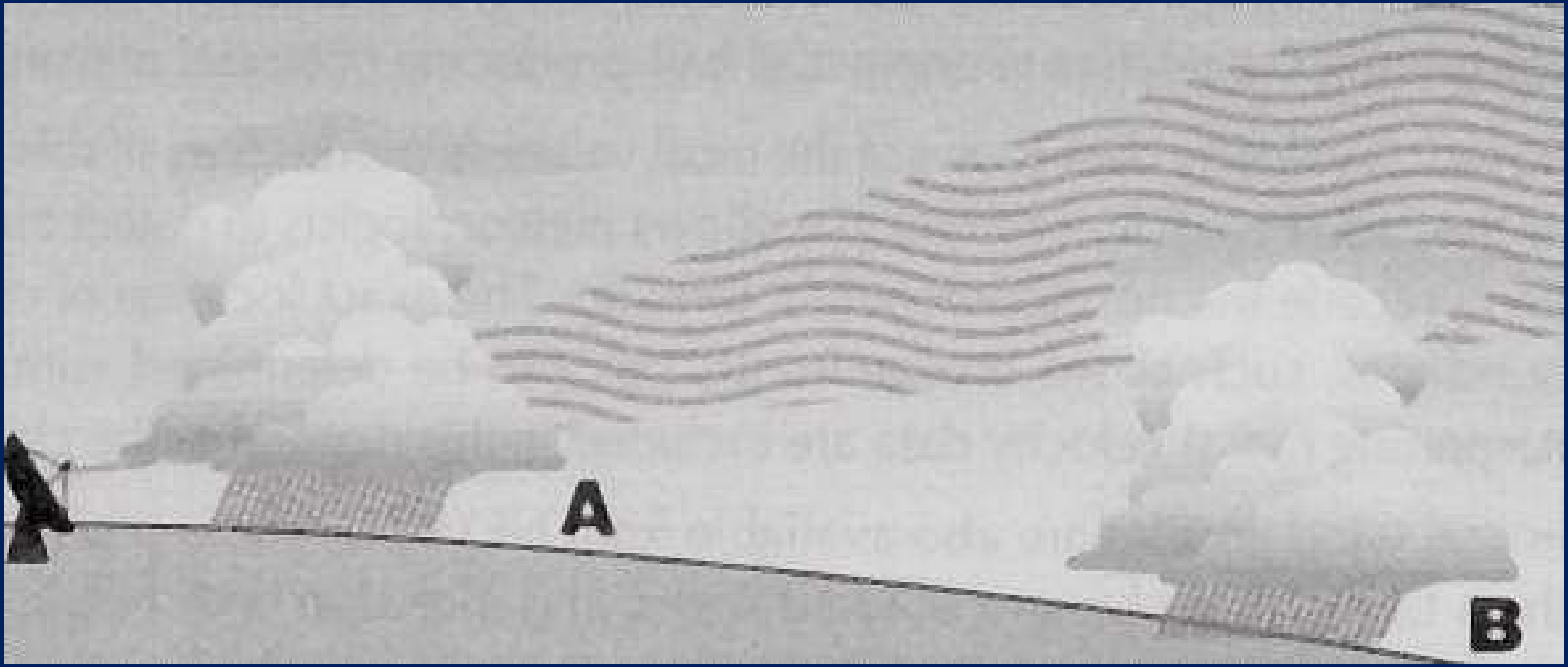
The WSR-88D’s 10-centimeter wavelength is not significantly attenuated by precipitation. However, aircraft radars, which typically have 3-centimeter wavelengths, have a significant precipitation attenuation problem. As a result, aircraft weather radar typically only shows the leading edge of extreme intensity echoes.



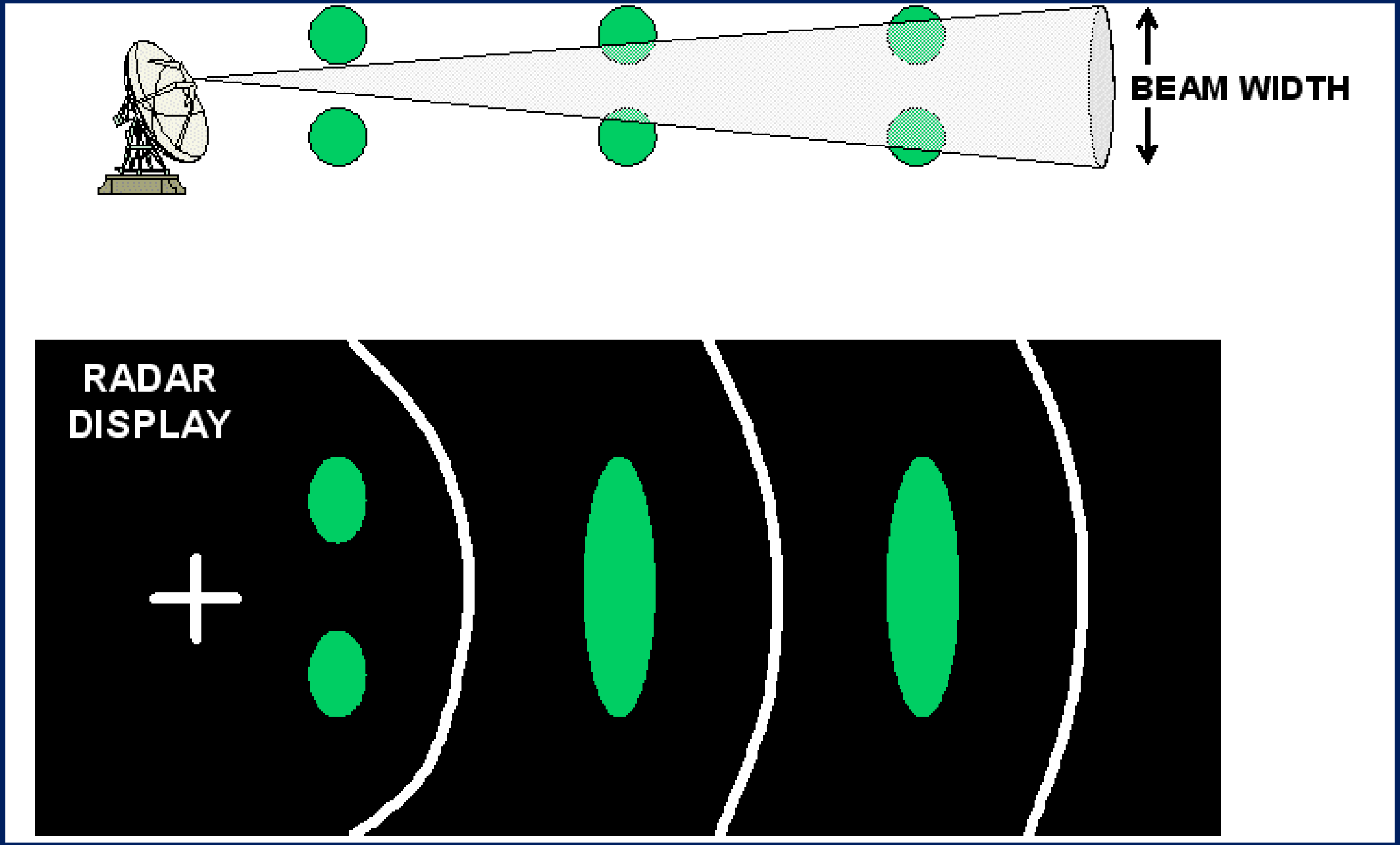


Range attenuation is the decrease of the intensity of energy within the radar beam as the beam gets farther away from the antenna. If not compensated for, a target that is farther away from the radar will appear less intense than an identical target closer to the radar.

Range attenuation is automatically compensated for by the WSR-88D. However, most airborne radars only compensate for range attenuation out to a distance of 50 to 75 nautical miles (NM). Targets beyond these ranges will appear less intense than they actually are.



Beam resolution is the ability of the radar to identify targets separately at the same range, but different azimuths

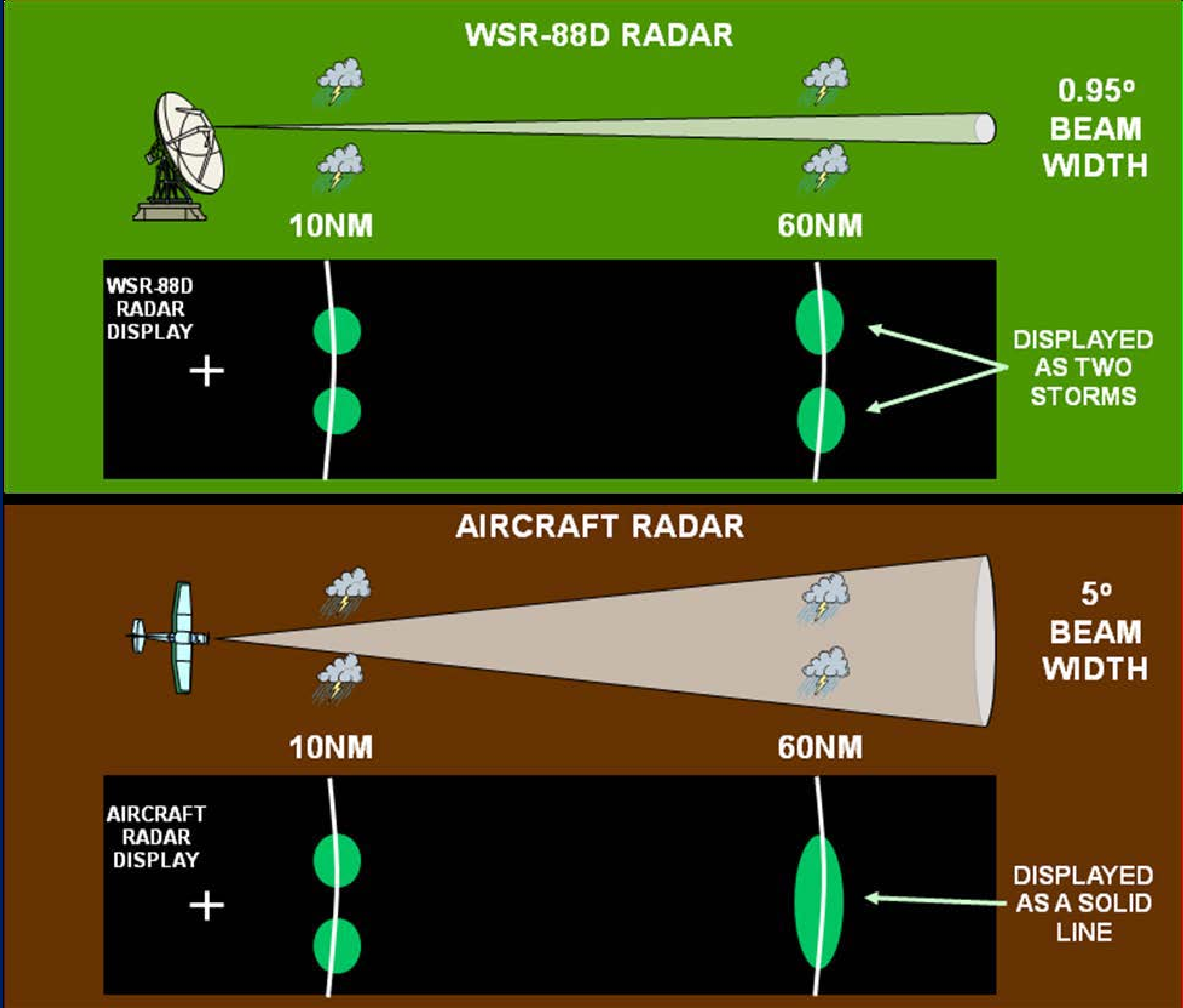


Two targets must be separated by at least one beam width (diameter) in order to be displayed as two separate echoes on a radar image.

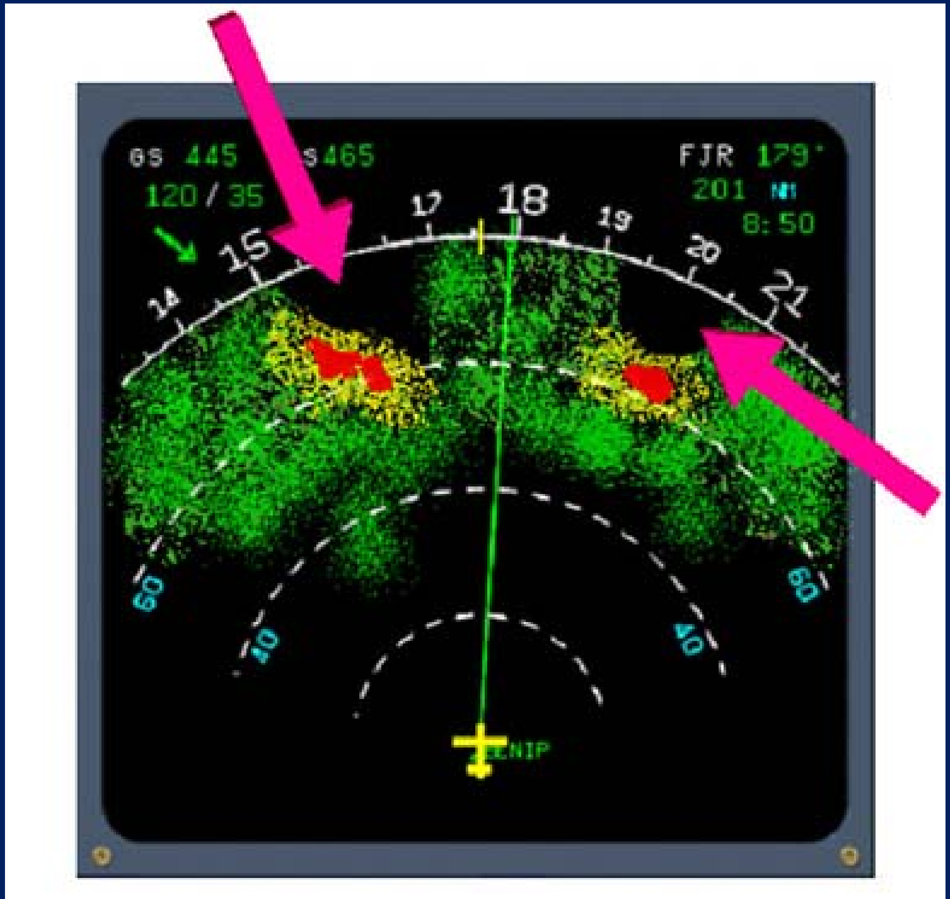
The WSR-88D has a beam width of 0.95°. Therefore, at a range of 60 NM, targets separated by at least 1 NM will be displayed separately. At a range of 120 NM, targets separated by at least 2 NM will be displayed separately.

Aircraft radar have beam widths that vary between 3 and 10°. Assuming an average beam width of 5° at a range of 60 NM, targets separated by at least 5.5 NM will be displayed separately. At a range of 120 NM, targets separated by at least 10 NM will be displayed separately.

In the example above, the targets (thunderstorms) are at the same range in azimuths for both the aircraft and WSR-88D radar. At 10 NM, the beam width is small enough for both the WSR-88D and aircraft radar to display the thunderstorms separately. At 60 NM, the WSR-88D beam width is still small enough to display both thunderstorms separately. However, the aircraft radar beam width is larger, which results in the two thunderstorms being displayed as one echo.



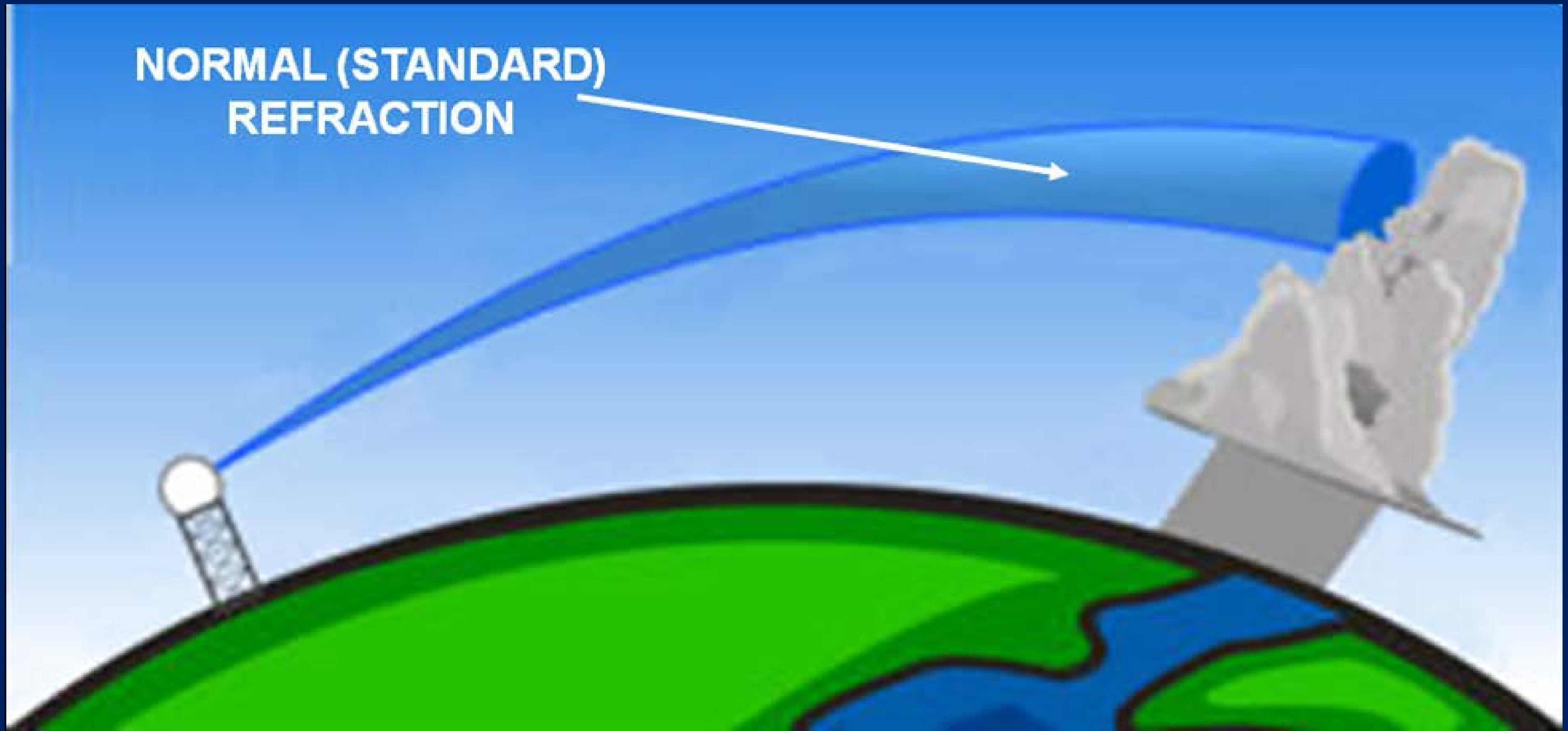
Note that the beam becomes wider at greater distances from the radar. Therefore, the beam resolution decreases with increasing range from the radar. As a result, lines of precipitation may appear to break up as they move closer to the radar. In reality, the breaks in the precipitation were most likely always there.



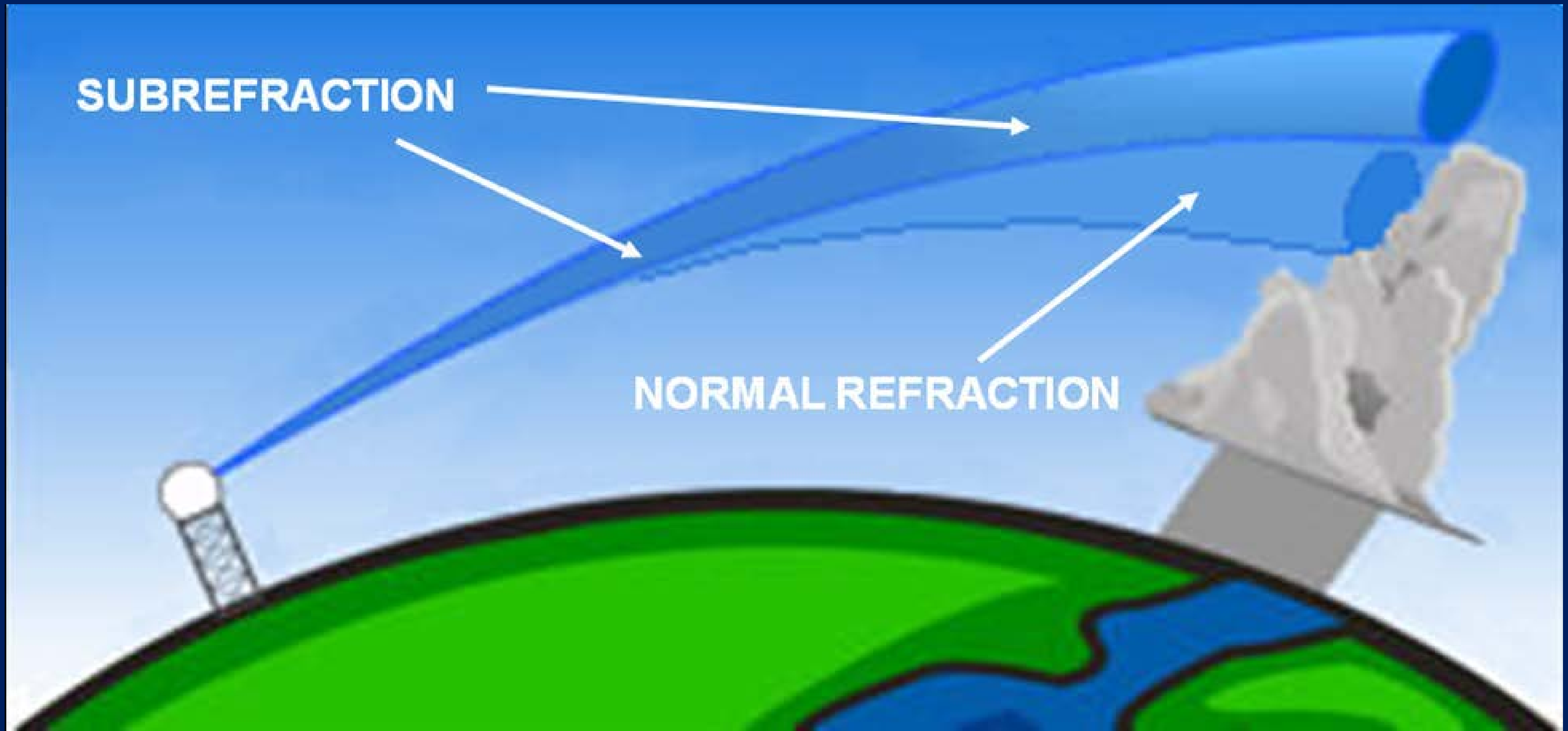
Radar beams do not travel in a straight line. The beam is bent due to differences in atmospheric density. These density differences, caused by variations in temperature, moisture, and pressure, occur in both the vertical and horizontal directions, and affect the speed and direction of the radar beam.

In a denser atmosphere, the beam travels slower. Conversely, in the less dense atmosphere, the beam travels faster. Changes in density can occur over very small distances, so it is common for the beam to be in areas of different densities at the same time as it gets larger. The beam will bend in the direction of the slower portion of the wave.

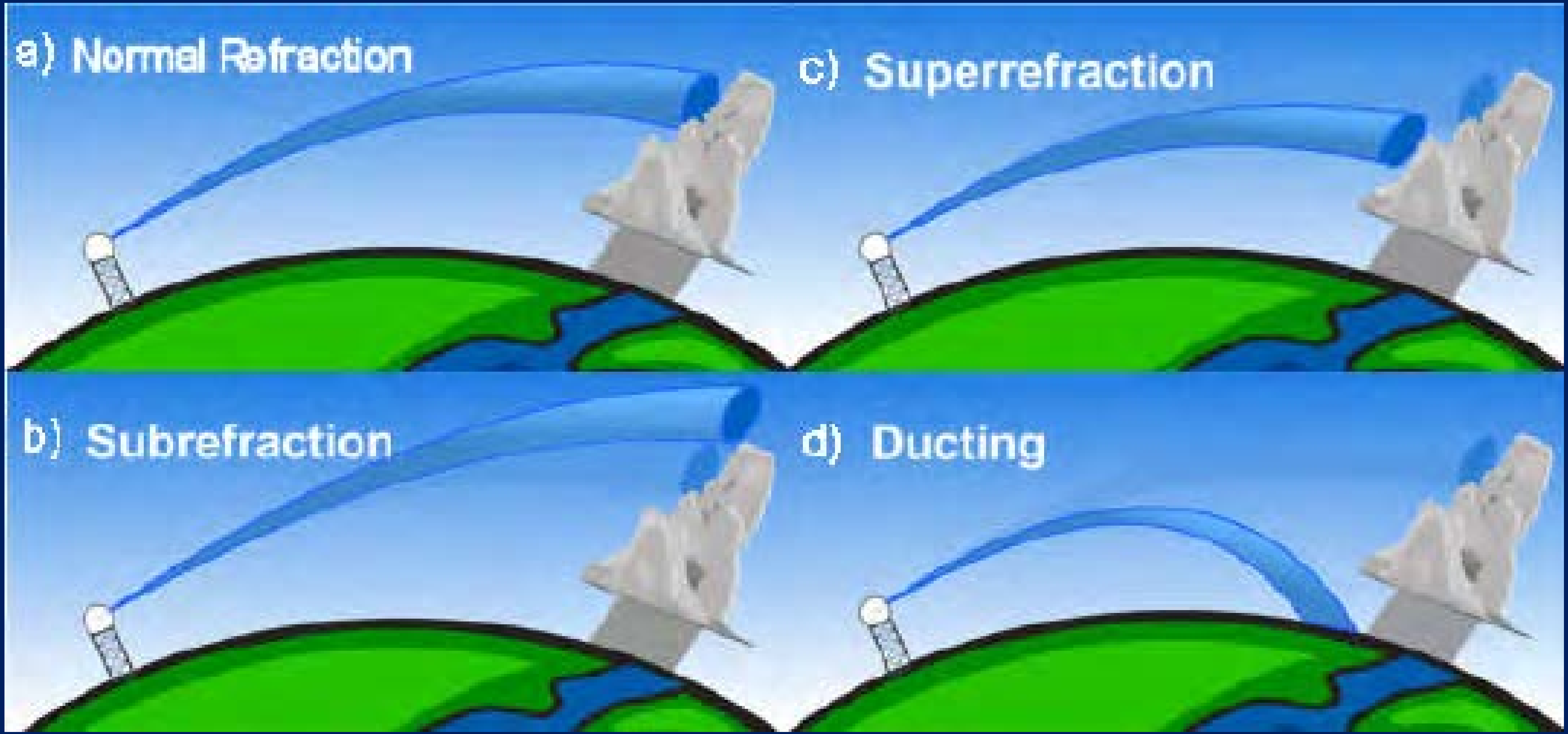
Under normal (i.e., standard) conditions, the atmosphere's density gradually decreases with increasing height. As a result, the upper portion of a radar beam travels faster than the lower portion of the beam. This causes the beam to bend downward The radar beam curvature is less than the curvature of the Earth. Therefore, the height of the radar beam above the Earth's surface increases with an increasing range.



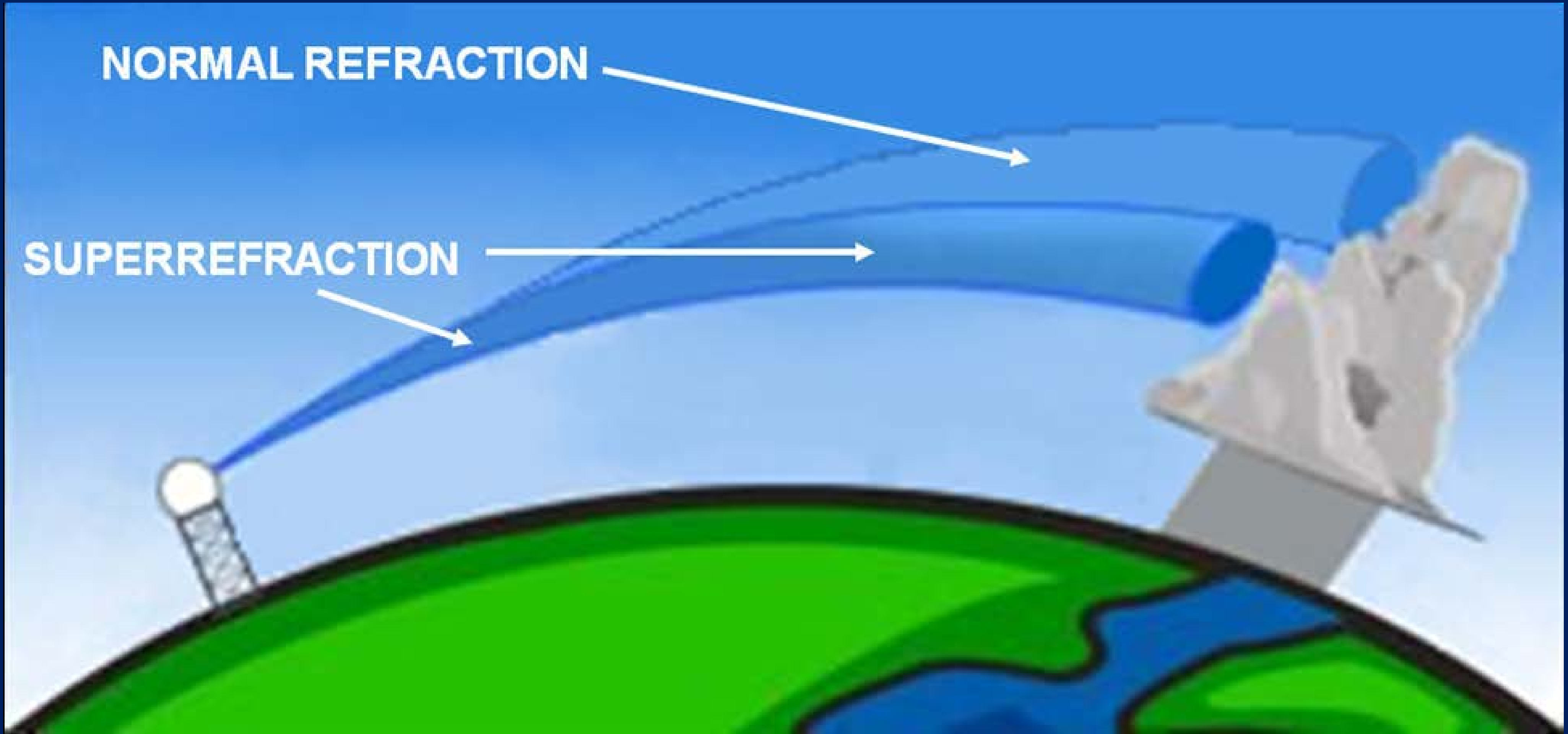
Atmospheric conditions are never normal or standard. Sometimes, the density of the atmosphere decreases with height at a more than normal rate. When this occurs, the radar beam bends less than normal. This phenomenon is known as subrefraction



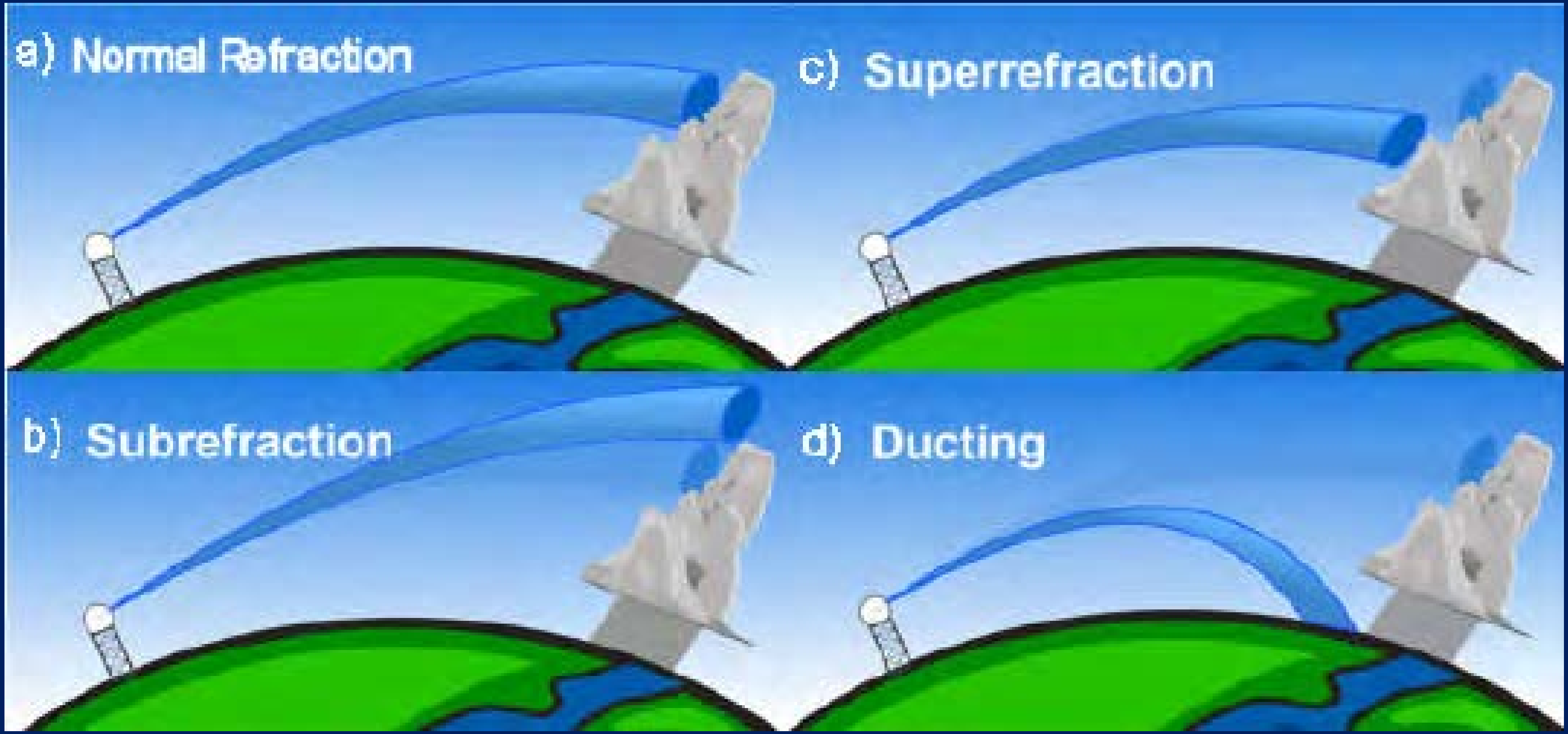
Subrefraction may cause the radar beam to overshoot objects that would normally be detected. For example, distant thunderstorms may not be detected with subrefraction. Subrefraction may also cause radar to underestimate the true strength of a thunderstorm. Thunderstorms may appear weaker on radar because subrefraction causes the radar beam to strike the thunderstorm near the top of the cumulonimbus cloud, where the precipitation particles tend to be smaller.



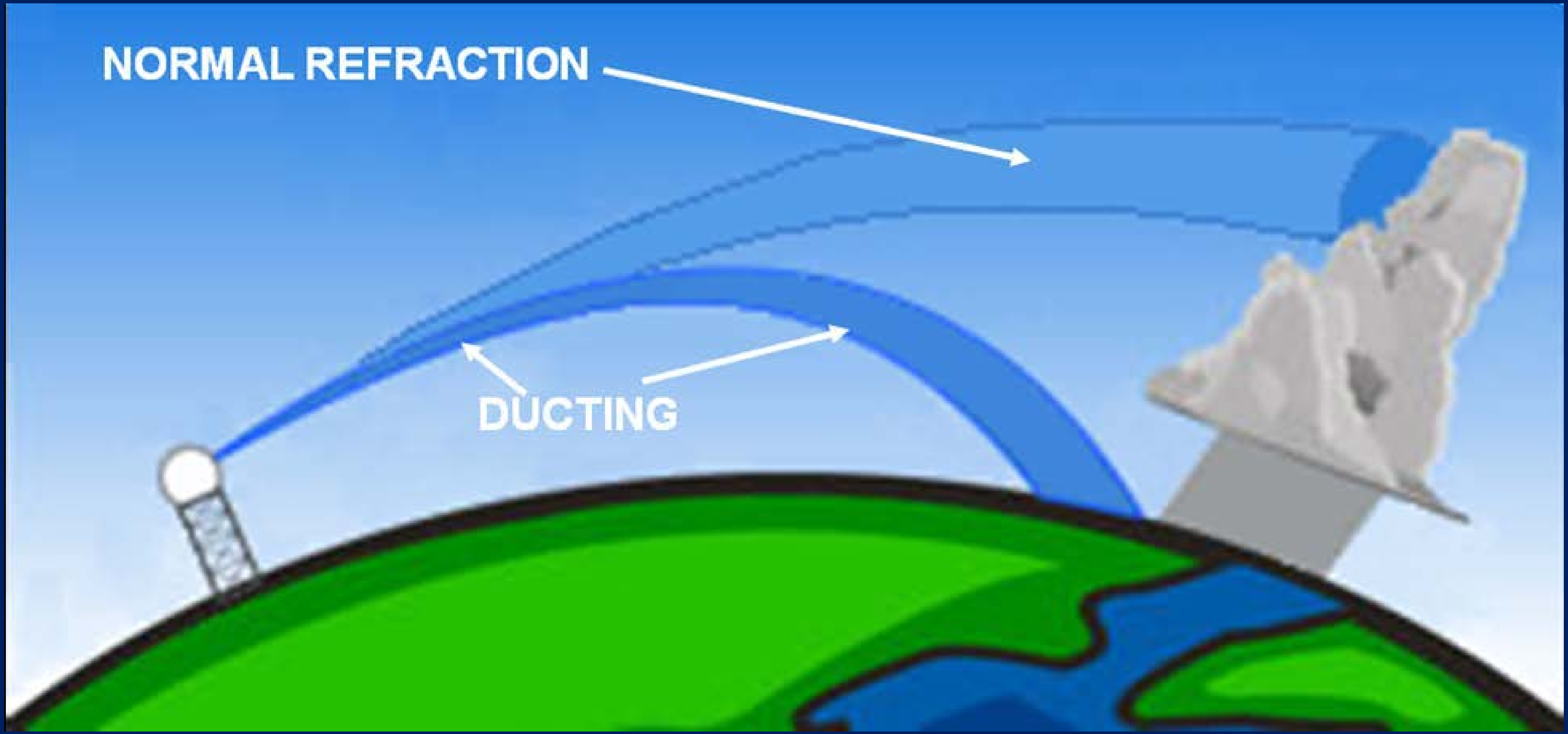
Conversely, sometimes the density of the atmosphere decreases with height at a less than normal rate, or even increases with height. When this occurs, the radar beam will bend more than normal. This phenomenon is called superrefraction



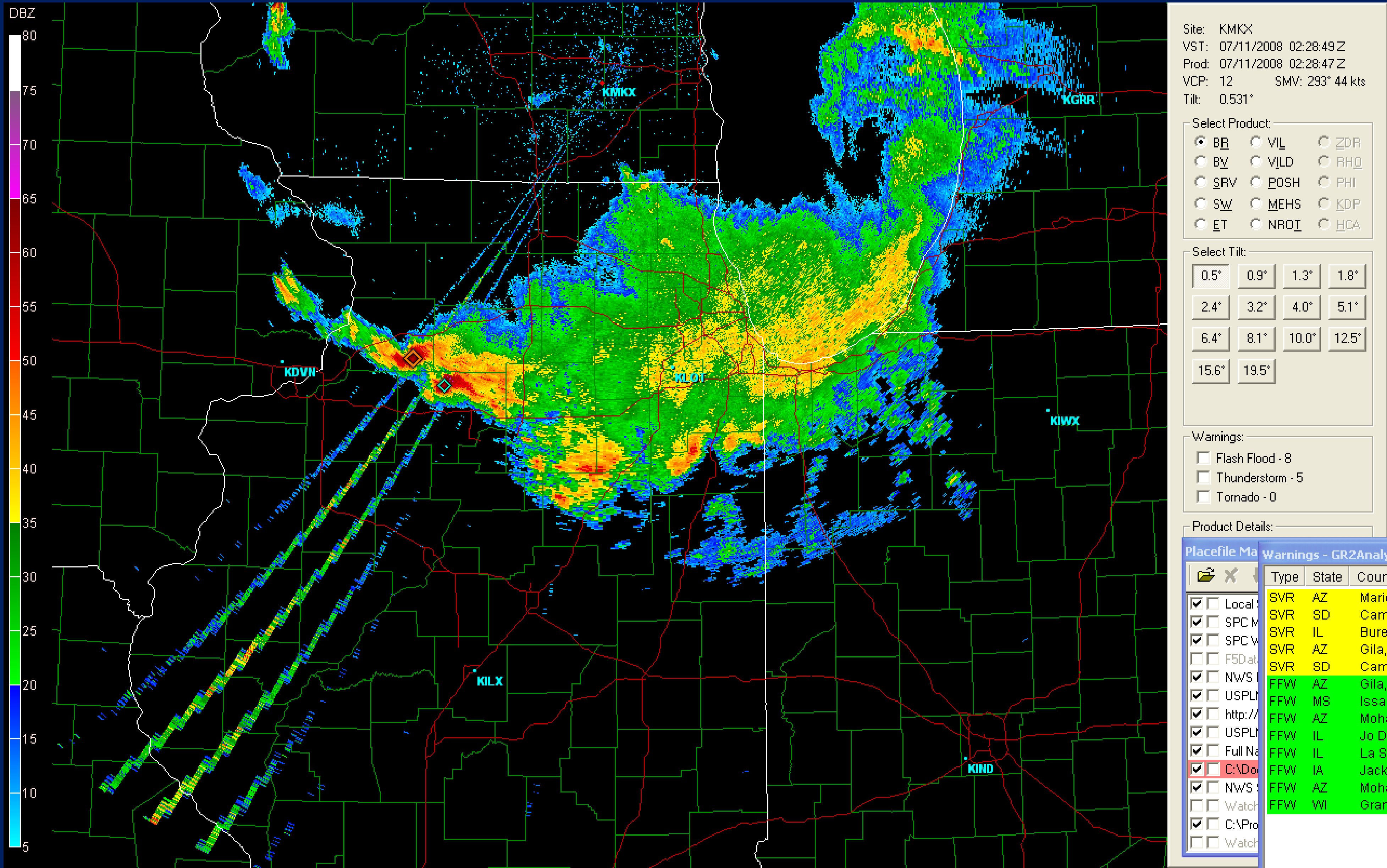
Superrefraction causes the radar beam to travel closer to the Earth’s surface than what would occur in a normal atmosphere. This can lead to overestimating the strength of a thunderstorm, as the beam would detect the stronger core of the storm, where precipitation-sized particles are larger.



If the atmospheric condition that causes superrefraction bends the beam equal to, or greater than, the Earth's curvature then a condition called ducting, or trapping, occurs



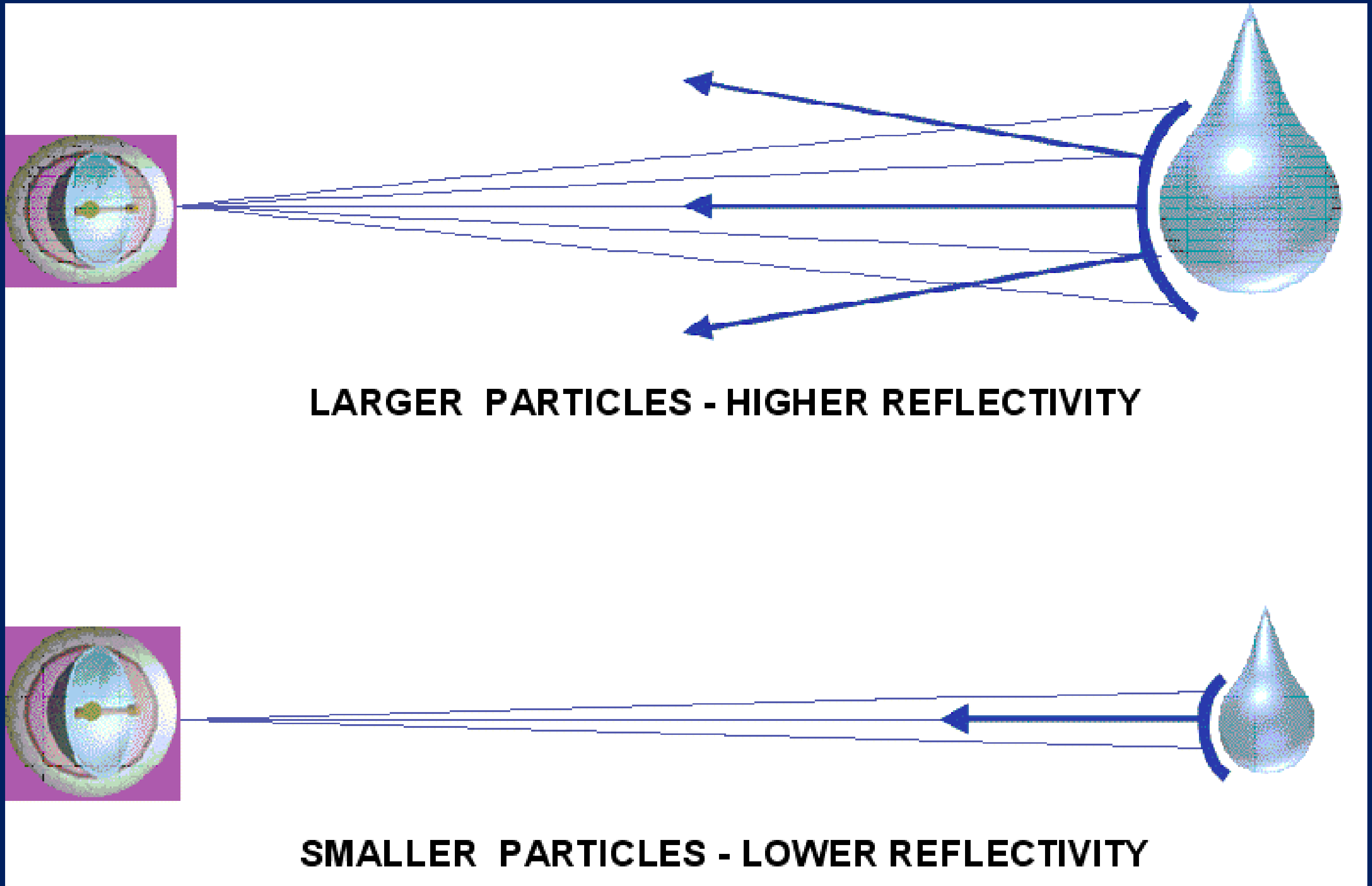
When ducting occurs, the radar beam will hit the surface of the Earth, causing some of the beam's energy to backscatter. This often leads to false echoes, also known as anomalous propagation (AP), to appear in the radar display.



The intensity of precipitation is determined from the amount of energy backscattered by precipitation, also known as reflectivity. Reflectivity is determined by:

- The size of precipitation particles;
- The precipitation state (liquid or solid);
- The concentration of precipitation (particles per volume); and
- The shape of the precipitation.

Intensity of Liquid Precipitation. The most significant factor in determining the reflectivity of liquid particles is the size of the precipitation particle



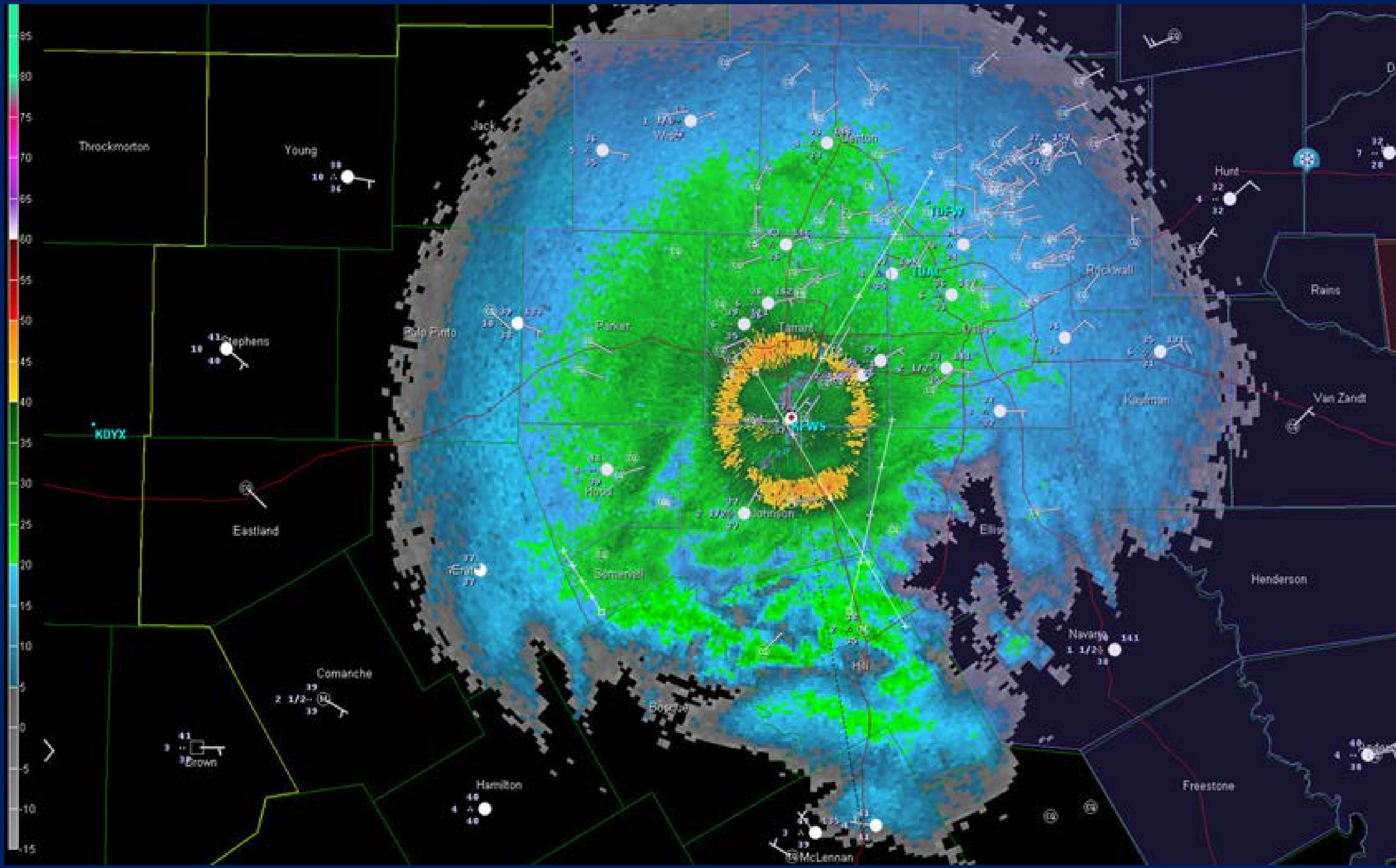
Larger particles have greater reflectivity than smaller particles. For example, a particle with a 1/4-inch diameter backscatters the same amount of energy as 64 particles that each have a 1/8-inch diameter.

Radar images/intensity scales are associated with reflectivities that are measured in decibels of Z (dBZ). The dBZ values increase based on the strength of the return signal from targets in the atmosphere.

Typically, liquid precipitation-sized particle reflectivities are associated with values that are 15 dBZ or greater. Values less than 15 dBZ are typically associated with liquid cloud-sized particles. However, these lower values can also be associated with dust, pollen, insects, or other small particles in the atmosphere.

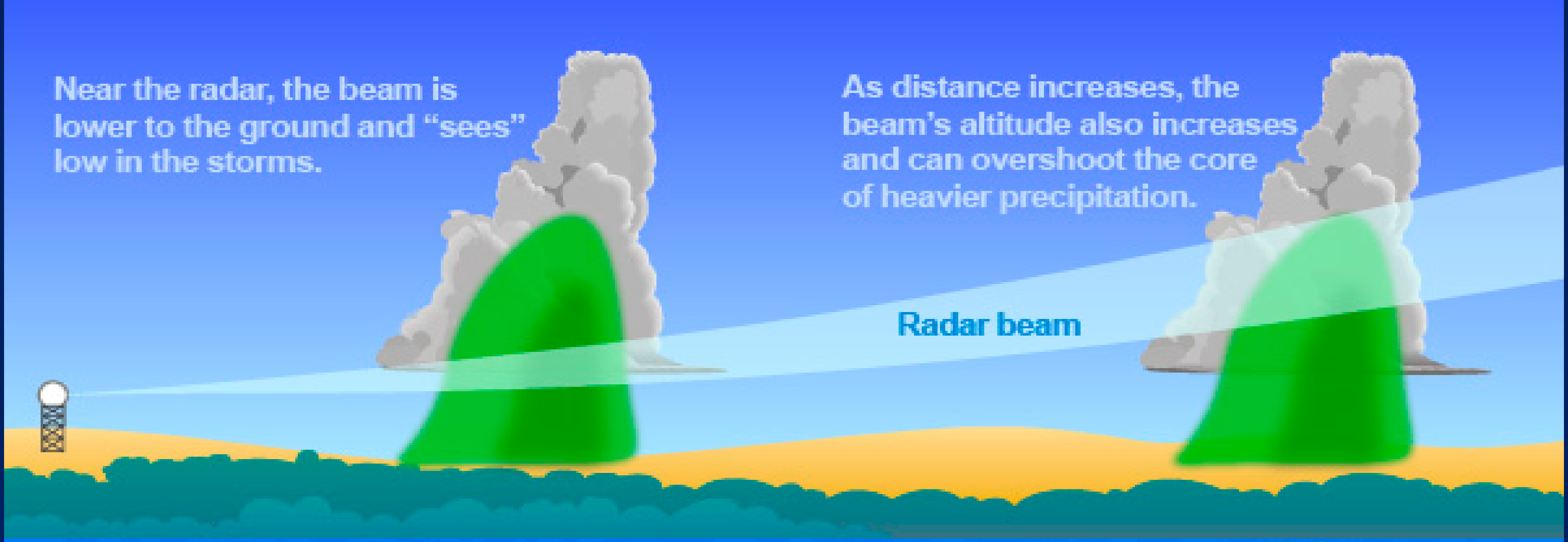
Intensity of Snow. A radar image cannot reliably be used to determine the intensity of snowfall. However, in general, snowfall rates generally increase with increasing reflectivity.

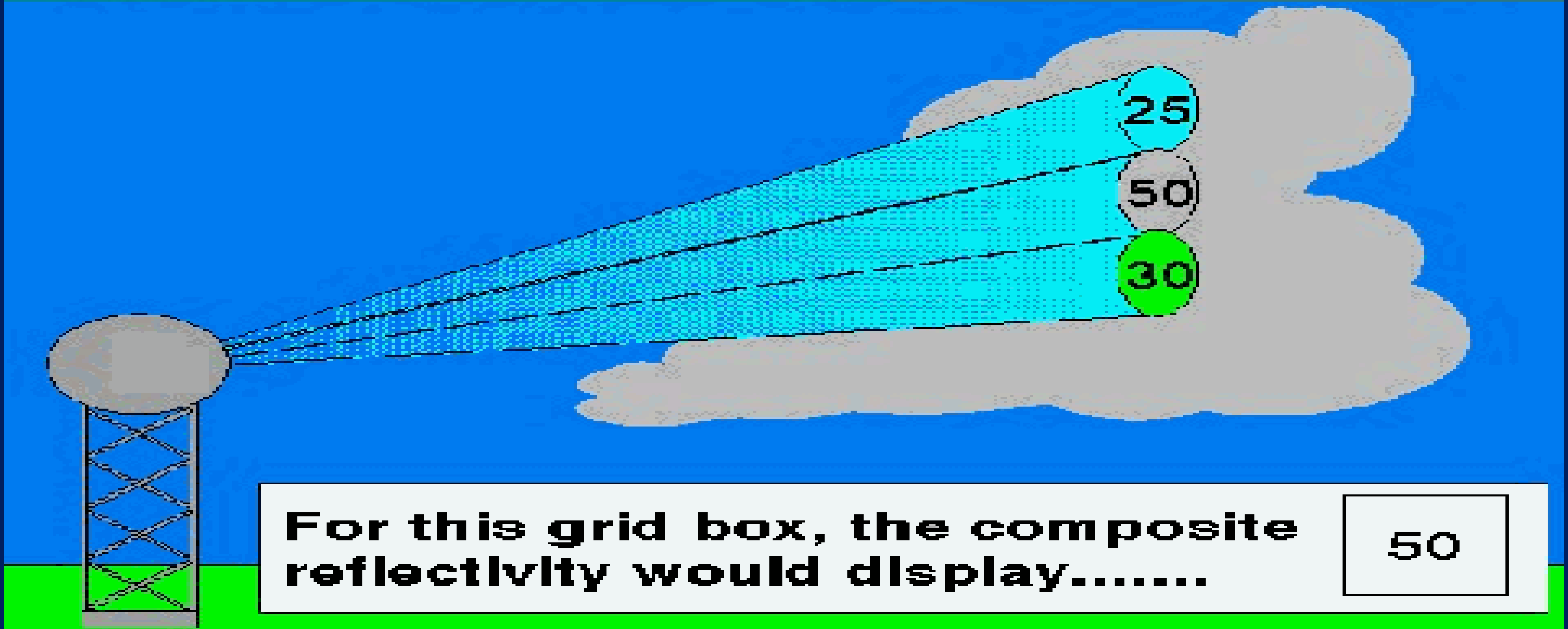
Bright Band. Bright band is a distinct feature observed by radar that denotes the freezing (melting) level. The term originates from a band of enhanced reflectivity that can result when a radar antenna scans through precipitation. The freezing level in a cloud contains ice particles that are coated with liquid water. These particles reflect significantly more energy (appearing to the radar as large raindrops) than the portions of the cloud above and below the freezing layer.



RADAR

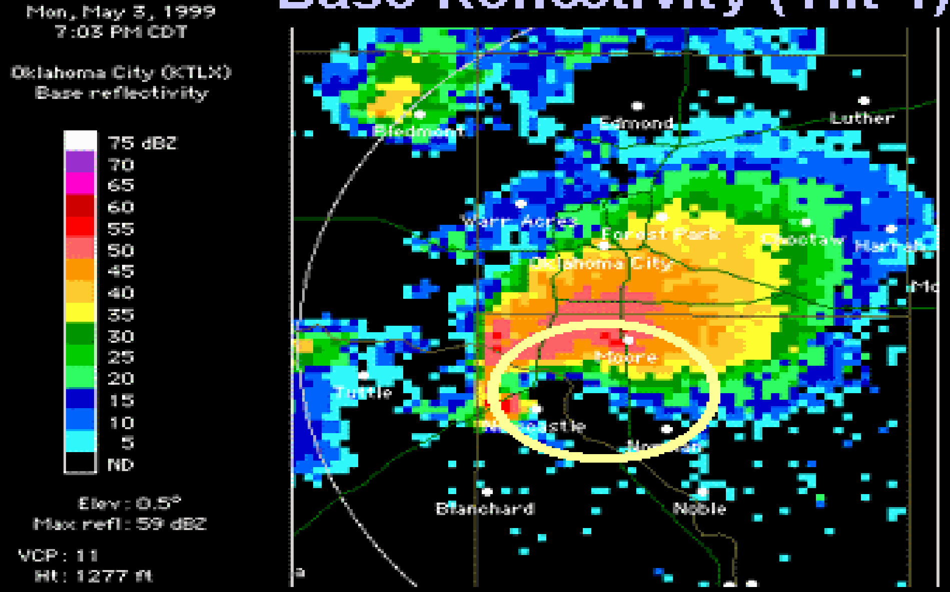
Composite Radar Reflectivity: The radar takes several sweeps of the atmosphere and combines the images into one image. Problem is it makes showers appear as storms.

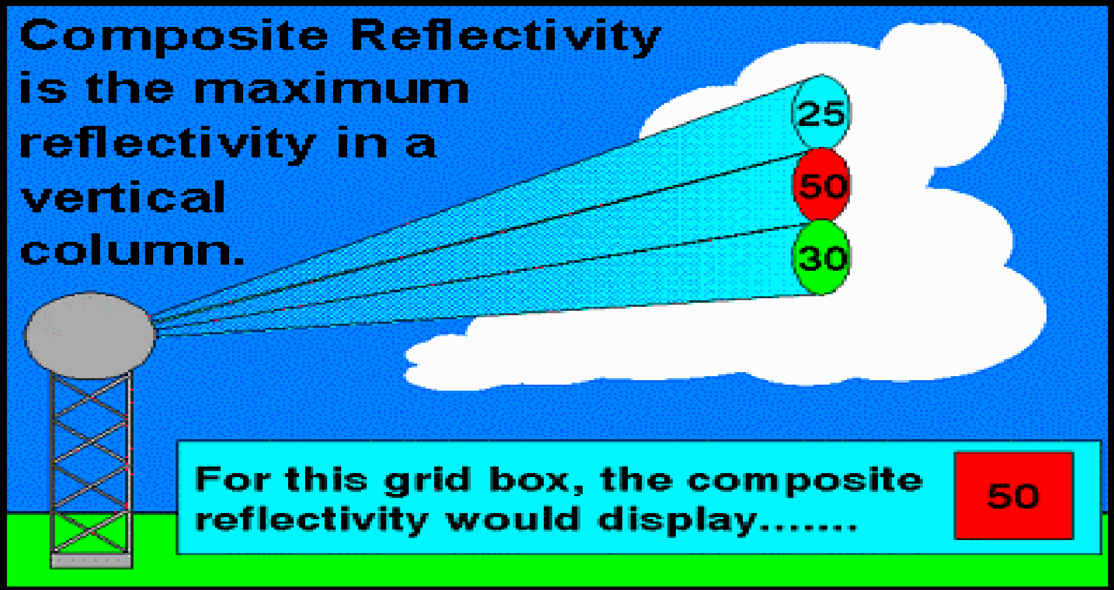

Near the radar, the beam is lower to the ground and "sees" low in the storms.
As distance increases, the beam's altitude also increases and can overshoot the core of heavier precipitation.
Radar beam


25
50
30
For this grid box, the composite reflectivity would display.......
50

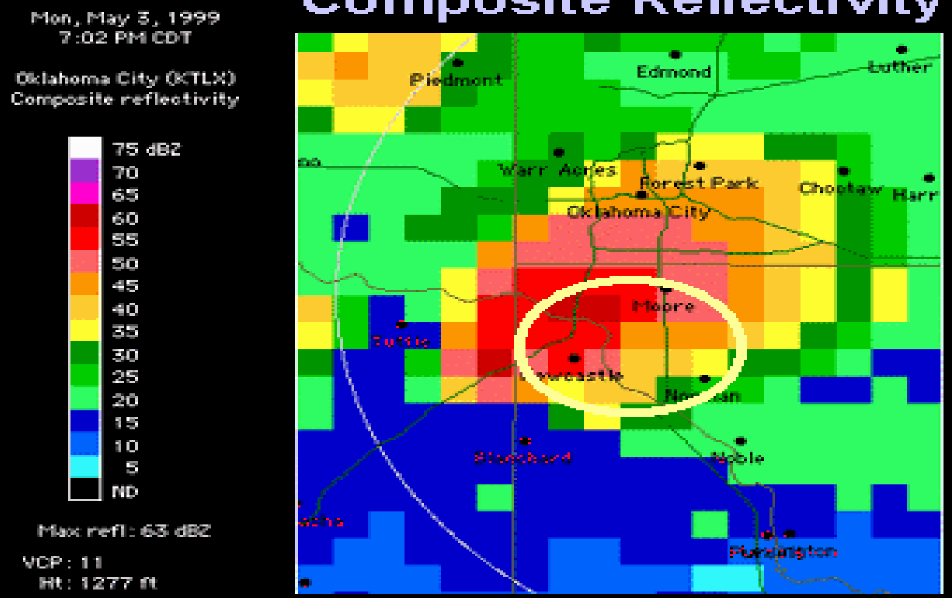
Composite Reflectivity

Base Reflectivity (Tilt 1)





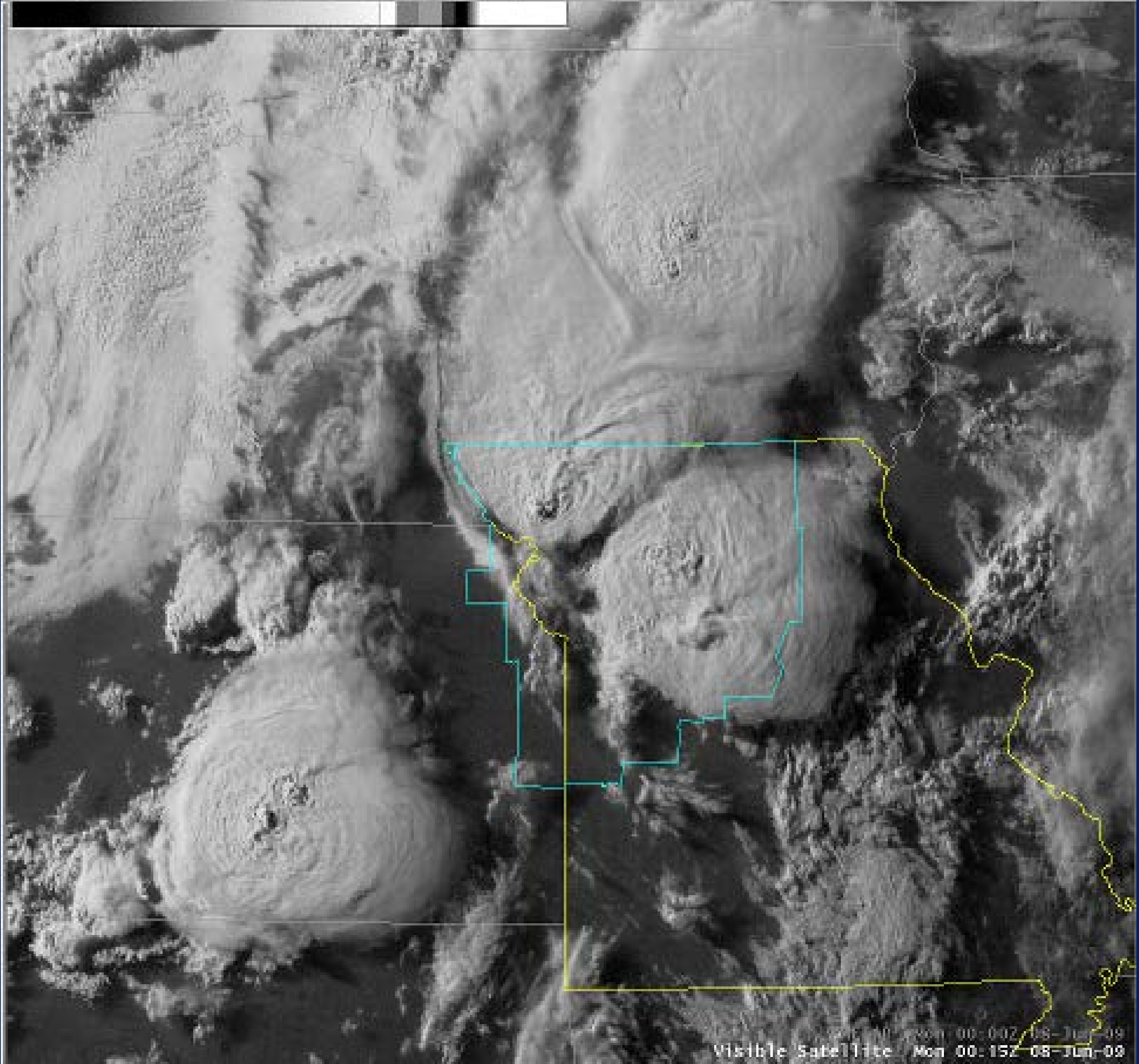
Composite Reflectivity



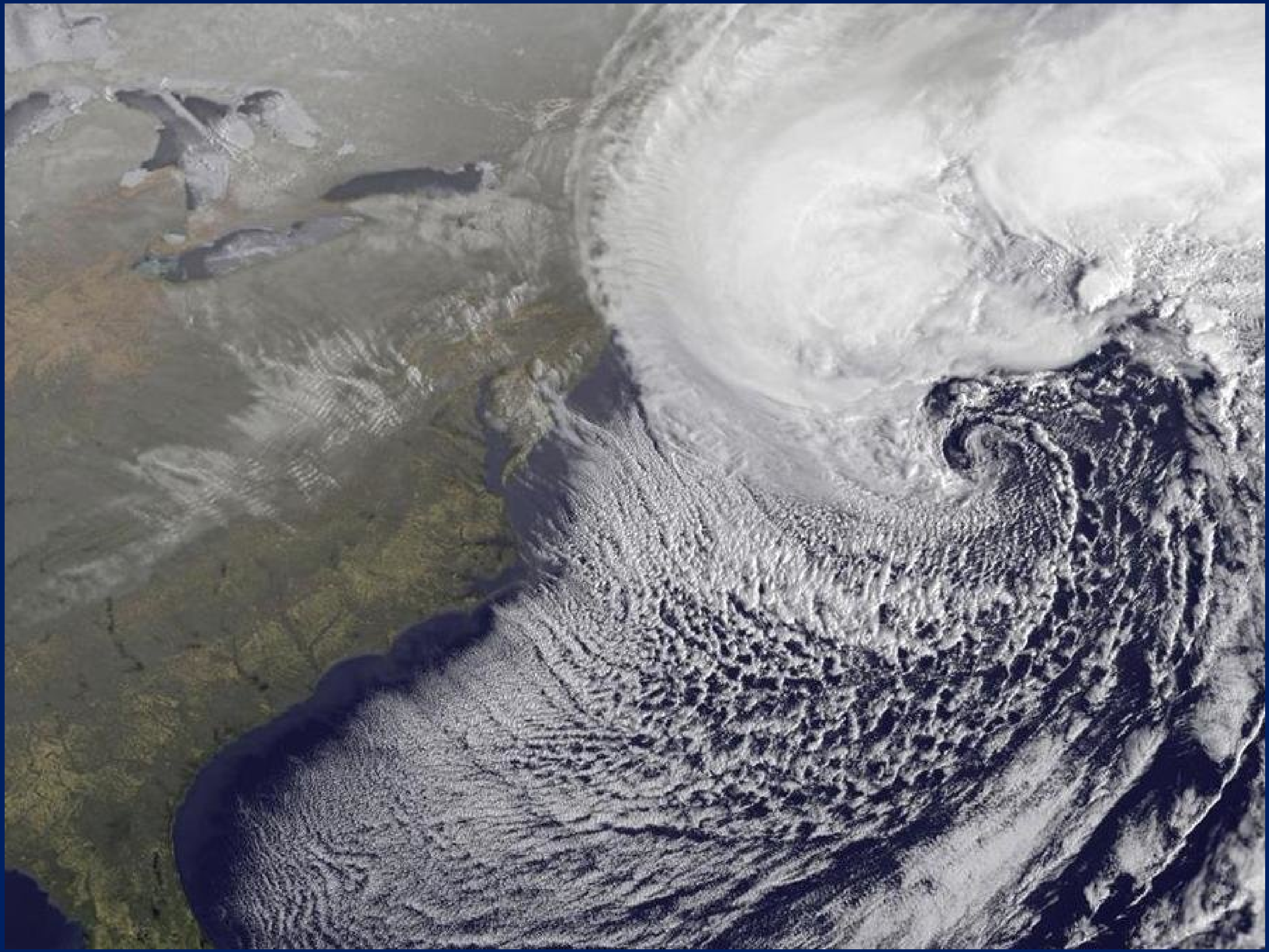
Echoes south of Moore and east of Newcastle appear in Composite Reflectivity but not in Tilt 1 of Base Reflectivity. These echoes must be observed at some level above Tilt 1.

Be careful when interpreting Composite Reflectivity. It masks low-level features, like hook echoes!

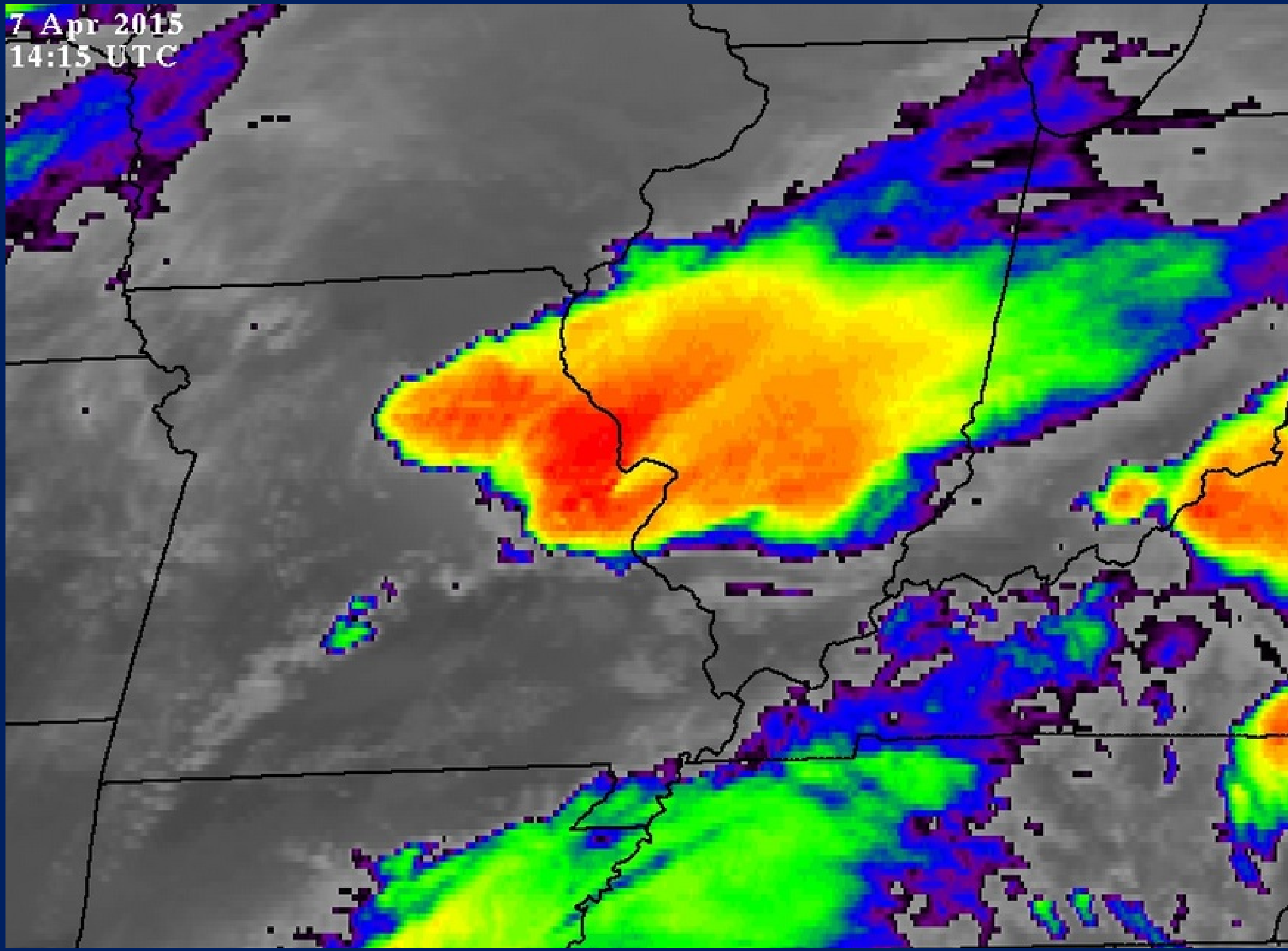
Visible (VIS) satellite imagery and infrared (IR) imagery have different ways of detecting clouds. Visible imagery is produced by the sun's rays reflecting off of clouds. Infrared is produced by sensing the emitted radiation coming off of clouds. The temperature of the cloud will determine the wavelength of radiation emitted from the cloud. Some advantages of visible imagery is that it has a higher resolution, shows cloud texture better, and can be used to get a good idea of the thickness of the cloud. Some advantages of infrared imagery is that is can be used day and night, it can be used to determine the temperature of cloud tops and earth surface features, and it can be used to get a general idea of how high clouds are.



Notice the visible image has a higher resolution of the clouds. On visible it is easier to see the individual cloud elements. There is more texture on visible also. In general you will be able to see vertical development on visible better than on infrared imagery. Brighter white on visible represents thicker cloud. Where there is no cloud you can see the land surface. On visible it is also easier to see land features. Since different land surfaces have a different amount of reflection (different albedo), areas with more reflection will show whiter and less reflection will be darker.



A cloud that is very white of infrared imagery is a cloud that is very cold. Since temperature tends to decrease with height in the troposphere, upper level clouds will be very white while clouds closer to the surface will not be as white. If the clouds near the surface are the same temperature as the land surface it can be difficult to distinguish the clouds from land. In the example infrared image above the clouds are much whiter than the land. From this we know the clouds are colder than the land. Since the clouds are not bright white though this suggest these clouds are low and middle level clouds and not high clouds. The lumpy appearance of the clouds on visible suggests the clouds are cumulus and stratocumulus type. Since the clouds are not wispy and not very bright white like thunderstorm clouds, this suggests the clouds are not very thick and are thus within the low and middle levels of the troposphere.



Below are some general rules to determine cloud characteristics when comparing visible and infrared satellite images.

1. If the cloud is bright white on infrared then it is a high cloud or has a cloud top that is developed high into the troposphere.

2. If a cloud is bright white on visible but is not bright on infrared then it is likely this is a cloud that is close to the earth's surface. This can happen when there is a thick layer of fog or stratus near the surface.

3. If cloud is seen on visible but very hard to see on infrared then it could be a layer of fog or shallow stratus near the surface.

4. Thunderstorms will show bright white on both visible and infrared. A thick cloud will be bright white on visible and cold cloud tops will show bright white on infrared. Look for other features also to make sure it is a thunderstorm such as anvil blowoff, overshooting top and extremely textured on visible imagery.

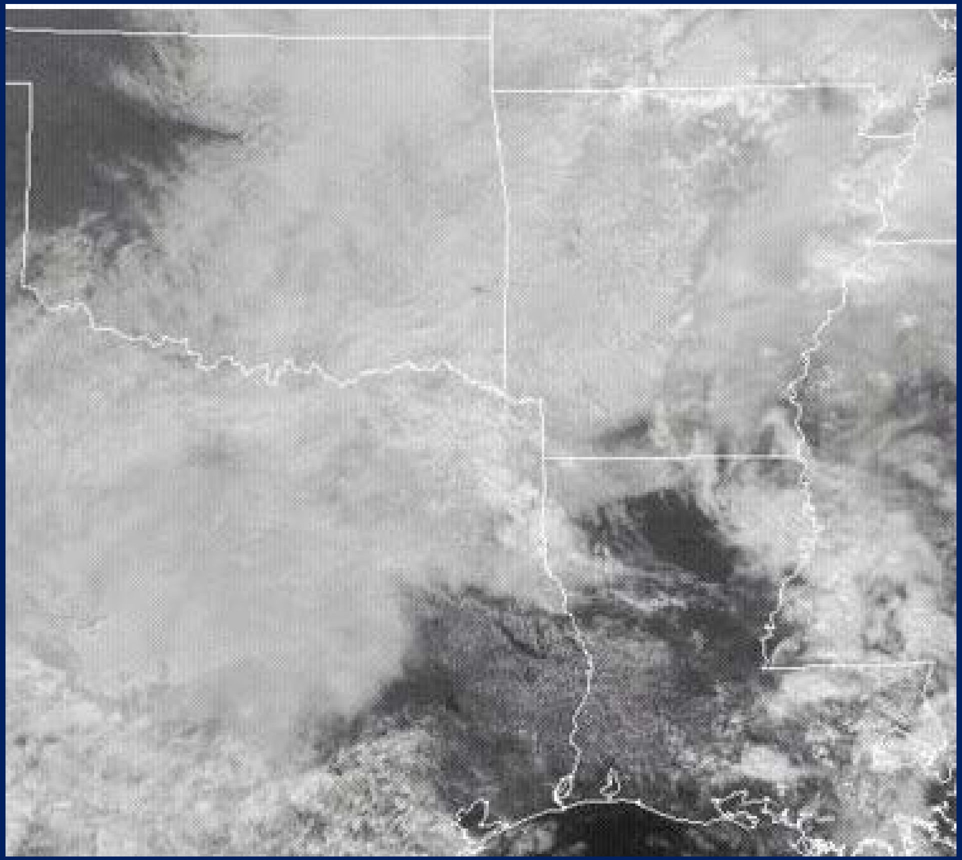
5. If a cloud is not very white on visible then it is likely a thin cloud. If a cloud is not very white on infrared then it is likely a cloud near the surface or it is a very thin cloud.

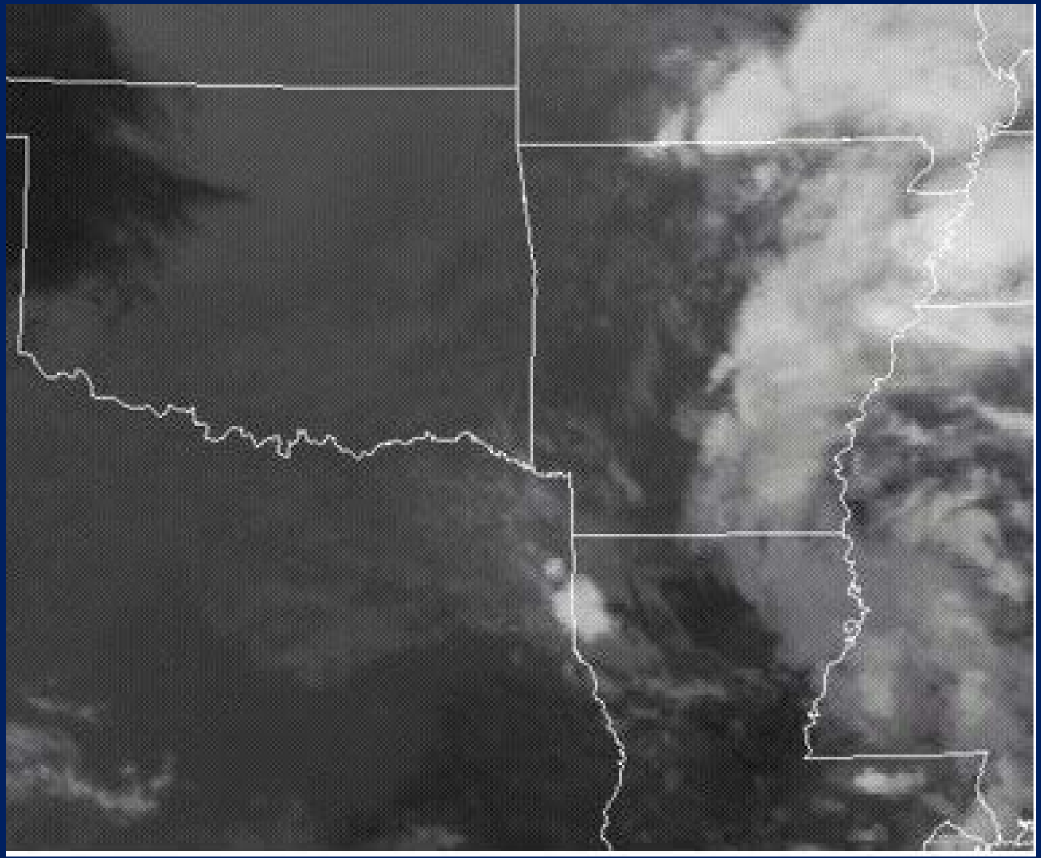
6. When the sun is close to setting, clouds will not show up as white on visible imagery due to less reflection.

7. Wispy looking clouds on visible that are very white on infrared are likely high level clouds such as cirrus or anvil blowoff.

8. Cumulus clouds have a lumpy texture. Stratus clouds have a flat texture especially on infrared. Cirrus clouds tend to be thin and show up white on infrared.

Below is a direct comparison between a VIS and IR image with some important notes about the comparison. Notice much of the cloud is bright white on VIS in Texas but a much darker shade on IR. This indicates low clouds. There are thunderstorms in eastern Tennessee. Notice those cloud areas are bright white on both VIS and IR. There is light rain falling in western Mississippi. These clouds are not as white as the thunderstorm clouds but are more white than the low clouds in much of Texas on IR.

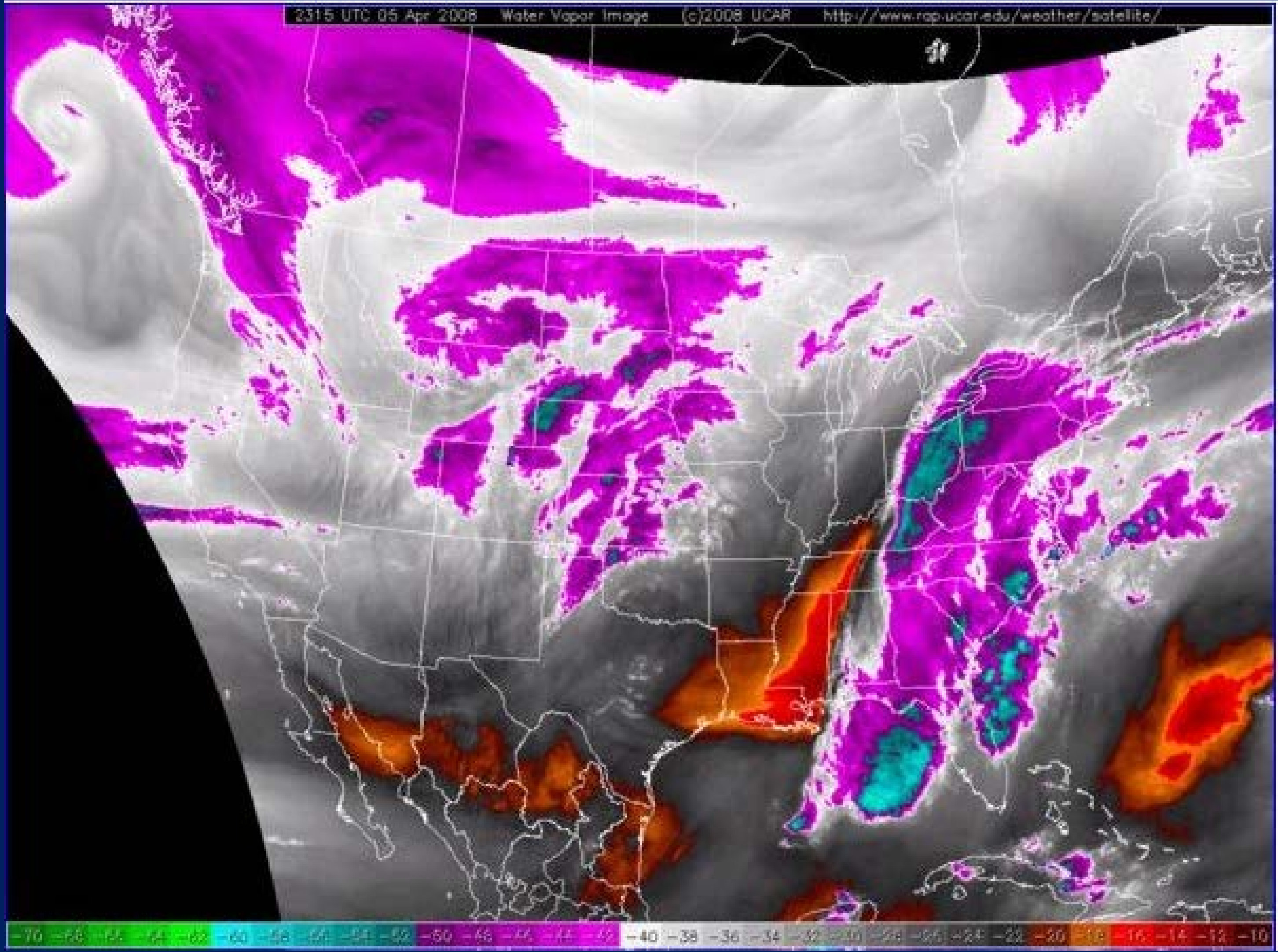




Water vapor imagery is used to analyze the presence and movement of water vapor moisture in the upper and middle levels of the atmosphere. The wavelength spectrum used to detect water vapor is in the 6.7 to 7.3 micrometer wavelength range. The upper and middle levels of the atmosphere are from about 650 mb to the top of the troposphere. Above the troposphere there is very little moisture.

A dark color or warm color indicates a relative lack of upper level moisture. It does not mean though there is a lack of moisture in the lower levels or at the surface. It could be very moist at the surface or it could be fairly dry. A white or cold color indicates a high concentration of water vapor. This layer of water vapor is absorbing radiation in the 6.7 to 7.3 micron range

An example water vapor image that is colorized. The red and orange colors (warmer areas) indicate there is a relative lack of upper and middle level water vapor. Less radiation is being absorbed by water vapor thus the satellite is detecting warmer levels of the atmosphere. Air can be relatively dry by either dry air advecting (moving) over an area or the drying of air by it sinking. When air is sinking it is going to force moisture to stay closer to the surface and not convect or move up into the upper troposphere. The purple, blue and green areas indicates an abundance of upper level moisture. This is moisture advecting or vertically rising into the upper troposphere. This layer of moisture will be cold since temperature in the upper troposphere are very cold. Although the air is very cold, it is saturated or near saturation and thus has much more moisture than it would if the air was sinking. Clouds will show as bright white or colored with cold temperatures and upper level clouds will be very cold. Water vapor can be detected without the presence of clouds.



Below are some uses of water vapor imagery.

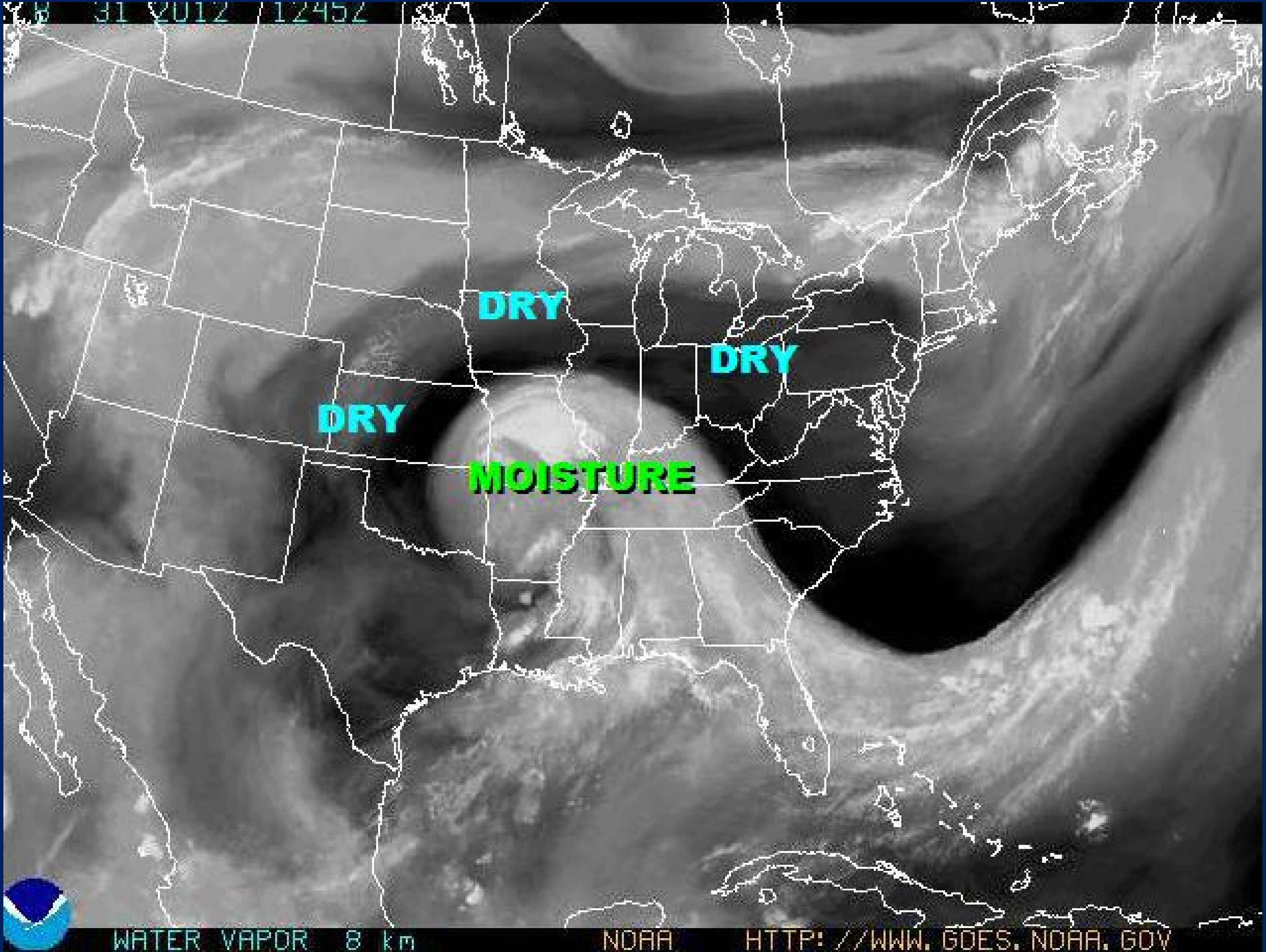
1. Water vapor imagery can be used to detect dry slots. Within the dry slot precipitation intensity diminishes and precipitation chance is reduced. Dry slots can happen when a mid-latitude cyclone or tropical system advects air from a dry air source into its circulation.

2. Water vapor imagery can be used to detect moisture advecting in from the tropics. This moisture laden air can produce big precipitation events when it is advected into a storm system.

3. Dry air in the middle and upper atmosphere indicates there are no significant upper level dynamics aloft that will cause the air to rise over those areas. Very moist air aloft though indicates there could be significant dynamic lifting the air such as jet stream divergence and positive vorticity advection.

4. Water vapor imagery allows the forecaster to see a complete atmospheric motion that is not just where the clouds are. This circulation can be used to point out troughs and ridges and where vertical motions are rising and sinking.

5. Water vapor imagery can be used to pick out the exact position of upper level lows.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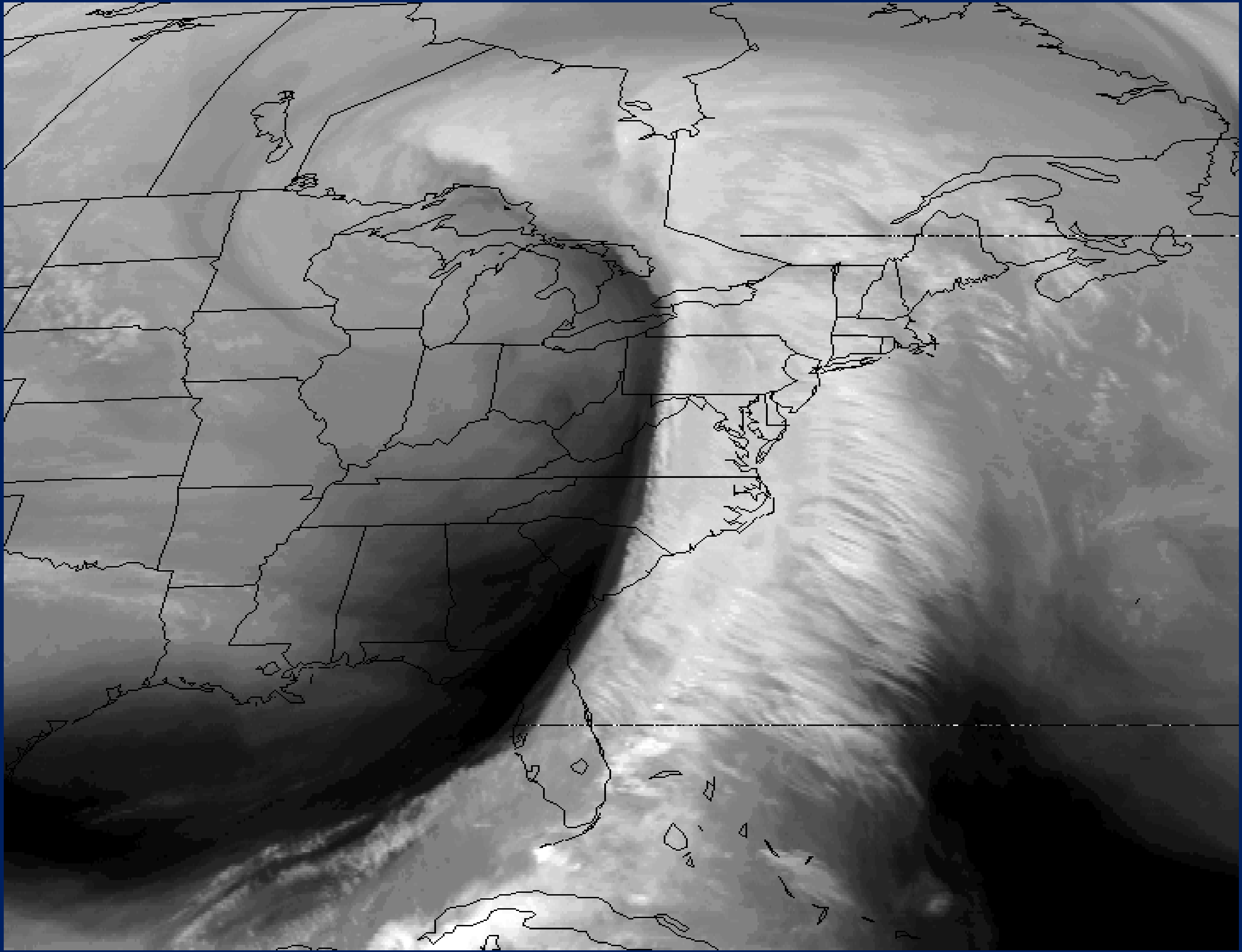

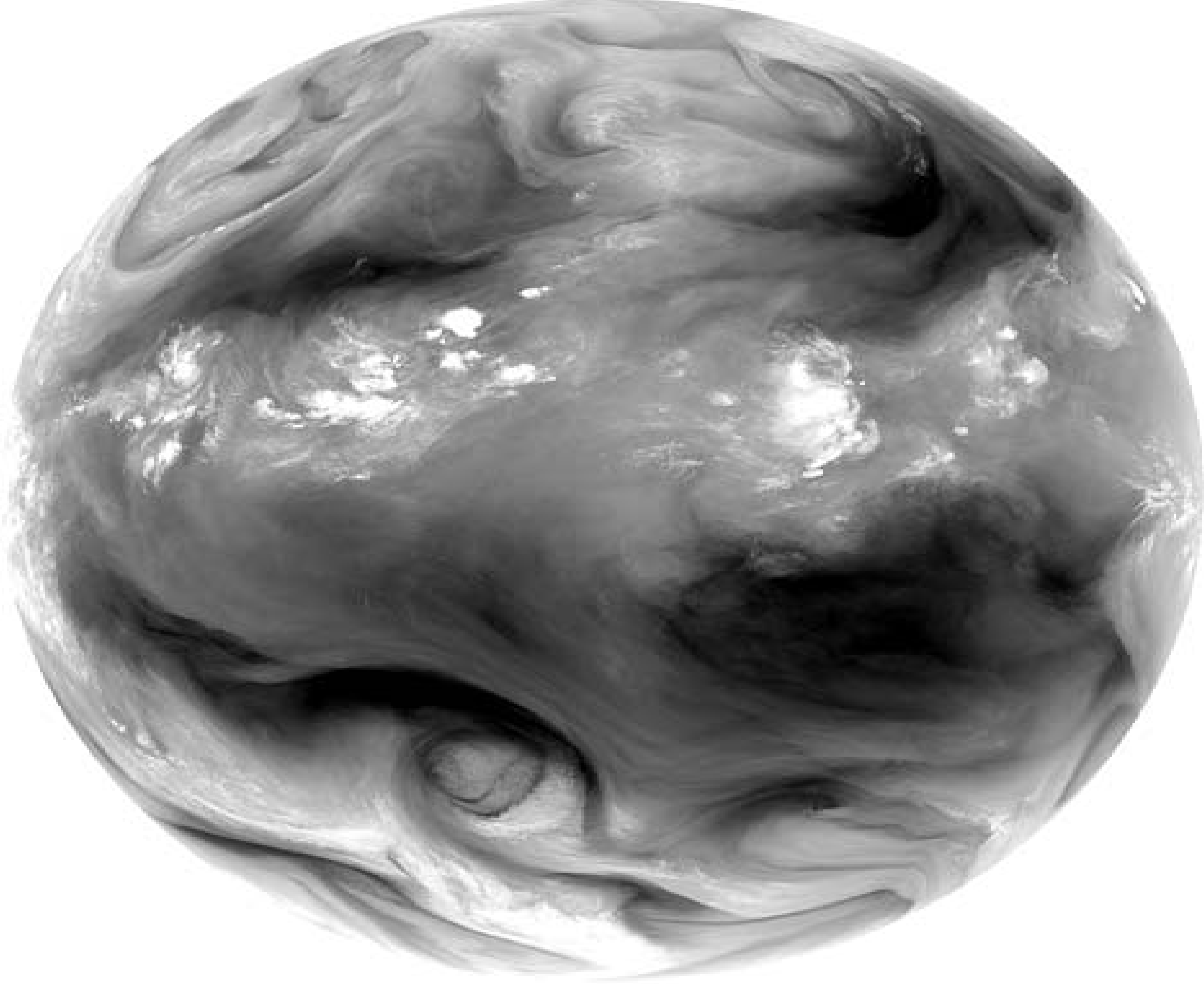

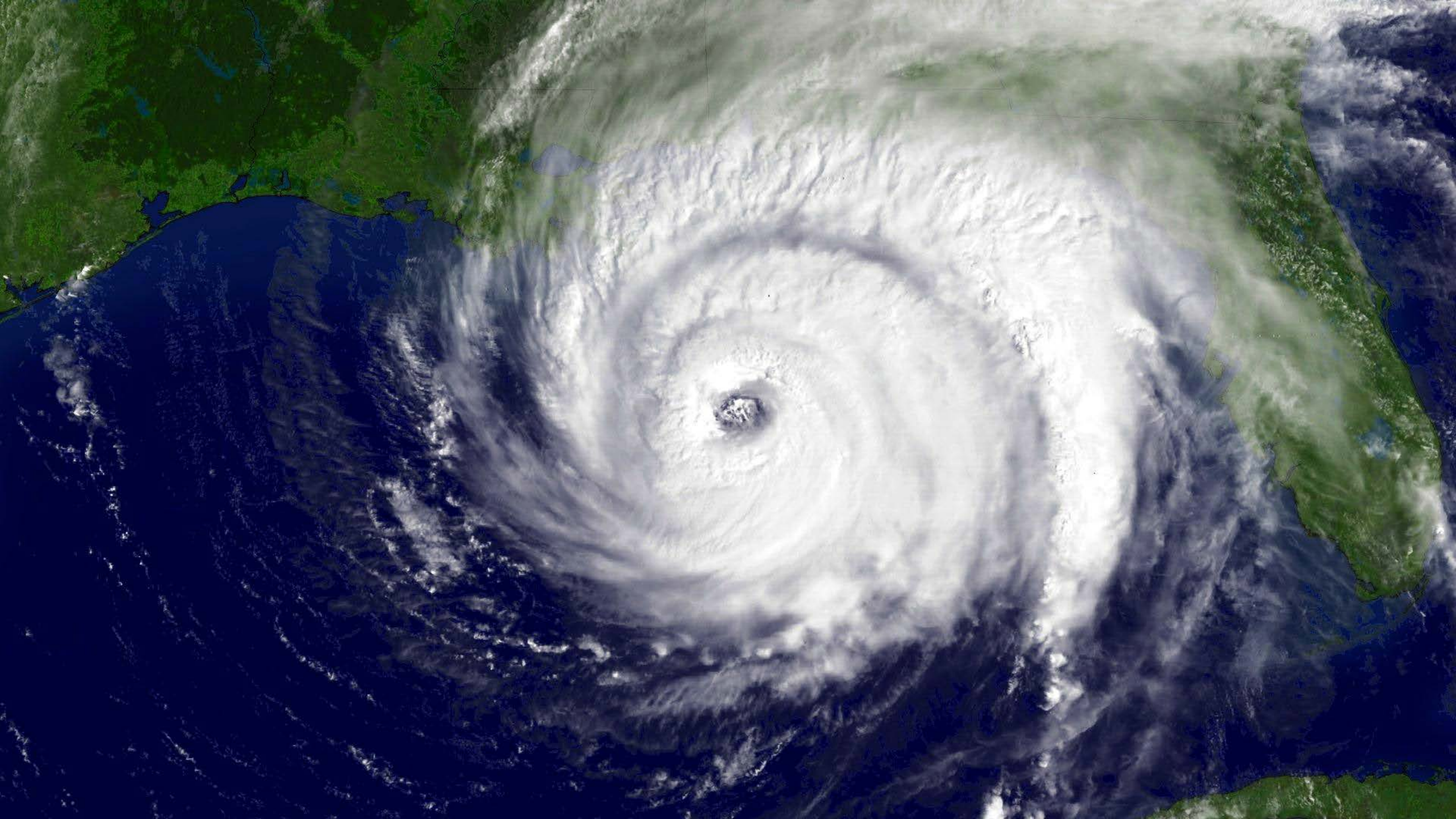

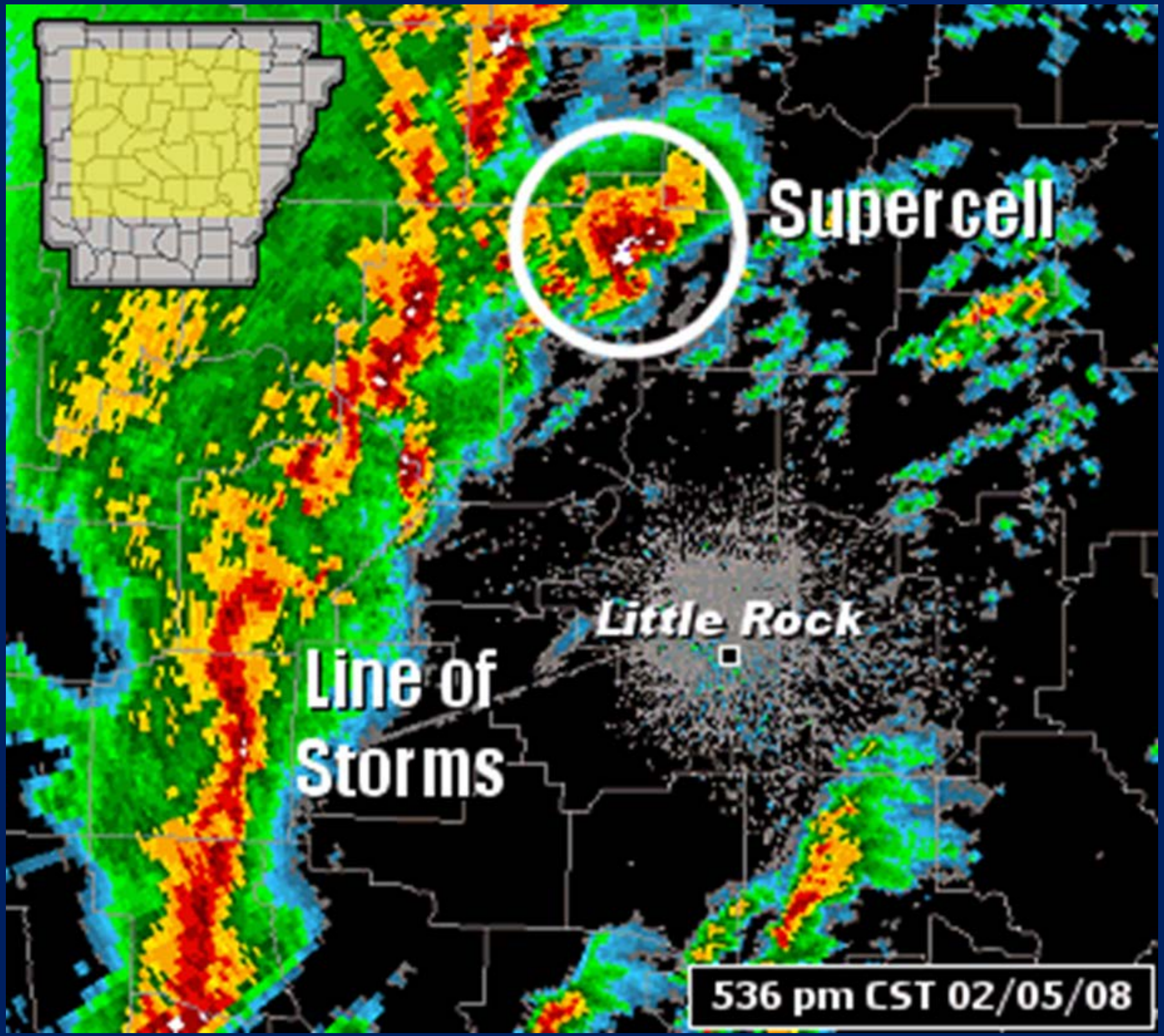
Supercell
Little Rock
Line of
Storms
536 pm CST 02/05/08

Vilonia