Taking SKYWARN to the Next Level:

An Advanced Weather & Storm Spotting Course

National Weather Service – Columbia, SC

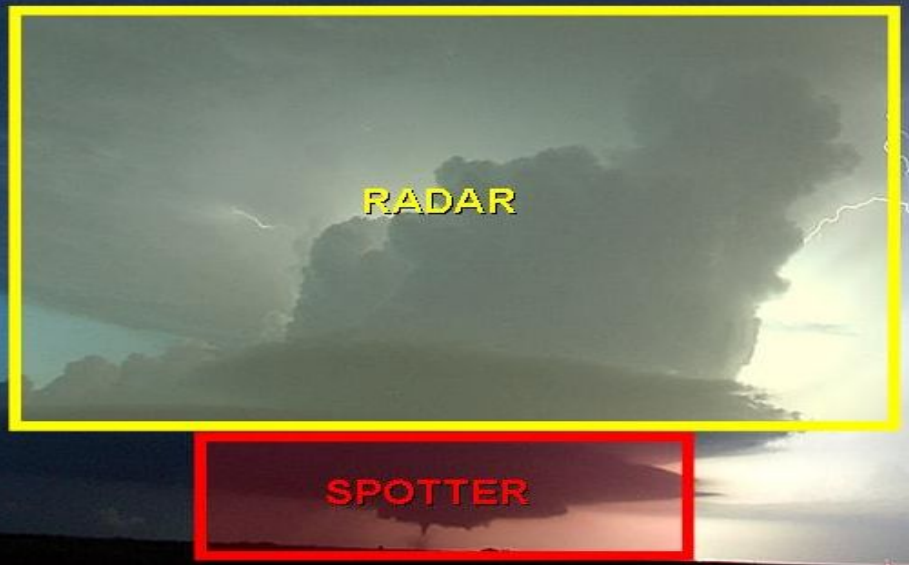
Course Information

- **Purpose –**
  - To *expand* upon material presented in the basic SKYWARN course
- **General Outline –**
  - Understanding the Atmosphere
  - Severe Weather Ingredients
  - Radar Principles, Advantages and Limitations
  - Radar and Storm Structure
    - Review of Impact-Based Warnings
  - Reporting Procedures

Importance of Spotters

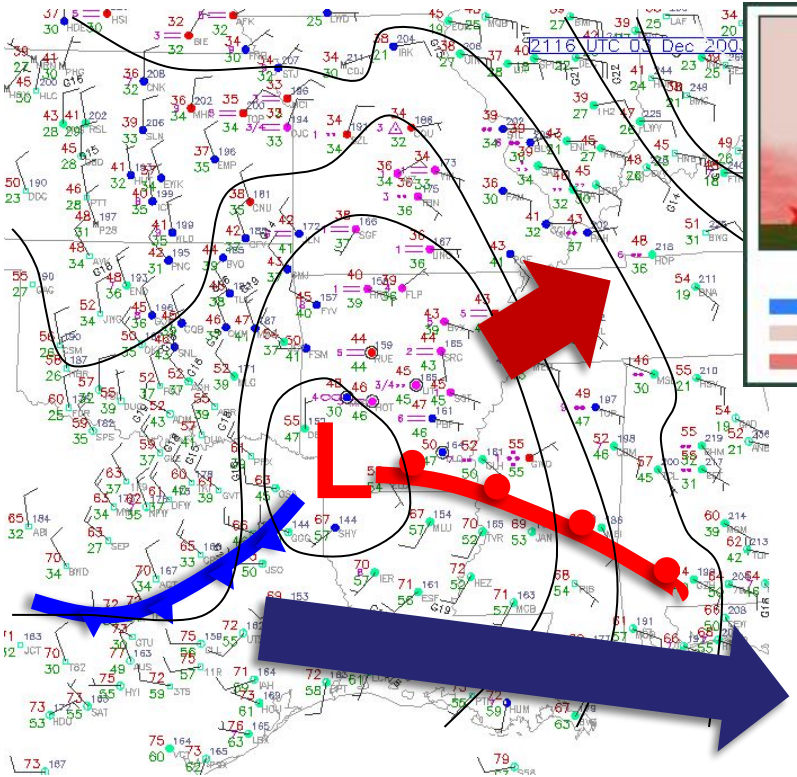
- **Provide "Ground Truth"**
  - Our "eyes" out there!
- **Detailed storm reports can…**
  - Add value to existing/new warnings
  - Verify warnings
- **Can assist with post-storm analysis, research and training**
- **Can mitigate limitations with radar coverage**

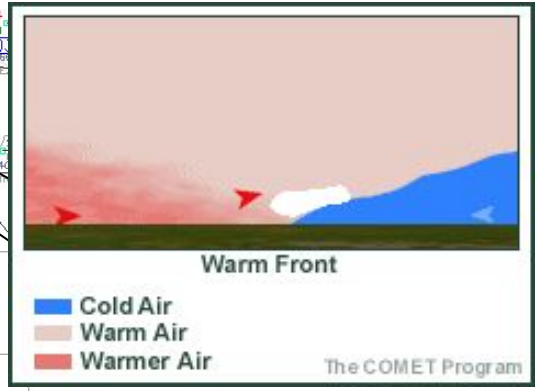
Spotters provide critical details on what's happening at ground level.

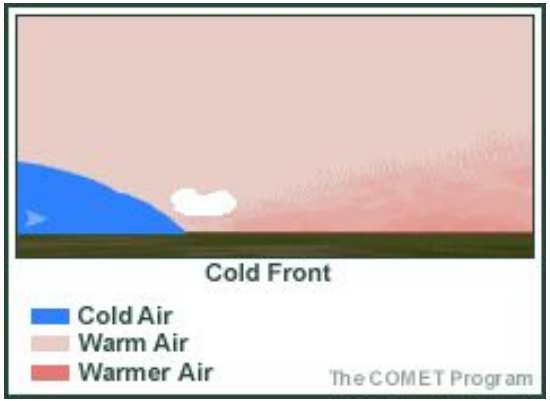


Chris Gullikson WWW.F5HUNTER.COM

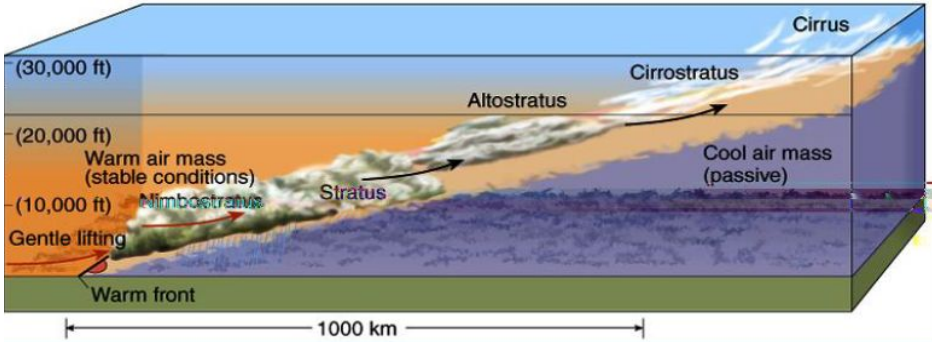
The 3-D Atmosphere



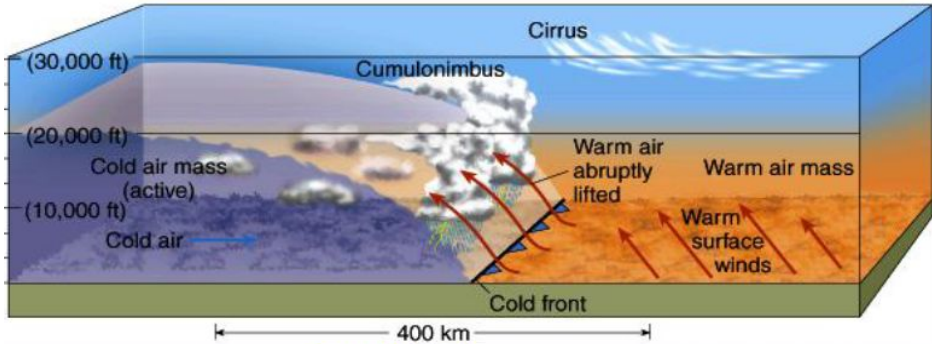




The 3-D Atmosphere



Warm Front



Cold Front

Ingredients

Thunderstorm Development

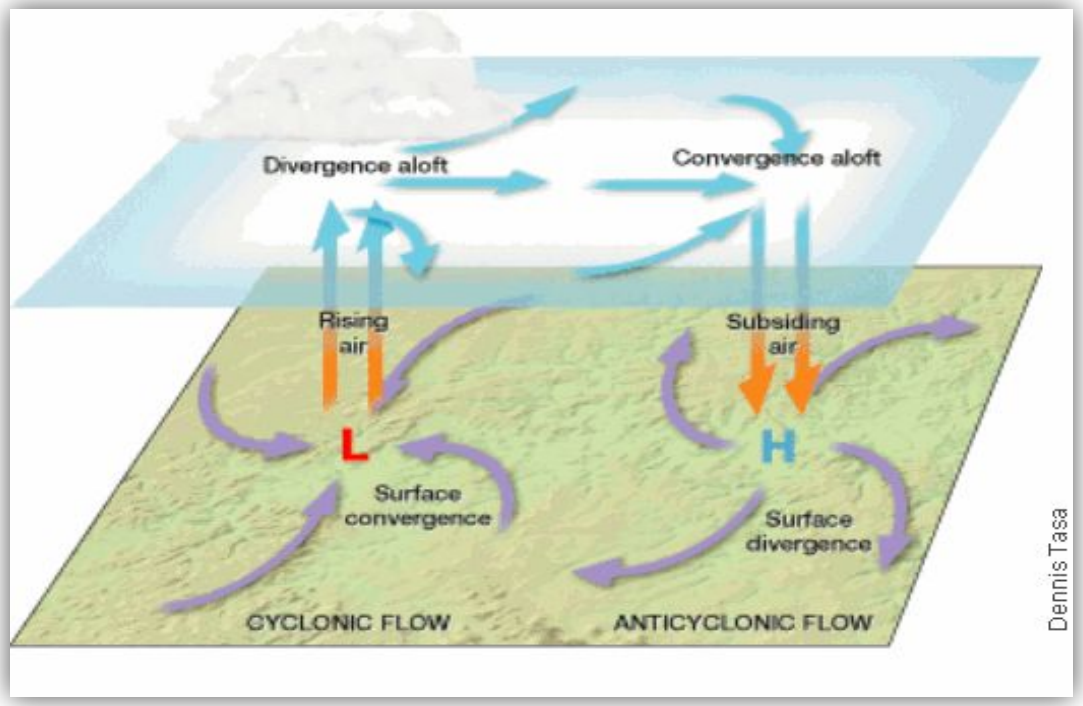
- Moisture
- Trigger / Lift
- Instability

Determining Factors (severity):

- Instability
- Wind Shear

What is Stability?

- The degree to which vertical motion in the atmosphere is <u>enhanced</u> or <u>suppressed</u>
- Depending on the vertical temperature profile of the atmosphere, air will: rise, sink, remain at rest

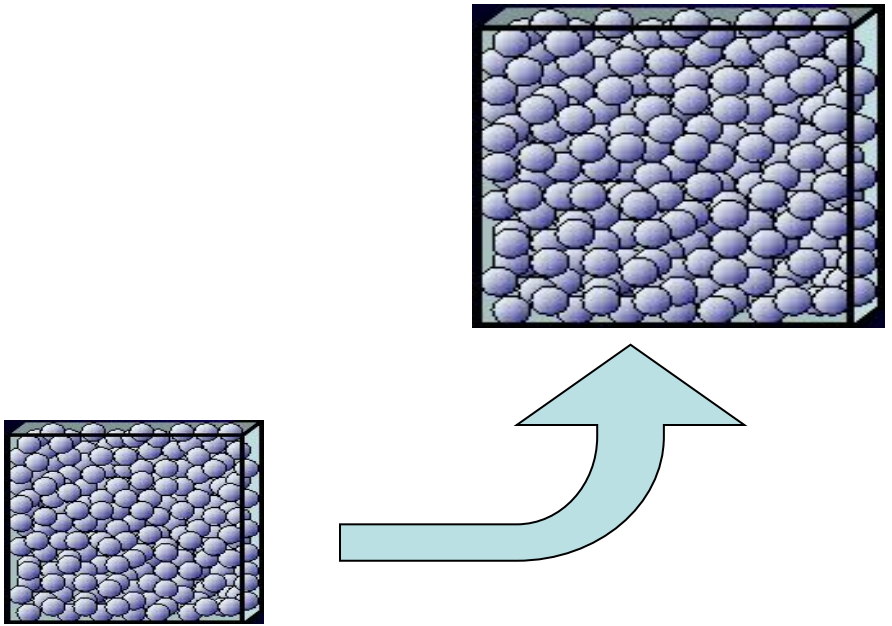


Three Types of Stability

- **Unstable Atmosphere**
  - Enhances or encourages vertical movement of air
- **Stable Atmosphere**
  - Suppress or resists vertical movement of air
- **Neutral Atmosphere**
  - Neither suppresses nor enhances vertical movement of air

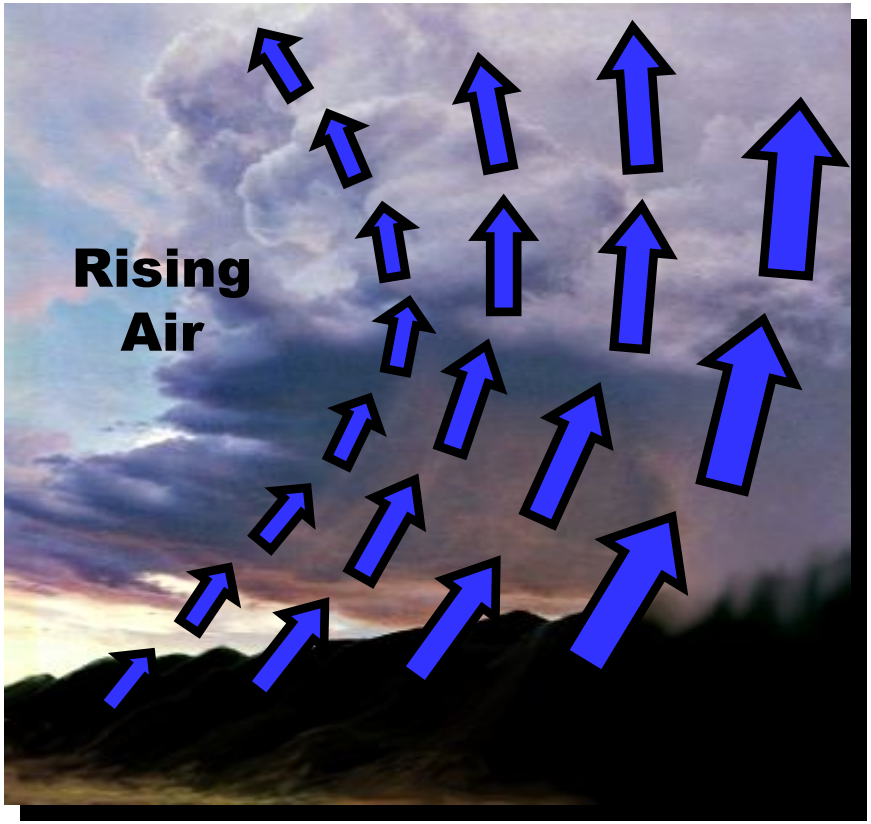
Unstable Atmosphere

- Air parcels will continue to rise



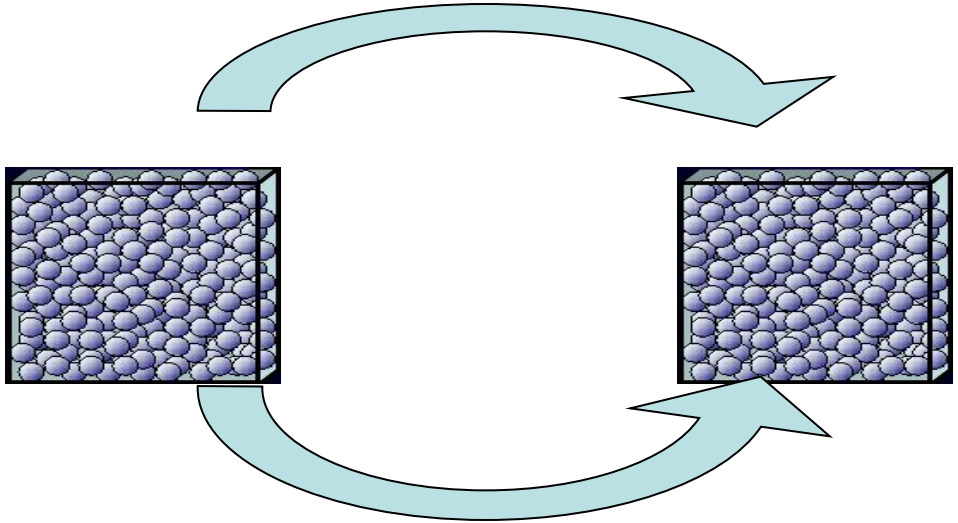
Unstable Atmosphere

- Promotes the formation and growth of vertically developed clouds, thunderstorms and tall smoke columns



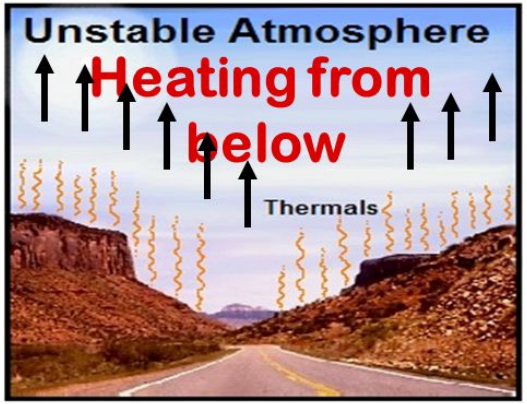
Stable Atmosphere

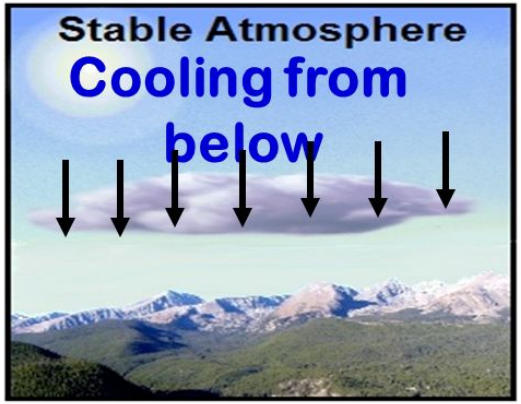
- Air parcels displaced upward (downward) will eventually return to their level of origin

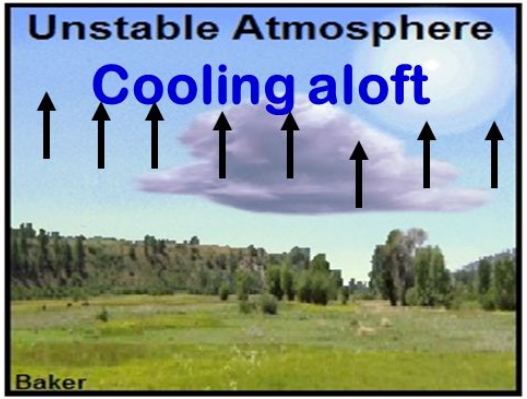


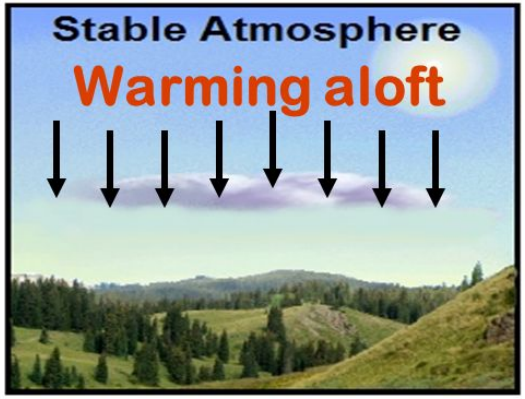
Atmospheric Stability

- 4 ways to change atmospheric stability







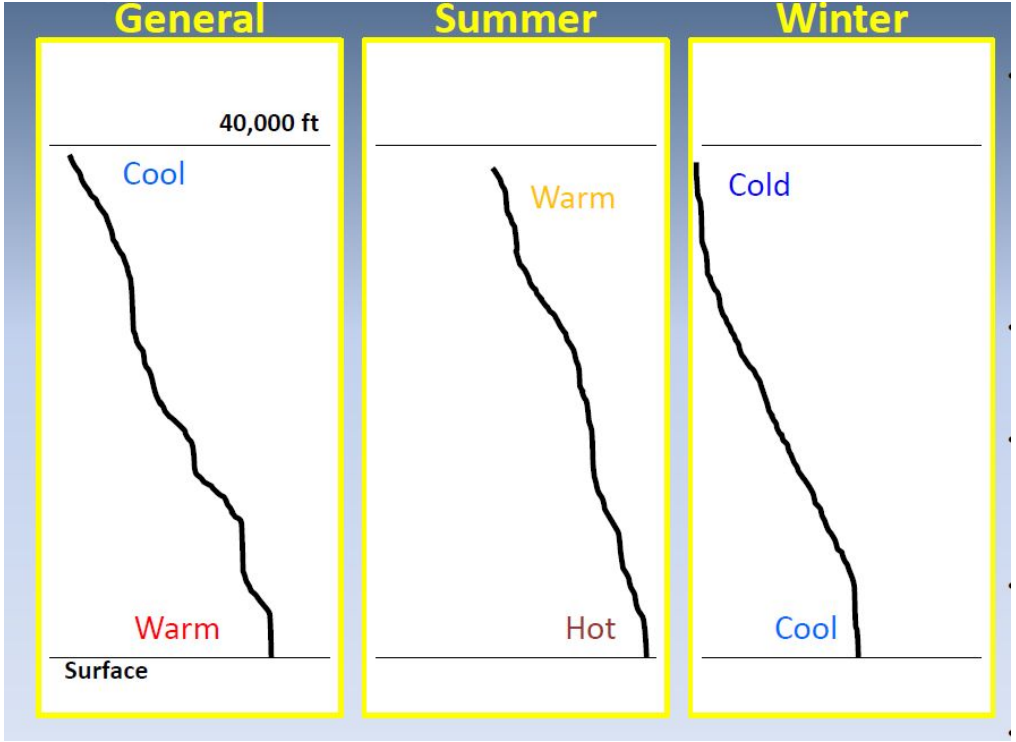


Temperature Lapse Rates

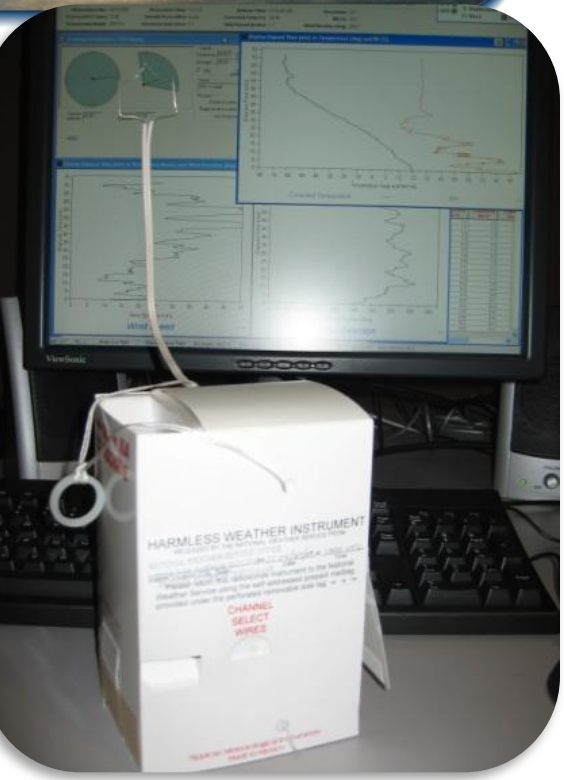
Change in Temperature

Change in Altitude

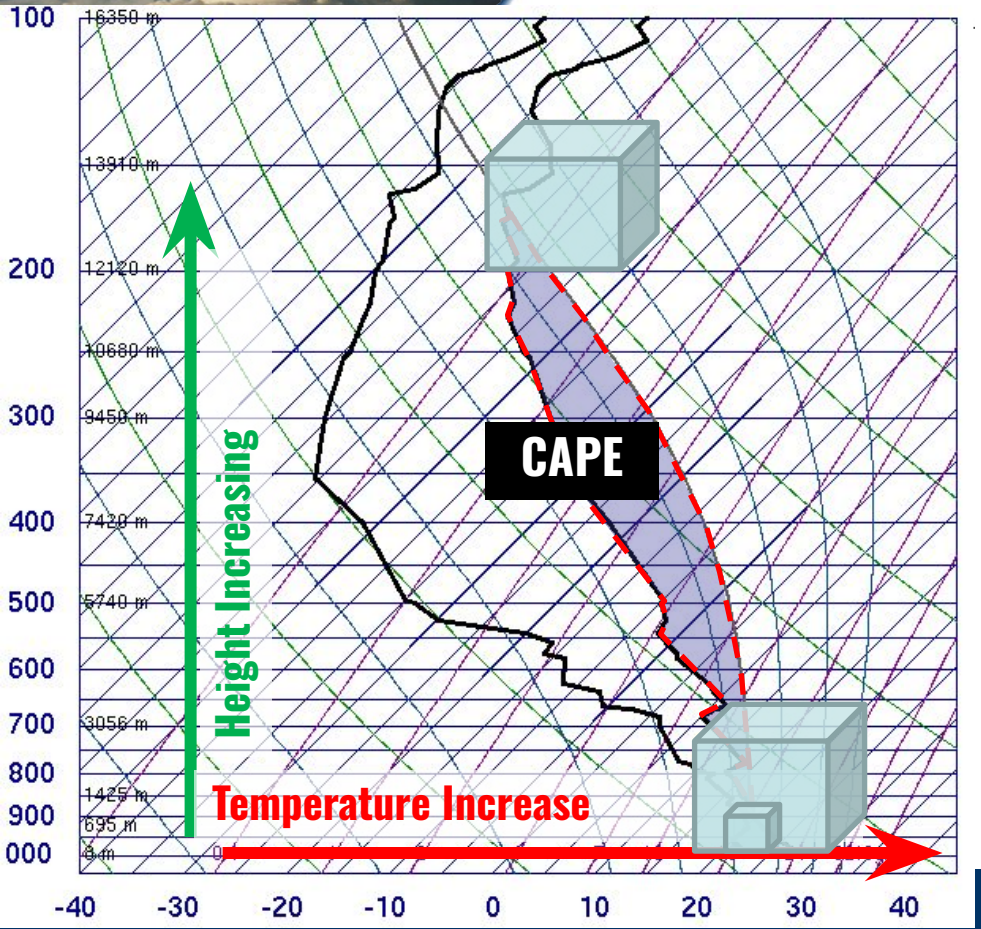
- **Instability** is based upon how warm it is at the surface vs. how cold it is aloft



Measuring Stability



Instability

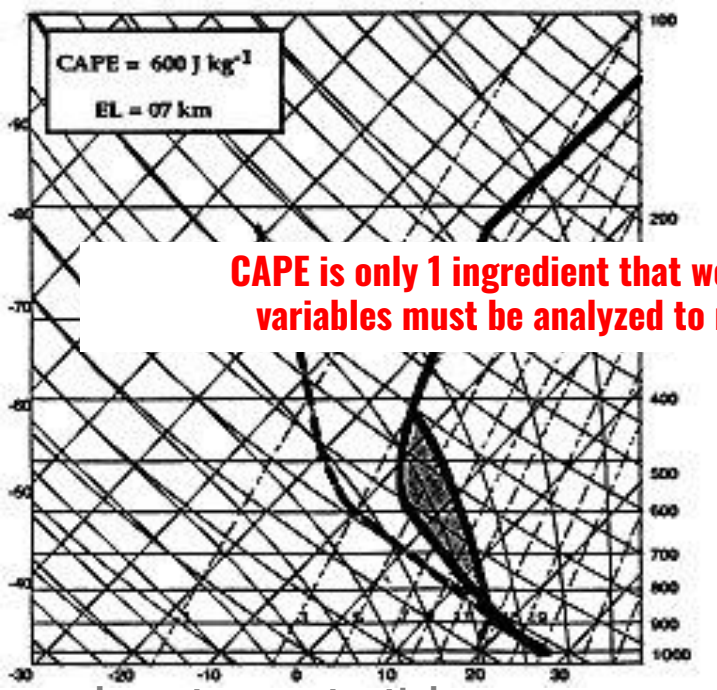


CAPE stands for the:
Convective
Available
Potential
Energy

- Depending on what type of CAPE exists (tall, short, skinny, fat) will determine the type and amount of thunderstorms that are possible (potential).

High CAPE vs. Low CAPE

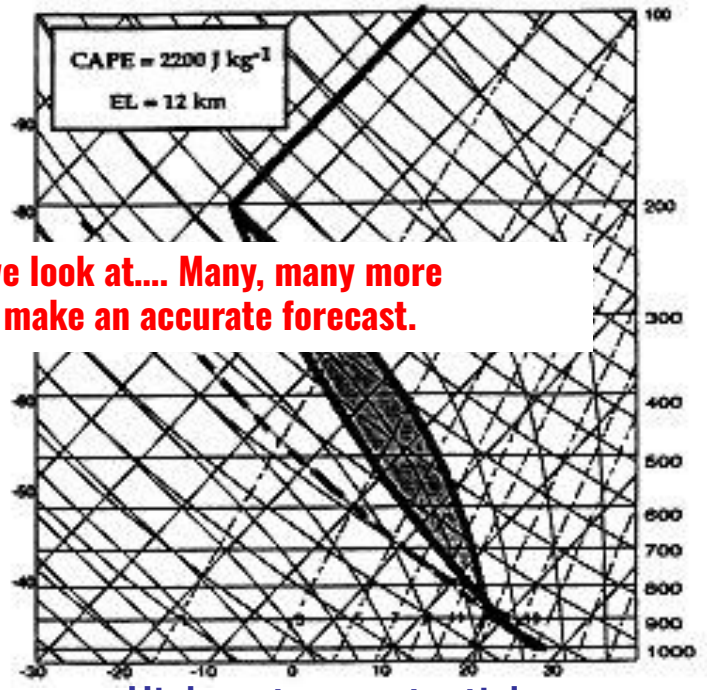
Low CAPE



- Low storm potential
- Weak lapse rate

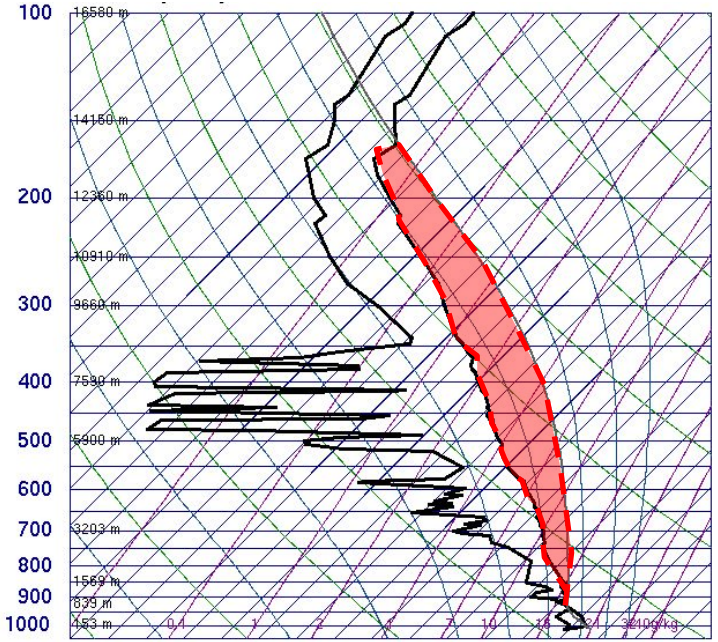
CAPE is only 1 ingredient that we look at…. Many, many more variables must be analyzed to make an accurate forecast.

High CAPE

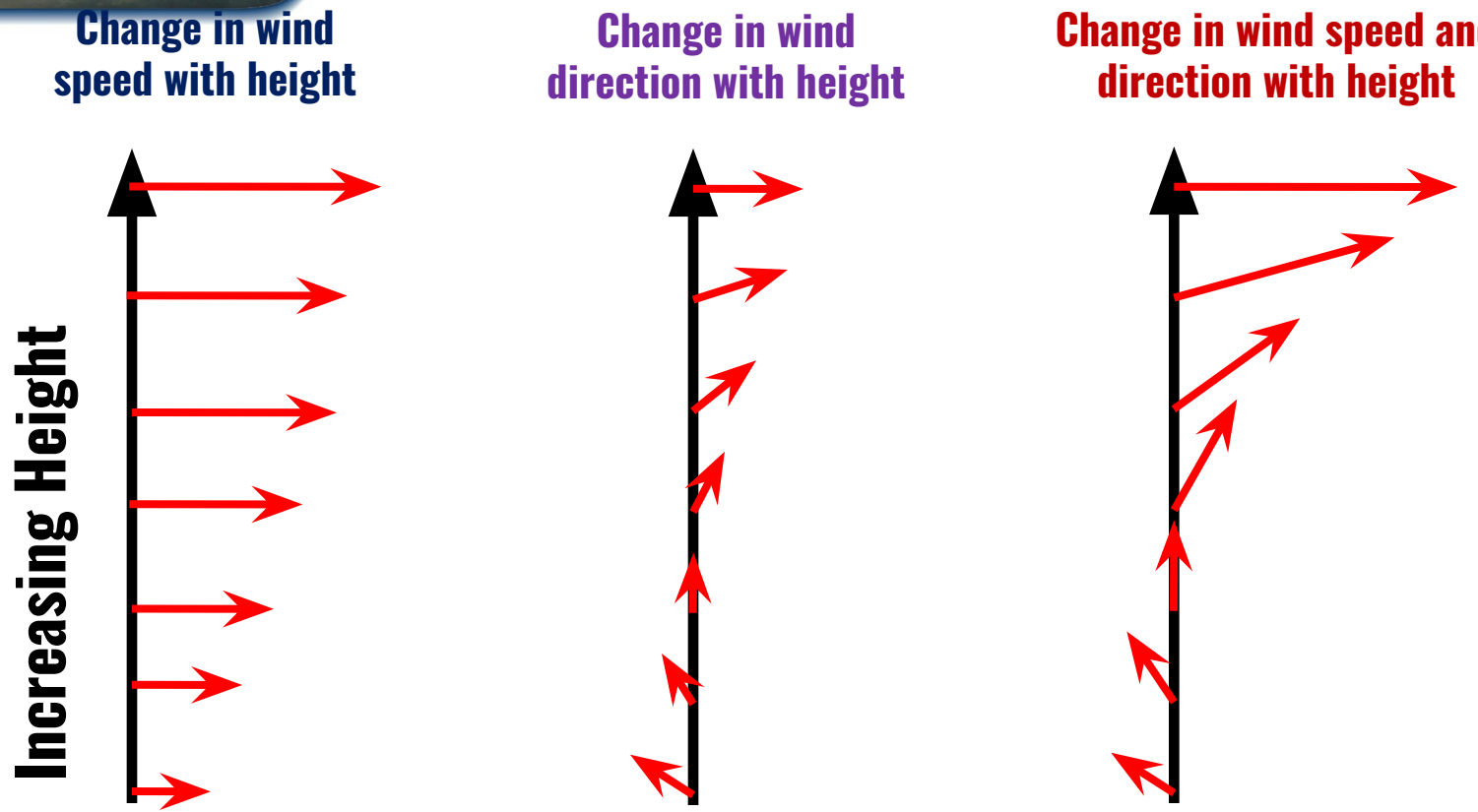


- Higher storm potential
- Steep lapse rate

CAPE and Thunderstorms



Wind Shear: What is it?

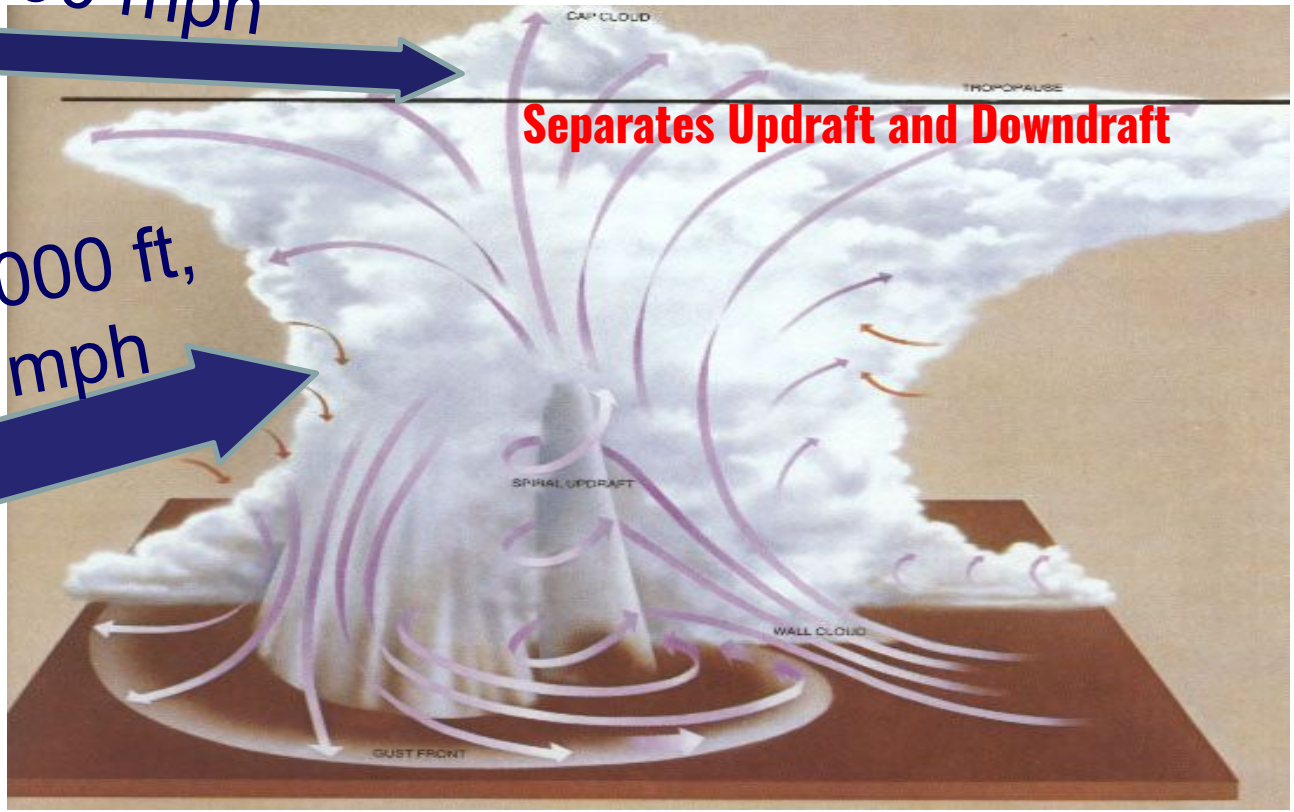


Why Wind Shear

Separate Updrafts and downdrafts allow the storm to keep refueling.

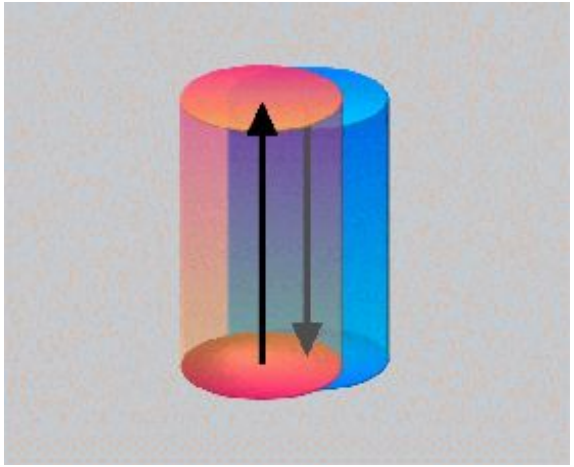
40,000 ft, 90 mph

10,000 ft, 60 mph



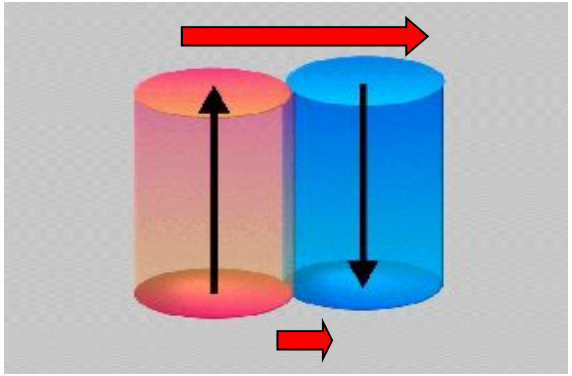
Wind Shear

Weak



Downdraft chokes updraft causing storm be short-lived

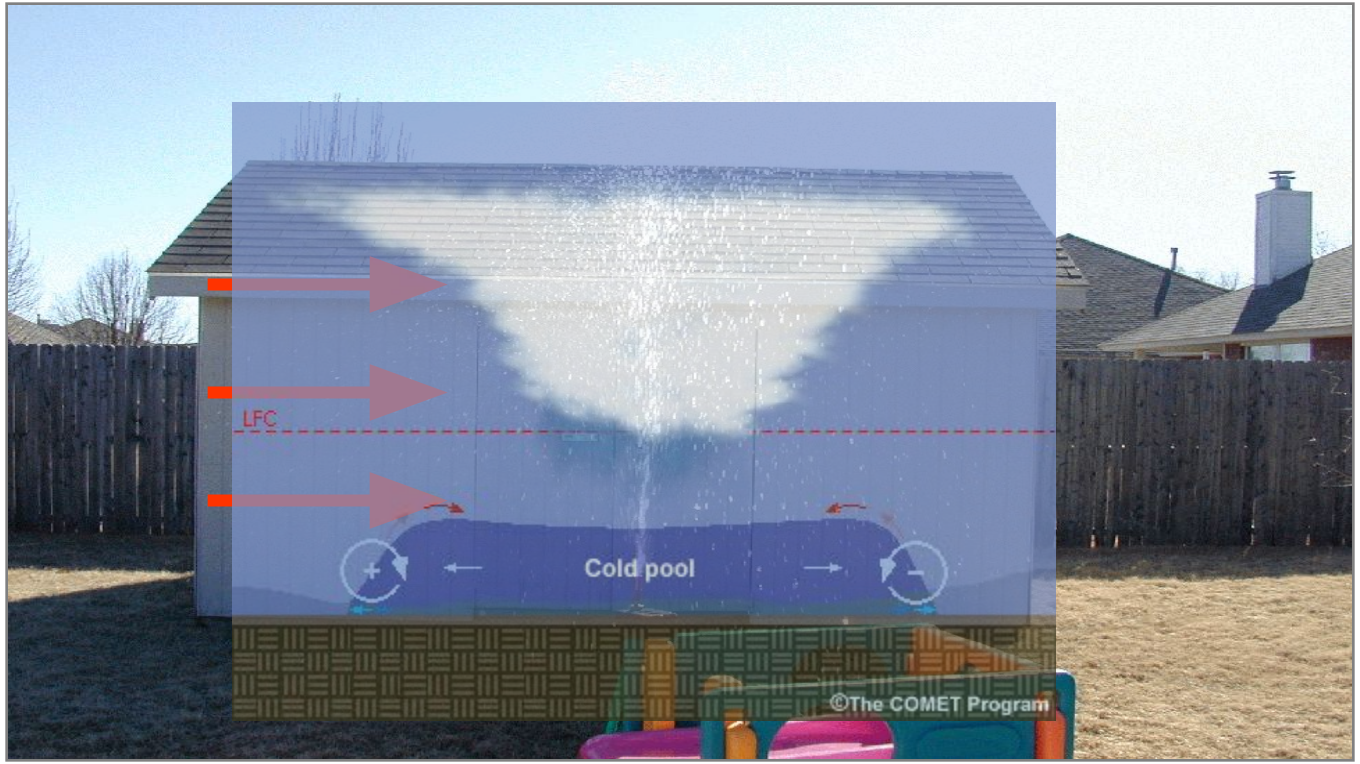
Strong



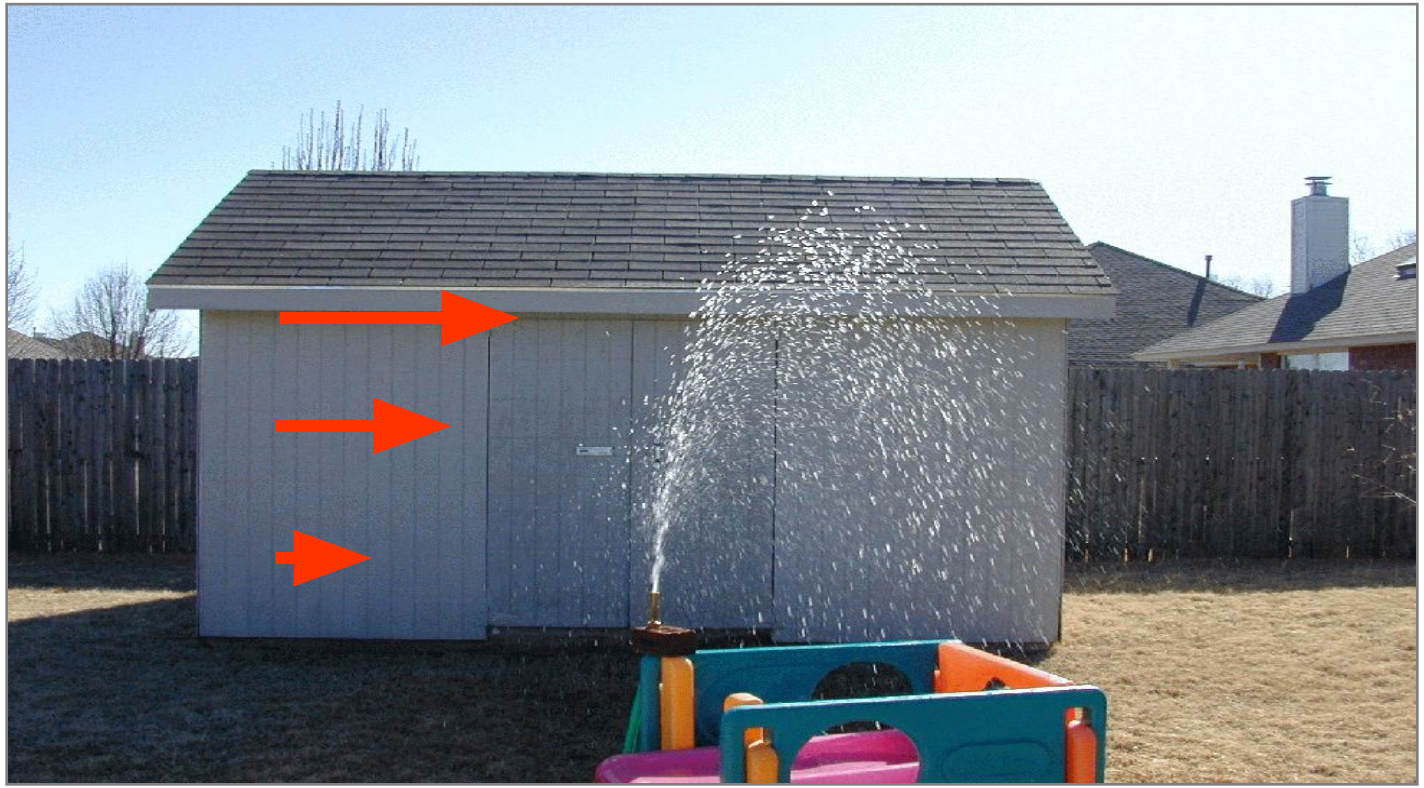
Updraft & downdraft are separated, the storm lives longer

Updraft in Weak Wind SPEED Shear

Updraft in Weak Wind SPEED Shear



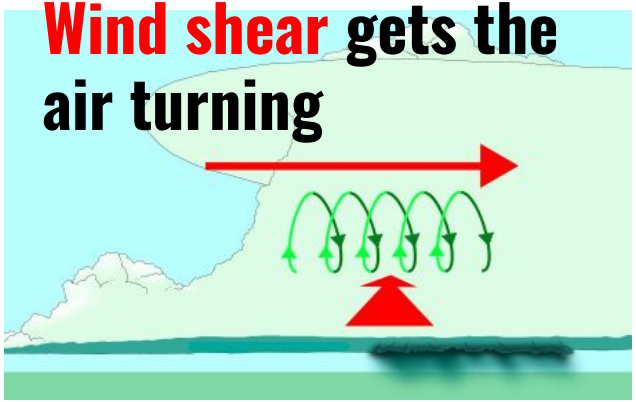
Updraft in Strong Wind SPEED Shear



Updraft in Strong Wind SPEED Shear

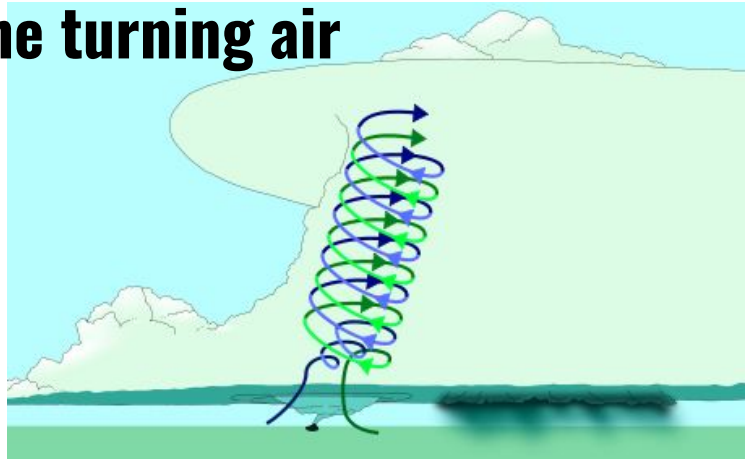
Wind Shear & Supercells

Wind shear gets the air turning



The **updraft** bends the turning air upward.

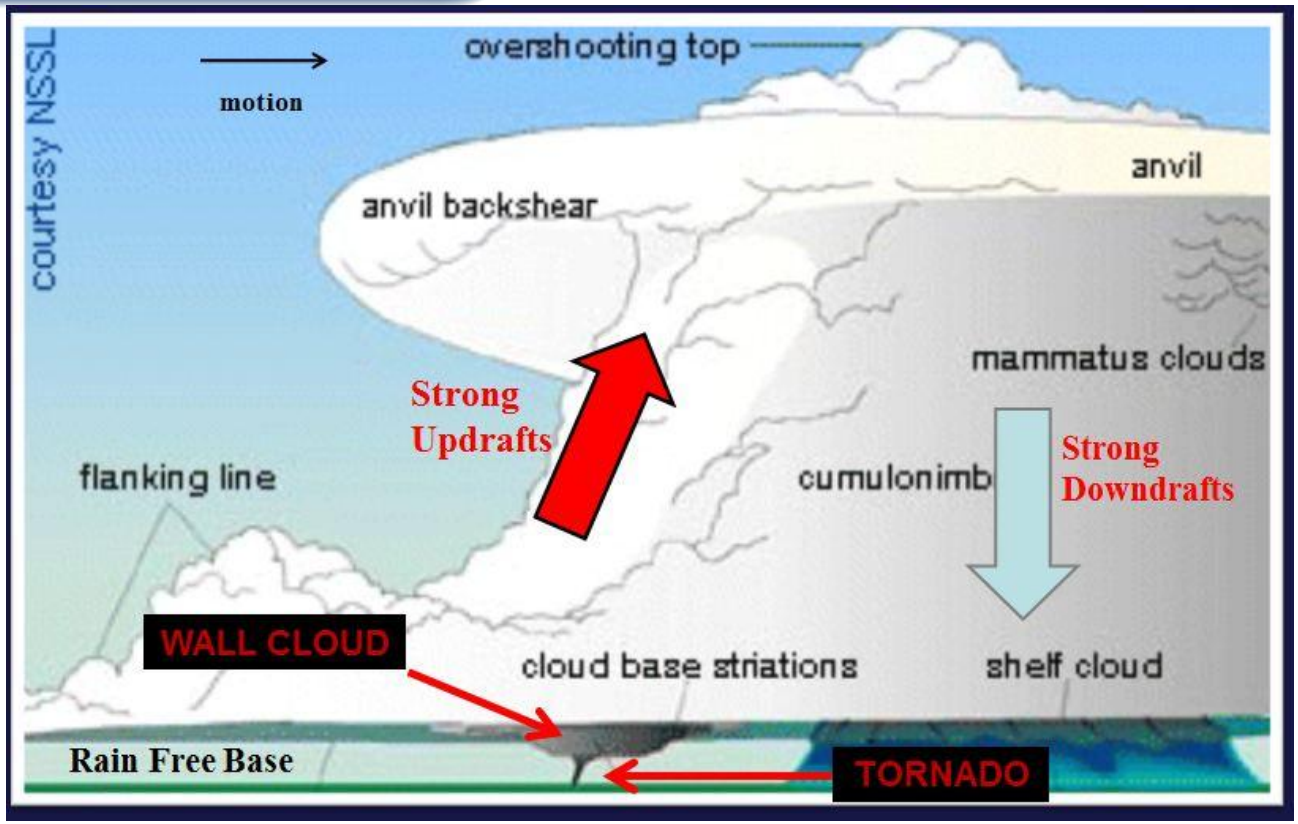
The **updraft** begins spinning with the turning air



Wind shear is quantified using terms like ***Helicity*** and ***Bulk Shear***

Supercell – Rotating Updraft

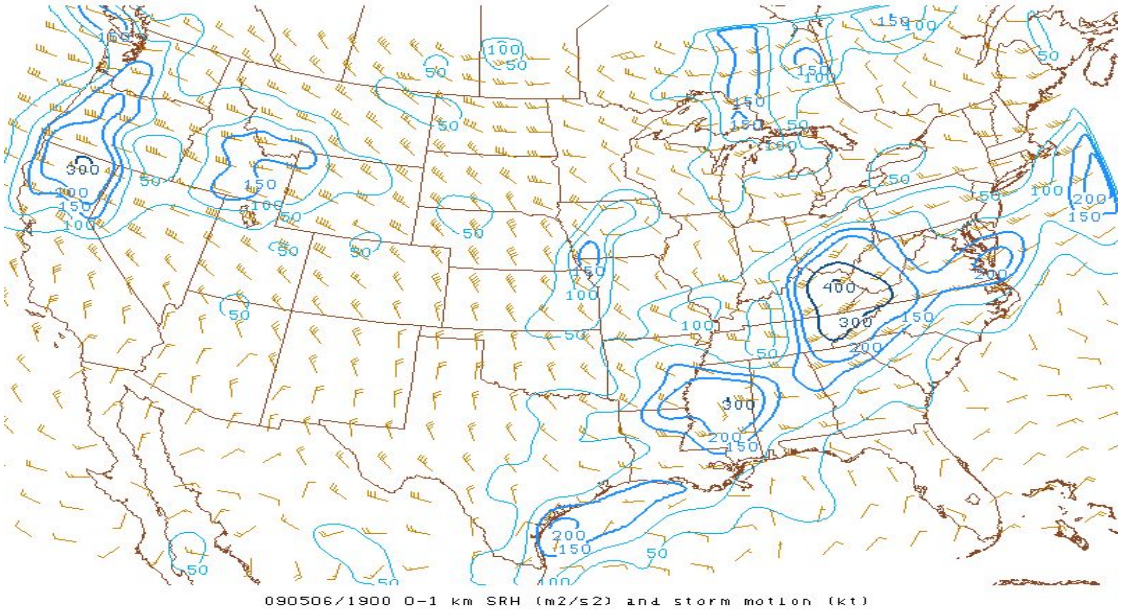
Supercell Thunderstorm



Same Ingredients as a basic Thunderstorm.

But add significant amounts of speed and directional shear

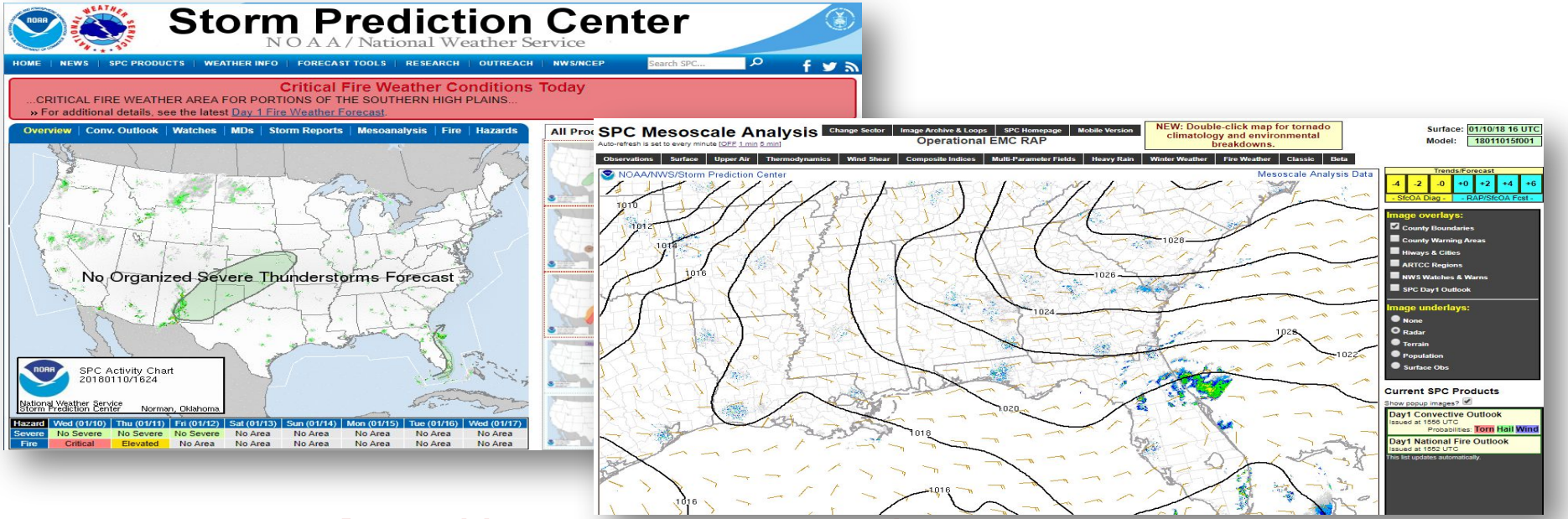
Measuring Wind Shear



HELICITY FACTS:

- Measured at several height levels
- Aids in determining storm type and "convective mode"
- 0-6 km = Storm Motion
- 0-3 km = Storm Type
- 0-1 km = Tornadoes?

Storm-scale/Environment Information readily available!



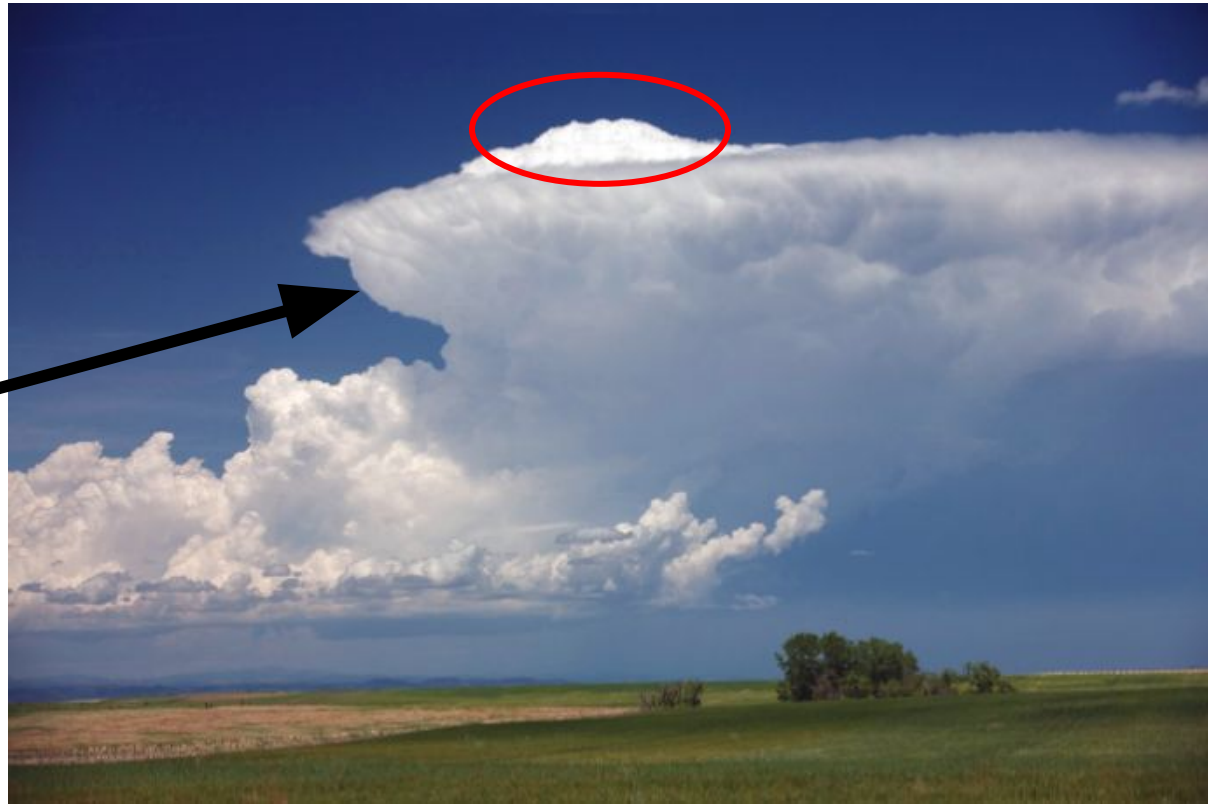
http://www.spc.noaa.gov/

http://www.spc.noaa.gov/exper/mesoanalysis/

Evaluate Storm: Upper Levels

Strong Updraft indicated by:

- Overshooting Top
- Thick, cumuliform anvil

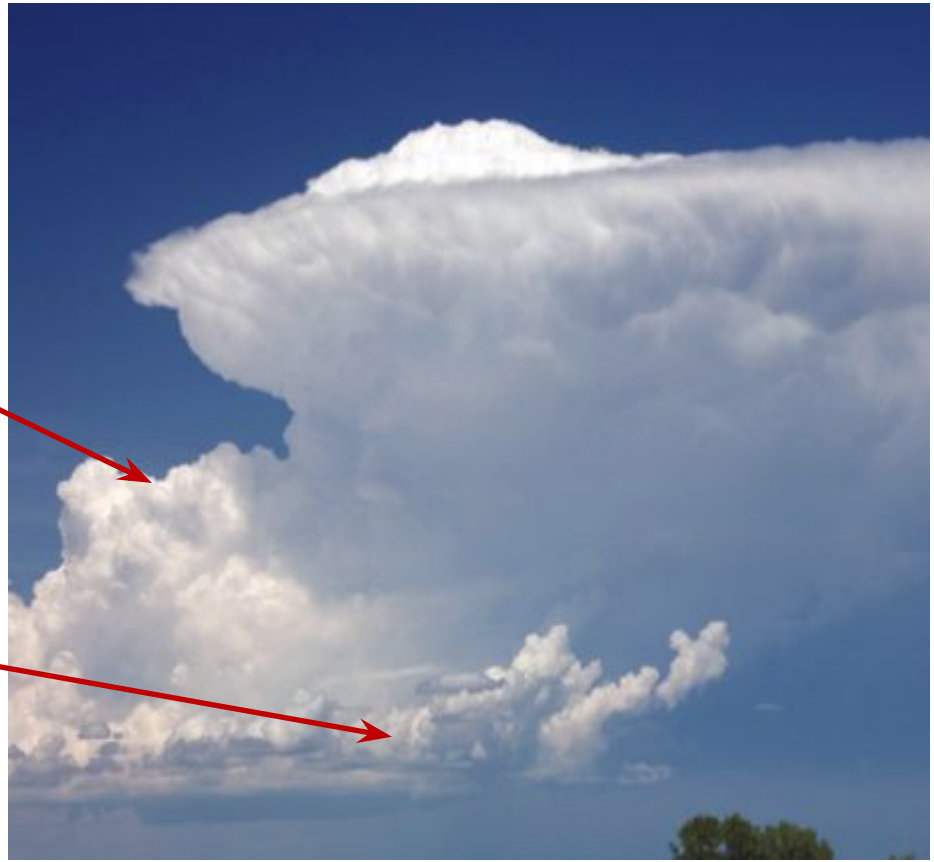


Evaluate Storm: Mid Levels

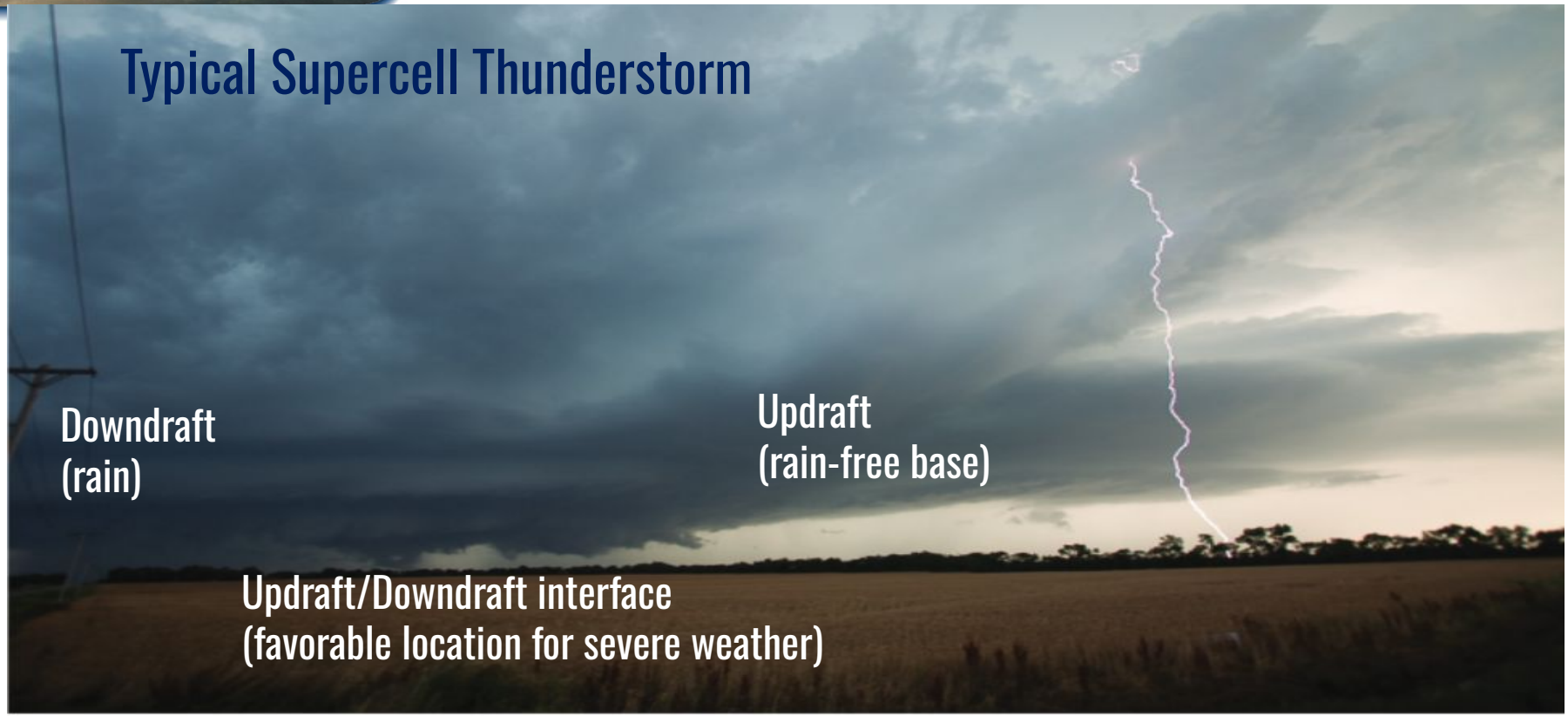
Stronger Storms:

Main Storm Tower
- Hard, sharp cauliflower look

Presence of a flanking line
- Greater storm organization



Evaluate Storm: Low Levels



Lower level storm features, including the updraft and downdraft area. Photo by Jim LaDue.

Evaluate Storm: Low Levels

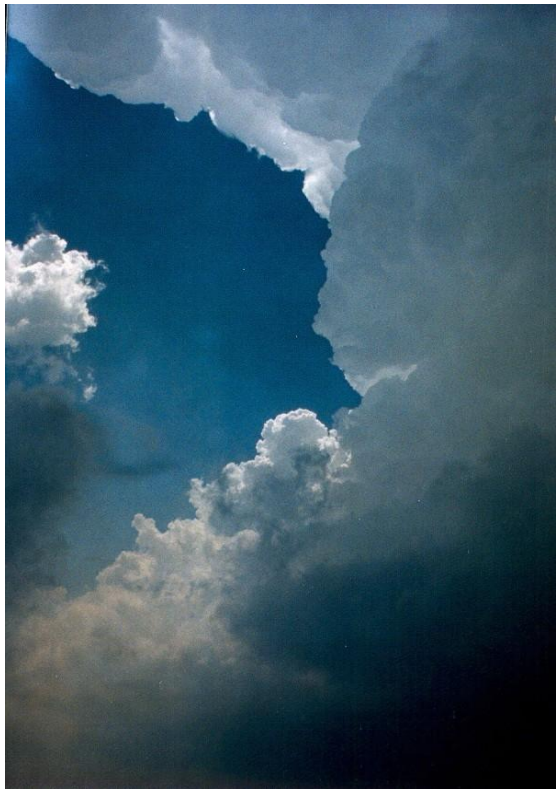
Lower level storm features, including the updraft and downdraft area. Photo by Jim LaDue.

Wall vs. Shelf Clouds

Wall cloud
Rotates along a vertical axis

Shelf cloud
Rotates along a horizontal axis

Strong or Weak Updraft?



Strong!
Sharp, bubbly towers with a cauliflower look to it.

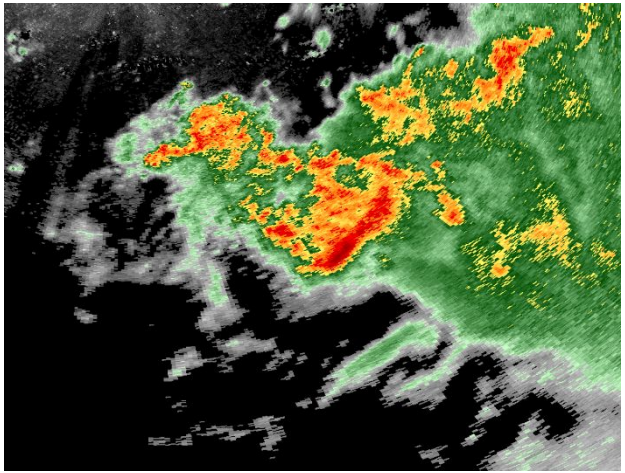
Strong or Weak Updraft?

Weak!
Fuzzier look to the cloud. Parts are translucent and edges are not nearly as sharp.

Shelf or Wall Cloud?

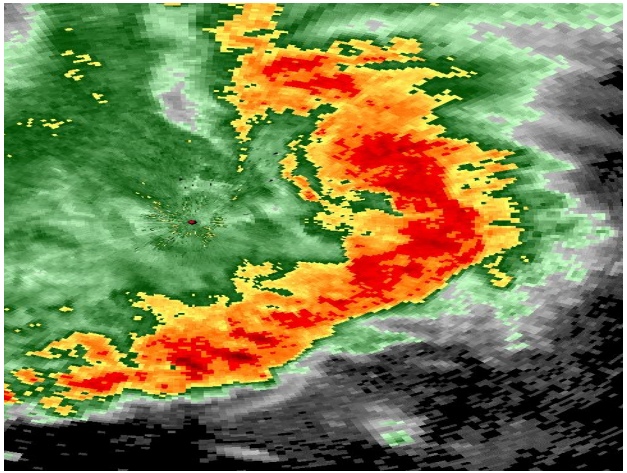
Wall cloud
Lowering of the rain free base. If there was video you would be able to observe rotation around a vertical axis

Storm Type



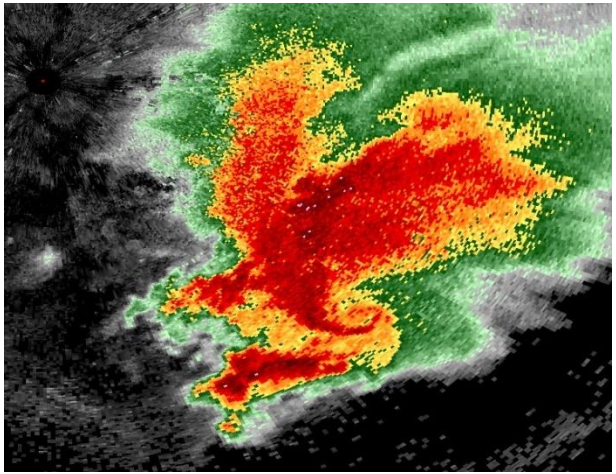
Multi-Cell Cluster

- Downburst Winds
- Hail
- Flash Flooding
- Tornadoes (usually low)



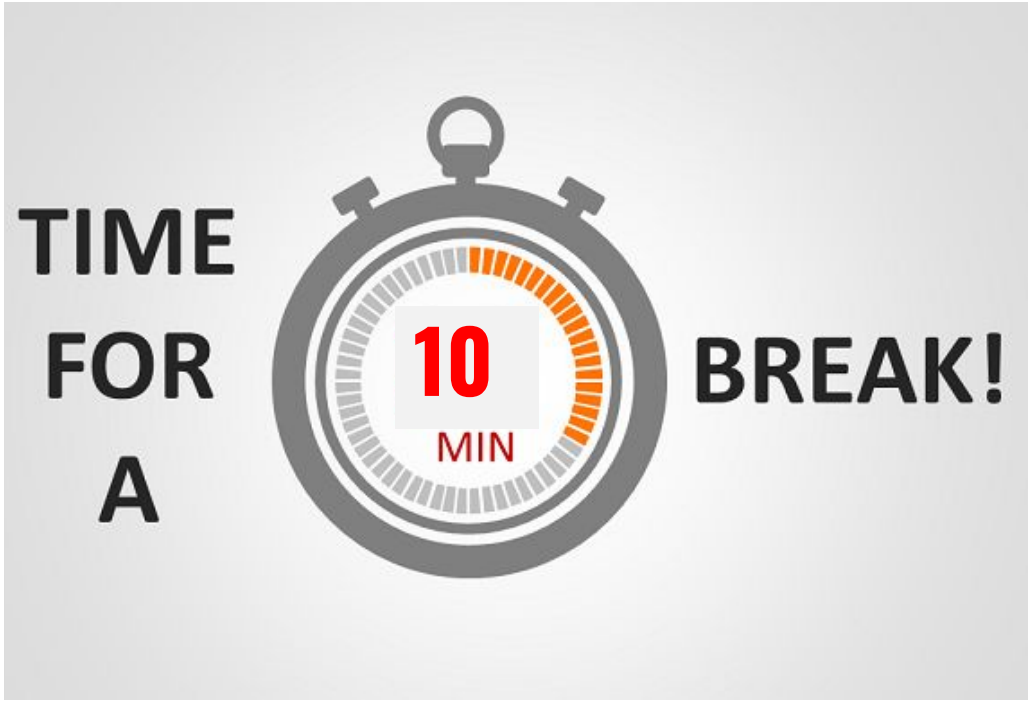
Multi-Cell Bow Echo

- Damaging Winds
- Isolated Tornadoes
- Flash Flooding
- Hail (usually low)



Supercell

- Tornadoes
- Large Hail
- Damaging Winds
- Flash Flooding


TIME
FOR
A
10
MIN
BREAK!

What is Radar?

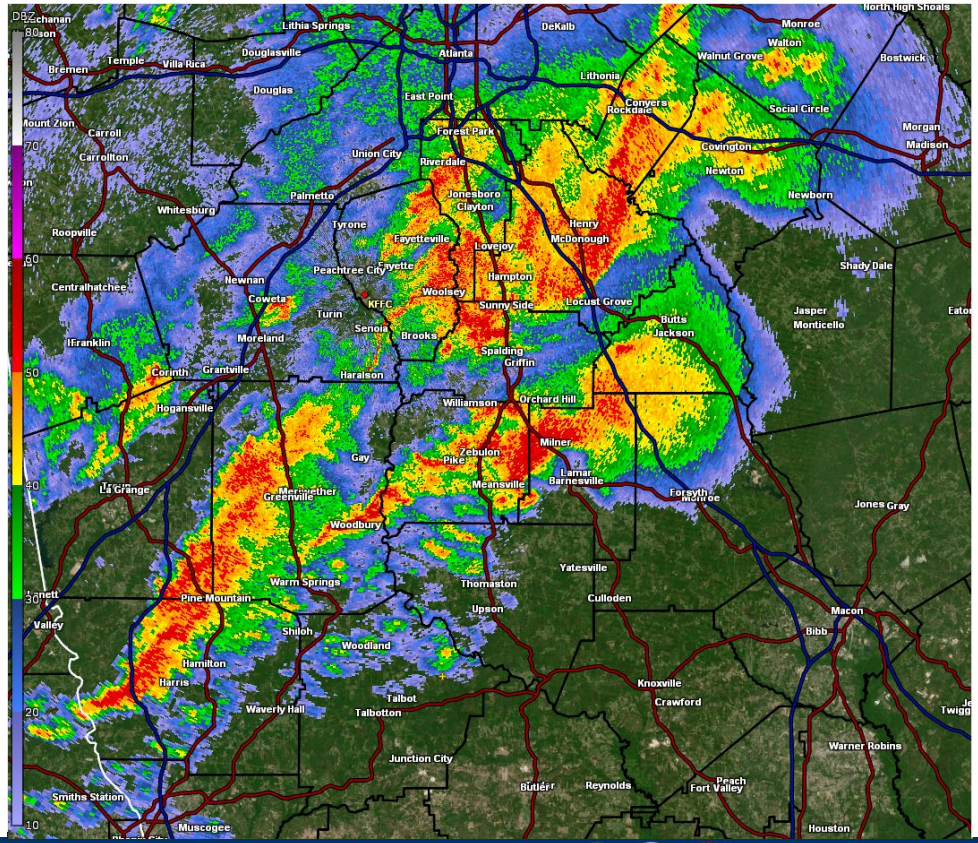
- **Radio Detection and Ranging**
  - Detects the distance to and power returned from a target
- **Weather radar is designed to detect targets made of water**

Raindrop, snowflake, hail, insect, dust, etc.

- Many brief microwave pulses per second are transmitted
- In between the pulses, the radar is "listening" for a reflected signal, or "echo"
- The amount of reflected signal received is called reflectivity

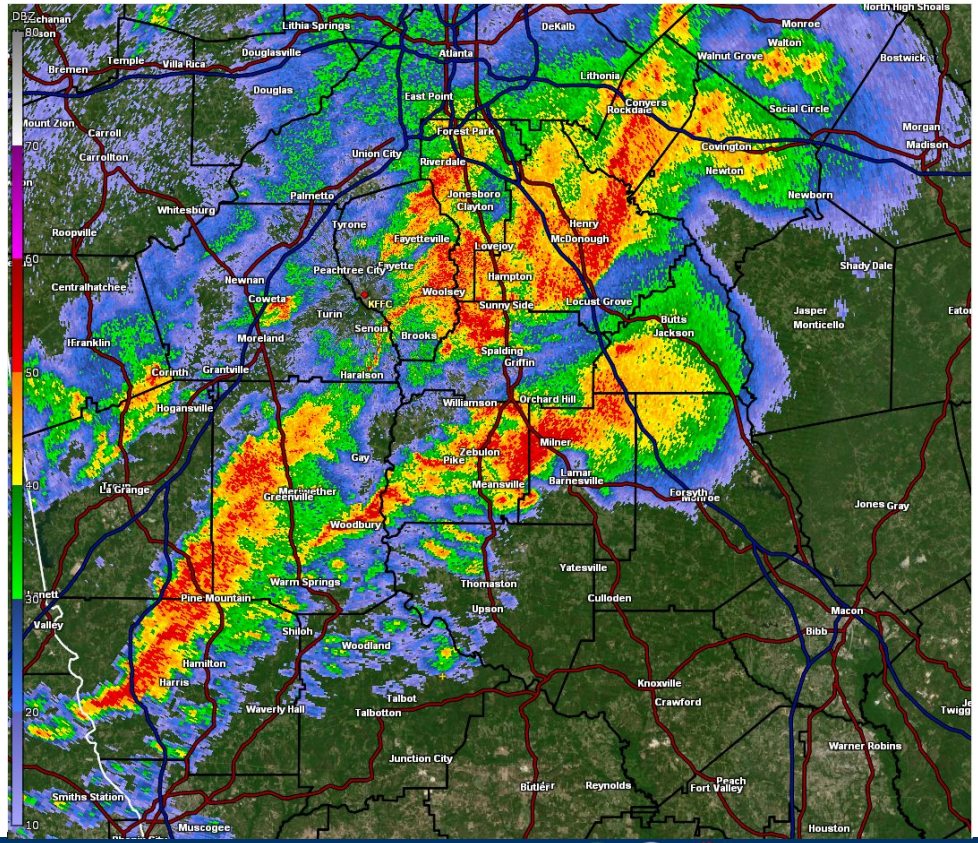
What is Reflectivity?

- The higher the reflectivity, the heavier the rainfall
- Colors are used to display low and high reflectivity
  - Warm colors = high
  - Cool colors = low
  - Always use the color legend
- Threats seen: Heavy rain, hail, snow
  - Can also see birds, insects, leaves (tornado debris)

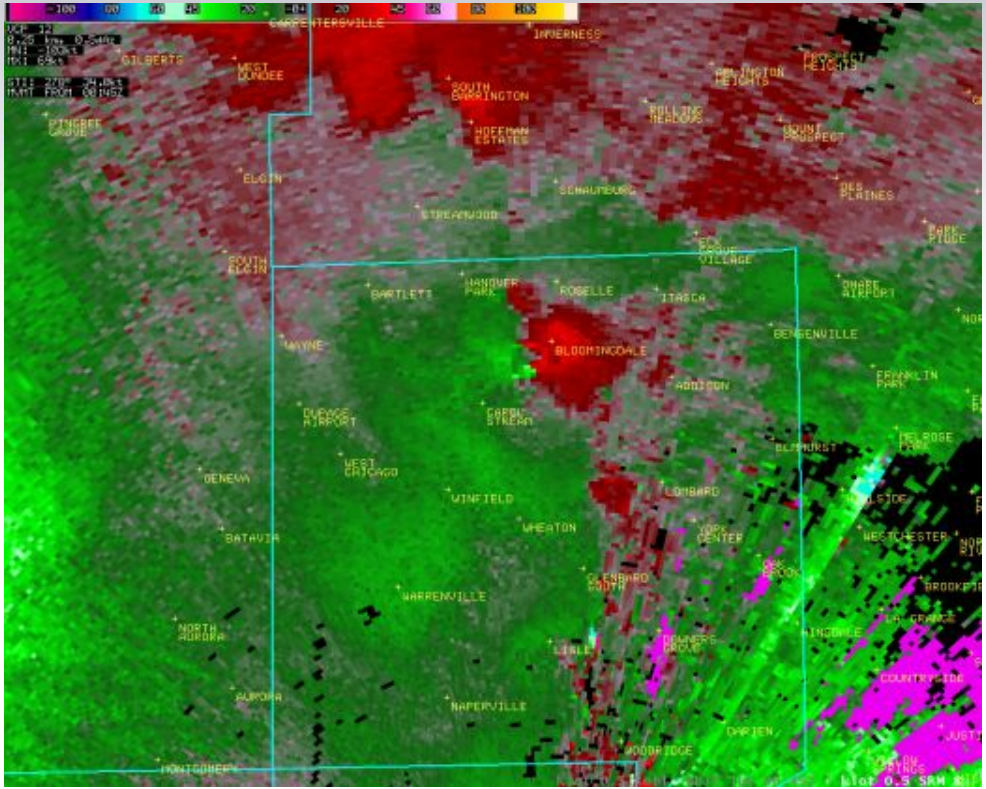


The Doppler Effect

- Doppler effect is a change in frequency of a moving object
- Targets moving toward the radar are colored green
- Targets moving away from the radar are colored red
- The brighter the color, the stronger the wind
- Threats seen: Damaging wind, tornadoes



Velocity

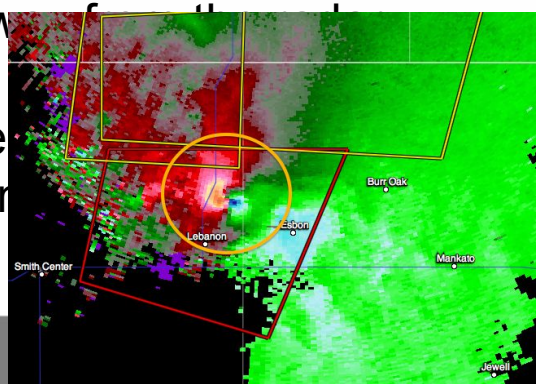


Base Velocity and **Storm Relative Velocity**

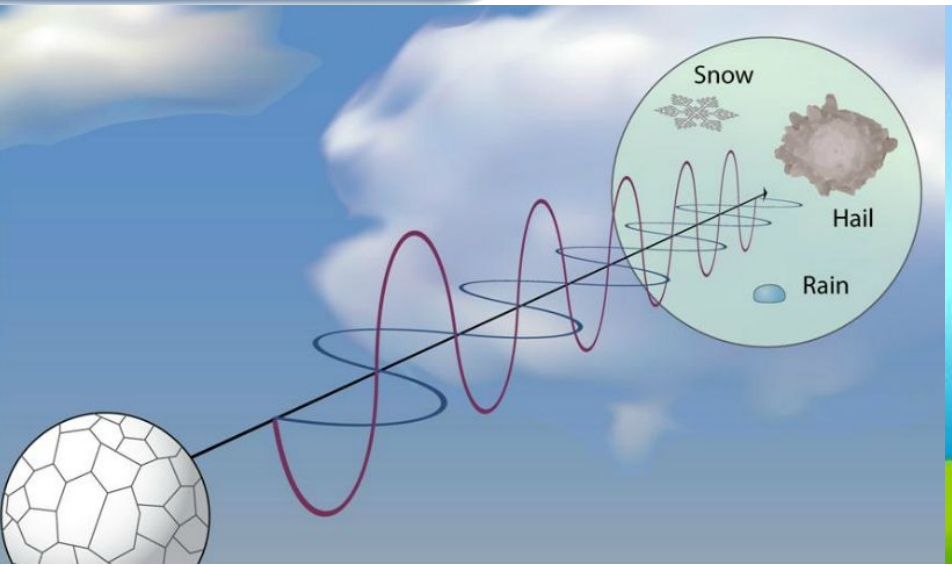
What separates storm relative motion from base velocity is the motion of storms are "subtracted" from the overall flow of the wind.

Green = Motion towards the radar
Red = Motion aw

Couplet: Intense
to intense inbou



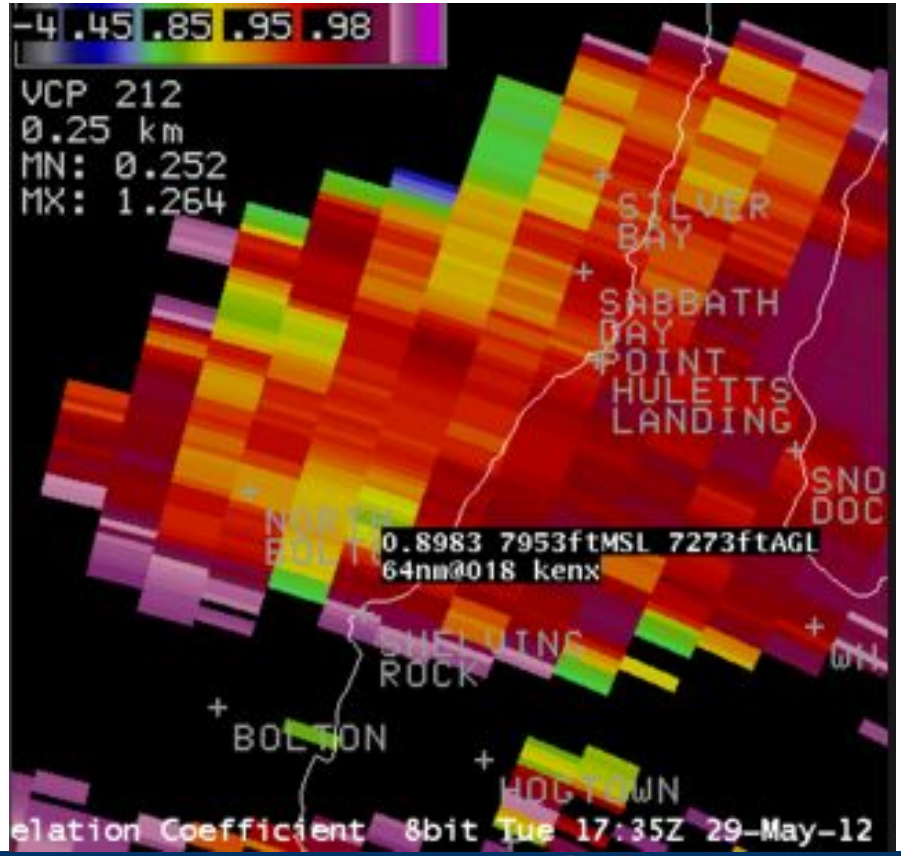
Dual-Polarization Radar



- Radar waves <u>polarized</u> horizontally *and* vertically
- Can see the size and shape of weather and non-weather targets
- Threats seen: Hail, heavy rainfall, tornado debris

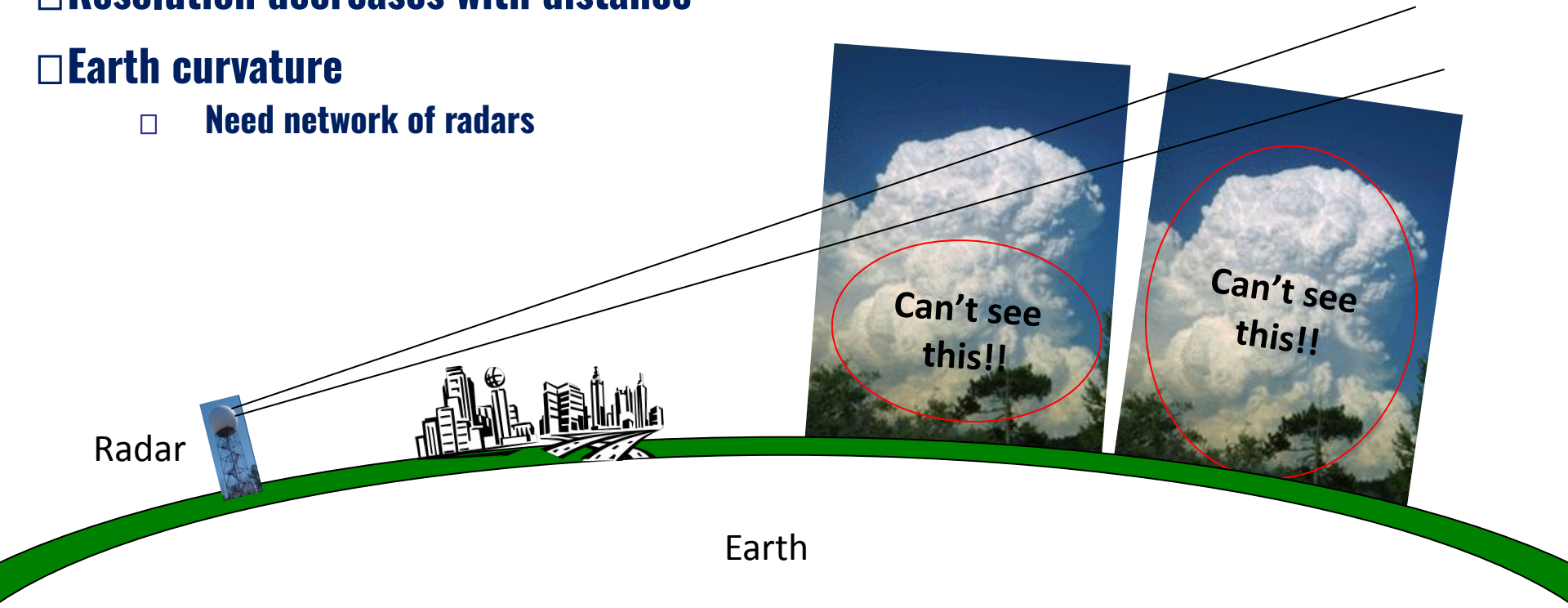
Correlation Coefficient

- A correlation between the reflected horizontal and vertical power returns
- Good indicator of hydrometeor diversity
- High values = Uniform targets (rain)
- Low values = Other targets mixed in (hail, debris, bugs, etc.)



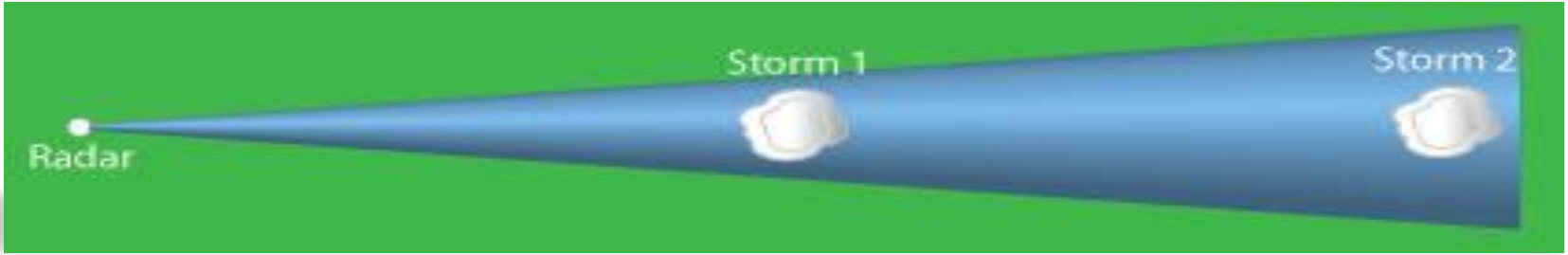
Limitations of Radar

- Resolution decreases with distance
- Earth curvature
  - Need network of radars



Limitations of Radar

Beam Spreading:

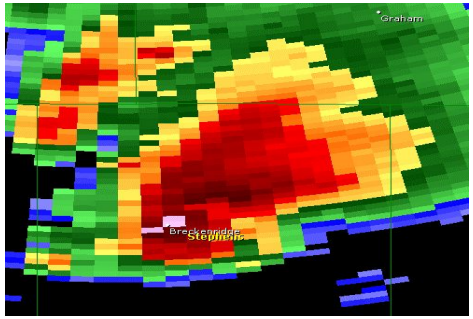


- Beam spreads nearly 1,000 ft for every 10 miles of travel.
  - At 60 miles from the radar the beam is over 6,000 feet wide.
  - At 120 miles from the radar the beam is well over 2 miles wide.

Beam spreading affects resolution capability of the radar!

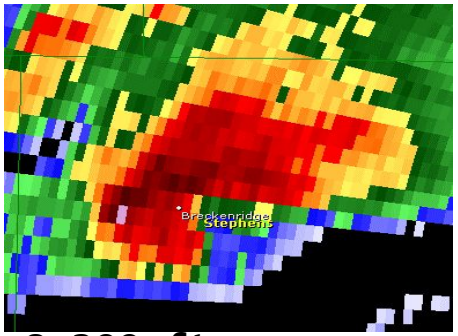
Small scale features which can be easily discerned near the radar often become obscured at greater distances.

Effects of Beam Spreading:
Same Storm w/ 4 different Radars



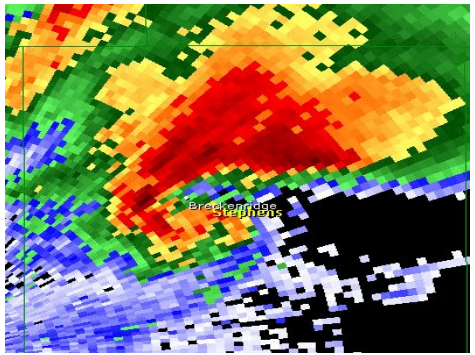
Frederick

112 miles / 11,200 ft



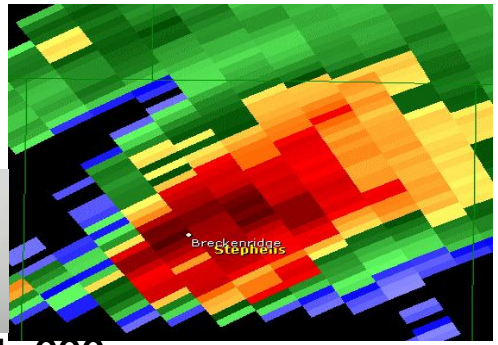
Fort Worth

94 miles / 8,300 ft



Dyess AFB

25 miles / 1,700 ft

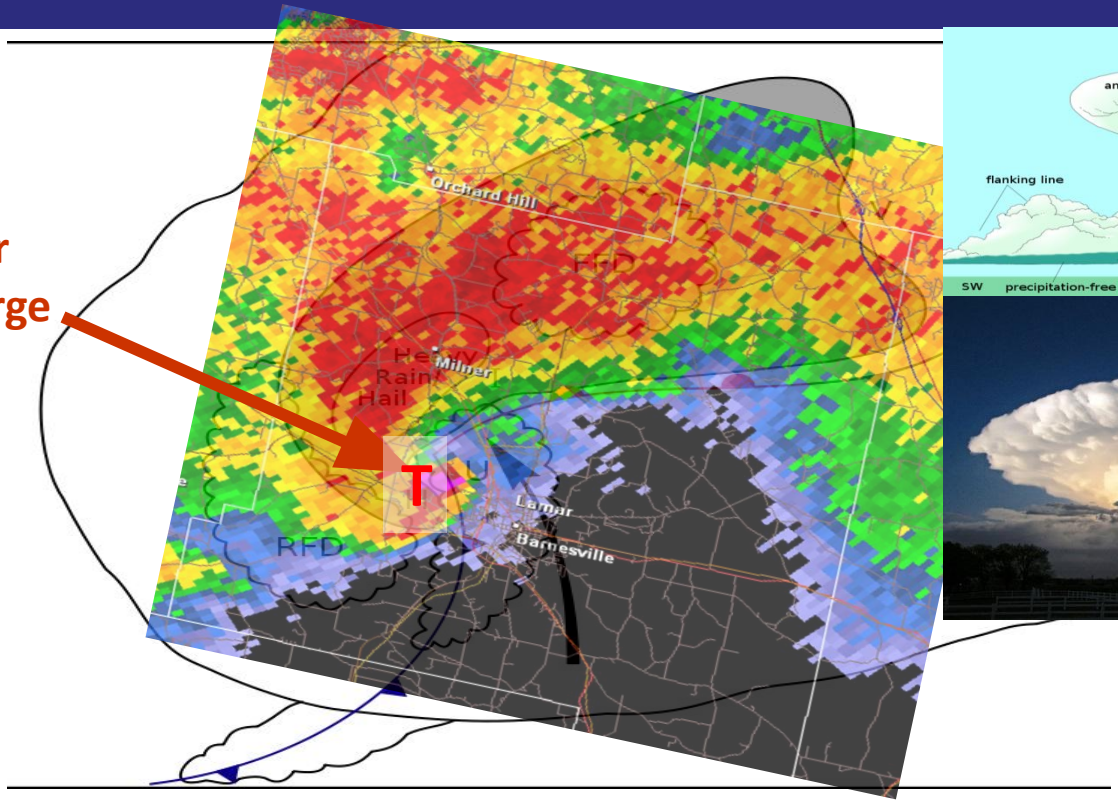


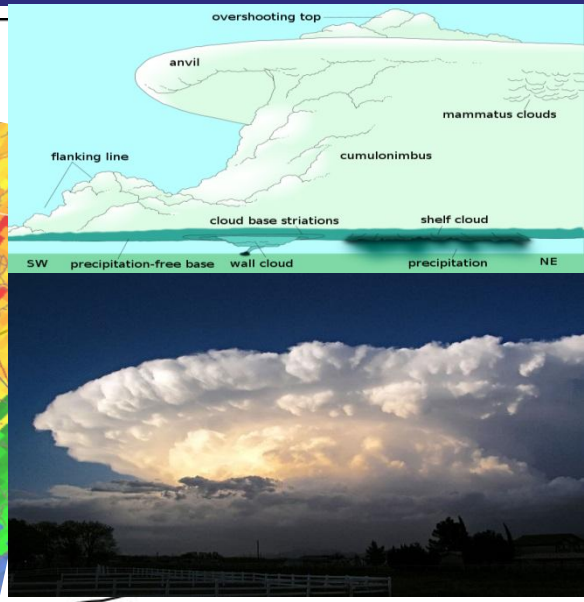
Granger

167 miles / 21,000 ft

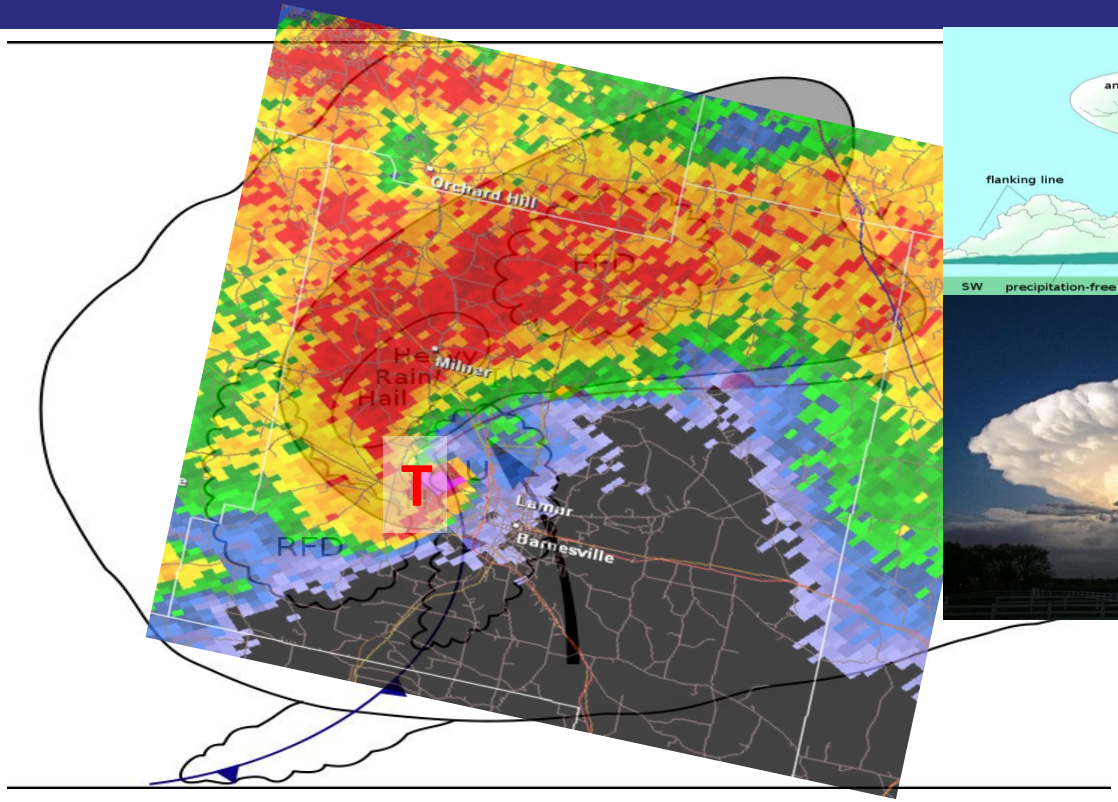
Storm Structure - Reflectivity

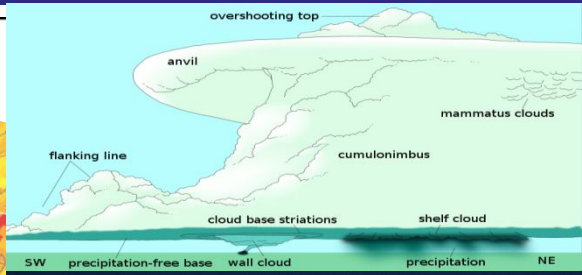
Most likely area for damaging wind, large hail and tornadoes



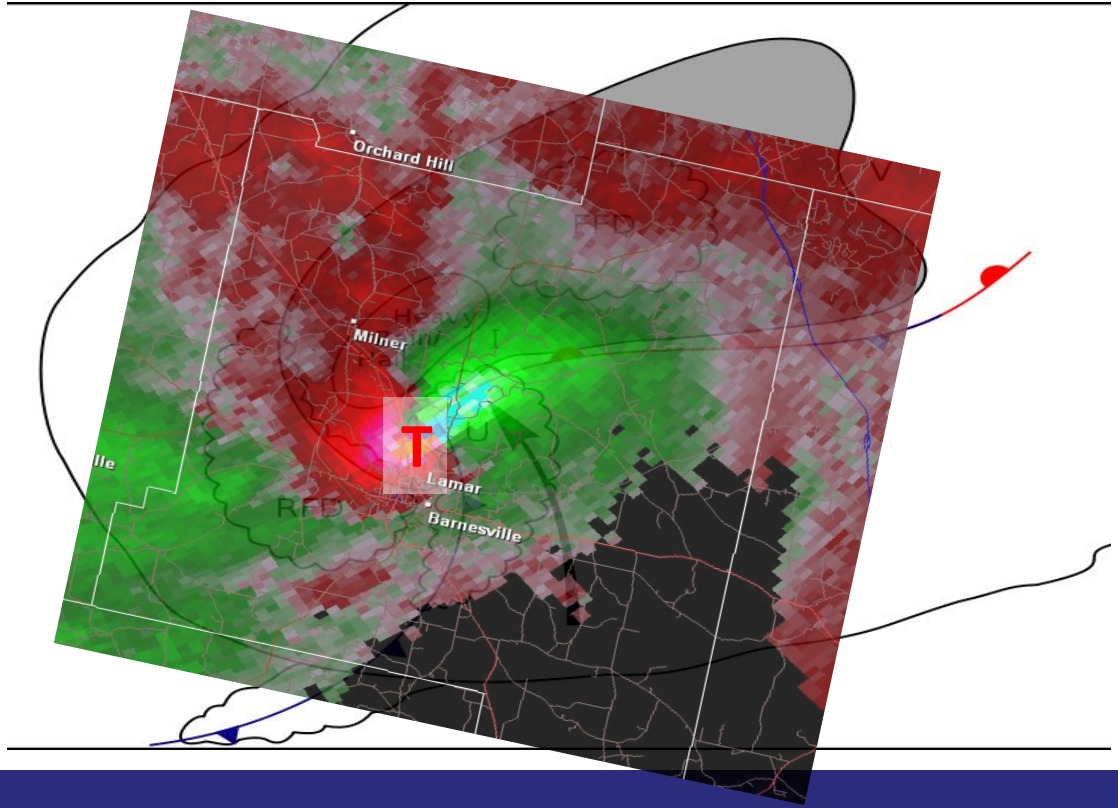


Storm Structure - Reflectivity

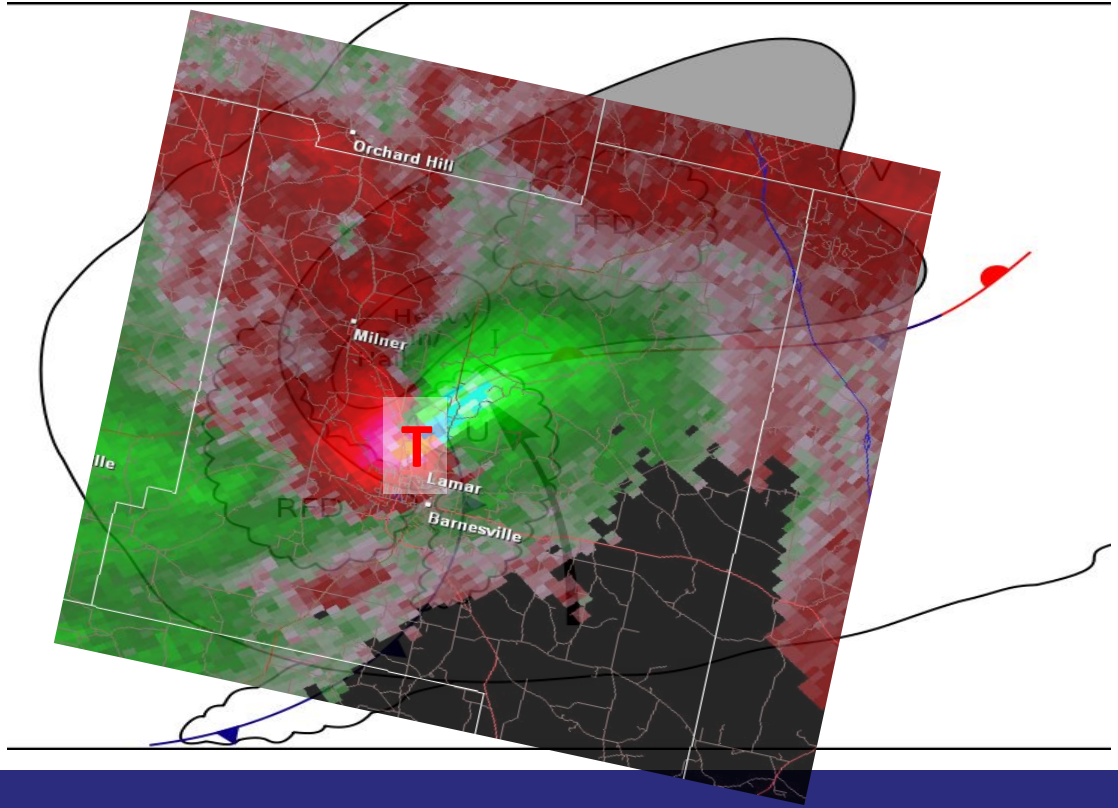




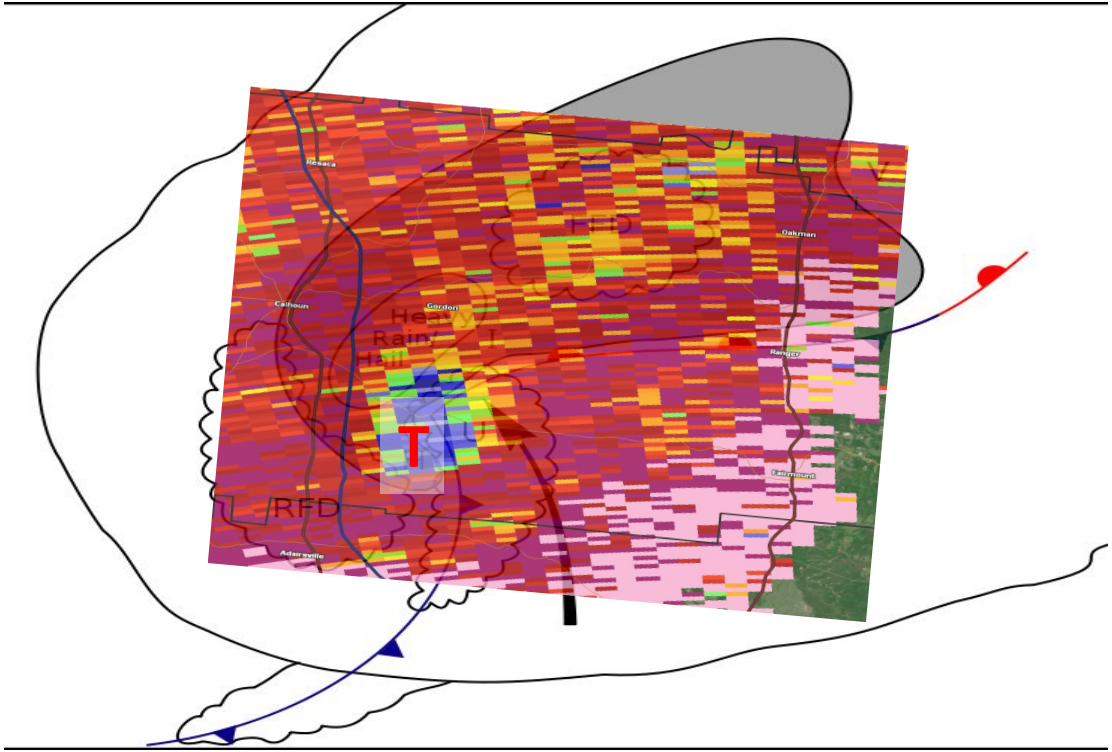
Storm Structure - Velocity



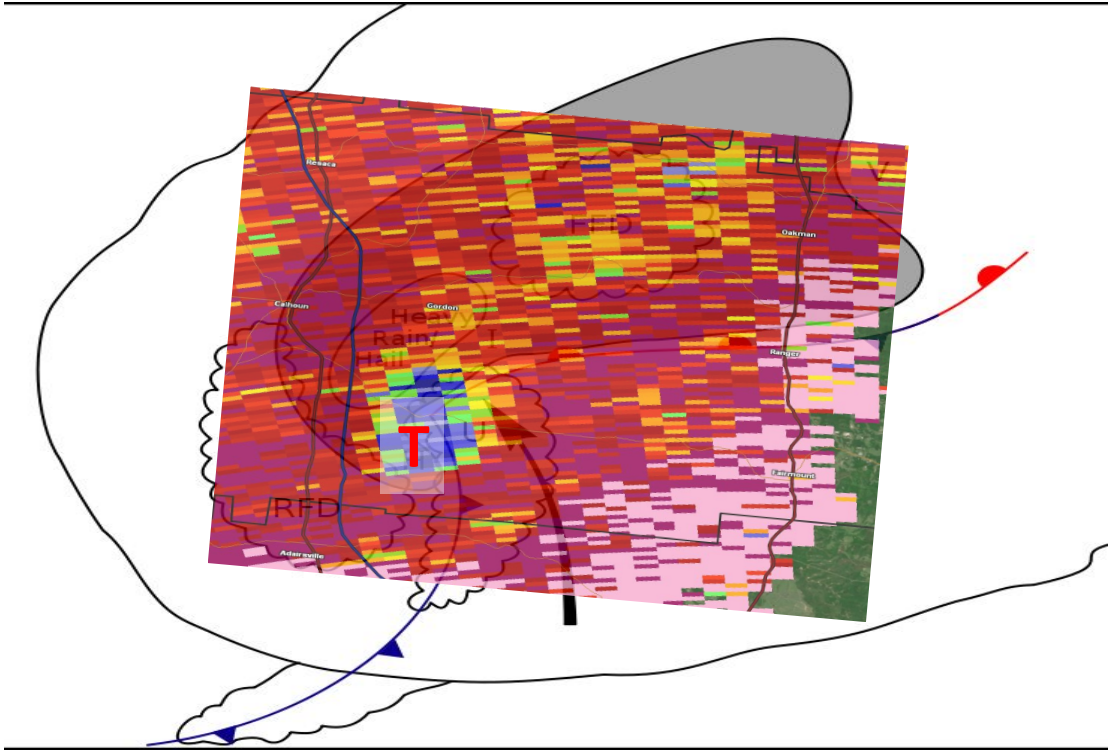
Storm Structure - Velocity



Storm Structure – Dual-polarization



Storm Structure – Dual-polarization



Impact-Based Warnings

Tags

Tags will appear at the bottom of Tornado and Severe Thunderstorm Warnings, and in the Severe Weather Statements that update the warnings.

In a *Severe Thunderstorm Warning*, tags will be used to define:

- hail size
- wind speed
- possible tornado (if necessary)

In a *Tornado Warning*, two types of tags can be used:

- Tornado tag (always used)
  - radar indicated
  - observed
- Damage threat tag (optional)
  - considerable damage
  - catastrophic damage

Tags will appear in NWSChat

(4:39:41 PM) nwsbot: LSX issues Tornado Warning [tornado: RADAR INDICATED, hail: <.75 IN] PRODUCING A TORNADO WAS LOCATED NEAR BROWNSTOWN...AND MOVING EAST AT 55

Tornado Tag	
TORNADO...RADAR INDICATED	Evidence on radar and near storm environment is supportive, but no confirmation.
TORNADO...OBSERVED	Tornado is confirmed by spotters, law enforcement, or radar (tornado debris signature).
Tornado Damage Threat Tag	
No Tag	Use most of the time, when tornado damage is possible within the warning polygon. Tornado duration generally expected to be short lived.
TORNADO DAMAGE THREAT...CONSIDERABLE	Use rarely, when there is credible evidence that a tornado, capable of producing considerable damage, is imminent or ongoing. Tornado duration generally expected to be long lived.
TORNADO DAMAGE THREAT...CATASTROPHIC	Extremely rare. A severe threat to human life and catastrophic damage from a tornado is occurring, and will only be used when reliable sources confirm a violent tornado. Tornado duration generally expected to be long lived.
Tornado Tag in Severe Thunderstorm Warnings	
TORNADO...POSSIBLE	A severe thunderstorm has some potential for producing a tornado although forecaster confidence is not high enough to issue a Tornado Warning.

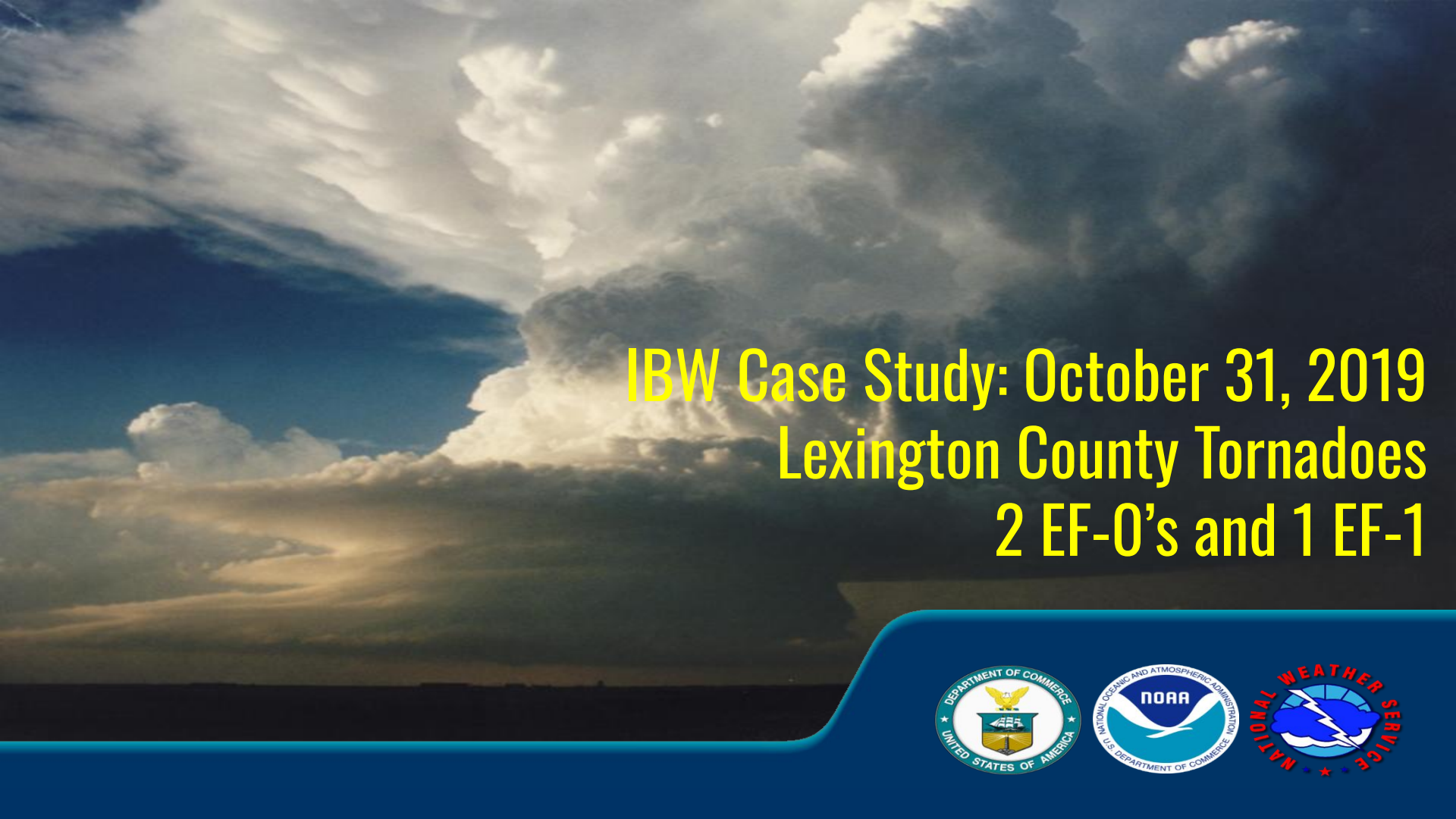
Purpose:
Impact Based Warnings

Meteorology: Newer (88D/Dual-Pol) Radar technology & products can affect NWS warning decision-making

Social Science: Small, yet critical, wording changes in Warnings & Follow-up statements (SVS)

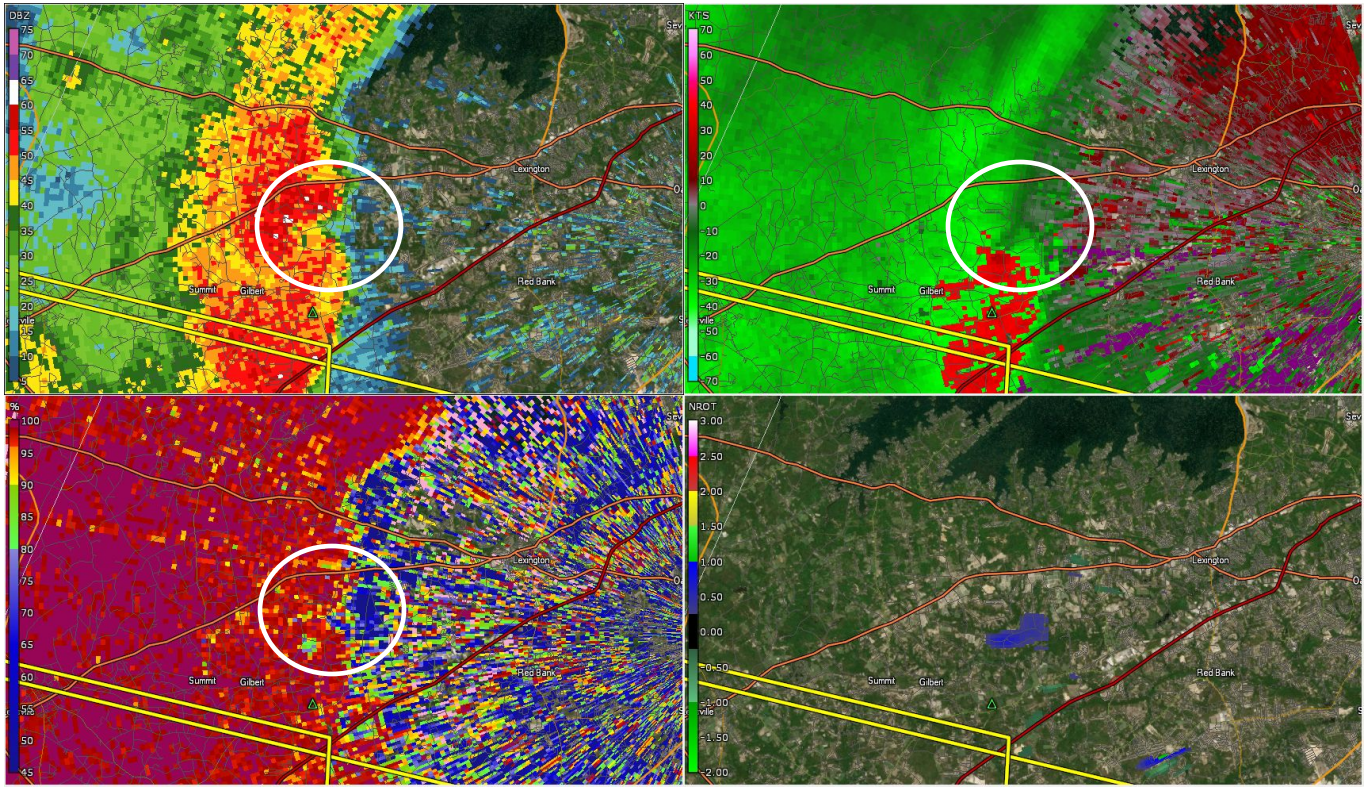
- Hazard/Source/Impacts/Tags

Media & Public: easier to key in on the most important parts of warning (threats & impacts)

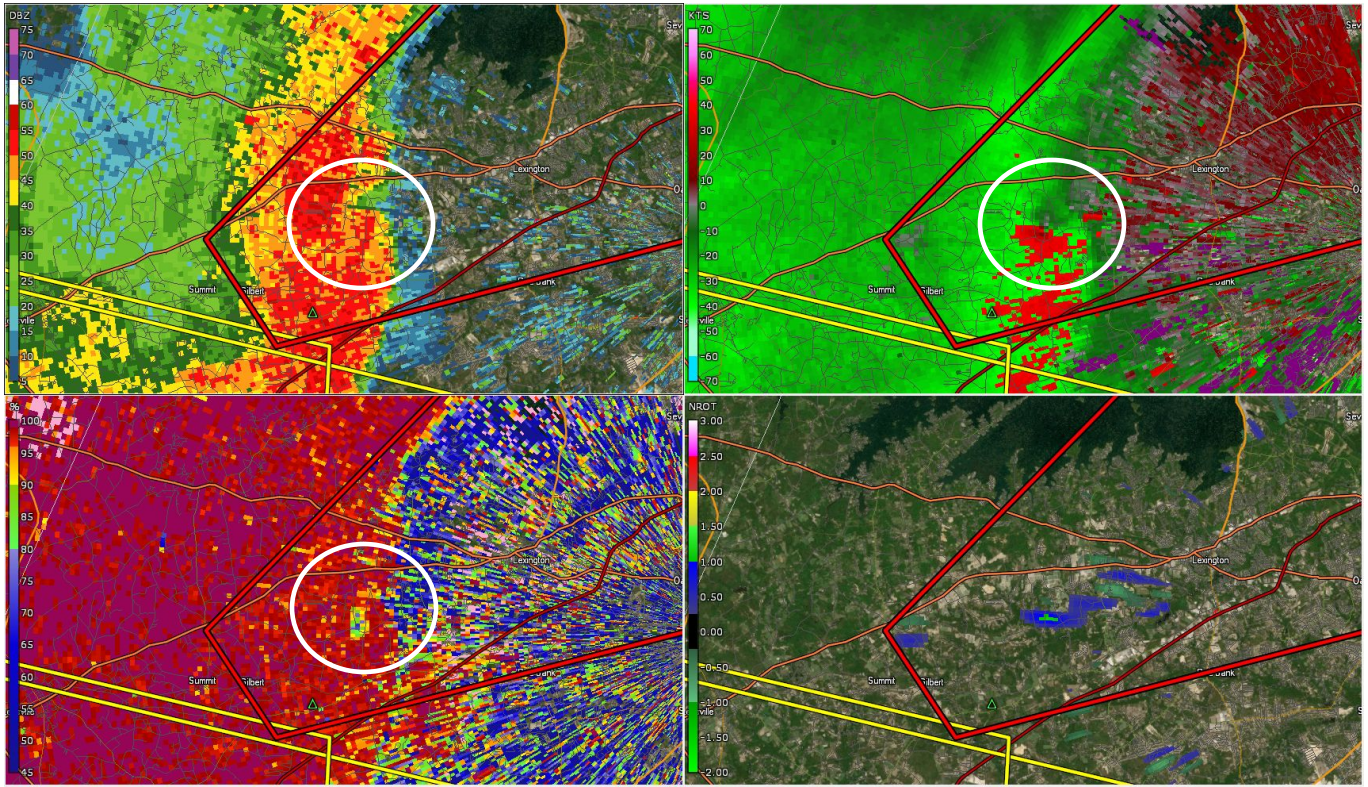


IBW Case Study: October 31, 2019
Lexington County Tornadoes
2 EF-0's and 1 EF-1

4-panel from CAE Radar:
5:57 PM EDT



4-panel from CAE Radar:
5:59 PM EDT



Initial TORNADO Warning Issued at 5:59 PM EDT

Routine Tornado Warning
(radar indicated, no damage tag)

BULLETIN - EAS ACTIVATION REQUESTED
Tornado Warning
National Weather Service Columbia SC
559 PM EDT Thu Oct 31 2019

The National Weather Service in Columbia has issued a

* Tornado Warning for...
  Central Lexington County in central South Carolina...
  Northwestern Richland County in central South Carolina...

* Until 630 PM EDT.

* At 558 PM EDT, a severe thunderstorm capable of producing a tornado
  was located near Red Bank, moving northeast at 45 mph.

HAZARD...Tornado.

SOURCE...Radar indicated rotation.

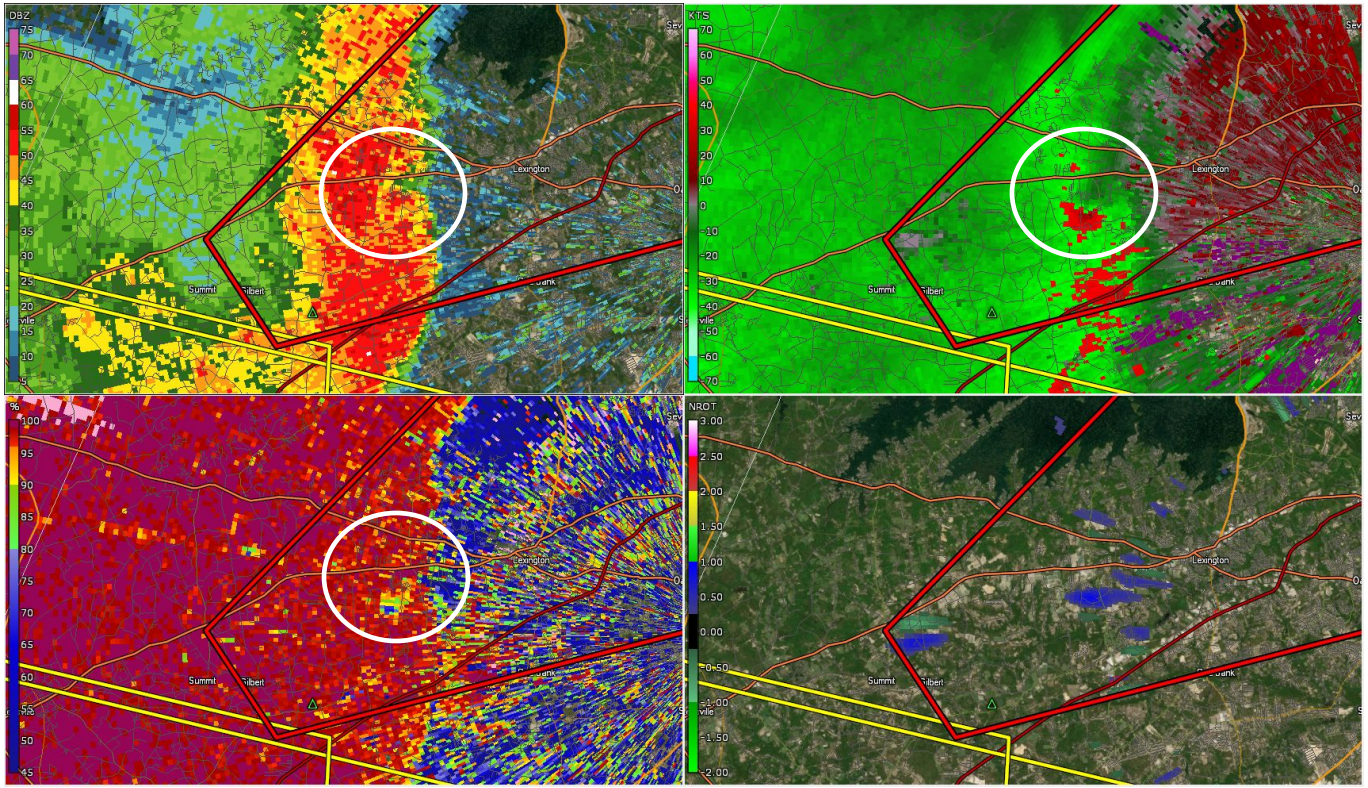
IMPACT...Flying debris will be dangerous to those caught without
shelter. Mobile homes will be damaged or destroyed.
Damage to roofs, windows, and vehicles will occur. Tree
damage is likely.

* This dangerous storm will be near...
  Lexington, Cayce and Highway 6 at Lake Murray Dam around 610 PM EDT.
  Columbia, West Columbia, Irmo, Springdale and Oak Grove around 615 PM EDT.
  St. Andrews, Columbia International University, Harbison State
  Forest, Riverbanks Zoo, West Columbia Riverwalk, Five Points and
  SC State Fair Grounds around 620 PM EDT.

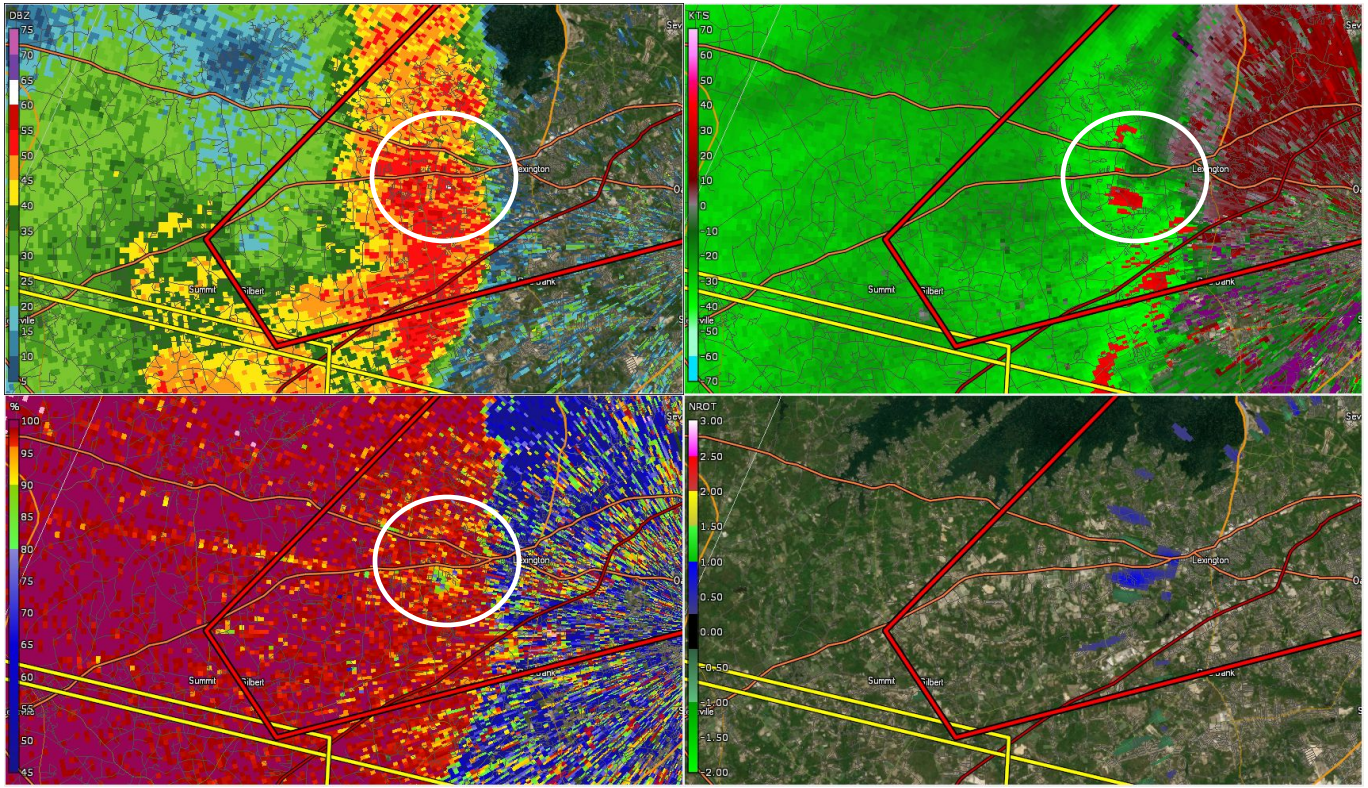
LAT...LON 3402 8082 3390 8138 3395 8142 3422 8110
3422 8108 3423 8107 3424 8105 3423 8104
3425 8098
TIME...MOT...LOC 2158Z 240DEG 41KT 3395 8133

TORNADO...RADAR INDICATED
HAIL...0.00IN

4-panel from CAE Radar:
6:01 PM EDT



4-panel from CAE Radar:
6:04 PM EDT



Follow-up Severe Weather Statement
Issued at 6:06 PM EDT

Observed Tornado Warning
(radar confirmed tornado, no damage tag)

SCC063-079-312230-
/O.CON.KCAE.TO.W.0021.000000T0000Z-191031T2230Z/
Lexington SC-Richland SC-
606 PM EDT Thu Oct 31 2019

...A TORNADO WARNING REMAINS IN EFFECT UNTIL 630 PM EDT FOR NORTHEASTERN LEXINGTON AND NORTHWESTERN RICHLAND COUNTIES...

At 605 PM EDT, a confirmed tornado was located over Lexington, moving northeast at 45 mph. This tornado is approaching Lexington now.

HAZARD...Damaging tornado.

SOURCE...Radar confirmed tornado.

IMPACT...Flying debris will be dangerous to those caught without shelter. Mobile homes will be damaged or destroyed. Damage to roofs, windows, and vehicles will occur. Tree damage is likely.

This tornado will be near...
Cayce and Highway 6 at Lake Murray Dam around 610 PM EDT.
Irmo and Oak Grove around 615 PM EDT.
Columbia, West Columbia, St. Andrews, Columbia International University, Harbison State Forest, Riverbanks Zoo, West Columbia Riverwalk and Five Points around 620 PM EDT.

PRECAUTIONARY/PREPAREDNESS ACTIONS...

Report tornadoes, large hail, damaging winds or flooding directly to the Columbia National Weather Service at 803-234-4115 when it is safe to do so. You can also send reports by Facebook or Twitter to NWSColumbia or by e-mail at NWS.Columbia@noaa.gov.

&

LAT...LON 3403 8083 3394 8129 3398 8133 3422 8110
3422 8108 3423 8107 3424 8105 3423 8104
3425 8098
TIME...MOT...LOC 2205Z 239DEG 39KT 3399 8125

TORNADO...OBSERVED

Potential Statements for strengthening tornado

Considerable Tornado Warning
(observed tornado, considerable damage tag)

SCC063-079-312230-
/O.CON.KCAE.TO.W.0021.000000T0000Z-191031T2230Z/
Lexington SC-Richland SC-
610 PM EDT Thu Oct 31 2019

...A TORNADO WARNING REMAINS IN EFFECT UNTIL 630 PM EDT FOR NORTHEASTERN LEXINGTON AND NORTHWESTERN RICHLAND COUNTIES...

At 610 PM EDT, a confirmed tornado was located over Lexington, moving northeast at 45 mph.

THIS IS A PARTICULARLY DANGEROUS SITUATION

HAZARD...Damaging tornado.

SOURCE...Emergency Management confirmed tornado.

IMPACT...You are in a life threatening situation. Mobile homes will be destroyed. Considerable damage to homes, businesses and vehicles is likely and complete destruction is possible. Flying debris will be Deadly to people and animals. Expect trees to be uprooted or snapped.

This tornado will be near...
Irmo and Oak Grove around 615 PM EDT.
Columbia, West Columbia, St. Andrews, Columbia International University, Harbison State Forest, Riverbanks Zoo, West Columbia Riverwalk and Five Points around 620 PM EDT.

PRECAUTIONARY/PREPAREDNESS ACTIONS...

A large, extremely dangerous and potentially deadly tornado is on the ground.
To protect your life, take cover now!

&&

LAT...LON 3403 8083 3394 8129 3398 8133 3422 8110
3422 8108 3423 8107 3424 8105 3423 8104
3425 8098
TIME...MOT...LOC 2205Z 239DEG 39KT 3399 8125

TORNADO...OBSERVED
TORNADO DAMAGE THREAT...CONSIDERABLE
HAIL...1.00IN

Catastrophic Tornado Warning
(observed tornado, catastrophic damage tag)

SCC063-079-312230-
/O.CON.KCAE.TO.W.0021.000000T0000Z-191031T2230Z/
Lexington SC-Richland SC-
615 PM EDT Thu Oct 31 2019

...TORNADO EMERGENCY FOR COLUMBIA...

...A TORNADO WARNING REMAINS IN EFFECT UNTIL 630 PM EDT FOR NORTHEASTERN LEXINGTON AND NORTHWESTERN RICHLAND COUNTIES...

At 615 PM EDT, a confirmed tornado was located over West Columbia, moving northeast at 45 mph.

THIS IS A TORNADO EMERGENCY FOR THE CITY OF COLUMBIA. TAKE COVER NOW.
THIS IS A PARTICULARLY DANGEROUS SITUATION.

HAZARD...Deadly tornado.

SOURCE...Law Enforcement confirmed tornado.

IMPACT...You are in a life threatening situation. Mobile homes will be destroyed. Considerable damage to homes, businesses and vehicles is likely and complete destruction is possible. Flying debris will be Deadly to people and animals. Expect trees to be uprooted or snapped.

This tornado will be near...
Columbia, St. Andrews, Harbison State Forest, Riverbanks Zoo, West Columbia Riverwalk and Five Points around 620 PM EDT.

PRECAUTIONARY/PREPAREDNESS ACTIONS...

A large, extremely dangerous and potentially deadly tornado is on the ground.
To protect your life, take cover now!

&&

LAT...LON 3403 8083 3394 8129 3398 8133 3422 8110
3422 8108 3423 8107 3424 8105 3423 8104
TIME...MOT...LOC 2205Z 239DEG 39KT 3399 8125

TORNADO...OBSERVED
TORNADO DAMAGE THREAT...CATASTROPHIC
HAIL...1.50IN

What to Report

- Measured or Estimated Winds 50+ mph
- Wind Damage (downed trees/tree limbs, power lines, cars, etc.)
- Tornadoes/Waterspouts
- Funnel Clouds
- Significant Flooding (roads impassable/closed, water into homes/businesses, etc.)
- Hail (any size)...report largest piece