Taking SKYWARN to the Next Level:
An Advanced Weather & Storm Spotting Course

John Quagliariello
National Weather Service – Columbia, SC

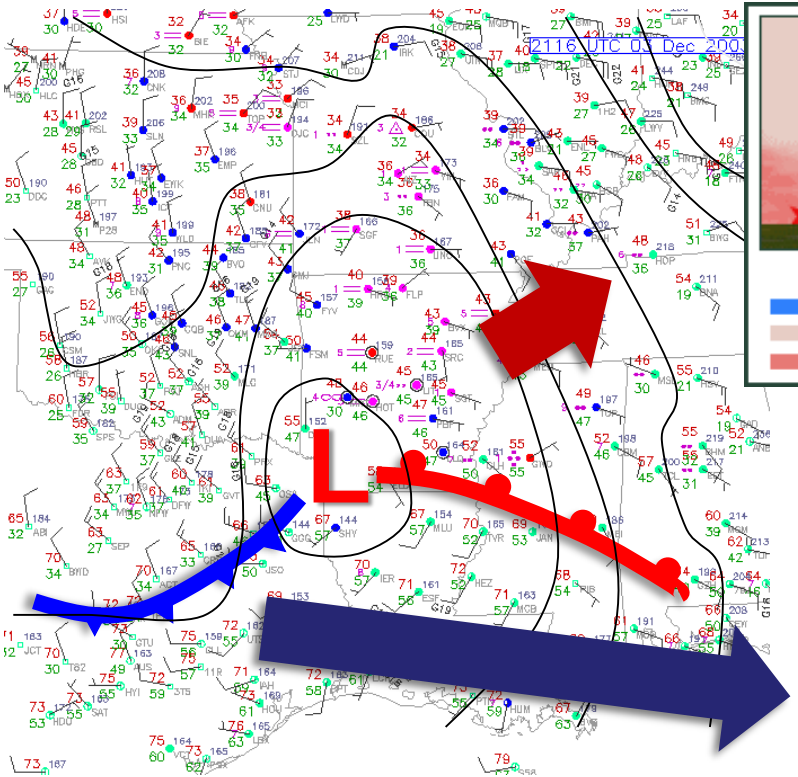
Course Information

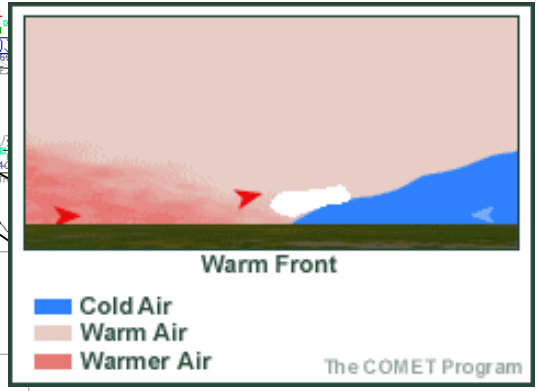
- **Purpose –**
  - To *expand* upon material presented in the basic SKYWARN course
- **General Outline –**
  - Understanding the Atmosphere
  - Severe Weather Ingredients
  - Radar Principles, Advantages and Limitations
  - Radar and Storm Structure
    - Review of Impact-Based Warnings
  - Reporting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

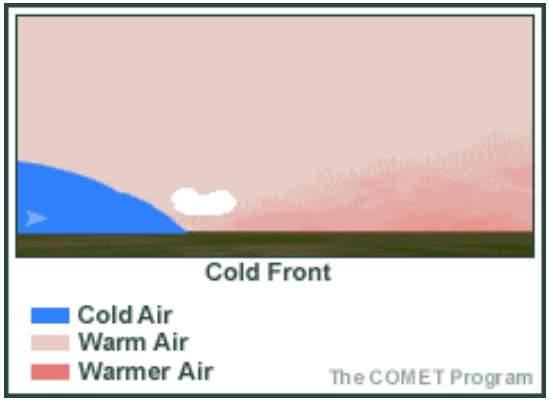
Importance of Spotters

- **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**

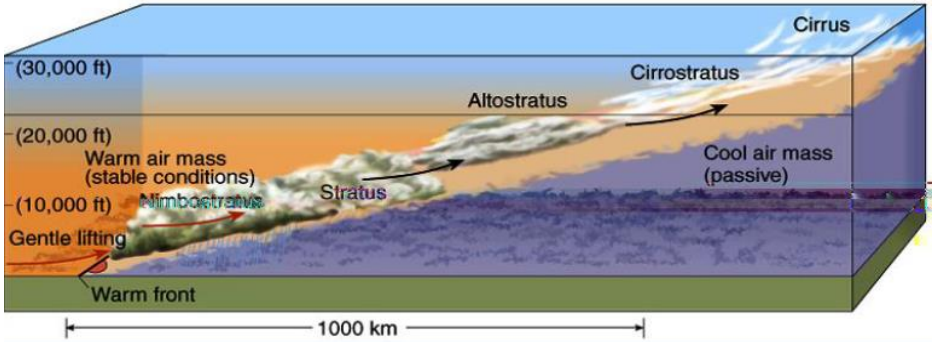
The 3-D Atmosphere



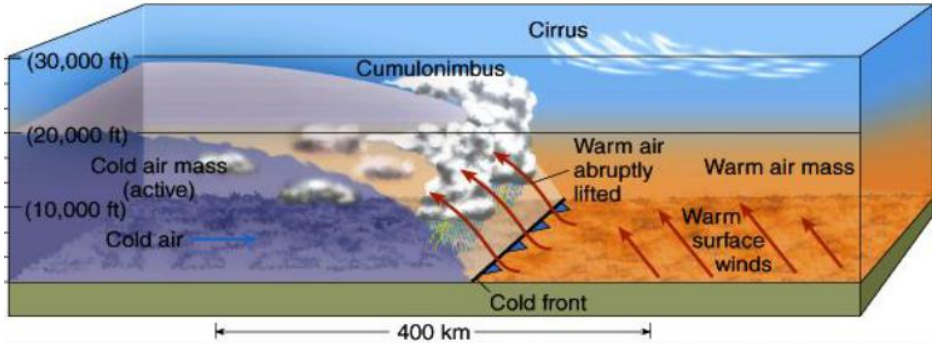




The 3-D Atmosphere



Warm Front



Cold Front

Ingredients

Thunderstorm Development

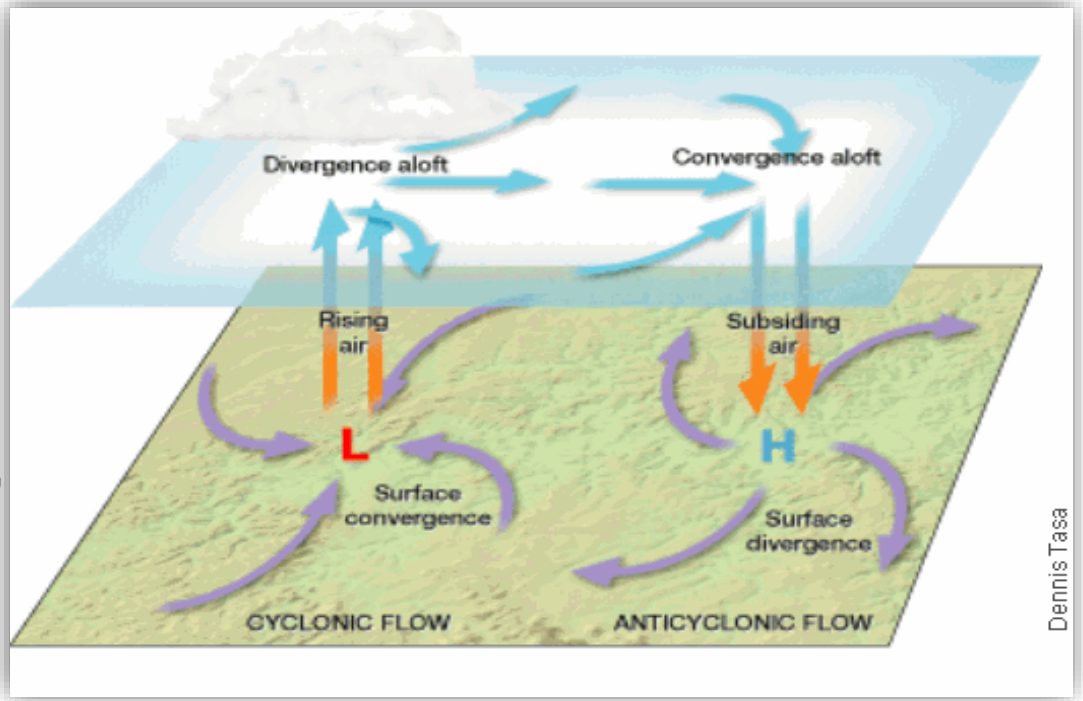
- Moisture
- Trigger / Lift
- Instability

Determining Factors:

- 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**

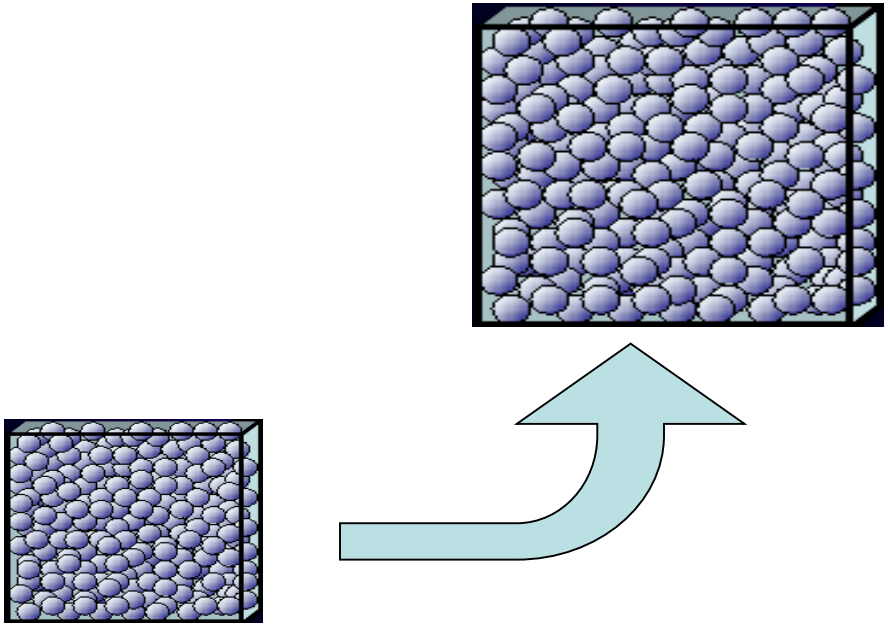


Three Types of Stability

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

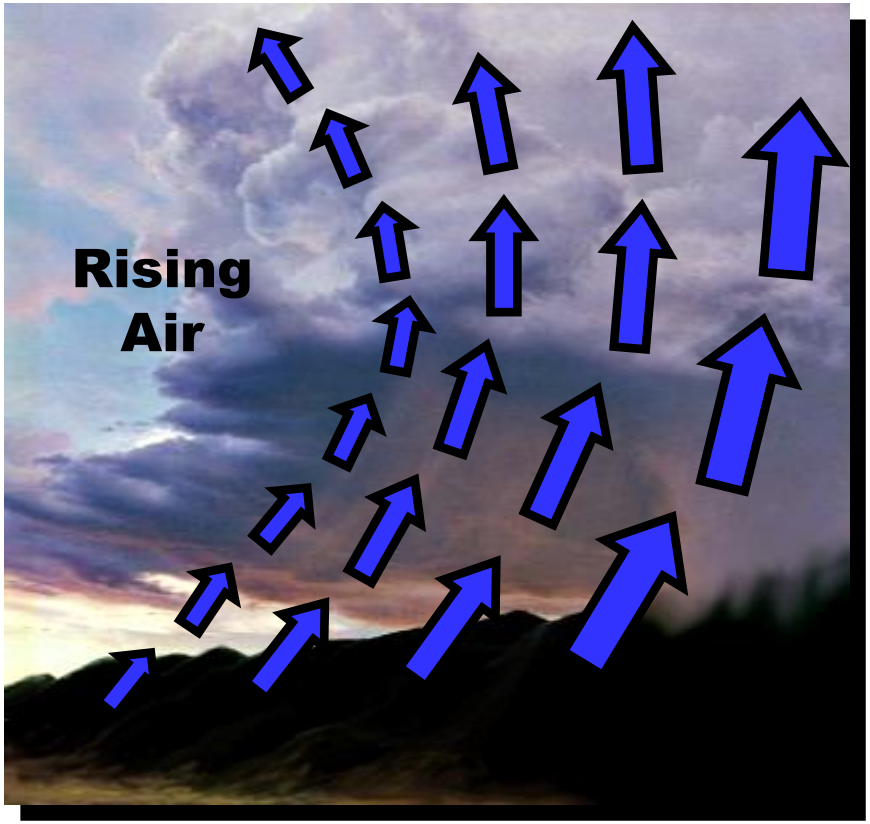
Unstable Atmosphere

- Air parcels will continue to rise



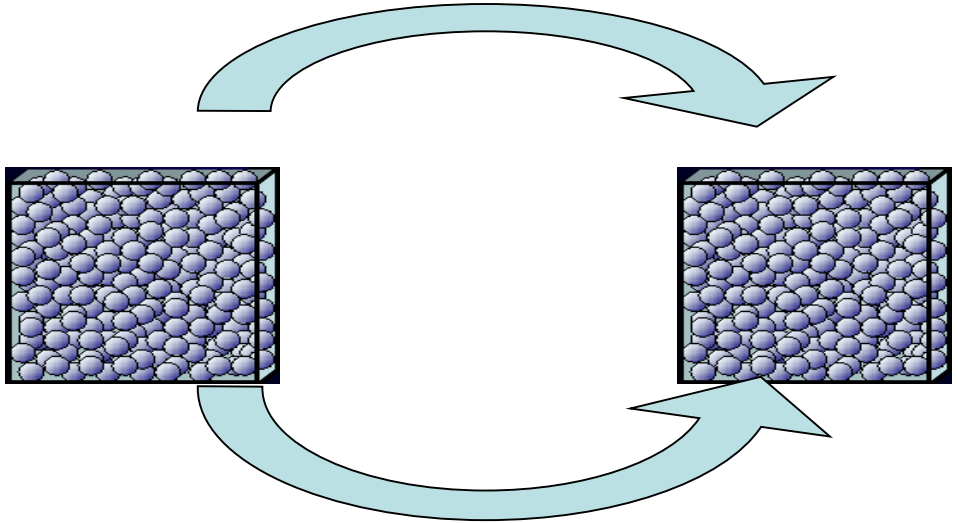
Unstable Atmosphere

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



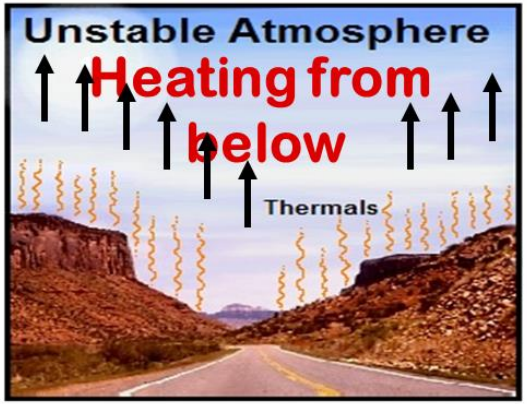
Stable Atmosphere

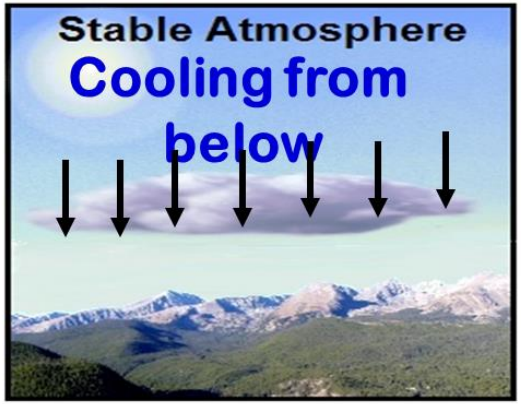
- Air parcels displaced upward (downward) will eventually return to their level of origin

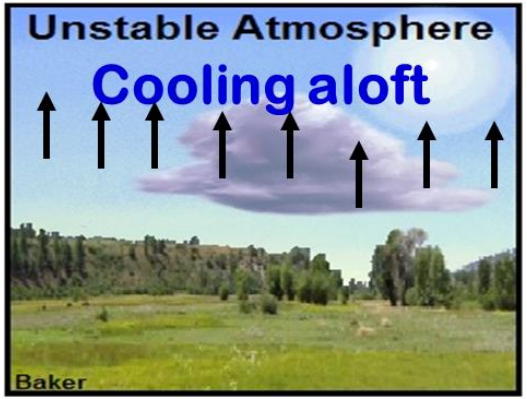


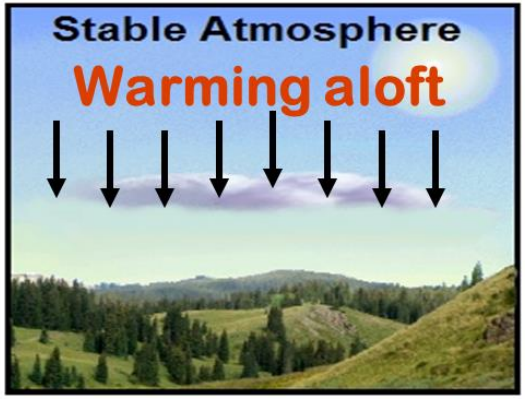
Atmospheric Stability

- 4 ways to change atmospheric stability





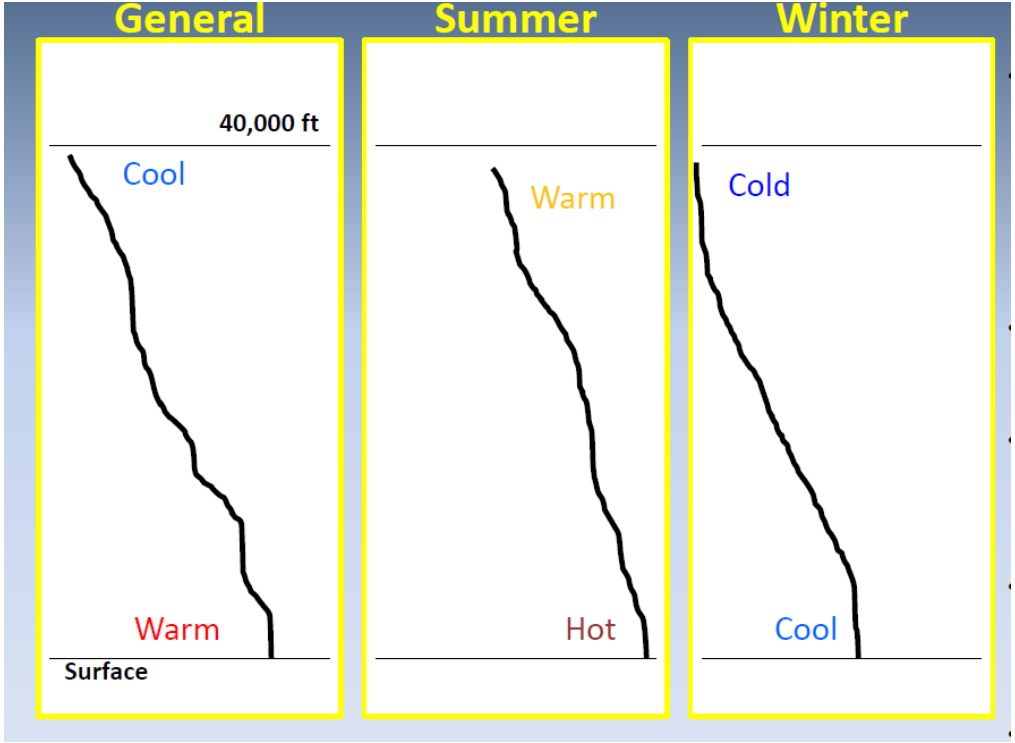




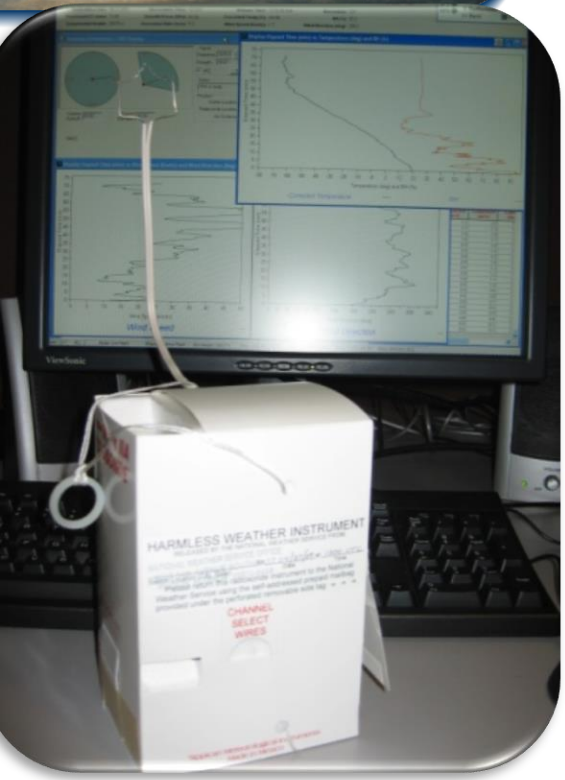
Temperature Lapse Rates

Change in Temperature / Change in Altitude

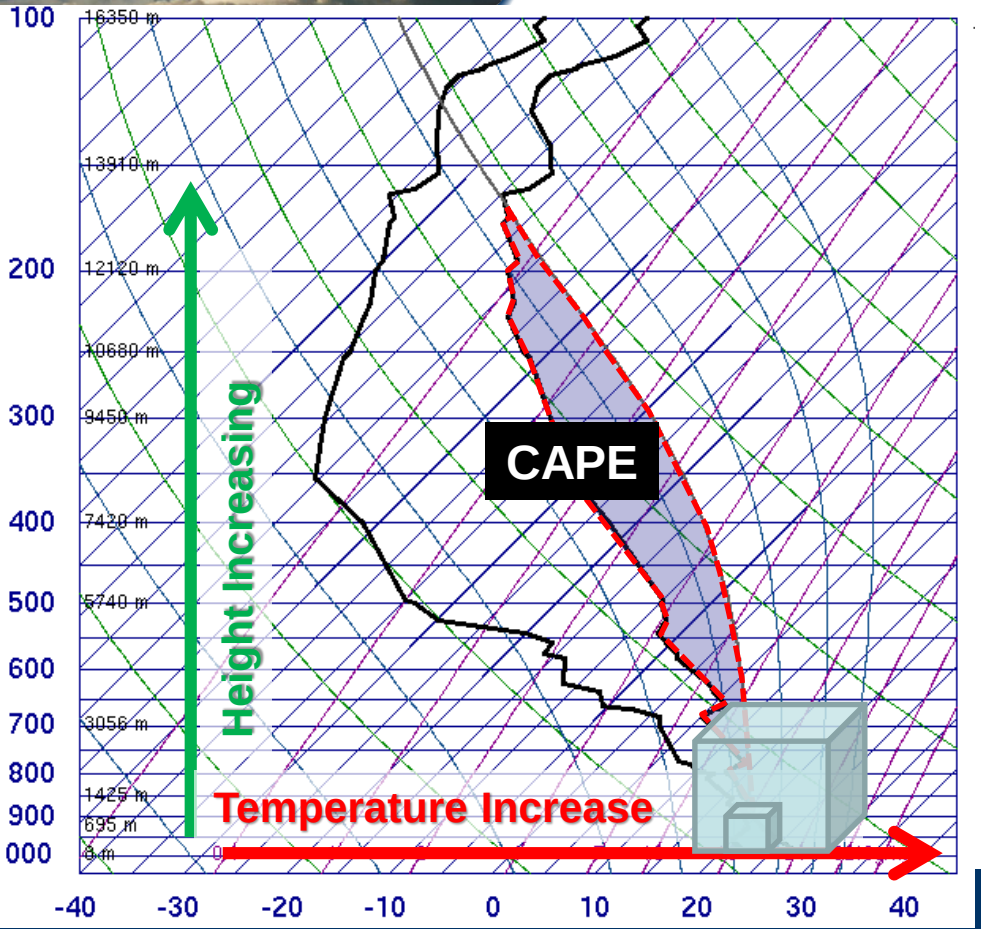
- **Instability** is based upon how warm it is at the surface vs. how cold it is aloft



Measuring Stability



Instability

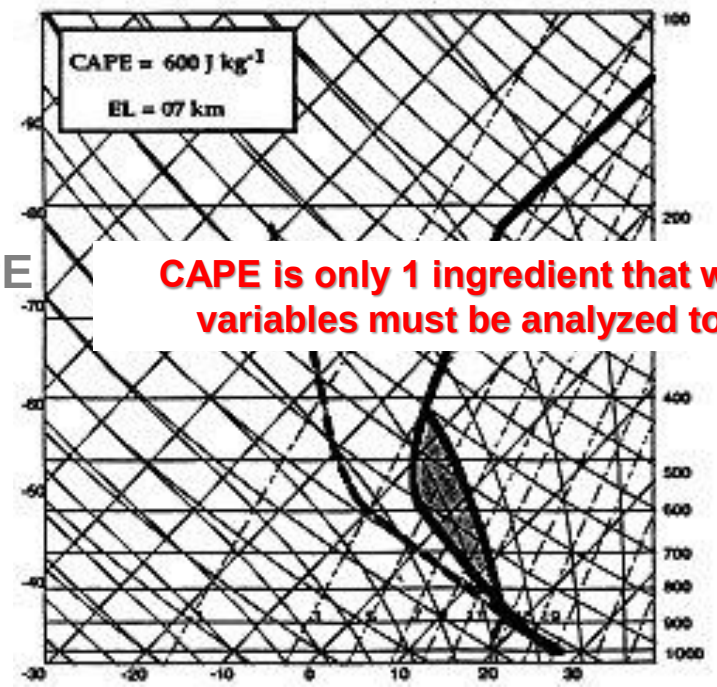


CAPE stands for the:
Convective
Available
Potential
Energy

•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

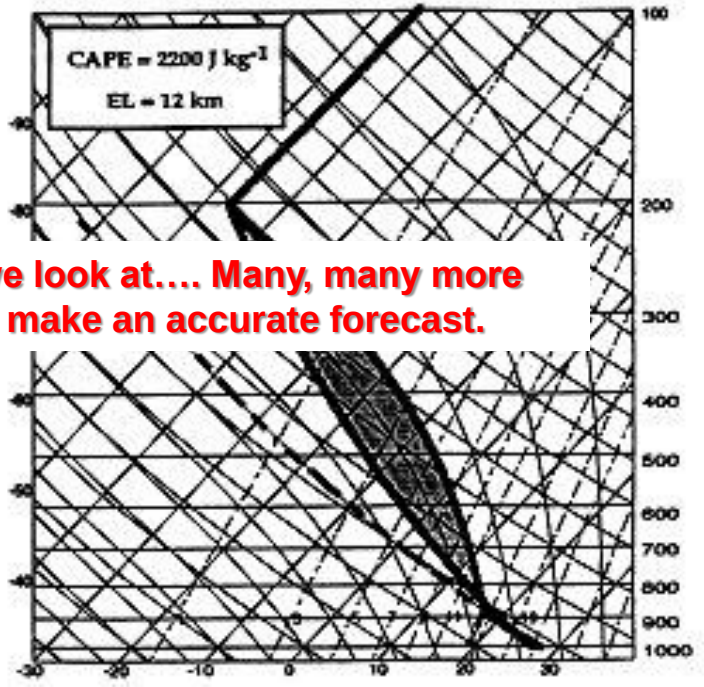
Low CAPE



- Low storm potential
- Weak lapse rate

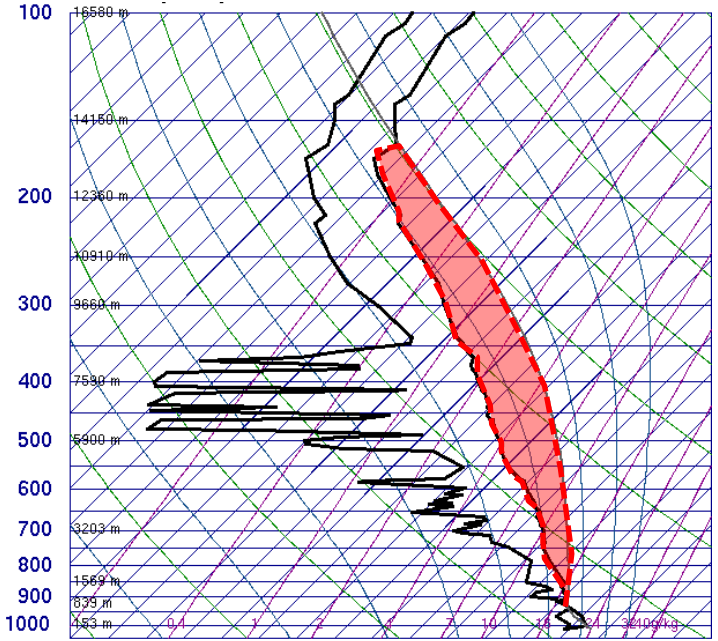
CAPE is only 1 ingredient that we look at…. Many, many more variables must be analyzed to make an accurate forecast.

High CAPE

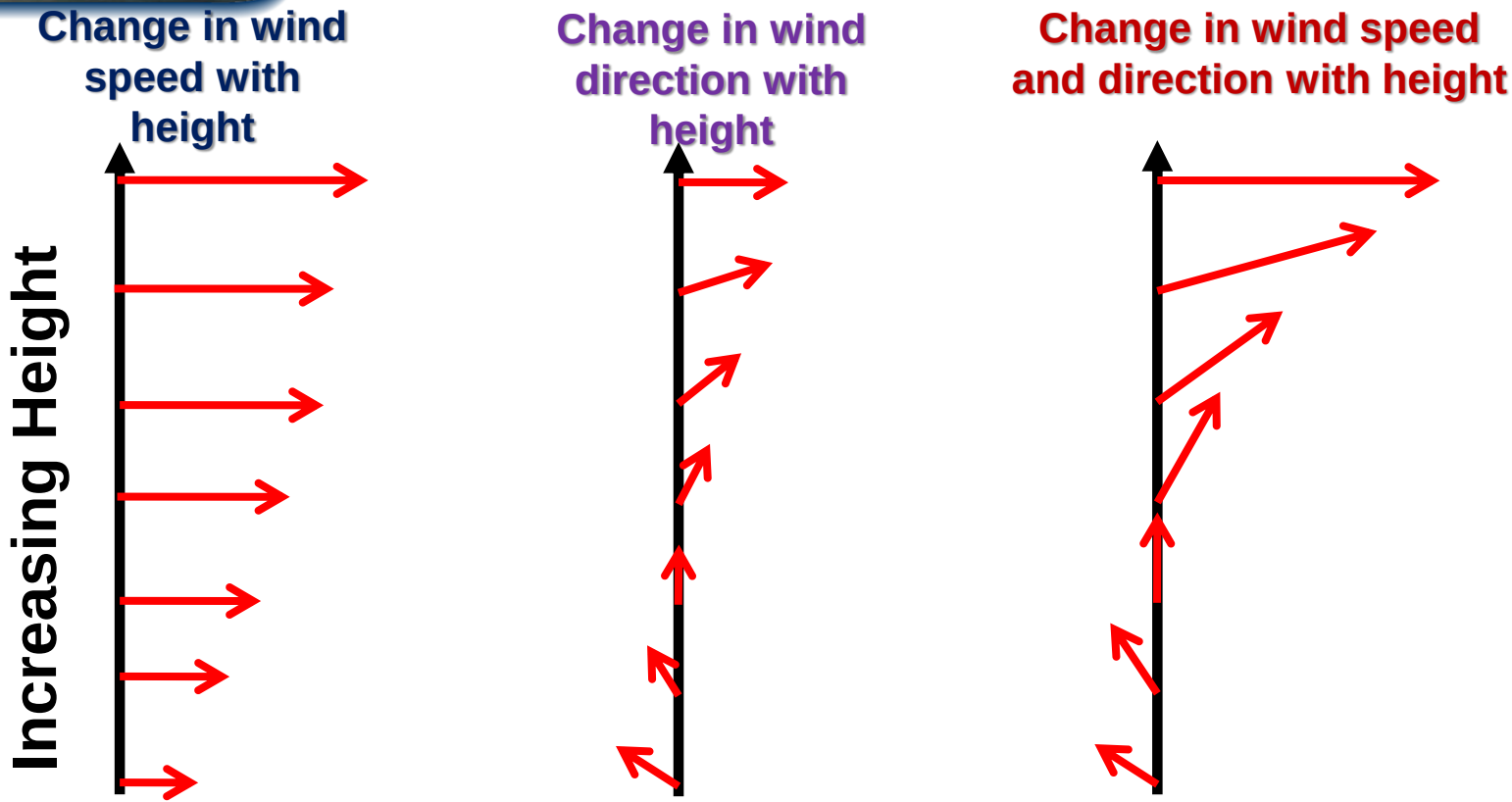


- Higher storm potential
- Steep lapse rate

CAPE and Thunderstorms

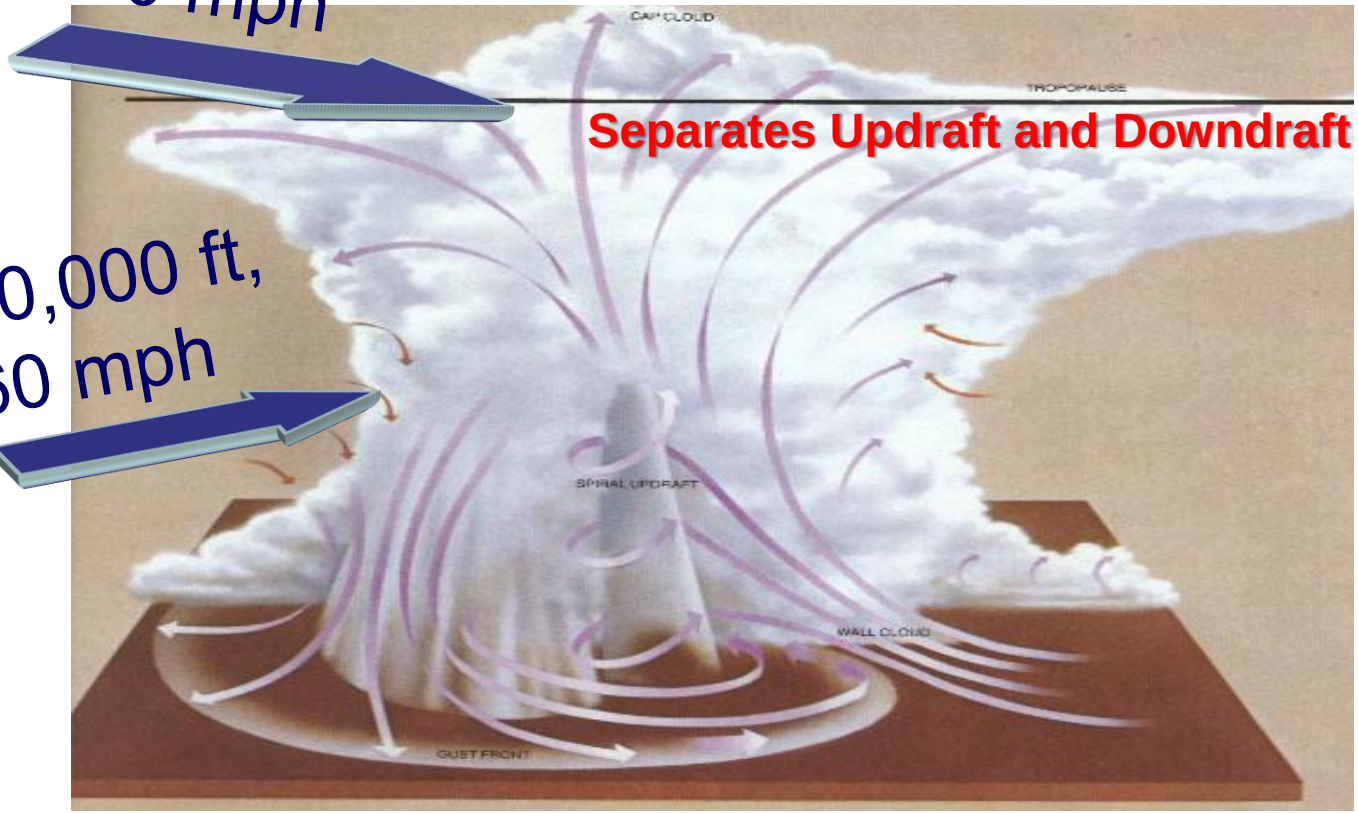


Wind Shear: What is it?



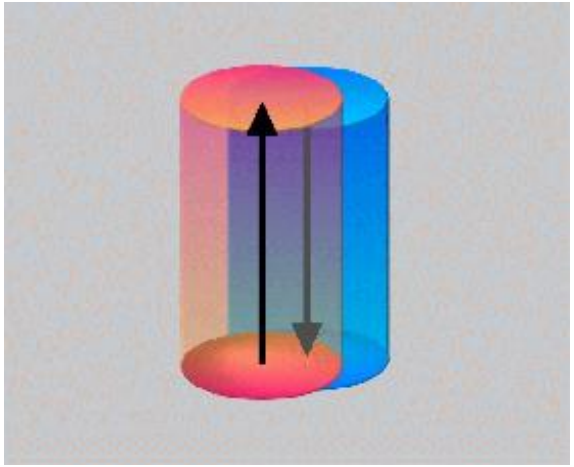
Why Wind Shear

Separate Updrafts and downdrafts allow the storm to keep refueling.



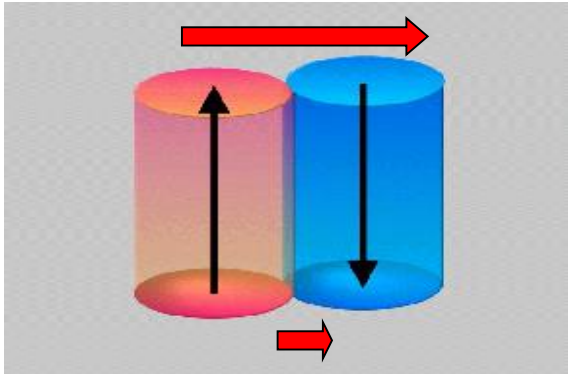
Wind Shear

Weak



Downdraft chokes updraft causing storm be short-lived

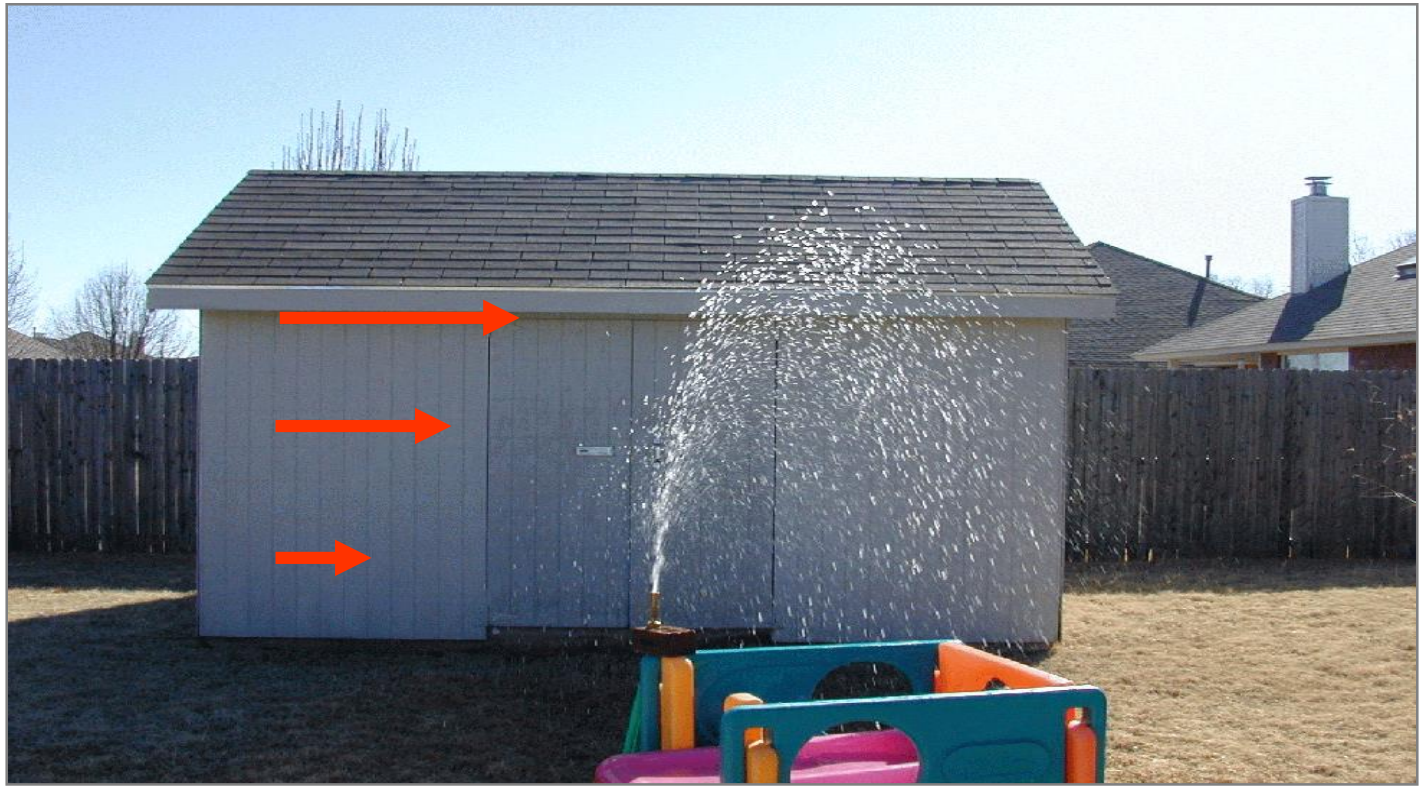
Strong



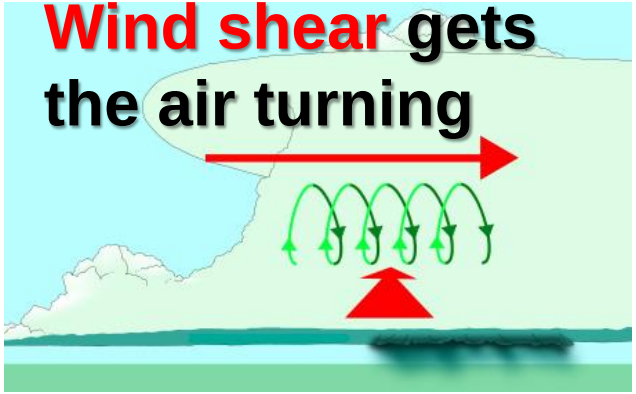
Updraft & downdraft are separated, the storm lives longer

Updraft in Weak Wind SPEED Shear

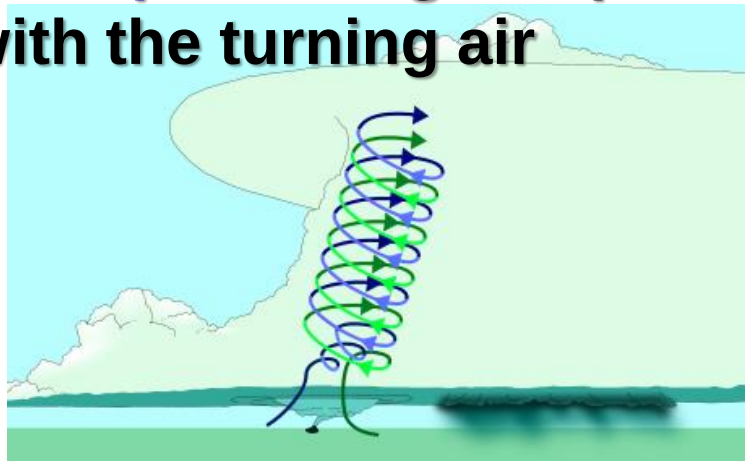
Updraft in Strong Wind SPEED Shear



Wind Shear & Supercells



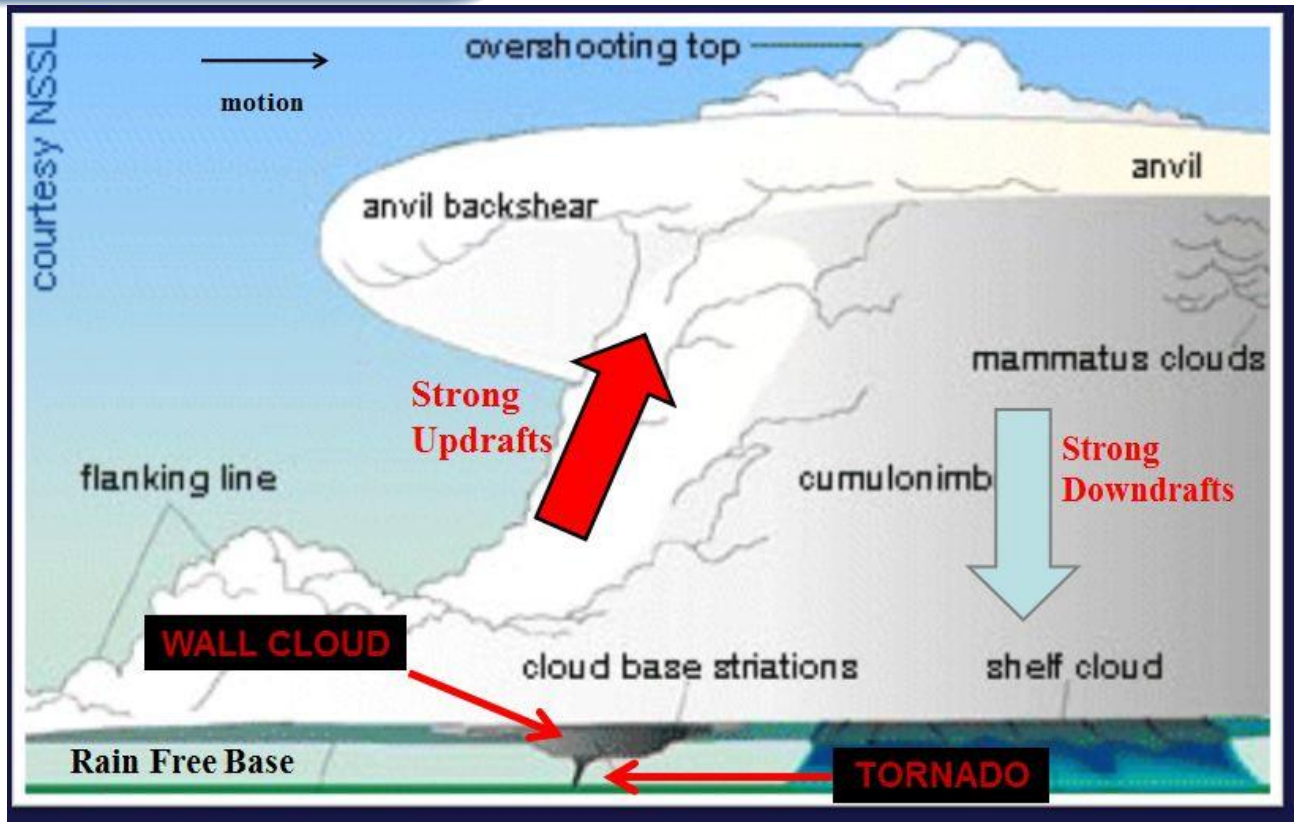
The updraft begins spinning with the turning air



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

Supercell – Rotating Updraft

Supercell Thunderstorm



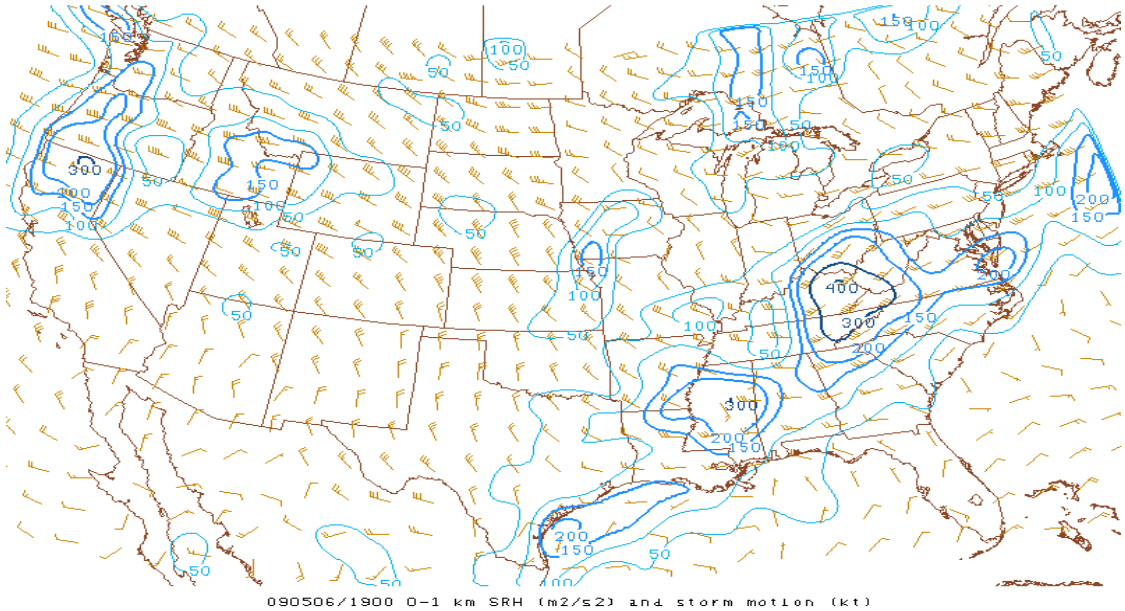
Same Ingredients as a basic Thunderstorm.

But add significant amounts of speed and directional shear

Finding the Perfect Balance
Instability versus Wind Shear

- Finding the perfect balance between instability and wind shear remains a forecast challenge.
- All about the favorable mode of convection.

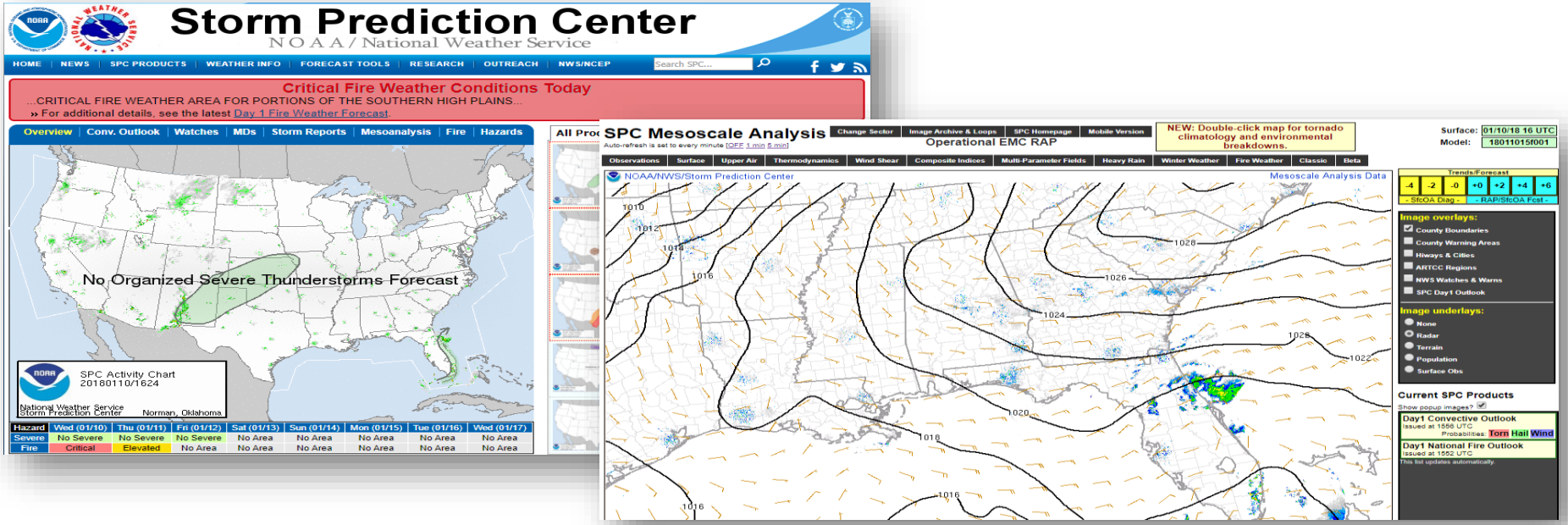
Measuring Wind Shear



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?

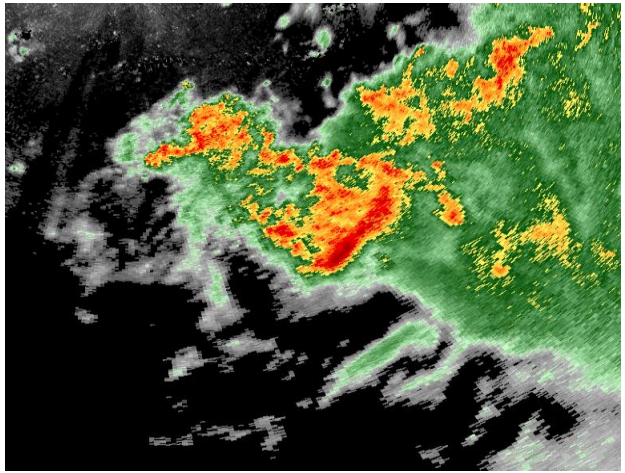
Storm-scale/Environment Information readily available!



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

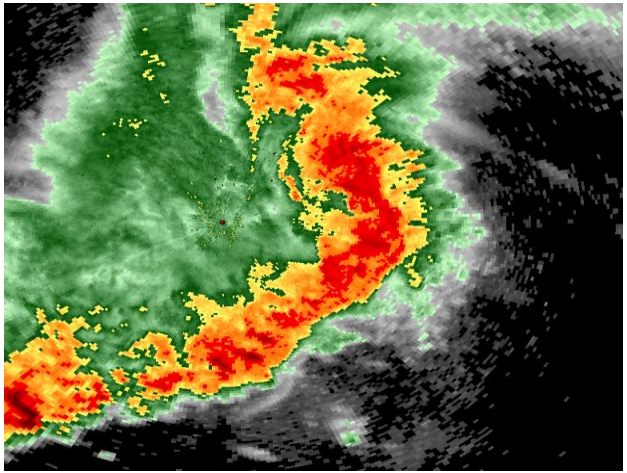
http://www.spc.noaa.gov/exper/mesoanalysis/

Storm Type



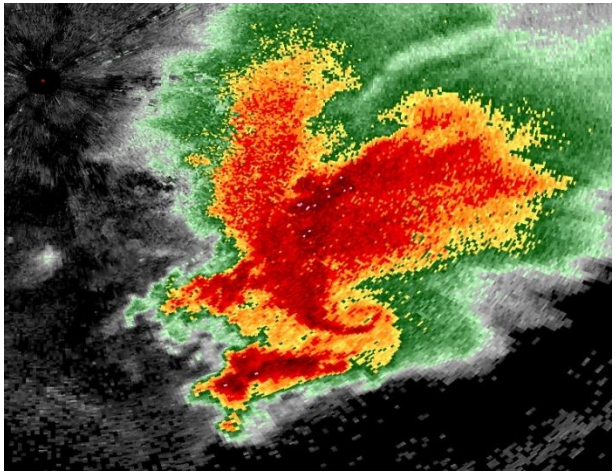
Multi-Cell Cluster

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



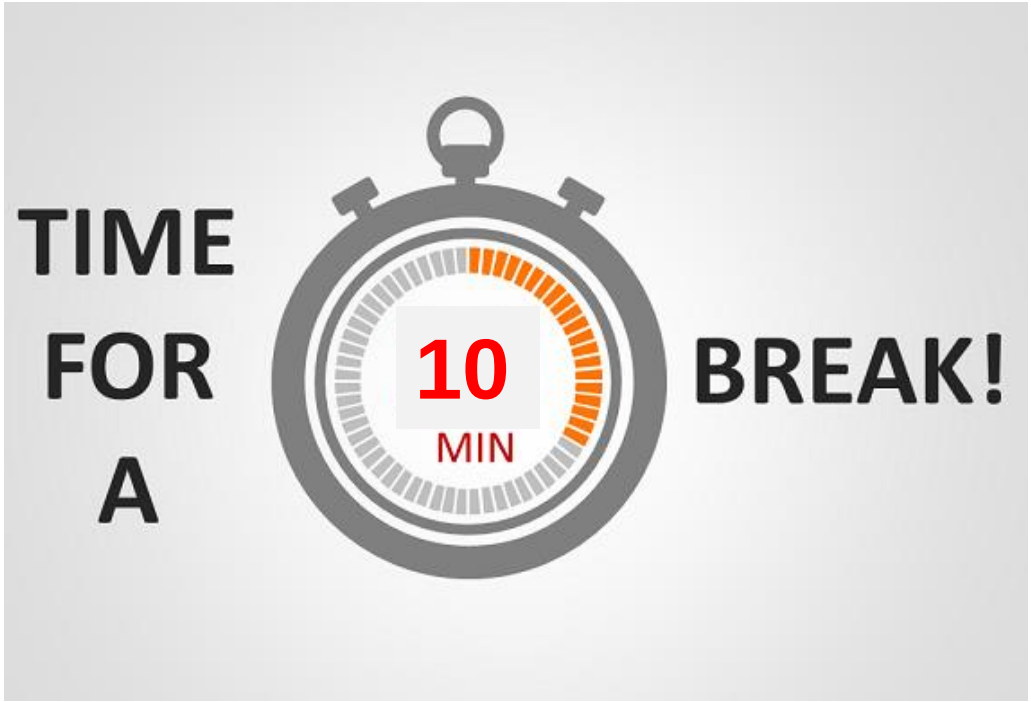
Multi-Cell Bow Echo

- 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?

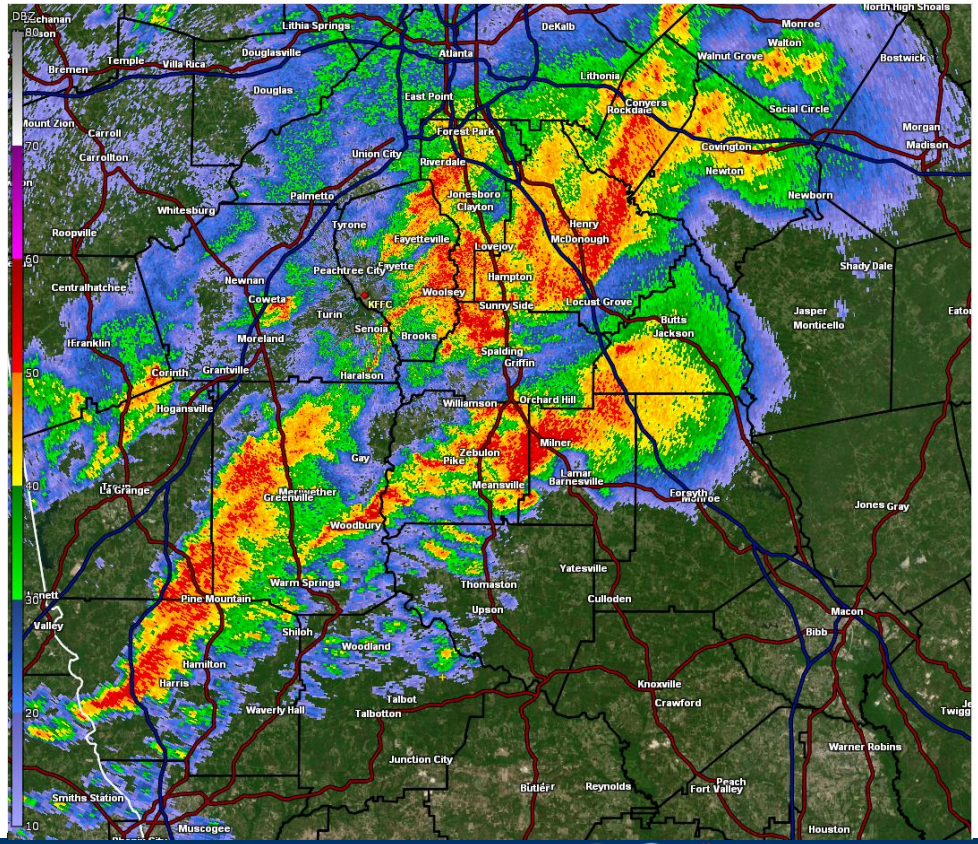
- **Radio Detection and Ranging**
  - **Detects the distance to and power returned from a target**
- **Weather radar is designed to detect targets made of water**

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**

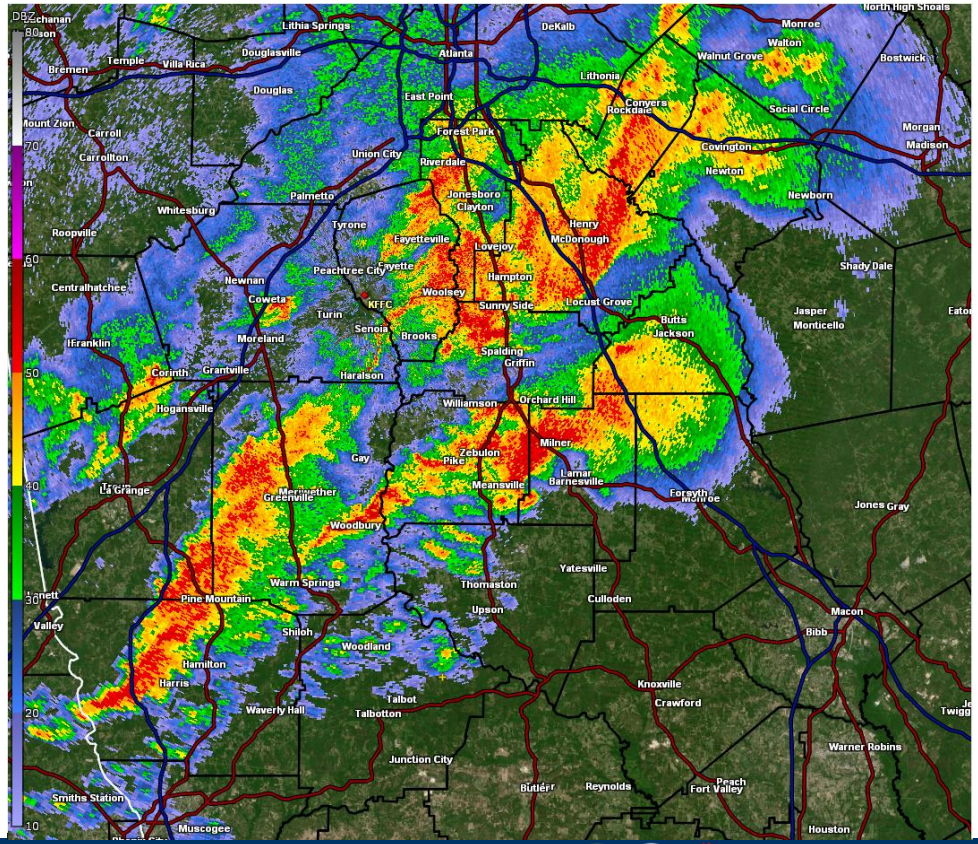
What is Reflectivity?

- 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)

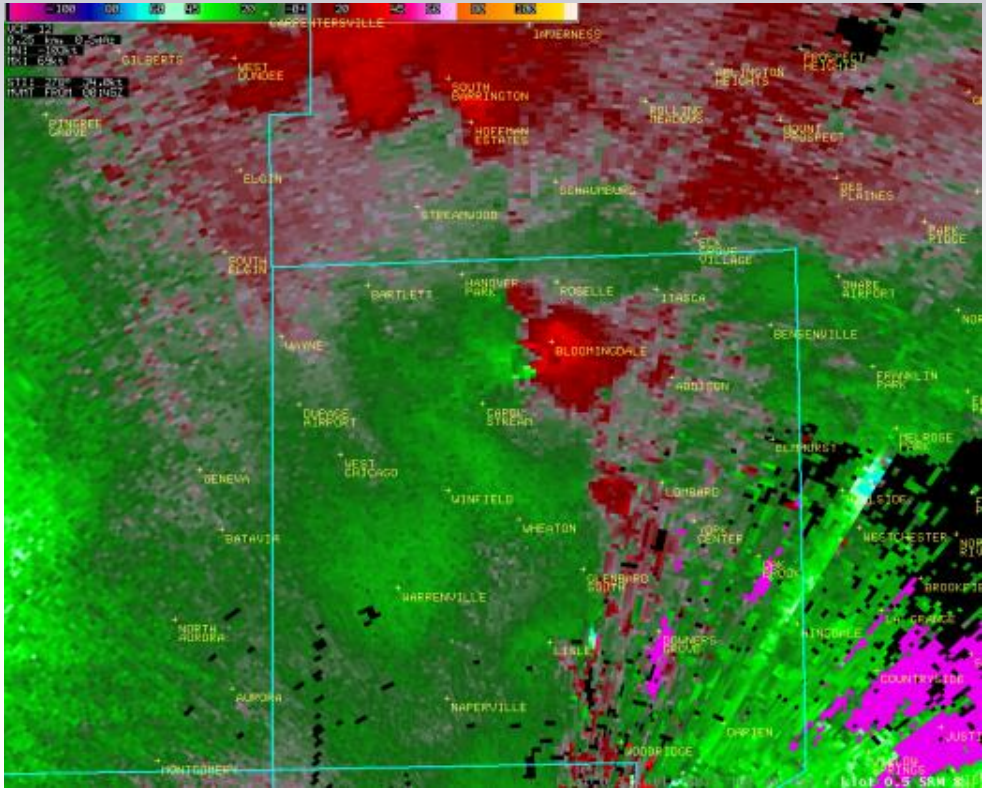


The Doppler Effect

- 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

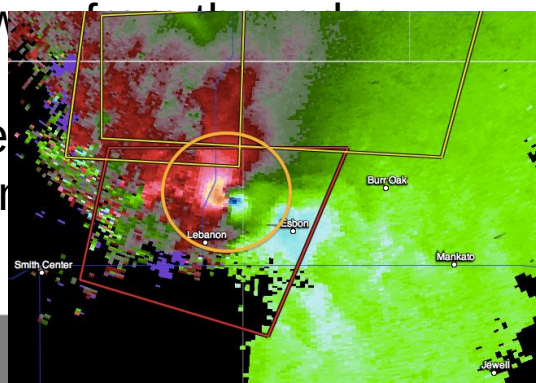


Base Velocity and **Storm Relative Velocity**

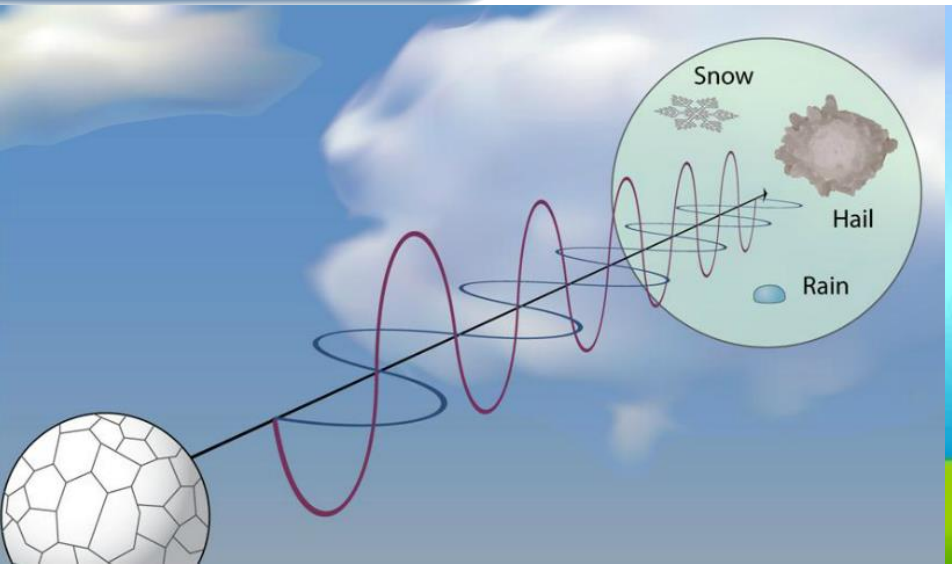
What separates storm relative motion from base velocity is the motion of storms are "subtracted" from the overall flow of the wind.

Green = Motion towards the radar
Red = Motion aw

Couplet: Intense
to intense inbou



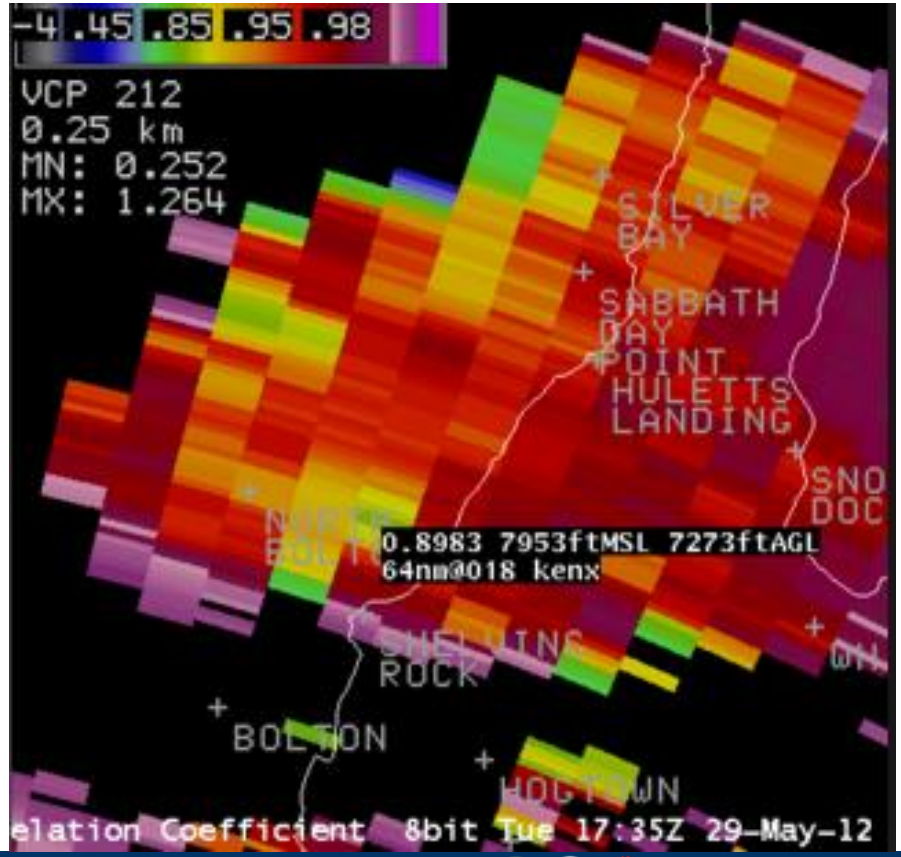
Dual-Polarization Radar



- 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

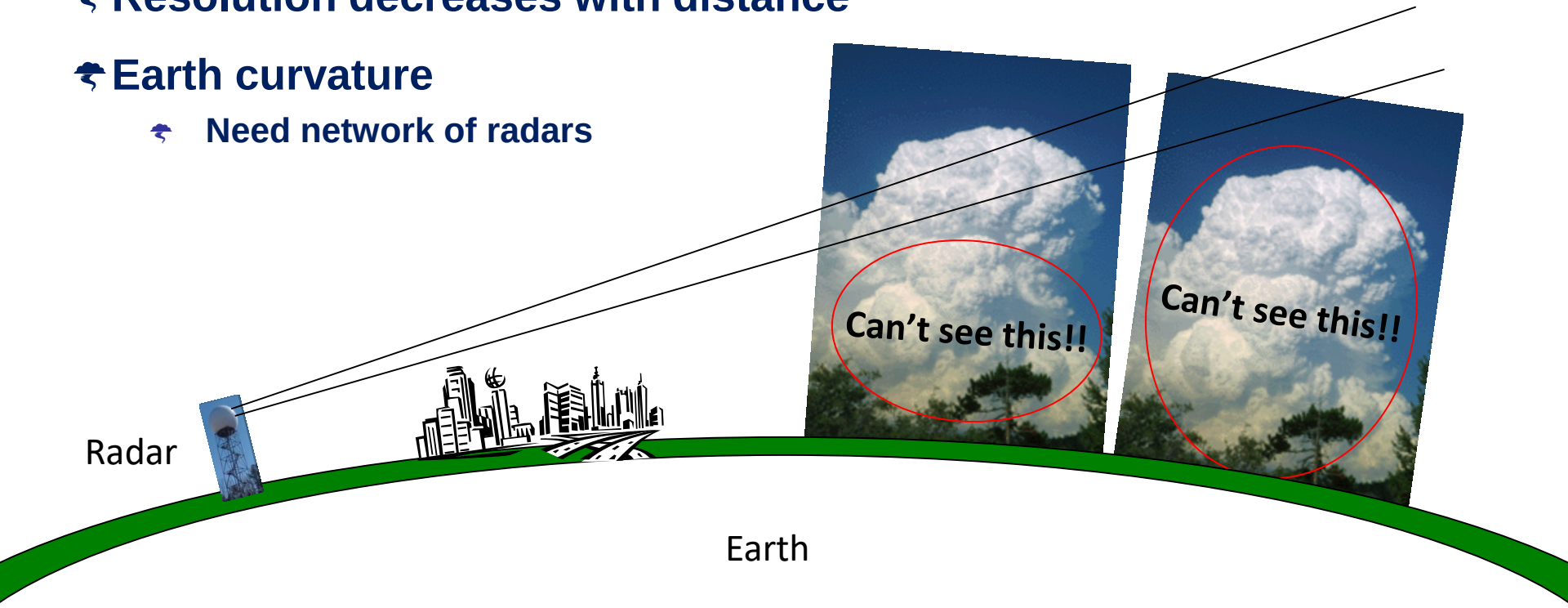
Correlation Coefficient

- 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

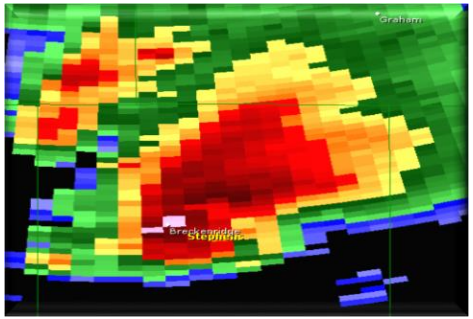
Beam Spreading:

- 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.

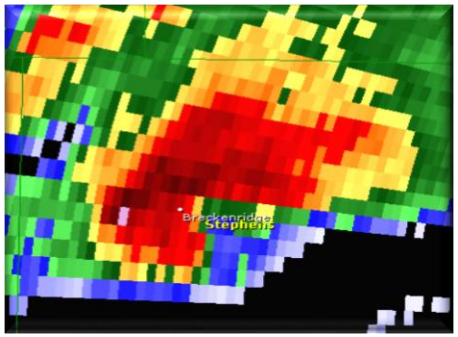
Beam spreading affects resolution capability of the radar!

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

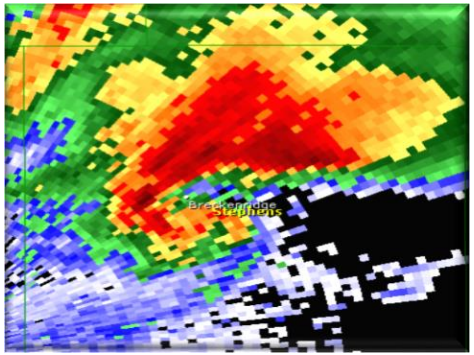
Effects of Beam Spreading:
Same Storm w/ 4 different Radars



Frederick
112 miles / 11,200 ft

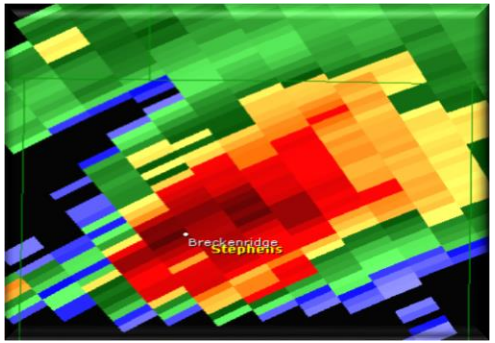


Fort Worth
94 miles / 8,300 ft



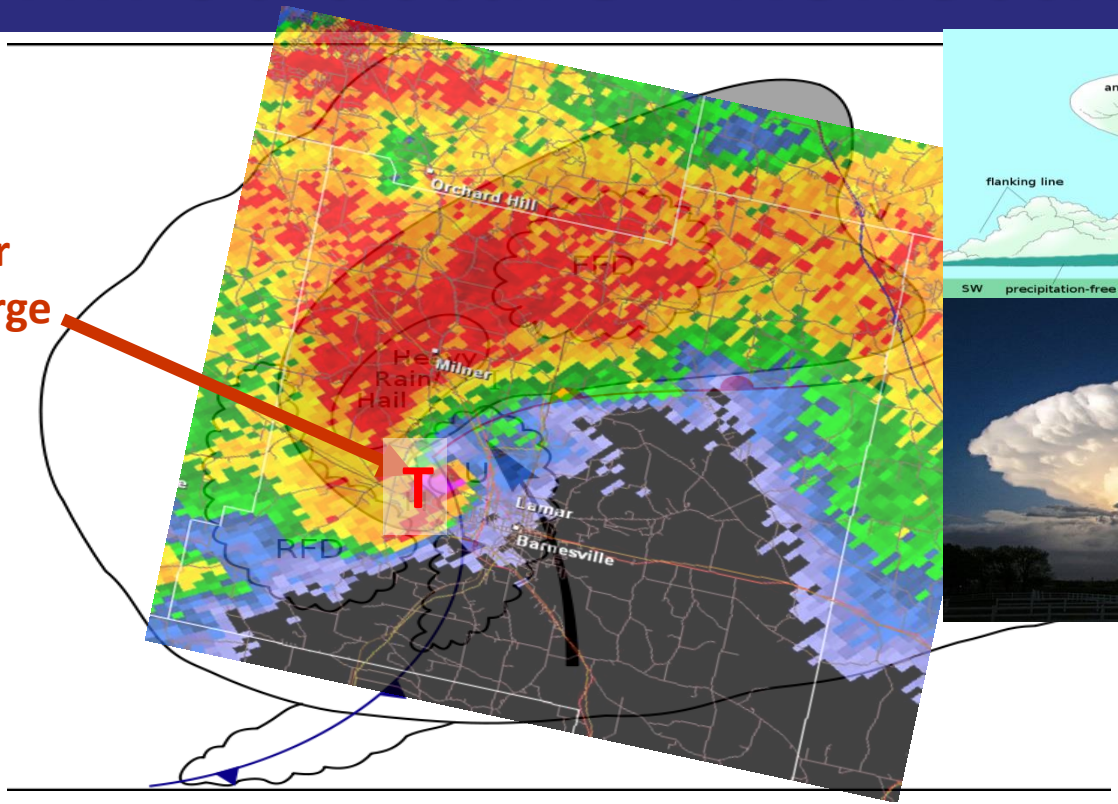
Dyess AFB
25 miles / 1,700 ft

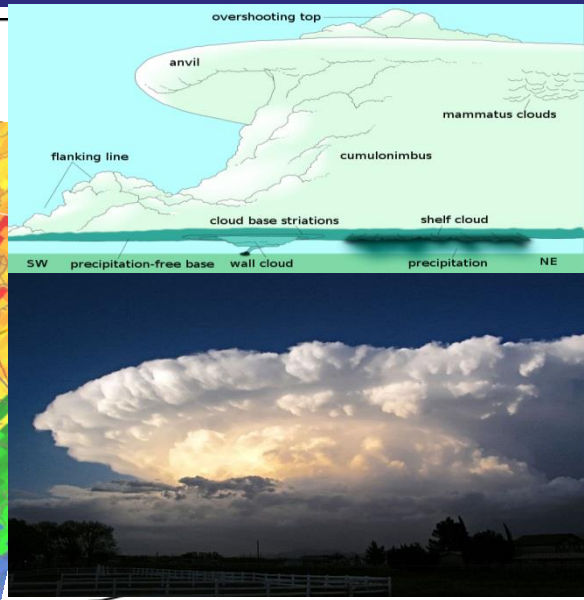
Granger
167 miles / 21,000 ft



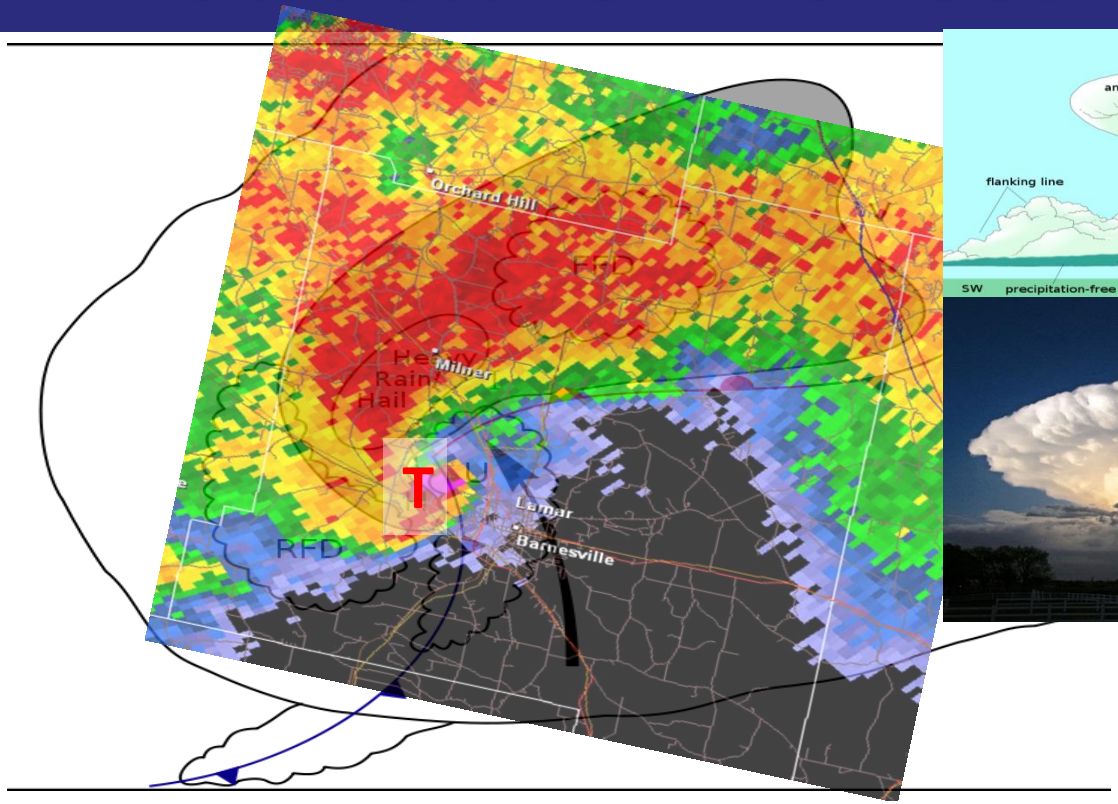
Storm Structure - Reflectivity

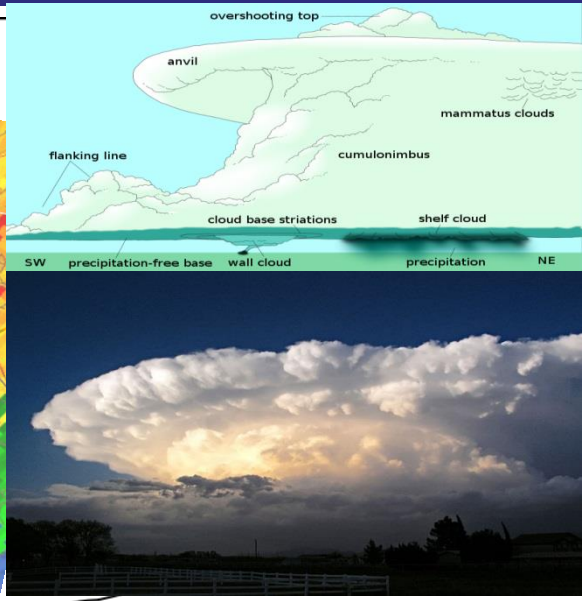
Most likely area for damaging wind, large hail and tornadoes





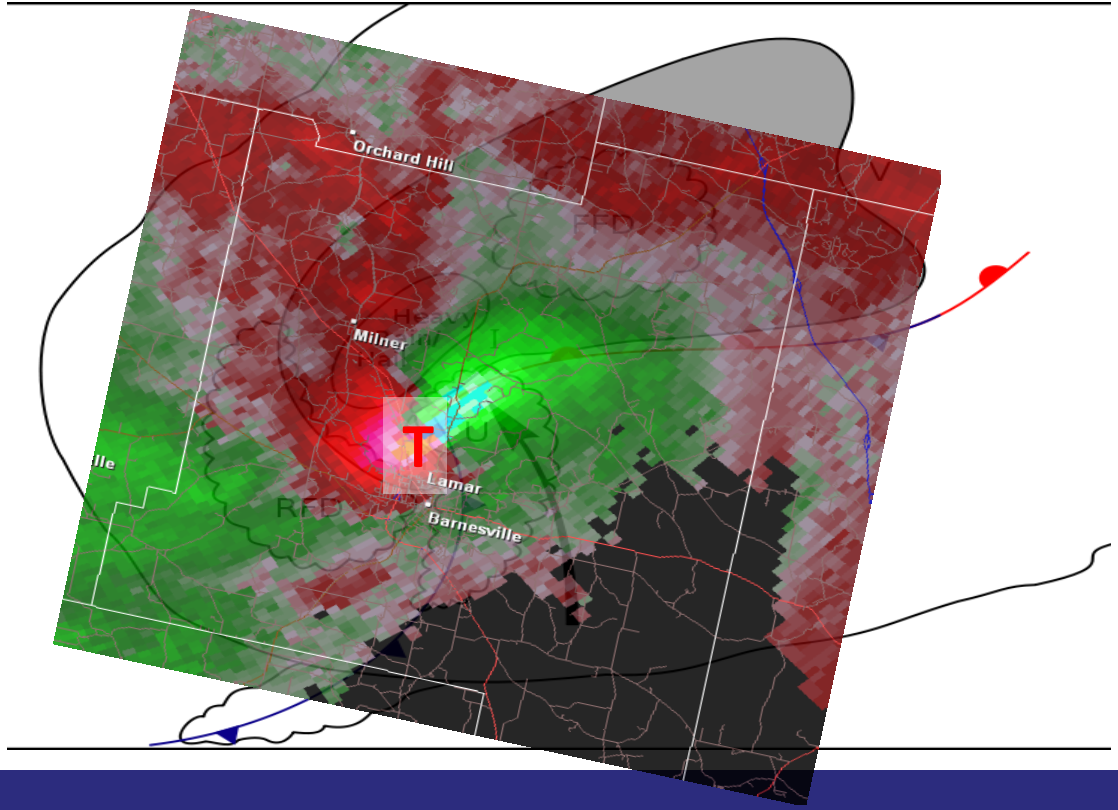
Storm Structure - Reflectivity



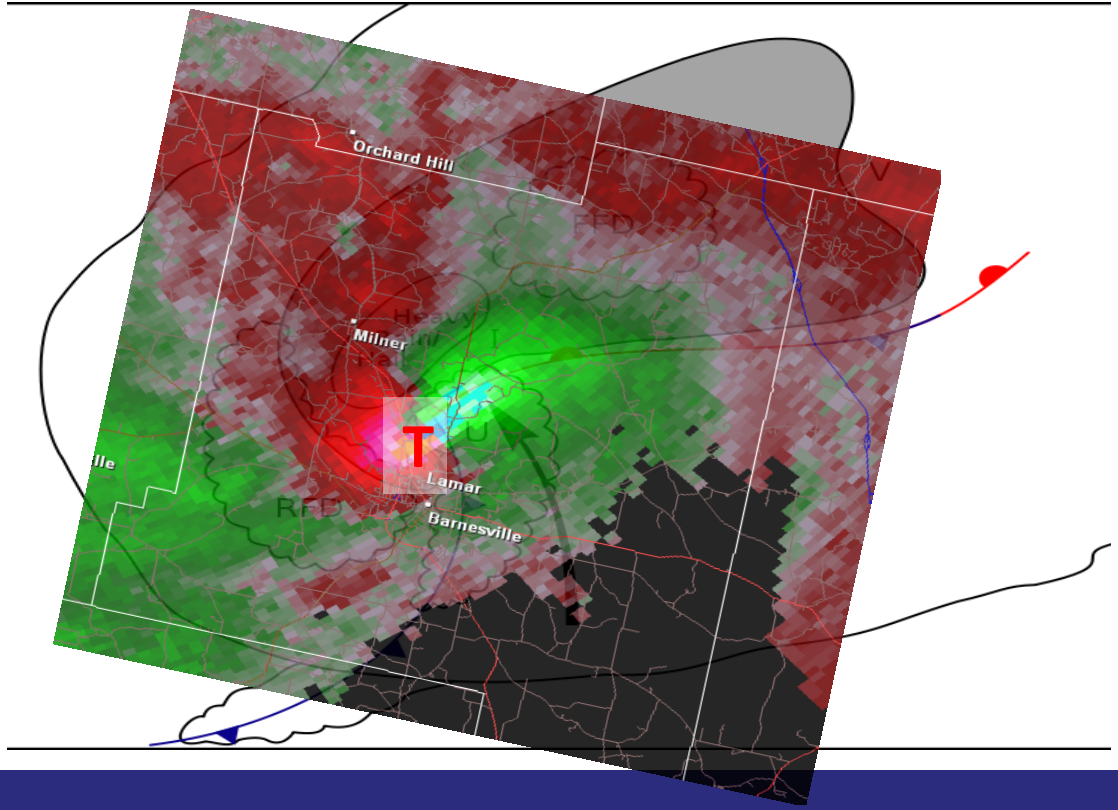


HP Supercells:
Rain-Wrapped Tornado

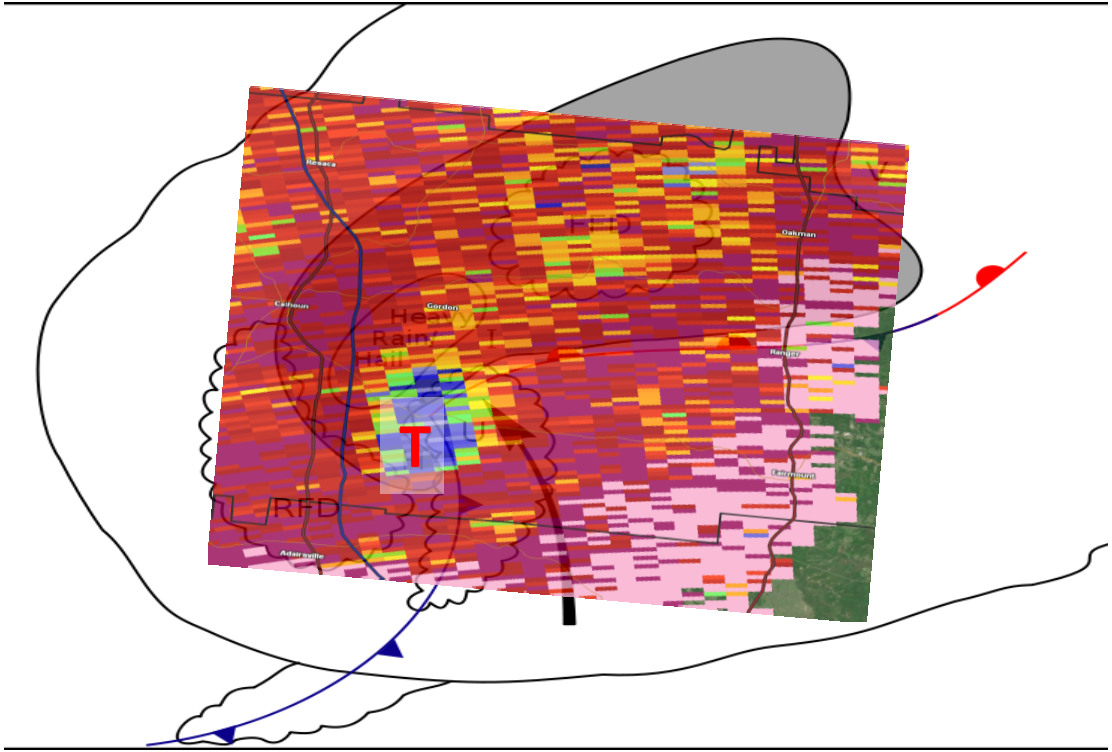
Storm Structure - Velocity



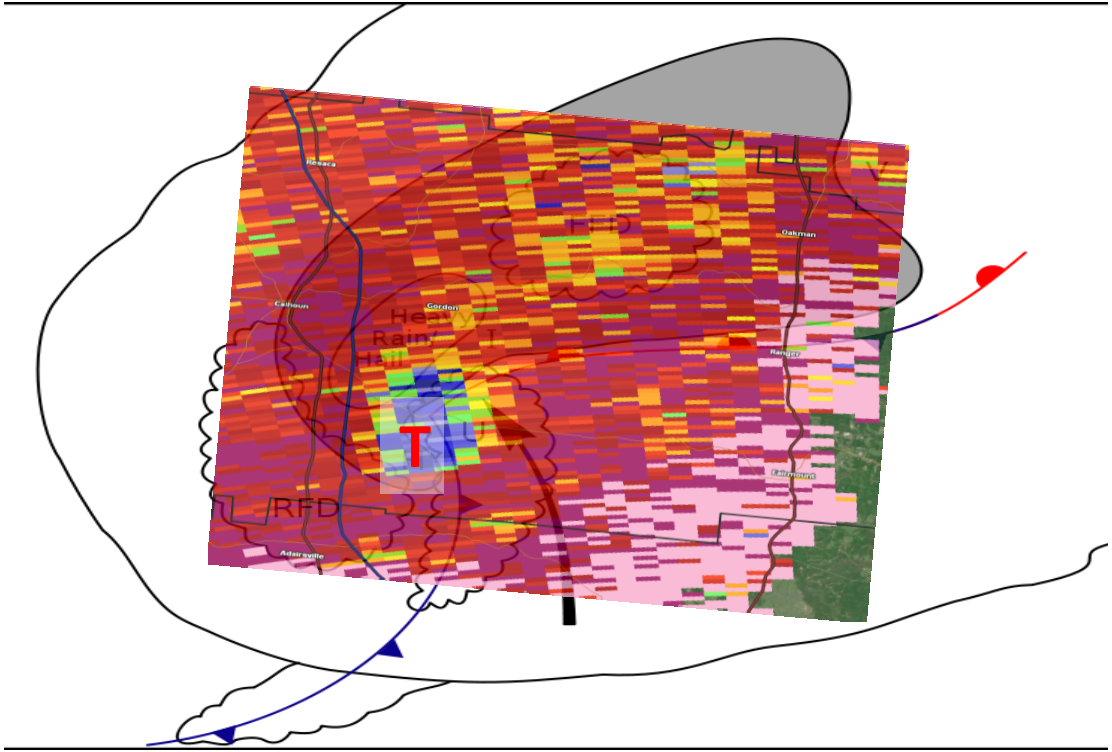
Storm Structure - Velocity



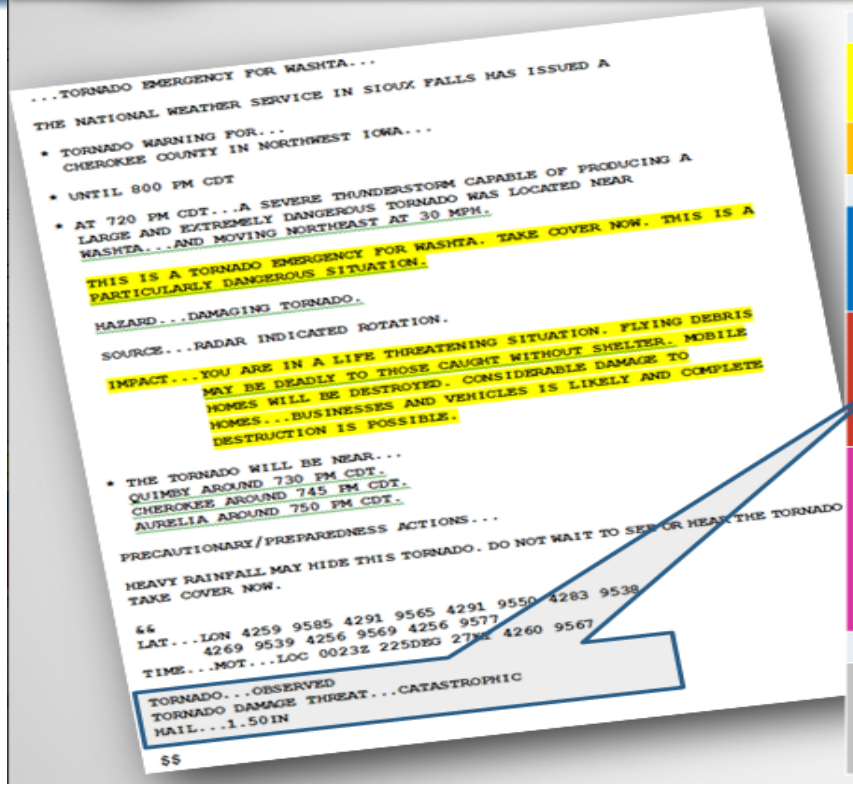
Storm Structure – Dual-polarization



Storm Structure – Dual-polarization



Impact-Based Warnings



...TORNADO EMERGENCY FOR WASHTA...

THE NATIONAL WEATHER SERVICE IN SIOUX FALLS HAS ISSUED A

* TORNADO WARNING FOR...
  CHEROKEE COUNTY IN NORTHWEST IOWA...

* UNTIL 800 PM CDT

* AT 720 PM CDT...A SEVERE THUNDERSTORM CAPABLE OF PRODUCING A LARGE AND EXTREMELY DANGEROUS TORNADO WAS LOCATED NEAR WASHTA...AND MOVING NORTHEAST AT 30 MPH.

THIS IS A TORNADO EMERGENCY FOR WASHTA. TAKE COVER NOW. THIS IS A PARTICULARLY DANGEROUS SITUATION.

HAZARD...DAMAGING TORNADO.

SOURCE...RADAR INDICATED ROTATION.

IMPACT...YOU ARE IN A LIFE THREATENING SITUATION. FLYING DEBRIS MAY BE DEADLY TO THOSE CAUGHT WITHOUT SHELTER. MOBILE HOMES WILL BE DESTROYED. CONSIDERABLE DAMAGE TO HOMES...BUSINESSES AND VEHICLES IS LIKELY AND COMPLETE DESTRUCTION IS POSSIBLE.

* THE TORNADO WILL BE NEAR...
  QUIMBY AROUND 730 PM CDT.
  CHEROKEE AROUND 745 PM CDT.
  AURELIA AROUND 750 PM CDT.

PRECAUTIONARY/PREPAREDNESS ACTIONS...

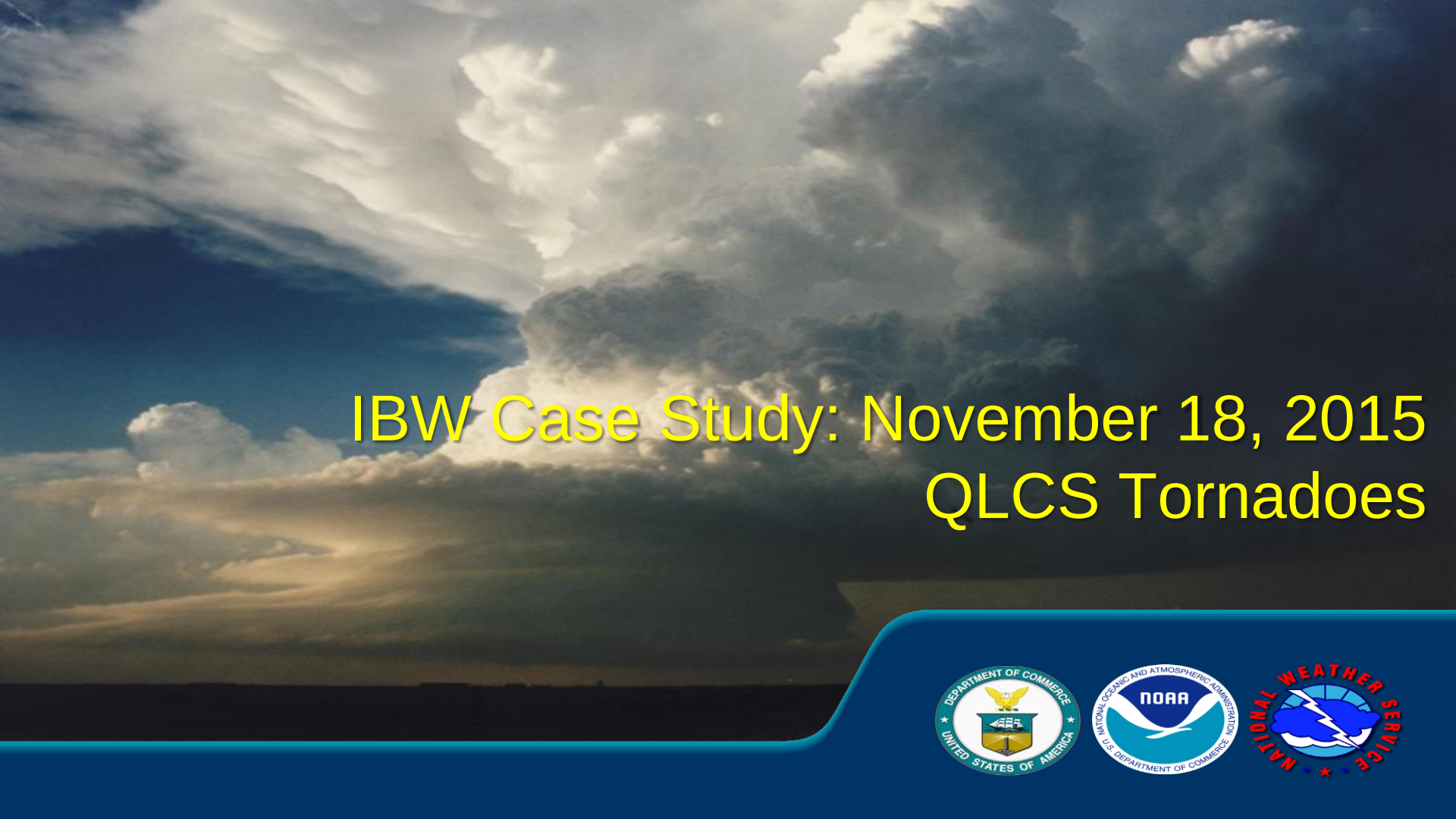
HEAVY RAINFALL MAY HIDE THIS TORNADO. DO NOT WAIT TO SEE OR HEAR THE TORNADO TAKE COVER NOW.

&&
LAT...LON 4259 9585 4291 9565 4291 9550 4283 9538
4269 9539 4256 9569 4256 9577
TIME...MOT...LOC 0023Z 225DEG 27KT 4260 9567

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

$$

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, etc.
Tornado Damage Threat Tag	
No Tag	Use most of the time, when tornado damage 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	Use exceedingly rarely, when 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.



IBW Case Study: November 18, 2015 QLCS Tornadoes

Purpose:
Impact Based Warnings

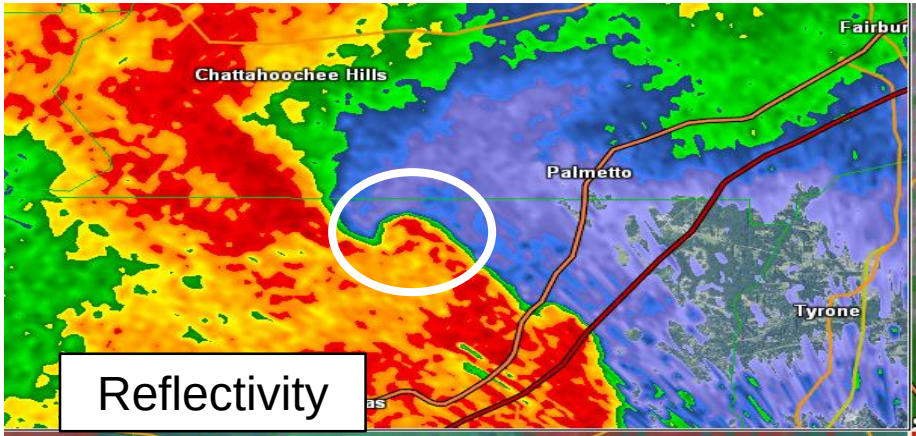
Meteorology: Newer (88D/Dual-Pol) Radar technology & products can affect NWS warning decision-making

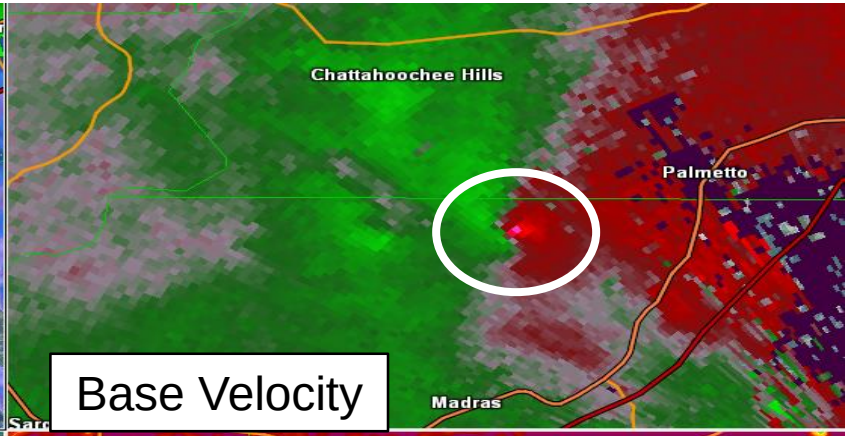
Social Science: Small, yet critical, wording changes in Warnings & Follow-up statements (SVS)

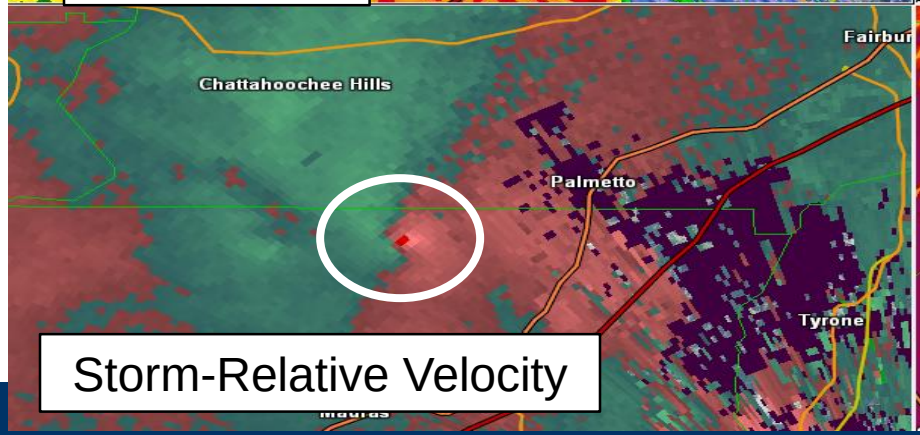
- Hazard/Source/Impacts/Tags

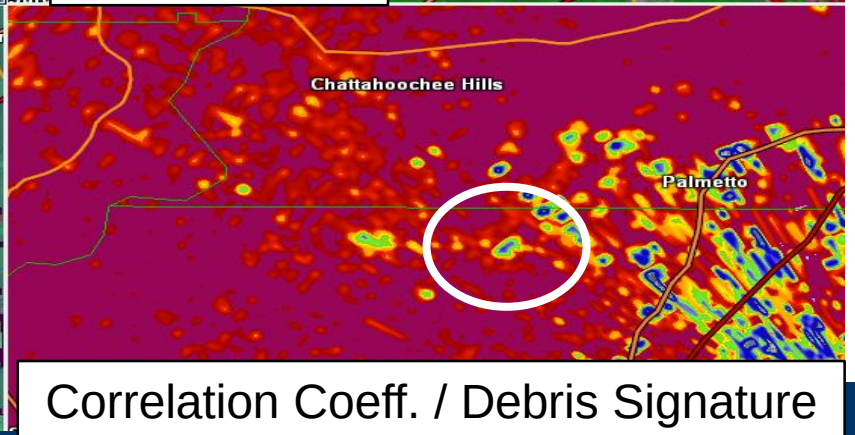
Media & Public: easier to key in on the most important parts of warning (threats & impacts)

4-panel from FFC Radar:
4:45 PM EST









Initial TORNADO Warning Issued at 4:47 PM EST

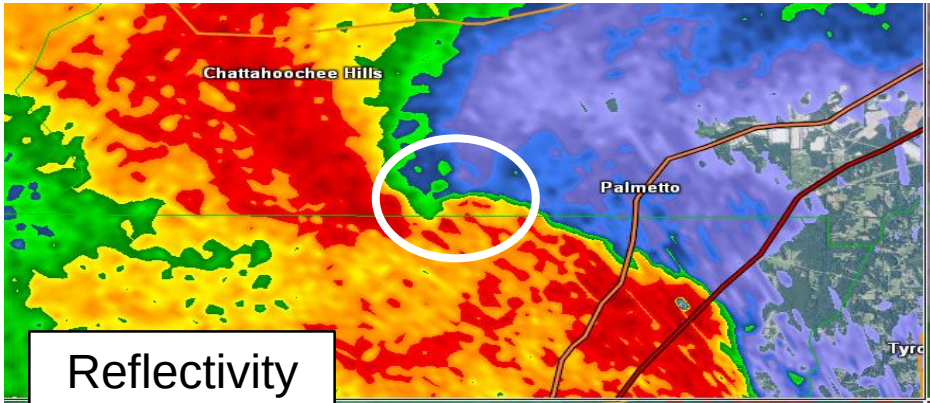
Confidence LOW with confirmation / HIGH tornado occurring

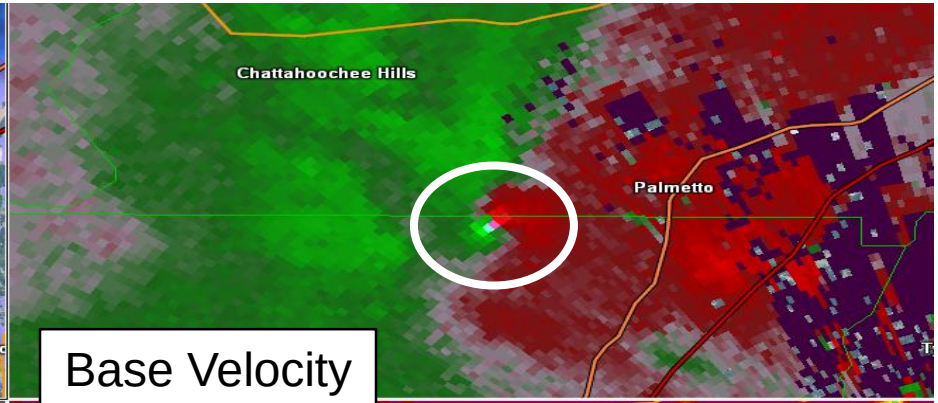
Source / Tag:

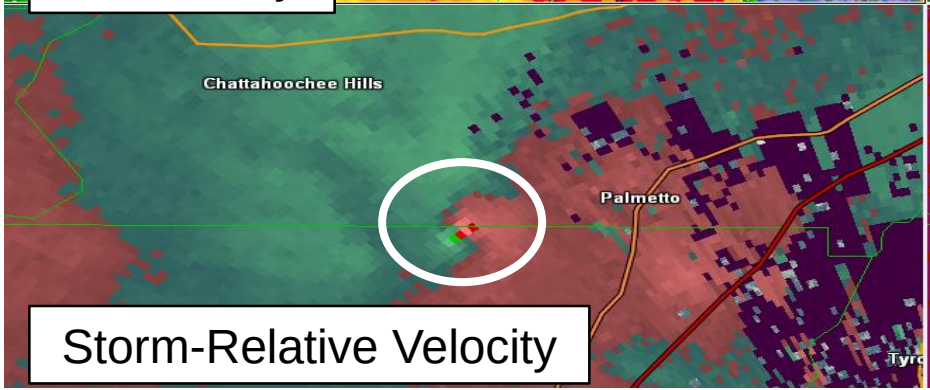
- “Radar Indicated”

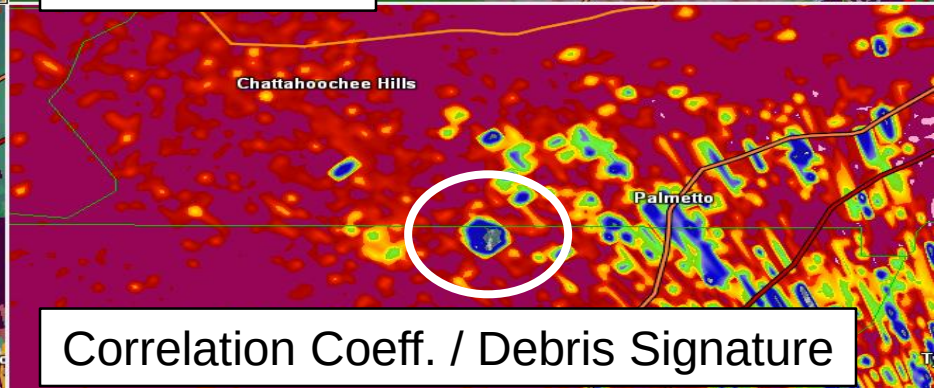
```
THE NATIONAL WEATHER SERVICE IN PEACHTREE CITY HAS ISSUED A

* TORNADO WARNING FOR...
  NORTHERN FAYETTE COUNTY IN NORTH CENTRAL GEORGIA...
  NORTH CENTRAL COWETA COUNTY IN WEST CENTRAL GEORGIA...
  SOUTH CENTRAL FULTON COUNTY IN NORTH CENTRAL GEORGIA...

* UNTIL 515 PM EST

* AT 447 PM EST...A SEVERE THUNDERSTORM CAPABLE OF PRODUCING A
  TORNADO WAS LOCATED OVER PALMETTO...OR 10 MILES NORTHEAST OF
  NEWNAN...MOVING NORTHEAST AT 30 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.

* OTHER LOCATIONS IN THE WARNING INCLUDE BUT ARE NOT LIMITED TO
  FAYETTEVILLE...UNION CITY...FAIRBURN...TYRONE...PALMETTO...SANDY
  CREEK AND CANNONGATE.

PRECAUTIONARY/PREPAREDNESS ACTIONS...

TAKE COVER NOW! MOVE TO A BASEMENT OR AN INTERIOR ROOM ON THE LOWEST
FLOOR OF A STURDY BUILDING. AVOID WINDOWS. IF YOU ARE OUTDOORS...IN A
MOBILE HOME...OR IN A VEHICLE...MOVE TO THE CLOSEST SUBSTANTIAL
SHELTER AND PROTECT YOURSELF FROM FLYING DEBRIS.

IF YOU SEE WIND DAMAGE...HAIL OR FLOODING...WAIT UNTIL THE STORM HAS
PASSED...AND THEN CALL THE NATIONAL WEATHER SERVICE TOLL FREE AT 1 8
6 6 7 6 3 4 4 6 6 OR TWEET US YOUR REPORT AT NWSATLANTA.

&&

LAT...LON 3346 8472 3351 8476 3367 8456 3347 8442
TIME...MOT...LOC 2147Z 244DEG 25KT 3351 8471

TORNADO...RADAR INDICATED
HAIL...<.75IN
```

4-panel from FFC Radar:
4:48 PM EST

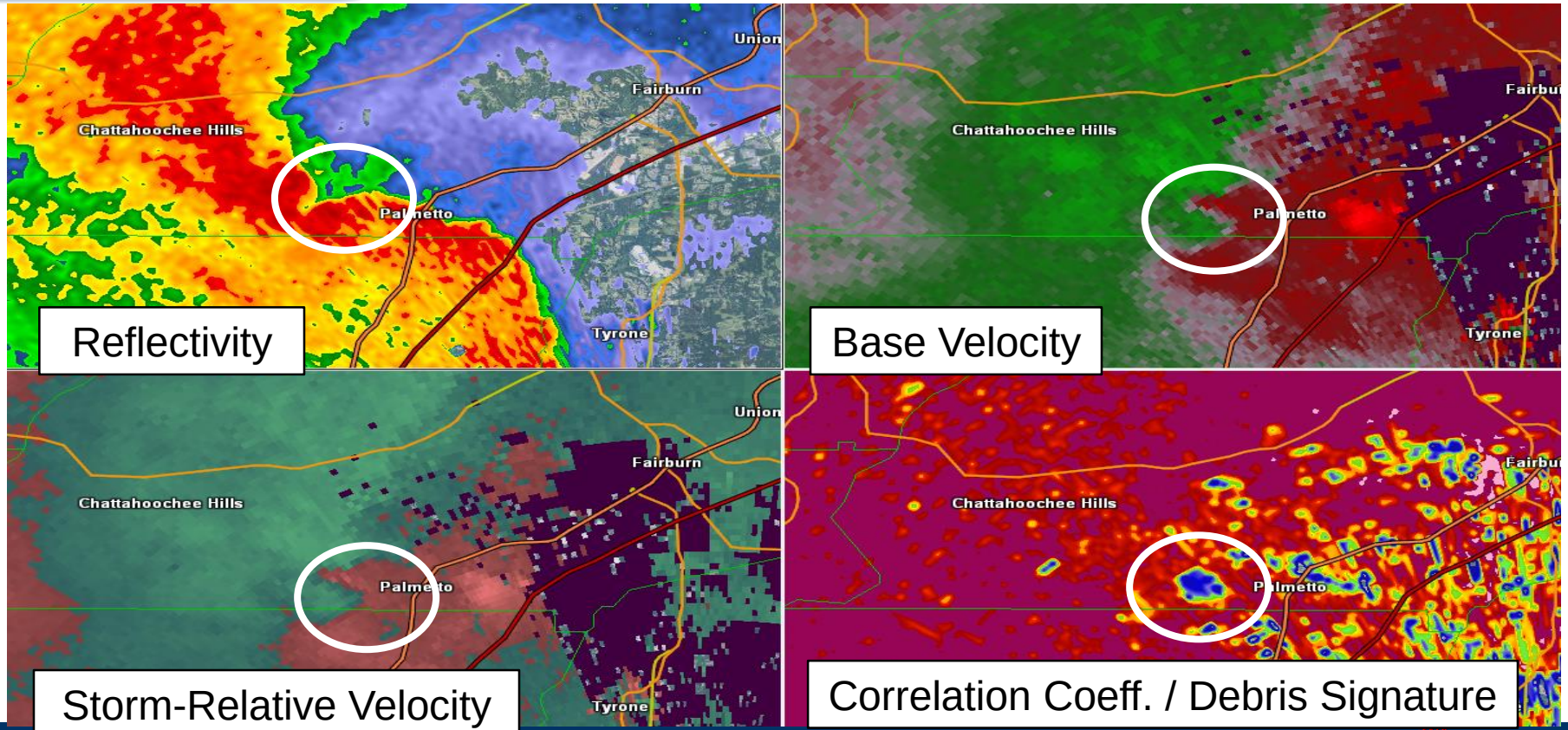








4-panel from FFC Radar:
4:51 PM EST



Follow-up Severe Weather Statement (SVS) -- continuing TOR Warning

Confidence HIGH confirmed tornado producing damage!

Based on Radar (TDS)

Source:

- Radar Confirmed

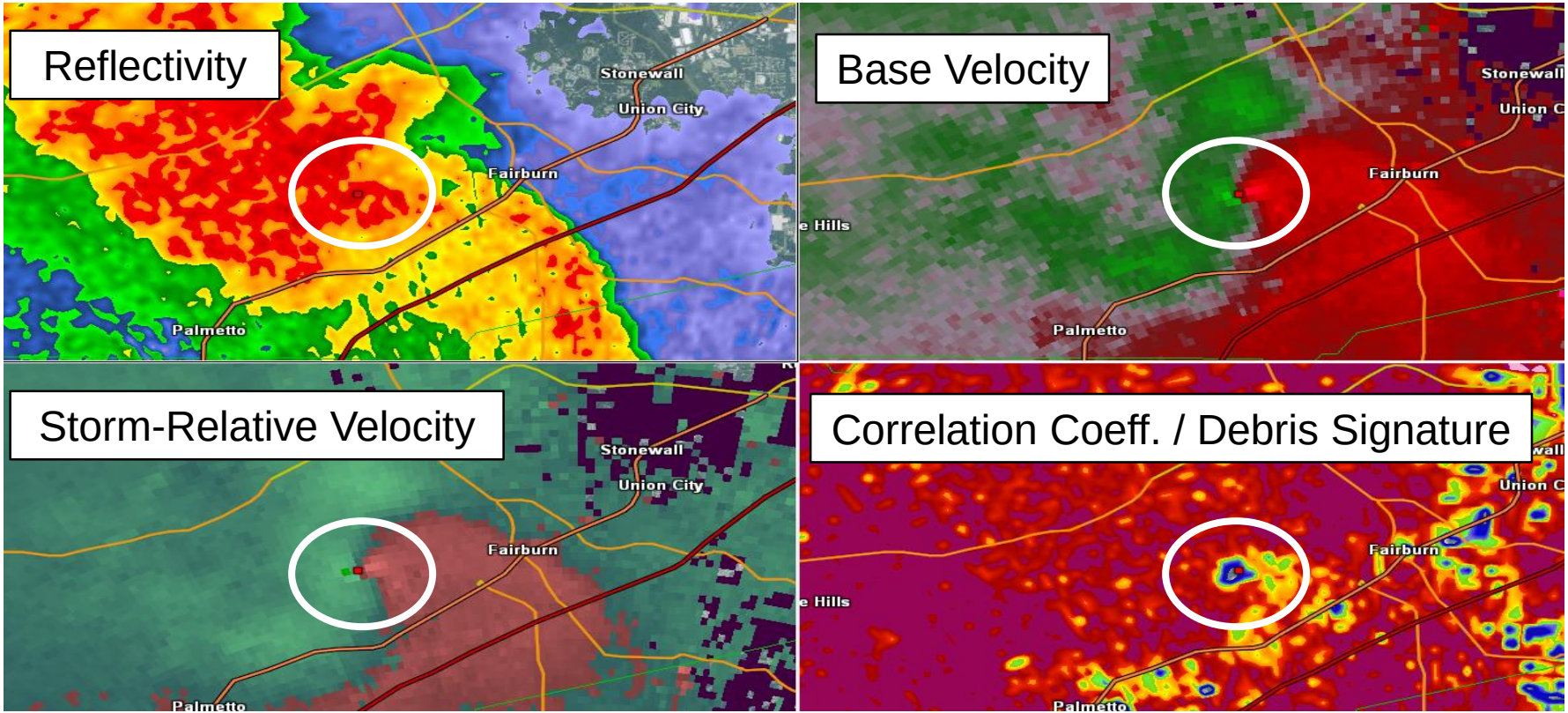
Tag:

- Observed

Hazard/PPA statements change

```
...A TORNADO WARNING REMAINS IN EFFECT UNTIL 515 PM EST FOR SOUTH
CENTRAL FULTON COUNTY...

AT 458 PM EST...A CONFIRMED TORNADO WAS LOCATED OVER FAIRBURN...OR 12
MILES NORTHWEST OF FAYETTEVILLE...MOVING NORTHEAST AT 30 MPH.

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.

OTHER LOCATIONS IN THE WARNING INCLUDE BUT ARE NOT LIMITED TO
UNION CITY...FAIRBURN AND PALMETTO.

PRECAUTIONARY/PREPAREDNESS ACTIONS...

TO REPEAT...A TORNADO IS ON THE GROUND. TAKE COVER NOW! MOVE TO A
BASEMENT OR AN INTERIOR ROOM ON THE LOWEST FLOOR OF A STURDY
BUILDING. AVOID WINDOWS. IF YOU ARE OUTDOORS...IN A MOBILE HOME...OR
IN A VEHICLE...MOVE TO THE CLOSEST SUBSTANTIAL SHELTER AND PROTECT
YOURSELF FROM FLYING DEBRIS.

IF YOU SEE WIND DAMAGE...HAIL OR FLOODING...WAIT UNTIL THE STORM HAS
PASSED...AND THEN CALL THE NATIONAL WEATHER SERVICE TOLL FREE AT 1 8

&&

LAT...LON 3367 8456 3355 8448 3353 8455 3351 8467
      3355 8470
TIME...MOT...LOC 2158Z 236DEG 28KT 3356 8462

TORNADO...OBSERVED
HAIL...<.75IN
```

4-panel from FFC Radar:
4:58 PM EST – 2nd Tornado



What to Report

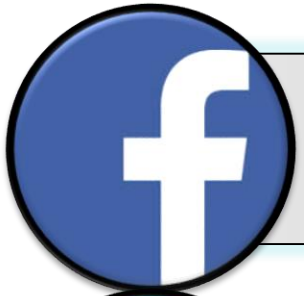
- Measured or Estimated Winds 50+ mph
- Wind Damage (downed trees/tree limbs, power lines, cars, etc.)
- Tornadoes/Waterspouts
- Funnel Clouds
- Significant Flooding (roads impassable/closed, water into homes/businesses, etc.)
- Hail (any size)…report largest piece

How to Report

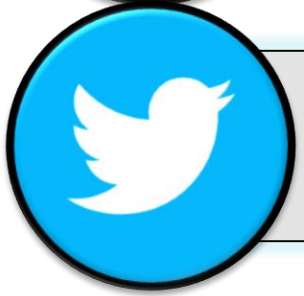
Web:
http://weather.gov/cae

Phone (unlisted):
On Quick Reference Sheet

E-mail:
NWS.Columbia@noaa.gov



Facebook:
NWSColumbia



Twitter:
@NWSColumbia

weather.gov/cae/register

- Register as a spotter to enter our database
- Receive your spotter certificate
- May infrequently be contacted for severe weather reports

NATIONAL WEATHER SERVICE
COLUMBIA, SC WEATHER FORECAST OFFICE

Certificate of Completion

Presented to:

First Last

For successfully completing the:

Basic SKYWARN® Spotter Training Course

September 5, 2016
Class Date

SKYWARN

John A. Quagliariello
Warning Coordination Meteorologist