ATM S 103

# Hurricanes and Thunderstorms

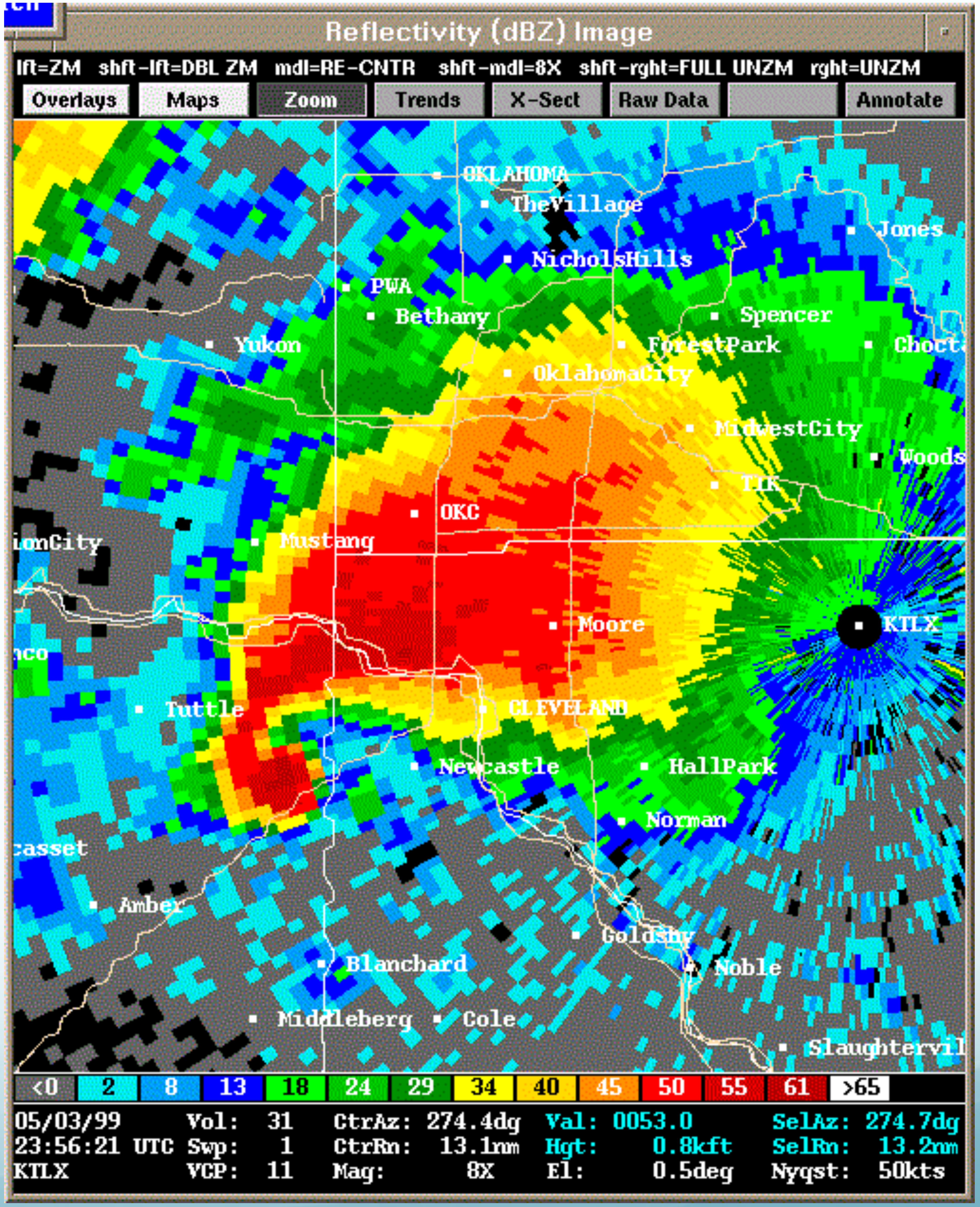
## Their Science and Impacts

# Radar Fundamentals

- Radar sends out pulses and listens for the “reflection” of those pulses off the “target”
- Reflectivity measures the strength of the reflection off the target.
- The Doppler velocity measures the speed of the target.

# Radar Reflectivity for a Supercell

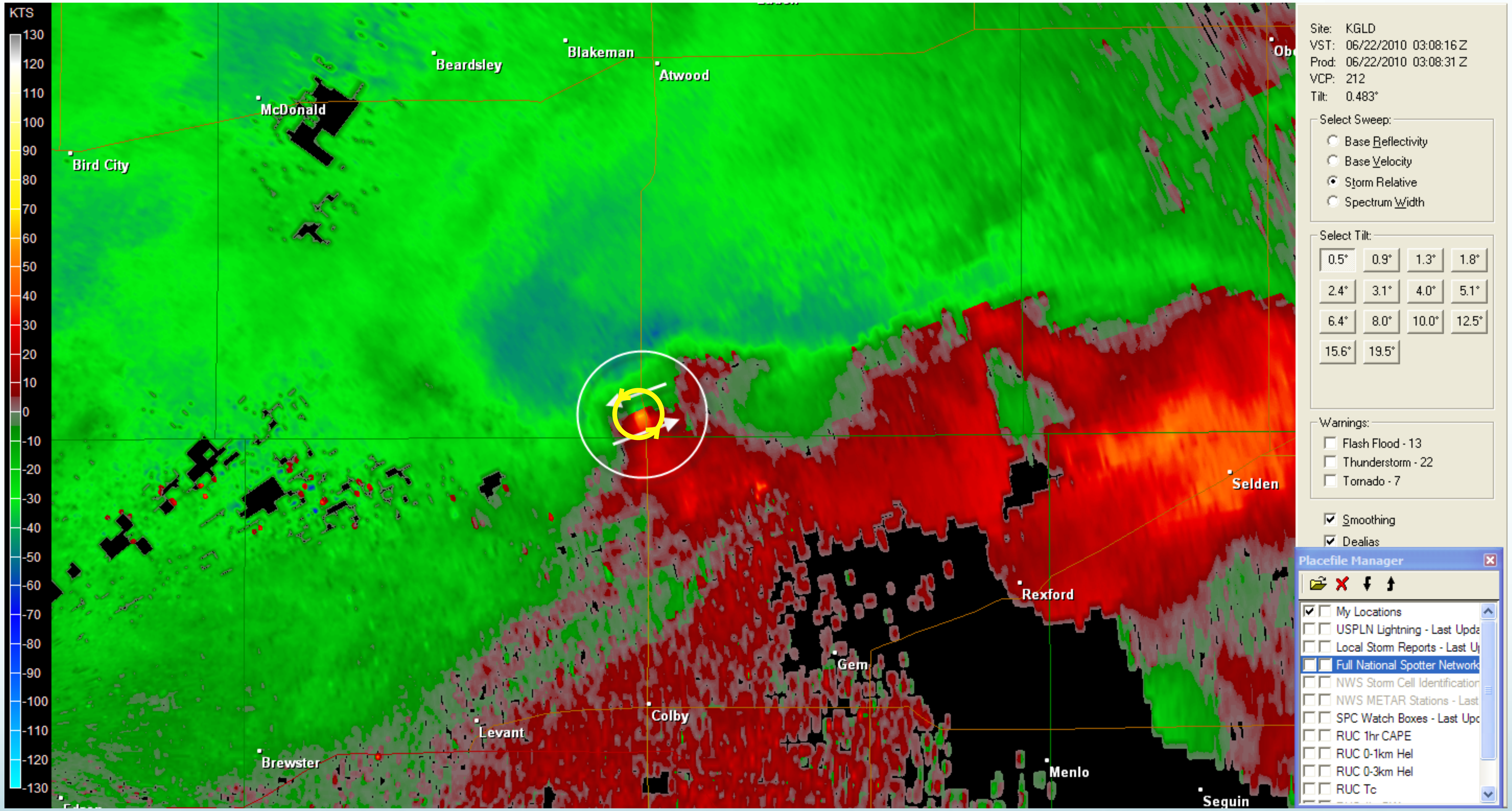
| dBZ | type |
|---|---|
| 20 | Very light rain |
| 30 | Light to moderate |
| 40 | Moderate rain |
| 50 | Heavy rain |
| 60 | Moderate hail |



# Velocity Data

- Obtained from the change in the signal reflected back to the radar between two consecutive pulses.
- Very complicated to understand for most realistic cases, so it's never shown on TV.
- Exception: the velocity signature associated with strong rotating supercell updrafts.
  - "Easy" to understand
  - Is shown on TV in tornado prone areas.

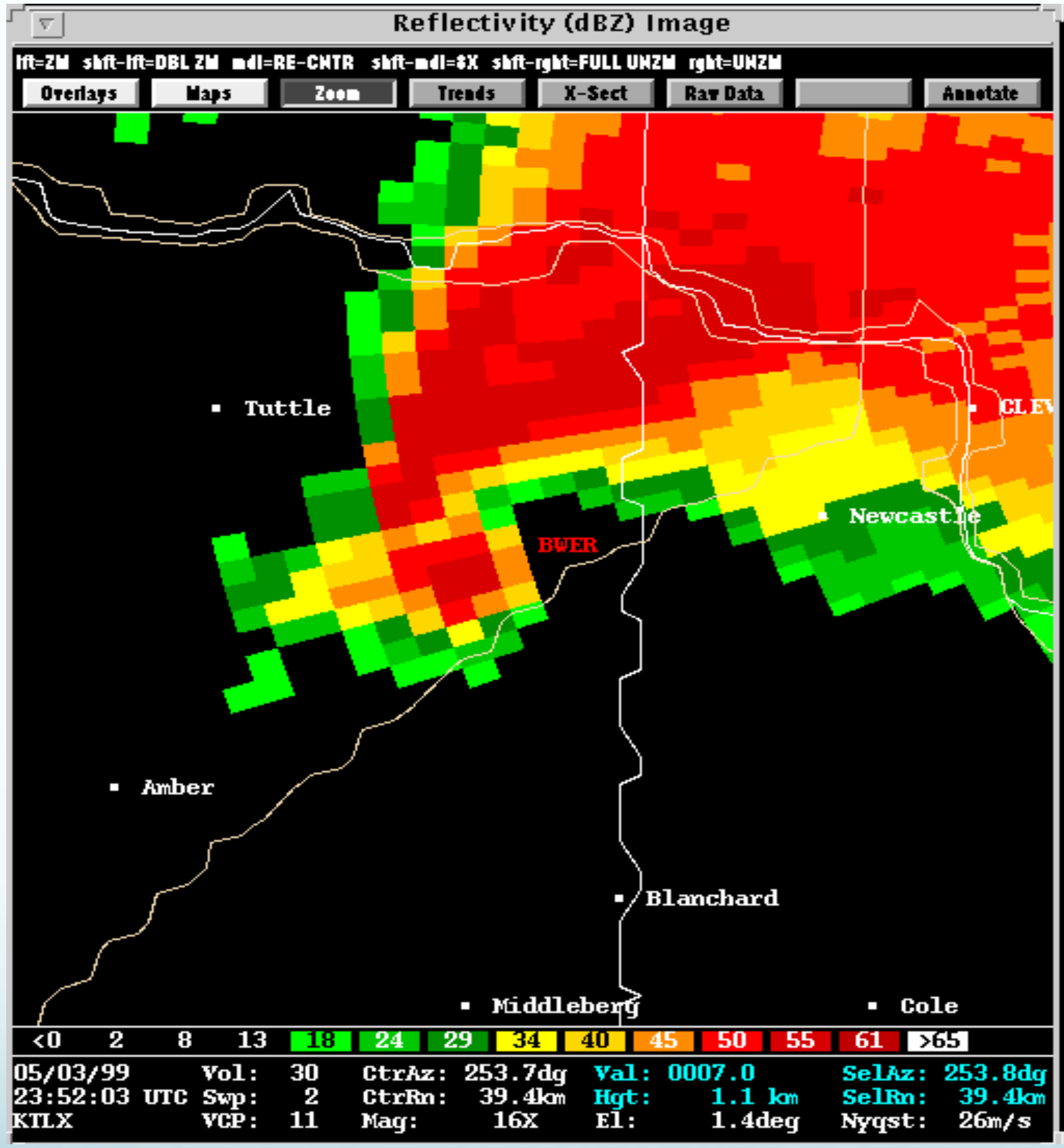
# Goodland, Kansas Radar
# June 22, 2010

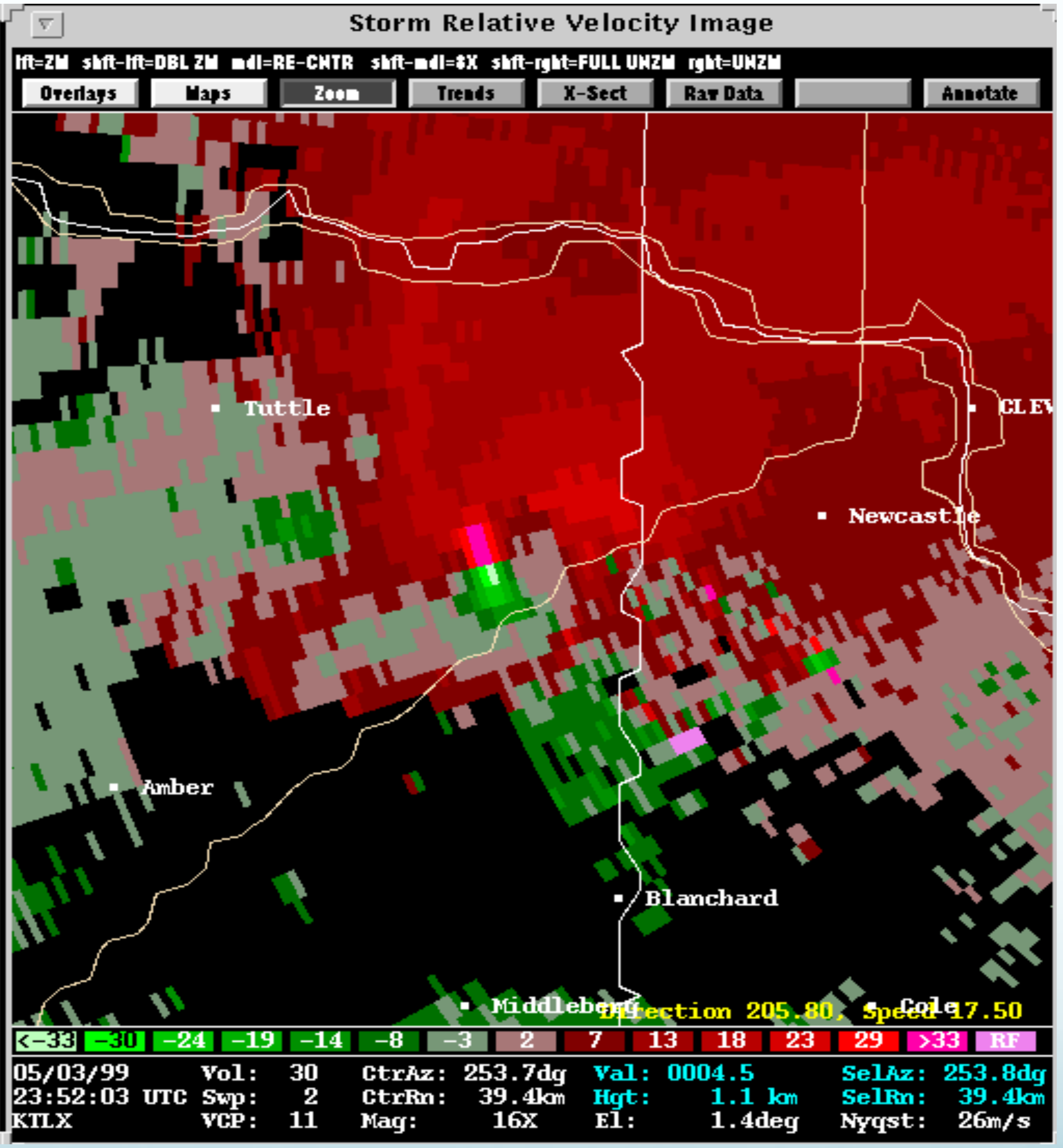


# Tornado Vortex Signature

- Doppler-radar software looks for couplets of high inbound and out bound velocity in adjacent cells and flashes a warning.

# Hook echo (reflectivity) and Doppler (velocity) couplet

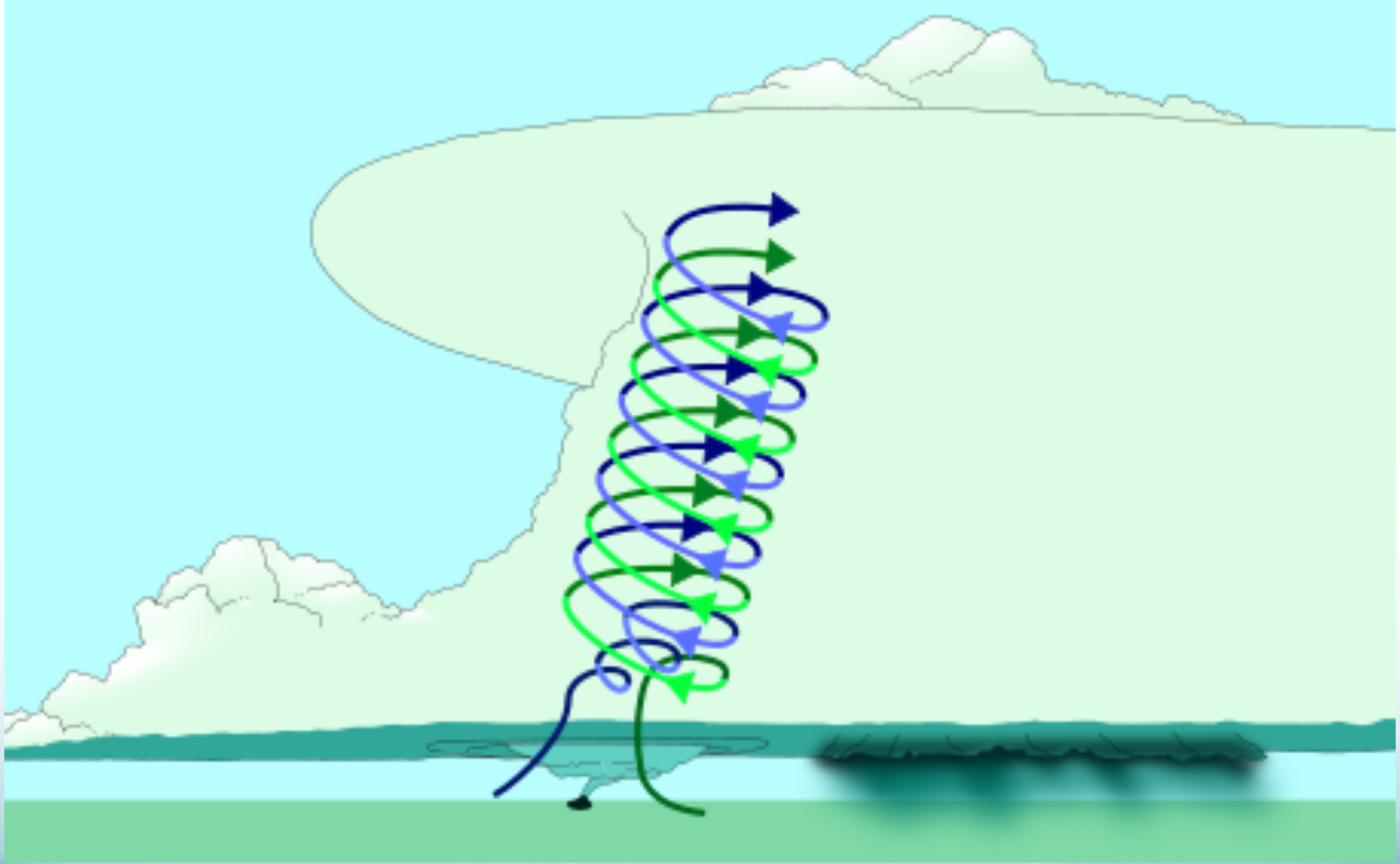


# What is the Radar Seeing

- Too big to be the tornado
- Quite high above the ground
- Too slow to be the tornado (50 knots ~ 58 mph)
- The radar is picking up the larger rotating updraft, the *mesocyclone*
  - 2-5 miles wide
  - Extends at least halfway to the tropopause (where the storm top flattens out).
  - We've been looking at the bottom of mesocyclones in the previous videos.

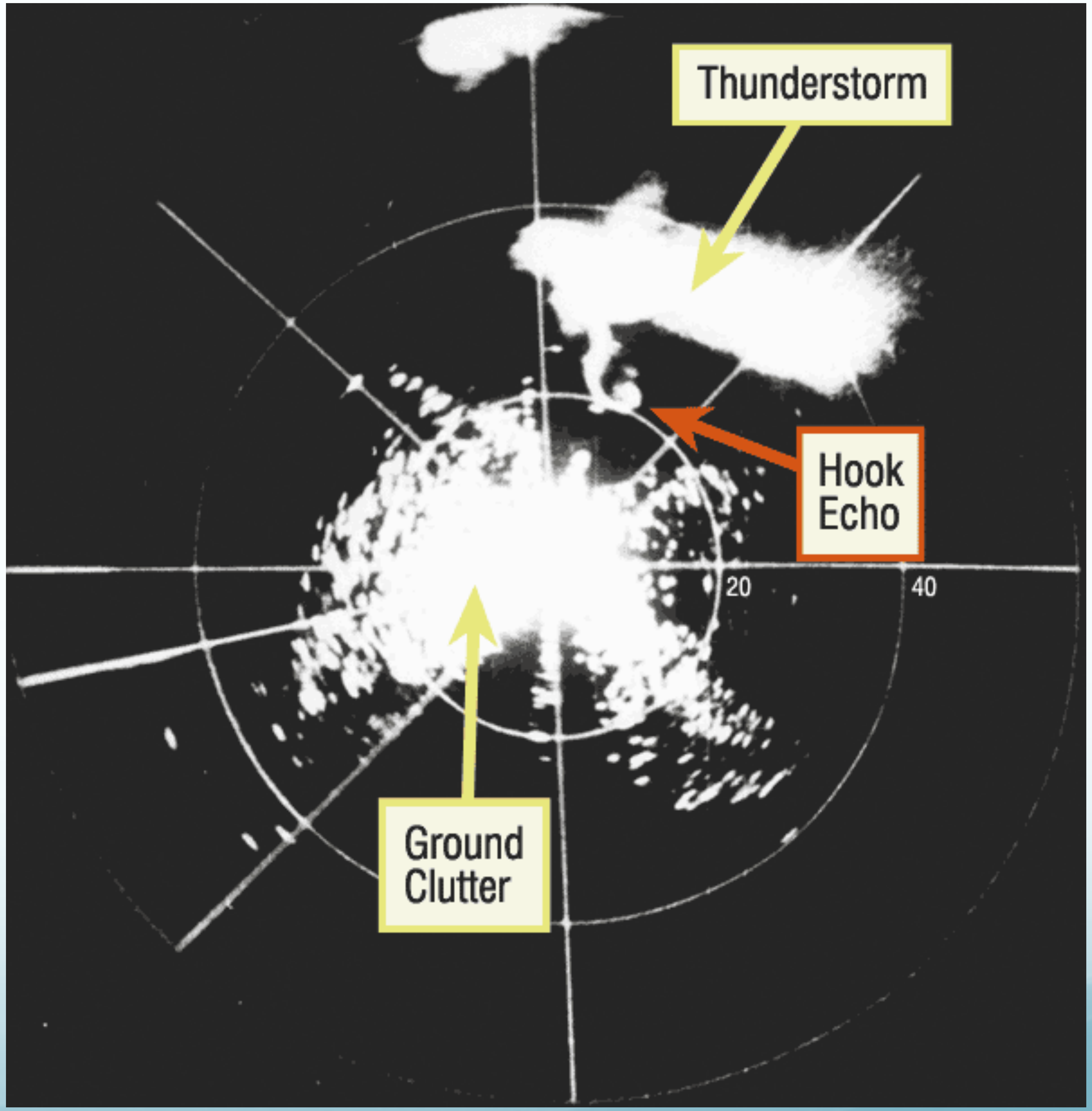
# Mesocyclone



# Wall cloud with tornado

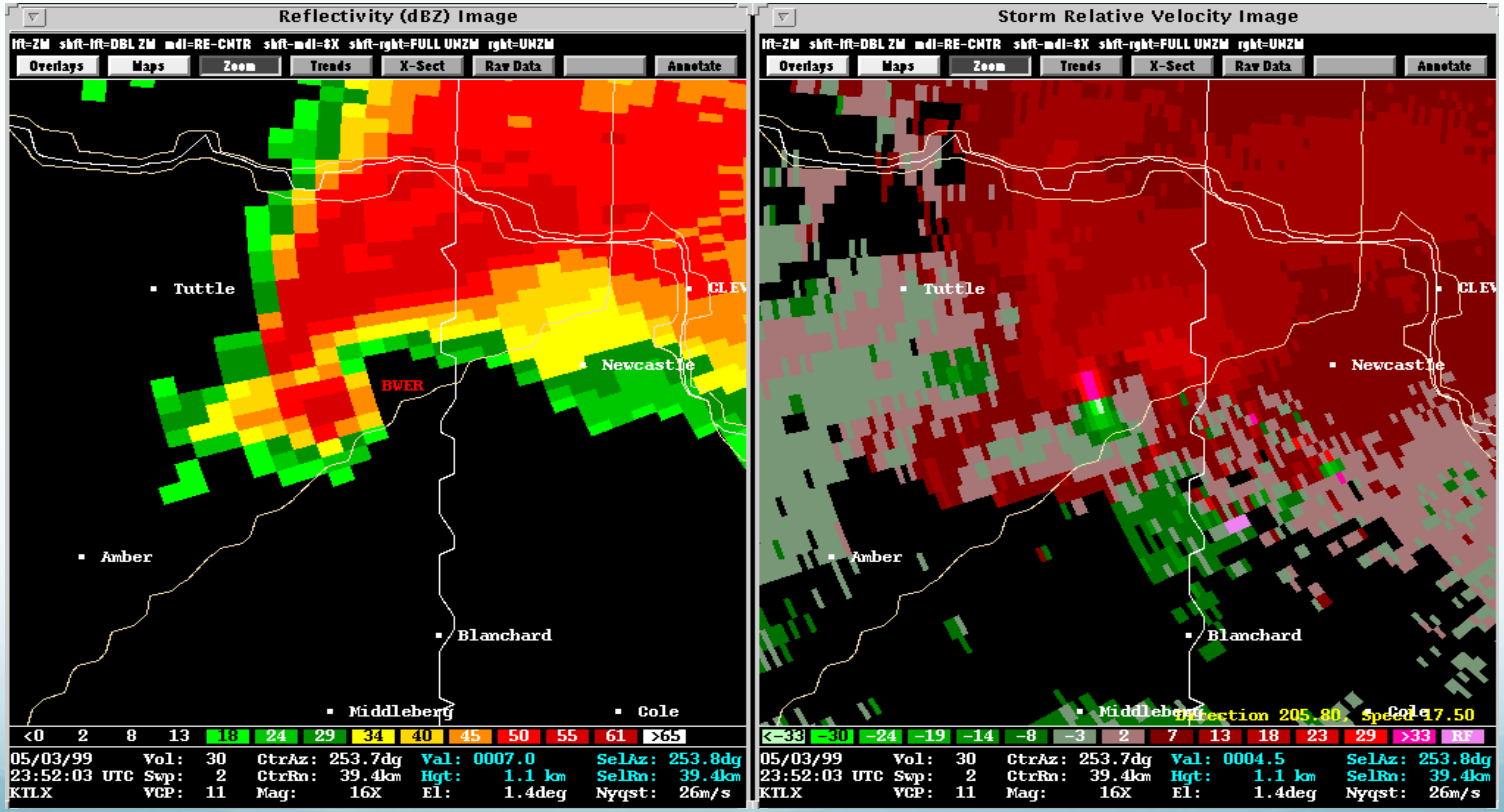
# Weather Radar: 1953

Prior to Doppler radar, the *hook echo* was the key feature indicating of  a strong mesocyclone.



# Why the Hook Echo?

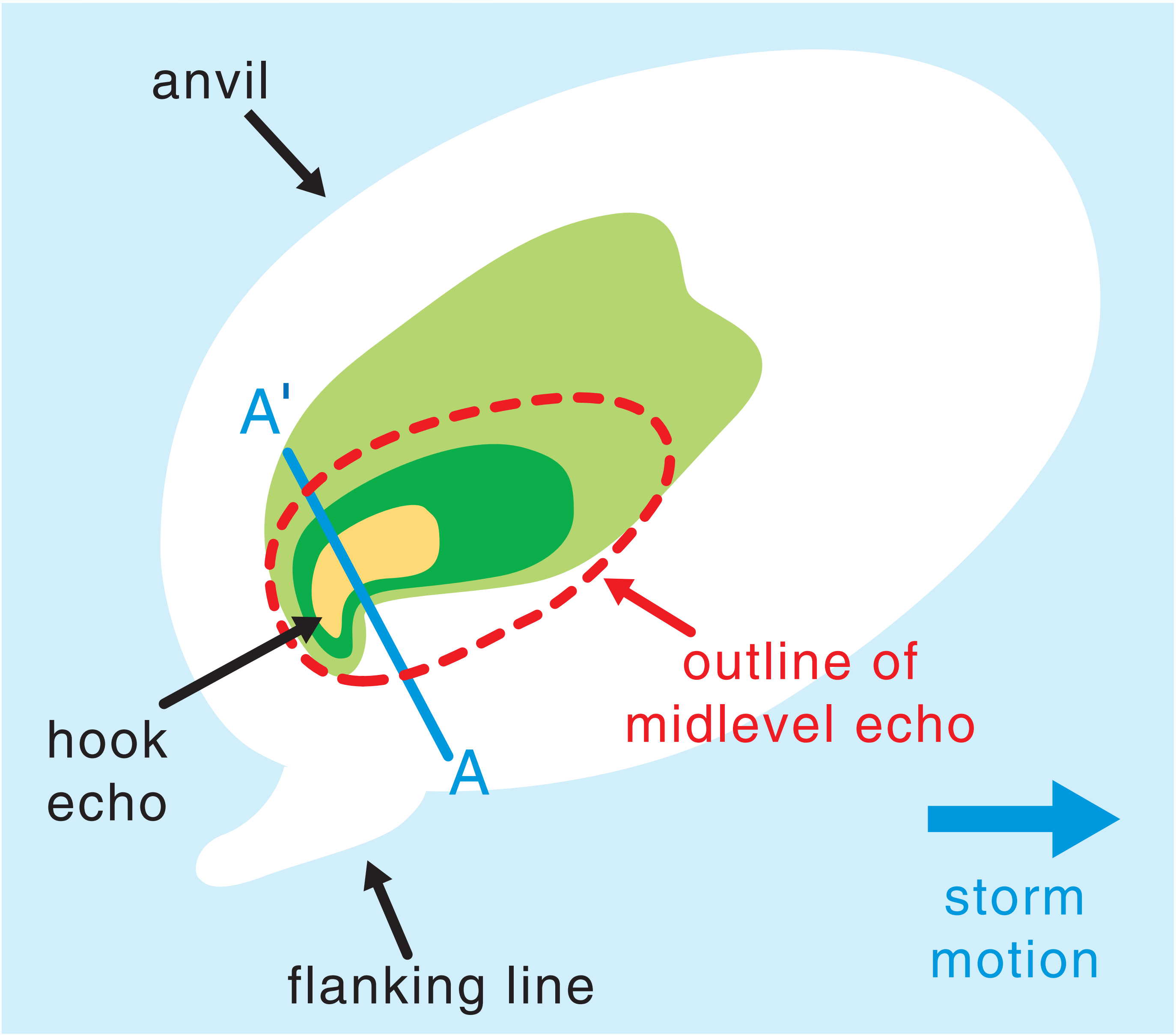
The low reflectivity region inside the hook IS within the updraft.

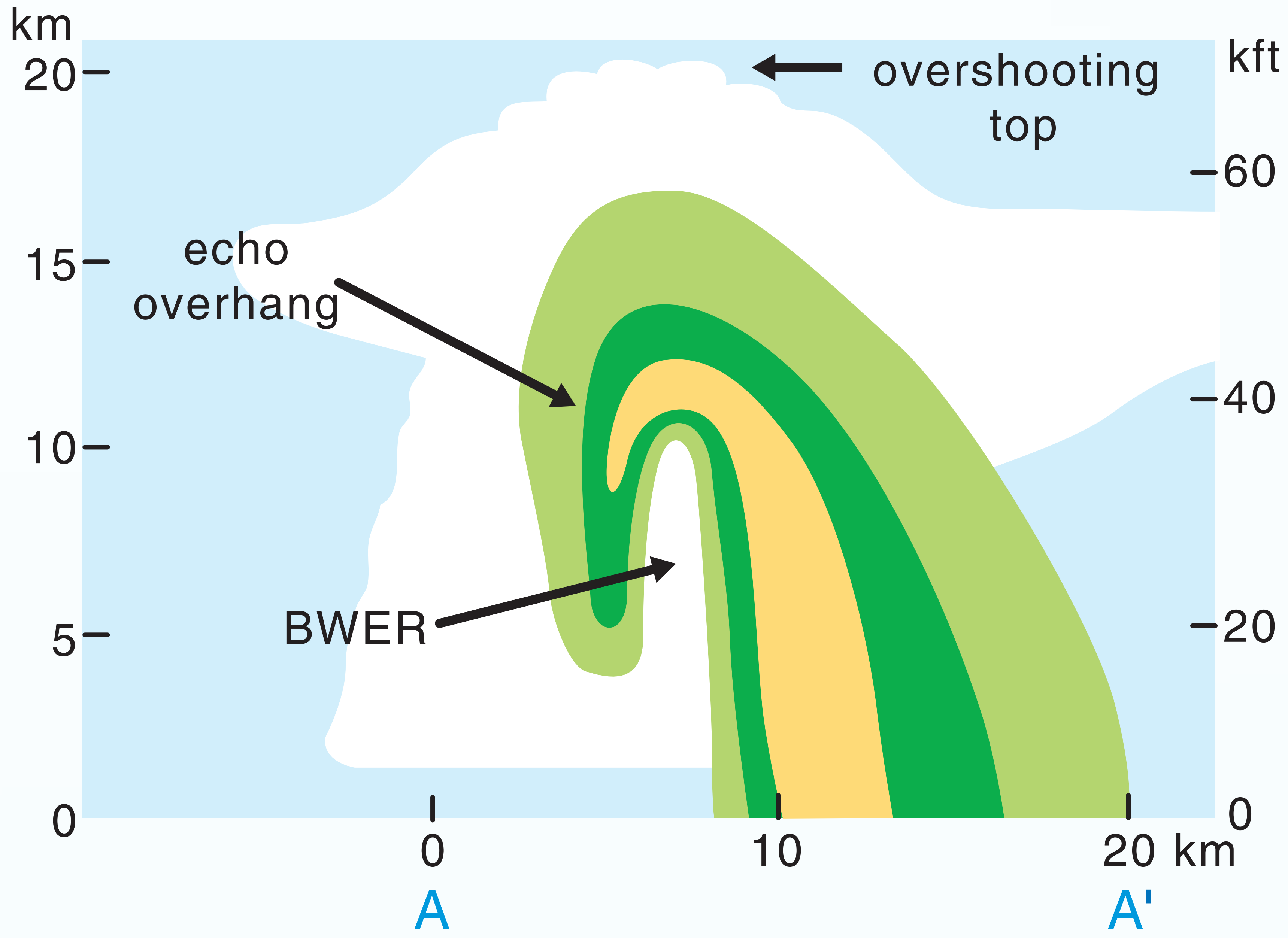


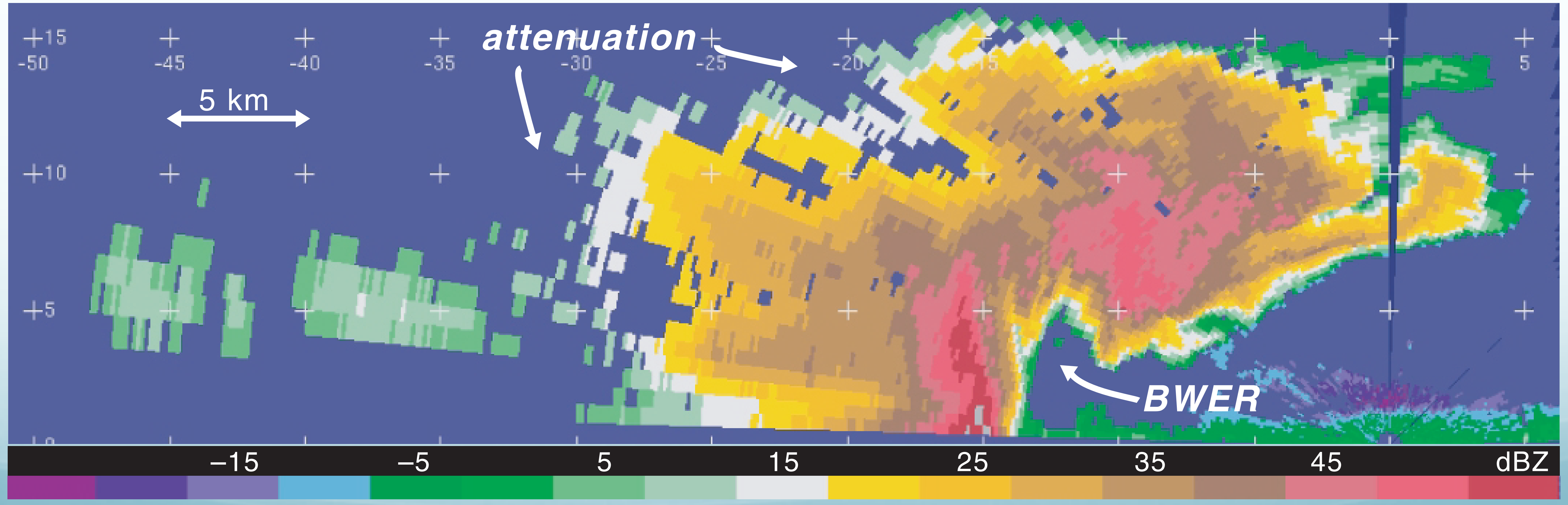
# Why the Hook Echo?

- *Air is rising so fast* in the updraft that
  - *Precipitation* trying to fall through this region *is held aloft*.
  - *Cloud droplets do not have time to grow* into raindrops and produce a radar return.
- Called a Bounded Weak Echo Region (BWER)
- A *debris* ball may define the “barb” *at the end of the hook*.

# BWER structure

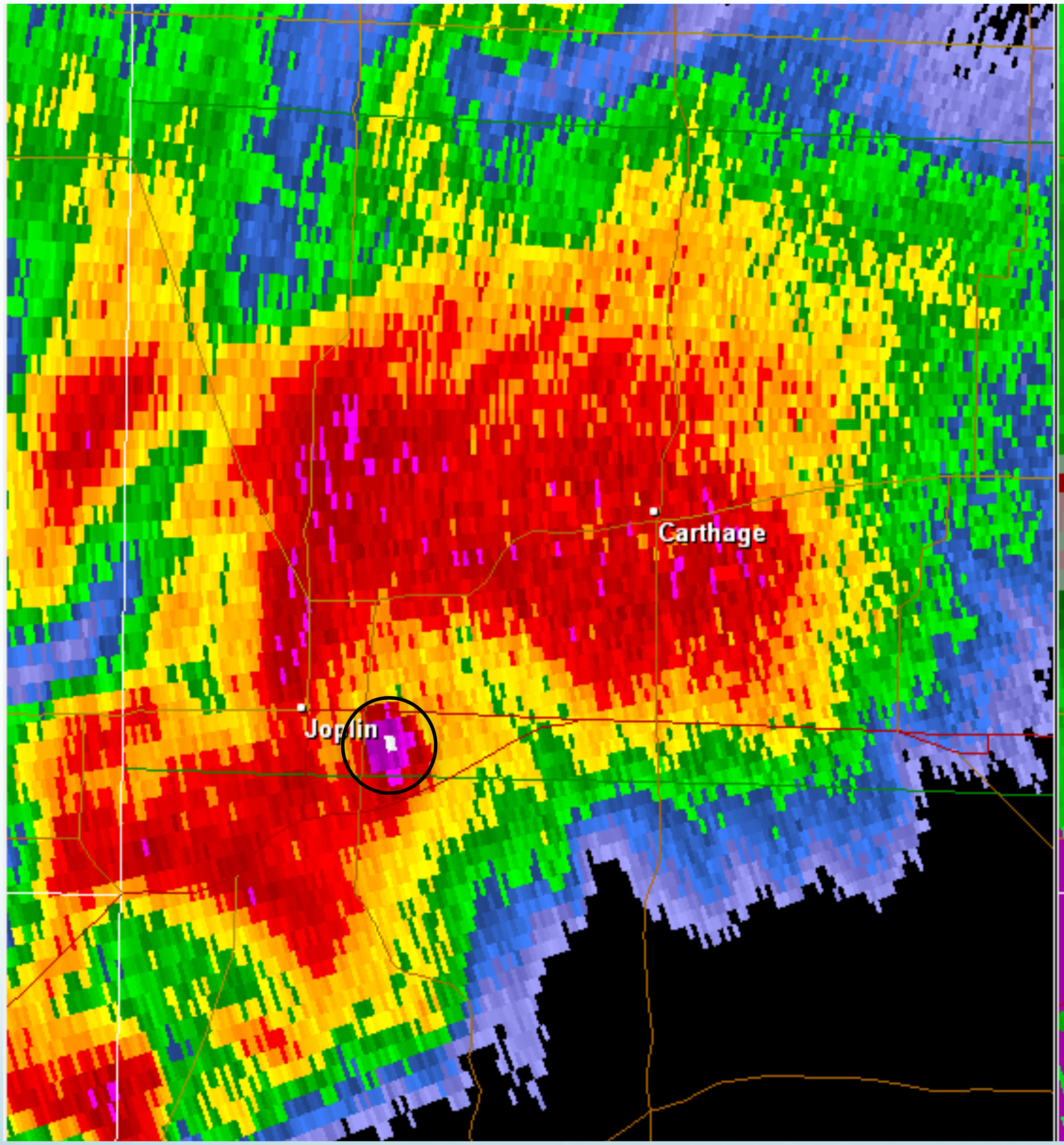


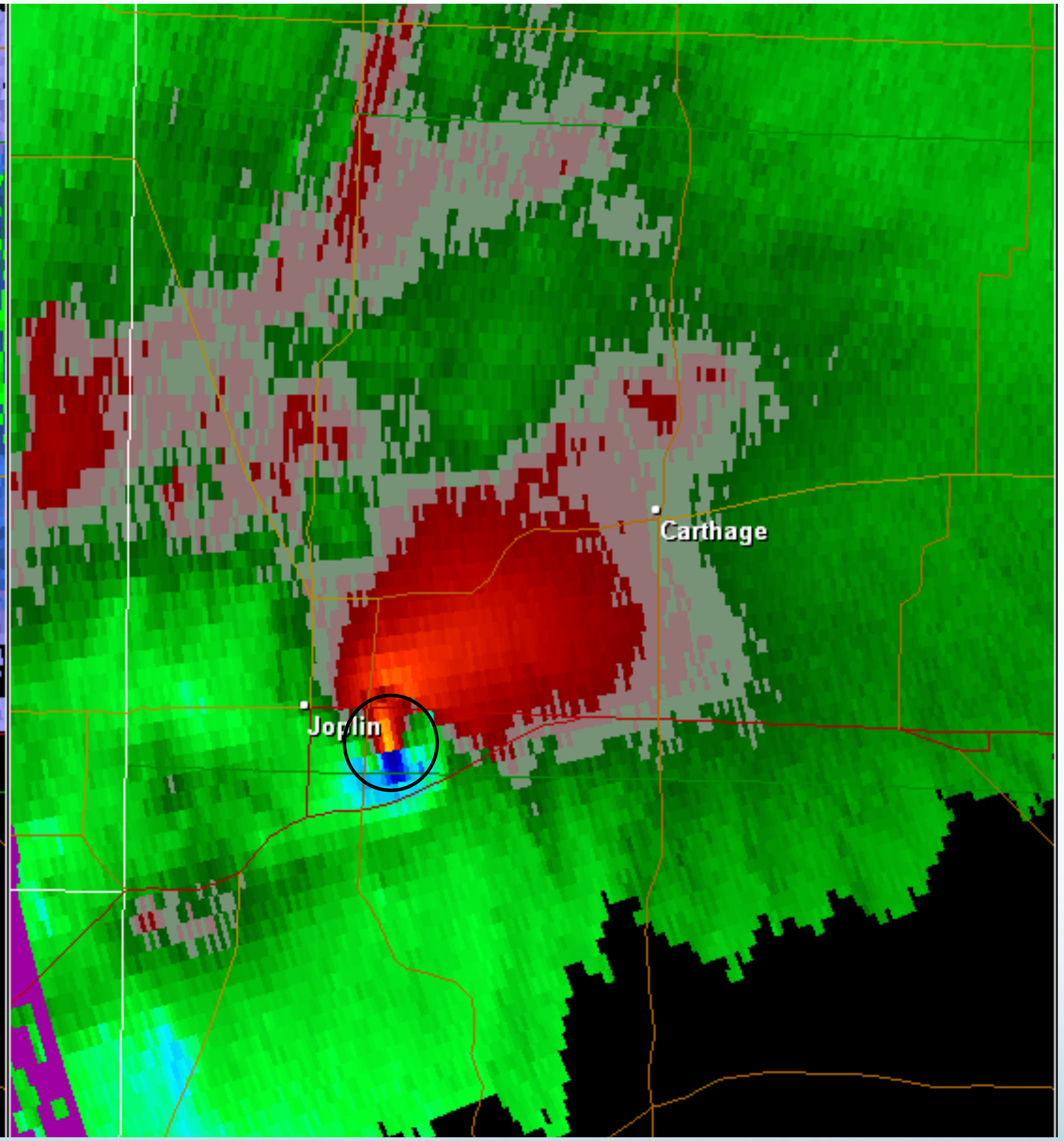



# Debris aloft in Joplin, Mo

Reflectivity




Radial velocity



# Tornadoes

# Lots of Mesocyclones, Few Make Tornadoes

- Tornadoes are relatively infrequent, even in supercells.
- 5 – 25% of mesocyclones detected by radar spawn tornadoes
  - Variation comes from the criteria for mesocyclone detection.
- Very strong mesocyclones do not necessarily spawn tornadoes

# What makes a tornado?

- Process is a bit complicated for strong and severe tornadoes.
- But all tornadoes intensify, at least in part, through one common process
  - We will start by looking at this common factor

# Common factor in forming all tornadoes

- Need to suck air, that is already rotating a little, into the updraft.
- Relates to conservation of angular momentum
  Ice skater

# Fluid Analog to Conservation of Angular Momentum

(Animated notes, 3rd frame)

- Blob of fluid is stretched vertically in an updraft
- Initial rotation rate increases as fluid is drawn into central updraft
- Such rotating "vortices" tend to last much longer than random turbulent motions.

# Dust Devil

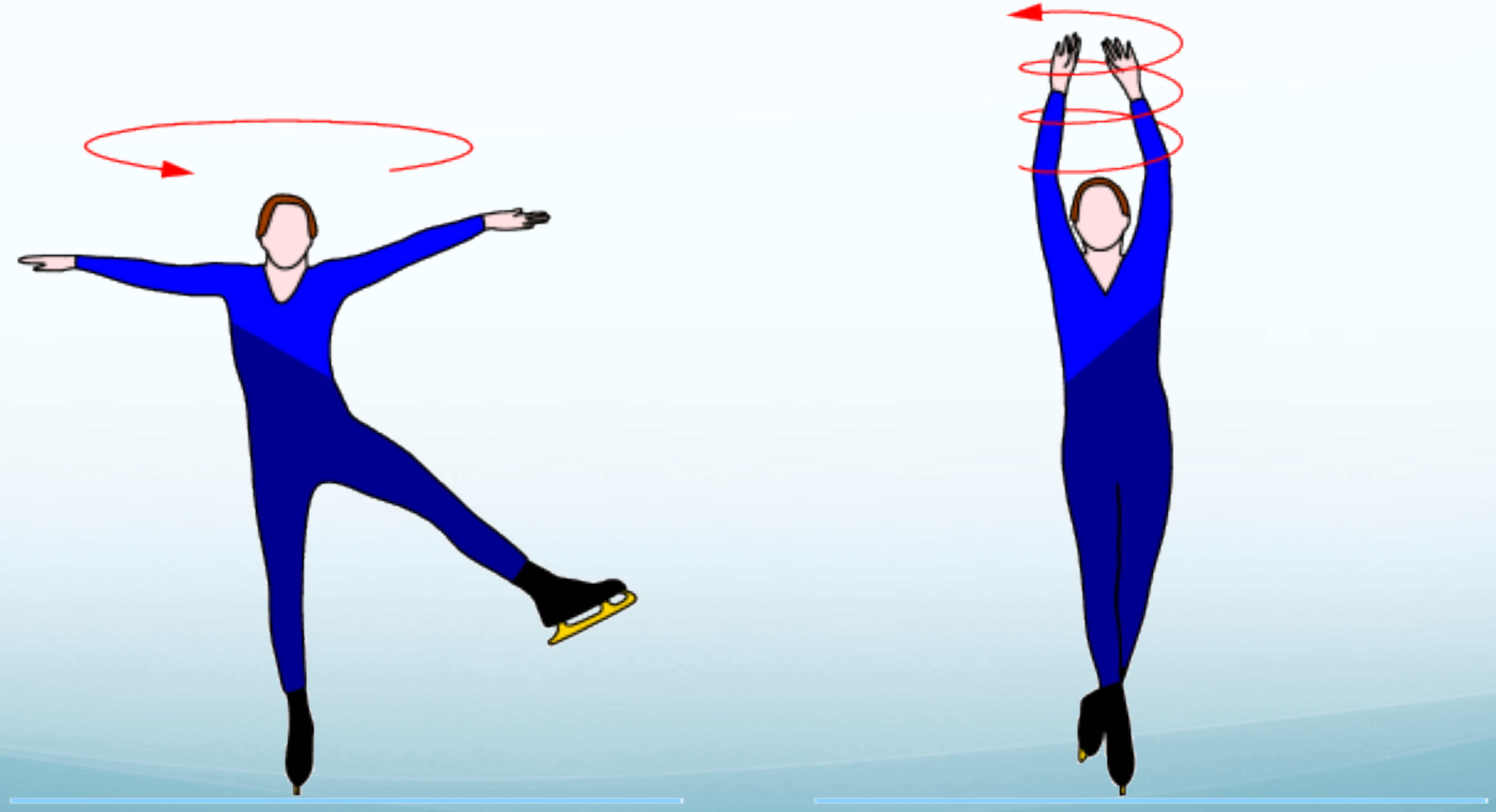
May form by concentrating randomly generated swirling motions on very hot calm days.

Fun during a picnic

Dust devil in Japan

# In tornadoes, dust devils, etc, initially rotating air gets sucked into an updraft

Rotation speeds up as air is drawn in toward the centerline of an updraft (conserving angular momentum)

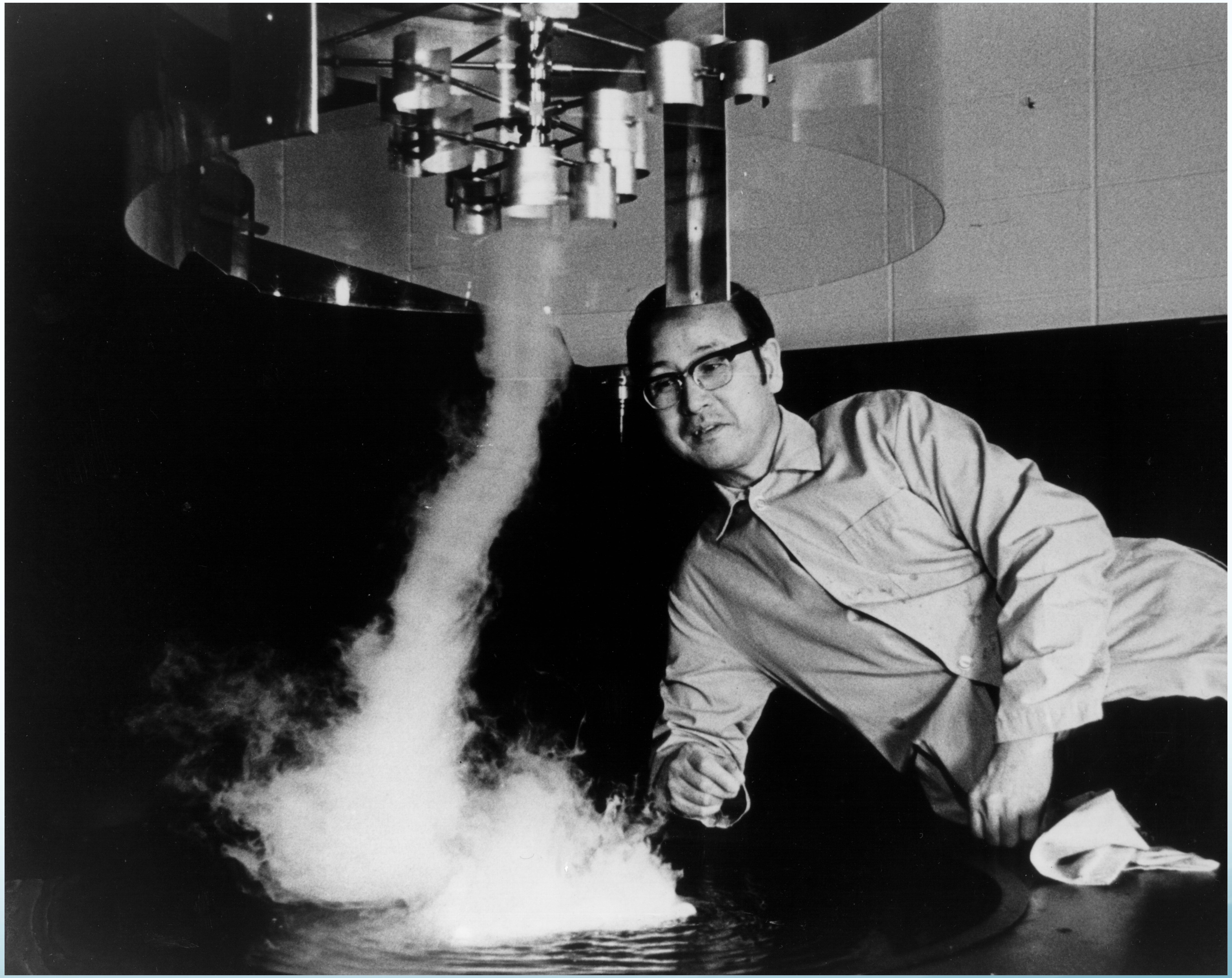


# When is it a tornado

- *Definition* of a tornado:
  - A violently rotating column of air
  - In contact with the ground
  - Connecting up to a cumulus cloud
  - Often (not always) visible as a funnel cloud
- Connection to a (vigorous) cumulus cloud:
  - Excludes dust devils and steam devils
  - Makes a stronger updraft and a more intense swirl

# Tornado Intensity: Enhanced Fujita Scale

- *Based on the damage*
- Wind speeds are estimates
- EF-0 through EF-5



| EF Rating | Wind Speeds | Expected Damage | | |
|---|---|---|---|---|
| **EF-0** | 65-85 mph | 'Minor' damage: shingles blown off or parts of a roof peeled off, damage to gutters/siding, branches broken off trees, shallow rooted trees toppled. |  |  |
| **EF-1** | 86-110 mph | 'Moderate' damage: more significant roof damage, windows broken, exterior doors damaged or lost, mobile homes overturned or badly damaged. |  |  |
| **EF-2** | 111-135 mph | 'Considerable' damage: roofs torn off well constructed homes, homes shifted off their foundation, mobile homes completely destroyed, large trees snapped or uprooted, cars can be tossed. |  |  |
| **EF-3** | 136-165 mph | 'Severe' damage: entire stories of well constructed homes destroyed, significant damage done to large buildings, homes with weak foundations can be blown away, trees begin to lose their bark. |  |  |
| **EF-4** | 166-200 mph | 'Extreme' damage: Well constructed homes are leveled, cars are thrown significant distances, top story exterior walls of masonry buildings would likely collapse. |  |  |
| **EF-5** | > 200 mph | 'Massive/incredible' damage: Well constructed homes are swept away, steel-reinforced concrete structures are critically damaged, high-rise buildings sustain severe structural damage, trees are usually completely debarked, stripped of branches and snapped. |  |  |