Knowledge of Convective Storm Structure, Risk Management, and Situational Awareness During Severe Weather Events

By

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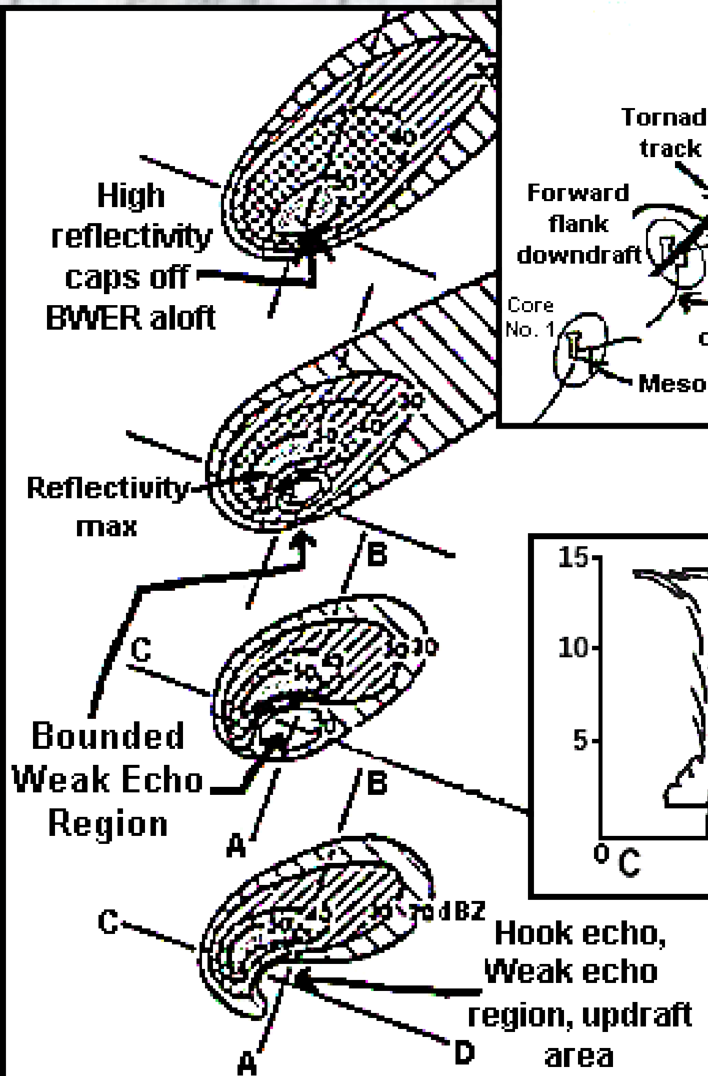
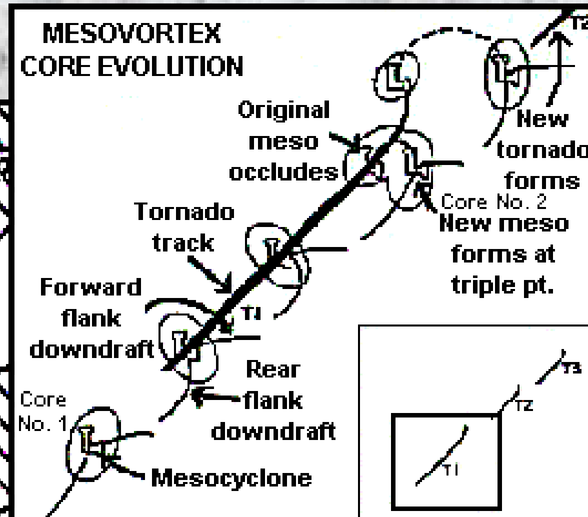
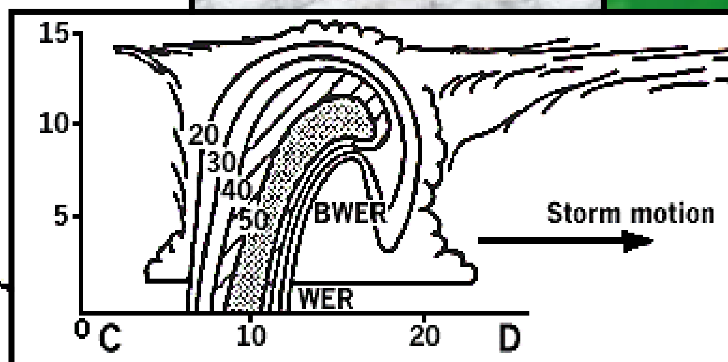
Severe Convective Storm Structure: A Quick Review

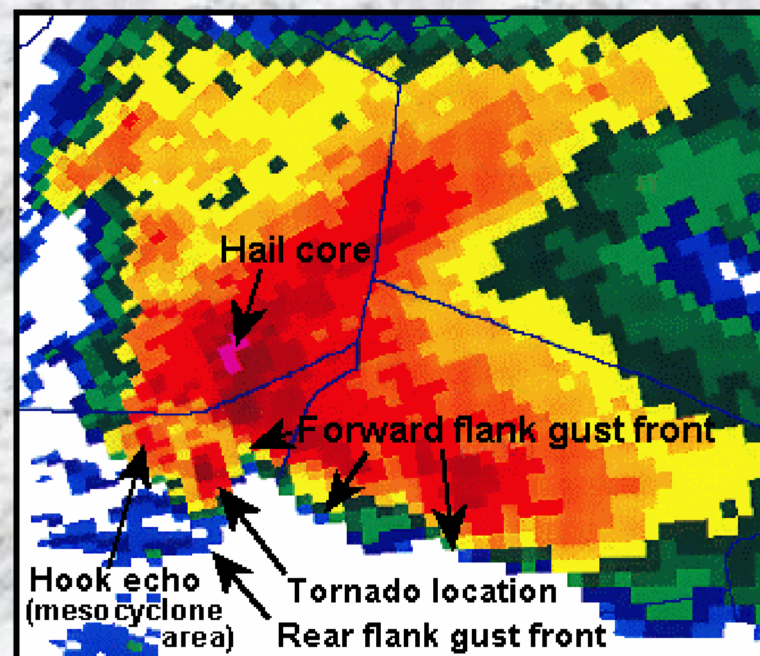
As warning forecasters, first and foremost, we must thoroughly understand the typical structure and evolution of various severe convective storm types, associated radar signatures, and the implications of these signatures.

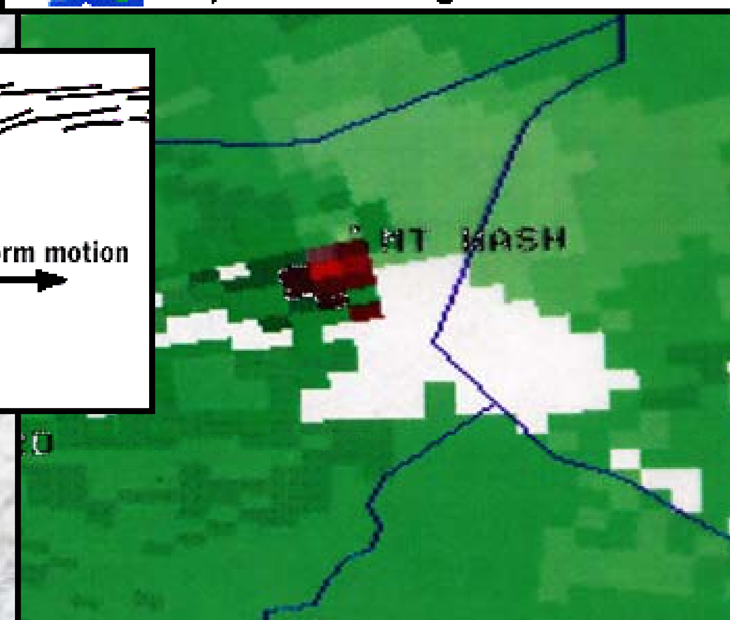
Classic Supercells



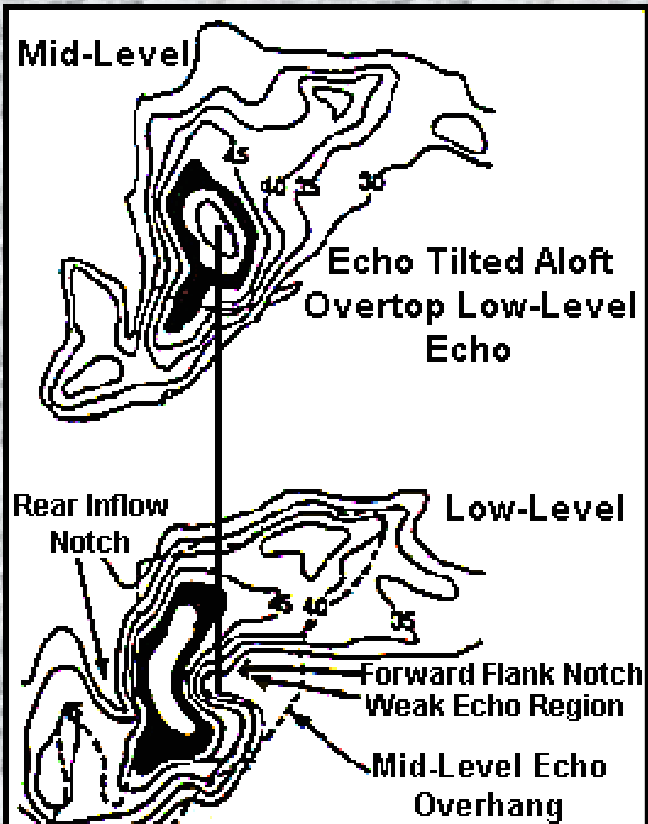


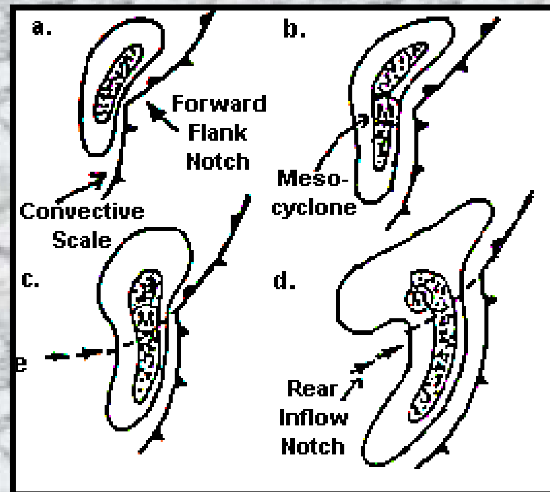


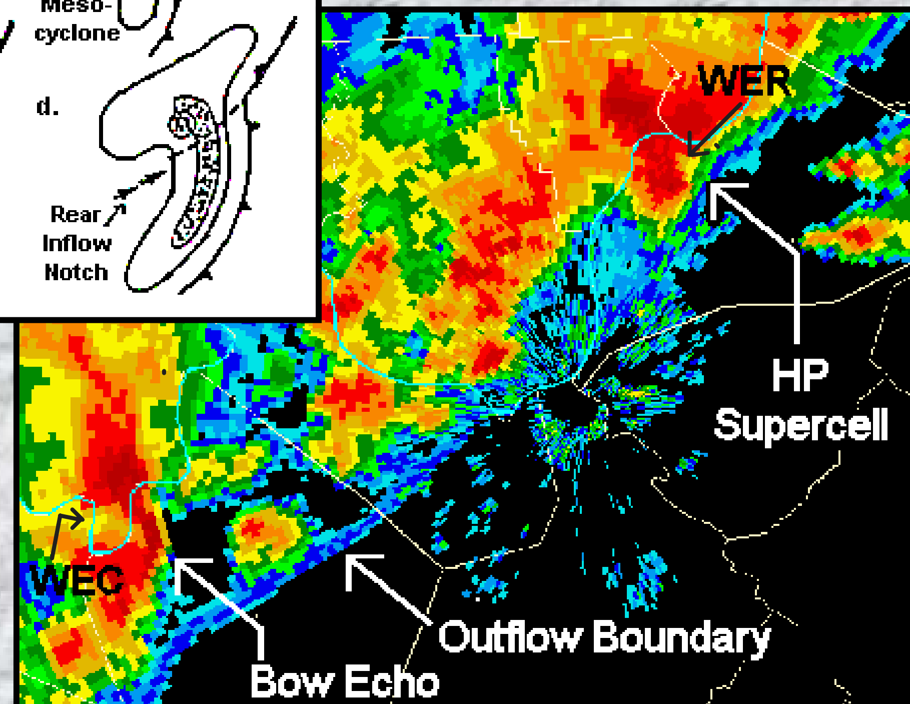




High Precipitation (HP) Supercells

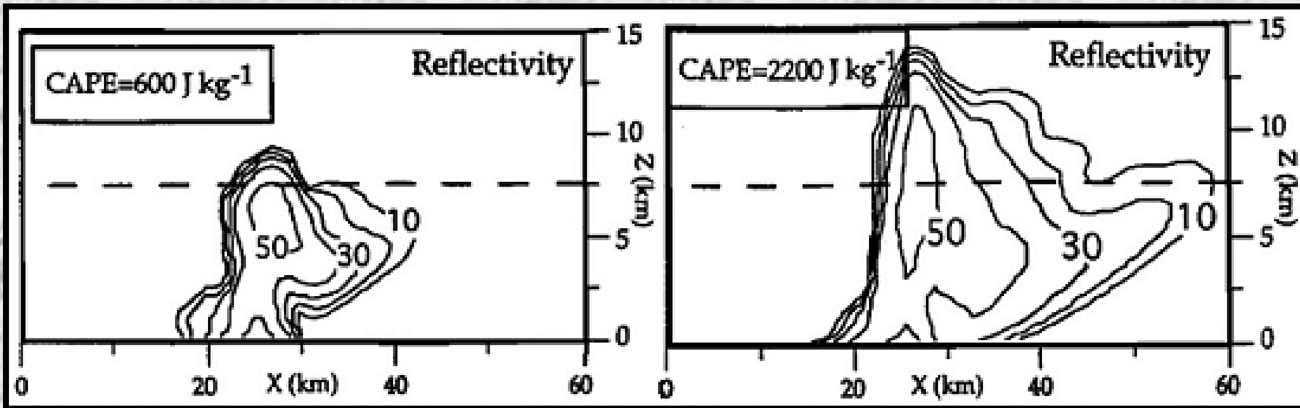




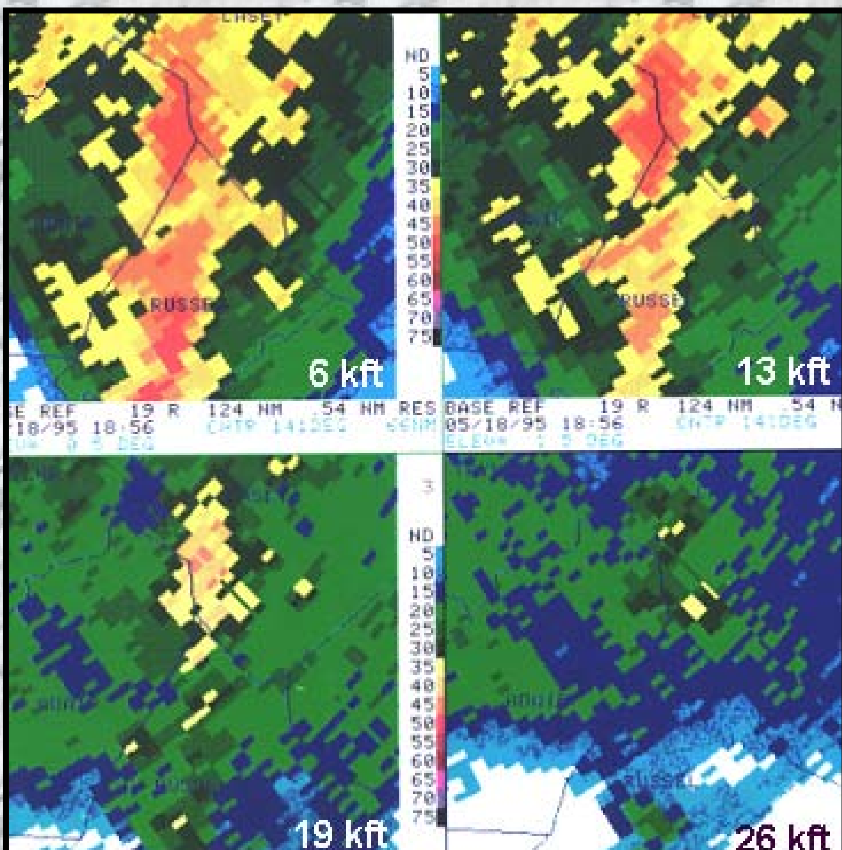


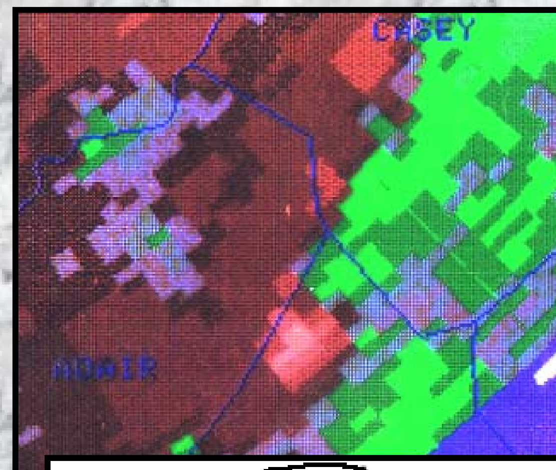
HP supercells exhibit similar features as classic supercells. However, low-levels often show a broad high reflectivity pendent or notch (i.e., kidney bean shape) on leading edge, indicating location of rotating updraft. HP mesocyclones may be embedded in heavy rain. HP storms often are embedded within squall lines and travel along boundaries. They occur in environments with rich low-level moisture and moderate-to-strong wind shear, and may cause tornadoes, large hail, damaging winds, and flash floods.

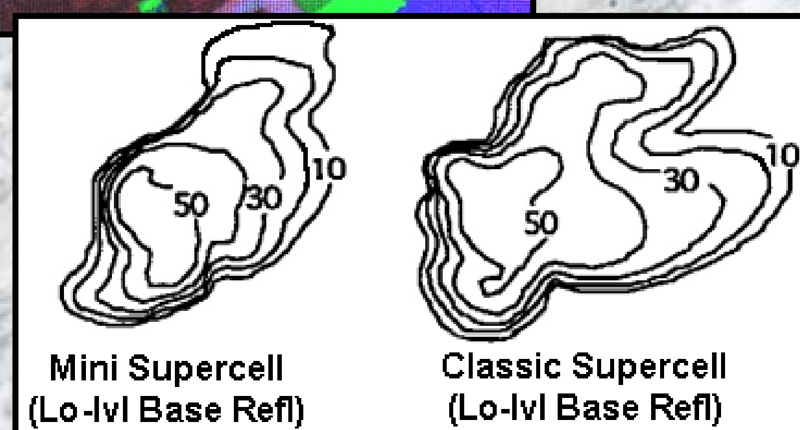
Mini Supercells



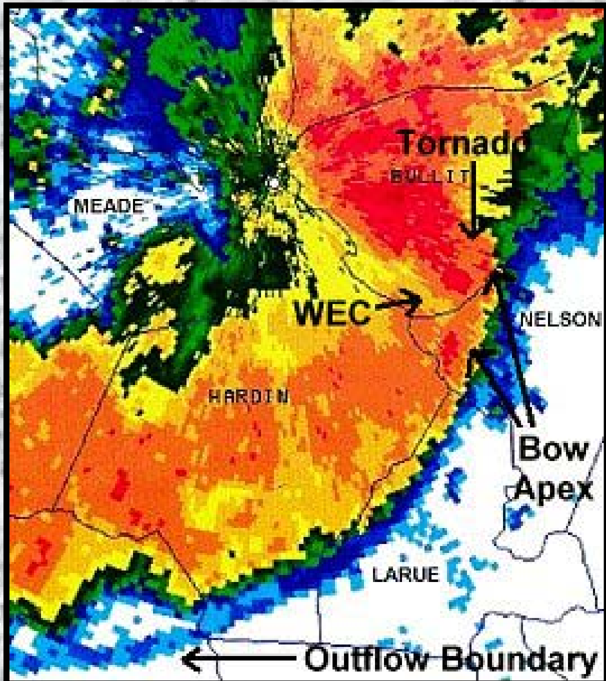
Attributes are similar to classic supercells, but dimensions, values, and appearance are less and/or more subtle, making detection more difficult; occur in an environment with weak instability but moderate-to-strong shear, or where the tropopause is low (i.e., under a cold pool aloft)

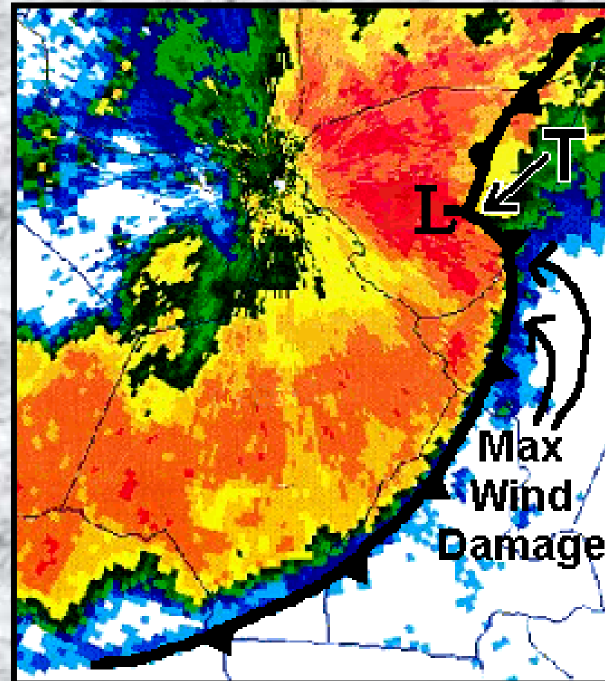


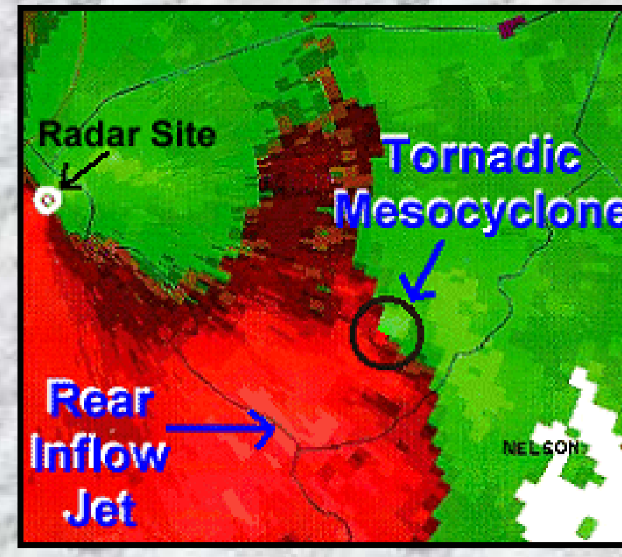




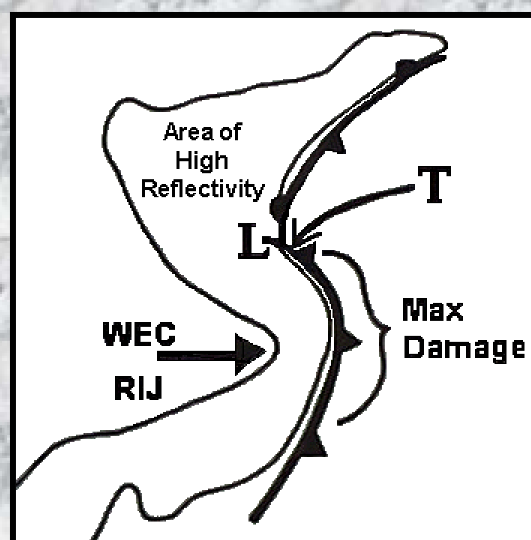
Squall Lines/Bow Echoes

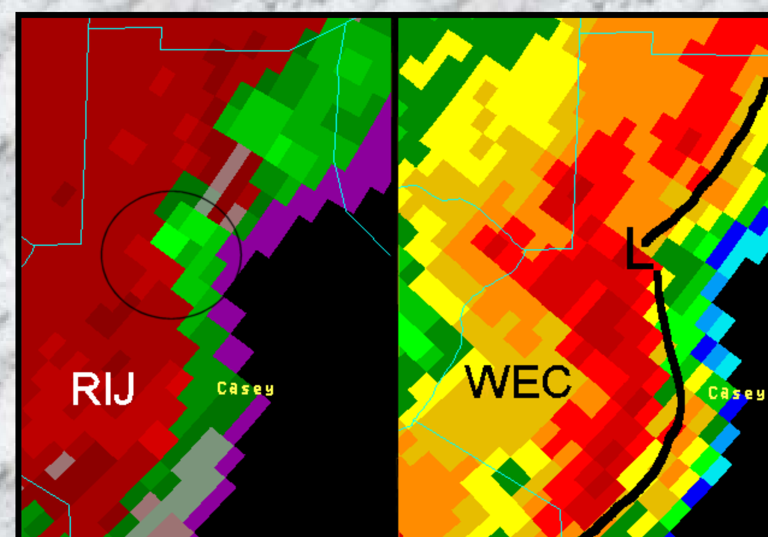






Key Signatures:
- Bowing line
- Tight reflec gradient on leading edge
- Weak echo channel behind line coincident with rear inflow jet
- Cyclonic vortex just north of apex, where transient tornadoes can develop rapidly





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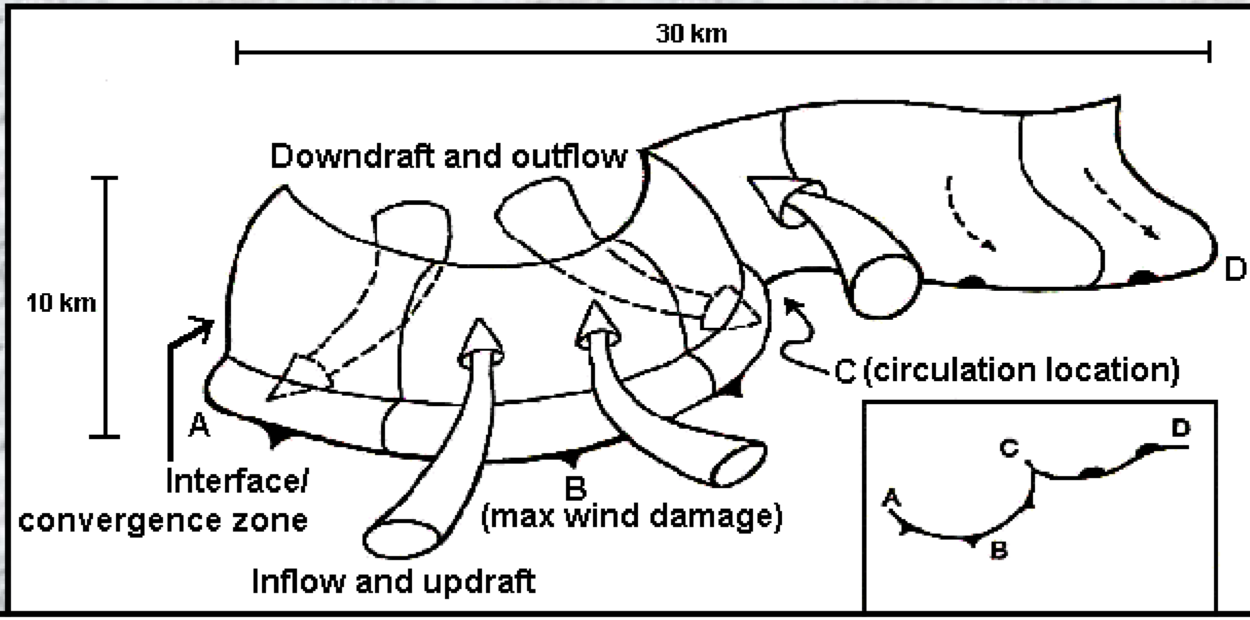

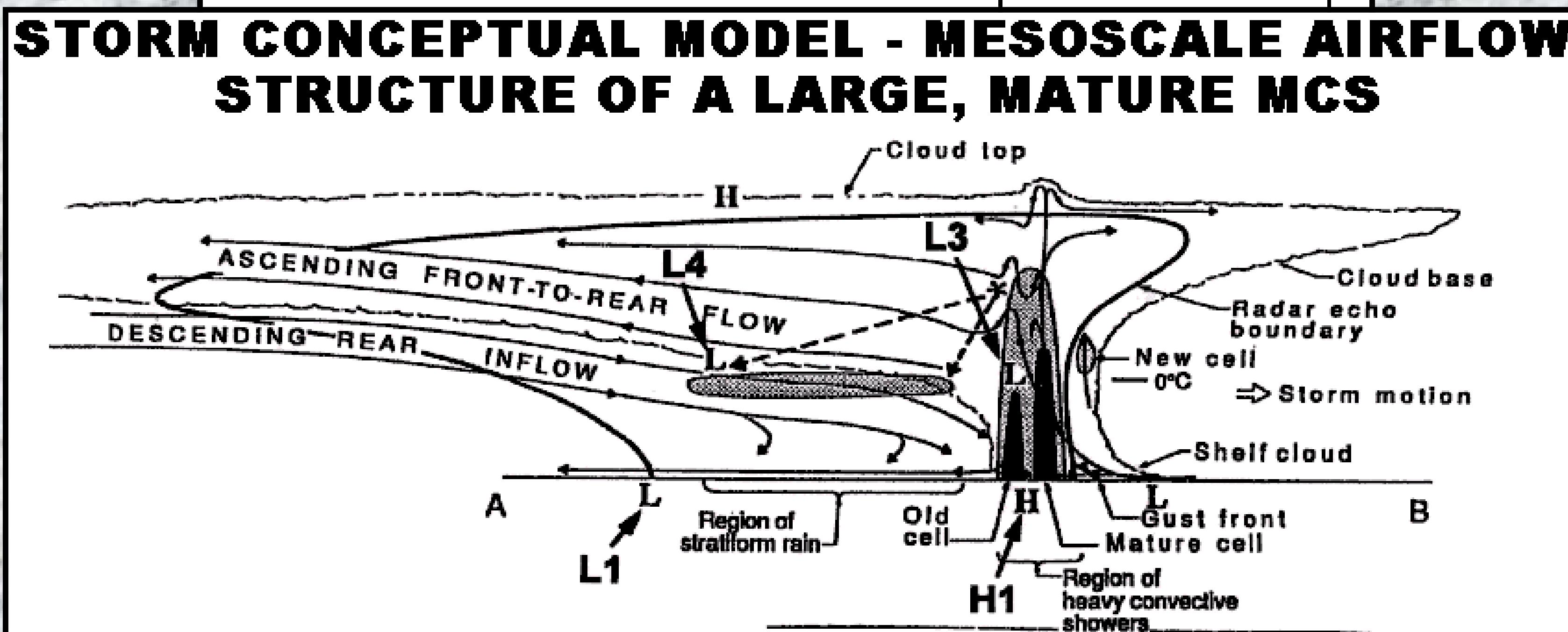

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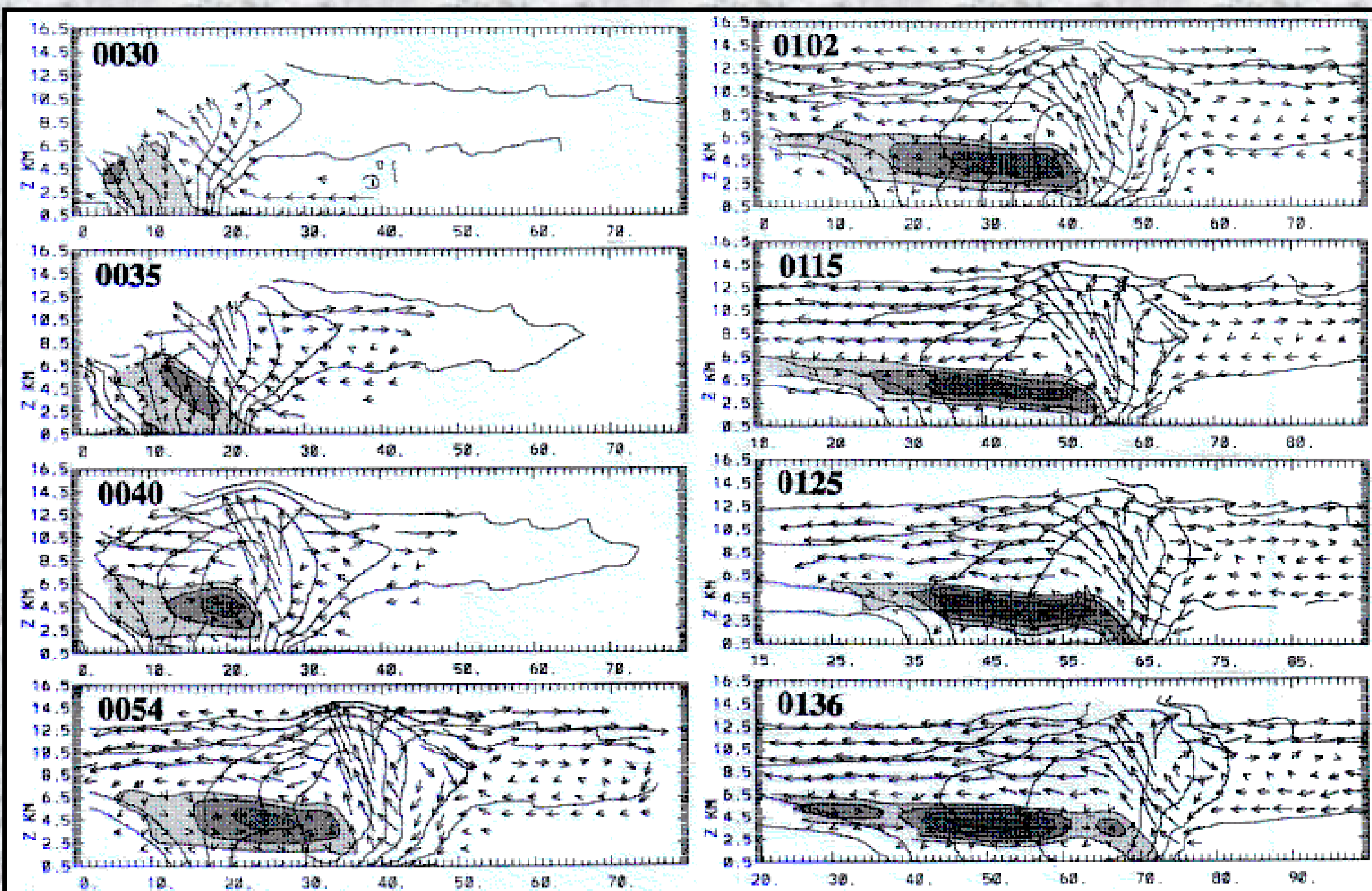


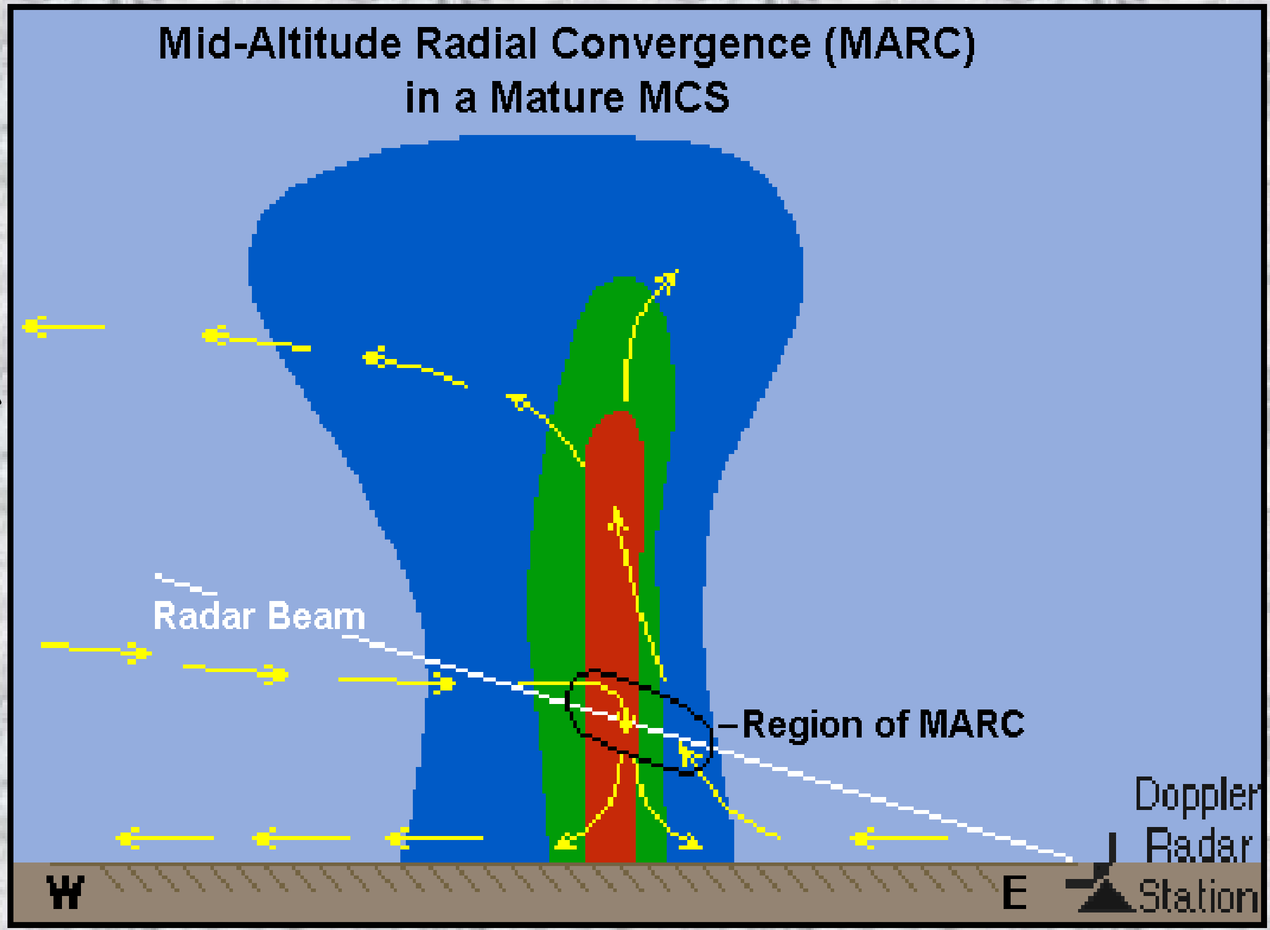
Reflectivity contours are solid. Shaded region represents evolution of rear inflow jet. RIJ deflects down to surface near updraft/downdraft interface along leading line.

Mid Altitude Radial Convergence (MARC) in a Squall Line/Bow Echo

-Strong MARC can occur along forward flank of squall lines before they begin to bow out

-Persistent areas of MARC (enhanced convergent velocity differential along a radial) within larger zone of convergence along for-ward flank of line appears to be linked to greatest degree of wind damage

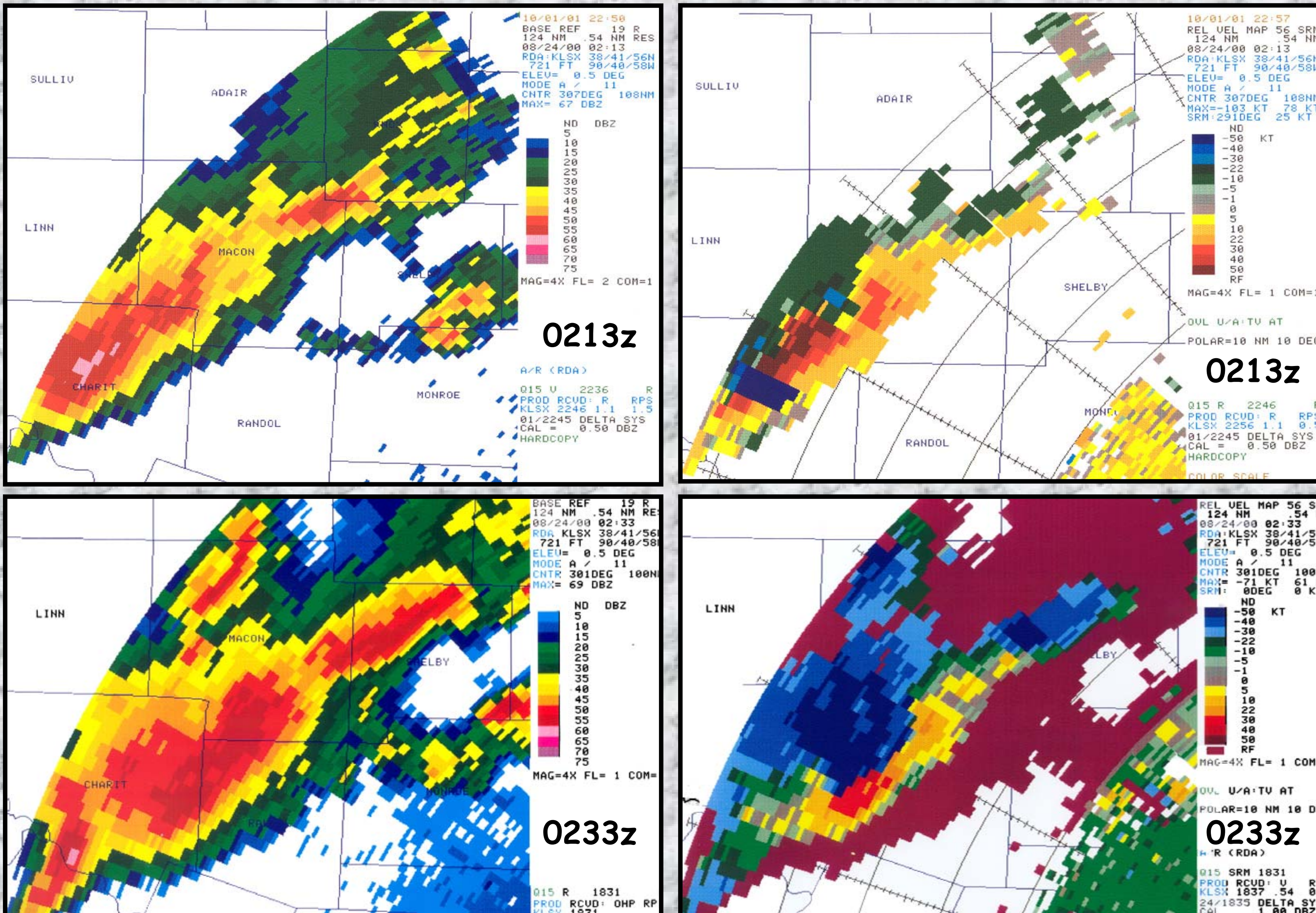
-Persistent MARC usually located in or just downwind of high reflectivity cores along leading edge of line



-Enhanced areas of convergence usually are less than 15 km in length/7 km in width

-A strong velocity gradient between inbound and outbound maxima (nearly gate to gate) yields strongest actual convergence and best downburst potential

Mid Altitude Radial Convergence (MARC)



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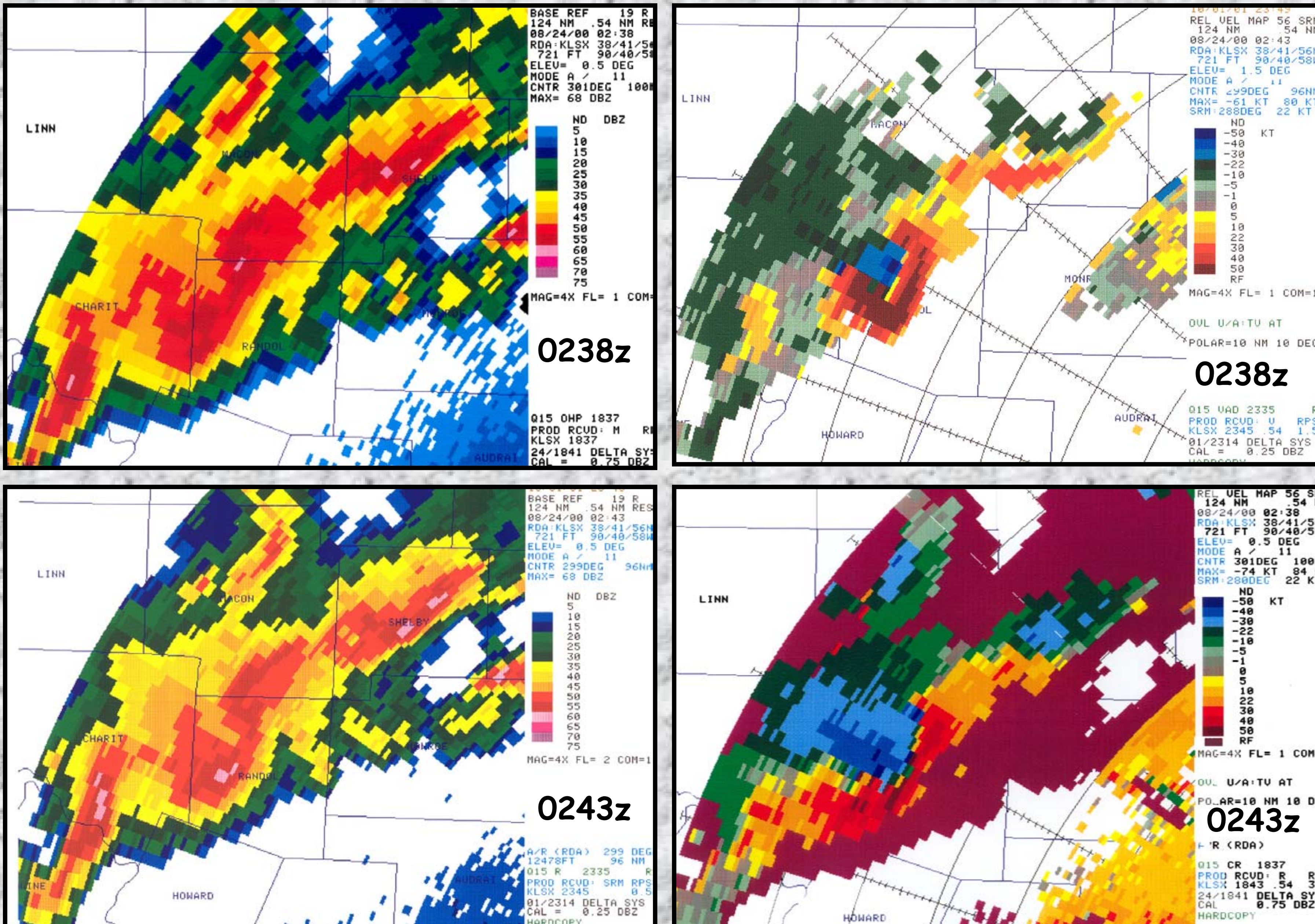


Mid Altitude Radial Convergence (MARC)

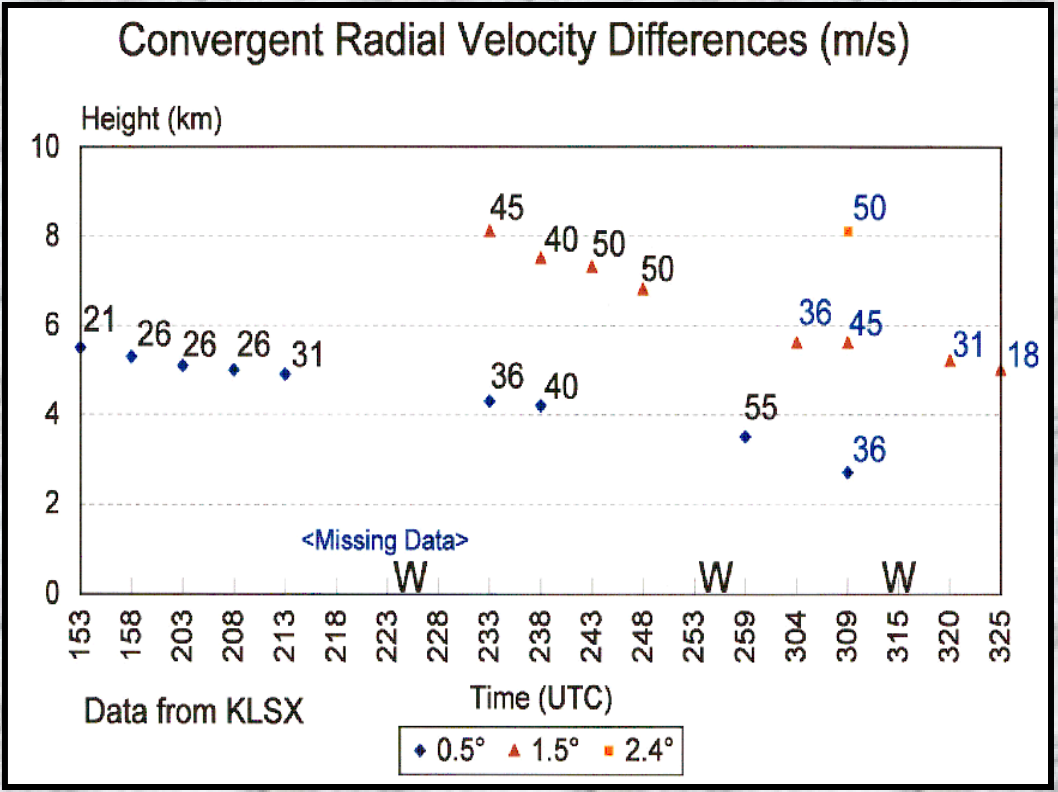
-MARC velocity signature values > 25 m/s or 50 kt provided avg lead times of almost 20 minutes prior to 1st damage report

-MARC often identified before development of well-defined bow echo

-MARC usually identified at height btwn 4-5 km (12-17 kft) along forward flank of line (near high reflectivity cores)

-Can be detected as far as 120 nm from radar using lowest elevation slice

-MARC has been observed more frequently with a nearly solid linear convective line compared to discrete, more isolated cells



-Importance of viewing angle: MARC will be underestimated when convective line is not orthogonal (perpendicular) to radial

-When evaluating MARC and subsequent wind damage potential, you must understand environment it is occurring in. Even with a strong MARC signature, damaging surface winds are less likely if a deep (greater than or equal to 2 km), cool, stable boundary layer is present (i.e., convection is not surface-based but is elevated north of a stationary/warm front)

Risk Management

Do you consider RISK in making convective warning decisions?

UNCERTAINTY relates to the likelihood of occurrence of the event.

RISK is the probability of an undesirable event occurring **and** the significance of the consequence of the occurrence. So, to understand when a given decision is "risky," one must have an understanding of potential impacts resulting from the occurrence/nonoccurrence of the event. In essence, decisions are riskier over population centers than in rural locations since the consequences of wrong decisions are greater.

Thus, knowledge of convective storm structure and radar data analysis is critical, but may not be enough. We must use 3 data sets simultaneously to an effort to reduce risk and increase the chance of success: radar, environmental data, spotters

Risk

Potential sources of uncertainty or misinterpretation associated with the following (not a complete listing):

WSR-88D Output

a. Beam width/height vs range
b. Viewing angle (velocity)
c. Range folding
d. Lower res. data vs 8-bit
e. Data overload in big events
f. VIL when max refl>60 dBZ
g. Improper de-aliasing
h. SRM vs base velocity

Near-Storm Environment Data Sets

a. Inaccurate observations
b. Large distance between obs
c. Is environment changing as data suggests (or is resolution a problem?)
d. Conflicting data
e. Model data w/out observational support

Spotter Reports

a. Lack of spotters
b. Conflicting reports
c. Location of spotters (are they in position to see a feature in storm)
d. Which storm is report for?
e. Inaccurate report (are they really seeing what they are reporting?)

Risk

Radar Data

Risk increases with increasing range, decreasing feature size, range folding

Risk decreases with decreasing range, increasing feature size

Environment Data Sets

Risk increases with increasing dependency on model data, decreasing observation coverage, questionable observations

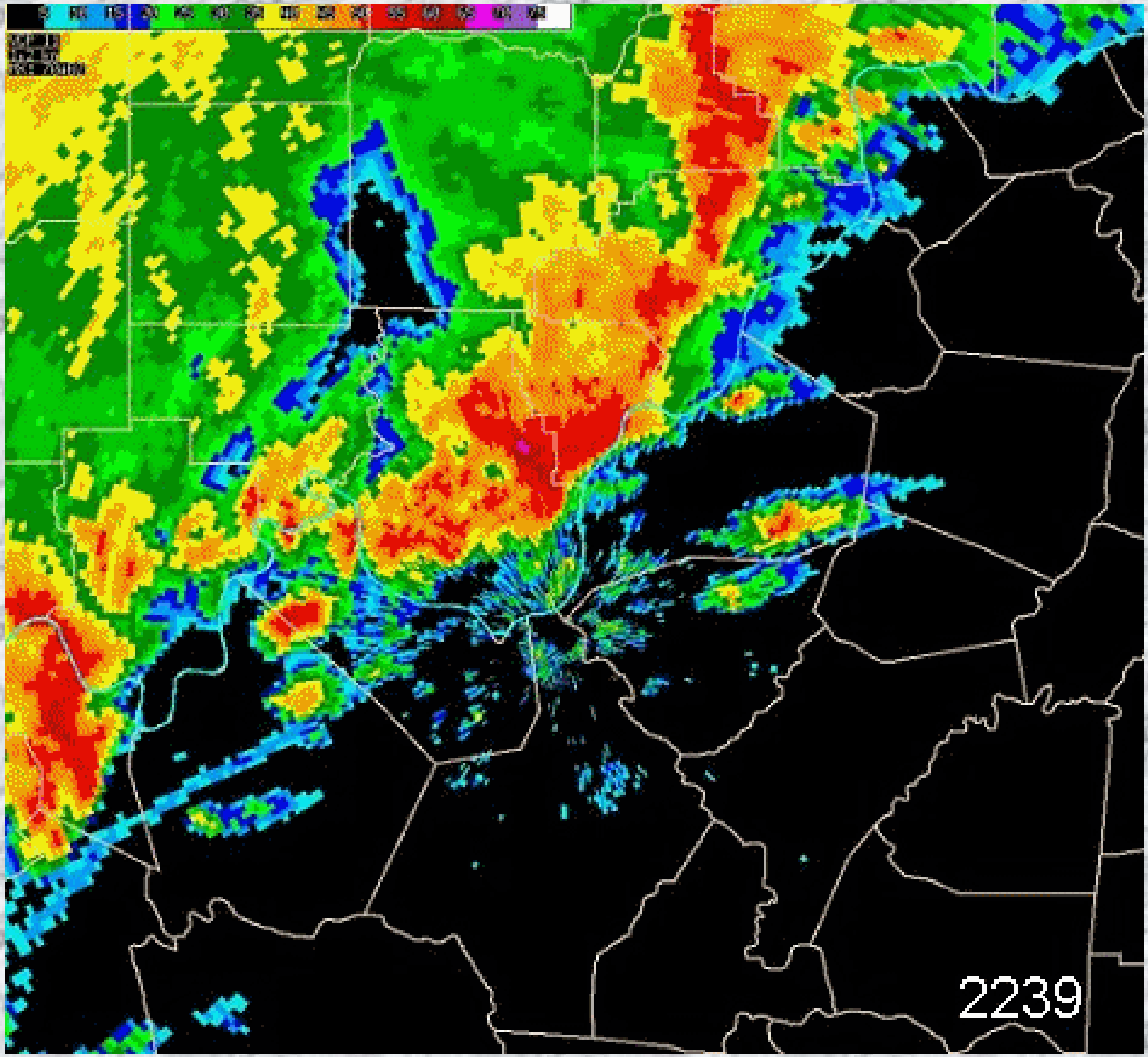
Risk decreases with increasing dependency on multiple observations, increasing observation coverage, reliable obs

Spotter Reports

Risk increases with decreased number of spotters, decreased level of training (untrained public report), unfavorable spotter location, unreliable report

Risk decreases with increasing number of spotters (to confirm each other's reports) and favorable spotter location

Uncertainty in Radar Data Interpretation

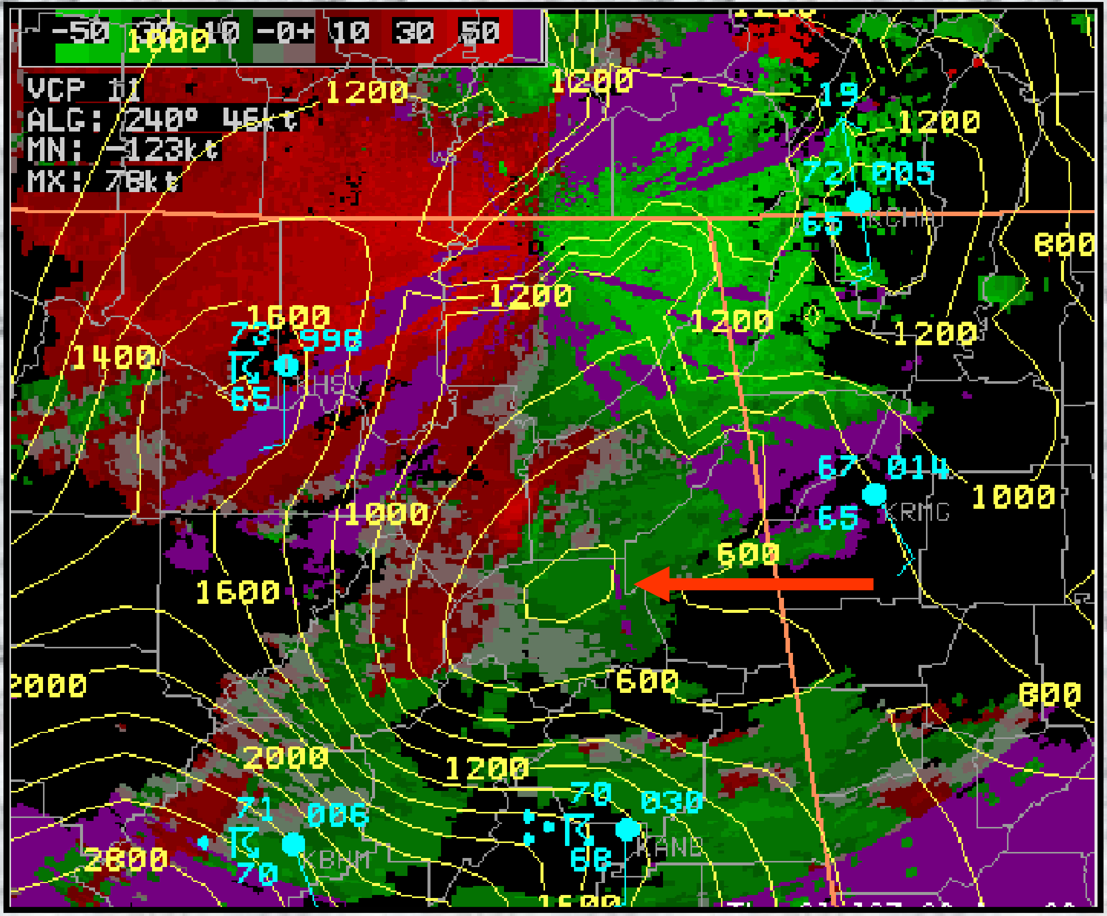


November 11, 2002: What does radar data show and does it fit our conceptual models? Are we interpreting the data correctly? Do we understand what interactions are occurring within the convective line and the effects these will have on future convective evolution?

Uncertainty in Environmental Data

Does the environment exist/change in time and space exactly as our data sets suggest (or is the data misleading or not resolving important features)?

Are we correctly interpreting how the environment is changing in time and space?



Example: Note the CAPE minimum over northeast Alabama on the LAPS plot (where arrow is pointing). There are no surface observations here to help confirm the accuracy of this feature. How does this affect our thoughts concerning the cyclonic circulation near this supposed minimum?

Uncertainty in Spotter Reports

Radar 30nm away shows a supercell with a strong mesocyclone but no spotter reports have been received.

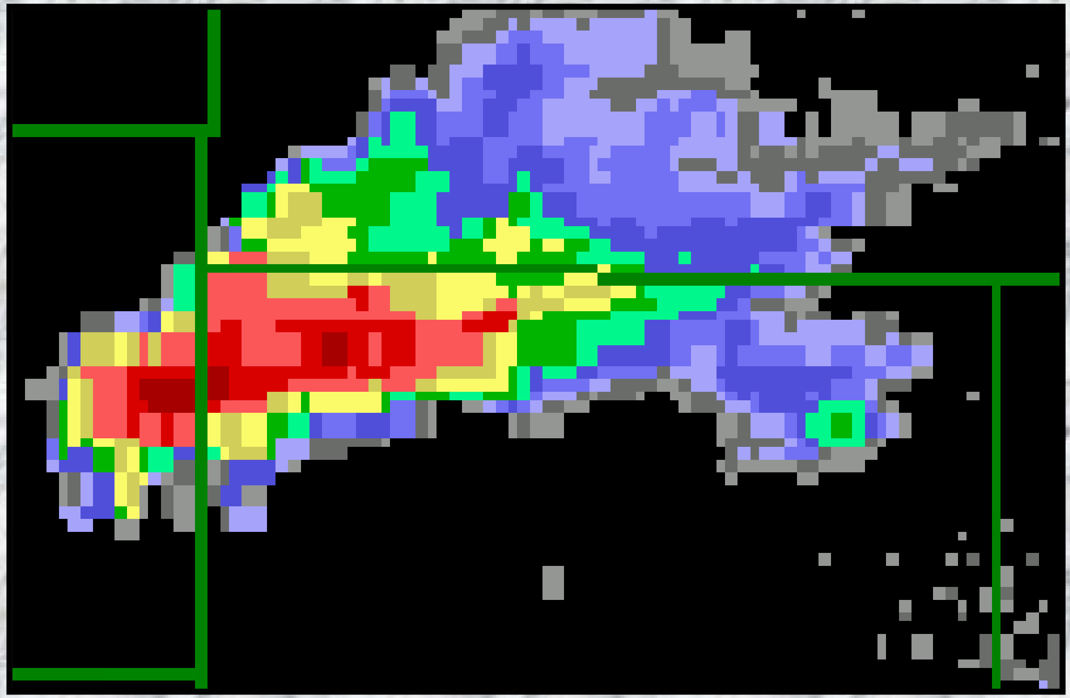
A spotter then calls in reporting a dark, turbulent sky, but no evidence of any funnel or wall cloud whatsoever.

Do you issue a tornado warning? Was the spotter report accurate? Did you ask him his location with respect to the storm?

A couple minutes later, you find out he was positioned north of the storm looking south.

A few minutes later, another spotter calls in south of the storm revealing a rotating wall cloud and tornadogenesis in progress.

This storm in Kansas produced a significant tornado.



What do you do when the data disagree?

Radar shows no organized rotation, but a spotter reports a funnel cloud and the storm is approaching a major town or city?

Radar shows a strong mesocyclone aloft and a spotter reports a rotating wall cloud, but the storm is in an area with a strong low-level inversion and weak shear?

Radar shows a supercell with moderate rotation in a favorable environment for tornadoes, but spotters underneath the storm report no funnels, and barely even a wall cloud, and the storm is over a large rural area where few live?

Radar shows a massive supercell with a VIL of 80, but velocity data is masked in range-folding, and given that it's nighttime, there are no spotters available?

Weigh The Evidence

Due to potential risk inherit in all 3 data sets (radar data, environmental data, spotter reports), the most informed warning decision is born out of an approach that effectively integrates information from all 3 sources, and **weighs the evidence**

This approach includes knowledge of data available, knowledge of data not available, knowledge of data accuracy/reliability, and ability to resolve conflicting data

Forecaster applies more weight to those data sources and types that decrease risk and less weight to those that are associated with increase risk

This also allows us the manage risk, i.e., understand the risk at hand, potential for error and resultant consequences; for example, it allows us to issue tornado warnings when needed but not for every rotating supercell

In effect, this approach allows for better **deterministic** warnings, and less **probabilistic** warnings

Situational Awareness in the Warning Environment

-Science

Do we know the environment and its relationship to storms; do we understand storm structure thoroughly in general and for the event at hand; are our conceptual models of tornadogenesis correct

-Technology

Do we have enough observations/data to help in our assessment of the environment and radar data; is the radar, AWIPS, and NWR working efficiently; are TV dissemination systems working correctly

-Human Factors

Are enough people present to handle the event; who's doing what; are we applying the science (conceptual models correctly); are we communicating information well with other staff members; are we using efficient warning strategies; what personal issues may affect our abilities, concentration, and thought processes that day (e.g., fatigue, stress, issues at home, coworkers, etc.)

-Interactions amongst all three

Is everything and everyone working properly and together to provide accurate, timely warning services to the public

Situational Awareness

Definition:

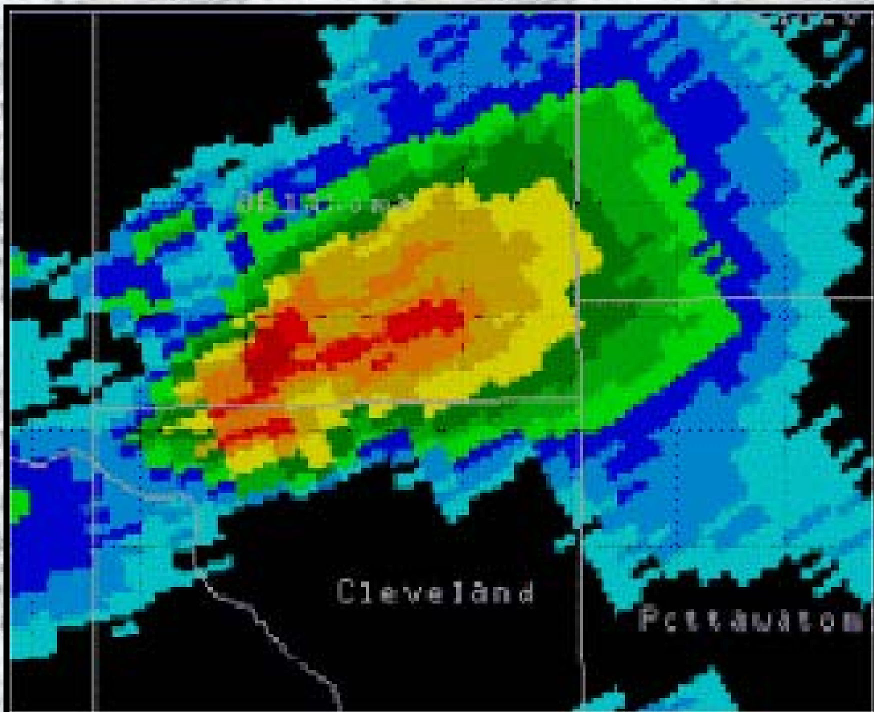
Perception of the elements of the environment within a volume of space and time

Comprehension of the meaning of these elements

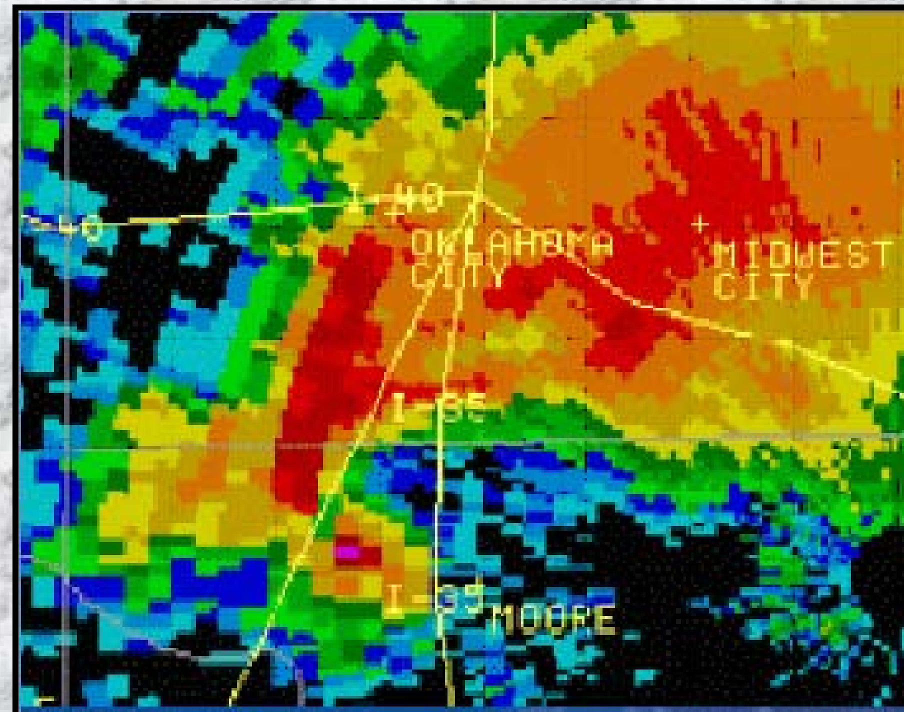
Projection of the status of the elements in the near future

Situational Awareness

Perception



Did you use our radar to view this relatively distant storm? Is this what your decision was based on?

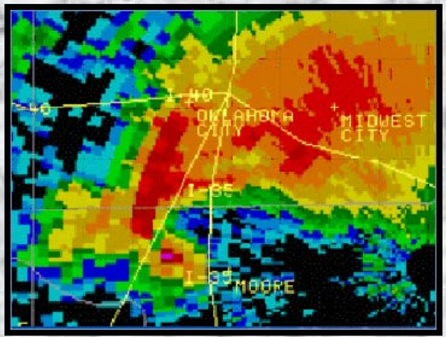


Or did you view the low-level os the same storm from a closer, neighboring radar? Did your perception change based on a different view?

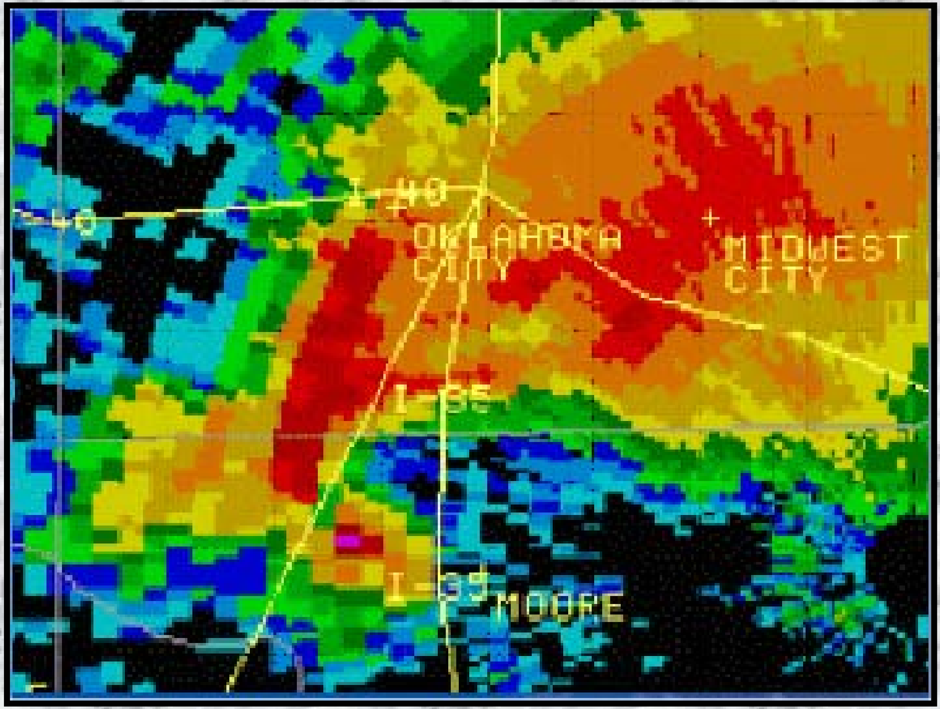
Situational Awareness

Comprehension

Perception



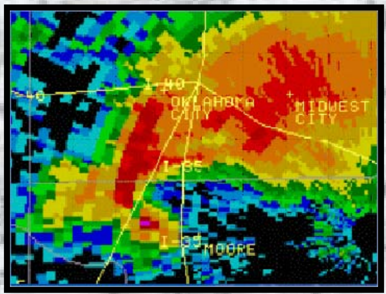
Did you see this?



Now that you've seen this, do you *understand* what is going on? Why is there a 65 dBZ core within the hook echo? Significant debris is concentrated here!

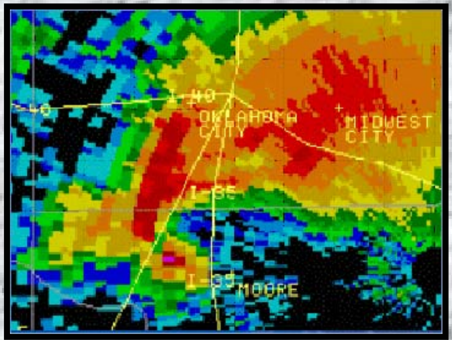
Situational Awareness

Perception



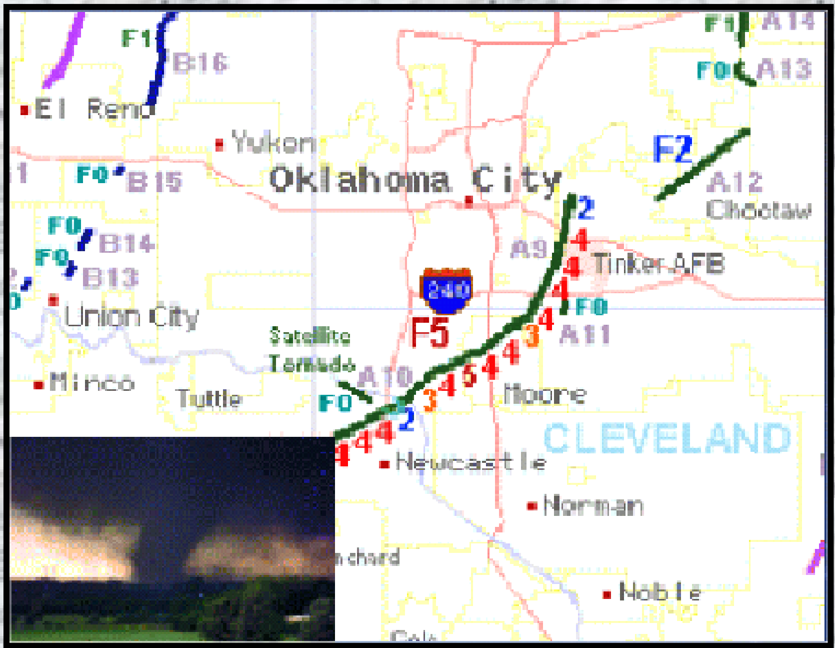
Did you see this?

Comprehension



Do you understand what this is and why there's a 65 dBZ core in the hook?

Do you realize what is happening and that a large tornado is on the ground? How should you project this information to the public, and what will the tornado do in the near future?



Project

Tornado Emergency for Oklahoma City metro area!

Situational Awareness and Workload

- Low SA, Low Workload
  - Don't know much, don't want to know
- Low SA, High Workload
  - Don't know much, but are trying very hard to find out
- High SA, High Workload
  - Do know plenty, but at a great effort (too much to do, can't keep this pace up for long)
- High SA, Low Workload
  - Do know plenty, and it comes easily

This is where we want to be…excellent situational awareness and a low workload where the science, equipment, humans, spotters and data sources (radar and environmental) are working well and as a team to ensure efficient, correct, and timely warning services!

We Want to Avoid This !