Meteorology – Lecture 18

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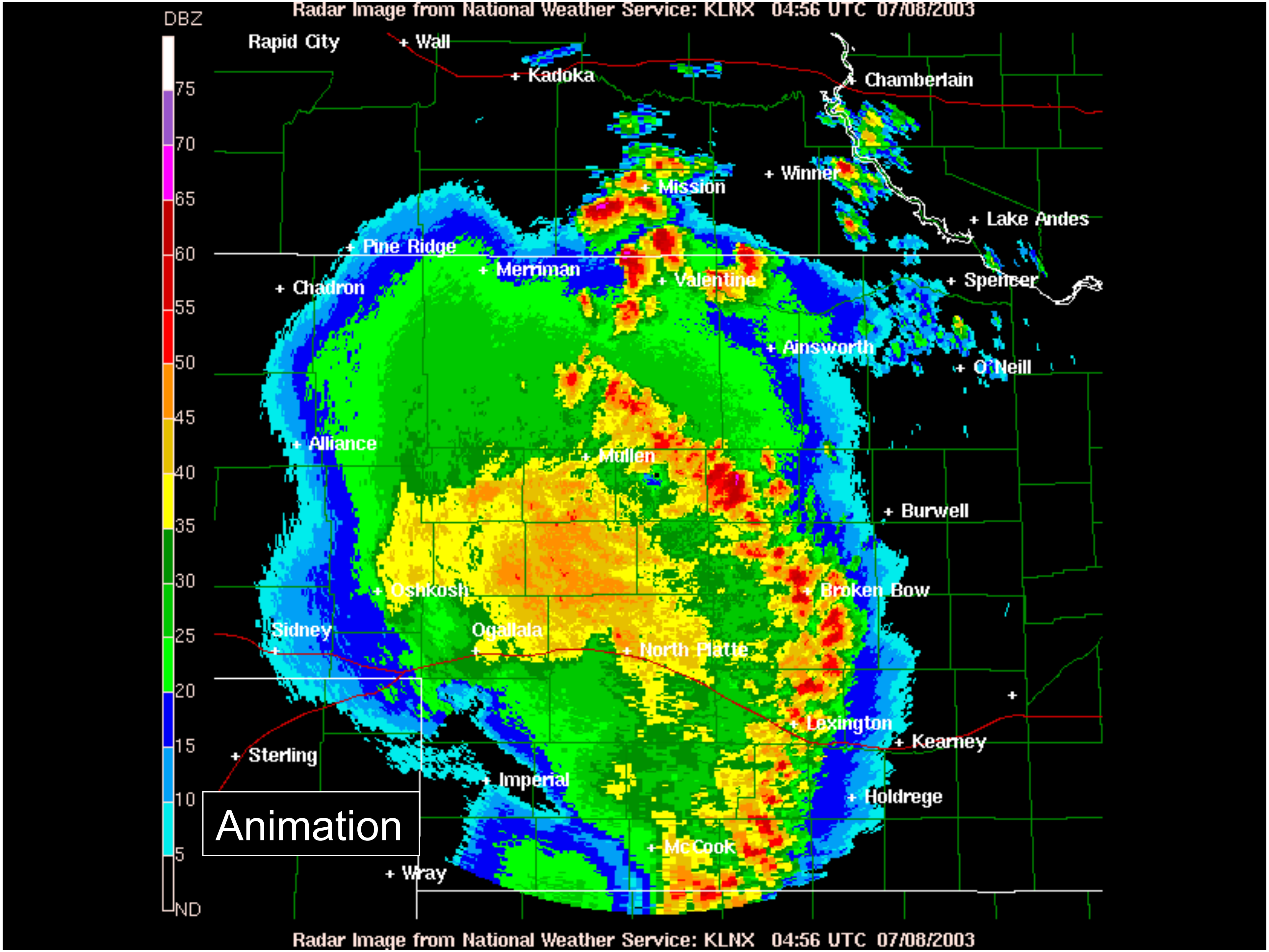
Important notes

- These slides show some figures and videos prepared by Robert G. Fovell (RGF) for his “Meteorology” course, published by The Great Courses (TGC). Unless otherwise identified, they were created by RGF.
- In some cases, the figures employed in the course video are different from what I present here, but these were the figures I provided to TGC at the time the course was taped.
- These figures are intended to supplement the videos, in order to facilitate understanding of the concepts discussed in the course. *These slide shows cannot, and are not intended to, replace the course itself and are not expected to be understandable in isolation.*
- Accordingly, these presentations do not represent a summary of each lecture, and neither do they contain each lecture’s full content.

Animations linked in the PowerPoint version of these slides may also be found here:

http://people.atmos.ucla.edu/fovell/meteo/

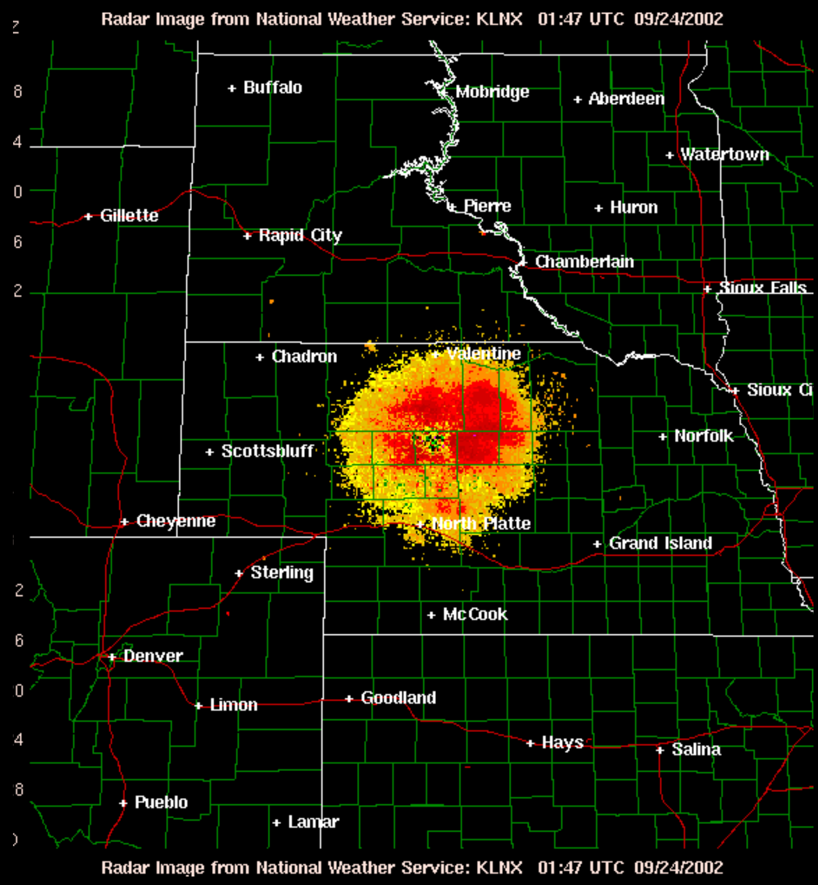
Weather radar

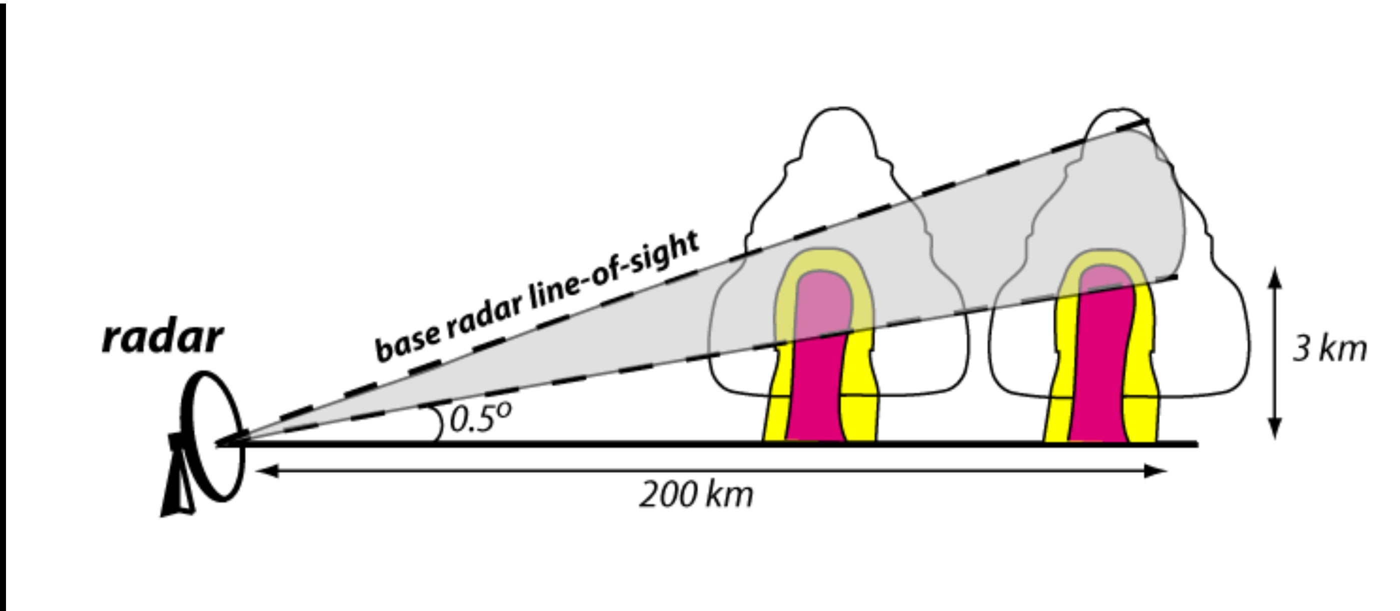


Radar Image from National Weather Service: KLNX 04:56 UTC 07/08/2003

Animation

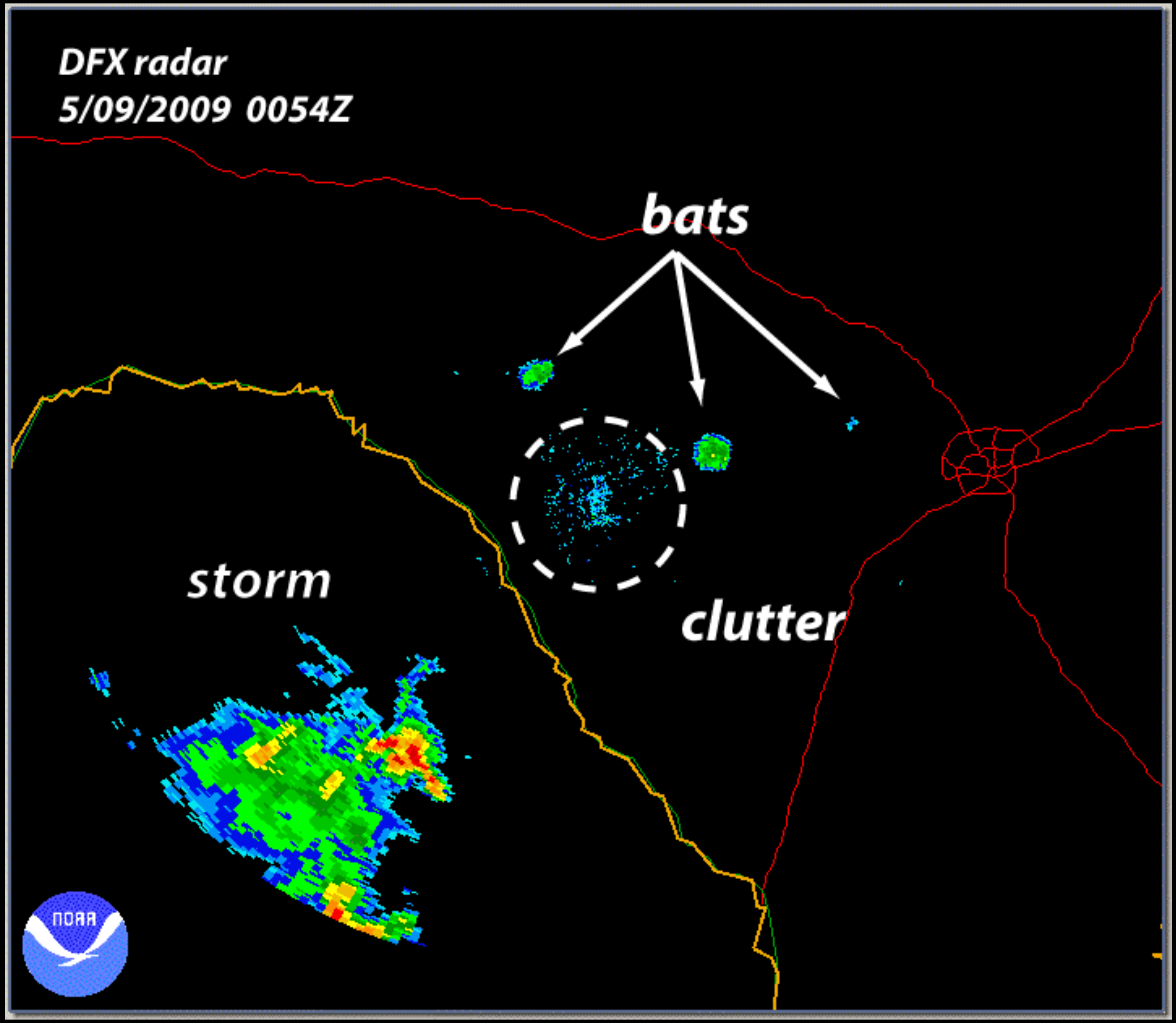
Ground clutter

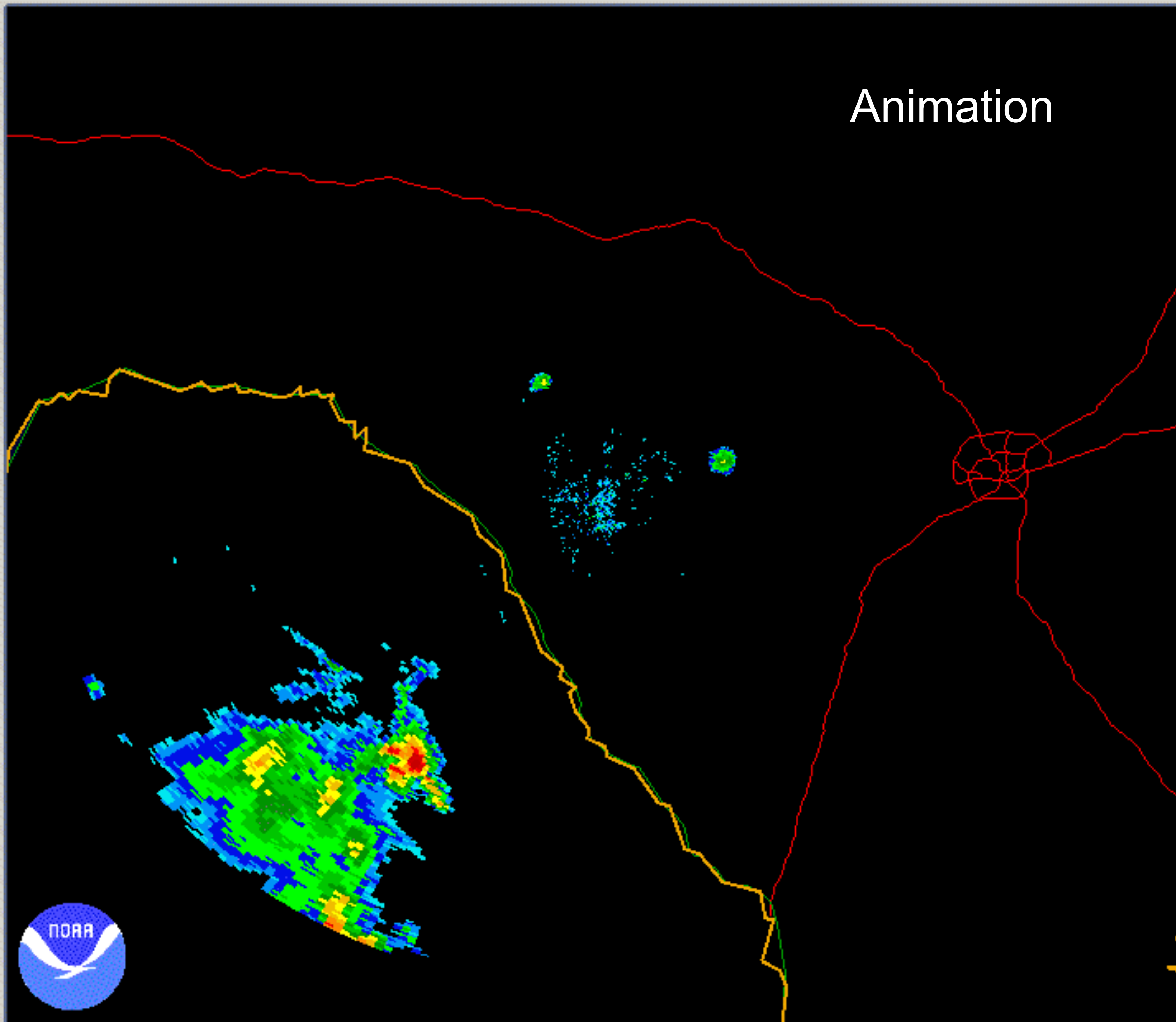




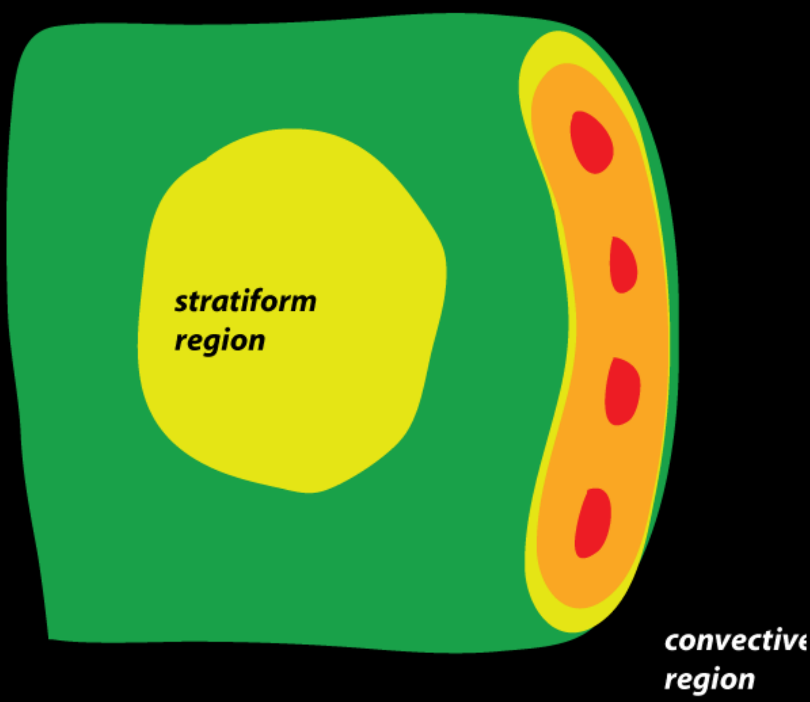
Weather radars are at the ground and look up as well as out, starting at a small angle to the horizontal.

Base elevation is 0.5° above ground level. The radar beam expands and the bottom rises with distance.

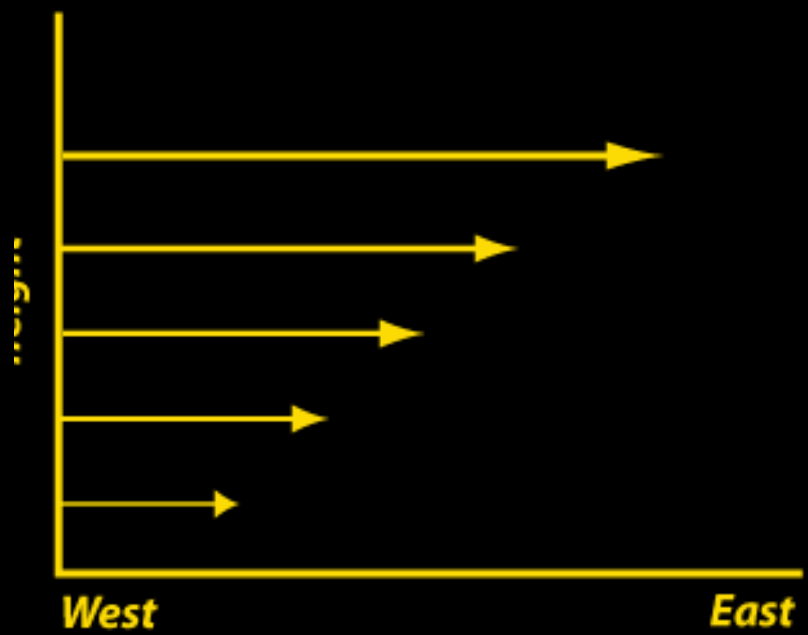

DFX radar
5/09/2009 0054Z
bats
storm
clutter
NOAA


Animation

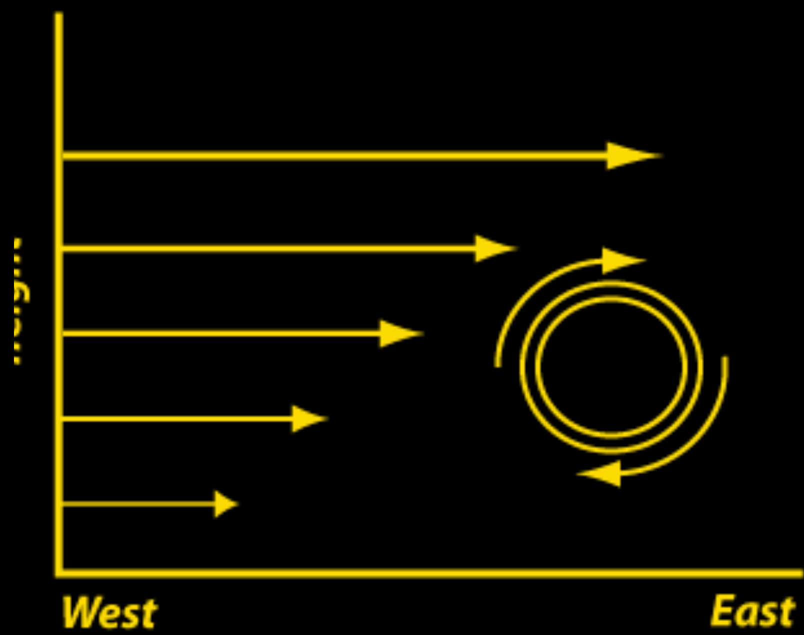
Squall lines



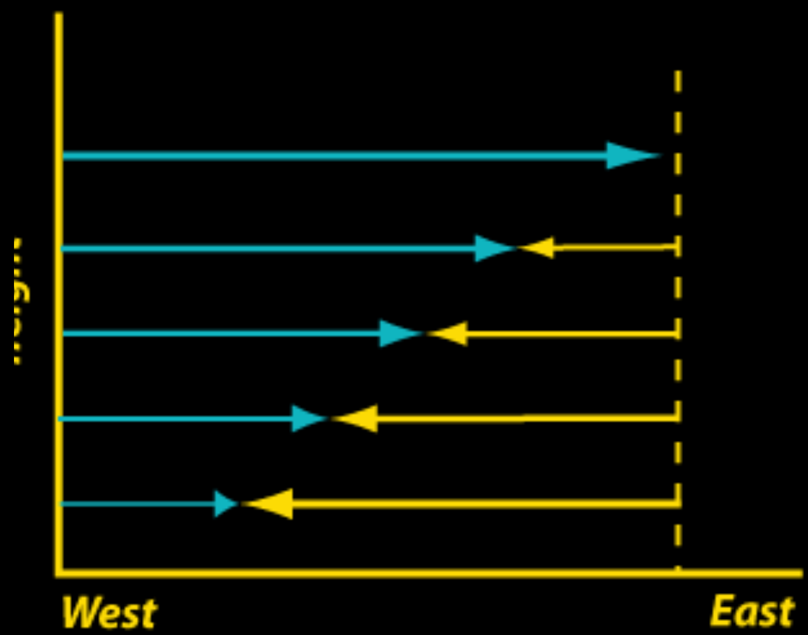
- This schematic depicts a squall line in maturity
- It’s moving to the right



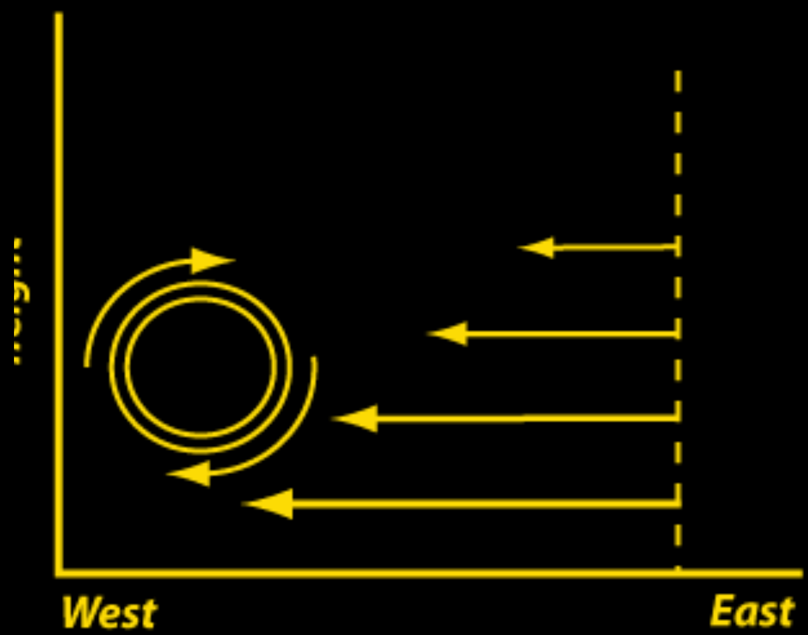
- We’re going to look at the vertical structure and airflow through a squall-line storm
- Before we do, I want you to think about TWO POINTS
- Here’s how the W-E winds may vary with height in a midlatitude location.
- Winds are westerly and increase in magnitude with height
- We have westerly vertical wind shear… because it’s colder to the N



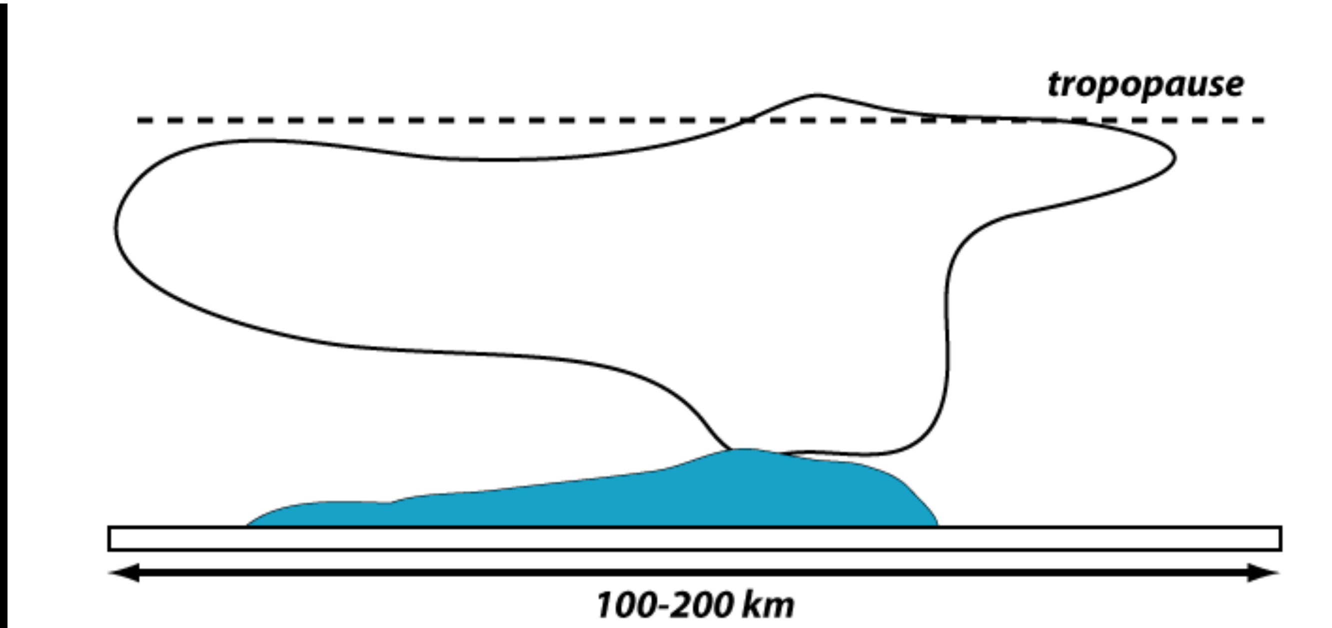
- Vertical wind shear establishes spin in a vertical plane. This is called horizontal vorticity, since the axis of rotation is horizontal.
- In midlatitudes, the winds are often westerly (from west to east) and the shear is also westerly



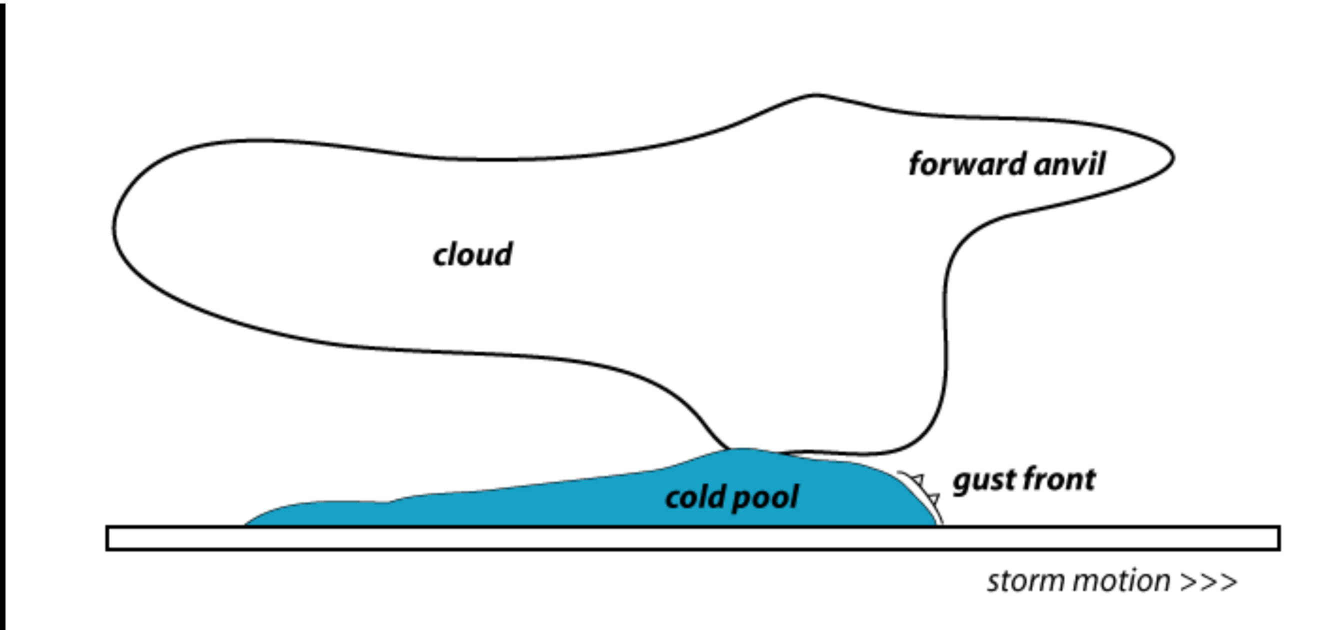
- We have changed the frame of reference to that of the squall line, which is propagating eastward faster than the westerly winds in which it is embedded.



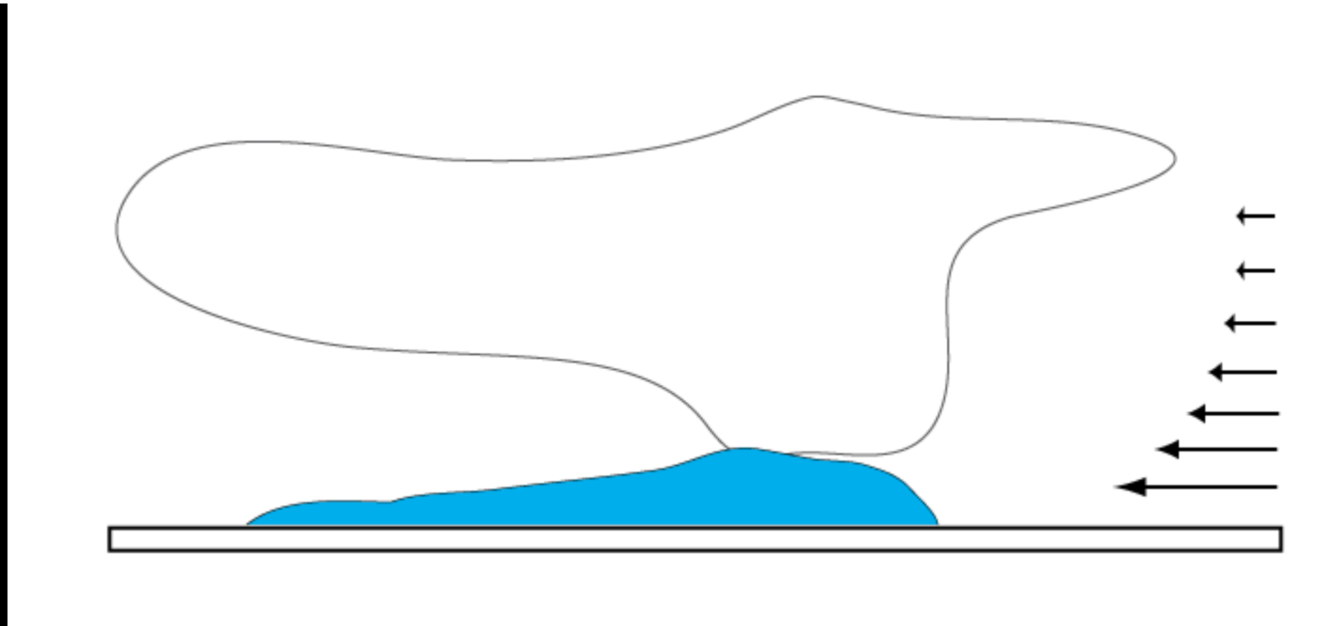
- But the point is we STILL have westerly vertical wind shear, and the shear STILL wants things to spin CW in this vertical plane



Vertical cross-section of squall line cloud.
Sort of shaped like an anvil.

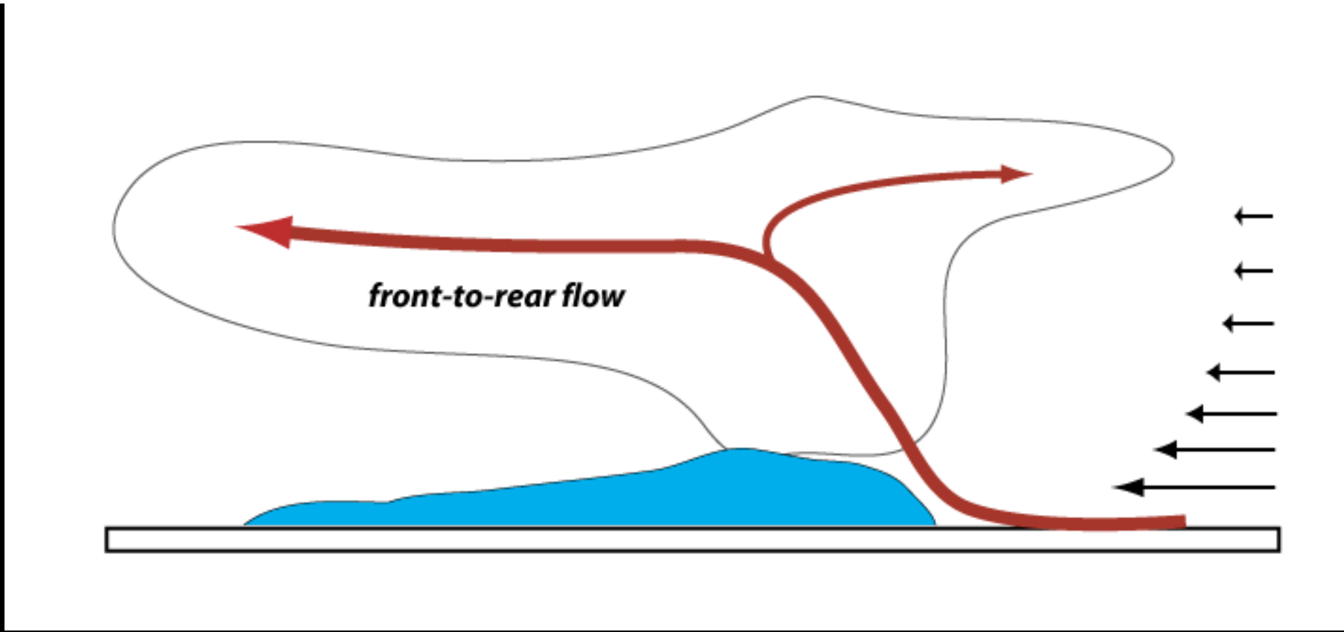


We see the FORWARD ANVIL at upper right.
Below the cloud shield is the SUBCLOUD COLD POOL.
It's very much like a cold front, but usually much stronger.
The leading edge of the cold pool is called
the "gust front". The wind gusts pick up after it passes you.

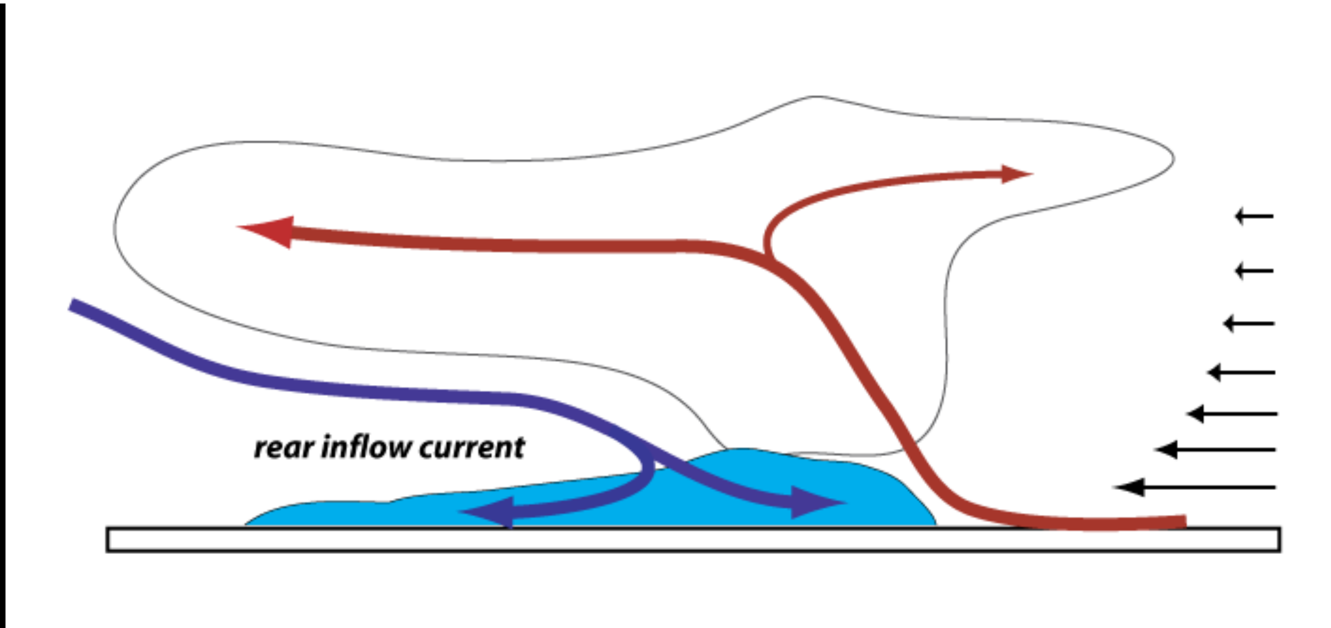


Often, but not always, these storms are oriented N-S and propagate eastward in the midlatitude westerlies.

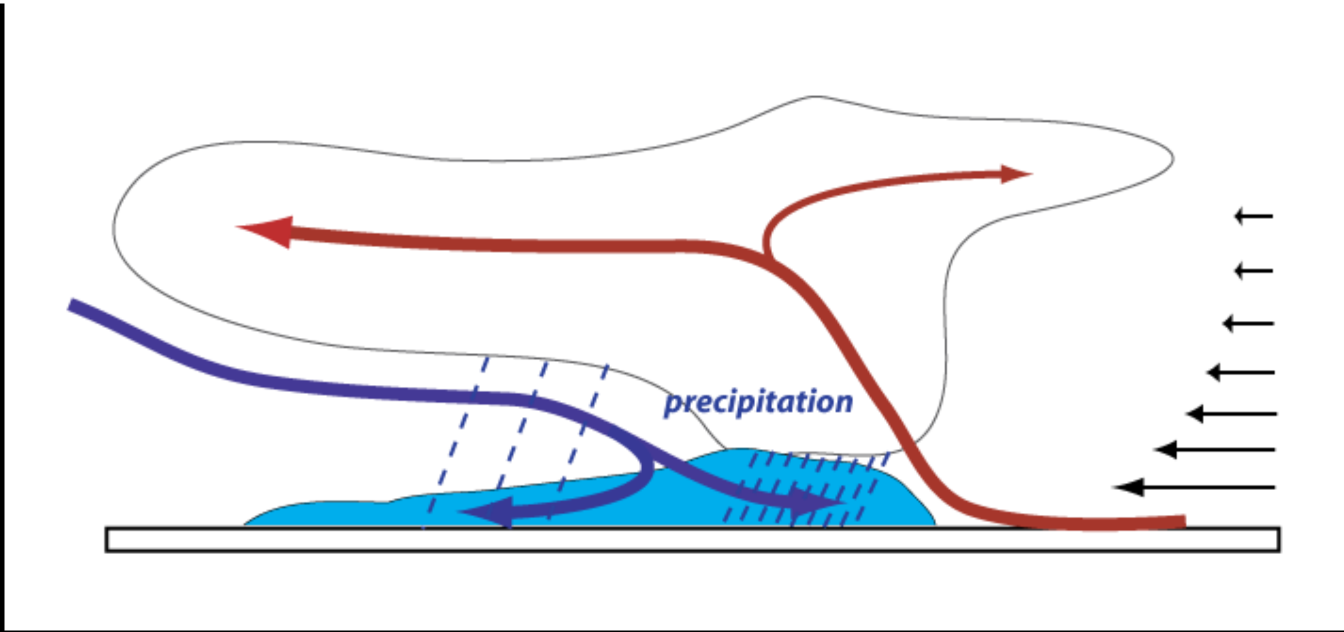
But the storms also tend to move FASTER than the westerlies so the storm-relative flow is TOWARDS the line, and largest at low levels where the moisture is!
Note also we have westerly vertical shear. We'll see the role this shear plays later on.



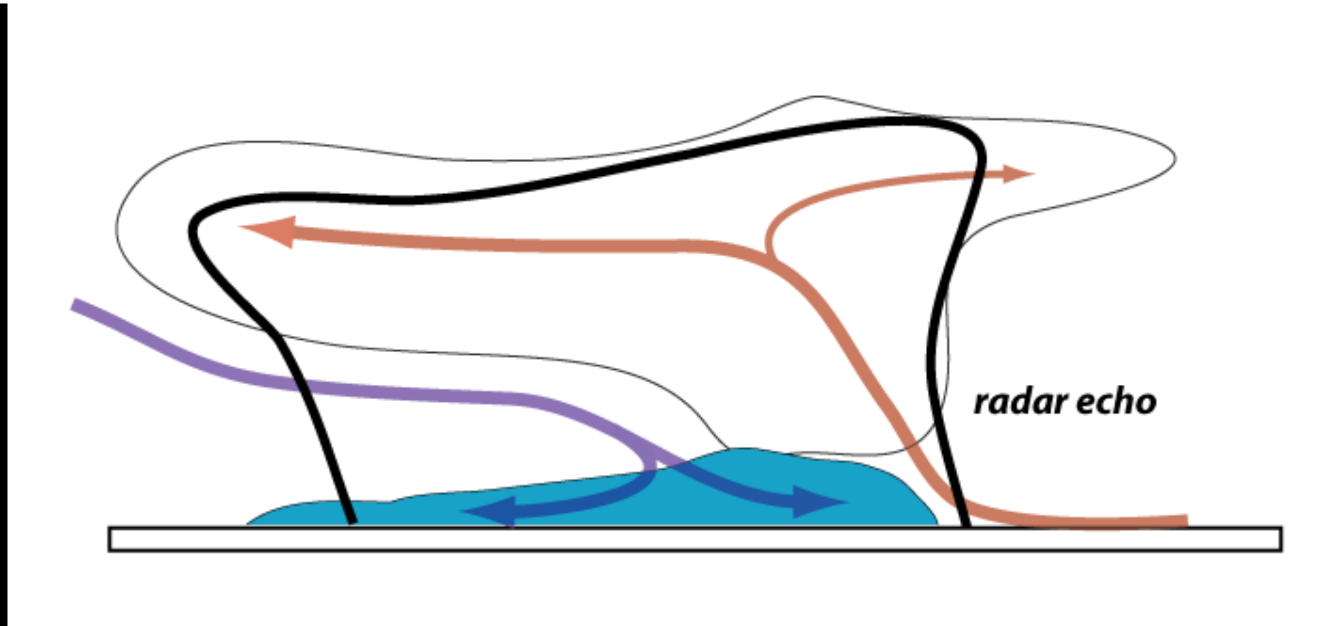
This low-level inflow collides with the cold pool’s gust front, and rises to saturation and positive buoyancy , thereby forming the storm’s **front-to-rear flow**.
Some of the flow overturns to form the forward anvil.



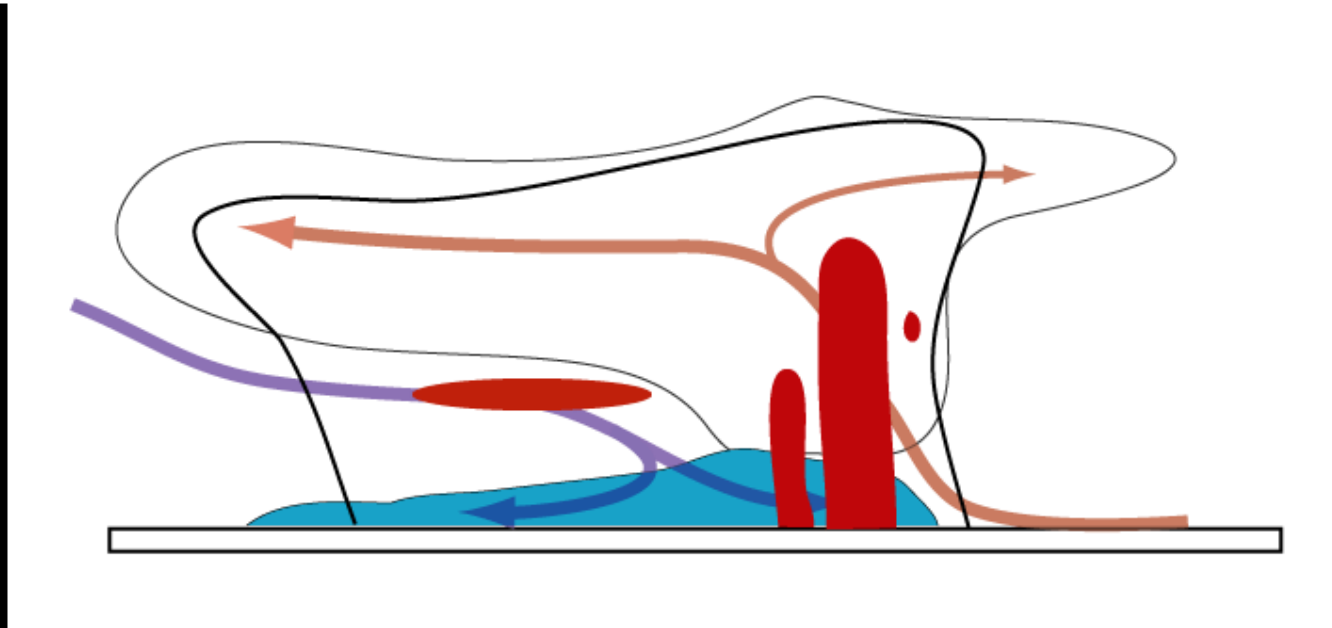
Beneath is the **rear inflow current** extending forward from the storm's rear. These are NOT westerly winds catching the storm from behind. Rather, they're induced by the storm's own circulation.



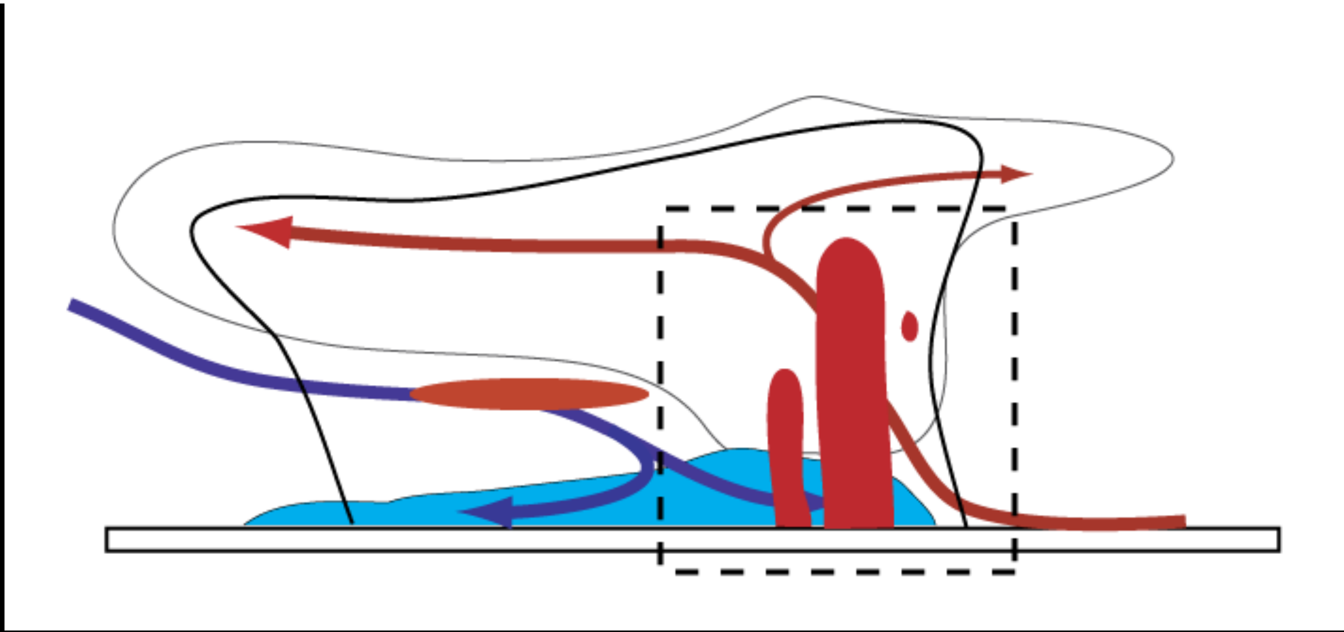
Note the rear inflow descends to the surface as it moves forward. This is because of precipitation. Specifically, precipitation that EVAPORATES and makes the rear inflow air COLD and NEGATIVELY BUOYANT. Sometimes the descending rear inflow can bring extremely strong winds to the surface and cause a lot of damage.



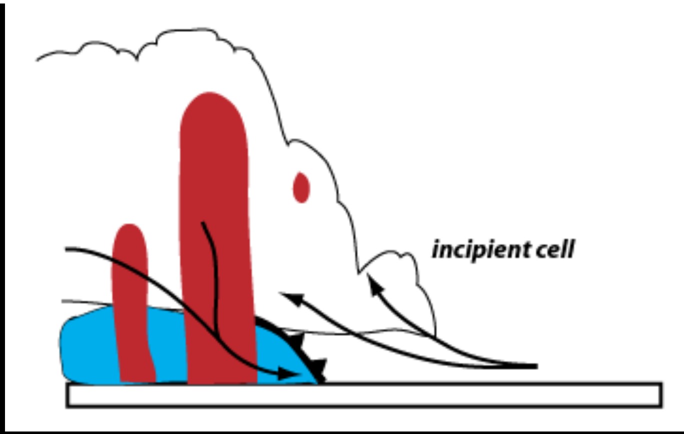
This is the part of the storm visible to 10 cm weather radar -- depending on how far from the radar it is, of course.



Principal echo features seen on radar: In the convective region at right -- young, mature and decaying cells.
In the stratiform region at left -- a narrow “bright band” made by melting snow drifting downward.
The freezing level is just above the bright band.

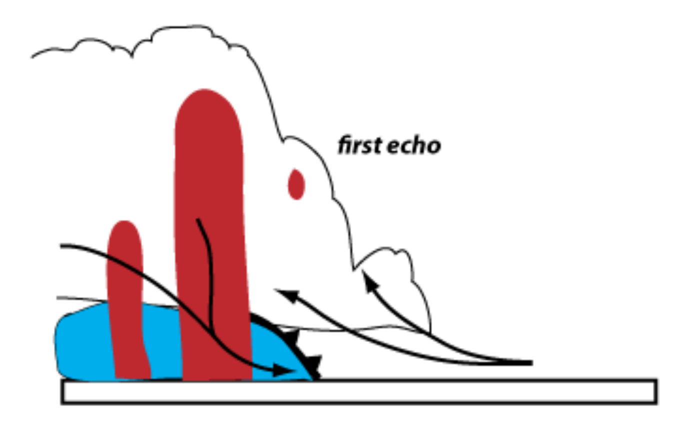


Our squall line represents a collection of thunderstorm cells, at various stages of their life cycle.

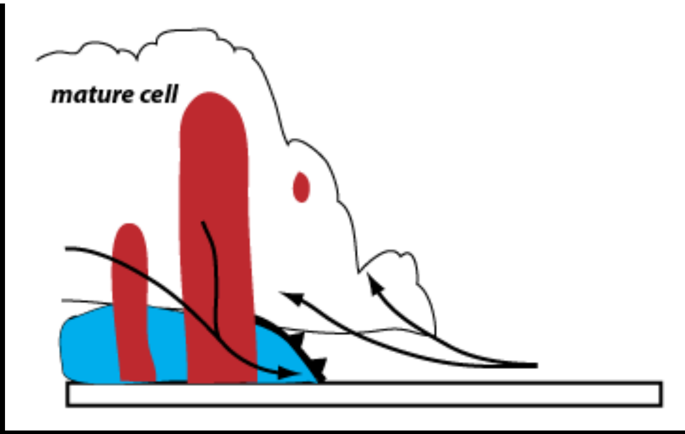


This schematic can represent a family of cells spanning four generations, but also be interpreted as the life stages of a SINGLE CELL as it evolves and moves through the storm from right to left.

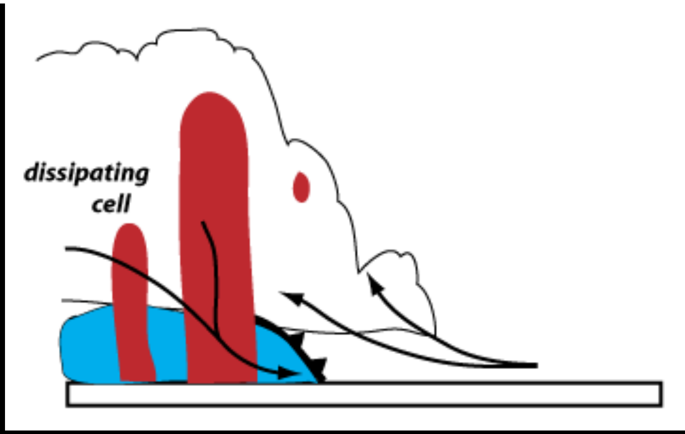
We start above the gust front with an incipient cell, just cloud droplets at this time, *invisible* to radar. It's the **cumulus stage** of the cell.



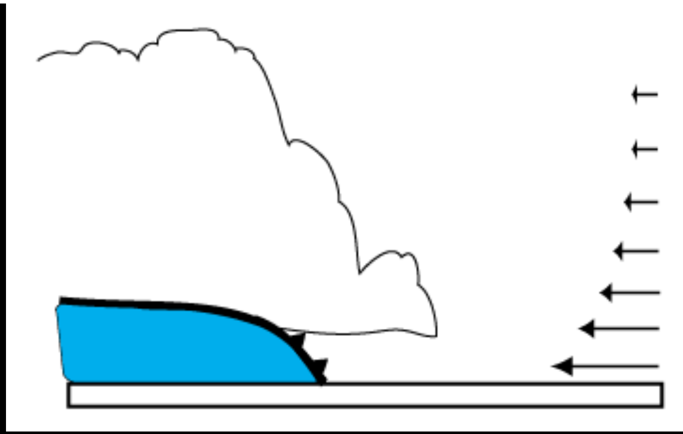
Next to the left is a growing cell, much deeper now. Precipitation-sized particles have appeared, and we have what we call "first echo".



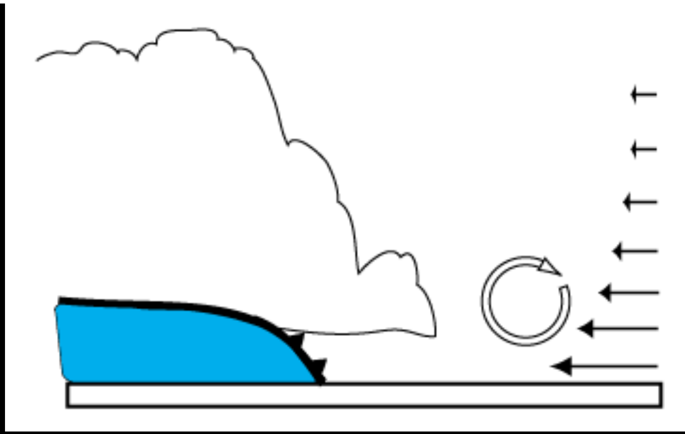
Next: **a mature cell**, yielding heavy precipitation, but its end is in sight.



And finally a **dissipating** or decayed **cell**, the detritus of the convective region, passing rearward to become incorporated into the light stratiform rain area to the rear.

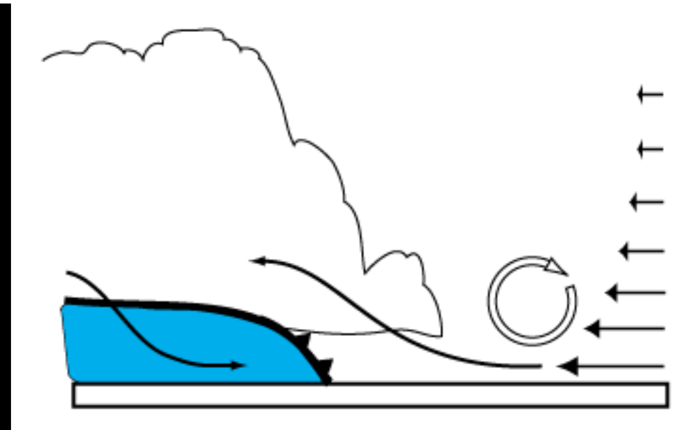


Now focus on the storm inflow. I noted the wind was vertically sheared and this resulted in horizontal vorticity… spin in a vertical plane.



By itself, the shear's circulation is trying to make the cloud lean to the right with height, in the direction we call DOWNSHEAR, in the direction the wind is sheared.

In this case, downshear is to the *right*, or east because the shear is westerly … west to east.



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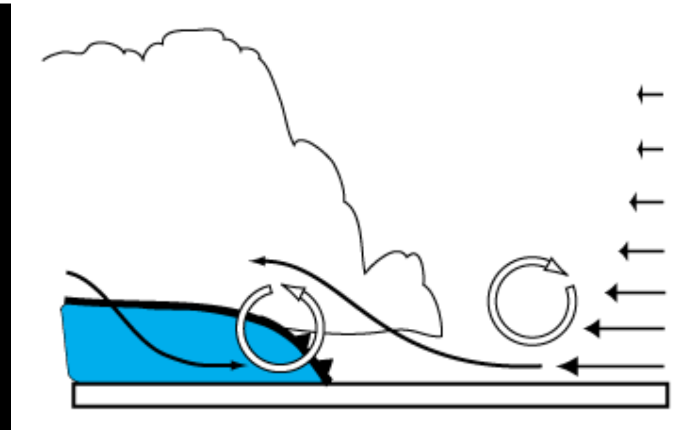
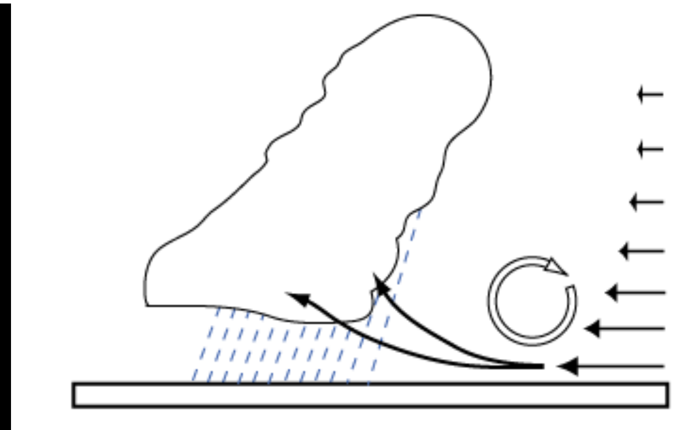
But the storm isn’t leaning downshear. Why not? Note the circulation around the cold pool. This negative buoyancy also produces a circulation, and it’s directed CCW from our point of view, OPPOSITE to the shear’s induced circulation.



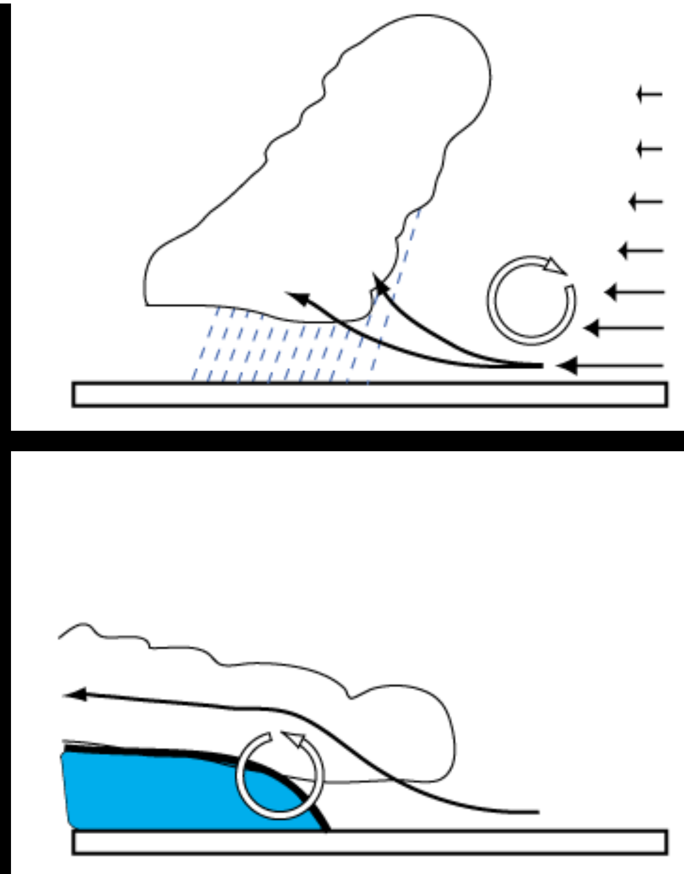
So, we have two competing circulations, and the fate of air rising over the gust front and into the storm depends on their relative strengths.

In this case, the cold pool circulation is stronger, so the flow tilts UPSHEAR instead of downshear.

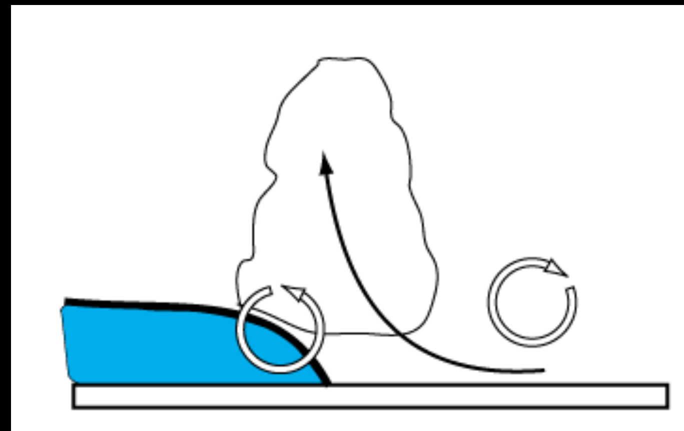


This illustrates why squall-line storms need SOME vertical shear, but NOT TOO MUCH.

Shear alone would make the storm tilt downshear, into the wind. Note this would make it precipitate into its OWN inflow. Evaporation cooling would decrease the CAPE of its inflow. This storm might not last very long.

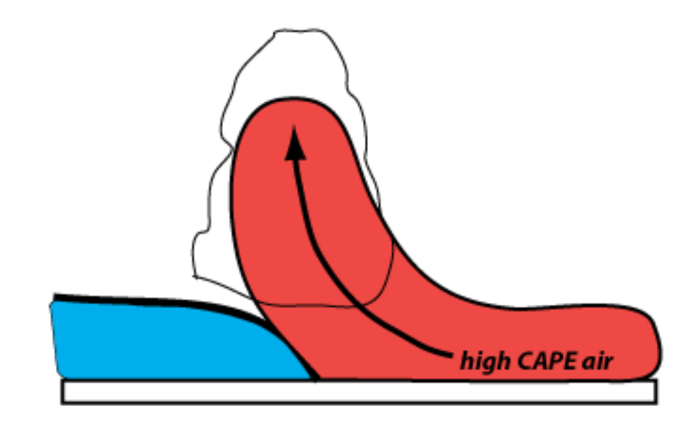


With only the cold pool, and no shear, the inflowing air might be lifted to saturation, but it will also be accelerated quickly rearward by the pool circulation, severely LIMITING its lift.



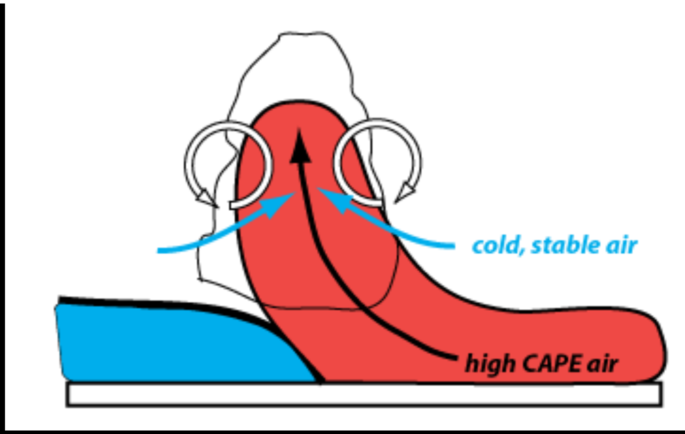
Just enough of EACH circulation can result in the most effective lifting and the strongest storm.

Storms need to tilt a little upshear so they unload their precipitation BEHIND the updraft.



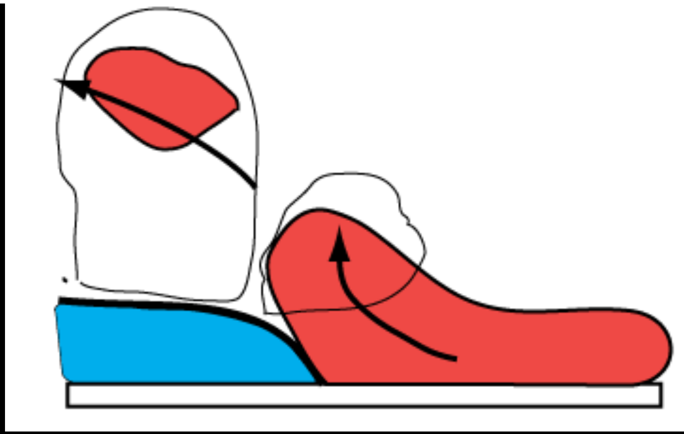
Now we consider why these storms are multicellular, and unsteady.

Picture high CAPE air from the inflow rising over the surface gust front, associated with a new convective cell.



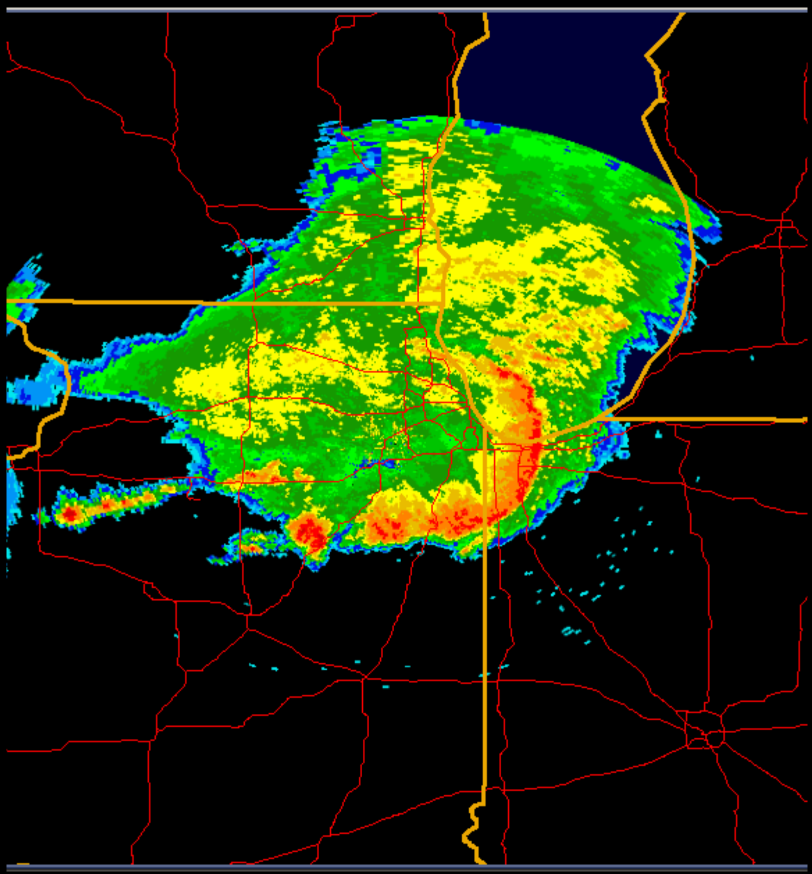
Positive buoyancy in our young, growing cell generates a circulation -- Up in the cloud, down on its flanks.

The circulation forces drier, less favorable favorable air into the updraft, choking it.



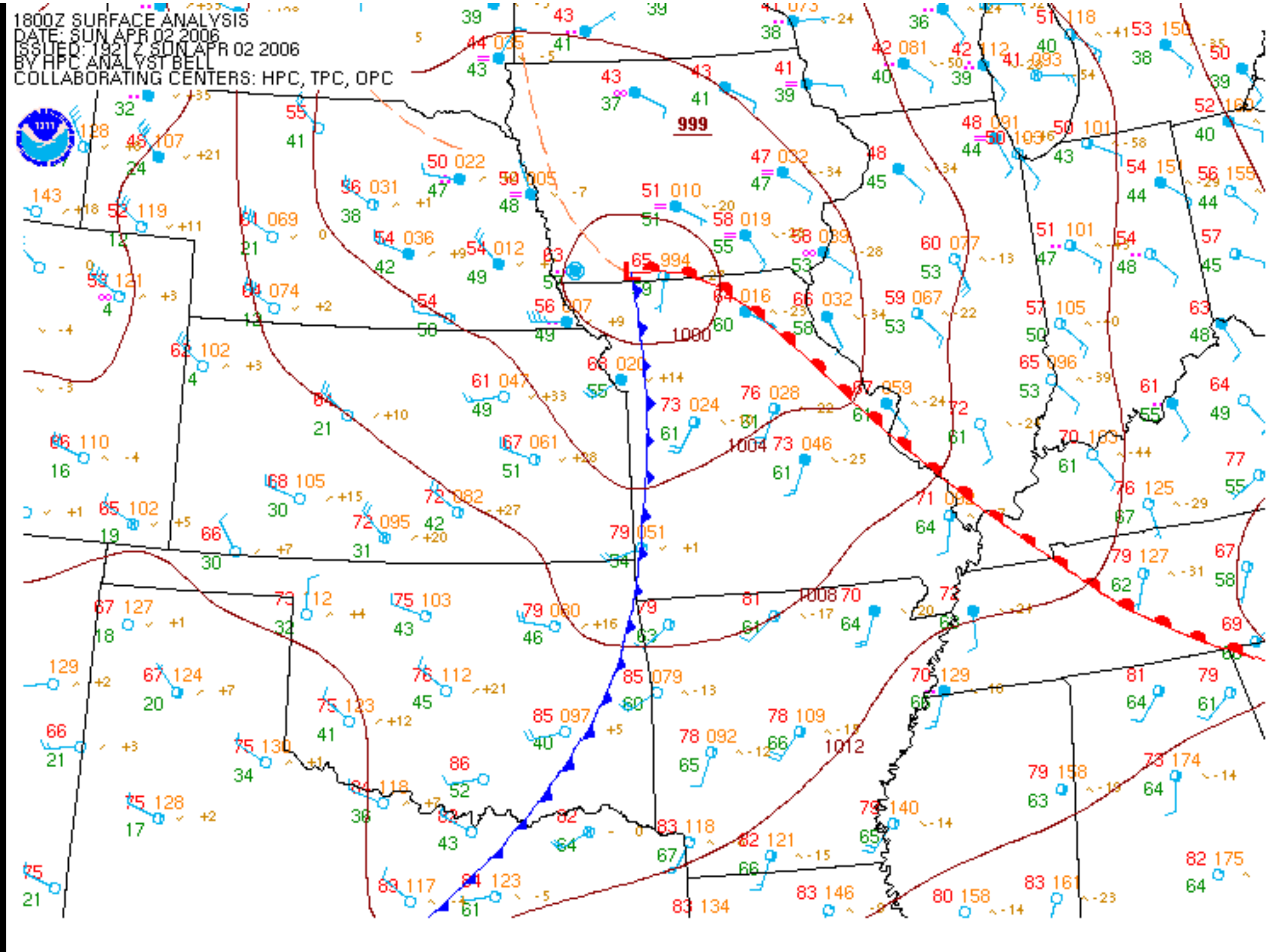
The choked-off piece gets carried rearward, to live out its life cycle. It is growing and intensifying, but its end is already in sight.

Bow echoes and derechos

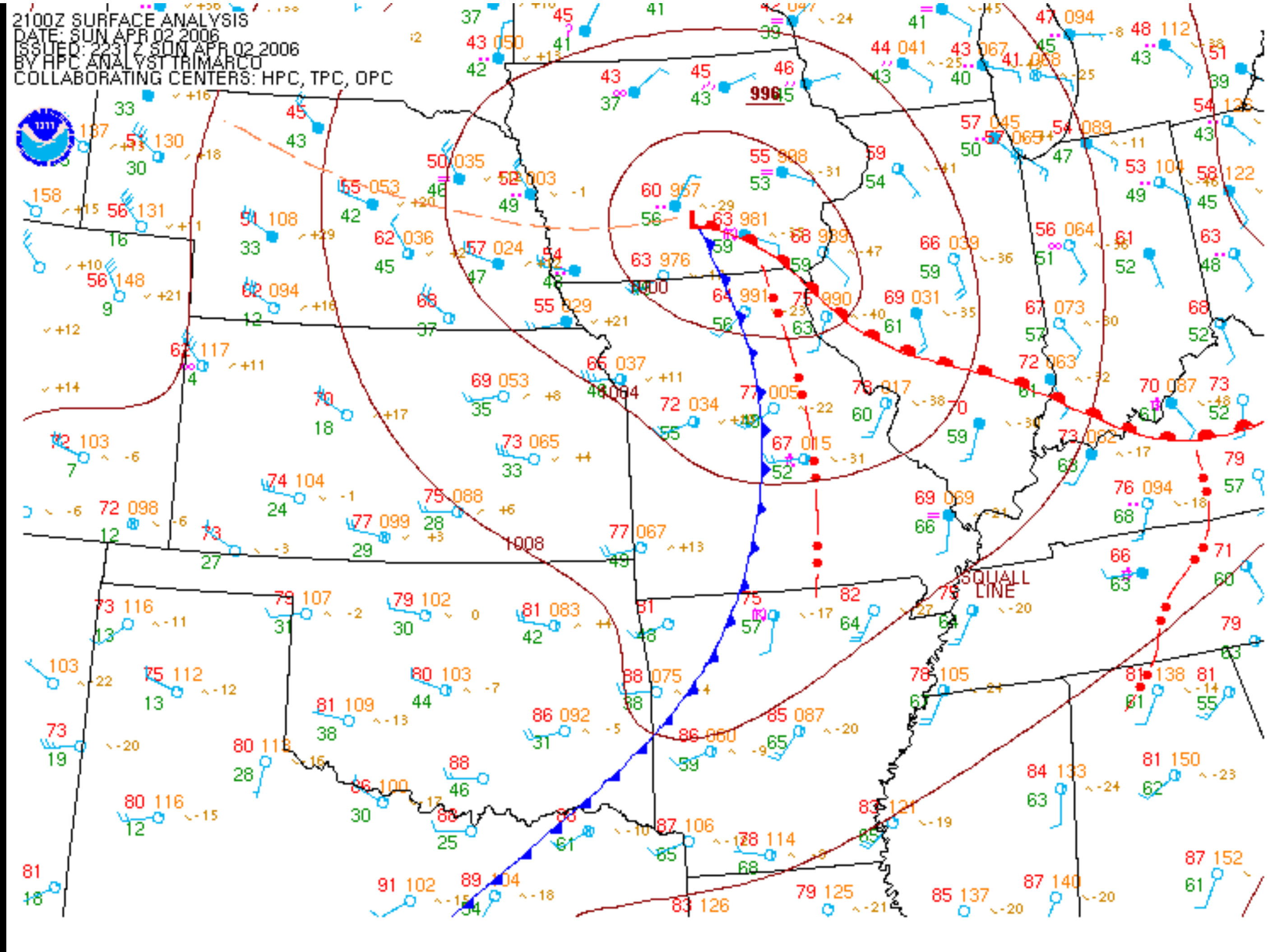


- Sometimes you'll see squall lines take on a strongly curved appearance
- These are called **bow echoes**
- Behind these echoes, the rear inflow current has descended to the ground, potentially bringing very high winds, also called **derechos** (Spanish for "straight")

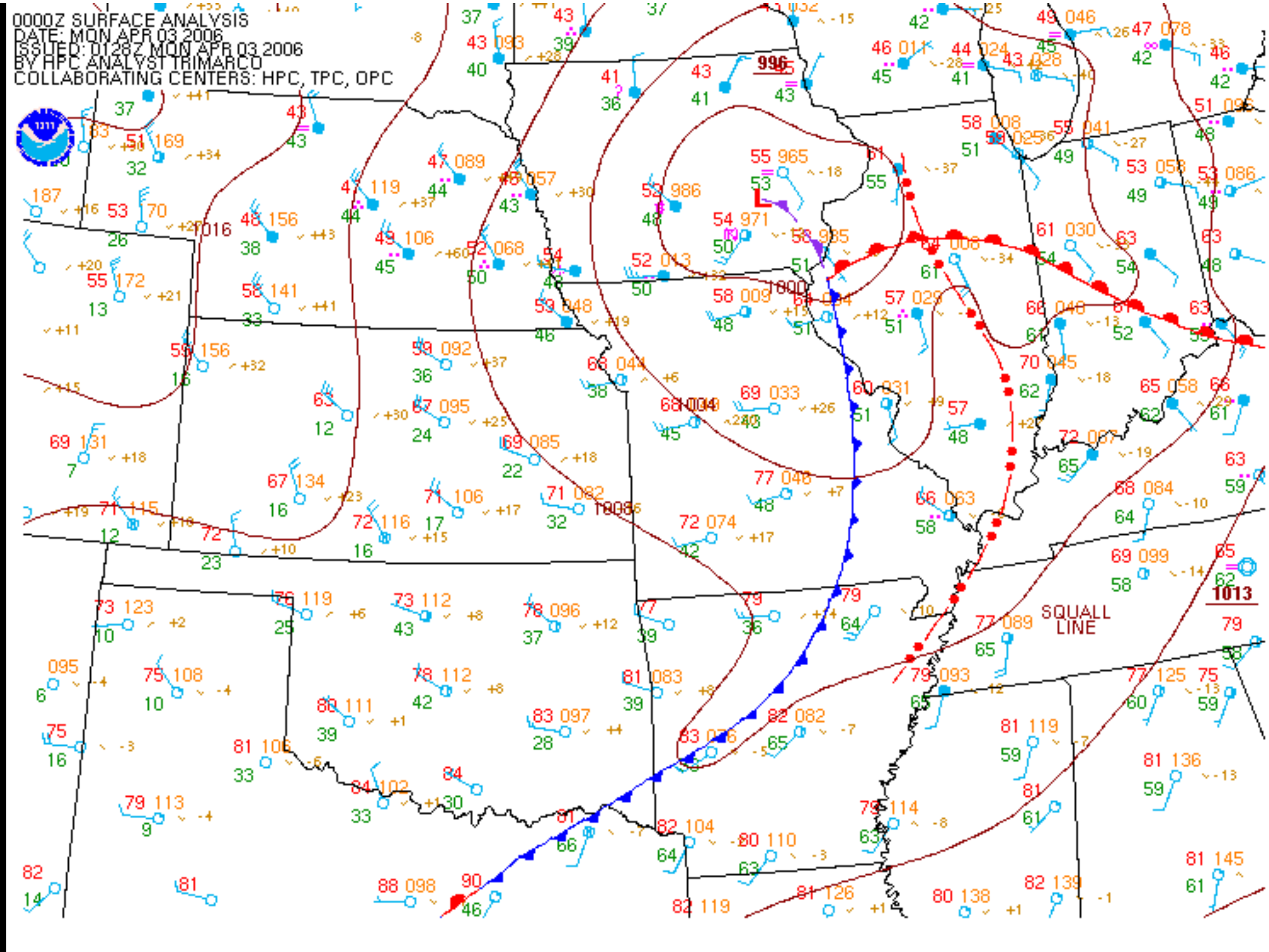
2-3 April 2006 case study



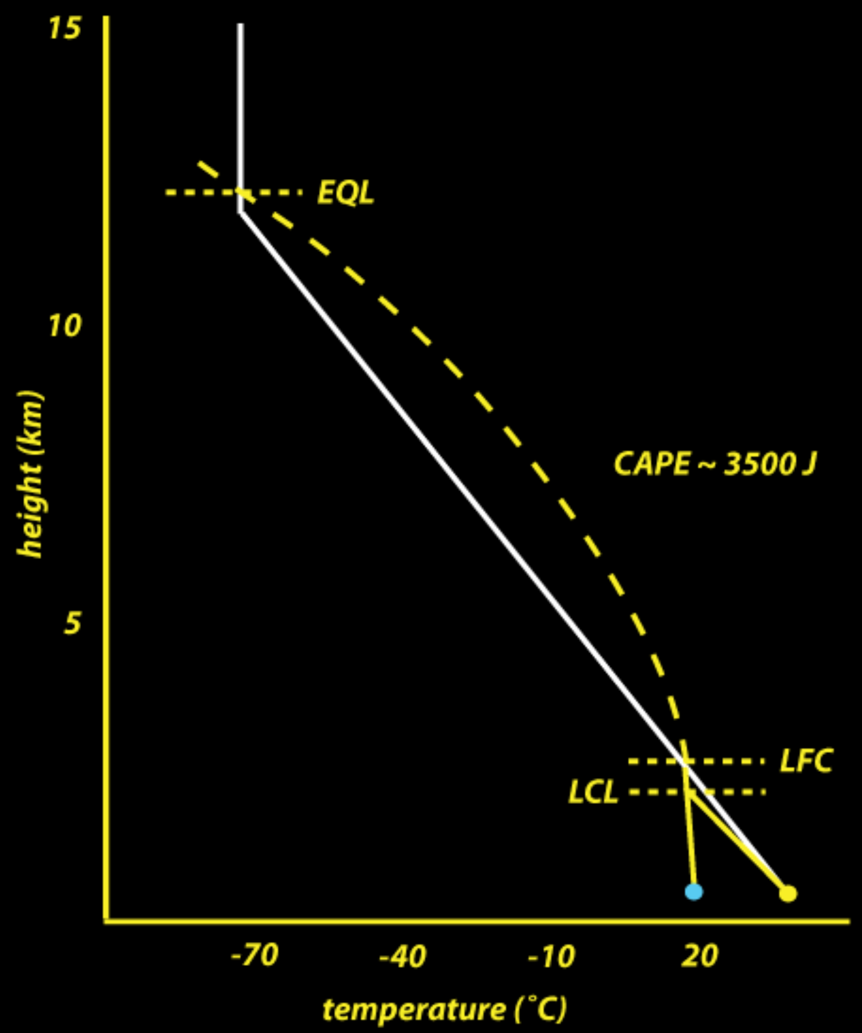
18Z April 2, 2006. 1 PM CDT. A close-to-textbook extratropical cyclone in S Iowa. NW'ly winds behind cold front, SW'ly winds in warm sector.



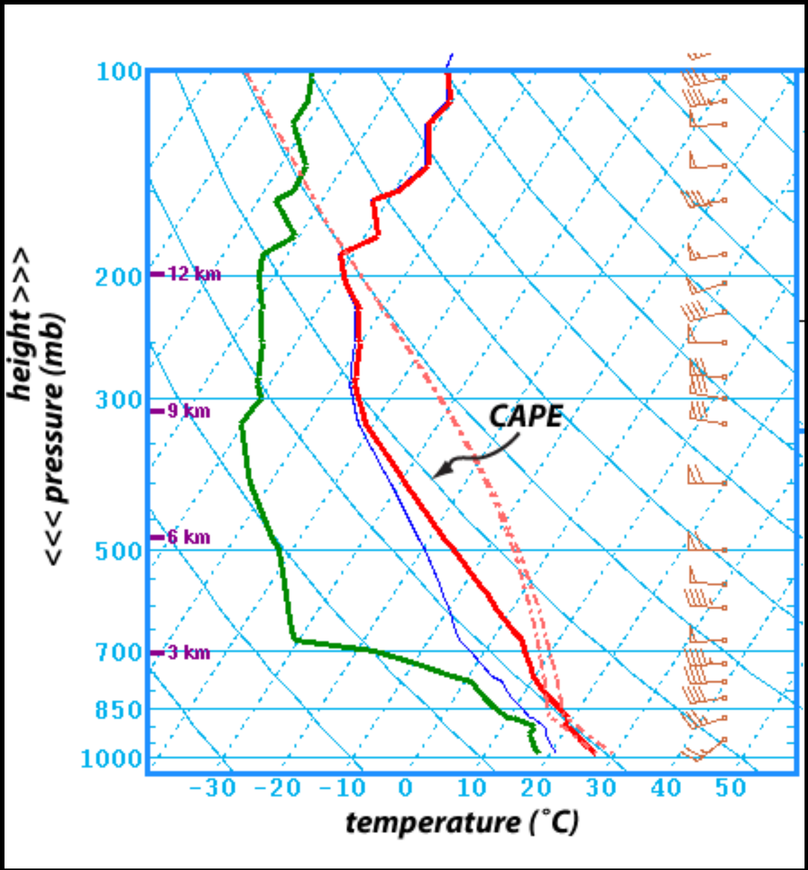
By 21Z, a squall line has appeared in the warm sector ahead of & parallel to the cold front.   It's location is marked by the orange dot-dashed line.



3 h later, we see the cyclone has started to occlude and the squall line has moved farther ahead of the cold front. Squall lines generally move as their cold pools spread.

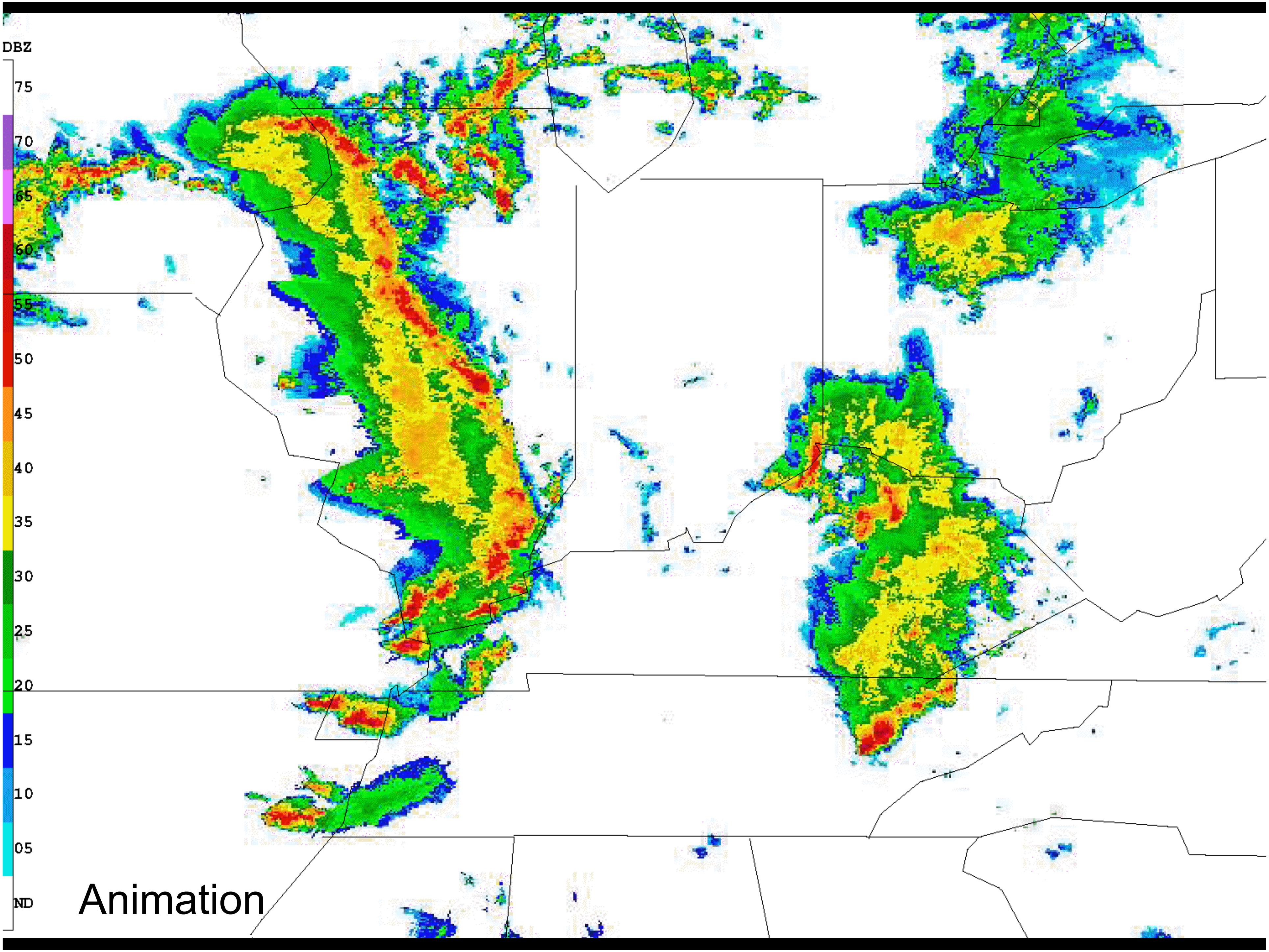


• Representative sounding from warm sector, prior to squall line passage. It has a lot of convective instability = CAPE.

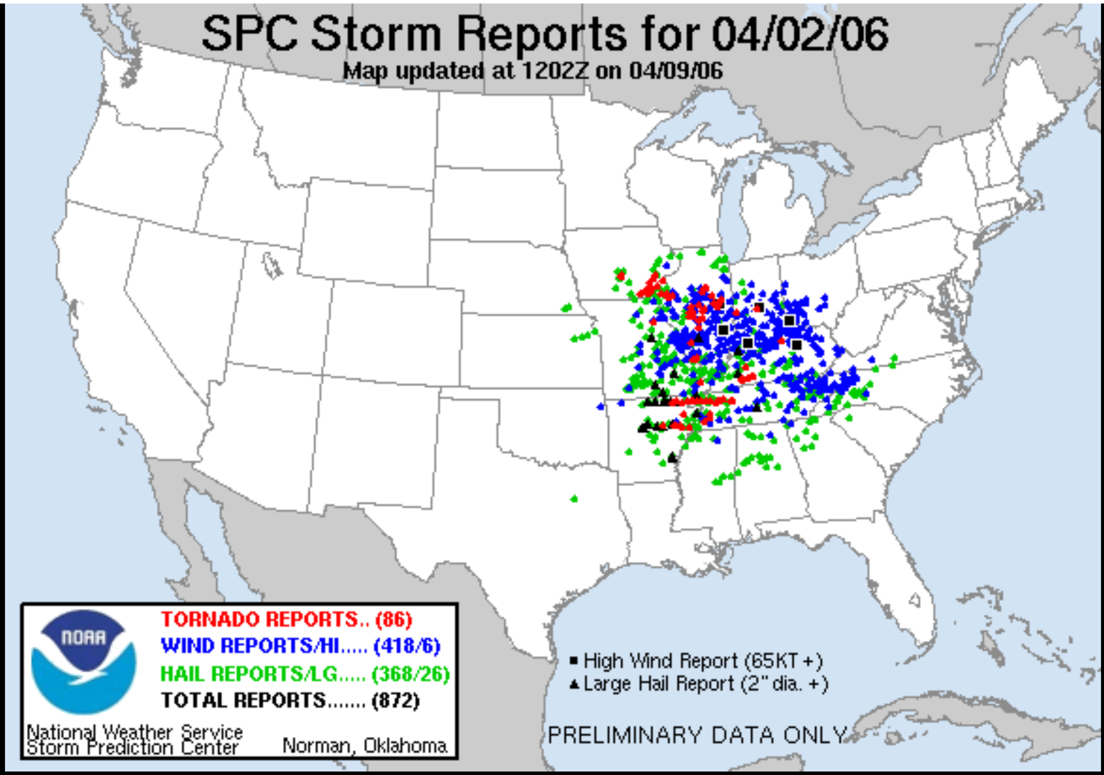


- On the web, you're more likely to encounter soundings presented in this way
- "Skew-T" diagram
- Lines of constant T go from lower left to upper right, instead of straight up as in the figures I have been showing

NOAA/NWS/Storm Prediction Center
http://w1.spc.woc.noaa.gov/exper/archive/events/060402/index.html



Animation



The NWS Storm Prediction Center collects and archives severe weather reports… tornadoes, hail, high winds. Here are the reports for this storm.

[end]