1. Storm Interrogation

Instructor Notes: Welcome to the AWOC – Severe Track IC3-I-A Location of weakly sheared updrafts This presentation is 33 slides long and should take 20 minutes to complete

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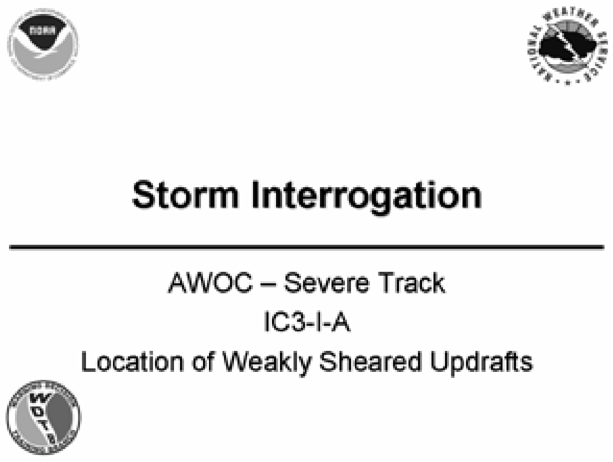

Storm Interrogation

AWOC – Severe Track
IC3-I-A
Location of Weakly Sheared Updrafts

2. Weakly sheared updraft location

Instructor Notes: This module shows several examples of where the updraft is most likely to be located depending on where in the storm is in its lifecycle. Not only clues in reflectivity and velocity can help us discriminate between updraft and downdraft within the mid- to upper-level of a convective cell but also at the source level of initiation, a level which is often overlooked during the cell's initial stages.

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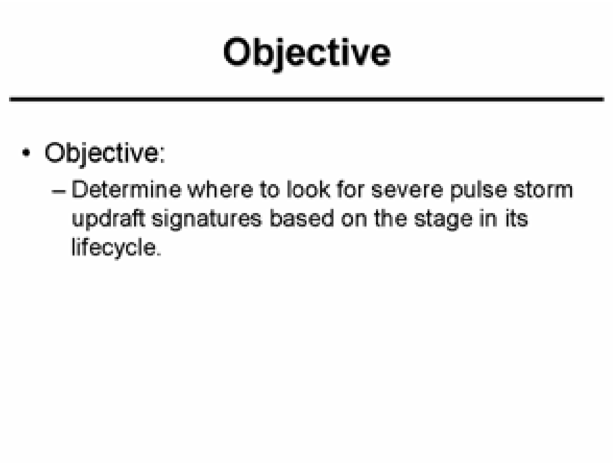

Objective

- Objective:
  - – Determine where to look for severe pulse storm updraft signatures based on the stage in its lifecycle.

3. Weakly sheared updraft location

Instructor Notes: A typical low shear thunderstorm updraft is more accurately pictured as a pulse of updraft air than a steady current of ascent. For example, a reflectivity core in an initiating thunderstorm indicate the presence of updraft. However, as the storm matures, the same reflectivity signature is more likely to be downdraft. Likewise, kinematic patterns that you'd look for where an updraft exists are transitory. Let's take a look at a couple scenarios.

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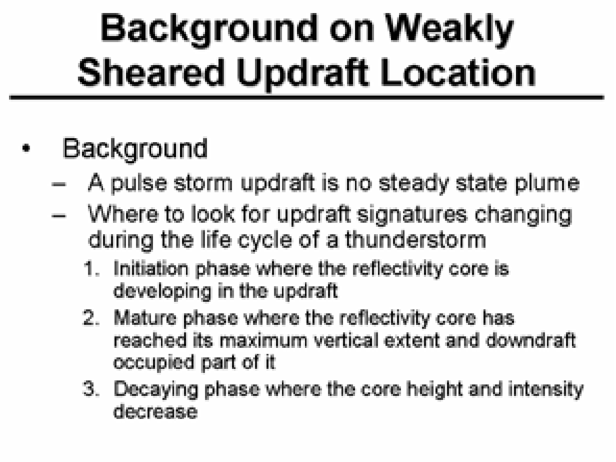


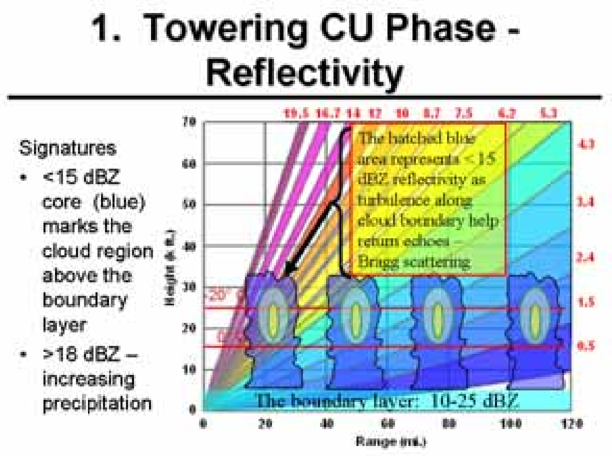
Background on Weakly Sheared Updraft Location

- Background
  - A pulse storm updraft is no steady state plume
  - Where to look for updraft signatures changing during the life cycle of a thunderstorm
    1. Initiation phase where the reflectivity core is developing in the updraft
    2. Mature phase where the reflectivity core has reached its maximum vertical extent and downdraft occupied part of it
    3. Decaying phase where the core height and intensity decrease

4. 1. Towering CU phase - reflectivity

Instructor Notes: In the initiation stages before significant core develops, the towering cumulus itself returns echoes through a process called Bragg scattering. This mechanism comes about as temperature and moisture gradients embedded along the turbulent edges of a growing cumulus cloud act as a source for scattering incident microwave energy. It's not a very strong scatterer, but enough energy gets returned back to the radar to result in 15-20 dBZ echoes above the boundary layer. The cloud edges are the regions of strongest Bragg scattering and you would think there would be weak echo regions in the interior of towering cumulus clouds. However, there is very little of a typical towering cumulus cloud that could be said to have an updraft without any influence from dry air entrainment from the environment, and therefore, be completely homogeneous in temperature and moisture. Not much time passes before hydrometeors begin to fill the interior of a towering cumulus cloud, especially as it passes above the –10 to –20° C level. As the reflectivity of a towering cumulus exceeds 18dBZ, current conventional thinking is that the radar is detecting first hydrometeor formation. The background chart shows VCP 11 elevation cuts and what slice you would expect to see reflectivities from towering cumulus from Bragg scattering and hydrometeor formation given your range from radar. This is for a typical environment given the height of the 0° and -20° C level labeled here. For colder atmospheres, you would need to supress the elevations of the developing hydrometeor cores so that they're relative to the lower freezing levels. In marine climates, or very humid environments, reflectivity cores would be more due to warm rain processes and thus the core altitudes would also be depressed.

Student Notes:



1. Towering CU Phase - Reflectivity

Signatures
- <15 dBZ core (blue) marks the cloud region above the boundary layer
- >18 dBZ – increasing precipitation

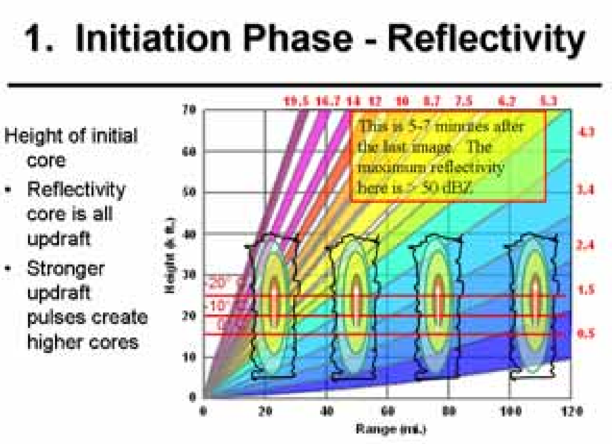
The hatched blue area represents < 15 dBZ reflectivity as turbulence along cloud boundary help return echoes – Bragg scattering

The boundary layer: 10-25 dBZ

5. 1. Initiation phase - reflectivity

Instructor Notes: It only takes about 5-7 minutes from the previous image to produce significant reflectivities in the subfreezing air. At this point, the core is likely greater than 50 dBZ and completely elevated above the freezing layer. Stronger initiating cells produce cores that extend to higher altitudes. The VCP 11 background chart shows that far range initiating cells may not show an initial elevated core between elevation slices. Switching to VCP 12 may help some in that event, although we would really need a slice < 0.5°.

Student Notes:



1. Initiation Phase - Reflectivity

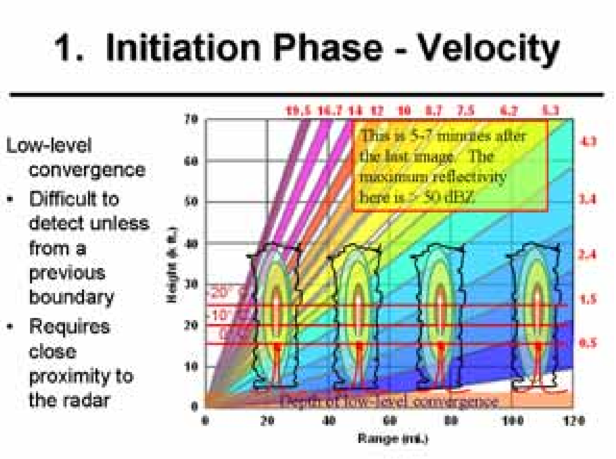
Height of initial core
- Reflectivity core is all updraft
- Stronger updraft pulses create higher cores

This is 5-7 minutes after the last image. The maximum reflectivity here is > 50 dBZ

6. 1. Initiation phase - velocity

Instructor Notes: Low-level convergence exists in all cases of initiating Deep, Moist Convection,or DMC for short. Detecting the convergence is problematic because it's so weak. Typically it's on the order of 10-3 s-1, or 2 kts of delta-V over a km when DMC initiates. The inflow into a typical pulse storm occurs over a fairly broad depth, and likewise, so is the convergence. When DMC initiates off of an outflow boundary, front or other convergence line, the source convergence is a bit more easy to see and can be more intense. Either way, the depth of the low-level convergence prevents us from detecting it beyond 40-60 nm.

Student Notes:



1. Initiation Phase - Velocity

Low-level convergence

- Difficult to detect unless from a previous boundary
- Requires close proximity to the radar

This is 5-7 minutes after the last image. The maximum reflectivity here is > 50 dBZ.

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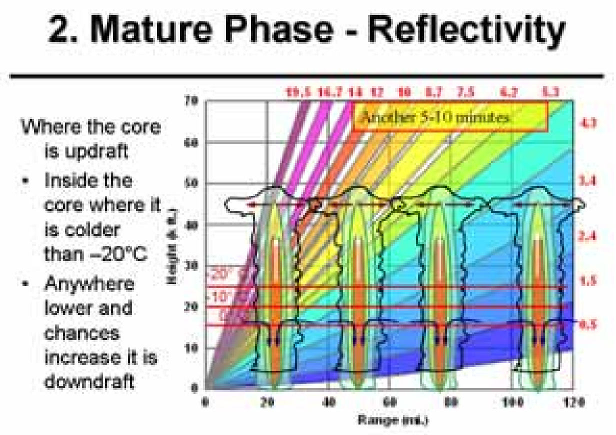
7. 2. Mature phase - reflectivity

Instructor Notes: Another 5-10 minutes or 15-20 minutes after first echo, the mature cell's reflectivity core reaches ground with a downdraft. Now, the lower half of the core is occupied by downdraft and the other half, by updraft. In this stage, any intense core above the -20° C level is the most likely part of the core still in updraft. The top part of the downdraft is where midlevel velocity convergence can usually be detected. Anywhere between the significant midlevel convergence and the anvil-level divergence is where updraft would be located here.

Student Notes:



2. Mature Phase - Reflectivity

Where the core is updraft

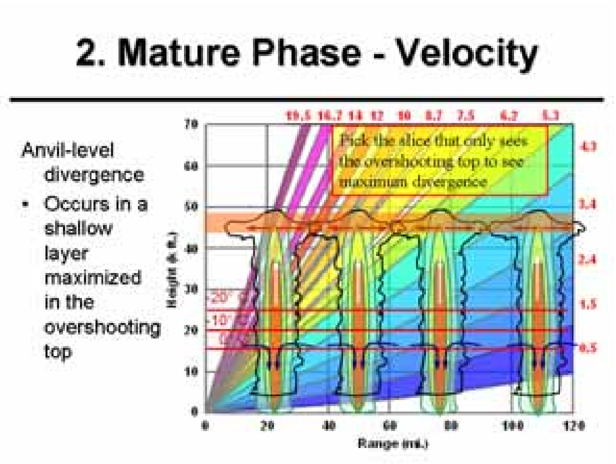
- Inside the core where it is colder than –20°C
- Anywhere lower and chances increase it is downdraft

Another 5-10 minutes

8. 2. Mature phase - velocity

Instructor Notes: Anvil top divergence is shallow but still should be detected, even though the full magnitude of it may not be. The strongest stormtop divergence may be at the equilibrium level or slightly above. The equilibrium level is not that of the proximity sounding, but that of the storm itself.

Student Notes:



2. Mature Phase - Velocity

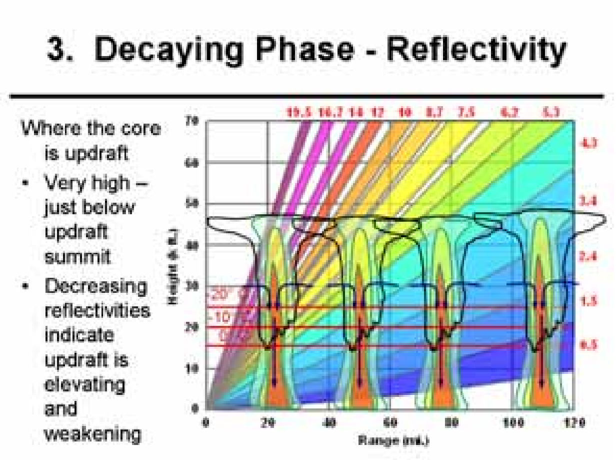
Anvil-level divergence
- Occurs in a shallow layer maximized in the overshooting top

Pick the slice that only sees the overshooting top to see maximum divergence

9. 3. Decaying phase -reflectivity

Instructor Notes: The end cycle of the storm is when the upper-level reflectivities decrease, and the anvil-top divergence dies off. Usually the demise of anvil-top divergence is quite sudden, occuring within a volume scan.

Student Notes:



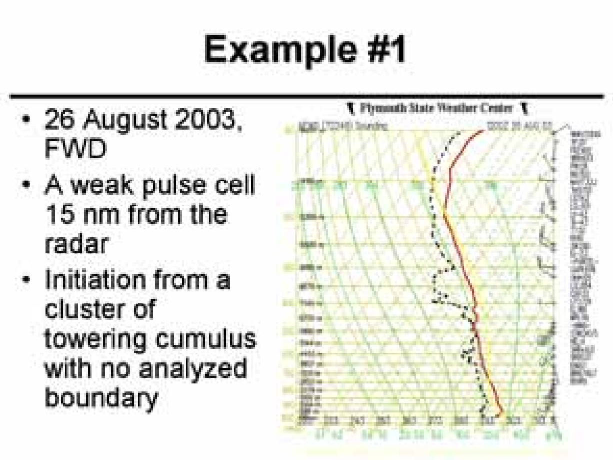
3. Decaying Phase - Reflectivity

Where the core is updraft
- Very high – just below updraft summit
- Decreasing reflectivities indicate updraft is elevating and weakening

10. Example 1

Instructor Notes: Here are several examples taken from a typical low shear pulse thunderstorm day, in this case from the Dallas area. The first cell initiated from a cluster of towering cumulus without any obvious boundary in existence.

Student Notes:



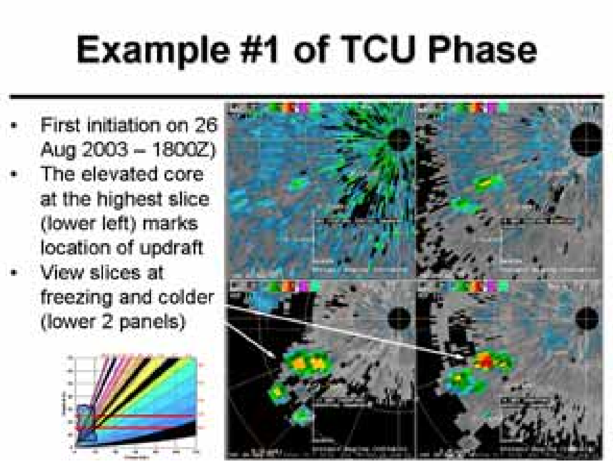
Example #1

- 26 August 2003, FWD
- A weak pulse cell 15 nm from the radar
- Initiation from a cluster of towering cumulus with no analyzed boundary

11. Example 1 of TCU phase

Instructor Notes: A nearby cell forms showing development of 50 dBZ, a 30 dBZ increase inside of 5 minutes from freezing to nearly –20° C. For many of these sessions, the VCP chart shows an iconic thunderstorm pointing out its position relative to the radar and its slices. While there are many VCPs being used now, the VCP 11 chart is shown with the displayed slices darkened. The heights of the freezing and –20° C level are displayed as the two horizontal red lines on the chart. I will be emphasizing the heights of echoes, and their significance relative to these two isotherms. In a similar way, this is how the Hail Detection Algorithm works. More of this is discussed in the hail modules.

Student Notes:



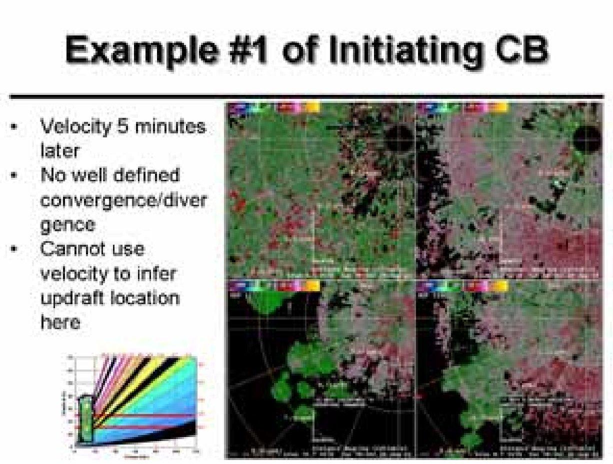
Example #1 of TCU Phase

- First initiation on 26 Aug 2003 – 1800Z)
- The elevated core at the highest slice (lower left) marks location of updraft
- View slices at freezing and colder (lower 2 panels)

12. Example 1 of Initiating CB

Instructor Notes: The initiating phase of this pulse storm shows no well defined low-level convergence. First pulse storms often fail to show the velocity convergence you'd think is necessary to compensate for the updraft above the surface. It is there, just very weak.

Student Notes:



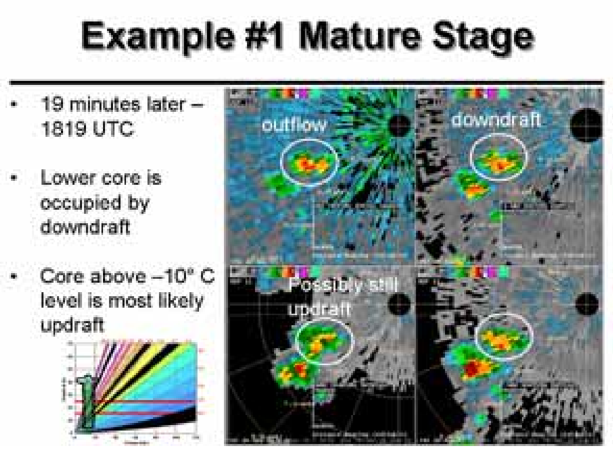
Example #1 of Initiating CB

- Velocity 5 minutes later
- No well defined convergence/divergence
- Cannot use velocity to infer updraft location here

13. Example 1 mature stage

Instructor Notes: Nineteen minutes after initiation and the core with its downdraft have reached the surface.

Student Notes:



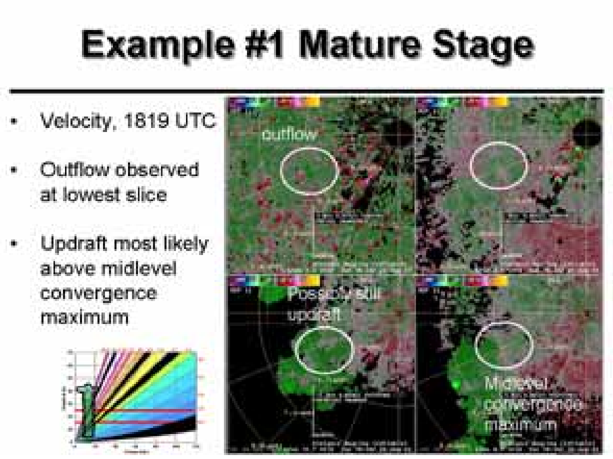
Example #1 Mature Stage

- 19 minutes later – 1819 UTC
- Lower core is occupied by downdraft
- Core above –10° C level is most likely updraft

14. Example 1 mature stage

Instructor Notes: Divergence is visible as the downdraft reaches the ground with the core in the 0.5° slice (upper left). At 8.7°, weak midlevel convergence can be seen (lower right). Anywhere between the midlevel convergence and storm top, updraft is most likely to exist.

Student Notes:



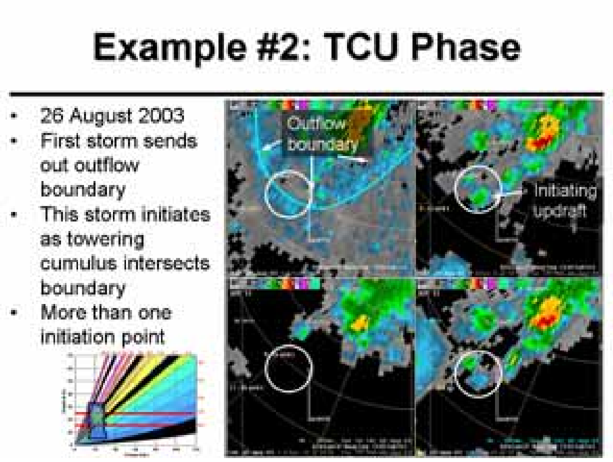
Example #1 Mature Stage

- Velocity, 1819 UTC
- Outflow observed at lowest slice
- Updraft most likely above midlevel convergence maximum

15. Example 2: TCU phase

Instructor Notes: The first couple cells die out and in so doing, they send out a ring of outflow marked by a fineline seen in the 0.5° slice. This ring intersects another cluster of moderate cumulus a little further away from the radar. There are several towering CU that receive a boost of vertical velocity from the outflow boundary and start to develop elevated echoes. Here, the echoes are barely strong enough to be considered precipitation. Precipitation is likely responsible for the echo seen in the upper-right panel because the reflectivity is > than 20 dBZ. The lower-right panel is intersecting the top of the towering cumulus and here, Bragg scattering could be mostly responsible for the echo returns. Incidentally, the fineline echo at the lowest slice is probably a result of a combination of insects and Bragg scattering. Boundaries need a fairly strong density gradient and wind shear to cause Bragg scattering. Any boundary fineline echo over a large body of water is most likely a result of Bragg scattering since insects are typically confined to land.

Student Notes:



Example #2: TCU Phase

- 26 August 2003
- First storm sends out outflow boundary
- This storm initiates as towering cumulus intersects boundary
- More than one initiation point

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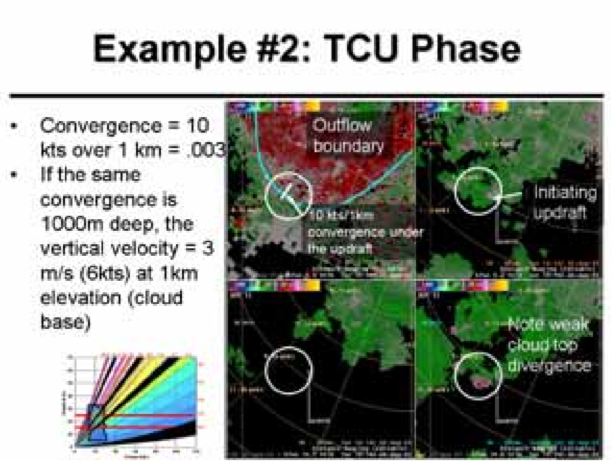
16. Example 2: TCU phase

Instructor Notes: The outflow boundary shows a ?V of 10 kts over about one km, or calculating out convergence, (?V/distance), results in a value of .003. Let's assume that is a mean convergence over 1000m depth. If I apply the continuity equation over that depth (sorry for the technicals), I get an extra 6kts of vertical velocity at 1km to supply to the towering cumulus and its vertical motion. The initiation should be stronger than with the first storm, all things being equal. Indeed, the 10° slice shows some weak but well formed cloud top divergence.

Student Notes:



Example #2: TCU Phase

- Convergence = 10 kts over 1 km = .003
- If the same convergence is 1000m deep, the vertical velocity = 3 m/s (6kts) at 1km elevation (cloud base)

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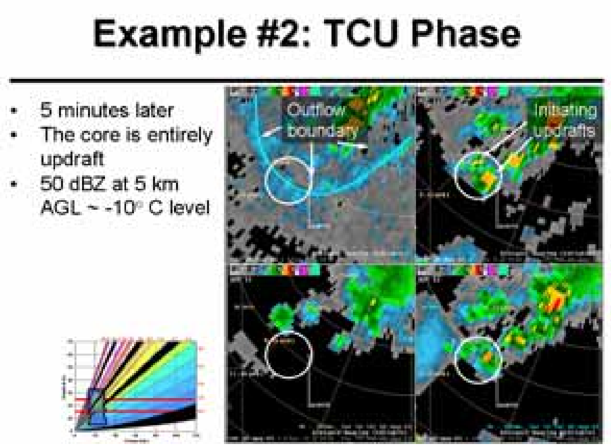
17. Example 2: TCU phase

Instructor Notes: Five minutes later, the initial towering cumulus develop a respectable 45 dBZ echo at -10° C. An echo this strong in the dendrite formation zone probably means there is graupel and snowflakes mixing together and electric charge separation is underway. First lightning is probably going to occur within 5 to 10 minutes of this scan.

Student Notes:



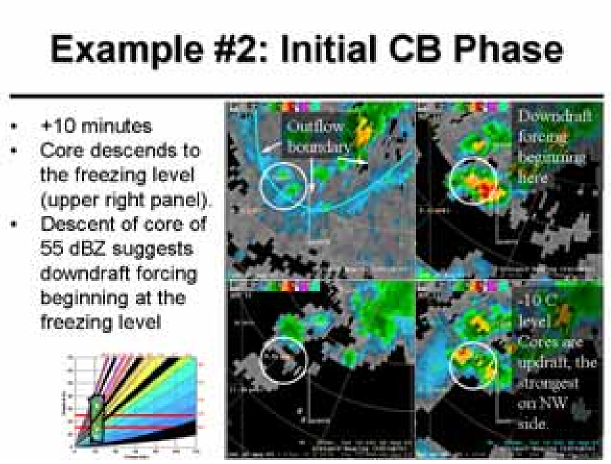
Example #2: TCU Phase

- 5 minutes later
- The core is entirely updraft
- 50 dBZ at 5 km AGL ~ -10° C level

18. Example 2: Initial CB phase

Instructor Notes: Add another 5 minutes and the core at the -10° C level is still updraft. More intense core is found just above the freezing layer (upper right panel), and it appears strong enough that downdraft may be inferred here.

Student Notes:



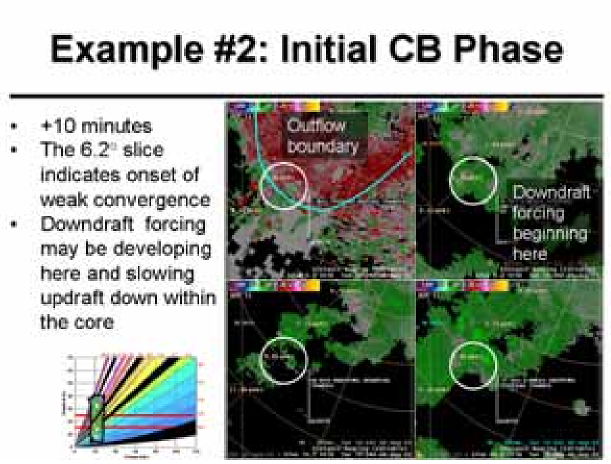
Example #2: Initial CB Phase

- +10 minutes
- Core descends to the freezing level (upper right panel).
- Descent of core of 55 dBZ suggests downdraft forcing beginning at the freezing level

19. Example 2: Initial CB phase

Instructor Notes: The velocity 4-panel for the same time indicates some weak convergence forming on the right side of the white circle at the 6.2° slice (or 15 kft and 0° C). Note the very weak outbounds in front of the broader inbounds. Downdraft is initiating within the 50 dBZ core. The outflow boundary in the 0.5° slice has not bypassed the storm yet. Updraft is still being forced above this level but below the descending core.

Student Notes:



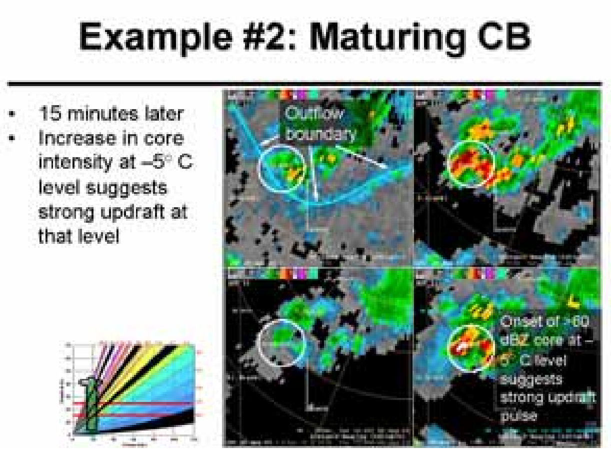
Example #2: Initial CB Phase

- +10 minutes
- The 6.2° slice indicates onset of weak convergence
- Downdraft forcing may be developing here and slowing updraft down within the core

20. Example 2 of initiating CB

Instructor Notes: Add another 5 minutes, or 15 minutes after first elevated echo, and the core of the first updraft pulse is reaching ground. Also note that another adjacent towering cumulus has pulsed upward even more strongly and its core reached > 60 dBZ in the 10° slice. Not much echo has reached to the 16.7° slice. But I am guessing the next 2 volume scans will show strong reflectivities to that level.

Student Notes:



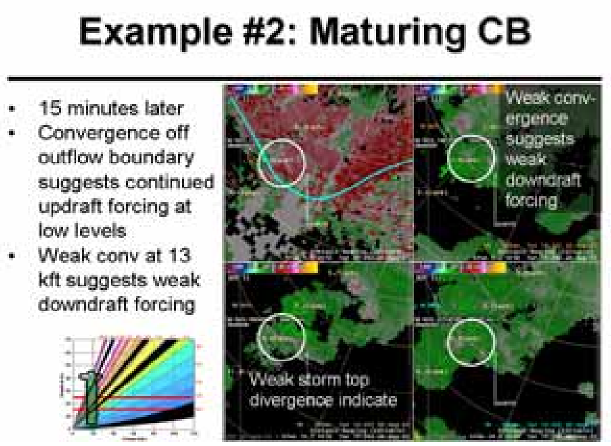
Example #2: Maturing CB

- 15 minutes later
- Increase in core intensity at –5° C level suggests strong updraft at that level

21. Example 2 of initiating CB

Instructor Notes: In fact, the storm top is at least at the 16.7° slice level, or 35 kft. There is storm top divergence there. Still weak convergence is visible at 6.2°, or 15 kft. Updraft is likely between 16 and 35 kft, and then above the surface outflow boundary. However, downdraft is coming down and a surface reflection will be visible shortly.

Student Notes:



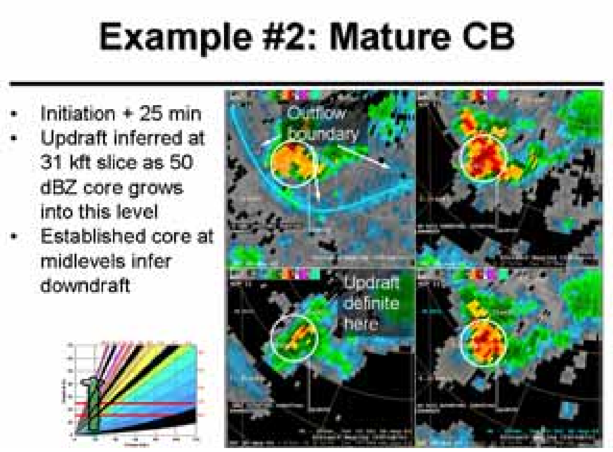
Example #2: Maturing CB

- 15 minutes later
- Convergence off outflow boundary suggests continued updraft forcing at low levels
- Weak conv at 13 kft suggests weak downdraft forcing

22. Example 2 mature CB

Instructor Notes: Let's add another 10 minutes so that we're at initiation +25 min. Now there's a solid core with its maximum vertical extent. The 16.7° slice now shows >50 dBZ core, which is most definitely occupied by updraft. I am not so certain that the 10° slice and below are still in updraft. The 6.2° slice is most definitely occupied by downdraft now. Let's take a look at the velocity.

Student Notes:



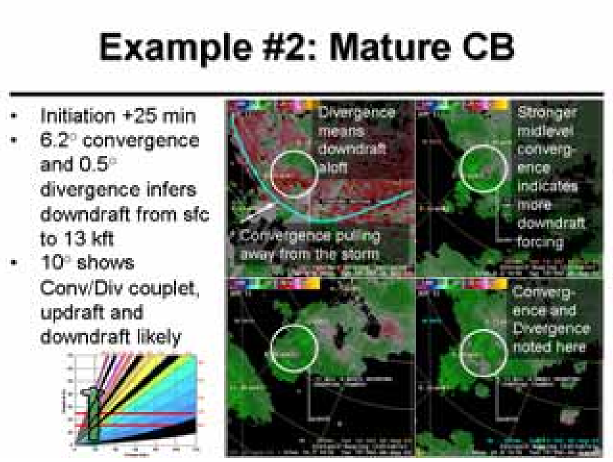
Example #2: Mature CB

- Initiation + 25 min
- Updraft inferred at 31 kft slice as 50 dBZ core grows into this level
- Established core at midlevels infer downdraft

23. Example 2 mature CB

Instructor Notes: Now there is a divergent velocity couplet at 0.5°. Updraft is most likely sloping back from over the outflow boundary to the front side (southwest) side of the cell towards 6.2° (15 kft). But in the core up to at least 20 kft, downdraft is probably dominant. Certainly the 15 kft level, there is stronger convergence than before within the reflectivity core. A confusing pattern of convergence and divergence, with some shear does not give me much confidence that the core is dominated by either updraft or downdraft. Updraft is most likely above 20 kft within the core itself. The storm top divergence is above the slices depicted here.

Student Notes:



Example #2: Mature CB

- Initiation +25 min
- 6.2° convergence and 0.5° divergence infers downdraft from sfc to 13 kft
- 10° shows Conv/Div couplet, updraft and downdraft likely

Divergence means downdraft aloft

Stronger midlevel converg-ence indicates more downdraft forcing

Convergence pulling away from the storm

Converg-ence and Divergence noted here

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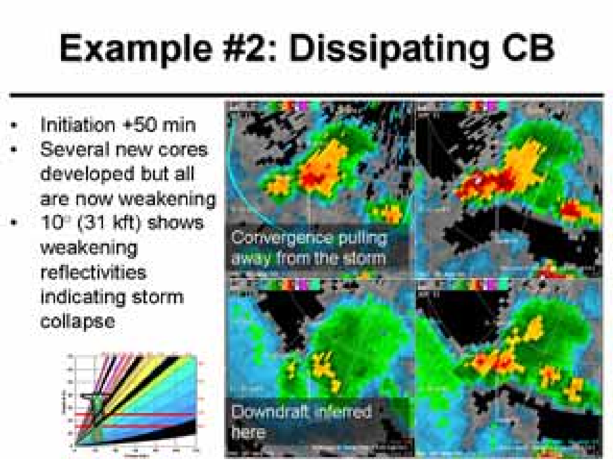
24. Example 2 dissipating CB

Instructor Notes: Fifty minutes after initiation, the upper-level core at 36 kft diminishes, a good sign that all is downdraft

Student Notes:



Example #2: Dissipating CB

- Initiation +50 min
- Several new cores developed but all are now weakening
- 10° (31 kft) shows weakening reflectivities indicating storm collapse

Convergence pulling away from the storm

Downdraft inferred here

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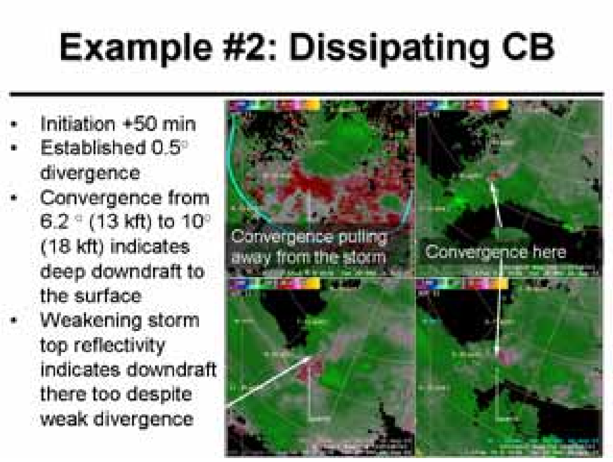
25. Example 2 dissipating CB

Instructor Notes: Convergence dominates most of the slices in the middle of the cell. At this stage, it is most likely that there is no updraft anywhere. Divergence is strongest near ground-level, and the outflow has spread wide enough to cut off any more source of lifting from the original outflow boundary.

Student Notes:



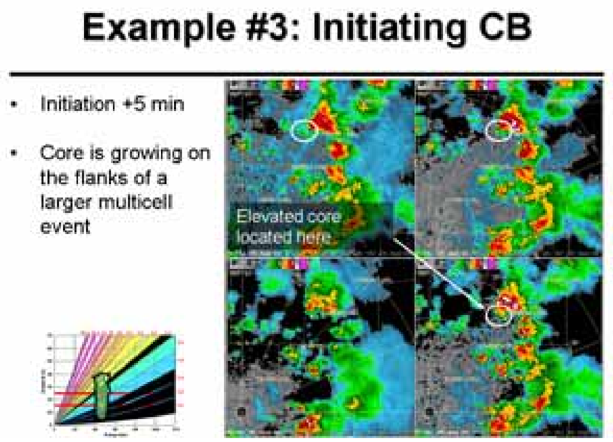
Example #2: Dissipating CB

- Initiation +50 min
- Established 0.5° divergence
- Convergence from 6.2° (13 kft) to 10° (18 kft) indicates deep downdraft to the surface
- Weakening storm top reflectivity indicates downdraft there too despite weak divergence

26. Example 3 initiating CB

Instructor Notes: The third example shows a more strongly forced set of cells with the one highlighted inside the white circle. The low-level forcing from this cell comes from a deep outflow boundary sent out by the complex to its northeast.

Student Notes:



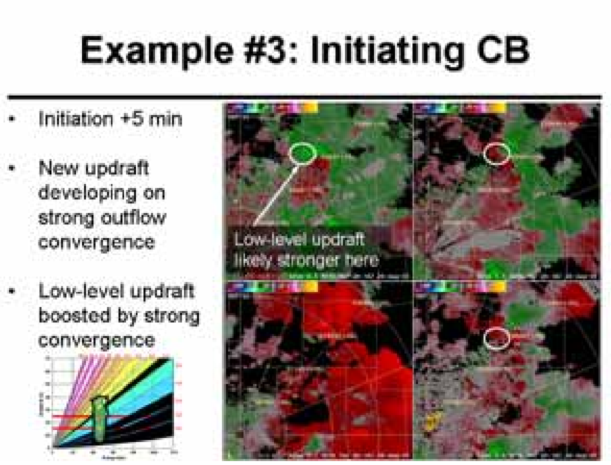
Example #3: Initiating CB

- Initiation +5 min
- Core is growing on the flanks of a larger multicell event

27. Example 3 initiating CB

Instructor Notes: It’s impressive to see strong velocity convergence in the 0.5° slice which is nearly 5 kft AGL. Initiation is likely to be strong with favorable consequences throughout its lifecycle.

Student Notes:



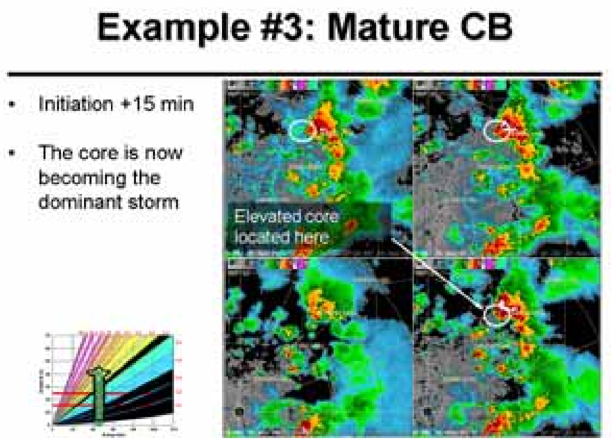
Example #3: Initiating CB

- Initiation +5 min
- New updraft developing on strong outflow convergence
- Low-level updraft boosted by strong convergence

28. Example 3 mature CB

Instructor Notes: Fifteen minutes after initiation, there is a solid 60 dBZ elevated core at 13 kft AGL (lower right). This new core will become the dominant updraft in this multi-cell event.

Student Notes:



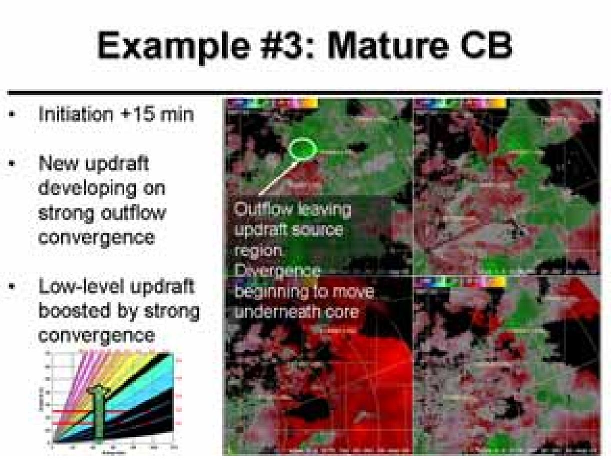
Example #3: Mature CB

- Initiation +15 min
- The core is now becoming the dominant storm

29. Example 3 mature CB

Instructor Notes: The deep cold pool boundary will soon pass away from this initiating cell but it has not done so yet.

Student Notes:



Example #3: Mature CB

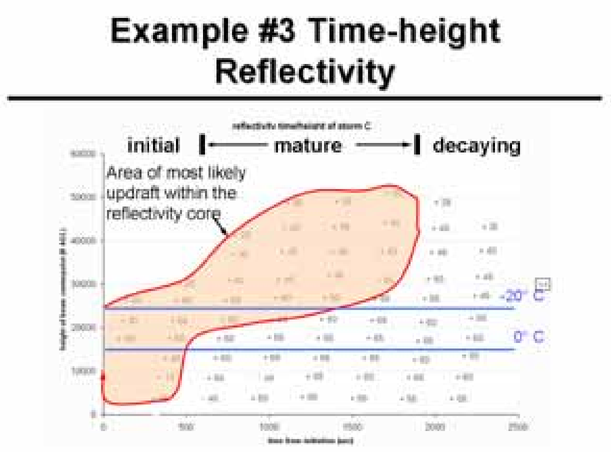
- Initiation +15 min
- New updraft developing on strong outflow convergence
- Low-level updraft boosted by strong convergence

Outflow leaving updraft source region. Divergence beginning to move underneath core

30. Example 3 time-height reflectivity

Instructor Notes: A time-height reflectivity profile shows what part of the high reflectivities this cell is most likely occupied by updraft. In the first two volume scans, the updraft is likely occupying everywhere in the core and below. Once the intense core begins to descend, it is likely not occupied by updraft below about 20 kft AGL. However, at the same time, intense updraft, still partially forced by the departing outflow boundary, and buoyancy, continues to lift the upper reaches of the core until 1500 seconds after initiation. The last set of 4-panels was taken about 700 seconds after initiation.

Student Notes:

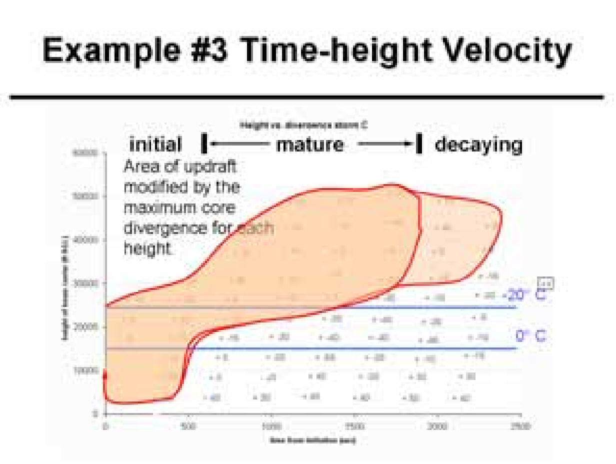


Example #3 Time-height Reflectivity

31. Example 3 time-height velocity

Instructor Notes: Now we go to the time height cross-section of the maximum convergence/divergence (displayed as maximum ?V) located within the confines of the 40 dBZ or greater echo. If updraft is likely anywhere above the level of maximum midlevel convergence, then the area of updraft has been modified to show some even after the maximum height of the reflectivity core begins to diminish. However, note that the storm top ?V, once at 70 kts diminishes even though it’s still positive through this figure.

Student Notes:

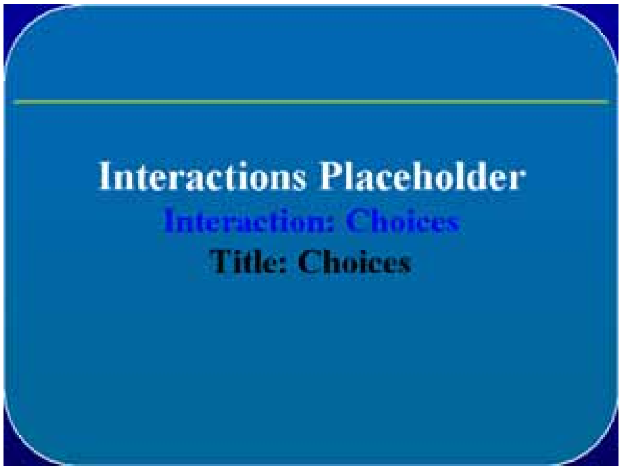


Example #3 Time-height Velocity

32. Choices

Instructor Notes:

Student Notes:



Interactions Placeholder

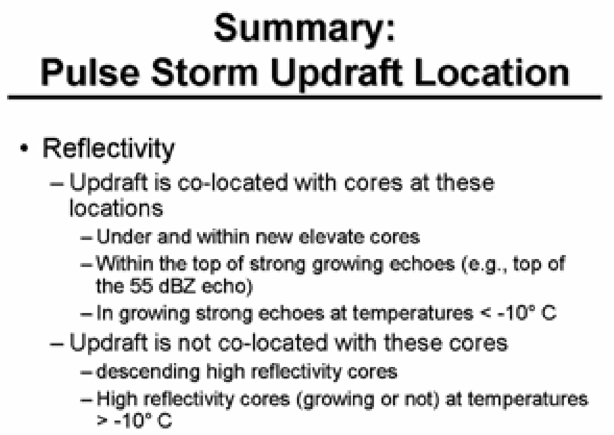
Interaction: Choices

Title: Choices

33. Summary: Pulse storm updraft location

Instructor Notes: Summarizing, Reflectivity Updraft is colocated with cores at these locations Under and within new elevate cores Within the top of strong growing echoes (e.g., top of the 55 dBZ echo) In growing strong echoes at temperatures < -10° C (this height rises though, in the late lifecycle of a pulse storm) Updraft is not colocated with these cores descending high reflectivity cores High reflectivity cores (growing or not) at temperatures > -10° C

Student Notes:



Summary: Pulse Storm Updraft Location

- Reflectivity
  - – Updraft is co-located with cores at these locations
    - – Under and within new elevate cores
    - – Within the top of strong growing echoes (e.g., top of the 55 dBZ echo)
    - – In growing strong echoes at temperatures < -10° C
  - – Updraft is not co-located with these cores
    - – descending high reflectivity cores
    - – High reflectivity cores (growing or not) at temperatures > -10° C

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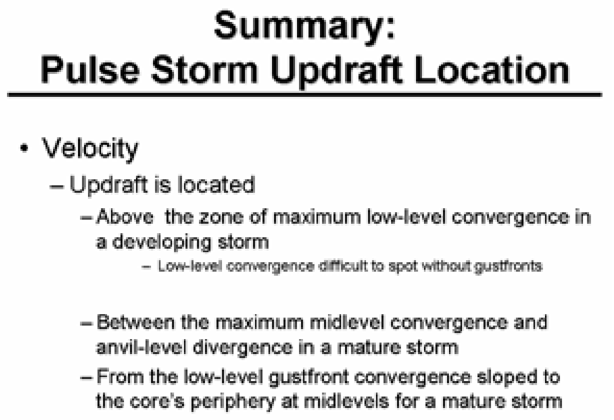
34. Summary:Pulse storm updraft location

Instructor Notes: Velocity Updraft is located (Remember this is most likely located) Above the zone of maximum low-level convergence in a developing storm Low-level convergence difficult to spot without gustfronts Between the maximum midlevel convergence and anvil-level divergence in a mature storm From the low-level gustfront convergence sloped to the core's periphery at midlevels for a mature storm For all of these pieces of evidence, none of them are direct measurements of vertical velocity. Also, as a cold pool spreads out from its axis upon the core reaching the ground, updrafts may grow on a preferred flank of the parent cell, resulting in a sloped updraft appearance. It is too simplistic really to show a time height diagram of maximum reflectivity and convergence and say specifically that the entire core is either updraft or downdraft. The flanks of a midlevel core can certainly be occupied by updraft while its center, downdraft. This is certainly true during the mature stages of a cell. Within the core, what I can say is that it is likely the core is dominated by either updraft or downdraft.

Student Notes:



Summary: Pulse Storm Updraft Location

- Velocity
  - – Updraft is located
    - – Above the zone of maximum low-level convergence in a developing storm
      - – Low-level convergence difficult to spot without gustfronts
    - – Between the maximum midlevel convergence and anvil-level divergence in a mature storm
    - – From the low-level gustfront convergence sloped to the core's periphery at midlevels for a mature storm