Storm Interrogation

AWOC Severe Track

IC3-VII-A

Hybrid/wet microburst detection

Welcome to the

AWOC Severe Track

IC3-VII-A

Hybrid/wet microburst detection

This session is 20 slides long and may take 20 to 25 minutes to complete.

Hybrid/wet microburst detection

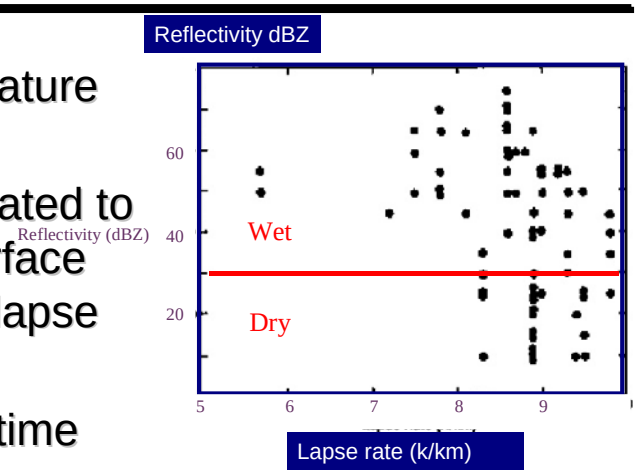
- Objective
  - Determine which microburst precursor signatures give
    - The most lead time
    - The highest probability of detection
- Motivation
  - Need to limit initial missed detections

The one objective of this lesson is to show which stormscale precursor signatures give you the most lead time and the highest probability of detection of wet and hybrid microbursts. The motivation for this session is to limit missed detections of the first microburst producing storm of the day and then increase the leadtime of all following microburst events.

We will limit ourselves to mostly stormscale signatures within the context of the environmental sounding.

Environmental consideration

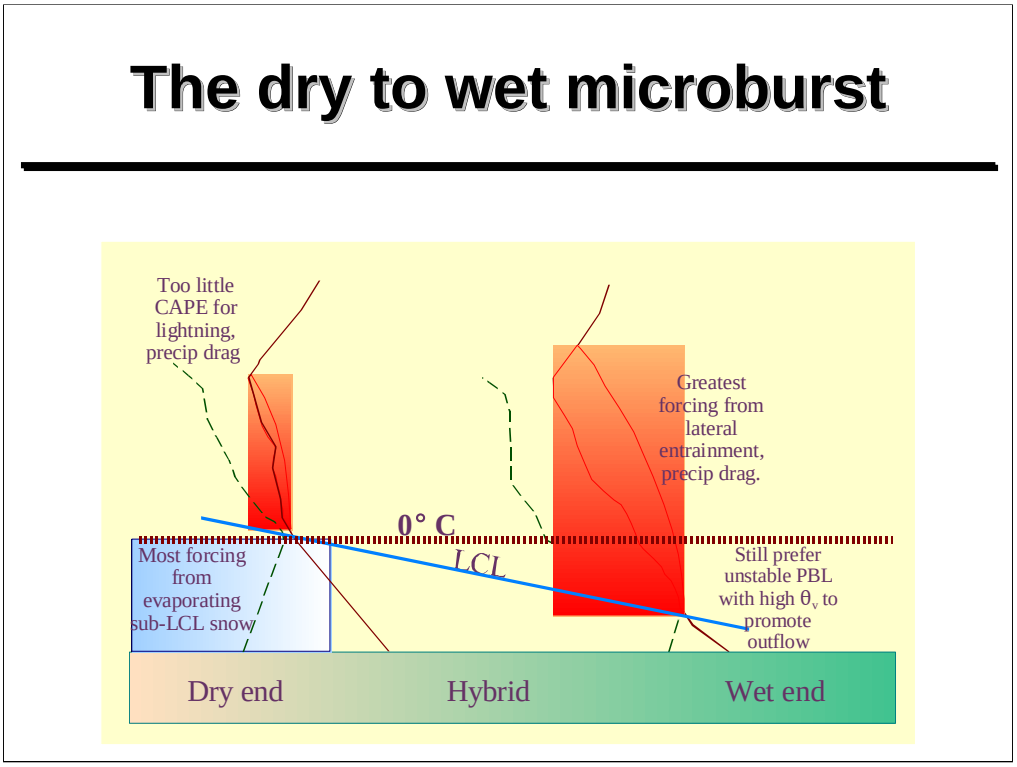
- Environmental precursor signature
- Microburst occurrence related to near storm surface to cloud base lapse rate
- Greatest lead time



Wet microbursts imply significant precipitation (>.01") associated. Srivastava (1985)

The first step in improving leadtime is recognizing the favorable microburst environment.

Srivastava 1985 plotted the surface to cloud base lapse rates versus the microburst reflectivity at 500m AGL for a population of low shear pulse storm microburst events. He found that no microburst events occurred with a lapse rate less than 5.5° K/km and most microbursts prefer greater than 7° K/km. Note that dry microbursts (microbursts with almost no surface precipitation) require a nearly dry adiabatic layer. All these microbursts were sampled during the JAWS project which took place east of Denver.



Microburst environments range the full spectrum with one end being dry, the other being wet.

Dry end microburst environments carry very little CAPE (< 500 j/kg), and extremely deep, mixed boundary layers

with LCLs near the freezing level and greater than 13000 ‘ AGL. In this case, both temperature and height coordinates

are important. Height coordinates are important because the higher the LCL, the more room for an accelerating downdraft

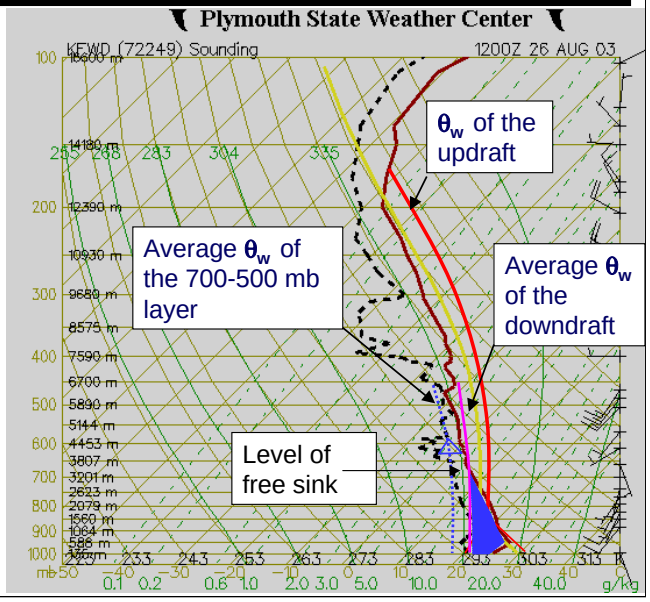
there is to reach severe speeds, DCAPE is larger. Temperature coordinates of the LCL are important only whether the LCL is higher or lower than the freezing level. If the LCL is higher, frozen hydrometeors become exposed to the subcloud air and you suddenly can add the latent heat of melting liquid to evaporation and increase the negative buoyancy of the downdraft. The downdraft forcing is almost entirely below the LCL and there is no significant precipitation loading. Maximum storm reflectivities are less than 35 dBZ in many cases.

Wet end microbursts feature significant CAPE and low LCL heights. These events feature large DCAPEs when midlevel dry air is present to act as a source of evaporational cooling when precipitation becomes mixes with the environmental air. The high CAPEs create intense reflectivities, and therefore, significant precipitation loading potential. Precipitation loading when reflectivities exceed 60 dBZ become as important as evaporational cooling. Look for wet microburst environments when there is a large θe difference between the surface-baesd updraft parcel, and the midlevels (3-6 km AGL). If you expect storms with 60 dBZ cores, precipitation loading becomes a big factor to consider. Most downdraft forcing occurs by lateral dry air entrainment in the midlevels, and very little comes from below the surface-based LCL. Surface based convection is highly favored for microbursts since you don’t want significant surface-based CIN.

Many environments favoring microbursts may have a little bit of both dry and wet microburst characteristics. Environments where significant CAPE resides above high LCLs (above

Wet microburst case 1

- The orange parcel is the best estimate for the afternoon Θ_w.
- Blue dotted parcel is the average Θ_w of the 700-500 mb environment
- Purple parcel is the best guess downdraft Θ_w
- Blue shaded area is the estimated DCAPE area



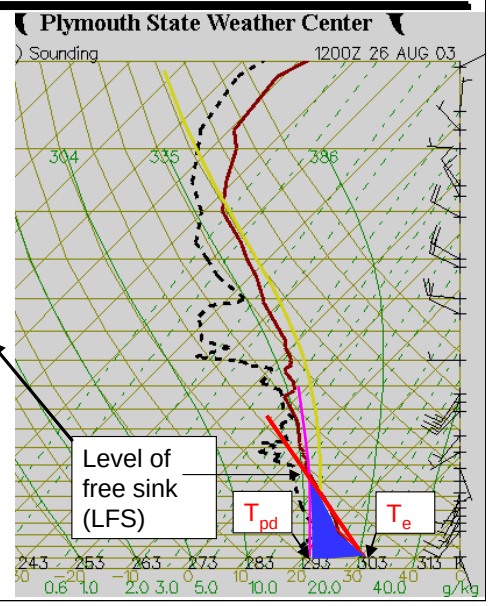
On 26 August 2003, the Dallas area is in the middle of a fairly active summertime convective period. You've probably seen this case presented before in the hail storm interrogation and in the sessions on locating pulse storm updrafts. The morning sounding modified for the afternoon temperature/dewpoint combination shows significant CAPE but somewhat marginal source of dry air, except for a layer that is typically too high to consider as a downdraft initiation level (400 mb). This sounding is not a classic high end microburst environment. We should have

Let's calculate what shape the DCAPE may look like. We'll assume that the downdraft air will have a mix of temperature and dewpoint between the updraft air parcel and the environment. As long as that's a safe assumption, we can visualize DCAPE as following:

1. First, we find a representative θ_w for the environment around the midlevels, say about 630 mb. The θ_w can be found at midlevels by launching the environmental air parcel using the temperature and dewpoint at that level and raising it to its LCL. Note the little blue triangle, the left vertex being the dewpoint at 630 mb, the right vertex being the temperature, the top vertex being the LCL. The point at the LCL is the θ_w at that level. I highlighted that θ_w as a dotted blue curve.
2. Then I launch the surface-based, or mixed layer parcel from the ground up and call it the updraft θ_w visualized as the solid red curve.
3. The mixed layer downdraft parcel should be somewhere in the middle, and I chose the magenta θ_w curve as the curve the downdraft will follow.
4. The negatively buoyant area for the downdraft is anywhere the downdraft temperature is lower than the environment. Note that there is a small layer just below my downdraft initiation level where the downdraft air is positively buoyant, and then it reaches the Level of Free Sink (LFS) where the downdraft is unobstructed from accelerating. The LFS is exactly analogous to the LFC for updrafts.

Wet microburst case 1

- Estimating DCAPE
- Find these
  - Surface environment temperature (T_e)
  - Expected downdraft surface temp (T_{pd})
  - Depth of negatively buoyant air ΔZ (LFS to sfc)
- DCAPE ≅ ½ $g((T_e-T_{pd})/T_e)\ \Delta Z$ (LFS to sfc))
- DCAPE ≅ ½ 9.81((304-297/304)3300m
- DCAPE ≅ 372 m^2/s^2
- Maximum W ≅ $(2*DCAPE)^{1/2}$ ≅ $(2*372)^{1/2}$ ≅ 27 m/s
- Downdrafts almost never realize the theoretical DCAPE because they are unsaturated



The DCAPE can actually be estimated by taking the afternoon surface temperature minus your theoretical temperature of the downdraft at the surface, dividing it by the environmental surface temperature and multiplying by the depth of the layer from the surface to the LFS (meters), multiply again by gravity (9.81) and divide by 2 since we're calculating the area of a triangle, not a parallelogram.

DCAPE =1/2 $g((T_e - T_{pd})/ T_e)\Delta Z$

I estimate the environmental T_e to be 304 K, The downdraft T_{pd} is about 297 K, ΔZ is the distance from the LFS down to the surface and I will put in 3300 m. Entering in those numbers, I get this:

DCAPE=1/2[9.81((304-297)/304)3300] ≅ 372 m^2/s^2

If an updraft has a hard time realizing all of its theoretical CAPE, a downdraft will practically never realize its full DCAPE. In order for my theoretical T_{pd} to be fully realized, my downdraft would have to be saturated. In other words, saturated descent would be required for my downdraft to follow the downdraft θ_w all the way to the surface. Observations show that downdrafts are almost never saturated. Therefore, we have to be realistic and perhaps cut the DCAPE by a factor of 2. But let's use the 384 m^2/s^2 to compare with later cases.

As an additional task, we can take the DCAPE and estimate the maximum potential downdraft velocity from evaporational cooling mechanisms.

Maximum W=$(2DCAPE)^{1/2}$ = $(2*372)^{1/2}$ = 27 m/s

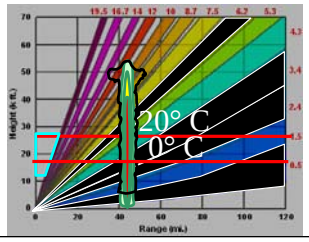
But if only half the theoretical DCAPE is realized, then Maximum W = $(2*186)^{1/2}$ = 19 m/s

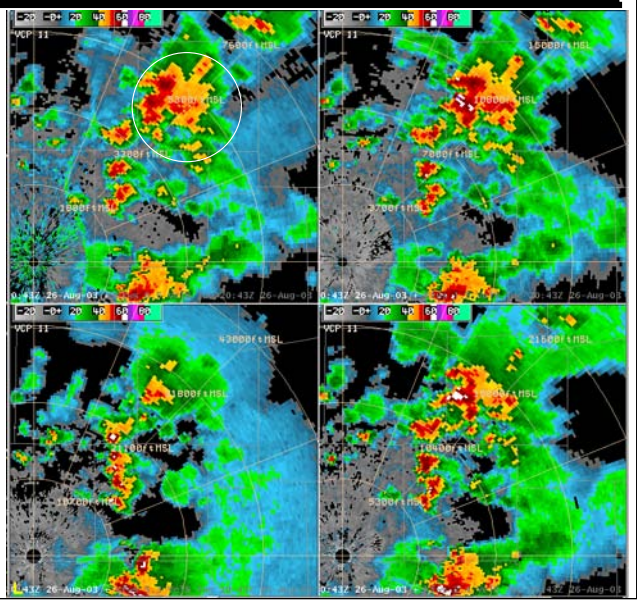
This downdraft strength is not likely to be very severe. However, we haven't considered:

- The precipitation loading factor to overall downdraft intensity. This will add further downward forcing to the evaporational cooling for which we calculated DCAPE.
- Potential changes in the environment

Example 1: FWS 26 Aug 2003

- Low shear multicell initiating on colliding boundaries

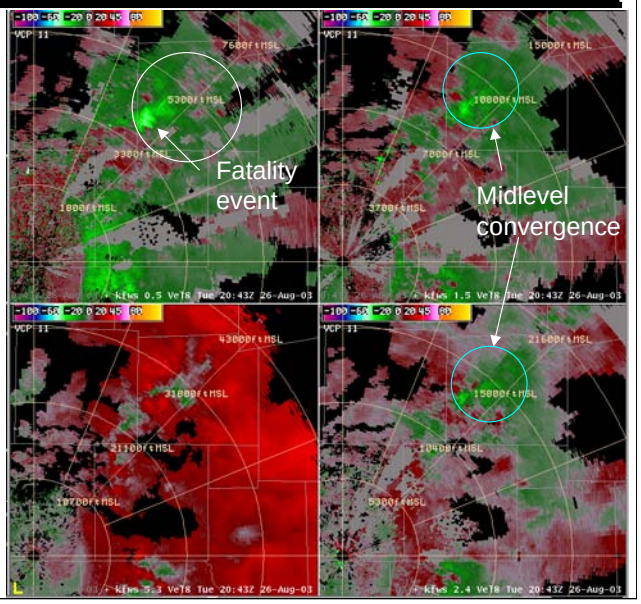


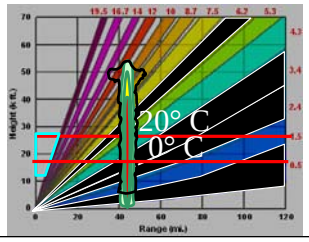


The multicell storm in question is inside the white circle. You may notice that the multicell is propagating down an outflow boundary merger with new cells forming on the southwest side of the complex. Strong reflectivities > 60 dBZ extend up to 21 kft in the storm just prior to 2043 UTC, the last frame of the loop.

Example 1: FWS 26 Aug 2003

- Well defined midlevel convergence forms

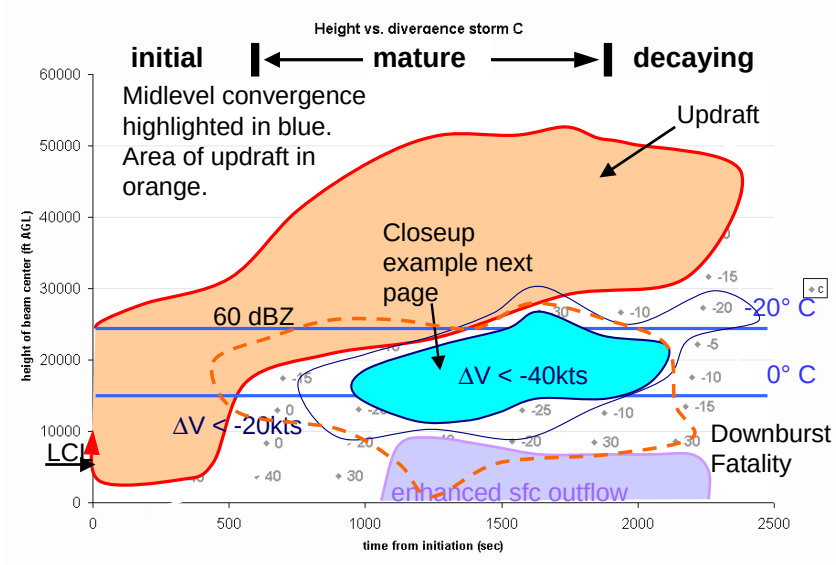




Note in the 4 panel velocity loop, the onset of strong midlevel convergence at 9000' AGL to above 15800' AGL just prior to the strong inbounds seen in the lowest slice (upper left). Weak midlevel convergence exists before with greater lead time to the surface downburst.

The strong winds at the surface were likely in existence for some time before it impacted the home construction site where the fatality existed.

Example 3 time-height velocity



I sampled the maximum reflectivity for each level of the storm, using new cells if they developed so close to the older ones that they were all one contiguous heavy reflectivity area.

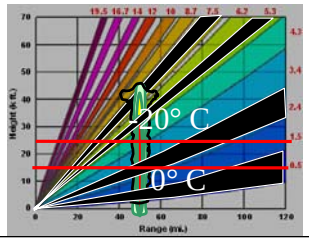
The first time height plot is of reflectivity.

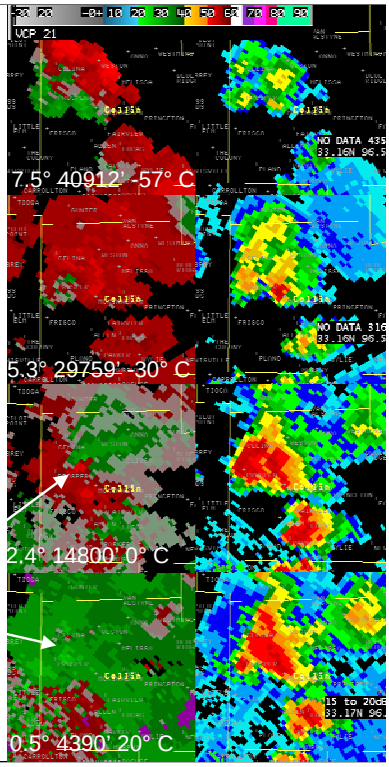
The next time height plot is the maximum velocity difference found within the bounds of the heavy reflectivity core. At the lowest slice (5000' AGL), there was strong convergence, mostly ahead of the precipitation core while divergence was found inside the core. I chose the divergence. At midlevels, I found strong negative velocity differences (convergence) in the core while divergence existed to some extent on either side. Midlevel convergence patterns are often complicated, sometimes the convergence axis being on the core edge. Perhaps that is not unexpected because of the complex nature of the cores themselves, and therefore, downdraft forcing mechanisms. The downdraft initiates, and the midlevel convergence follows.

Note that the midlevel convergence followed 5 – 10 minutes after the onset of > 60 dBZ reflectivities in the 0 to -20° C layer. Strong midlevel convergence < -40 kts appeared only 5 minutes before the onset of strong inbounds and divergence in the 0.5° elevation slice (4500' AGL). It was to be another 15 minutes before the fatality event. Several downburst surges probably occurred in this time span.

midlevel convergence

- Midlevel convergence is well detected here
- Damaging winds are quite possible here though the first report is 20 minutes later





This example shows very well the midlevel convergence at 14.8 kft AGL and near the freezing level right within the intense reflectivity core. Updraft is likely above this level but the midlevel convergence is likely a response to the downdraft already underway and beginning to show up as a divergence field at the surface. At this distance, the divergence at 4390' is nowhere nearly as strong as it would be had the radar sampled the lowest few hundred feet above ground.

Example 1: 26 Aug 2003

Precursor signatures in order of occurrence

Strong, large initial core, 55 dBZ 20 to 25 kft AGL (0 to –20 C) level:	leadtime = 10 – 15 min
Descent of high reflectivity's (>50 dBZ) to the surface:	leadtime = 5-10 min
Onset of midlevel 30kt convergence 12 – 20 kft AGL (0 to –10 C) level:	leadtime = 0-5 minutes

In this example, the 55 dBZ then 60 dBZ core appeared in the layer where we would expect initial downdraft formation, somewhere near the freezing level and just above. Downdraft forcing is likely occuring at lower levels too. Anywhere with midlevel convergence in reflectivity core, downdraft forcing is possible. The best leadtime is the onset of the strong core aloft, followed by the weak midlevel convergence, and finally, strong convergence (ΔV<-30 kts).

Example 1: 26 August 2003

- Large area of midlevel convergence in this large multicell event.
  - High magnitude convergence
  - Above the LCL suggesting lateral dry air entrainment and precipitation drag
- Best leadtime is earlier with strong elevated reflectivity after initiation

This event also had a large area of midlevel convergence. The convergence was strong and above the LCL suggesting that wet microburst processes were occurring, that is lateral dry air entrainment and precipitation drag.

Waiting till the onset of strong midlevel convergence before considering a warning will not give you any leadtime. But there will probably be a pretty low probability of a false alarm.

Example 2: 19 Aug 2003 LSV

- 19 Aug 2003
- Large CAPE implies big precip loading
- Larger DCAPE than with FWD
  - 1009 m^2/s^2
- Both combine to increase threat of downbursts

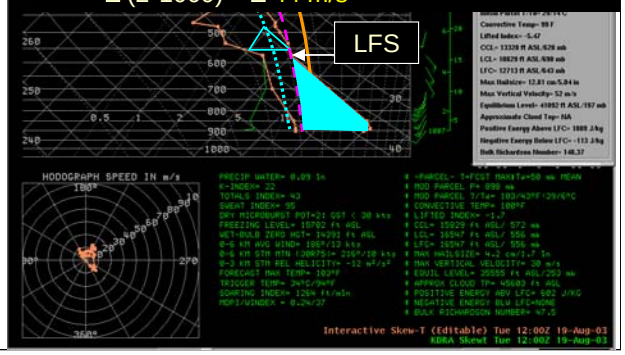
•DCAPE ≅ ½ $g((T_e-T_{pd})/T_e)\ \Delta Z$ (LFS to sfc)\

•DCAPE ≅ ½ 9.81((311-295/311)4000m

•DCAPE ≅ 1009 m^2/s^2

•Maximum W ≅ $(2*DCAPE)^{1/2}$

•≅ $(2*1009)^{1/2}$ ≅ 44 m/s



Now we go to the 19 August Las Vegas storm of 2003. All sorts of severe weather occurred on this day, including high winds.

Low-level monsoon moisture entered into the valley after this sounding was taken allowing for high CAPEs. The hot surface temperatures made sure that the LCL was high and that plenty of negative buoyancy would be available below.

1. Following the same method of visualizing the potential DCAPE area, launching a midlevel air parcel (note the cyan triangle) helps to

estimate the midlevel θ_w. Remember that there is a lot of flexibility as to what midlevel parcel height to choose for the θ_w.

2. Next, choosing a representative parcel at the surface gives us the updraft parcel θ_w in the orange curve.

3. Then the magenta dashed line represents an average of the two θw curves and that becomes our downdraft θ_w.

4. The DCAPE area occupies everywhere the downdraft θ_w is colder than the environmental temperature,

I estimate the surface environmental temperature Te to be 311 K, The downdraft surface temperature is about 295 K, the starting point of my downdraft is 4000 meters above ground.

Entering in those numbers, I get this:

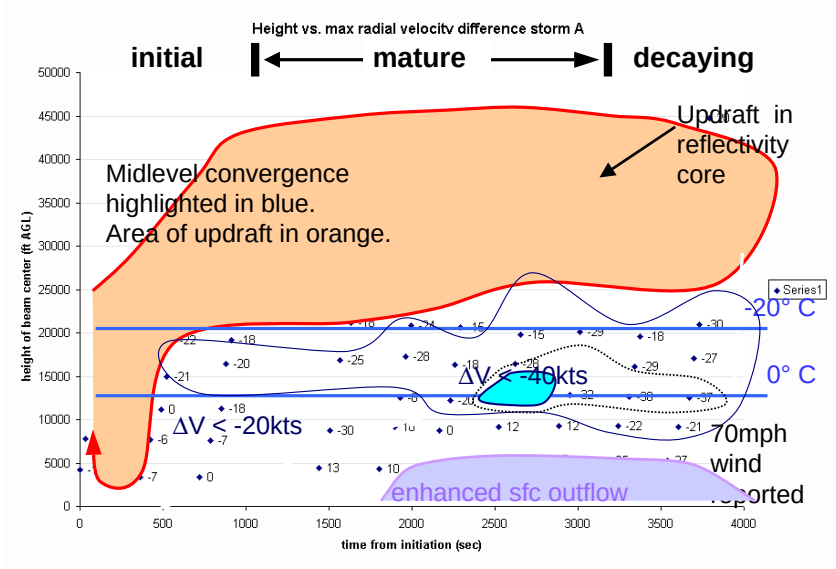
DCAPE ≅ 9.81((311-295)/311)4000/2 ≅ 1009 m^2/s^2

This value is larger than the Dallas event. Add big CAPE precipitation loading potential and the downburst potential is quite high.

Maximum theoretical W = $(2*DCAPE)^{1/2}$ = 44 m/s

Again, this is likely overestimating the potential some but the purpose here is to show the numbers are larger than for the Dallas microburst event.

LSV storm time-height reflectivity/velocity



I was still able to find several gates with < -40 kts of midlevel velocity difference. But for the most part, the midlevel convergence was narrow and fairly weak. The updraft appeared strong on radar throughout this event, with two main cells making sure some strong updraft was always present. Enhanced low-level divergence appeared about 15 minutes before the 70 mph wind was reported. Strong winds were likely occuring well before the wind report.

Example 2: 19 Aug 2003

Precursor signatures in order of occurrence

Strong, large initial core, 55 dBZ 20 to 25 kft AGL (0 to –20 C) level:	leadtime = >15 min
Descent of high reflectivity's (>50 dBZ) to the surface:	leadtime = 15 min
Onset of midlevel 30kt convergence 12 – 20 kft AGL (0 to –10 C) level:	leadtime = 0 minutes

The best leadtime was the onset of a large initial core > 55 dBZ above 20 kft AGL.

The descent of the high reflectivity core would give you about 15 minutes leadtime

The onset of –30 kt velocity difference at 12 – 20 kft would have given you nearly 0 leadtime to the onset of low-level divergence.

Example 2 summ: 19 August 2003 – Las Vegas

- Midlevel convergence is actually weaker except for one volume slice – no leadtime
  - Inflow into midlevel convergence may have been mostly tangential
- But larger DCAPE and stronger reflectivity core than Ft. Worth event suggests bigger potential for damaging downburst

This may be speculative but the axis of inflow into the downdraft at midlevels was possibly oriented in a way that prevented the radar from detecting it. Note that the long axis of the core is down radial. If the axis of convergence followed a similar orientation, then the inflow into the downdraft could be mostly tangential and hard to detect.

The strength of the core above the freezing level in conjunction with the environment should give you an idea that strong downburst would be likely once that core descended to ground.

Example 3: 12 Nov 2003 LAX

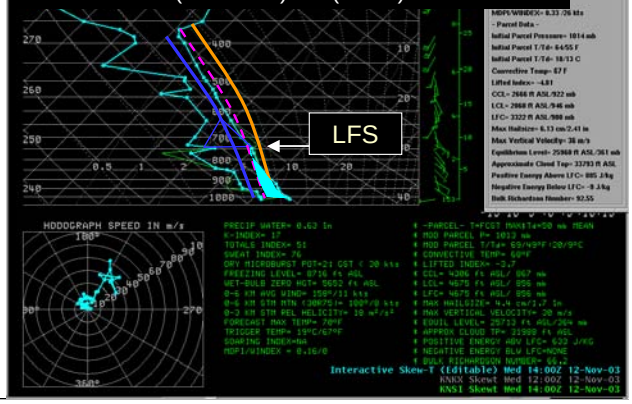
- Smaller CAPE, but high buoyancy (orange parcel)
- Small DCAPE (cyan shaded region)

DCAPE ≅ ½ $g((T_e-T_{pd})/T_e)\ \Delta Z_{\text{(LFS to sfc)}}$

DCAPE ≅ ½ 9.81((289-285/289)2400m

DCAPE ≅ 162 m^2/s^2

Maximum W ≅ $(2*DCAPE)^{1/2}$ ≅ $(2*162)^{1/2}$ ≅ 18 m/s



Contrast the Las Vegas and Dallas events with a cool season, low topped event. There is actually a fair amount of dry air and low θ_w air in the midlevels. CAPE is low only because the equilibrium level is low. Buoyancy or CAPE density is high relative to the total CAPE.

Putting the numbers in,

DCAPE ≅ ½ $g((T_e-T_{pd})/T_e)\ \Delta Z_{\text{(LFS to sfc)}}$

DCAPE ≅ ½ 9.81((289-285/289)2400m

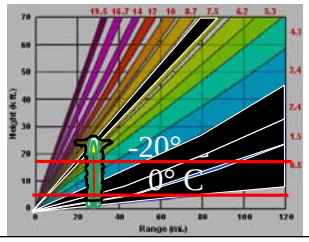
DCAPE ≅ 162 m^2/s^2

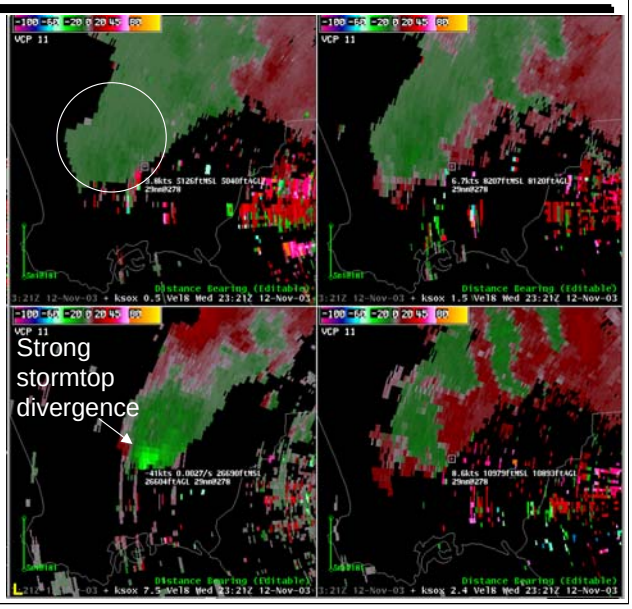
Maximum W ≅ $(2*DCAPE)^{1/2}$ ≅ $(2*162)^{1/2}$ ≅ 18 m/s

These numbers are small compared to the other two cases. Unless there is an exception, or precipitation loading is a big factor, or other downdraft forcing mechanisms are at work (e.g., Rear Flank Downdraft), then we don't expect severe downdrafts in this environment.

Example 3: 12 Nov 2003 LAX

- Midlevel convergence (ΔV) peaks at -30 kts at 2.4° (10 kft, -4° C)





This cell does have a midlevel convergence axis and a downdraft is being generated. The differential velocity across the convergence is weak, perhaps 25 to 30 kts. Reflectivities are high and precipitation could be a factor. However, several parameters work against a severe downdraft in this case:

1. Depth of the negative buoyancy is small and DCAPE is small
2. Weak midlevel convergence supports the idea that downdraft may not be strong.
3. Precipitation loading is there but the depth of its forcing is small too.
4. Lack of very strong horizontal environmental flow means no vertical mixing of horizontal momentum.

The last point is something not typically considered, however weak shear pulse convection can occur in strong wind environments. They do produce severe surface winds without strong downdrafts.

Example 3: summ 12 Nov 2003

- CAPE = 800 j/kg, DCAPE much smaller than first two cases
- > 60 dBZ core implying precipitation loading is significant but depth is small
- Midlevel convergence –30 kts compared to –54 kts for FTW case and –40 kts LSV case
  - Likely well sampled midlevel convergence based on orientation of its axis
- No severe wind reports

No severe winds were reported with the Los Angeles hail storm. The midlevel convergence appears well sampled with the axis perpendicular to the radials. But the values were weaker than for the other two cases. The depth of the convection was smaller too resulting in less room for downward acceleration of air to achieve high velocities. There was no other downdraft forcing besides precipitation loading and that is even limited by the shallow depth of the high reflectivities. This is the kind of environment and storm structure in which severe winds are not expected. No severe wind reports have been received from this storm as far as I'm aware.

Summary: Hybrid/Wet downbursts

Precursor signatures

Signature	FAR	leadtime
1 Large enough CAPE to produce significant precipitation loading	high	Day 1
2 Significant DCAPE – evaporational cooling	high	Day 1
3 Strong initiation with high reflectivities (see updraft strength sessions)	med	15 min
4 Descent of high reflectivity core	med	5-10 min
5 Onset of midlevel convergence	med	0-10 min
6 Midlevel convergence (ΔV) > 50 kts	low	0 - 5 min

In summary, I present a table of microburst precursor signatures ordered with respect to the lead time each one offers.

The environment makes up for the most lead time but individual storm behavior precludes using the environment as a sole warning tool for every storm and thus the FAR is potentially high.

The best set of parameters to view in conjunction with the environment is to watch for the storms with rapid initiation capable of sending high reflectivities to greater altitudes than other adjacent storm. The descent of the high reflectivity core results in lower lead time but is usually when a warning is sent out since the descending core occurs rather rapidly. It is usually when the reflectivity core descends that the onset of midlevel convergence occurs. Don't wait for the midlevel convergence to reach some large value since large values of midlevel convergence and the period of strongest outflow occur nearly simultaneously.

In this session, I have not mentioned situations of weak shear convection embedded in strong horizontal winds. There have been many events where even weak showers have been able to initiate downdrafts bringing the high horizontal winds to the surface.

I encourage the use of DCAPE more than other parameters, because it accounts for downdraft forcing by lateral and sub cloud base dry air entrainment for a wider variety of situations. The method shown in this lesson is something that can be applied relatively quickly on the day of an expected event. There are some caveats to its use. Note that it assumes a constant lapse rate of environmental temperature from the surface to the level of free sink. In many cases, the bumps and wiggles in the vertical temperature profile tend to cancel each other out. Sometimes they don't. DCAPE is best applied for isolated convection either in weak or significant vertical wind shear. DCAPE becomes less relevant when you are faced with an organized multicell cold pool or in situations of weak convection embedded in strong horizontal winds.