Storm Interrogation

AWOC Severe Track

IC 3-I-B: Updraft location in a sheared convective cell

Storm Interrogation – Updraft location in a sheared convective cell

This lesson is 16 slides long and may take 15 minutes to complete.

Sheared storm updraft shape and location

- Objective: Determine where and what shape the updraft is in a sheared convective cell
  - Specifically, locate the part of the Weak Echo Region occupied by updraft
  - How to determine if a WER exists in fast moving storm

This module builds on the one in which we determine the location of updrafts in pulse storms. Locating the updraft in sheared storms is something that is frequently done by warning forecasters. In this session, we show a methodology that may help your skills in discriminating the updraft size and shape at different altitudes. In addition, we discuss what a real echo overhang and underlying weak echo region is from that which is artificially generated by the volume scan with a moving storm.

Then we show a case emphasizing where in a weak echo region may lie the main updraft of a sheared cell.

Sheared storm updraft shape and location

- Motivation
  - Greatest severe weather potential adjacent to updraft/downdraft interface
  - Inform spotters of updraft location
  - Size matters for hail severity, rainfall

Why locate an updraft? For one, the updraft is the 'business end' of a sheared severe storm, or in other words, the end of the storm where most of the severe weather is likely to be adjacent or within. Also, determining which side of a reflectivity core lies an updraft gives you information on the structure and morphology of the cell (e.g., whether the severe weather will be most likely ahead or behind most of the precipitation). Giving information to the spotters on the updraft nature of the storm may allow them to better position themselves to report what's there. It is not only the location of the updraft, but its shape that's also important. As an example, for hail size, the size of the updraft is important, as is its shape. Is the updraft elongated in such a way to maximize residence time for growing embryos? This kind of question makes knowing the shape of an updraft as important as anything else if you want to improve your skills over that of the algorithms.

Sheared storm updraft shape and location

- Less dependent on point in storm lifecycle because
  - updraft lasts longer than the transit time of air parcels from base to top of the convective layer

What we mean by a sheared cell is one whose updraft is experiencing vertical wind shear of such a degree that

the updraft persists longer than any individual parcel resides in the updraft. The storm is persistent, and more steady

state than a typical pulse cell, and includes supercells, and persistent updrafts even if there is no significant mesocyclone.

Low-shear cell updrafts (pulse storms) exhibit an updraft that's more akin to an explosion than that of a chimney flue.

In an explosion, there is almost no steady state draft. The updraft rises as a bubble with no follow through parcels.

Contrast that to a high shear cell (including supercells), where the updraft is more analogous to a chimney flue or a

plume where the updraft persists longer than any individual air parcel. This allows features such as echo overhangs

to persist longer than the time allowed for the hydrometeors to fall from high altitudes, and therefore be identified

with strong, persistent updraft plumes.

Sheared storm updraft shape and location

- Low-level updraft definition
  - Is near the sharp reflectivity gradient facing storm-relative inflow at updraft base
  - Over and in the inflow notch or concave regions of sharp reflectivity gradient
  - Somewhere within the WER.
  - Updraft will be above region of low-level convergence
  - When present, low Spectrum Width values helps define updraft
  - Mesocyclone*

We break updraft signatures in radar to those that occur at low-levels, say warmer than -10° C, and those that occur at colder temperatures.

The kinematic signatures may not be so dependent on actual temperature as they are on height relative to the ground and the equilibrium level.

As you look at all the signatures, here are some things to consider:

Preferentially sharp reflectivity gradient, concave regions, and inflow notches are the most range-independent updraft signatures. Even at far ranges with broad beam widths, these features tend to stand out in varying degrees. It's no surprise that the sharp reflectivity gradient is a deep feature. It stands at the interface between up and downdrafts anywhere from the midlevels and down. The concave region embedded in the enhanced reflectivity gradient is either the region of enhanced low-level inflow, or simply reflectivity core partially surrounding a midlevel updraft.

The WER is also quite range independent provided the lowest beam intersects the storm lower than around the -10° C level. Above that level, and you stand to just sample the core embedded in updraft at upper-levels. Any Bounded Weak Echo Region at that distance is unlikely to be detected as will be seen later.

Low-level convergence signatures can be detected at farther ranges than for typical pulse cells for some of the more severe sheared cells. Deep convergence zones are discussed in more detail in another module. However, this signature fails to be reliably detectable as far as the reflectivity-based signatures above.

Low spectrum width values sometimes occur within the core of updrafts. If an updraft is much larger than the individual beams sampling it, and it has a core of undiluted ascent inside its turbulent borders, and its presence is not obscured by a three body scatter spike, there is a chance of this feature being visible. Undiluted updrafts are typically free of turbulence which may explain the low spectrum widths.

One final signature I failed to note is the presence of a mesocyclone. Mature mesocyclones are split between updraft and downdraft in the lower half of supercells. Be sure to pick the inflow half.

Sheared storm updraft shape and location

- Upper-level updraft definition
  - Partly occupies the echo overhang > 45 dBZ
  - Intense core below the -15° C level is likely occupied by updraft
  - The BWER pinpoints the updraft when present

  - Below storm top divergence center
  - On the inflow side of deep convergence zones
  - In areas of low spectrum width that are colocated with the signatures above
  - Mesocyclone*

Reflectivity signatures colder than -10° to -15° C are a little different. than the lower level counterparts. Instead of the WER, you look for the echo overhang, although one depends on the other for its existence. Intense elevated cores is one feature that is ubiquitious to low and high shear cells. It is also the most range independent feature of all the updraft features; the only twist being that it's the first to fail owing to

cone of silence issues. That is one reason to pick an alternative radar to examine near range storms. The BWER is the most range limited upper-level reflectivity updraft signature. We will show how range limited this feature is owing to its small size.

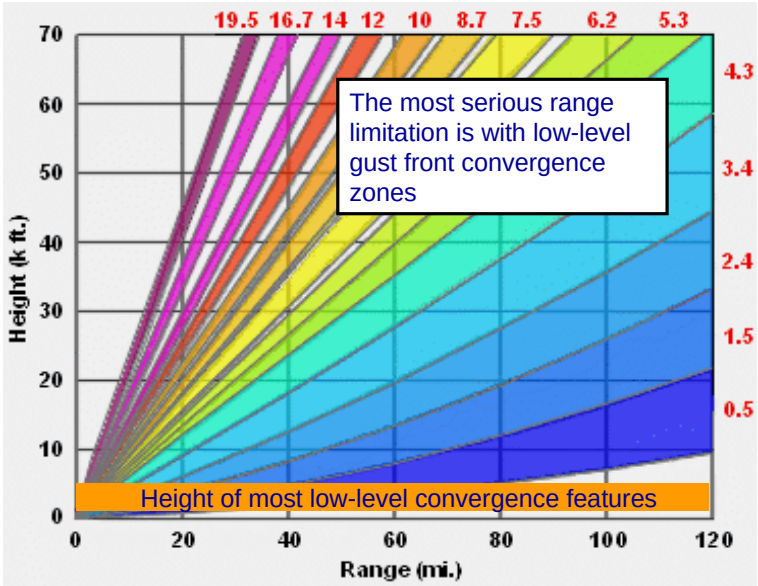
Velocity signatures in upper-levels for updrafts concentrate near the equilibrium level of a particular cell through its anvil-level divergence values. Consider that the center of divergence need not necessarily be the location of the zero isodop. It is the center of maximum divergence or ΔV. Deep convergence zones are rare that they reach well into subfreezing air. However, some of the most damaging HP supercells will have these extending to altitudes > 20 kft or -10° C. Remember that a deep convergence zone is only deep relative to the storm top for which it resides. However, the maximum detection range is absolute. That means a shallow topped storm with a deep convergence zone may be just as significant as its tall storm counterpart but the radar range limitations are much more significant.

Low spectrum width in upper-reaches of an updraft are probably harder to come by because of the proliferation of large hydrometeors occupying its core.

The real confidence of locating the updraft increases when more of these signatures become colocated, both in lower and upper regions of a sheared cell.

At upper-levels, most mesocyclones should be occupied by updraft. However, that may not be the case, and picking the threshold at which a downdraft partly occupies a mesocyclone to a level in which it doesn't may be extending our detection ability beyond reason. Therefore, I will say that use the mesocyclone to help confirm other updraft signatures.

Sheared storm updraft shape and location

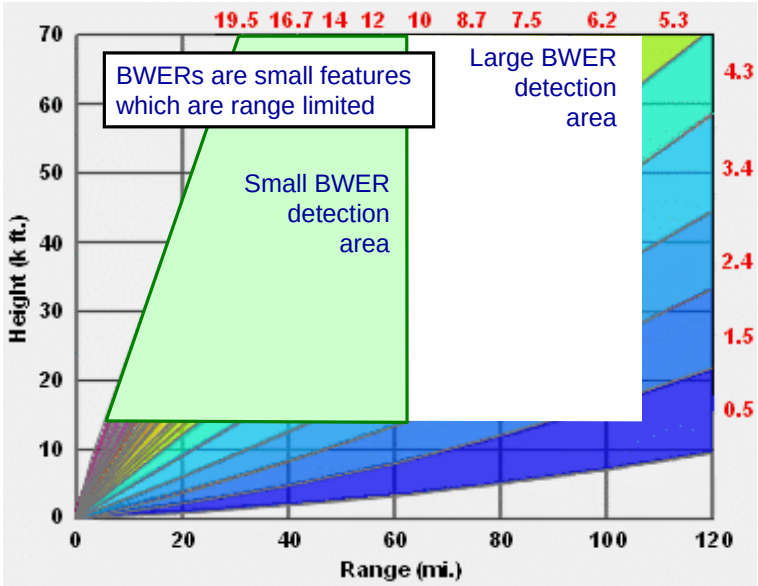


Here is an illustration of the range limitations for most low-level convergence signatures that can help you isolate updraft

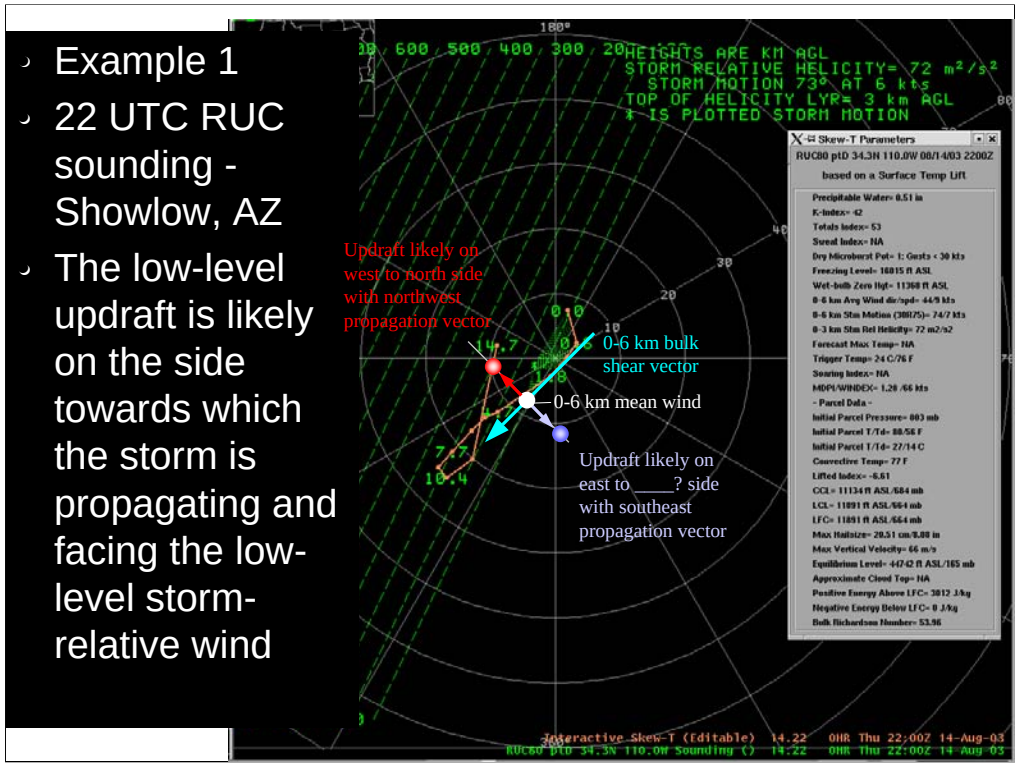
regions. Most convergence signatures are less than 6000' deep. If there is no deep convergence zone, then this signature

fails to provide any information beyond about 60 nm range.

Sheared storm updraft shape and location

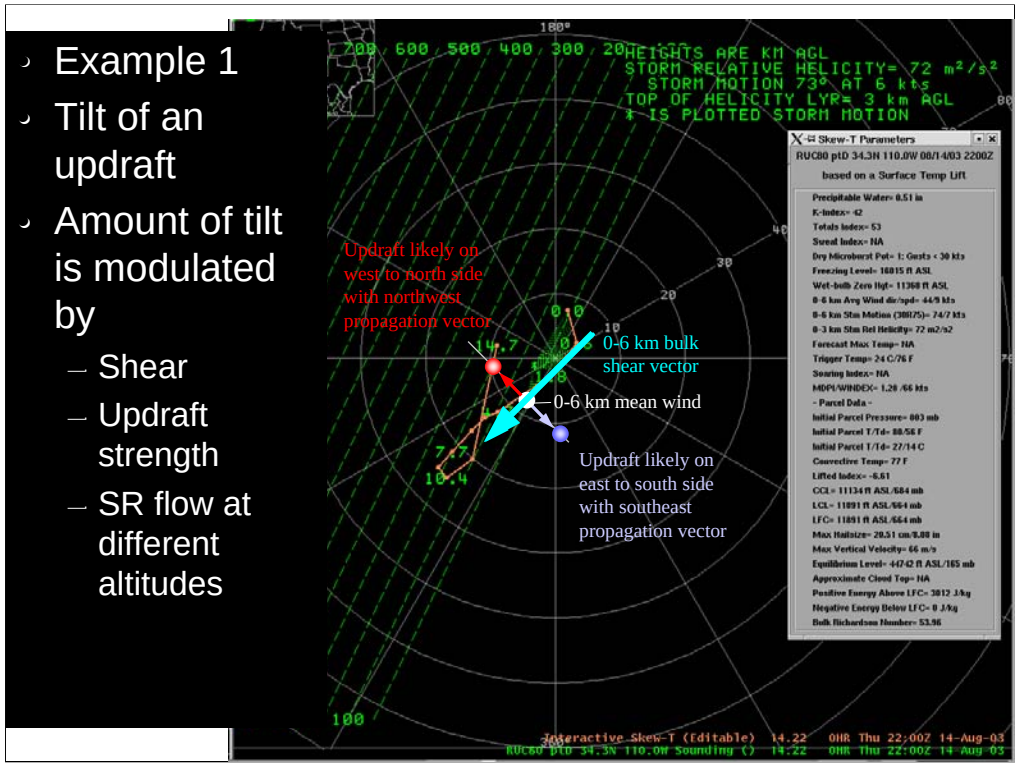


BWER detection is also highly range limited. Most BWERs become undetectable beyond 80 nm. Even the larger ones (longest dimension=5mi) are undetectable much beyond 90 mi. Thus, this figure is being very generous. As a note, small BWERs are anything about 2mi and less in its longest dimension. Note the inner range limitation. Do you have an alternative radar that can detect a BWER straight overhead?



Let's use an example to apply all the signatures we see to an interesting case of a strong easterly wave passing through Arizona as part of a monsoon event. The skewt is from the 80 km RUC at 22 UTC for Showlow, AZ. It is pretty representative of the environment on this day. This event is analogous to the typical springtime severe storm events east of the Rockies in which an elevated mixed layer is advected off the high terrain to supply regions with high lapse rates and large CAPEs, only in this case, the easterlies are advecting the mixed layer westward.

Zooming in on the hodograph, there is more than adequate shear for supercells with a 0-6 km shear of 25 m/s. Applying the ID method to derive storm motion, a right-mover (left-mover) should move straight west (south) at 10 (13) m/s. A right-mover (left-mover) would experience low-level Storm-Relative (SR) flow from the west (south). Somewhere on that face should lie the updraft base. For a right-mover, that is from the west to north. How about the left mover?

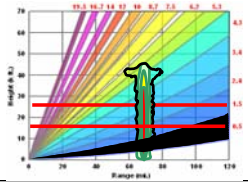


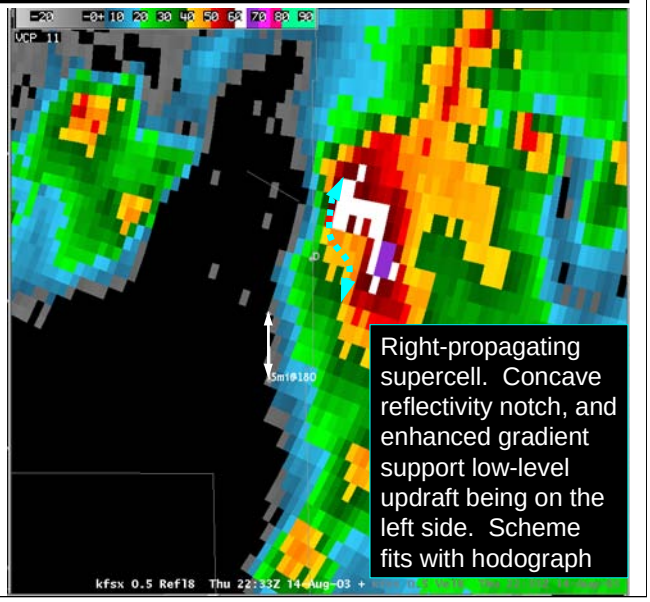
Given the orientation of the shear vector, the SR flow and its strength should give us an idea of its tilt. Both updrafts will tend to tilt toward the arrow head of the shear vector if the storms are moving off the hodograph. If a storm is moving along with the hodograph, its tilt will be directly down the shear vector.

An answer to the question on the previous page, note that the low-level updraft for the left mover is most likely to be on its east to south side.

Sheared updraft shape and location

- Example 1
  - Midrange Reflectivity considerat-ions
  - Lowest slice loop





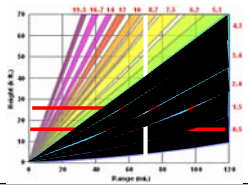
Right-propagating supercell. Concave reflectivity notch, and enhanced gradient support low-level updraft being on the left side. Scheme fits with hodograph

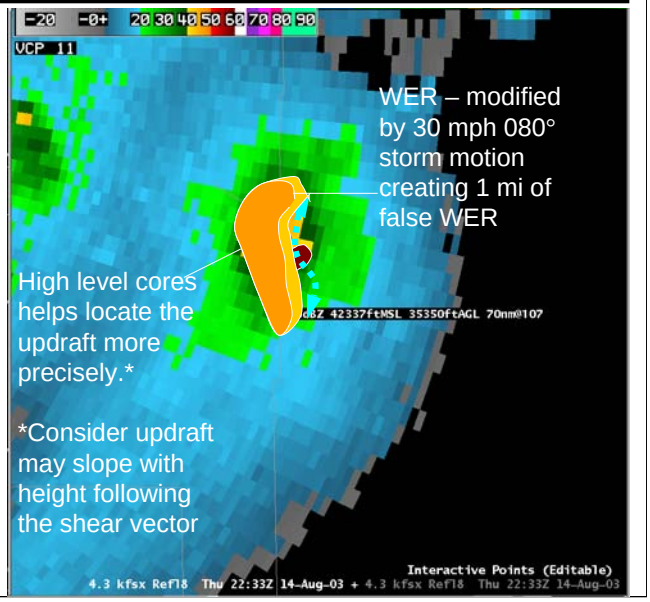
Here is a short time loop for one of the right-moving supercells on the Mogillon rim near ShowLow, AZ. The distance from the radar means that we may have difficulty viewing some low-level signatures and the BWER. The lowest scan is near 7000' AGL.

You can see that as this loop is stepped forward in time, the cell is moving westward. The concave reflectivity notch and enhanced gradient suggests the updraft is west of the core and leading it.

Sheared updraft shape and location

- Example 1
  - Midrange reflectivity considerat-ions
  - All-tilts





In this example, we discriminate the updraft area by applying the reflectivity signatures for low and high levels that we listed. At the lowest slice, this storm exhibits locally enhanced reflectivity gradient in a concave shape on its western side. We'll highlight it with a blue dashed line

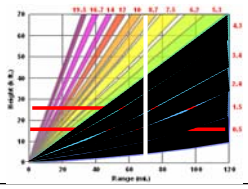
Advancing upward by two slices, we reach the intense echo overhang around 20 kft, or about -10° C. However, because the updraft is preceding the main core of this supercell, and because the supercell is moving westward at 30mph, the supercell echo overhang advanced forward approximately one mile in the time the radar took to reach this altitude. The effect is an spuriously large WER. We will shave about one mile off the width of the WER, still leaving a significantly large real WER.

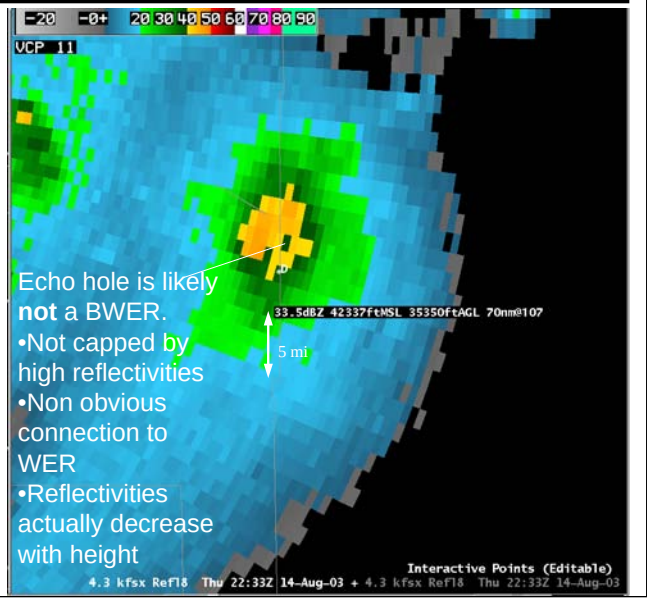
Going upward in height above the -20° C level means the actual reflectivity core is more likely in updraft. The highest slice is fairly near the storm top and here we mark it as updraft.

Note that the highest two slices have a weak echo hole. Is this a BWER? A BWER associated with a core of extremely strong updraft should be connected to the WER below and extend upward underneath the overshooting top. Reflectivities should begin as low as the WER within the lower parts of the BWER, and then gradually increase as hydrometeor production and entrainment commences. High reflectivities in the storm summit should cap off the top of the BWER, although in some cases, the BWER may extend very close to the storm summit. We'll consider whether this is a BWER in the next page.

Sheared updraft shape and location

- Example 1
- Is the echo hole a BWER?



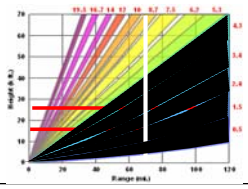


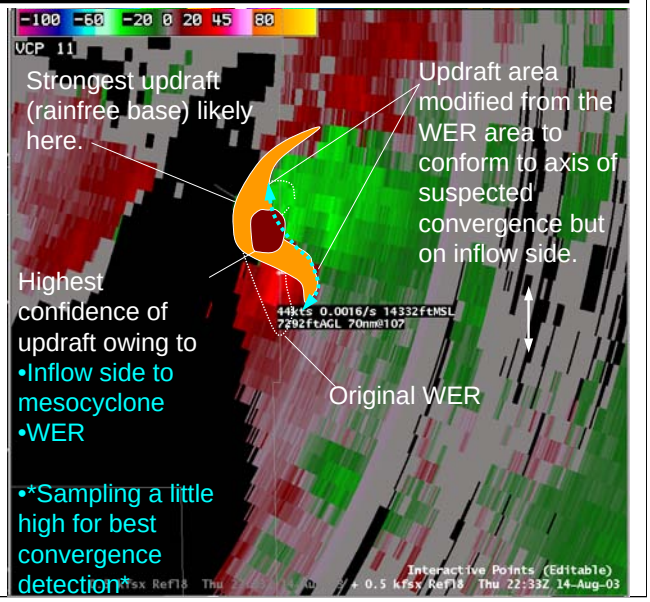
This echo hole is not capped by very high reflectivities. The reflectivities decrease with height, and there's no obvious connection with the WER.

These are three strikes against calling this feature a BWER associated with intense updraft. Most likely, the updraft is northwest of this echo hole and the BWER is really a weak echo region between two main updrafts. This would explain why reflectivities decrease with height.

Sheared updraft shape and location

- Example 1
  - Velocity considerat-ions
  - Low-levels (7200ft AGL)



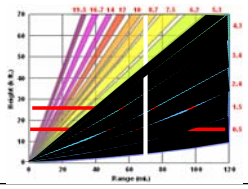


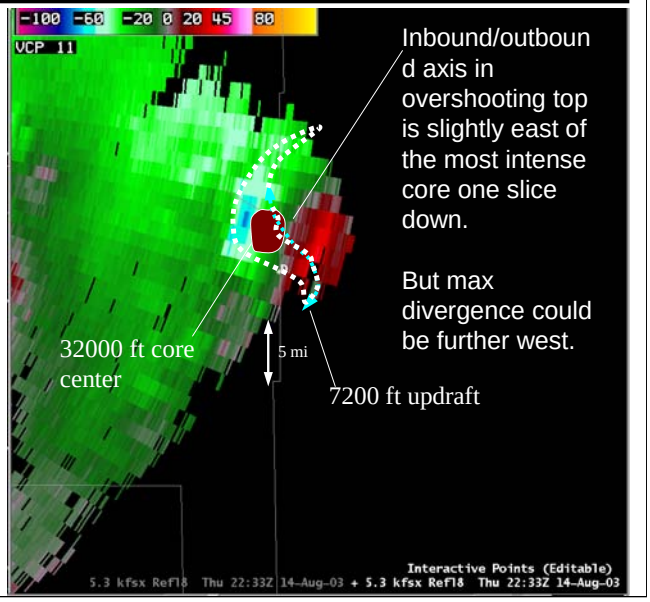
We're not done discriminating updraft region yet until we look at volumetric velocity. Starting where we left off with the reflectivity, adding the lowest velocity scan shows a classic mesocyclone with almost pure rotation. However, there is evidence of strong convergence on its northern flank, due west of the Rear Flank Downdraft and marked by the orange overlay.

Care must be taken not to confuse the decrease in radial velocity where outbound goes to inbound with increasing range with that of onvergence. If you have a pure rotational velocity couplet, you will see radial velocities decrease with increasing range. The convergent signatures should show more abrupt velocity gradients than that associated with pure circulation.

Sheared updraft shape and location

- Example 1
  - Velocity considerat-ions
  - high-levels (4400ft AGL)





Going up in altitude to storm summit, the strongest divergence is located a little west of the zero isodop. Therefore, the upper-level updraft is most likely in the location marked by the rough circle.

Putting all the pieces of evidence together, this storm has a low-level updraft roughly paralleling the gustfront, coinciding with the inflow portion of the mesocyclone, and then and upper-level updraft where the strongest storm summit divergence is located. Coincidentally, the storm summit divergence overlies the strongest portion of upper-level reflectivity core.

Summary: Sheared storm Updraft location

- Low-levels
  - Facing low-level SR flow side
  - Tight reflectivity gradient
  - Concave shape reflectivity gradient
  - Enhanced velocity convergence
  - WER
- High levels
  - Intense echo overhang (>45 dBZ)
  - On inflow side to mesocyclone
  - Storm summit divergence and echo center
  - BWER core
  - Low spectrum width

To summarize, the updraft location in a sheared storm is more likely than not to tilt with height. Therefore, look for reflectivity and velocity signatures at both low and high altitudes to gain a better understanding of the nature of particular storm's tilt.

At low-levels, you want to look for the updraft on the side roughly facing the low-level storm-relative inflow where there is a tight reflectivity gradient, preferably in a concave shape. You should see enhanced velocity convergence if your lower slices are below 4 to 5000 feet AGL. This area may lie in a weak echo region capped by intense reflectivity overhang. Recall that the echo overhang is not entirely occupied by low-level updraft. But the coincidence of more pieces of evidence at any point, does lead to higher confidence that the echo overhang is updraft.

At higher levels, the intense echo overhang, below an upper-level reflectivity maxima, under the region of strongest storm summit divergence gives you most of what you need to call the area an updraft. Your confidence increases if this area is in a BWER overlaid by high reflectivities, and in the vicinity of a mesocyclone. Remember that mature mesocyclones are partially occupied by rear flank downdraft, even at high altitudes.