Storm Interrogation

AWOC – Severe Track

IC3-III-C

Tornado Warning Guidance – Stormscale induced storm relative helicity signatures

Storm Interrogation – Tornado Warning Guidance – Stormscale Induced Storm Relative Helicity Signatures

This lesson is relatively short, only 11 pages long. It should take 10 to 11 minutes to complete.

Stormscale enhancement to SRH

- Objective
  - Determine the likelihood that a storm is enhancing low-level SRH in its inflow
- Motivation
  - Some storms enhance SRH more than others from the base state environment

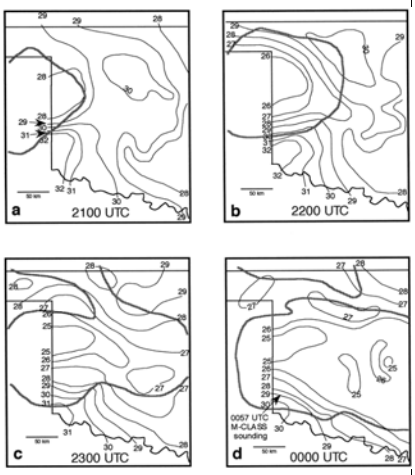
The objective of this lesson is to provide you considerations on how a potentially tornadic supercell may enhance Storm-Relative Helicities (SRH) in its stormscale environment. These considerations are based on results from recent project VORTEX experiments and other studies.

It is important to know which storms enhance SRH more than others due to factors that you cannot detect on the mesoscales.

Some storms may modify their local environment more than others and it is important to determine which ones may do so.

Anvil-induced baroclinicity

- Cooling along south anvil edge results from shadow. Baroclinity results leading to horizontal vorticity.
- Strongest 1 km SRH enhancement may occur when low-level inflow parallels anvil edge.
- Need sunlit ground right of anvil.



Markowski, MWR 1998, pg2924

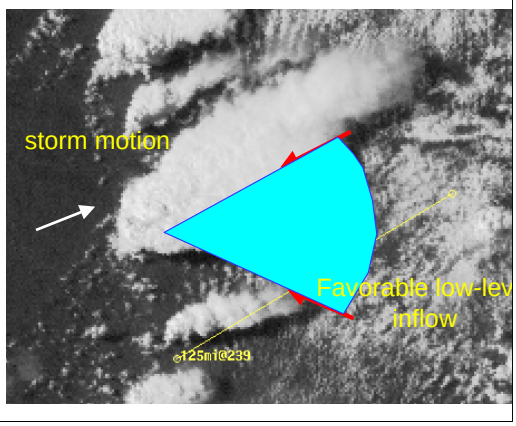
Anvil shading induced baroclinicity is a phenomenon that was proposed by Markowski 1998 after examining several cases, some going back to the early 1980's to several events from project VORTEX including the June 08, 1995 tornado outbreak in the Texas Panhandle. In these cases, Markowski noted significant surface temperature drops induced by the loss of solar insolation under the forward anvils of supercells. The June 08 case shown above is an analysis of surface temperatures from the Oklahoma mesonet. Note the significant temperature gradient forming under the southern anvil edge. After a scale analysis of horizontal vorticity production resulting from this temperature gradient, Markowski found that mesocyclonic vorticities can develop in as little as 20 minutes for air parcels residing in this anvil shadow induced temperature gradient.

Three features are needed to support evidence of horizontal vorticity production by anvil shading:

1. The low-level inflow needs to be roughly parallel to the anvil-layer SR flow so that the low level flow parallels the anvil edge.
2. Solar insolation must reach the ground away from the anvil to set up the relative cooling under the anvil.

Anvil-induced baroclinicity

- Prefer low-level inflow to be nearly parallel to anvil-level SR flow.
- Anvil-induced baroclinicity is not a well documented mechanism for enhancing SRH.



This event, occurring on May 6, 2001 in Southern Oklahoma shows an anvil that may be a good candidate for anvil-induced horizontal vorticity production. The anvil layer SR flow and storm motion are nearly parallel. Low-level inflow is nearly opposite to the anvil layer SR flow. The anvil shadow edge should remain relatively fixed. Low-level air parcels acquire increasing horizontal vorticity in the anvil edge-induced thermal gradient the longer they remained in that region. Markowski found that 20 minutes residence time was sufficient to generate mesocyclonic horizontal vorticity of .01 s-1. The depth of shadow-induced cooling was found to be less than 200 m deep. However, the shallow layer shear is also the greatest tornado/nontornado discriminator for mesocyclonic tornadoes.

Perhaps there is some forecasting value to looking for anvil-induced enhancements to 0-1km SRH but the evidence to date is weak. This is certainly a parameter not to depend on to make your tornado warning decision. But if the situation presents itself favorably, you may want to take note.

Forward Flank Downdraft gust fronts?

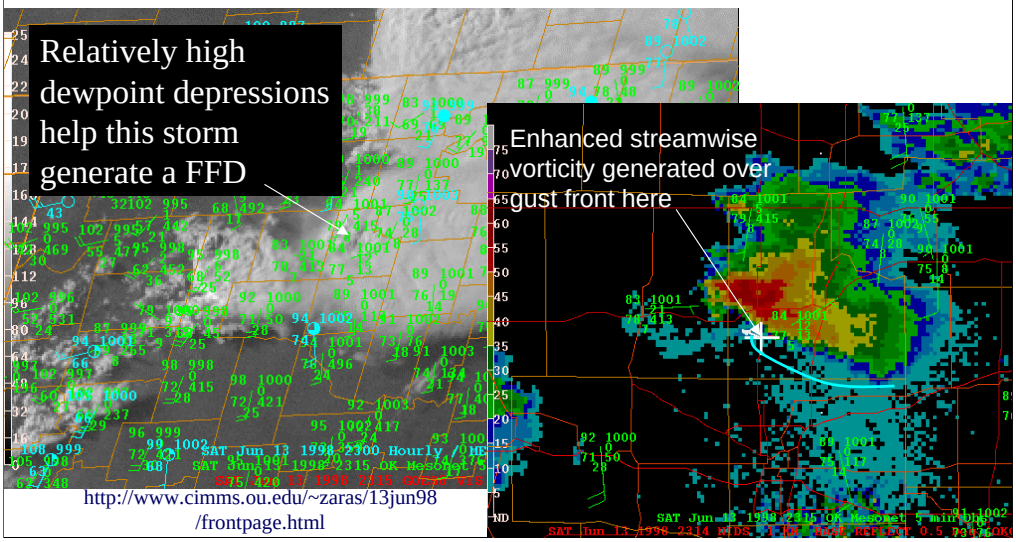
- Theory supports FFDs enhancing 1 km SRH and tornadogenesis through numerical analysis.
- VORTEX (1994-2000) observations unable to observe FFDs in most tornadic supercells.
- The role of FFDs in enhancing SRH and tornadogenesis may help in some cases but is not a necessary condition.

Forward flank downdraft gust fronts have long been recognized as a potential source of enhanced SRH through buoyancy gradient induced horizontal vorticity formation. Numerous stormscale numerical modeling studies continue to support the production of low-level mesocyclogenesis through tilting of forward flank gust front horizontal vorticity.

This mechanism had failed to show up for most VORTEX project cases in 1994 to 1995, and most cases afterwards that were sampled by mobile mesonets. Clearly the necessity of a forward flank gust front for tornado production was shown not to be true in general. However, do not ignore the presence of a forward flank gust front when one does materialize. There have been several documented events with marginal low-level pre-storm shear that likely were enhanced by the production of a forward flank gustfront horizontal vorticity.

Forward Flank Downdraft gust fronts?

Storm with a FFD



http://www.cimms.ou.edu/~zaras/13jun98/frontpage.html

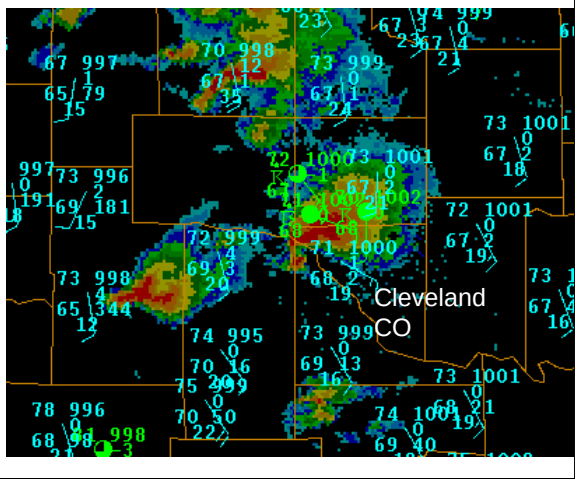
Low-level Forward Flank Downdrafts (FFD) and gustfronts are favored in environments with evaporational cooling potential from sufficiently large near surface dewpoint depressions. This event on 13 June 1998 is a strong candidate for this kind of event. On this day, there was strong deep layer shear and very large CAPEs. Dewpoint depressions averaged between 15 and 20° C.

Note 0.5 ° radar scan overlaid by mesonet data for the same time shows one mesonet with a northeast wind on the south side of the forward flank core. Horizontal vorticity, and SRH are likely to be enhanced in this region just south of the core upon which the updraft ingests this to assist in low-level mesocyclogenesis. Shortly after this image, an F1 tornado formed and lasted about 10 minutes.

Forward Flank Downdraft gust fronts?

Storm **without** a FFD

- Low dewpoint depressions in the environment
- Most VORTEX cases showed similar results.
- A FFD is not required to for tornadogenesis.

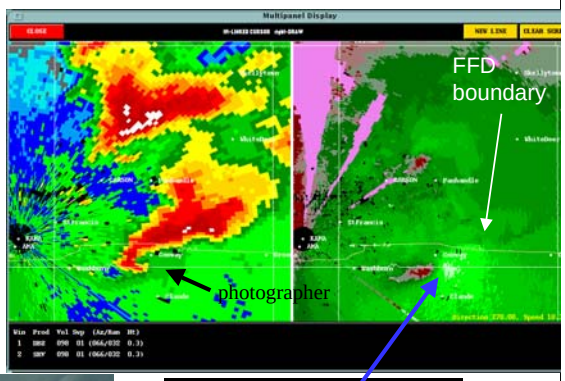


If an environment with 15 to 20 ° F dewpoint depressions can generate a FFD gustfront, then an environment with a nearly saturated boundary layer may inhibit FFD formation. May 3, 1999 provided a classic example. Here, dewpoint depressions were on the order of a few degrees. There was much weaker evidence of a significant FFD gustfront across the south edge of the forward flank core in northern Cleveland County.

Despite the lack of well defined FFD boundaries, this day produced exceptionally long tracked, violent tornadoes. Many of the VORTEX cases had similar environments.

Accelerated inflow

- A case with a forward flank gust front and…
- Inflow acceleration to increase SRH



Inflow acceleration seen best in this storm why?

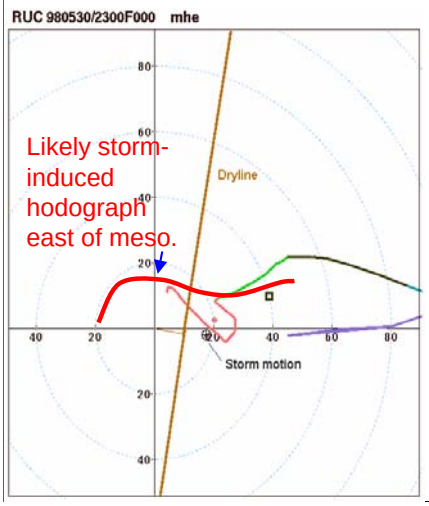
Mesocyclones, by virtue of their enhanced vertical pressure gradients, often assist buoyancy in generating a strong updraft, and consequently, enhanced inflow. Enhancing inflow speeds also enhances SRH given the same embedded streamwise vorticity.

The southern supercell shows very obvious enhanced inflow while the northern one does not. I will let you speculate as to why that is the case.

This event which occurred on 29 May 2001 east of Amarillo, TX produced several tornadoes, but only from the northern supercell.

Note that a FFD boundary shows up in the velocity product in the southern storm. This boundary is likely to reside along the inflow cloud band observed in the photograph.

Accelerated inflow

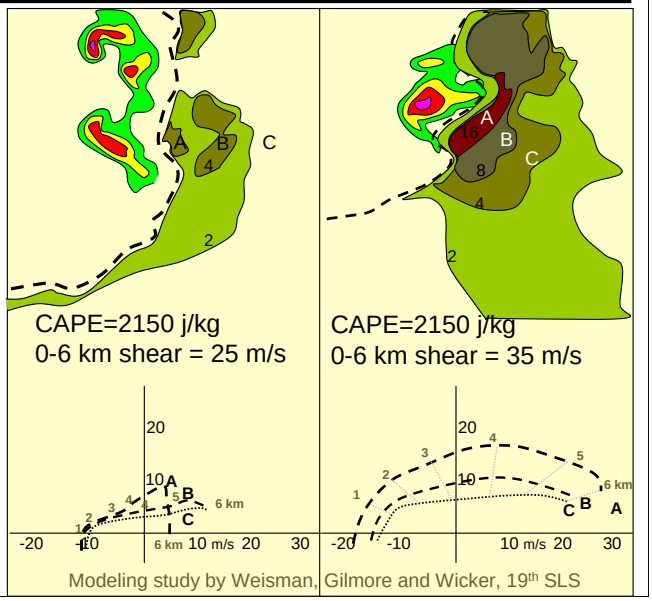


- Weak synoptic scale SRH is often augmented by enhanced inflow into supercells. Two examples are:
  - Spencer, SD 5-31-98
  - East Oklahoma 5-26-97
- Both had strong 0-6 km shear, very high CAPE (>4500 j/kg), low CIN and low LCL.

Accelerated inflow is often not just a shallow feature, and seems to be increase in strength as the deep layer shear increases. Observations from the field also suggest that supercells utilizing very high CAPE (>4500 j/kg) appear to have significantly stronger inflows than weaker CAPE storms. The hodograph on the left was taken from the RUC model sounding east of the Spencer, SD tornadic storm on 30 May 1998. Environmental low-level flow was almost nonexistent. However, there was extreme CAPE and very strong 0-6 km shear (50 kts). Spotters just ahead of the supercell reported inflow of at least 20 kts. Using a little artistic license, the hodograph has been modified in the lowest 6 km based on their observations and a small numerical study by Weisman et. al (2000).

Accelerated inflow

- Multicell in 25 m/s 0-6 km shear increase the shear another 4 m/s
- Supercell in 35 m/s 0-6 km shear increase the shear another 16 m/s



Weisman et. al (2000) ran several experiments where the pre-storm environmental 0-6 km shear was changed, and then the 0-6 km shear was analyzed during the lifecycle of the modeled convection. Their experiments show a large increase in storm-induced shear, with shear values increasing with decreasing distance from the storm (see sounding points C to B to A) on the right hand side. The earth colored shaded regions ahead of the reflectivity core of the storm show where the storm has affected the 0-6 km shear fields. Some of the shear is induced by accelerated low-level inflow, while some is induced by accelerated midlevel flow on the south and southeast sides of the mesocyclone.

Lowering the pre-storm shear produces nonsupercell storms and lower enhancements to the storm proximity shear (see the left side).

Summary: Low-level SRH enhancement

- Close to radar, can detect
  - Forward flank outflow boundaries in velocity
  - Storm-induced inflow acceleration in velocity
- Far from the radar, must infer
  - FFD boundary right of the reflectivity core
  - Adequately high dewpoint depressions
- Anvil baroclinicity
  - Anvil must extend ahead of anticipated storm motion
  - Adequate solar heating right of anvil edge

Low-level SRH enhancement can be detected close to the radar in the form of forward flank outflow boundaries, and storm-induced inflow acceleration.

Far from the radar, your information content goes down and the need for inference and intuition go up. FFD boundaries are most likely to become prominent when supercells produce long forward flank cores and there are adequately high dewpoint depressions in the boundary layer.

Another, less tested consideration, is the anvil baroclinicity. Look for this where the anvil extends ahead of the anticipated storm motion and there is solar insolation outside the anvil shadow.