Threat Assessment

Advanced Warning Operations Course

IC Severe 2

Lesson 3

Updraft Persistence

Warning Decision Training Branch

The title for this instructional component is “Threat Assessment.” This is the 2nd instructional component for the AWOC Severe Track. This is Lesson 3.

Lesson 3 Learning Objectives

1. Identify some considerations for determining updraft persistence.
2. Determine movement and evolution of severe threats.

There are 3 objectives in lesson 3. We will discuss moisture pooling and horizontal rolls as they pertain to updraft persistence. In addition, we look at movement of convective systems, in particular, MCSs.

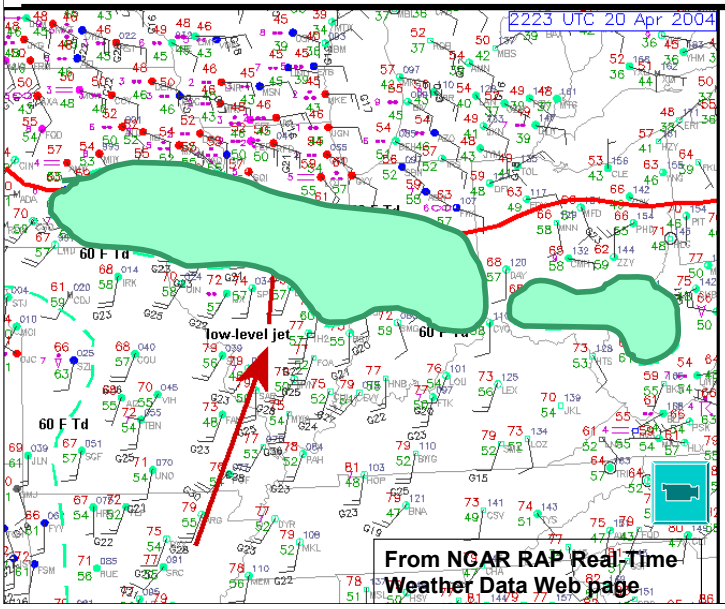
Considerations for Updraft Persistence

- Low-level moisture pooling, persistence
- Satellite indications of rolls, streets

Low-level moisture is an important source for low-level buoyancy and can help sustain updrafts when shear is constant. Numerical models often underestimate moisture in the vicinity of boundaries so satellite data can help locate cloud streets, or horizontal rolls. Horizontal rolls fit the definition of cloud streets as long-narrow lines of cumulus clouds that form due to shear and instability in the boundary layer, and align themselves with the integrated boundary shear vector. In most cases, and when there is sufficient moisture, there are numerous cloud streets, separated more or less equidistant from one another.

Moisture Pooling

April 20, 2004



Axis of >60F Td led to increased SBCAPE to ~ 1500 J/kg by 2200 UTC

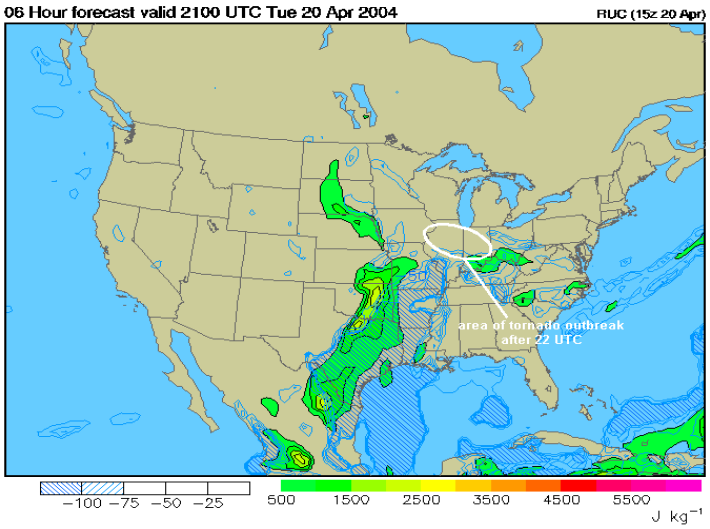
By the way, RUC and Eta both had CAPES ~ 0

This is an example where moisture pooling might have played a part in severe storm development. Area shaded in green are Td > 60 deg F. There are two satellite animations (water vapor and visible) that can be played with this slide to show how portions of northern IL/IN were able to clear out and destabilize during the afternoon.

Moisture Pooling

What the Models Showed

CAPE / CIN (J/kg)



From UCAR RAP page

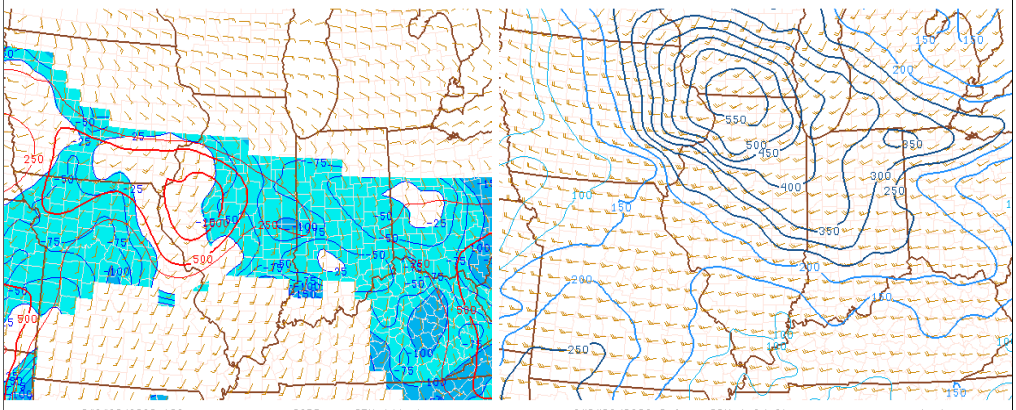
Both RUC and Eta indicated no CAPE across northern IL/IN.

Moisture Pooling

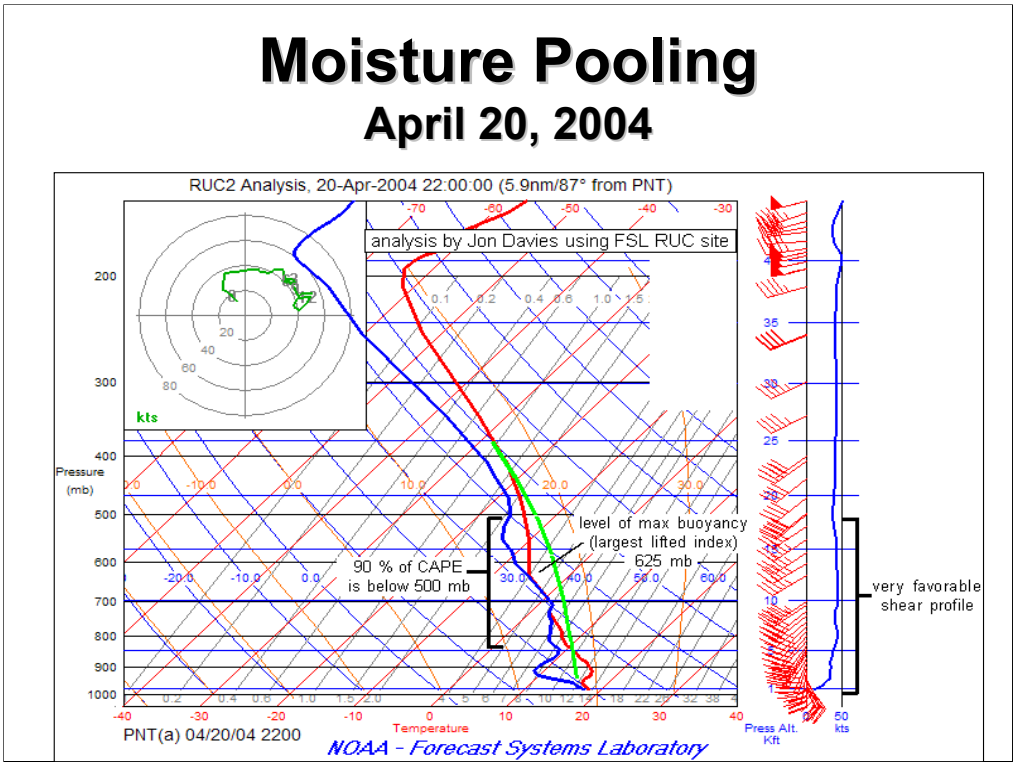
What the Models Showed

From SPC Mesoanalysis Page (RUC-based)

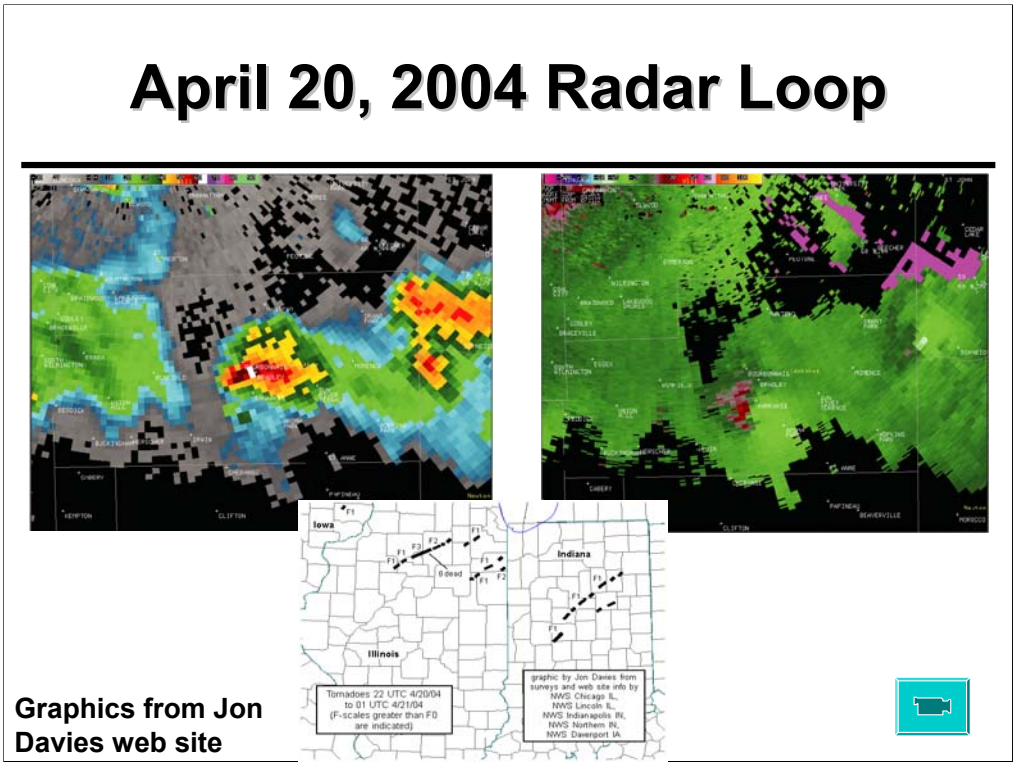
MLCAPE 2300z **SRH (0-1 km) 2300z**



There is a loop of RUC surface dew points on this slide.



This modification of a RUC forecast sounding at Pontiac, MI (PNT) just north of the warm front. In northern IL shows how quickly the environment could change from no CAPE to positive CAPE as the warm front approached. Just as important, notice on the modified profile how much of the CAPE would be located relatively low in the profile. This is a favorable "small CAPE" tornado profile with nearly all the CAPE below 500 mb and the level of maximum buoyancy centered below 600 mb. This is very different from typical spring tornado environments in the plains where only around a third of the CAPE is below 500 mb, and the maximum buoyancy is centered much higher (usually near 400 mb). These results are from a recent case study by Jon Davies (see http://members.cox.net/jondavies3/042004ilin/042004ilin.htm).



To summarize, here are key points from Jon Davies on this case study of April 20, 2004 , and others like it:

1) Model forecasts using lowest 100 mb CAPE largely overlooked and misrepresented the instability for this event.

2) Surface-based or shallower mixed parcels worked better when assessing relevant CAPE from model-derived products..

3) CAPE was located unusually low in the environment profiles for this event, suggesting the setting to be thermodynamically more favorable for tornadoes than total CAPE alone would indicate.

4) The "low-profile" CAPE in this event appeared to be ideally co-located in the vertical with available shear, possibly increasing tornado potential.

5) Monitoring of the rapidly advancing warm front was of key importance in anticipating rapid thermodynamic environment changes favorable for tornadoes.

Davies has noted (see his web site at http://members.cox.net/jondavies3/042004ilin/042004ilin.htm) in small CAPE tornado cases, around 50% or more of the CAPE is typically located below 500 mb, and the level of maximum buoyancy (most unstable lifted index) is centered below 500 mb. This matches nicely a detailed modeling study by McCaul and Weisman (*Monthly Weather Review*, April 2001) that found when shear was sizable and held constant, surface vorticity in simulated storms increased as *CAPE* was compressed into lower levels of the environment profile.

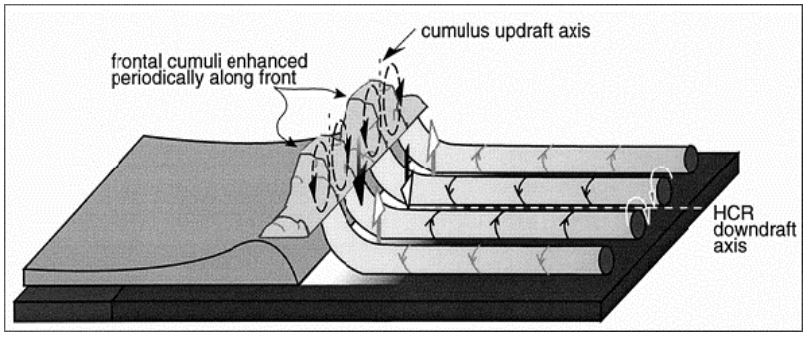
Determining Updraft Persistence

- Evaluate buoyancy via sounding analysis
- Assess large scale lifting (destabilizing effects)
- Assess intensity of mesoscale lift
- Identify horizontal rolls (cloud streets)

Initiation is favored where roll updrafts intersect another boundary, especially for large rolls or rolls with the largest cumulus street.

Horizontal Rolls and Lift

- Initiation often favored where large roll updrafts intersect another boundary (such as a large cumulus street)



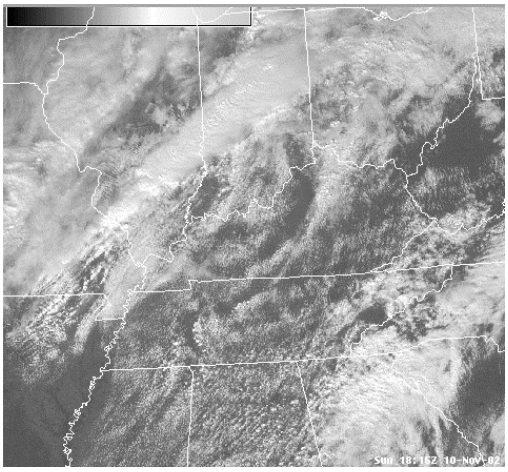
After Dailey and Fovell (1998)

These are some factors for initiation due to roll updrafts intersecting another boundary.

1) Applies best for large rolls or rolls with the largest cumulus street.
2) Note schematic figure from Dailey and Fovell (1998) which shows how the updraft axis of the rolls becomes superimposed on the ascending zone of the boundary to create enhanced regions of updraft. Conversely, the downdraft axis of the rolls will negate or cancel out the boundary ascending air to limit the potential for convection in these areas.
3) Most average roll spacing is only about 4km, the scale of cumulus clouds. There is not much room for enhanced cumulus to grow at the intersection points along a boundary. Occasionally, large or enhanced rolls exist with an aspect ratio of greater than 7. These rolls exhibit greater depths of circulations and will be even more likely areas of initiation where they intersect boundaries.

The initiation of GOES rapid scan (RSO) for severe weather operations is an important tool in diagnosing subtle boundary interactions like those shown in next example.

Roll Example



There is an animation from 10 Nov 2002 showing interaction of horizontal rolls or cloud street into the pre-frontal convective initiation.

Short-Term Threat Assessment
Key Tasks

- Evaluating mesoscale environment to determine
  - Location of significant lifting mechanisms and associated character of lift
  - Location & timing of severe development
  - Likelihood and intensity of specific hazard (tornadoes, flash flooding, etc.)
  - Evolution of threat (especially movement)

Next we will discuss the last 2 bullets.

Likelihood and Intensity of Specific Hazard

- Assessing the threat of a particular hazard
  - Related to conceptual models (See Severe IC1)
- Also,see http://wdtb.noaa.gov/DLCourses/dloc/ic57/ic57-1-screen.pdf (DLOC IC 5.7)

When determining the relative threats associated with a particular hazard, it is important to know the process associated with development - See IC 1. We also cover the hazardous threats in the Distance Learning Operations Course (DLOC), see

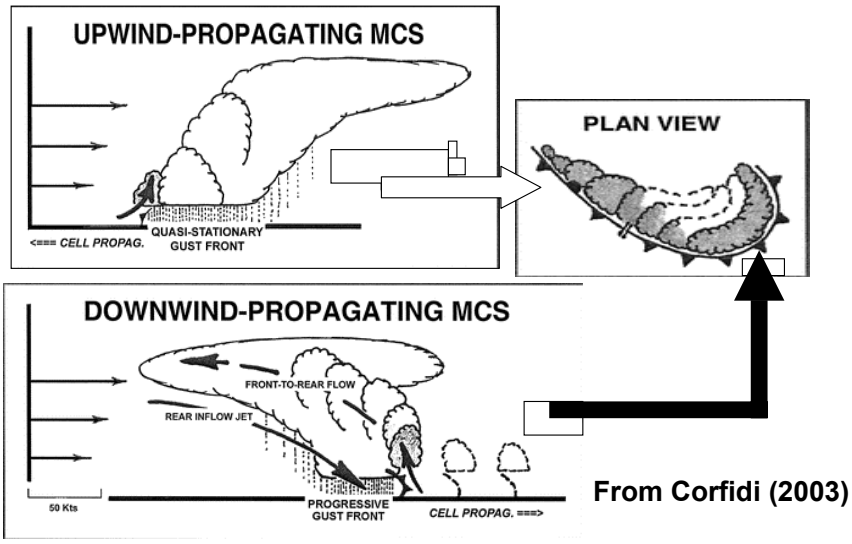
http://wdtb.noaa.gov/DLCourses/dloc/dlocmain.html.

Determining the Evolution of Threats (Especially Movement)

- Use storm/system motion estimate techniques (Bunker's ID method for supercells)
- Look at downstream buoyancy and storm relative inflow (will storms increase or decrease updraft potential)
- Evaluate multicell motion via Corfidi MBE vectors

For supercells, you can use the linear motion tool using motion on Bunker's ID method (See IC 1). For ordinary convection (pulse storms) storms usually move with the mean wind (0-12 km). For the next bullet, downstream buoyancy often, but not always – (see Richardson's (1999) study) influences movement and resulting longevity. Consider Oct.9, 2001 tornadic storms in west central OK (a DLOC mini-exercise) . We know the importance of instability and propagation on multicell motion and longevity (again IC 1) . Now you can use AWIPS or BUFKIT (better) to evaluate multicell propagation effects. But multicell system motion, especially in the early stages, is often quite complicated.

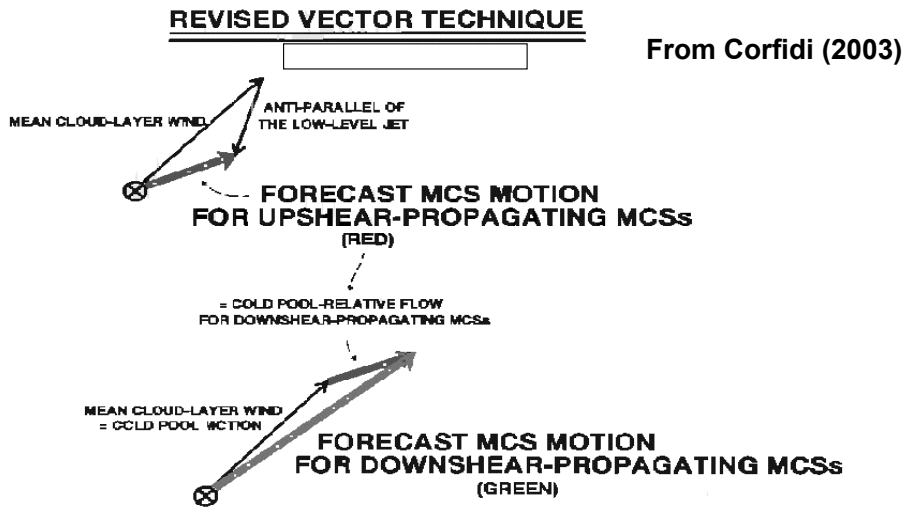
Downwind – Developing MCSs



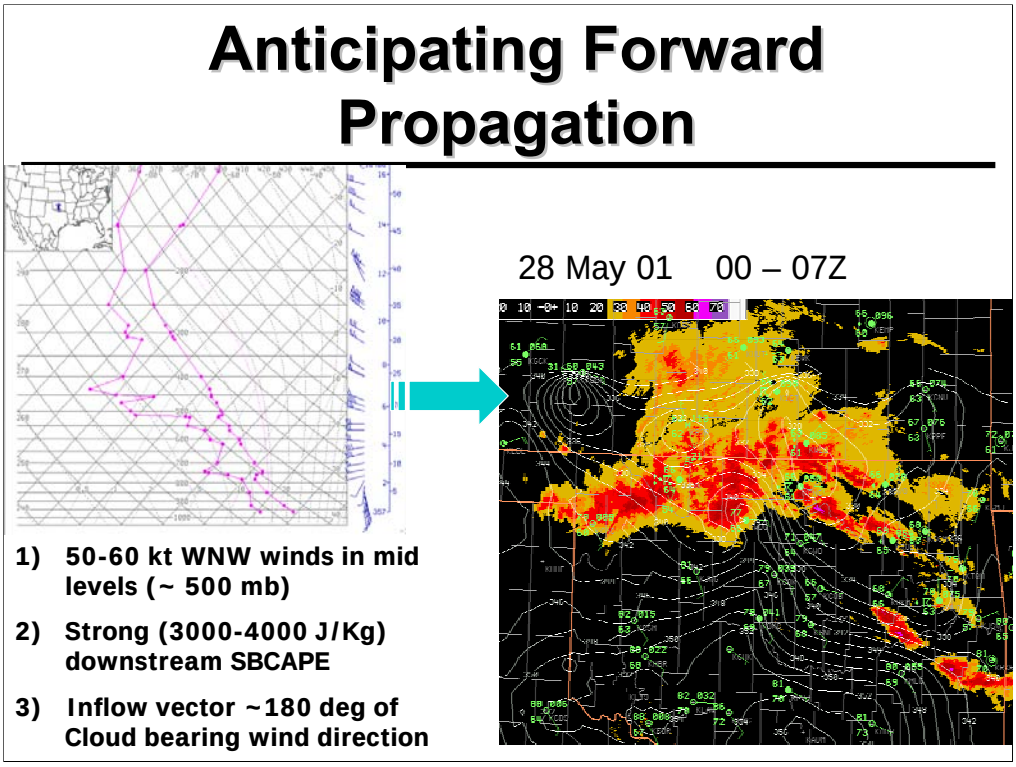
From Corfidi (2003)

Based on Corfidi's (2003) study, a cold pool will elongate in the direction of the mean cloud-layer wind as a result of momentum transfer. The degree of elongation increases as the wind profile becomes more unidirectional, and this effect occurs on all time and space scales. Propagation, or new cell development relative to existing storms, occurs most readily on the periphery of the cold pool (i.e., along those portions of the gust front), where the relative inflow is strongest and where surface-based convective instability is present . Upwind-developing MCSs are most favored along quasi-stationary (mean flow parallel) portions of the gust front, and downwind-developing MCSs are favored on the more progressive (mean flow perpendicular) parts of the boundary. Thermodynamic factors modulate the role played by gust-front orientation and motion. Upwind-developing environments are characterized by comparatively moist conditions through the low to midtroposphere and, therefore, relatively weak convective-scale downdrafts, and downwind-developing environments are characterized by comparatively dry conditions at midlevels and/or in the subcloud layer and, therefore, a tendency to produce strong convective-scale downdrafts.

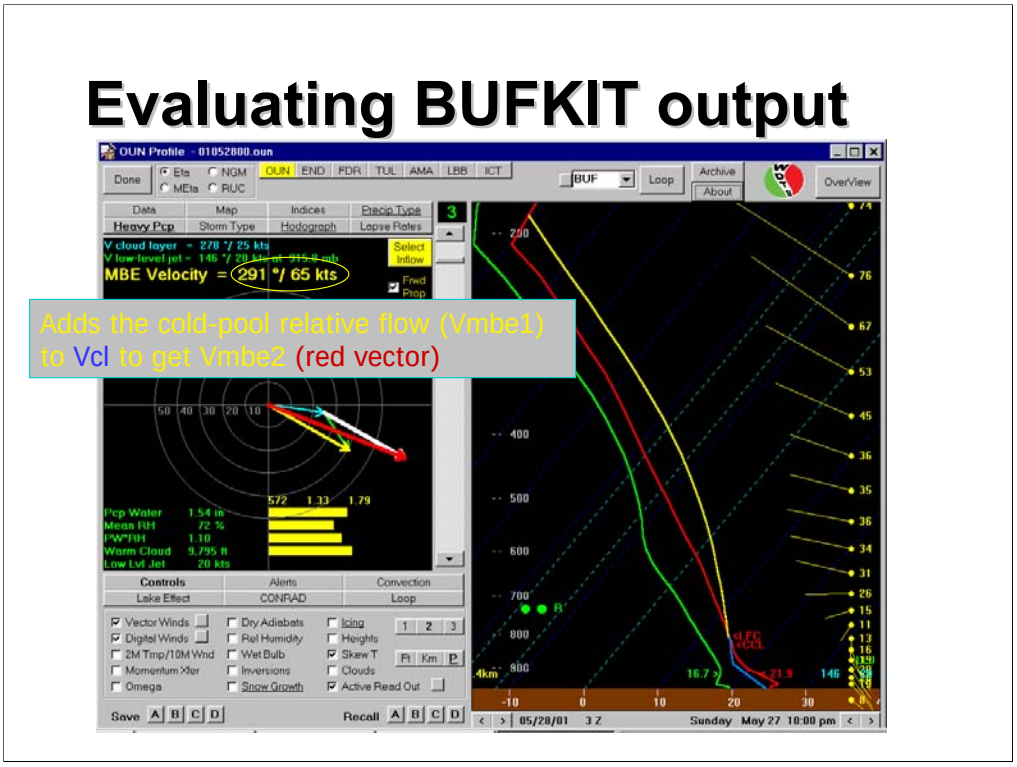
Revised MCS Vector technique



This is a technique from Corfidi (2003) . You can apply this in BUFKIT and AWIPS Volume Browser.

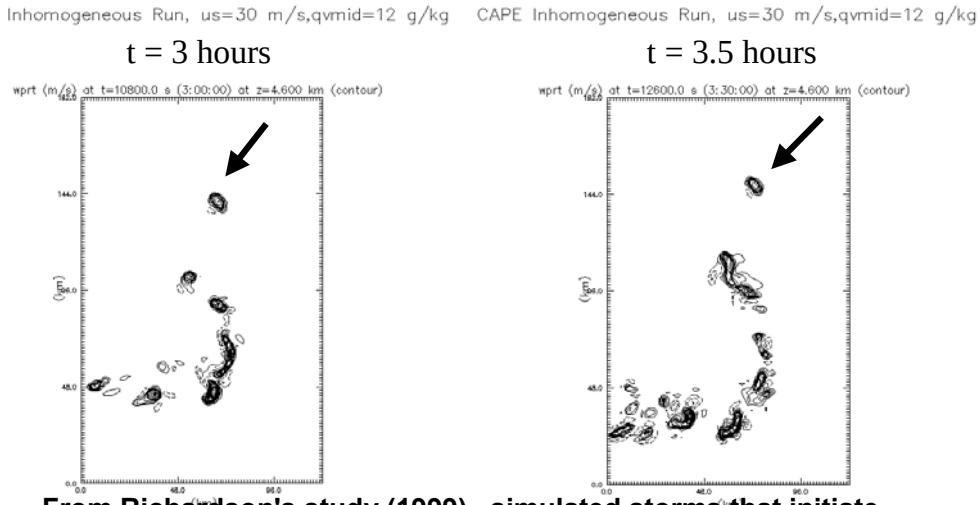


This was a case in OK in May of 2001. Over 100 reports of wind damage across the central and western parts of the state from this forward propagating MCS.



Using Corfidi's technique described in the WAF article, the MBE motion computed in BUFKIT (see vector magnitude circled in yellow and red vector on hodograph display – accessed from heavy pcp button) for a 3 hr Eta forecast sounding was 291 deg, 65 kts. Observed (radar) system motions on along the line were probably closer to 300 deg at 55 kts.

Storm Longevity vs. Environmental Constraints



From Richardson's study (1999), simulated storms that initiate in greater moisture can continue to exist as they move into unfavorable environments

There are also considerations of adjacent storms affecting the environment and subsequent movements. Richardson's study (1999) indicated that simulated storms initiated in greater moisture may continue to exist as they move into an environment that would not support a cell from inception. Split cell motion only mildly influenced by moisture distribution. Updraft strength and mid level rotation are enhanced by increased moisture. Complex cell interactions make definitive conclusions regarding low level rotation difficult. Thus, uncertainties regarding storm/system influences on the environment.

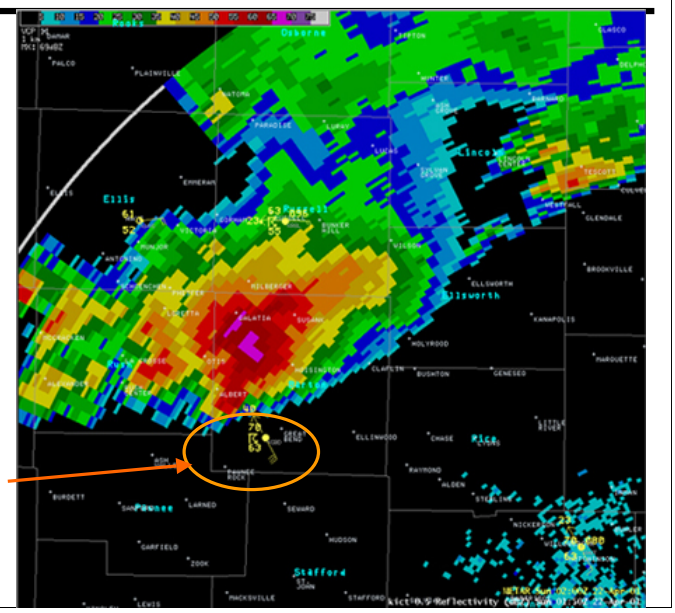
Storm Scale Effects

- How does the storm scale affect the environment (and vise versa?)
  - Anvil-induced shadows
  - Increased accelerations/shear in inflow region (within 30 km)

From Weisman (1998 SLS Preprint), there are significant enhancements in shear and SRH near the storm (10-50% of the environment) due to parcel accelerations in inflow region. To determine a mesoscale sounding that is not storm influenced, consider the effects of the storm in modifying the environment. This influence likely extends out to 30 km (15 mi) from the storm.

Evaluating Storm Scale Effects

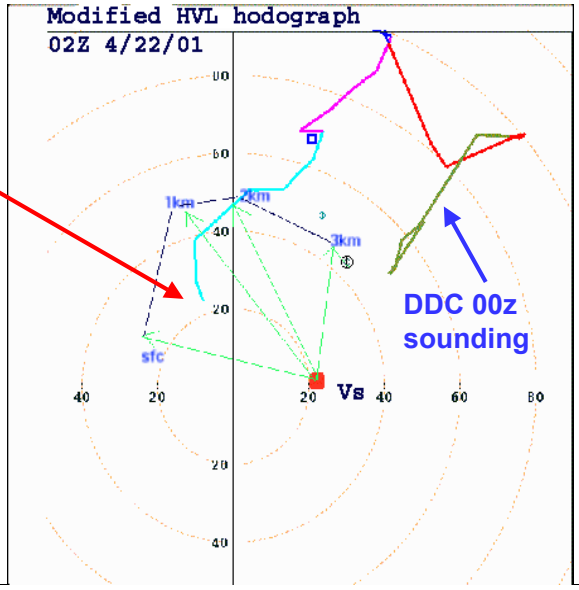
- KICT 0.5 deg. Z product , 20 min. prior to tornado touchdown



This was from the April 21, 2001 tornado near Hoisington, KS.

Determining Storm Induced Changes in Mesoscale

- Profiler at HVL showed large changes in 0-1 km SRH due to storm inflow prior to tornadic supercell development

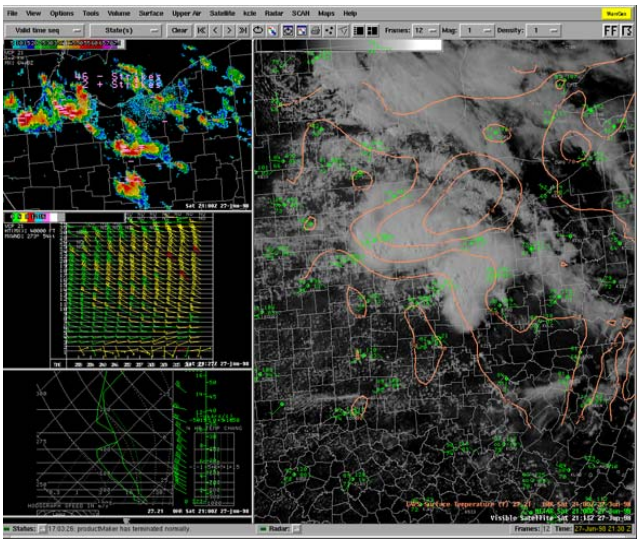


Diagnosing storm-induced changes in the environment (such as this) can provide considerable weight to warning decisions.

By the way, a large tornado (rated F4 damage) developed in Hoisington , KS in this environment

Threat Assessment
Sample AWIPS Layout

- Should include the ability to monitor convective storm development and evolution on the mesoscale throughout the lifetime of event



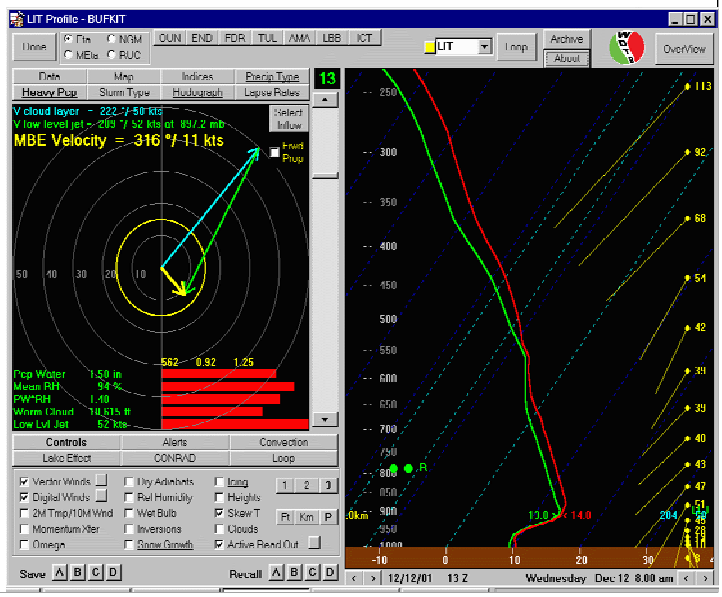
If a dedicated *Meso-analyst* is not available, we recommend **at least one** monitor on your AWIPS warning workstation dedicated to mesoanalysis for all situations when severe weather is expected. The Warning Met should utilize some panes on the AWIPS D2D workstation for proper mesoanalysis. In moderate to outbreak severe weather events, an entire AWIPS workstation position may be needed to perform the duties. It depends on staffing strategies, but some offices may combine the Mesoscale Analyst position with other positions (eg., HMT, long-term, aviation, short-term forecaster, etc.) .

There is a lot of room for personal preference here, but for any situation , the AWIPS workstation layout should provide the opportunity for the mesoscale analyst position to monitor storm development and evolution. Multiple AWIPS datasets providing routine and continuous analysis of the convective environment include GOES and POES satellite imagery, upper-air data, surface data, profiler data, model data, and radar data. In terms of radar data, the mesoscale threat assessment D2D layout should incorporate a **multi-state scale view** of the data so the forecaster can keep abreast of the “big picture”. This analysis is important for the warning Met as he/she often loses track of the big picture during the storm scale interrogation process.

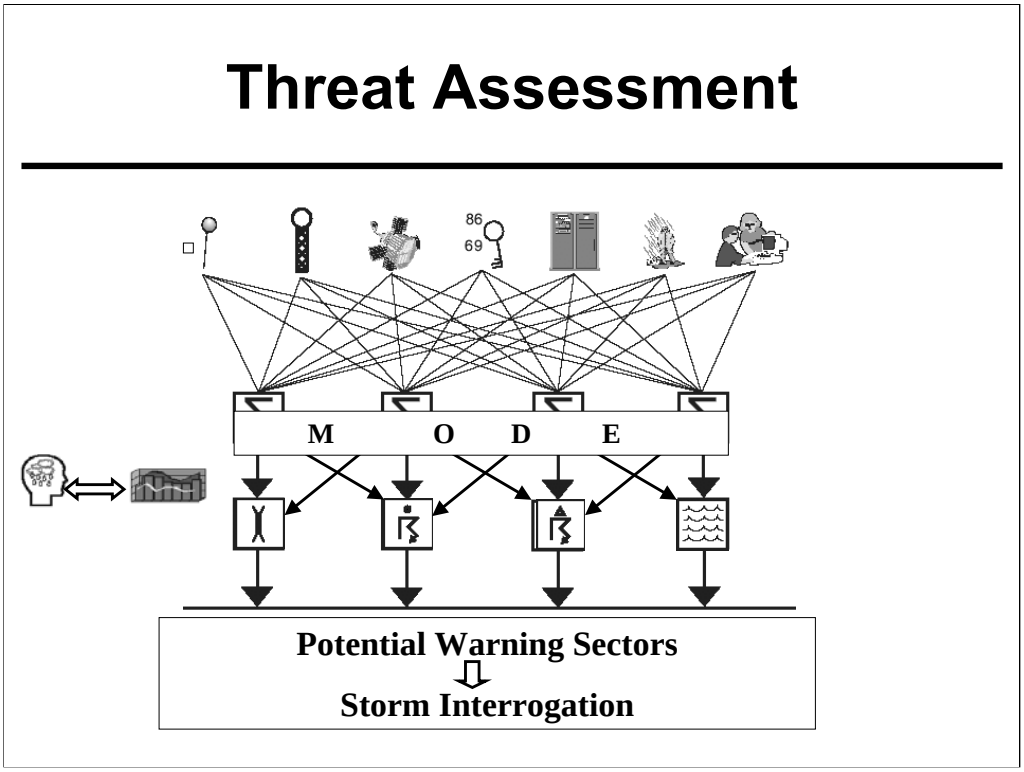
Threat Assessment Layout

- Include a PC box for BUFKIT

- Offers ability to forecast convective mode and motion using various techniques



The ability to recognize potential severe weather types and evolutions is crucial to maintaining situational awareness in a warning methodology. The mesoanalyst position is a vital link in the warning process. The use of hourly forecast profiles offers an excellent way to visualize spatial and temporal changes in the mesoscale.



To summarize the threat assessment process in warning methodology, you could envision an integrated synthesized approach of all synoptic and mesoscale data into a summative forecast of convective storm type. The little head symbol and bar graph on the left of the represent the pattern recognition process. The initial forecast of convective mode (supercells, multicells, pulse) should contain (if possible) an additional probability forecast of tornado, damaging winds, severe hail, and/or flash flooding (note, often multiple types of severe weather are associated with the same convective mode, so this process is often quiet difficult). The type of severe weather that we expect based on the environment gives the warning team initial thoughts for the warning strategy, such as determination of any needs to sectorize warning operations, what procedures, etc. This leads to interrogation process, which is the next step in the warning process.

Summary

- Threat Assessment
  - Outlook
  - Short-term
  - Continuous

Threat assessment is a continuous process on various time and space scales.

References

- See the reference page handout

Contact Information

- For questions on this IC
  - Contact your SOO
  - WDTB focal points for Severe Track IC2
    - icsvr2@wdtb.noaa.gov

There are some instructors at WDTB that can help you with questions on this IC. Send any questions to this e-mail address.

Severe Track IC 2
References

Bluestein, H. B., and M. L. Weisman (2000): The Interaction of Numerically Simulated Supercells Initiated along Lines. *Monthly Weather Review*: Vol. 128, No. 9, pp. 3128–3149.

COMET, 1996: Anticipating convective storm structure and evolution. CD-ROM.

COMET, 1999: Mesoscale Convective Systems: Squall Lines and Bow Echoes. Online training module, http://www.meted.ucar.edu/convectn/mcs/index.htm.

COMET, 2001: Understanding NWP Models and Their Processes, A Distance Learning Course, available at http://www.meted.ucar.edu/nwp/course/index.htm

Corfidi, S.F., 2003: Cold Pools and MCS Propagation: Forecasting the Motion of Downwind-Developing MCSs. *Wea. Forecasting.* Vol. 18, No. 6, 997-1017.

Crook, N. A., 1996: Sensitivity of moist convection forced by boundary layer processes to low- level thermodynamic fields. *Mon. Wea. Rev.*, 124, 1767-1785.

Davies, J., 2004: Tornadoes in a deceptively small CAPE setting: The "surprise" 4/20/04 outbreak in Illinois and Indiana. Web article at http://members.cox.net/jondavies3/042004ilin/042004ilin.htm.

Diagnosing the Potential for Surface Boundaries to Initiate Convection, A VISIT training session produced by WDTB (Jim LaDue, primary author), 2001. Available at http://www.nssl.noaa.gov/istpds/icu92/icu922web/ic922.html

Evans, J.S. and C. A. Doswell III, 2002: Investigating Derecho and Supercell Proximity Soundings**.** Preprints, 21st Conf. Severe Local Storms, San Antonio.

LaDue, J. L., 1998: The influence of two cold fronts on storm morphology. *Preprints*, 19th Conf. On Severe Storms, Minneapolis, MN, Amer. Meteor. Soc., 324-327.

Maddox, R.A., 1980: Mesoscale convective complexes. *Bull. Amer. Meteor. Soc*., 61, 1374-1387.

McCaul, E. W., and M. L. Weisman, 2000: The sensitivity of simulated storm structure and intensity to variations in the shapes of environment buoyancy and shear profiles. Mon. Wea. Rev., 129, 664-687.

Moncrieff, M. W., and C. Liu, 1999: Convection Initiation by Density Currents: Role of Convergence, Shear, and Dynamical Organization. *Monthly Weather Review*, 127, No. 10, pp. 2455–2464.

NWS Professional Development Series (PDS), *Forecasting and Warning Severe Convection*, available at http://www.nwstc.noaa.gov/nwstrn/d.ntp/meteor/svrpds.html

Newton, C. W., 1967: Dynamics of severe convective storms, *Met. Monographs*, 5, 33-58.

Richardson, Y.P., 1999: The Influence of horizontal variations in vertical shear and low-level moisture on numerically simulated convective storms. Ph.D. Dissertation, School of Meteorology, University of Oklahoma - Norman, 236 pp.

Rotunno, R., J. B., Klemp, and M. L. Weisman, 1988: A Theory for Strong, Long-Lived Squall Lines**.** *Journal of the Atmospheric Sciences*: Vol. 45, No. 3, pp. 463–485.

Rutledge, S. A., and R.A. Houze, 1987: A Diagnostic Modelling Study of the Trailing Stratiform Region of a Midlatitude Squall Line. *Journal of the Atmospheric Sciences*: Vol. 44, No. 18, pp. 2640–2656.

Schultz, D. M., 2001: Winter Weather Forecasting Topics at the WDTB Winter Weather Workshop, presentation available at http://wdtb.noaa.gov/workshop/WinterWxIV/presentations/SCHULTZ_.PPT

Trapp, J., R. D., M. Schultz, A. V. Ryzhkov, and R. L. Holle, 2000: Multiscale Structure and Evolution of an Oklahoma Precipitation Event , *Mon. Wea. Rev*., 129, 3, 486-501.

Using AWIPS to Detect Surface Boundaries, A VISIT training session produced by WDTB, 2000. Available at http://www.nssl.noaa.gov/istpds/icu92/ic921.html

Weaver, J. F., 1979: Storm Motion as related to boundary-layer convergence. *Mon. Wea. Rev.,* 107**,** 612-619.

Weisman, M. L., M.S. Gilmore, and L. J. Wicker, 1998: The Impact of Convective Storms on their Local Environment: What is an Appropriate Ambient Sounding? Preprints, 19th Conf. on Severe Local Storms, MPLS, 238-245.

____, 1993: The genesis of severe, long-lived bow echoes. *J. Atmos. Sci.,* 50, 645–670.

Wilson, J. W., and D. L. Megenhardt, 1997: Thunderstorm initiation, organization, and lifetime associated with Florida boundary layer convergence lines. *Mon. Wea. Rev.*, 125, 1507-1525.

Wolf, R. 2002: Doppler radar observations of squall line tornadogenesis near the KDVN WSR-88D. Preprints. 21st Conf. on Severe Local Storms, San Antonio, 507-510.

Ziegler, C. L., and E. N. Rasmussen, 1998: The Initiation of Moist Convection at the Dryline: Forecasting Issues from a Case Study Perspective**.** *Weather and Forecasting*: Vol. 13, No. 4, 1106–1131.