Train the Trainer Notes

Instructional Component 9.6

Using Near-Storm Environment In the Warning Decision Making Process

Produced by Pete Wolf and Brad Grant

I. Introduction:

The methodology of Warning Decision Making (WDM) takes into account both meteorological and non-meteorological factors (1995, Quoetone and Huckabee). An important meteorological aspect to effective decision-making is integration of Near-Storm Environment data (NSE) into the Convective Warning Process . Detailed information from analyzing the mesoscale pre-storm convective environment can provide clues to potential storm evolutions by helping forecasters recognize particular patterns and features that are known to produce specific types of severe weather. The recognition of expected severe weather evolution before an event unfolds is a very important step in the process of heightening the awareness in the user community. Analyzing the pre-storm environment can help forecasters evaluate the potential severe weather threat and often provide significant evidence that will help "tip the scales" in the ultimate warning decision. Moreover, by narrowing the range of expected weather, forecasters are not as likely to be caught "off-guard" in a severe weather warning situation.

Another benefit to the WDM process is that properly analyzing the NSE can help reduce false alarms. The high-resolution data sets currently available in AWIPS provide forecasters with an unprecedented means to perform comparative evaluations of the mesoscale environment for various storms across the County Warning Area (CWA). NSE data often show relative likelihoods of particular storms' severe potential. Thus, storms that are located in "less favorable" environmental regions of the County Warning Area can receive less consideration for potential tornado warnings than storms that are located in "more favorable" environments.

Determining the relative likelihood of severe weather for any given storm is a difficult task for forecasters due to limited data sets sampling the NSE in addition to radar sampling limitations. However, by considering the near-storm environment, the degree of warning uncertainty can often be lessensed.

Over the past ten years, National Weather Service (NWS) verification statistics for severe thunderstorm warnings (SVRs) and tornado warnings (TORs) have shown steady improvements in probability of detection (POD) scores, and slight improvements in average lead time (LT) values. Unfortunately, there has been no improvement in false alarm rate (FAR)scores.

This Instructional Component shows how NSE data can be integrated with radar data in making more informed and ultimately, better warning decisions. By combining NSE analysis with proper radar interrogation procedures and incorporating timely spotter information, an office can achieve improved verification results, especially lower FAR scores. These practices will ultimately improve our public service as a result of better warning decisions.

II. Specific Slide Notes:

Slide 2: The objectives of this Lesson are essentially twofold. First, we will show the usefulness of NSE data in the convective warning process; for better anticipating severe weather evolution, and for better discrimination of severe weather type during warning time. Second, we will show that , in order to use NSE data, you must be aware of the strengths and limitations.

Slide 3: Analyzing NSE data for direct input to the warning decision, which is a result of integrating all scales of data in the forecast funnel approach, is best (but perhaps not most easily) accomplished at the meso-alpha scale (2 km-20 km). Direct observations of storm scale processes (other than a daring storm spotter) are rarely available so often we have to infer the changes in storm morphology as a result of changes in the mesoscale. Analysis of Meso-beta scale (20km - 200km) and synoptic scale (200-400km) phenomena such as low-level jets, squall lines, and Mesoscale Convective Clusters are also very important in the severe weather forecasting/warning process because these features are always better sensed than meso-alpha scale features. The high resolution models (ETA, RUC, MSAS, LAPS) can then occasionally predict how these features will evolve. In both the anticipation and ongoing stages of the convective warning process, proper analysis of all mesoscale data can have a favorable impact on accuracy of subsequent decisions in severe weather outlooks, special weather statements, watches, and even warnings. For example, if a forecaster can correctly diagnose buoyancy and propagation vectors of an upstream squall line or bow echo, then he/she might be able to better estimate the timing of the onset of severe winds and then, parlay that information into NWS products.
Several methods of "pattern recognition" of meso-beta and synoptic scale severe weather phenomena have been researched over the years (by folks at the SPC, HPC, and other places) and there is a good web site which shows examples of this severe weather forecast process. Please see this web site: http://www.nwstc.noaa.gov/d.MET/svroutlk/Outlook.HTML
Identifying the threat area of expected severe weather is the first step in integrated convective warning process.

Slide 4: From Warning Decision Making (WDM) Workshops, a warning decision can be thought of as a balance where the weights of evidence from various data sources act to swing the balance of a warning. NSE data is another input (just like radar, spotter reports, gut feeling, etc) that can help to "accumulate the evidence" for issuing a warning. NSE data is also very important at helping to determine the type of warning (SVR or TOR).
Slide 5: NSE data is used extensively at the Storm Prediction Center to help make their Outlook and Watch decisions. This Tornado Watch example from April 9, 1998 has enhanced wording "particular dangerous situation"(PDS) terminology which is used when multiple strong tornadoes (F2 and F3) or at least 1 violent tornado (F4 or F5) are expected. Also, there is usually a high likelihood for 3 or more tornadoes when PDS watch is issued. For this case, a high risk outlook was also in effect for portions of AL and MS, so this should be a red flag for warning forecasters to carefully monitor the NSE for areas of greatest severe weather threat when storms do initiate.

Slide 6: Knowledge of the NSE , such as diagnosing where the most unstable areas will be located in the next hour, or where the largest pressure falls are occurring, can help direct the warning forecaster to very closely interrogate storms that form in those areas. If a storm or storm system is moving into a favorable area of enhanced storm-relative helicity (moving parallel to a boundary, for example), then this occurrence should heighten the forecaster's awareness of the tornado potential in that particular storm.

Slides 7-8: It is significant to note that the improvements in verification scores at NWS Wichita (ICT) are not observed regionally or nationally. The improvements at ICT are likely the result of the actions taken at the office to improve warning decision making. The trends here suggest that appropriately using NSE information in the warning decision making process can improve verification skill. Since the early 1990s, warning decisions across the NWS were primarily based on WSR-88D data, and occasionally, storm spotter reports. While these data have helped produce higher POD and LT scores, they have had little impact on the high FAR scores, a critical statistic for judging the accuracy of warning decisions and likely customer response to these decisions.

By comparison of national verification scores and trends during the past decade with those for NWS Wichita, the producers assert the following:
1) Current technological advancements and improved algorithms may help the NWS achieve higher POD scores and LT scores, but may only provide limited improvement to already high FAR scores.
2) Providing NSE information to NWS offices and training on how to properly apply the information will likely lead to substantially lower FAR scores, with little impact on POD or LT scores.
2) Further technological advancements such as dual-polarization radar data, D3D for 3-D imagery, algorithm improvements through incorporation of NSE data, combined with the proper training on how to utilize these tools, will likely provide the best scenario of both higher POD/LT scores and lower FAR scores. Such a solution will likely lead the NWS to reach its goals for TORs, and may assist in other goals such as those for flash flood warnings.

3) Wind profiler observations, surface mesonet observations, LAPS data, and enhanced satellite imagery and derived products can provide critical NSE information that forecasters can use to make more effective warning decisions.
Forecasters at NWS Wichita have noted numerous times where substantial environmental differences in time and space have been observed across the station's County Warning Area. In many situations, knowledge of these differences was critical for making the correct warning decisions. One example took place on April 19, 2000, when forecasters recognized important vertical shear over southeast Kansas, compared to surrounding areas, and correctly anticipated tornado development, going straight to TOR decisions instead of initial SVR decisions. This provided added lead time before damaging tornadoes struck populated areas, likely saving many lives. The Wichita WSR-88D radar was over 90 miles away, and did not show obvious signatures.
Another case occurred on April 3, 1999. Forecasters recognized environmental differences south and north of surface cold front, and correctly anticipated a diminished threat of damaging winds from a bow echo as it moved north of the front, despite impressive radar signatures. False alarms were prevented.
There were numerous similar examples in 2000 in which NSE data helped forecasters at NWS ICT to correctly decide to issue warnings,or **not** to issue warnings. Forecasters at NWS Wichita made better warning decisions by applying NSE information from AWIPS-era data sets in the warning decision-making process.
Slides 9-11: Although the benefits of analyzing the NSE are great, it does not come without some costs, mainly time and effort. To adequately accomplish detailed mesoscale analysis during

convective events, it takes a dedicated mesoanalyst position, something many NWS offices may not utilize. Too often, the warning forecaster is occupied with analyzing radar data solely and thus may overlook important NSE data. With AWIPS, one can easily call up many useful NSE data to complement WSR-88D data such as satellite, surface observations, profiler, lightning, and model output. A separate AWIPS workstation devoted to mesoscale analysis of the NSE is one way to perform these functions. Integrating the NSE data with radar observations is vital to staying abreast of the changing nature of the severe weather (or winter weather) event.
In 2000 at NWS Wichita, a mesoanalyst position was utilized during many convective events. In addition to issuing frequent short-term forecast products, this person kept the warning team updated on changes in the NSE by calling up wind profiler data, LAPS data, satellite, lightning, and other model output. This information was incorporated into all warning decisions.
In the unfortunate event that dedicated mesoanalysis is not utilized in a warning event, here are some fields which would represent at least a minimum of NSE data sets that should be analyzed in conjunction with radar data for warning operations:

1) **Surface Observations** (Analyze every hour, more often if mesonet obs are available) to detect local backing winds (enhanced low-level helicity), rapid pressure falls, and diminishing temperature/dew point temperature spreads. [(1)]
2) VAD Wind Profiler (or 414 MHz Profiler) Analyze every 5-10 minutes to assess changes in low-level vertical wind shear.
3) LAPS output of CAPE/CIN (plan view): Analyze hourly for local maxima and gradients, not so much absolute values.
4) LAPS Storm-Relative Environmental Helicity (SRH) (0-3 AGL) taken in the upstream pre-storm environment air mass. Analyze hourly and be ready to modify hodographs especially in lowest 0-1 km based on changes to surface wind fields.
5) Satellite Imagery (Analyze as soon as updated imagery is available) Analyze boundaries, jet streaks, rapidly cooling cloud tops, enhanced-V signatures, and accompanying changes in storm top growth characteristics. [Note: For an excellent paper on the use of analyzing mesoscale severe storm features using GOES satellite imagery , refer to "A Satellite Perspective of the 3 May 1999 Great Plains Tornado Outbreak" by Dan Bikos, John Weaver , and Brian Motta (paper submitted to Weather and Forecasting Feb. 2001)]

A more complete list of parameters to analyze including some established thresholds is available in Figures 1 and 2.(Note: These parameters and values have been evaluated by Pete Wolf to be useful for analyzing the Mesoscale convective environment in the NWS Wichita CWA. These parameters are intended to be used as tools and for guidance purposes **ONLY**! Values shown have been subjectively evaluated, and may vary from one location or season to another. Moreover, it is likely that there might be some variation in application of these values in other regions of the country.)

Slides 9-12: Impediments to Using NSE Data
Slide 9 represents an example of a typical problem models have with resolving mesoscale features in surface analysis. There are 3 different mean-sea-level pressure (MSLP) analyses at the same time shown here overlaid with the surface observations. The yellow contours are from

00hr Eta forecast at 18Z (30Jun 98), the blue lines are from the Mesoscale Surface Analysis System (MSAS), and the green lines are from the Local Analysis Prediction System (LAPS). Both the MSAS and the LAPS show some sort of a pressure trough or frontal boundary extending from a Low in central Iowa southwestward through southeastern Nebraska into northern Kansas, although the LAPS Surface analysis shows more detail with a strong Meso-high analyzed north of Omaha. The Eta 00hr forecast, on the other hand, depicts a surface high over Iowa and most of the area across western Iowa and eastern Nebraska in anticyclonic surface flow. For derived NSE products such as CAPE and SRH, model differences can even be more pronounced. Thus, for forecasters, these are typical of problems with determining which models and which fields can best be used to analyze the NSE. It takes time to verify model output with observations, which is something you should **always** do in analyzing the mesoscale environment.

Slide 10 shows an example of SCAN output (Storm Cell Table with SCAN products on a radar reflectivity product. Radar data can often preoccupy warning forecasters with its output so that you can lose "sight" of the environment and how it is changing, thus risking the loss of important situational awareness in warning decisions. Slides 11 and 12 illustrate another problem with monitoring the mesoscale environment. If you don't analyze for mesoscale changes, or, even worse, you analyze it erroneously, it can sometimes surprise you. This was an event that occurred in MN in July 1, 1997. Initially, there was a large capping inversion that inhibited deep convection over portions of Iowa, S. Dakota, and Nebraska. Anticipating the mode of convection was also problematic as shear profiles favored supercells but due to the fact that much of the convection formed along and just north of a warm front in southern/central MN, the resulting convection was in the form of a large bow echo complex and much of the severe weather was from damaging winds, non-supercell tornadoes, and flash flooding, not from supercell tornadoes. Refer to this web site for the importance of using observed or model data to assess changes in buoyancy and shear in the convective storm environment. There are three cases shown in this Instructional Component which illustrate the importance of utilizing mesoscale analysis to detect changes in storm evolutions. The bottom line is that it does takes time to do proper mesoscale analysis but the benefits are that it can reduce "surprises" in storm evolutions.

Slides 13-15 refer to the box of tools available for mesoscale analysis. It is important to know the strengths and weaknesses of all these available data sources and utilize them effectively in the integrated forecasting and warning process. For the purpose of this presentation we will discuss primarily model data (LAPS, MSAS, and some RUC) output.
MSAS uses persistence as a background and in data void (or data sparse areas) areas uses the NGM (Eta in Build 5.0) as a background grid (1st guess). The Eta grids are linearly combined with 1-hour persistence , using weights calculated to produce a persistence forecast over data-dense areas, a model forecast over data-sparse areas, and a smooth transition between the two. The MSAS covers a 40 km grid spanning the CONUS area and neighboring areas of Canada and Mexico. It provides hourly analyses of several surface parameters. MSAS provides continuity from observation to observation since it incorporates the previous analysis as the background for the current analysis. MSAS minimizes the effects of varying terrain by using potential temperature. It output is smoothed but it can provide some benefits by enhancing your mesoscale

analysis of fields such as temperature, pressure, and dewpoint. Analyzed fields such as 3-hr pressure falls or equivalent potential temperature are examples of some of the parameters fields to display. More information about MSAS is available at this web site: (http://www-sdd.fsl.noaa.gov/MSAS/msas.html)

It is always important to verify the MSAS analysis with observations (see frame #19) because often the MSAS misses important observations, such as this example. Note the 65 deg F dewpoint contours in the MSAS does not "catch" the 19Z METAR at KBGM. Because MSAS uses persistence as a background will often cause some observations to be omitted in its objective analysis. Slide 28 is a 6 hour loop of MSAS winds with surface obs and radar overlaid. You can see the effects of storm-induced outflow boundaries and wind shifts which do not get picked up in the analyses. These wind shifts are important NSE data to analyze because they can influence regions of local instability and shear. Thus, MSAS analysis should be augmented hourly by observations, or use a higher resolution surface analysis. In addition to the MSAS gridded output, you can also display observations used in each MSAS analysis.

Given adequate time, however, there is no replacement for hand mesoanalysis. Certain features such as boundaries, moisture ridges, etc., can be effectively analyzed with considerable detail by using hand mesoscale analysis of P, T, Td, wind, and pressure changes. AWIPS does provide a quick way to print out plots of surface obs.

Slide 29: Summary of MSAS performance during the 5/31/98 tornado outbreak: The surface analysis of temperature and moisture fields (Theta-E) showed well the axis of instability where storms in eastern New York initially developed and became severe. MSAS depiction of the degree of instability south of the first line of storms in BGM's CWA was not as representative of reality and this is where LAPS can (and should) be used.

Slides 30-32: The Local Analysis Prediction System (in AWIPS 5.0) contains analysis graphics (the predictive components are planned for later builds) on a 10 km grid and covers an area slightly large than the WFO scale. The AWIPS version of LAPS runs on the Application Server 2 (AS2) 20 minutes after the hour using NOAAPORT and LDAD data that has been translated into netCDF files on the AWIPS platform for use by the LAPS ingest processes. The Ingest flow chart (slide 30) shows the types of data used in LAPS (blue colored). The other data are being used in FSL's full-blown LAPS and can be potentially added to AWIPS LAPS if/when the data becomes available (5.1 or 5.2). RUC is the background model for LAPS. The LAPS modules included in this 5.0 version are surface, temperature, humidity, cloud, wind, derived parameters, and soil parameters. LAPS modules use a mixture of required and optional data to prepare their products. If the modules required data aren't present, the LAPS module does not run. If the module's optional data are not present, that LAPS module will run. Here are the data that LAPS uses:

- Model data (RUC is the first choice, the ETA is used if RUC is not available.

- Satellite Imagery (GOES-E or GOES-W IR Imagery)

- Surface METAR observations

- Profiler data (only used by midwest 404 MHz network sites)

- Surface buoys/Ship reports

- Radar reflectivity (0.5 deg. Z)

LAPS provides better overall detail than MSAS in the analysis of surface parameters, but if the required data are present and the optional data are not, the LAPS modules still run, creating LAPS products without the optional data. This can create variation from hour to hour for LAPS products and from site to site, depending on data availability. It provides better moisture profiles with 21 vertical levels (50 mb deep) used in the analyses. The current version of LAPS in AWIPS uses a successive correction method for the objective analysis scheme. It works like this: it starts out with RUC as the background (1st guess); it combines all the obs, does a satellite data analysis, does a moisture analysis using some variation techniques, does a temperature and wind analysis, does a radar analysis (which checks 0.5 deg Z for cloud and precip consistency), then finds the differences between the observations and model initialization. The observation corrections are successively analyzed to minimize the errors using a Barnes Incremental multiple error analysis scheme. Later versions of LAPS (5.1.2) will use a "balance package" which will balance output from the various analysis packages (Moisture, cloud, etc.). More information about LAPS is available at this FSL web site (http://laps.fsl.noaa.gov).

Slides 33-51: Performance of LAPS in 5/31/98 case
LAPS did a very good job of assessing changes in stability, general updraft strength (defined in terms of CAPE), and variations in SRH in the convective environment over the ALB and BGM CWA. There were some opportunities (ex. slide 48) where LAPS point soundings could be used to assess differences in CAPE/SRH with storms separated by only 2 counties! This NSE information could be used effectively in the warning decision. LAPS did a better job at showing the recovery of the airmass (sharper theta-E gradient) in advance of the second wave of storms in BGM's CWA.
One note of caution with using LAPS data: There are times when the mesoanalyst will need to investigate "spurious" maxima and minima which show up periodically in the LAPS analyses. Bad data will need to be flagged and should be removed from the analyses as part of a manual QC process. There is a way to blacklist portions of bad observations in Build 5.0.

Slides 52-83: Performance of MSAS and LAPS during 4/9/98 early Spring case.
LAPS seemed to do a pretty good job for the most part in delineating "favorable" over "not as favorable" areas in BMX's CWA. Fields such as CAPE, Theta-E , and Lifted Index especially

targeted the large supercell storm which first became severe in Pickens County, Alabama at 0002 UTC (first tornado report). This storm went on to became a long track supercell which produced 3 separate tornadoes over a 3-county area including a powerful F5 rated tornado which killed 32 people in Jefferson, County Alabama. LAPS provided some important storm comparative information to the warning decision making process in terms of variations of CAPE and Helicity (SRH). One storm which produced a small F1 tornado in DeKalb county at around 0123 UTC despite the fact that the storm was moving into an area characterized by LAPS as more stable (CAPES around 500 J/KG) than surrounding areas (See frame 81). Thus, it is important to use LAPS data cautiously (using observations to verify and QC the analyses) and be mindful of situations where the storm's environment presentation (CAPE and shear) may not be representative of the "true" storm environment. **Indeed, the radar signatures in base velocity, reflectivity and especially in derived algorithm products may actually show misleading representations of decreasing severe storm potential due to sampling (range) considerations.** In those cases, spotter reports may be most useful in helping to verify radar and NSE output.

Slides 84-91: Case #3
For this Cool-season case, LAPS showed some interesting differences in CAPE with 0-6 km shear and 0-3 km SRH pretty well uniformly distributed throughout the domain (See slide #85). The LAPS analysis showed that the highest CAPE remained in a narrow corridor along the squall line, thus storms that developed well ahead of the squall line may have had trouble maintaining deep persistent updrafts. Indeed, in comparing the two LAPS soundings at 08Z on slide #87 (point A) and slide #88 (point B), there was some indications that suggested updraft parcels for the pre-squall line storm at point B were becoming elevated (note cooler surface layer)as they moved rapidly off to the NE. Whether this may have played a part in the failure of pre-squall line storms (point B) to produce a tornado (despite strong persistent low-mid level circulation (TVS triggered on this storm 4 times!) is speculative. But the storms on the squall line (point A) did not show a clear velocity or reflective signature indicative of a tornadic storm, but clearly the NSE was more favorable for storms to persist along the central portion of the squall line.
Some differences were noted in the LAPS output for SRH. These result from some differences in how the various programs compute the storm motion vector. The plan view LAPS helicity values are based on integrating storm-relative environmental helicity (Storm-relative environmental) from the surface to 3 km AGL. It is numerically equal to -2 times the hodograph area. A calculated storm motion vector is used. First a layer from the sfc to 300 mb is used to compute the mean wind. A shear vector through the sfc to 300 mb layer is also calculated. The storm motion is assumed to equal the mean wind plus .15 times the shear vector (rotated for a right mover by a 90 degree angle with respect to the shear vector). Thus, the mean wind is from the sfc to 300 mb (approx 9.1 km).
On the other hand, the AWIPS interactive skew-T computes the mean wind from 0 to 6 km AGL and the SRH values listed are based on the storm motion that is 30 degrees to the right of and 75 % of the mean wind. In addition, a bigger bug that recently has been found in Build 5.0 is that AWIPS observed SRH values (shown as the number above the hodograph) are 2 times as high as what is actually computed from the hodograph. This is attributed to a units error. The plan view SRH values from the LAPS appear to be fairly representative of the actual SRH int henear-storm environment, but again be aware of data sparce areas where LAPS will heavily weight the

background model. Eta and RUC derived SRH values from soundings also show considerable hour to hour difference.
Thus, warning forecasters performing mesoanalysis of SRH must be aware of these model to model differences and how sensitive SRH is on storm motion. Using the observed storm motion from the Storm Track Algorithm or distance speed tool on AWIPS and then augmenting your local hodograph from LAPS, VWP, or profiler may provide the best best way to estimate SRH.

Slide 92: overall summary
Proper use of LAPs and MSAS datasets can provide timely analysis of the mesoscale environment and provide substantive input to the warning decision making process. The meso-analyst should perform hourly Quality Control of observations which get processed into the LAPS and MSAS analyses. Past verification statistics have shown that warning decisions based primarily on radar signatures and algorithm output result in high POD and FAR scores. Further improvement, especially in FAR scores, requires improved anticipation of severe weather conditions. Such improved anticipation requires knowledge of the NSE, and how environmental conditions change in time and space. Understanding NSE and the weather conditions supported by such environments, are important considerations for making better warning decisions.

Slide 93-109 (new case #4) Des Moines Derecho Event 6/30/98
This was an event that was challenging in the fact that forecasters needed to become aware of the scope of the event (a very high-end damaging wind event). In addition to the extremely high winds (some reports in excess of 120 mph) over a broad swath, there were some isolated tornadoes along the line.
A few things stood out in analyzing the NSE data. First, the ETA model vastly underestimated the amount of moisture and instability int he pre-storm environment (see the 6 hr forecast sounding valid at 18z and the mid-level drying- slide #97). There was quite a bit of CAPE , on the order of 3000-4000 J/kg at various times ahead of the line in cntrl/srn IA as the system rapidly instensified and moved Souteastward during the late morning of the 29th. LAPS showed this high CAPE. Also, the steep lapse rates (see slide #98) ahead of the system indicated a very high potential for damaging winds (Theta-E diiference from the surface to a minimum at 500 mb was 35-40 deg C). Large pressure falls at the surface (3 to 4 mb/hr) developed in response to a larger scale mesolow forming in cntrl IA (See slide #101). Low-level winds started to pick up and veer below 2 km between 16 and 18z which helped the line to accelerate and then a "big meso" developed just ahead of the line (btwn 18-1811Z). Low -level inflow then began to drive the storm as the line merged with the meso and the whole segment bowed out across Dallas and Polk Counties. This is where most of the most intense wind damage occurred.
LAPS and MSAS data, augmented by surface obs provided the best indications that the atmosphere was becoming extremely volatile for a big wind event.
Slides 110-111: This is some NSE data available on the night of April 21, 2001 in w cntrl KS. The Haviland Profiler from 00-02Z indicated increasingly strong shear from the surface to 4 km which, when combined with an unstable airmass helped storms to develop deep rotation. By modifying the hodograph from the Haviland profiler (which was considerably different than all other vertical wind profiles observed in the data earlier in the evening) with with the 02Z Great Bend METAR observation (approximately 20 miles south of the eventual tornadic storm) and a 270/20kt storm motion, you get a hodograph approximately similar to the one shown in slide

111. The estimated SRH (0-3 km) is over 450 m2/s2. This type of augmented SRH especially in the lowest levels (0-1 km) is important to detect because this means that storms that develop (or move) into this type of environment have a much greater likelihood for becoming tornadic than otherwise (unless the storm interacts with a pre-existing boundary). Often, one hour changes in the vertical wind profile can mean all the difference in the NSE. In mesoanalysis, it is very important to detect thse type of clues.
Slides 112-150: Warning Decision-Making Exercise .
Please use the Response Key (See Figure 3) for your answers.

Figure 1.

MESO-ANALYST SEVERE WEATHER GUIDE

Notes:

1. This tool is provided for **guidance only**. Values given are subjective, and may vary from one location or season to another.
2. Each factor provided should be considered INDEPENDENT of the others. Just because one is deemed unfavorable, does not mean the result (e.g. large hail) should not be expected.

Category	**FACTOR** (notes: see related number on next page)	**VERY FAVORABLE**	**FAVORABLE**	**SO - SO**	**UNFAVORABLE**
Storm Initiation	(1) Low Level Boundary(convergence, frontogns)	Strong	Moderate	Weak	Lack of boundary
	(2) 2 x Sqrt(CAPE) +SR-Inflow (Sqrt=square root)	> 125kts	100 - 125	80 - 99	< 80
	(3) CIN (J/Kg)	< 15 j/kg	15-30	30-60	> 60
	(4) 700-850mb Isentropic Flow	Strong Upglide	Weak/Mdt Upglide	Little/No Upglide	Downglide
	(5) B.Lyr - 400mb Wind Speed/Direction Difference	> 100	75-100	50-75	

					< 50
Large Hail	(6) 400-700mb SR-Flow (kts) (7) Environ. or Updraft Freezing Level Height (AGL) (8) Mesocyclone Intensity/Depth (2) 2 x Sqrt(CAPE) + SR-Inflow =	> 30 < 11,000 ft Strong, deep meso > 125 kts	20-29 11,500 - 13,500ft Mdt, deep meso 100-125	12-19 14,000 - 16,000ft Weak/shallow meso 80-99	< 12 17,000+ ft No meso < 80
Dmgg Winds	(9) 500-700mb Dewpt Depression (C) (10) 850-500mb Lapse Rate (C/km) (11) Sfc thetaE-lowest thetaE in 400-700mb layer (K) (6)400-700mb SR-Flow (kts) (12) 3-hour Surface Pressure Change (mb) (13) Lowest 50- to 100-mb Dewpt Depression	> 20 > 7.5 > 25 > 30 > 6 > 15 moist- to dry-adiab.	10-19 6.5-7.5 18-25 20-29 4 - 6 10 - 15 near moist adiab.	5-9 5.5-6.5 12-18 12-19 3 - 4 5 - 10 wk or shlw invrsn	< 5 < 5.5 <12 < 12 < 3 < 5 stg or deep invrsn

	(C) (14) Wet-Bulb Temperature curve below 700mb (15) Mvmt of storm line relative to 500-700mb flow	parallel	< 45 degree angle	45-60 degree angle	> 60 degree angle
Tornado	(16) 2 x Sqrt (Approx LFC-500mb CAPE) + SRI = (17) 0-2km SR-Helicity (near storm inflow region) (6) 400-700mb SR-Flow (18) Lowest 50-to 100-mb Dew Point Depression (19) Mesocyclone movement relative to pre-existing or storm-induced boundary	> 100kts > 400 > 30 kts < 11F (6C) On cool side of shallow boundary, or directly on deeper boundary (if inflow air sufficiently unstable)	80-99 250 - 400 20-29kts 12-18F (6-10C) Moving at small angle over cooler air behind a shallow boundary (if inflow air sufficiently unstable)	60 -79 150 - 250 10-19kts 19-27F (10 - 15C) No boundary detected, deviant motion observed.	< 60 < 150 < 10 kts (5) >27F (15C) Moving at sharp angle ovr cool, stable air, or on warm side of bndry moving away from bndry
Flash Flood	(20) Storm motion(kts) (21) Precipitable Water (% of	< 5 >200%	5 - 10 150-200%	10-20 100-150%	> 20 < 100%

	normal)				
	(22) "Corfidi Vectors" suggest:	Bckbldg/Stnry storms	Slow storm mvmt	Moderate mvmt	Fast storm mvmt
	(23) Precip Efficiency (look for warm rain process)	High	Moderate	Low	Very Low
	(24) Flash Flood Guidance	Well below normal	Below normal	Near normal	Above normal
	(25) "Training" Pattern	Classic (storm line stationary relative to training location)	Near-classic (storm line mvmt < 10kts relative to trng loc.)	Semi-training (Line mvmt 10-15kts relative to trng loc.)	No training pattern observed

Figure 2. N O T E S

***** This is for guidance purposes only. Specific criteria numbers are provided as guidance. *****

(1) Look at strength of convergence and frontogenetic/frontolytic nature of boundary (frontal circulation).
(2) Take 2 times the square root of CAPE, and add the low-level SR-Inflow in knots. You are incorporating both SR-inflow and CAPE to come up with a theoretical updraft intensity. (**Note:** Take square root of CAPE rather than square root of 2 x CAPE to account for factors like entrainment). Volume browser could be set up to help with this.
(3) Some CIN is a favorable condition for severe convection. Here, CIN values provided are given for anticipating storm formation, not severe nature of storms.
(4) At times, convection can initiate when isentropic upglide allows parcels aloft to reach their LFC.
(5) Incorporate both speed and directional shear below 400mb level by adding the amount of veering, in degrees, to the amount of speed shear, in knots. The greater either directional or speed shear, or both, the larger the result will be.**Note:**Do not utilize this factor when average wind speeds aloft are less than 20 kts.
(6) Compare average flow in the 400-700mb layer to individual storm motion (not average motion of all storms). Keep in mind weak SR-flow aloft can occur in microburst environments. **Note:** May want to look at SR-flow at the rear-inflow-jet level for squall lines.
(7) Environment Freezing Level (where environmental temp. curve crosses 0C) or Updraft Freezing Level (where updraft parcel crosses 0C): use appropriate one given situation (e.g. strong SR-flow aloft, use environment level...weak SR-flow aloft, use updraft level). This may be important for correctly accounting for hail melting potential.

(8) Look for mesocyclone to be at least 10,000 feet deep, persisting for at least several volume scans. Mesocyclonic flow alters storm-relative flow pattern such as to distribute precipitation away from the warm, saturated updraft core.
(9) Use the average dew point depression value in the 400-700mb layer. Volume browser can be set up to help with this.
(10) Volume browser can be used to determine this lapse rate.
(11) Take the difference between the surface theta-e and lowest theta-e value in the 400-700mb layer. Can do this with "DIFF" button on volume browser. This is helpful for determining the potential for damaging winds and wet-microbursts. The steeper the lapse rate, and/or the drier the air aloft, the greater this "difference" will be.
(12) Can get values on volume browser or LAPS/MSAS menus. This can be helpful for detecting the initiation of wake low damaging winds.
(13) Difference between surface temperature and dew point values...helpful for determining microburst potential.
(14) Subjective view of wet-bulb temperature (Tw) curve below 700mb. How deep of a Tw inversion is there, and how strong is it? Is the Tw curve closer to moist-adiabatic or dry-adiabatic? Damaging winds can reach the ground with a temperature inversion (e.g. during the evening hours), but this is more difficult when you have a wet-bulb temperature inversion (and thus little dry air for evaporative cooling to counter effects of low-level inversion). **Note:** Incorporate Tw inversion strength as well. The closer the Tw curve is to moist-adiabatic, the deeper it can be and still allow damaging winds to reach the ground.
(15) Damaging winds are often less likely to result from a line of storms moving at a sharp angle to the flow aloft compared to a line of storms moving along the mean flow (where momentum mixdown can result). Also look at environmental ingredients for damaging winds (dry air aloft, steep lapse rate, etc).
(16) Come up with approximation of CAPE below 500mb or 600mb and divide it by 100, then divide low-level SR-inflow (SRI) by 5, and add the two together. Research has found that CAPE in the lowest few hundred mb to be an important factor for determining tornado potential.
(17) 0-3 km layer may be too deep. Try to determine how much of calculated 0-3km SRH is within 0-2km layer from hodographs. Focus on small-scale wind changes near storm inflow region, not general environmental SRH values. Small-scale changes in near-surface wind can drive SRH up or down substantially.
(18) LCL heights can be approximated using lowest 50-mb or 100-mb average dew point depressions. Every 5F (~3C) of dew point depression roughly correlates to 1,000 feet of cloud base height AGL. Research suggests low LCL heights (below 1000 meters) is favorable for tornado development. **Note:** Influx of saturated air from FFD area into updraft can cause lowering of LCL height to favorable level.
(19) Determine movement of mesocyclone relative to pre-existing or storm-induced boundary. How deep is the cool air behind the boundary? Is the cooler air unstable enough to allow convection to survive, or will it be too stable and cause rapid storm weakening?
(20) Slower storm motion yields greater potential for excessive rainfall.
(21) Greater precipitable water values (relative to normal) increase potential for excessive rainfall.
(22) Back-building or slow moving convection has greater potential for producing excessive rainfall.
(23) Greater precipitation efficiency yields greater precipitation rates. Look for conditions

favoring warm rain process (e.g. depth of layer from LCL to freezing level at least 3-4 k cloud base heights, etc). Also look for weak SR-flow at storm top (don't lose as much precip through anvil), K-index values of 36+, etc.
(24) Lower flash flood guidance (FFG) values favor a greater flood threat.
(25) Are storms training over the exact area? If the overall line motion is near 0 (relative to the area where training is occurring), you have ideal training. The more a line moves, relative to its orientation (e.g. east/west mvmt of north-south oriented line), the less "ideal" the training setup is for excessive rainfall.

Figure 3. Warning Decision-making Case Exercise: RESPONSE KEY

After each clue is presented, you will be asked about your expectations of the worst conditions likely from the storm of interest. Your choices are given below for each of 2 categories, hail/wind and tornado. You will give your choice number for each category (e.g. if you think the storm is not severe, your hail/wind choice is "1", and your tornado choice is "1"). For the hail/wind category, use the hail or wind criteria that yields the greatest choice number (e.g. if you expect baseball hail and 50kt winds, use choice number "4").

Choice	**HAIL / WIND**	**TORNADO**
# 1 :	**No severe hail or wind**	**No Tornado**
# 2 :	**3/4 - 1 1/4" Hail ; 45-55 kt Wind**	**Brief F0 Tornado(s)**
# 3 :	**1.5 - 2.5" Hail ; 55-64 kt Wind**	**F1-F2 Tornado**
# 4 :	**> 2.50" Hail; > 64 kt Wind**	**F3-F5 Tornado**

III. References

Local Analysis Prediction System (LAPS) Notes at http://laps.fsl.noaa.gov/

Mesoscale Surface Analysis System (MSAS) Notes at http://www-sdd.fsl.noaa.gov/MSAS/msas.html

Quoetone, E.M., K. Huckabee, 1995: "Anatomy of an Effective Warning: Event anticipation, data integration, feature recognition". Preprints, 14th Conf. on Weather Analysis and Forecasting, AMS, Dallas, 420-425.

WDTB Homepage, 2001: WDM III Workshops. Mesoscale Input to Warnings, by Brad Grant at http://www.osf.noaa.gov/otb/workshop/wdmiii/NSE/index.html

Wolf, Peter, 2001: "Benefits of Real-Time Environmental Analysis, Storm Spotters, and Intensive Verification Efforts on Severe Weather Verification Results" 8 pp.

1. Values of 0-1 km SRH and surface temperature-dew point spreads have been shown to be related to strong tornado occurrences (See Rasmussen and Markowski, 2000 at http://mrd3.nssl.ucar.edu/~eras/www/SSR/Tornadoes/Forecasting/Tfrcstframeset.htm)