NWS Operations Proving Ground

Operational Readiness Evaluation Report

Evaluating the Integration of AWIPS Near-Storm Environment Awareness Tools in NWS Convective Warning Operations

NWS Operations Proving Ground

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Executive Summary

In May and June 2017, the National Weather Service (NWS) Operations Proving Ground (OPG) hosted twelve (12) NWS forecasters from diverse locations around the country to participate in an Operational Readiness Evaluation (ORE) of field-developed diagnostic tools designed to improve situational awareness in convective warning operations. The toolset is comprised of two components: the Near-Storm Environmental Awareness (NSEA) Cursor Readout and the NSEA Application or GUI (Graphical User Interface). Functionality of each will be discussed in Section 5 of this report.

A group of NWS Science and Operations Officers (SOOs) originated the NSEA project in an effort to improve NWS warning forecasters' ability to effectively interrogate the near-storm environment using AWIPS-based tools and datasets. Following more than two years of development and testing, the NSEA tools were deemed mature enough to warrant a pre-deployment readiness evaluation at the OPG. It is worth noting that this is the first National SOO Project to follow the R2O pathway from VLab development, to beta testing at field offices, to a formal ORE at the OPG.

Using a combination of historical simulations and live data exercises, participating forecasters incorporated NSEA tools into a variety of warning scenarios, ranging from pulse convection to classic supercells. The process was deliberately built in such a way that the complexity of the situation and the number of high-resolution data sets increased with each subsequent exercise. During some simulations, forecasters were placed in the role of warning forecasters at neighboring Weather Forecast Offices (WFOs). In others, they were assigned to operate as a team within the same WFO.

Feedback was gathered on the usability of the NSEA tools, their usefulness for decision making, software reliability, workload implications, and system performance issues. Additionally, some of the exercises evaluated application interoperability with other high-resolution datasets, such as GOES-16 imagery, WSR-88D radar, mesonet observations, mesoscale model output, and NOAA/CIMSS ProbSevere model guidance.

Results were documented and suggestions for improving the tools' value to forecasters were solicited. Findings and recommendations were gauged against the main objective, which was to determine whether, in the opinions of operational forecasters, these tools demonstrably increased situational awareness in convective storm environments to better anticipate thunderstorm evolution, make more confident warning decisions, and enhance messaging to stakeholders.

The most important forecaster observations, insights, and conclusions are described in the body of this report, with findings and recommendations summarized in Section 6.

The OPG recognizes that it is important to convey its findings and recommendations with care and restraint. There are inherent limitations, discussed within the body of the report, when completing evaluations of new tools and capabilities. Nevertheless, we believe the observations and concerns of these forecasters have merit. Furthermore, some generalizable conclusions can be drawn from the collective group experience, which can be used to guide implementation decisions and to inform future activities aimed at evaluating similar tools, testing new operating concepts, determining training gaps, and developing resources to address those needs.

With respect to the NSEA tools, the OPG endorses the NSEA Cursor Readout for immediate deployment to field offices, without reservation. The NSEA Application is also strongly supported for release in a future build with the following two caveats.

First, since it is not as intuitive as the cursor readout component, we recommend that a set of training materials be developed and delivered with the software.

Second, ORE participants discovered that the two NSEA components do not use the same calculation formulas for severe weather parameters. In most cases, the resulting values are similar but in a few instances, there were significant differences in parameters such as CAPE, LCL, and Bulk Shear. It would be preferable if this discrepancy could be resolved prior to distribution into the AWIPS baseline, ideally by adopting one set of calculation methods for both tools. If this is not possible, it is important to provide clear explanation to users on the sources of differences and guidance on which values to use in operations.

The report that follows explains our evaluation strategy and the process by which we drew conclusions about the exercises. If more detail is desired, all raw results from our surveys and recorded discussions are available upon request.

1. Background

The importance of maintaining environmental situational awareness is commonly cited as a best practice in NWS service assessments of severe weather events. Current NWS mesoanalysis tools, such as those available via the Storm Prediction Center (SPC) web page, utilize hourly surface data and the latest Rapid Refresh (RAP) model's tropospheric forecasts to build a three-dimensional atmospheric analysis. These hourly analyses are quite useful, and used extensively by operational forecasters, but there is no capability to modify these web-based datasets, nor is it possible to superimpose them on other imagery and datasets within AWIPS.

Beginning in 2015, several NWS SOOs and Lead Forecasters determined they would pool their talents and resources toward developing tools to improve operational forecaster capabilities in this area. The objective of this National SOO Project was to create a set of Near-Storm Environmental Awareness (NSEA) tools within the AWIPS platform. If successful, the resulting applications would improve forecasters' ability to maintain situational awareness of convective storm environments, to better anticipate thunderstorm hazards, and to translate that knowledge into effective risk communication to stakeholders.

Specific outcomes the project aimed to achieve, included greater:

- temporal and spatial resolution of near-storm environment observational data;
- integration between what is observed in radar/satellite characteristics, and what can be deduced about the near-storm environment;
- flexibility to change the input or background fields for environmental analysis, and configure the output to the user's needs;
- capability to monitor numerous environmental parameters quickly, in order to spin up and maintain situational awareness before and during a severe weather event.

The NSEA package is comprised of two tools: the Cursor Readout and the NSEA Application or GUI. Intended users of the NSEA tools are the warning team (i.e., the radar operator/warning meteorologist, the mesoanalyst, the enhanced short term forecaster, and in some cases, the storm coordinator).

The NSEA tools were developed and refined on the NWS Virtual Laboratory (VLab) platform (https://vlab.ncep.noaa.gov/), and beta tested at several WFOs. By 2016, the software had demonstrated a sufficient level of maturity and reliability to warrant an Operational Readiness Evaluation at the OPG. A proposal was submitted to OPG management and accepted for testing and evaluation in the FY17 Annual Operating Plan.

2. Participants

In total, twelve (12) NWS forecasters participated in the ORE. Selections were made through the NWS Regional Scientific Services Divisions (three each from Western, Central, Southern, and Eastern Regions). Home office areas of responsibility for all the participants are identified by the blue shaded regions in Fig. 1. The roster included three SOOs, five Lead Forecasters, and four General Forecasters.

In addition to the twelve forecasters, each week-long session featured a developer from the NSEA team attending as a Subject Matter Expert (SME). The gray areas on Fig. 1 represent home office locations of the four participating SMEs. Names of the participating forecasters, and the entire NSEA development team are listed in *Appendix A*.

3. Purpose and Goals

The overall purpose of this OPG evaluation was to assess the operational readiness of these tools by placing field forecasters in a realistic Weather Forecast Office (WFO) setting and having them use the tools in a variety of convective scenarios. Feedback was then gathered to evaluate effectiveness in six areas of interest:

- Usability of the tools in the operational workflow
- Usefulness for adding value to operational decision making
- Reliability and stability of the software
- Workload implications
- System performance issues
- Application interoperability with other high-resolution tools and datasets (e.g., GOES-16 imagery, WSR-88D radar, mesonet observations, mesoscale model output, ProbSevere model predictive guidance)

Suggestions for improving the tools' value to forecasters were also solicited. Feedback analysis was driven by the objective of determining whether, in the opinions of operational forecasters, these tools demonstrably increased situational awareness of convective storm environments to better anticipate thunderstorm evolution, make better warning decisions, and enhance messaging to stakeholders. Key findings and recommendations, listed in Section 6, emerged from that process.

4. Assessment Methodology and Description of Exercises

The OPG has developed the capability to emulate any NWS WFO (or up to three WFOs simultaneously) in system configuration, ingest and display of operational datasets, development and dissemination of products, and typical operational workflow. For the NSEA ORE, participating forecasters were asked to incorporate NSEA tools in a variety of convective warning environments, using a combination of historical simulations and live data exercises. The process was deliberately built in such a way that the complexity of the situation and the number of high-resolution data sets increased with each subsequent exercise. During some simulations, forecasters were placed in the role of warning forecasters at neighboring WFOs. In others, they were assigned to operate as a team within the same WFO. A copy of the detailed weekly schedule is provided in *Appendix B*.

For each exercise, forecasters were presented with a recorded in-brief to ensure consistency in the starting point for every group. In-briefs featured a discussion of the synoptic upper-air pattern, surface conditions, current radar and satellite imagery, an overview of severe weather potential (shear, instability, SPC outlook, etc.), a summary of data available for the exercise, and the task assignment. As an illustrative example, *Appendix C* contains the slides used for the Exercise 1 recorded in-brief.

A brief overview of each day's activities follows. The basic agenda for each of the four week-long sessions was identical, although locations and tasks for Days 3 and 4 varied, since they were dependent on what opportunities were presented by the ongoing weather.

Monday Morning: Orientation and Training

The first morning consisted of an orientation briefing, followed by a short training exercise to familiarize participants with the tools. Time was also given to allow forecasters to create AWIPS display procedures. The three historical evaluation exercises took place Monday afternoon, Tuesday morning, and Tuesday afternoon in the following sequence.

Monday Afternoon: Exercise 1 - Central Indiana Tornado Event, 24 AUG 2016

All three workstations were localized as WFO Indianapolis (IND). Forecasters were assigned to work individually with the task of monitoring convective development and issuing warnings or other products relevant to the unfolding event. Data was limited to radar, GOES-13 VIS/IR/WV imagery, surface observations, and numerical model output from the GFS, NAM, RAP and HRRR. The NSEA tools were, of course, available for use in storm interrogation.

Tuesday Morning: Exercise 2 - Pennsylvania High Shear/Low CAPE Event, 31 MAY 2015

All three workstations were localized as WFO State College (CTP). Forecasters were assigned to work individually with the task of monitoring convective development and issuing warnings or other products relevant to the unfolding event. Data included real-time ingest from three radars, GOES-14 1-minute VIS/IR/WV imagery, surface observations, and numerical model output from the GFS, NAM, RAP and HRRR. In addition, ProbSevere Model was available to load as guidance.

Tuesday Afternoon: Exercise 3 - Oklahoma Tornado Outbreak/Flash Flood Event, 8 May 2016

All three workstations were localized as WFO Norman (OUN). Forecasters were assigned to work as a team. The initial arrangement was for two forecasters to work as warning forecasters, sectorizing the areas of responsibility within the County Warning area (CWA). The third forecaster was assigned to serve as mesoanalyst, and communicate important observations about the evolving environment to the warning forecasters. One of the forecasters was assigned to be the Shift Lead with the authority to modify workload distribution later if needed. Data included real-time ingest from three radars, GOES-14 1-minute VIS/IR/WV imagery, surface observations, and numerical model output from the GFS, NAM, RAP and HRRR. In addition, ProbSevere Model was available to load as guidance.

Wednesday/Thursday: Real-Time Weather, Locations Chosen as a Group Each Morning

Live ingest to the OPG AWIPS was restored each Tuesday evening, to facilitate the use of real-time weather for Wednesday and Thursday exercises. For those days, forecasters had access to the full array of data they normally acquire in operations, including GOES-16 cloud and moisture imagery and the experimental GOES-16 GLM data.

After discussing insights and observations from the previous day, forecasters spent an hour or so analyzing the synoptic setting, formulating ideas about the expected evolution of weather for the day, and selecting locations from which they would monitor development and ultimately issue simulated warnings and other products. While this tactic can be risky in the sense that it’s possible there will be no weather of interest to focus on, experience has proven that complementing archived cases with real-time weather forecasting creates a richer, more robust WFO simulation experience. While it is certainly important and valuable to evaluate performance during events in which the outcome is known in advance, participants have an idea that something significant is going to unfold within the chosen area where the simulation takes place. Including days in which the forecasters choose their area of responsibility, and work the shift without knowing exactly what unfolds until the next day adds an extra dimension of realism to the evaluation process.

During each exercise, participants used web-based logs to document their observations about the value and problems experienced with NSEA and other data sets tested. At the conclusion of each exercise, OPG staff facilitated a group discussion. These discussions, which were recorded with participants' permission, were invaluable as they allowed time for an in-depth and uninterrupted time of conversation. These debriefs were useful for forecasters to raise questions about the process, the data, their interpretations and decision processes, or simply to share insights they did not have time to document in their observation logs.

On each Friday morning, participants completed an anonymous on-line survey, in which they discussed in detail their overall experiences, opinions, concerns, and suggestions. This was followed by an informal group debrief session, usually lasting approximately one hour. The results presented in the next section are derived from a combination of the mechanisms just described.

5. Overall Results

Admittedly, the conclusions here are derived from a relatively small sample size. Despite this limitation, the breadth of diversity in geography and experience represented by these forecasters lends credence to their observations, findings, and recommendations. We are confident that they are sufficiently generalizable to the opinions and work habits of the average field forecaster and, thus, translate into meaningful conclusions.

5a. NSEA Cursor Readout

The digital cursor readout was developed to facilitate increased situational awareness for radar operators and mesoanalysts by displaying critical parameters about the mesoscale environment, typically superimposed on radar data. When sampling is turned on, readouts are displayed for select parameters without needing to load those elements as images, as is currently required in AWIPS.

Categories for display include a variety of stability and shear parameters, composite indices, storm motion, and critical heights (e.g., 50dBZ hgt or hgt of -20C level, etc.). Parameters can either be loaded individually, or as preset bundles.

To illustrate how it is used, Fig. 2 shows an example from 17 June 2017, zoomed in on a cell over southern Iowa. This figure depicts the RAP13 Hail Environment bundle loaded on top of the 4.0 degree reflectivity slice. At the cursor location, the RAP13 indicates height of the -20C level, for example, is ~23,600 ft AGL, with the radar indicating a 63dBZ core in excess of 25,000 ft AGL. The forecaster had already determined these numbers correlated well with proximity sounding information, so in this case the Cursor Readout is providing information that at the very least confirms to the warning forecaster a strong likelihood of severe hail production by this storm. During the actual event, the WFO Des Moines office issued a warning a few minutes later (2229 UTC) and at 2246 UTC – about 32 minutes after the image in Fig. 2 – a trained spotter reported golf-ball sized hail in association with that storm.

Forecaster opinions of this tool were overwhelmingly favorable. The consensus conclusion was that the NSEA Cursor Readout is intuitive and easy to use. It was deemed an extremely valuable aid to situational awareness during convective warning operations. Eleven of the twelve participating forecasters indicated the Cursor Readout improved their ability to make effective warning and short-term forecasting decisions, *and* increased their confidence in those decisions.

The overall opinion about the value of this tool is best captured in this quote from one of the Week 1 participants: *"This tool just works and the field needs it. I know we've made some suggestions for improving it, but there's no need to wait for it be perfect before releasing it. Plus the NSEA team is very quick to implement changes. I would use this tomorrow, as is."*

Based on this ORE, the NSEA Cursor Readout is endorsed without reservation for immediate field deployment.

5b. NSEA Application

Operational forecasters are familiar with the SPC mesoanalysis page, which has been an indispensable tool for diagnosing potential for severe convective weather for years. The NSEA Application builds on the strengths of that page, and attempts to address a few of its inherent limitations, exploiting ancillary data sets available within the AWIPS platform. For example, the NSEA GUI offers user-defined model source as a background field; configurable observation station lists; an interactive display that allows sampling of observation sites to depict tabular displays of shear, instability, and a variety of severe weather indices; and the ability to display time series graphs of those parameters. The NSEA Application also offers editable Skew-T and hodograph plots for any station by leveraging SharpPy code within AWIPS. When compared to the legacy N-Sharp sounding program currently built into AWIPS, the SharpPy software is far superior in both functionality and user friendliness.

The default plan view display of the NSEA Application is illustrated in Fig. 3. Note the variety of shear, stability, and composite index parameters listed in the menu on the left. In this case, the user selected ML CAPE for display in the main viewing window. Color-coded values make it easier to quickly identify the areas of highest instability, and to visualize gradients. The thresholds for these values are configurable, so that users can customize them to their own local needs, whether driven by the synoptic situation, the season, or regional climatology.

If the user clicks on one of the plotted values, an array of time-series graphs appears for the station selected. For example, notice the highest ML CAPE value depicted is 2615 J/kg at the Clinton-Sherman Airport (CSM). Clicking on that station label yields the display shown in Fig. 4. This presents the past two hours of observations, and the next six hours of forecast values from the selected model for each of the parameters in the application bundle. The current reading is denoted by a blue vertical dashed line. In this example, the yellow oval highlights the time series for Significant Tornado Parameter (STP) at CSM. It has been steadily increasing for the past two hours and is expected to exceed the "extremely high" threshold, as defined by the user, in this case a value of 4.

By selecting the "Sounding" tab, the user is presented with an editable Skew-T diagram and accompanying hodograph, along with several tables of calculated severe weather parameters, as shown in Fig. 5.

The NSEA Application is less intuitive than the Cursor Readout, but the majority of participants expressed the opinion that it has significant potential, especially in the pre-convective environment. In order to alleviate the less intuitive nature, we recommend a brief, focused training package be included with the software. These materials could be as simple as an electronic booklet and job sheets, or as sophisticated as an interactive online module.

On several occasions, the value of severe weather parameters displayed on the NSEA Application's plan view plots were substantially different from those depicted at the same location on the Cursor Readout. Further investigation revealed that the two NSEA tools use different calculation formulas for some of the shear and stability parameters. The NSEA Application uses the same formulas employed by the SPC Mesoanalysis web page, while the the Cursor Readout uses legacy formulas that have been used in AWIPS since the late 1990s. Neither method is mathematically incorrect. The problem traces to factors such as layers over which integration occurs, precision of rounding, source of data used to estimate surface or boundary layer values, etc. In most cases, differences in results are not significant. But for those cases in which they are, it introduces doubt in the minds of users about which tool to trust. Without knowing why the differences are present, the tendency might be to not use either. Many participants (8 of 12) explicitly stated concern that this issue could be detrimental to acceptance of the tools by forecasters in the field.

In the interest of full disclosure, there was one additional major finding during the ORE, which has now been resolved. Several forecasters experienced instability in the software, with as many as four crashes in one exercise. These crashes caused them to close and restart their CAVE sessions, losing valuable time and inhibiting situational awareness while severe convective weather was developing. Initially, this was identified as a critical issue which would preclude the deployment of the NSEA Application. However, the NSEA developers have resolved those issues since the conclusion of the ORE. Code deficiencies were identified and the updated software seems to be performing reliably now.

In ORE surveys, nine of the twelve forecasters scored the NSEA Application's value as very high in enhancing big picture awareness, especially in pre-convective environments. (All twelve indicated they would likely shift focus to the NSEA Cursor Readout once warning operations commenced.)

All twelve forecasters had high praise for incorporating SharpPy functionality within AWIPS.

This quote from one of the Week 4 forecasters is a good representation of the collective opinions shared about the NSEA Application: *"I really like these tools, and I can envision using them to augment my situational awareness for many situations: monitoring the overall synoptic pattern, depicting the location and evolution of gradients, identifying areas where convective initiation might be favored, etc. I also LOVE the availability of SharpPy within AWIPS!"* *

Based on these findings, it is our opinion that the NSEA Application be released in a future AWIPS Build, with two caveats:

a. A brief, focused set of training materials should be developed and delivered with the software, and

b. It would be preferable if the significant discrepancies in parameter calculations between the NSEA Cursor Readout and the NSEA Application are resolved before deployment. If this is not possible for some reason (e.g., cost prohibitive to have Raytheon change internal code for these formulas), clear instructions about the differences and guidance concerning when/how to use each must be distributed to the field.

5b. Integrating NSEA Tools with Other High-Resolution Data Sets

As mentioned earlier, on Wednesday and Thursday of each evaluation week, forecasters were assigned to identify an area of challenging weather that was expected to develop on that day in real time, and assume the responsibility for all convective products and messaging for that location. Participants were asked to incorporate NSEA tools, along with other high-resolution data sets they have at their disposal as they monitored the evolving situation. They were encouraged to stretch themselves in the context of integrating various data and decision aids into their workflow and operational decisions, and to experiment with different data display arrangements to enhance their overall ability to maintain situational awareness and/or to improve their warning performance.

As an example, Fig. 6 depicts a display provided for use in the real-time weather exercises, in which the cursor readout data was superimposed on GOES-16 imagery at the top, low-level Z/V data in the middle panels, and at the bottom, ProbSevere along with MRMS reflectivity and MRMS rotation tracks.

The cursor is placed where the strong updraft is located on radar, and the corresponding overshooting top can be seen in the upper right (displaced northward somewhat due to parallax). While that storm is quite vigorous, the cursor readout suggests the local environment in not especially conducive to tornado spin-up; tornado development parameters are modest at best. Granted these indicators are model-derived, so care must be taken but assuming some diagnosis has been done to assess the credibility of these data, it can be a useful input.

At the same time, it is a very strong and broad updraft, and it is moving steadily southeastward, to the right of the mean wind. Placing the cursor a little farther to the southeast, as shown by the cursor location in Fig. 7, one can see that the environment becomes much more favorable. Should the storm manage to maintain its integrity and move into a position that allows it to ingest that airmass, the potential for tornado production will become more likely.

A final quick example of how fusing high resolution data sets can be informative is illustrated in Fig. 8. By adjusting the color table of the visible (VIS) and infrared (IR) satellite imagery such that clear skies are made transparent, a forecaster can both validate the representativeness of the underlying model data (in this case, RAP13 surface dew points) and, if deemed reasonable, he/she can visualize useful information related to, say, timing and location of convective initiation.

In this image the boundary layer convergence zone is slightly farther north than what the model is predicting but adjusting for that, the area that is favored for initiating deep moist convection is along the gradient where the rich moisture is starting to pool. When animated, several orphan anvils are evident, emerging from cells along the dry line and blowing downstream as they decouple from the weak parent updraft (not shown). Eventually, as seen in Fig. 9, strong moisture convergence along the boundary, assisted by large scale ascent associated with a jet streak in the upper left portion of the image, erodes the capping layer and extremely vigorous deep convection explodes, with several overshooting tops evident in the merged VIS/IR image.

These methods of fusing various data sets together are both important and popular due to their value toward improving visualization and diagnosis of the local environment, providing tools for validating mesoscale model information, and enhancing forecaster understanding of convective mode and evolution. More will be said about this in Section 5, but the continued increase in data volume being presented to forecasters will accentuate the importance of developing tools such as this in the future. NWS should place a high priority on developing training, products, and best practices aimed at fusing high-resolution data sets, or intelligently extracting the most critical information from multiple sources, and displaying those data in ways that enable and enhance effective warning and forecast decisions.

On a related note, one specific need highlighted through these exercises was the emerging urgency to articulate best practices for the mesoanalyst in the warning environment, and to develop appropriate proficiency training aimed at the skills needed for that role. With the advent of GOES-R, convective resolving models, and probabilistic decision aids, the value of the mesoanalyst will gain unprecedented importance. Therefore, it would be valuable for NWS to stand up a team of experts (including field personnel) to explore how best to incorporate that role into convective warning operations, or other situations in which the mesoscale environment is evolving rapidly.

Important Opinions Shared by all Participants Concerning Integration of Multiple Data Sets

Several observations were made unanimously among the twelve participants, with respect to the benefits and challenges of integrating multiple high-resolution data sets in ways that enhance forecast decisions and communication to stakeholders. Some of these are relevant strictly to high-stress situations such as convective warning environments; others are applicable in a broader sense.

All twelve participants favored **the use of ProbSevere** Model as a useful tool for the warning forecaster.

All twelve participants shared the opinion that **GOES-16 cloud and moisture imagery adds significant value to the warning process –** on multiple levels, including:

- *Improving some warning lead times*
- *Improving the quality of warnings*
- *Improving confidence in warning decisions*
- *Less reacting, more anticipating, development*

All twelve participants suggested that the **NSEA tools** would be even **more valuable** if the program allowed users to **customize the parameters being displayed** to suit their own purposes. These suggestions came in two distinct forms. Some participants expressed a desire to more easily select what is displayed within a preset bundle; others specified a preference for configuring new bundles of their own, aimed at enhancing diagnosis of forecast challenges other than severe convection (e.g., fire weather, tropical weather, winter weather, flash flood potential, etc.). The overall tenor was a clear opinion that expanded configurability would represent a marked improvement in the likelihood that the tools would be widely accepted and used in the field.

All twelve participants agreed that the **role of the mesoanalyst is more critical** than ever before to maximizing the effectiveness of NWS warning services.

6. Findings and Recommendations

Presented below is the list of findings and associated recommendations, which emerged from the evaluation. Context and rationale for these findings are contained within Section 5 of the report.

FINDING 1: The NSEA Cursor Readout is intuitive and easy to use. It was deemed an extremely valuable aid to situational awareness during convective warning operations by all twelve participating forecasters.

RECOMMENDATION 1: The NSEA Cursor Readout is endorsed without reservation for immediate deployment to NWS field offices.

FINDING 2: The pre-packaged Cursor Readout bundles were very useful but somewhat restrictive.

RECOMMENDATION 2: Expand options for customizing the NSEA parameters to suit individual and regional needs, and to create configurations aimed at enhancing diagnosis of forecast challenges other than severe convection (e.g., fire weather, tropical weather, winter storms, flash flood potential).

FINDING 3: The NSEA Application is less intuitive than the Cursor Readout, but it does offer potential value, especially as a tool for quickly assessing the overall synoptic setting, or for monitoring the pre-convective mesoscale environment. Sometimes parameters depicted on the plan view display of the NSEA Application differ significantly from the values calculated by the NSEA Cursor Readout. This traces back to each component using different computational methods. It is inherently confusing and introduces doubt as to reliability of data, which translates into lack of confidence in using the tools.

RECOMMENDATION 3: The NSEA Application is approved for release in a future AWIPS Build, with two caveats:

a. A brief, focused set of training materials should be developed and delivered with the software, and

b. It would be preferable if both NSEA tools used the same calculation formulas. If it is not possible to resolve this discrepancy prior to deployment for some reason (e.g., cost prohibitive to have Raytheon change internal code for these formulas), clear instructions about the different methods being employed, along with guidance concerning when/how to use each must be distributed to the field.

FINDING 4: The NSEA Application display graphs were often too cluttered. Also, plots are too small to be legible on large CWA domains. The ability to select a limited set of stations, severe weather parameters, and time series graphs would greatly improve the application’s usefulness and usability.

RECOMMENDATION 4: Add the capability to customize configurations for both the severe weather parameter plots and the time series graphs.

FINDING 5: The SharpPy sounding program is far superior in functionality, flexibility, and user friendliness than the standard N-Sharp sounding program built into AWIPS.

RECOMMENDATION 5: Include the SharpPy code in the implementation package for the NSEA Application.

FINDING 6: There is a growing body of support among NWS forecasters that integrating the GOES-16 cloud and moisture imagery, and select RGB composites, with radar data adds significant insight into the warning decision process. All participants (12/12) expressed the opinion that it is important for forecasters to learn to do this as the warning forecaster or, in cases where the convective environment is particularly complex, to ensure a mesoanalyst is actively monitoring GOES-16 data and communicating observations to the warning team.

RECOMMENDATION 6: The NWS OCLO Warning Decision Training Division should consider incorporating methods for integrating satellite and radar data as the warning forecaster in the next iteration of instructional design for their Radar Applications Course and Advanced Severe Weather Operations training.

FINDING 7: With the advent of GOES-R, convection resolving models, and probabilistic decision aids, the value of the mesoanalyst will gain unprecedented importance. That position is used sparsely in the NWS and the best practices for exercising the role effectively need to be reformulated to take into account the availability of these high-resolution data sets, as well as new technologies and methods for communicating among the members of the warning team.

RECOMMENDATION 7: It would be valuable for the NWS to bring together a team of experts (including field personnel) to explore how best to incorporate the mesoanalyst role into convective warning operations, or other situations in which the mesoscale environment is evolving rapidly. Training which incorporates those skills and behaviors should then be developed and made available on the Commerce Learning Center.

FINDING 8: During the RT-weather exercises, forecasters noted several significant anomalies associated with the Geostationary Lightning Mapper (GLM) data. The most critical issues traced back to errors in data processing, geo-location and navigation. These problems produced a GLM dataset of unacceptable and unusable quality. Other less egregious problems were connected to mapping and visualization within AWIPS. Similar problems were documented by forecasters attending the Hazardous Weather Tested Spring Experiment, which was ongoing at the same time as our OPG ORE. The primary concern expressed by both groups was that releasing these data to the field without addressing the critical issues identified, will almost certainly elicit negative consequences on forecasters' first impressions of the GLM data.

RECOMMENDATION 8: Recommendations for resolving the most critical data quality issues are multi-faceted, and beyond the scope of this ORE. OPG Management, in collaboration with scientists from National Severe Storms Laboratory, NASA SPoRT, and the CONUS SSD Chiefs, composed a "Three Things Memo," which outlined the GLM problems in detail and articulated five recommendations for resolving them. That memo was distributed to NWS Leadership and the AWIPS Program Office to determine appropriate courses of action. It is available upon request for personnel with appropriate authority and need to know.

7. Figures

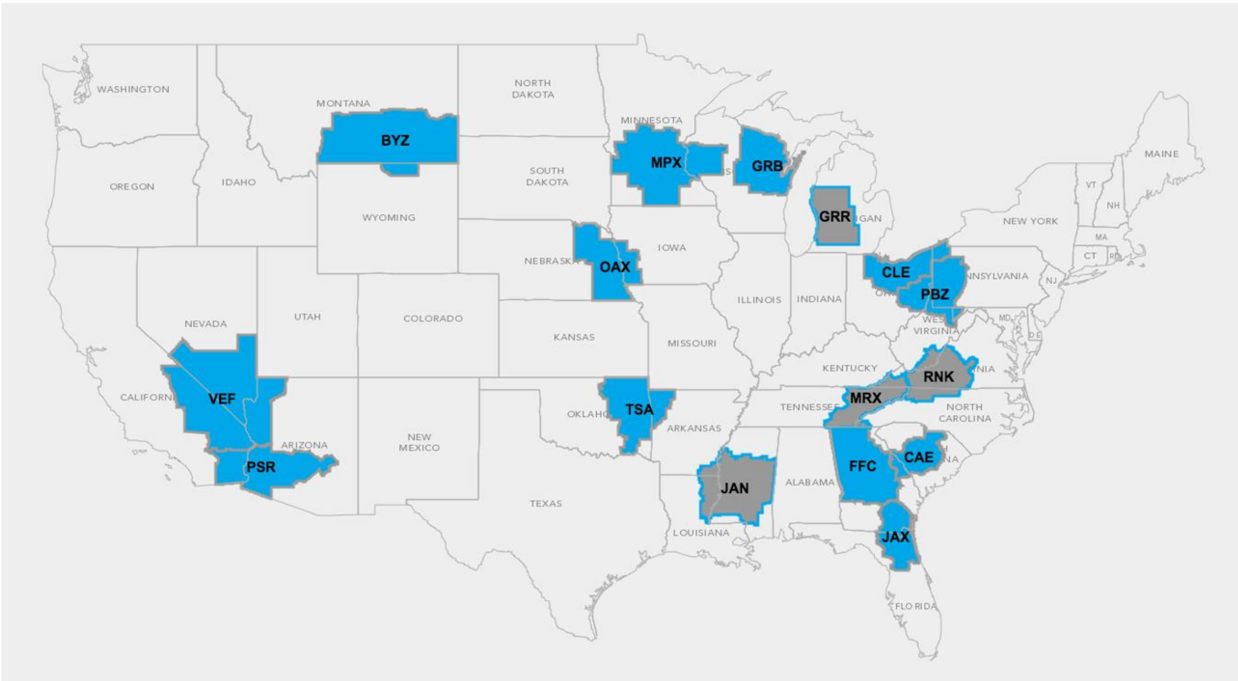


Figure 1 - Map illustrating NSEA participation. Areas shaded in blue represent the home office are NWS County Warning Area (CWA) of each participating forecaster. Areas shaded in gray represent the CWA of each Subject Matter Expert who attended.

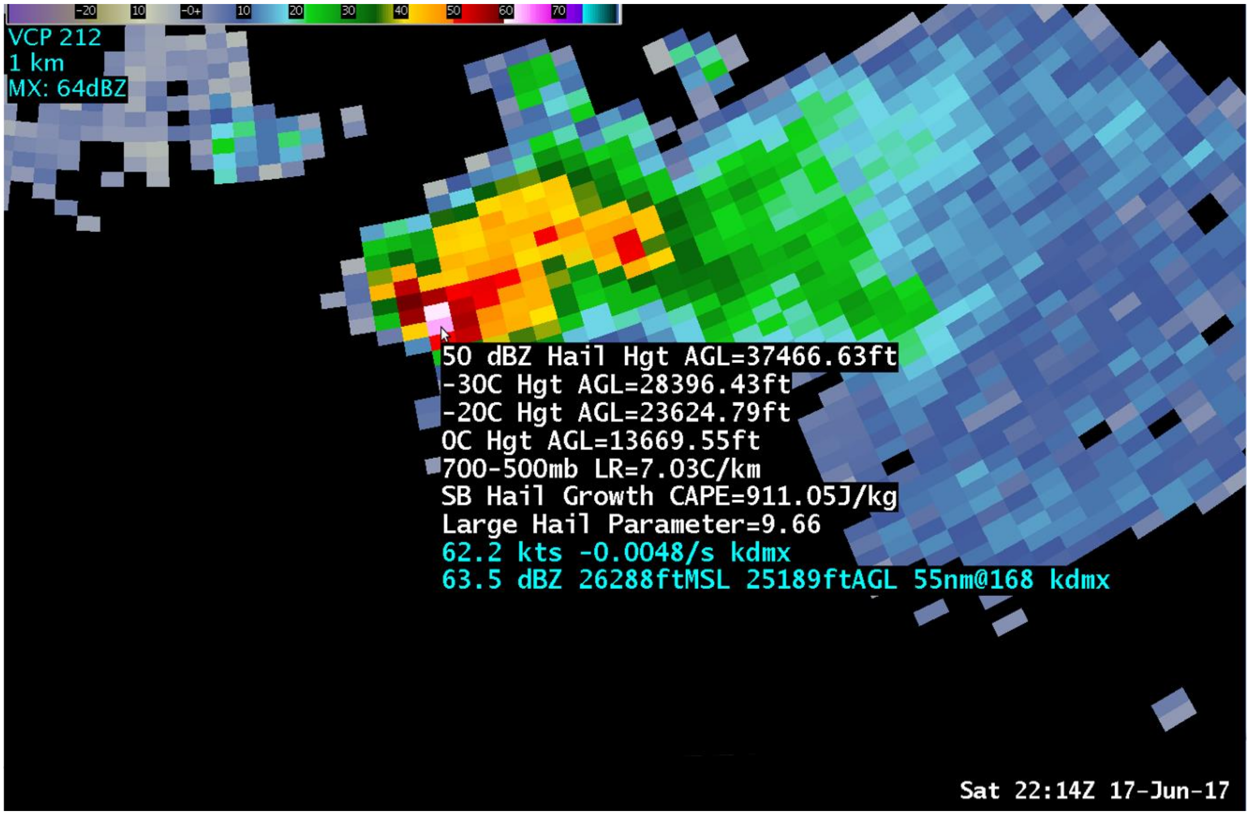


Figure 2 - NSEA RAP13 Hail Bundle superimposed on 4.0-degree reflectivity from DMX WSR-88D radar at 2214 UTC, 17 June 2017. Note the radar indicates a 63 dBZ reflectivity core more than 1000 ft higher than the height of the -20C level. This signature gave confidence to the forecaster's decision to issue a severe thunderstorm warning for large hail.

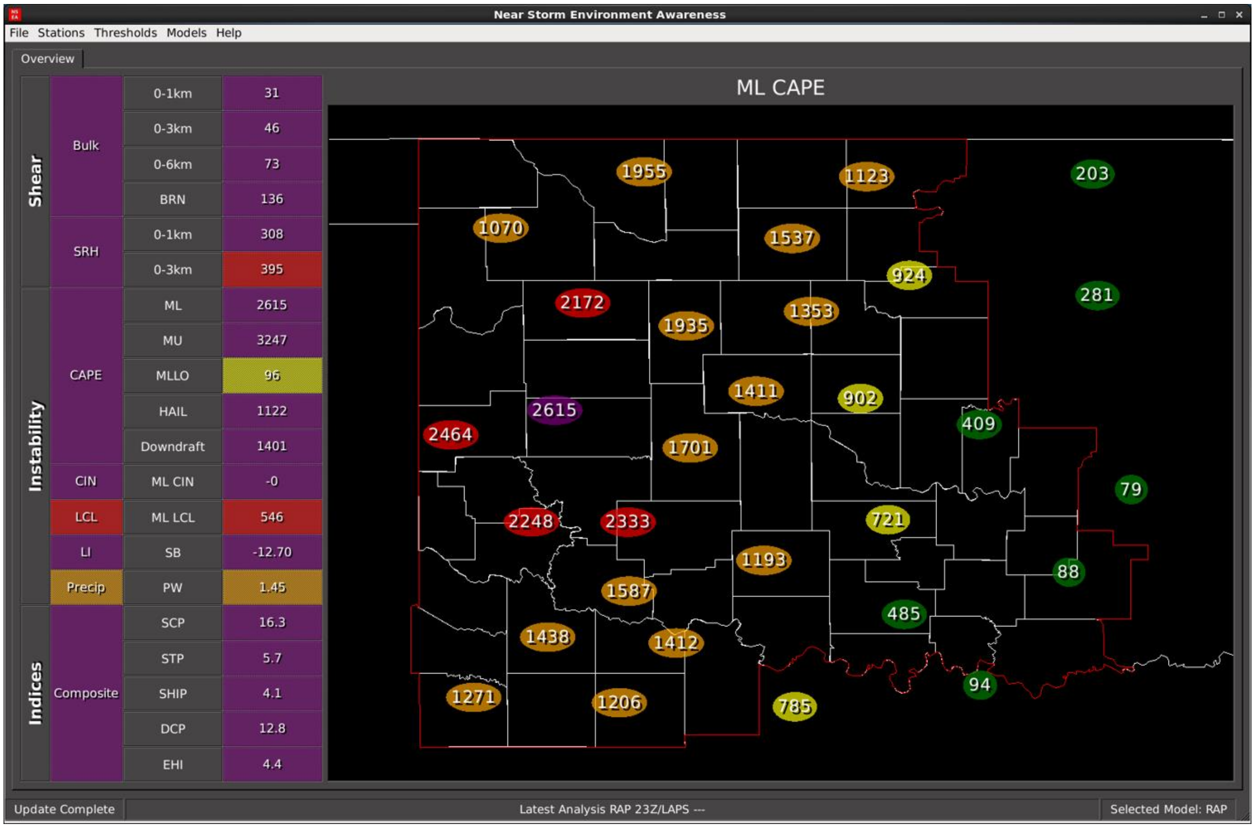


Figure 3 - NSEA Application plan view display. Menu of shear, stability, and composite index options is on the left. Mixed Layer Convectively Available Potential Energy (ML CAPE) is displayed in the main viewing window to the right of the menu. Units are J/kg. Color-coded thresholds are configurable.

Figure 4 - NSEA Application Time Series Graphs, plotted for all severe weather parameters at Clinton-Sherman Airport, OK (CSM), on 8 MAY 2016. Base time is 2300 UTC, denoted by blue, vertical dashed line. Previous two hours of observed information are plotted to the left of the current time and presented with a blue fill. Ensuring six hourly forecasts, based on the RAP13, are plotted to the right and presented with a white fill. Trends for the Significant Tornado Parameter are highlighted in the graph within the yellow oval.

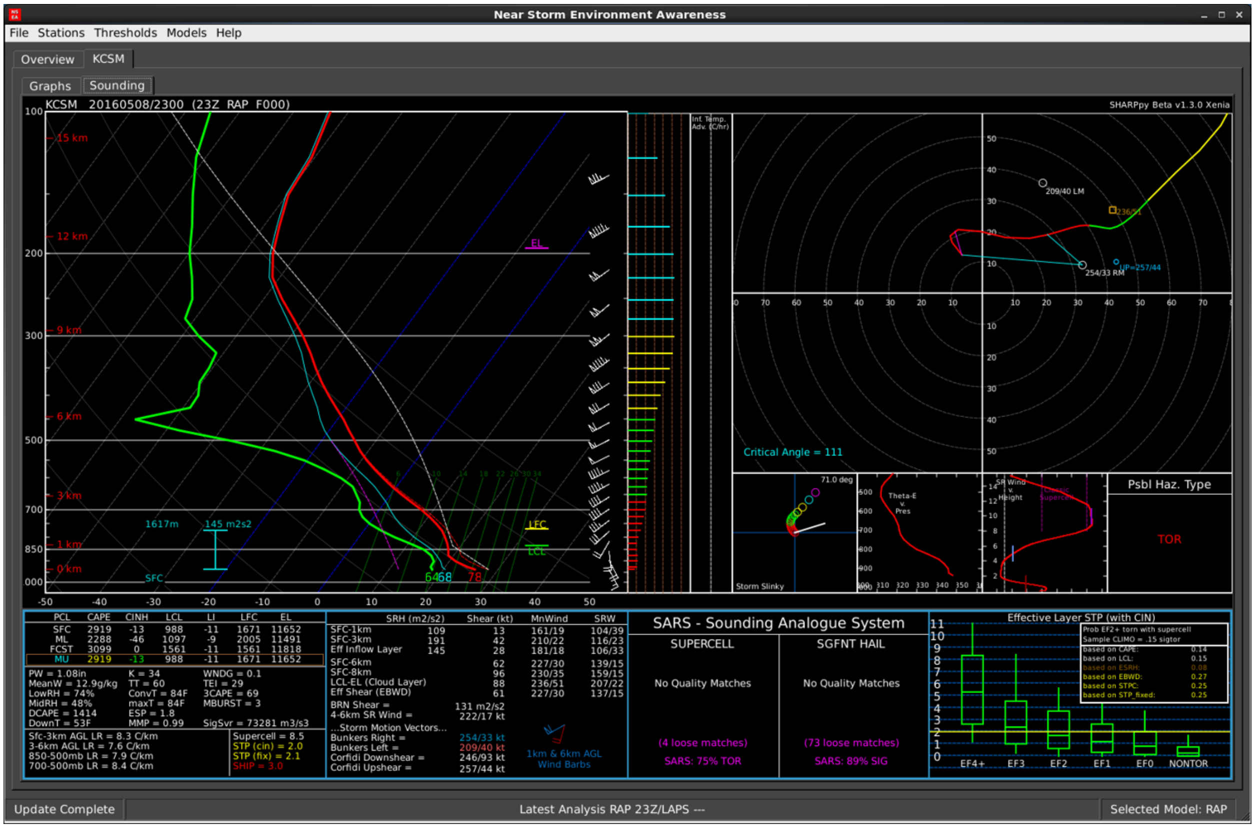


Figure 5 - Editable SharpPy Skew-T diagram and hodograph, along with several tables of calculated severe weather parameter. Functionality, presentation, configurability, and ease of manipulation were all rated as far superior to the sounding program currently in AWIPS.

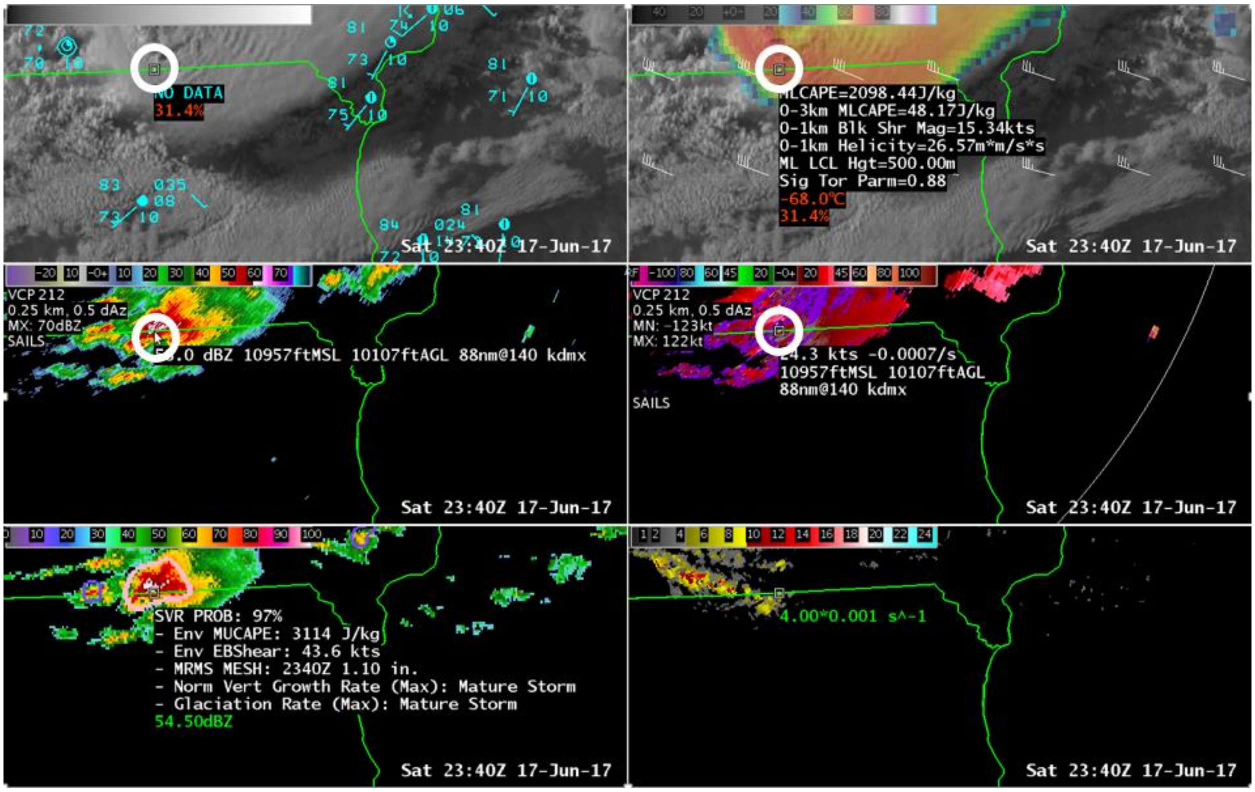


Figure 6 - One of the displays provided for real-time exercises, in which the challenge was to integrate multiple high-resolution data sets into warning decisions. In this example, the NSEA Cursor Readout data is superimposed on GOES-16 imagery in the two top panels; low-level radar reflectivity and velocity are displayed in the middle left and right, respectively; and at the bottom, ProbSevere model output can be viewed, along with MRMS reflectivity and MRMS rotation tracks. The cursor location, within the white circle, is placed where the main updraft is located radar reflectivity suggests the main updraft is positioned. The upper right panel depicts the apparent difference in its location relative to the satellite-indicated overshooting top, a displacement caused by parallax.

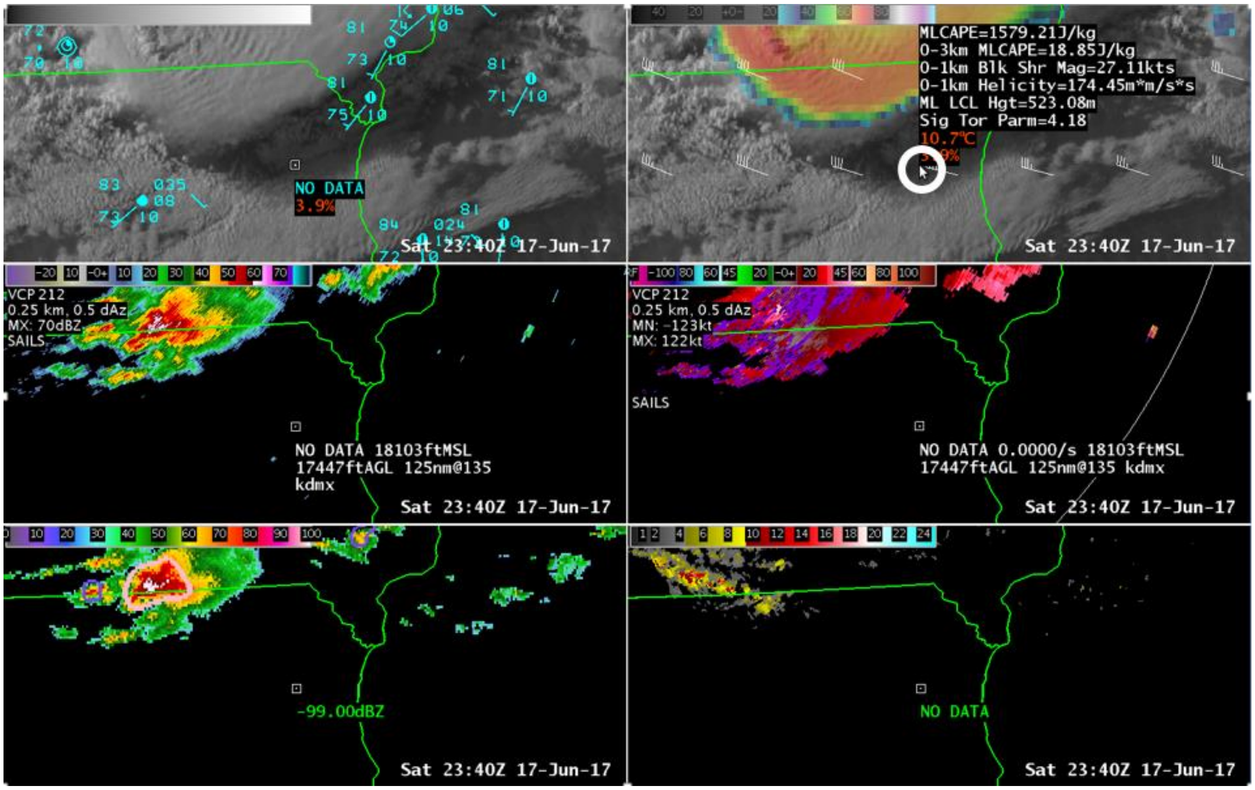


Figure 7 - Same display as in Figure 6, but with the cursor situated approximately 40 miles to the southeast of the main updraft location identified in Figure 6. Note the environment is much more favorable for potential tornado production here.

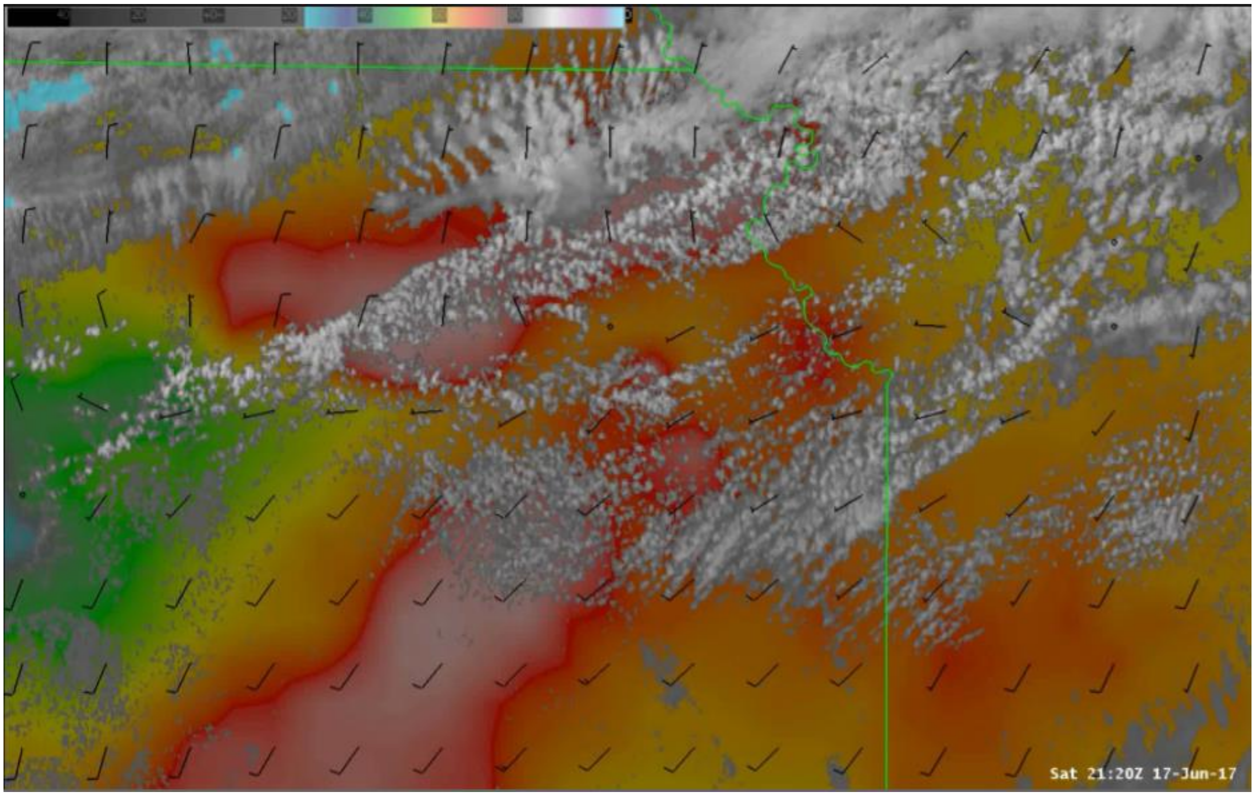


Figure 8 - Plan view of satellite imagery superimposed on RAP13 model output. In this example from 2120 UTC, 17 JUNE 2017, the satellite color table has been modified such that clear sky pixels are made transparent, allowing the underlying image (in this case, RAP13 surface dewpoints) to be viewable in areas that are not cloudy. Boundary layer (BL) winds are also depicted (wind barbs in knots). Two observations of note: (1) the RAP13 has the right overall idea concerning a NE-SW oriented line of BL convergence, but satellite imagery indicates it is positioned slightly farther north of where the model predicted; and (2) the area where vigorous, deep convection is most likely to initiate is suggested by the area where BL convergence is juxtaposed with a pool of higher dewpoints, or perhaps in the gradient between modest moisture and rich moisture. Large scale ascent associated with the mid-level jetstreak in the northwest portion of the image will also support this area of development.

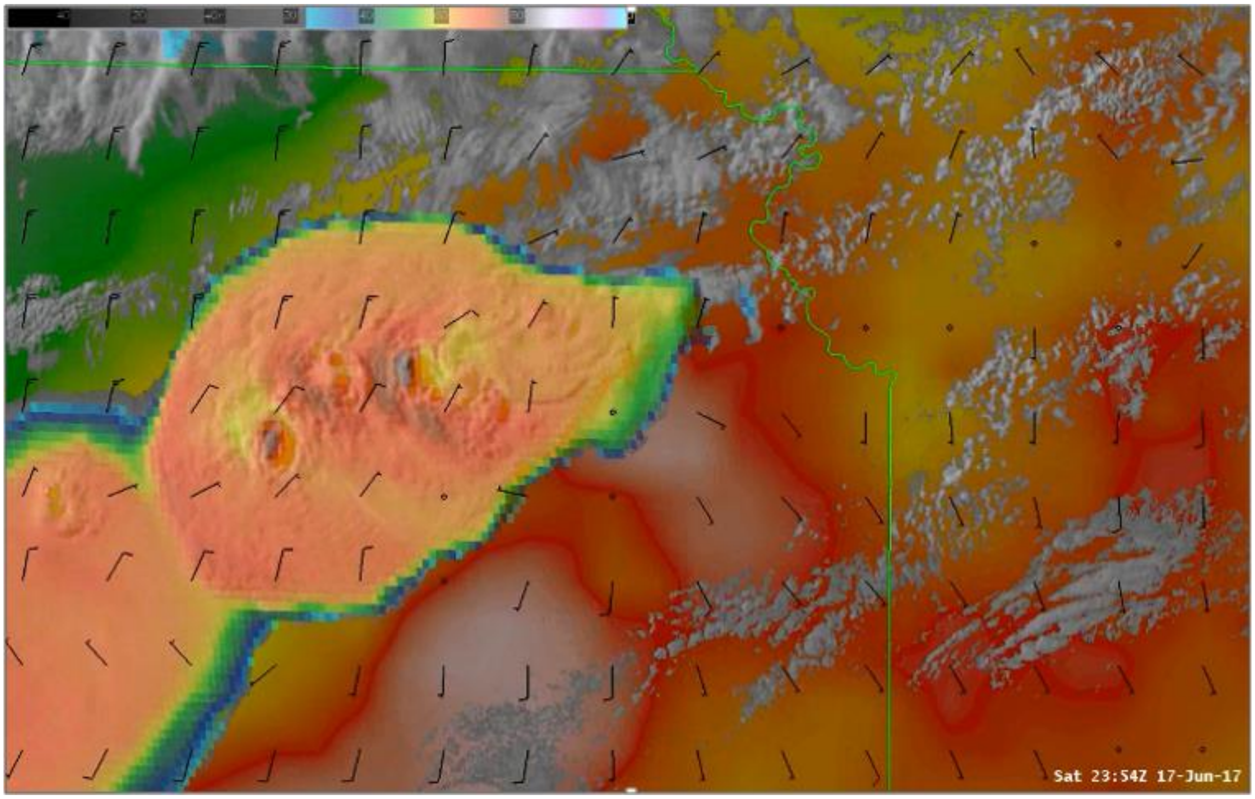


Figure 9 - Same area shown in Figure 8, at 2354 UTC, 17 JUNE 2017. The cap has broken, and vigorous deep, moist convection is actively growing along the frontal convergence zone. The so-called “sandwich product technique” used here accentuates the texture of the overshooting tops in visible imagery, while also allowing the cold cloud-top temperatures to appear in the colorized IR portion of the image. And as with Figure 8, the forecaster can use the merged imagery to validate the accuracy of the mesoscale model output, and make mental adjustments accordingly.

8. Appendices

APPENDIX A - ORE Participating Forecasters and NSEA Development Team

"Integration of NSEA and Other High-Resolution Data Sets in Convective Warning Operations"

Participating Forecasters

Week 1 (May 8-12)

Ryan Walsh	General Forecaster	WFO Billings, MT
Corey Mead	Lead Forecaster	WFO Omaha, NE
Cindy Elsenheimer	Lead Forecaster	WFO Jacksonville, FL

Week 2 (May 22-26)

Reid Wolcott	Lead Forecaster	WFO Las Vegas, NV
Cory Mottice	General Forecaster	WFO Cleveland, OH
Gene Brusky	SOO	WFO Green Bay, WI

Week 3 (June 5-9)

Mark O'Malley	Lead Forecaster	WFO Phoenix, AZ
Hunter Coleman	General Forecaster	WFO Columbia, SC
Steve Nelson	SOO	WFO Atlanta, GA

Week 4 (June 19-23)

Brad McGavok	Lead Forecaster	WFO Tulsa, OK
Jacob Beitlich	General Forecaster	WFO Minneapolis, MN
Matthew Kramar	SOO	WFO Pittsburgh, PA

Members of the NSEA Development Team

David Hotz, SOO	WFO Morristown, TN	(SME for Week 1)
TJ Turnage, SOO	WFO Grand Rapids, MI	(SME for Week 2)
Chad Entremont, SOO	WFO Jackson, MS	(SME for Week 3)
Steve Keighton, SOO	WFO Blacksburg, VA	(SME for Week 4)
Jason Schaumann, LF	WFO Springfield, MO	
Jerry Wiedenfeld, ITO	WFO Milwaukee, WI	
Aaron Anderson, ITO	WFO Norman, OK	
Patrick Marsh, WCM	Storm Prediction Center	
Joe Dellocarpini, SOO	WFO Boston/Taunton, MA	
Mike Sutton, LF	WFO Grand Rapids, MI	

APPENDIX B – Weekly Schedule

"Integration of NSEA and Other High-Resolution Data Sets in Convective Warning Operations"

MONDAY

8:00 AM - Introductions, Initial Orientation (1 h)
8:15 AM - Begin Ingest of Training Exercise (Case 0) at 25 May 2016 at 2030 UTC
****Restart EDEX after RAP data begins ingesting****
8:30 AM - Set up AWIPS Workstations and Windows Desktops (Derrick)
9:00 AM - Shift Briefing Video and Training Exercise (25 May 2016 2115-2345 UTC)
9:05 AM - NSEA Application Startup and Configuration
9:15 AM - NSEA Application Overview
9:35 AM - NSEA Application Parameter Graphs Tab
9:45 AM - NSEA Application Sounding Display Tab
10:00 AM - Create AWIPS Radar Procedures
10:45 AM - NSEA Cursor Readouts
11:30 AM - Lunch (off site) until 1:00 PM
12:15 PM - Begin Ingest of Exercise 1 (Case 1) at 24 Aug 2016 at 1640 UTC
****Restart EDEX after RAP data begins ingesting****
12:30 PM - Set up AWIPS Workstations and Windows Desktops (Derrick)
1 PM - Shift Briefing Video and Exercise 1 (24 August 2016 1725-1955 UTC)
3:30 PM - Break
3:45 PM - Exercise 1 Feedback Survey and Discussion
4:30 PM - End of Day

TUESDAY

7:30 AM - Begin Ingest of Exercise 2 (Case 2) at 31 May 2016 at 1400 UTC
****Restart EDEX after RAP data begins ingesting****
7:45 AM - Set up AWIPS Workstations and Windows Desktops (Derrick)
8 AM - Forecasters Arrive
8:15 AM - Shift Briefing Video and Exercise 2 (31 May 2015 1445-1715 UTC)
10:45 AM - Break
11:00 AM - Exercise 2 Feedback Survey and Discussion
11:30 AM - Lunch (off site) until 1:00 PM
12:15 PM - Begin Ingest of Exercise 3 (Case 3) at 8 May 2016 at 1945 UTC
****Restart EDEX after RAP data begins ingesting****
12:30 PM - Set up AWIPS Workstations and Windows Desktops (Derrick)
1 PM - Shift Briefing Video and Exercise 3 (8 May 2016 2030-2300 UTC)
3:30 PM - Break
3:45 PM - Exercise 3 Feedback Survey and Discussion
4:00 PM - Discussion
4:30 PM - End of Day

WEDNESDAY

9:30 AM - Arrive and Discuss Today
10:00 AM - Analyze Short-term Model Output and Pick Locations
11:00 AM - Monitor Chosen Locations for Convection
12:00 PM - Lunch (on site) until 1:00 PM
1:00 PM - Continue Monitoring for Convection
6:00 PM - End of Day

THURSDAY

9:30 AM - Arrive and Discuss Yesterday
10:00 AM - Analyze Short-term Model Output and Pick Locations
11:00 AM - Monitor Chosen Locations for Convection
12:00 PM - Lunch (on site) until 1:00 PM
1:00 PM - Continue Monitoring for Convection
6:00 PM - End of Day

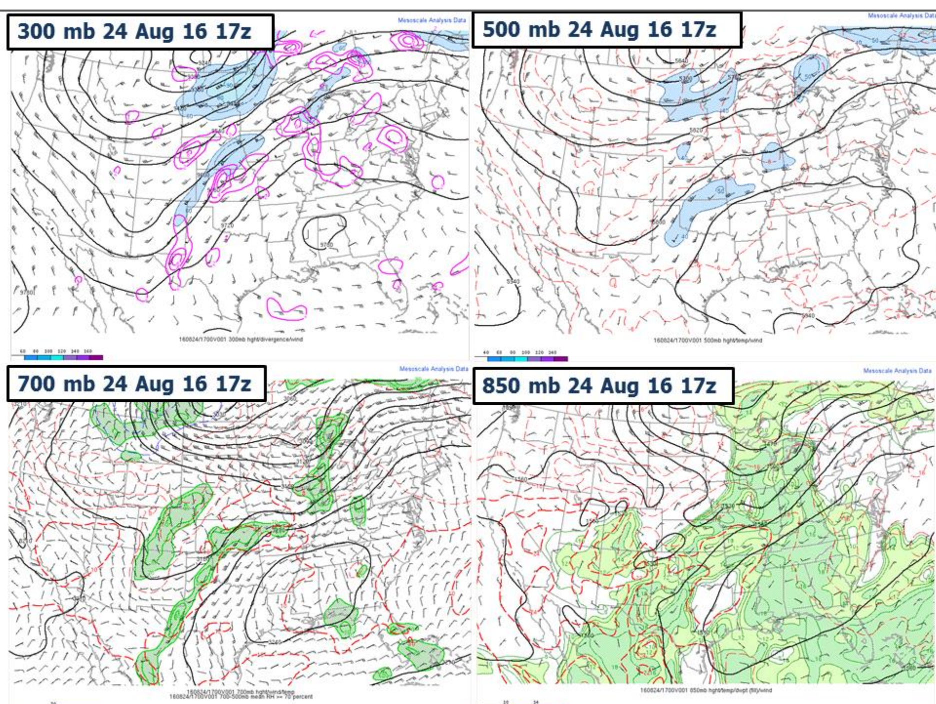
FRIDAY

8:00 AM - Arrive and Final Survey
9:30 AM - Final Discussion
11:00 AM - End of Evaluation Week

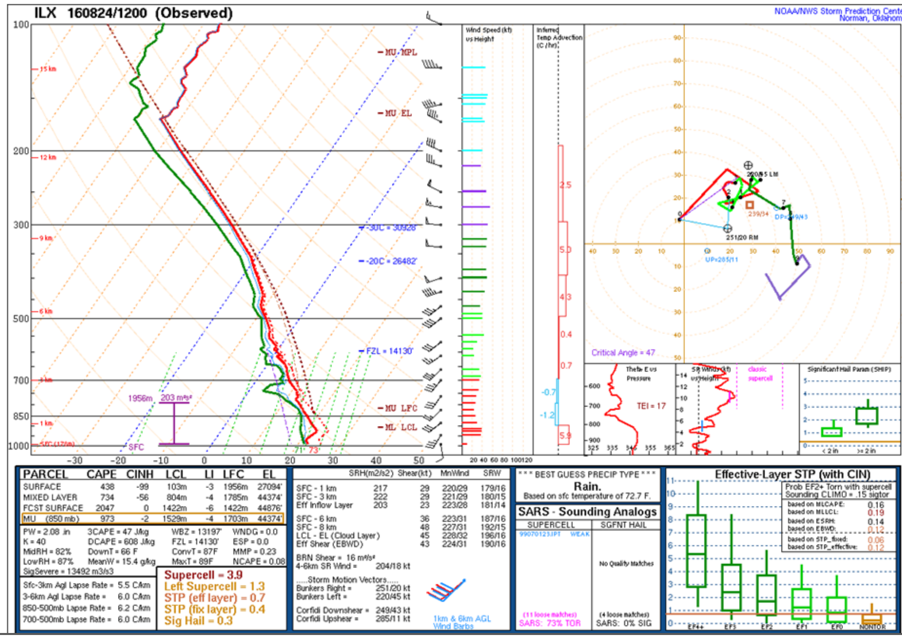
APPENDIX C – Example of In-Brief Slides for Evaluation Exercises

"Integration of NSEA and Other High-Resolution Data Sets in Convective Warning Operations"

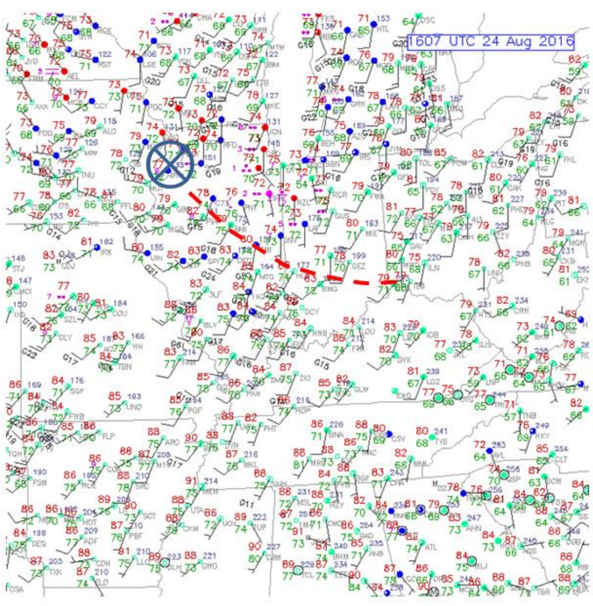
Exercise 1
Central Indiana
24 August 2016 Begin at 1725 UTC



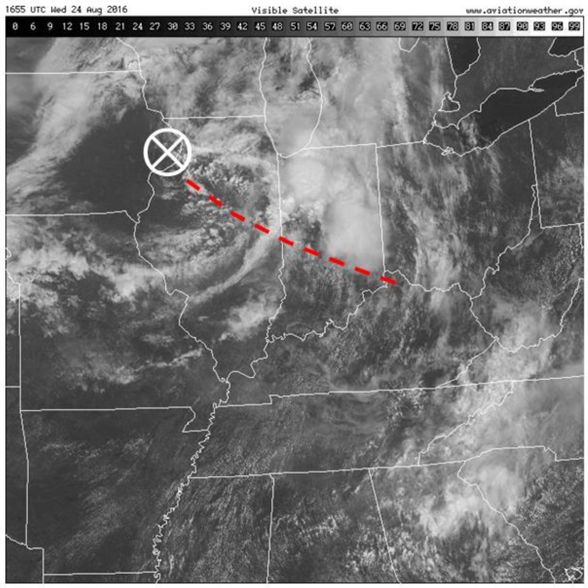
ILX Sounding – 12 UTC



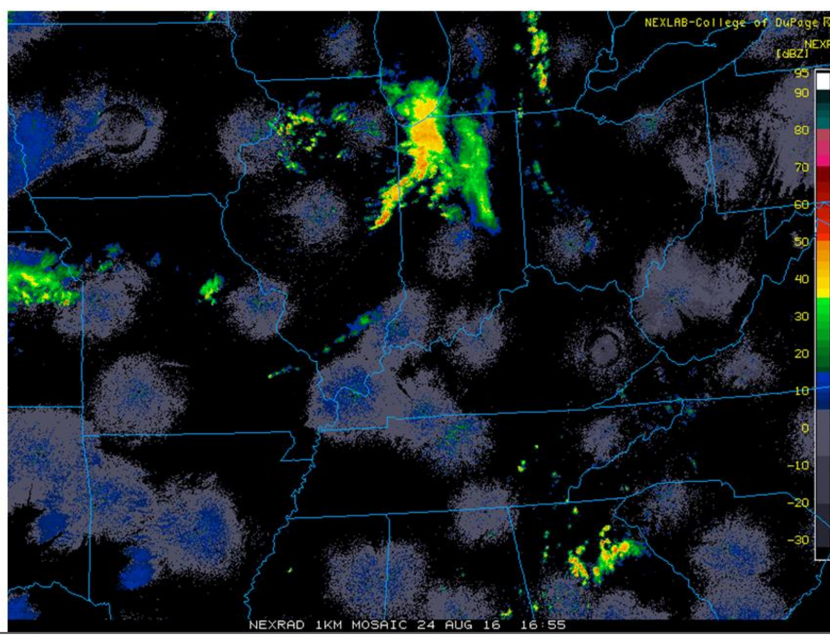
Surface Observations – 1607 UTC



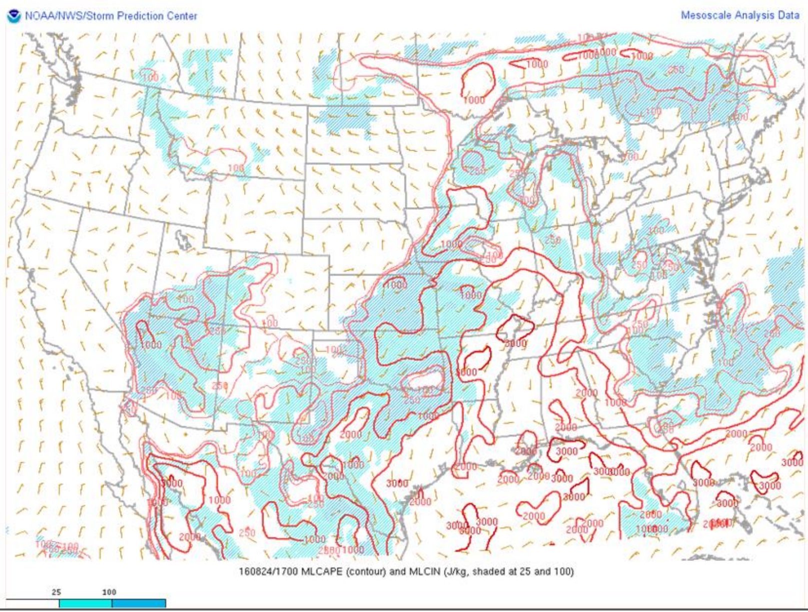
Current Vis – 1655 UTC



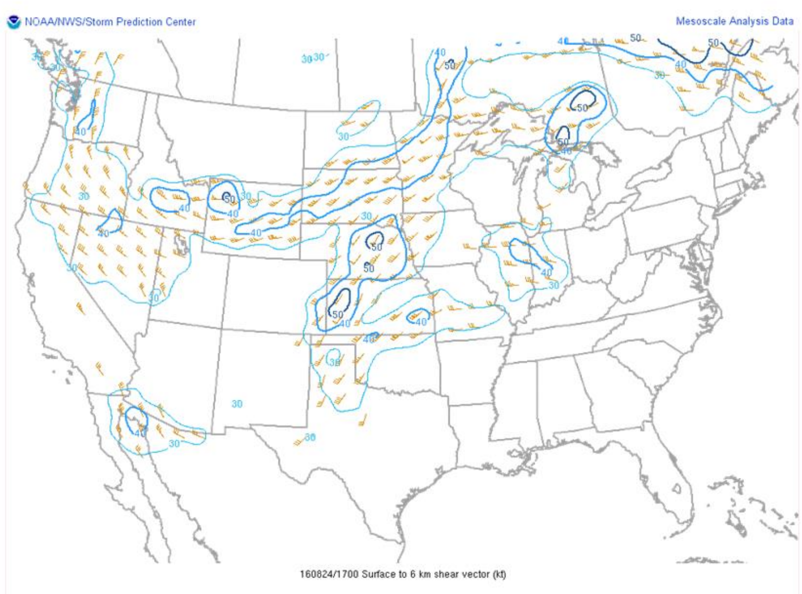
Regional Radar – 1655 UTC



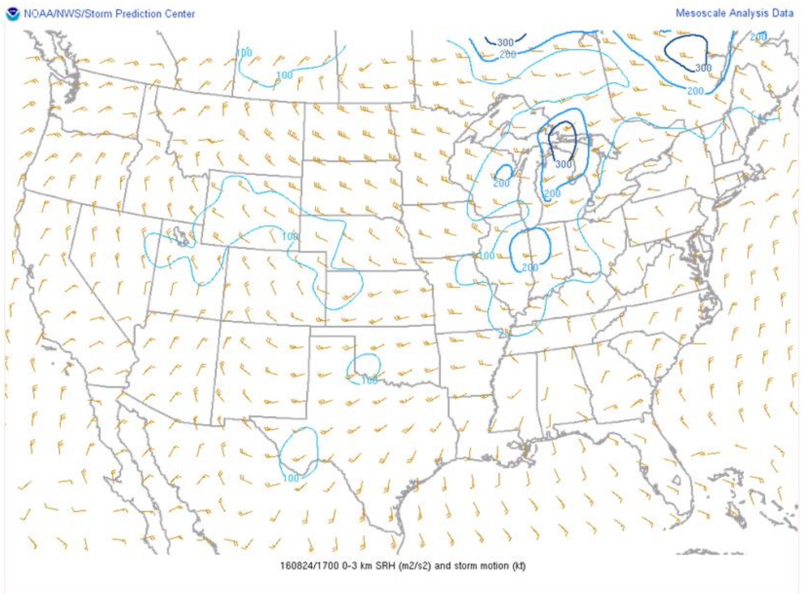
Mixed-Layer CAPE/CIN – 1700 UTC



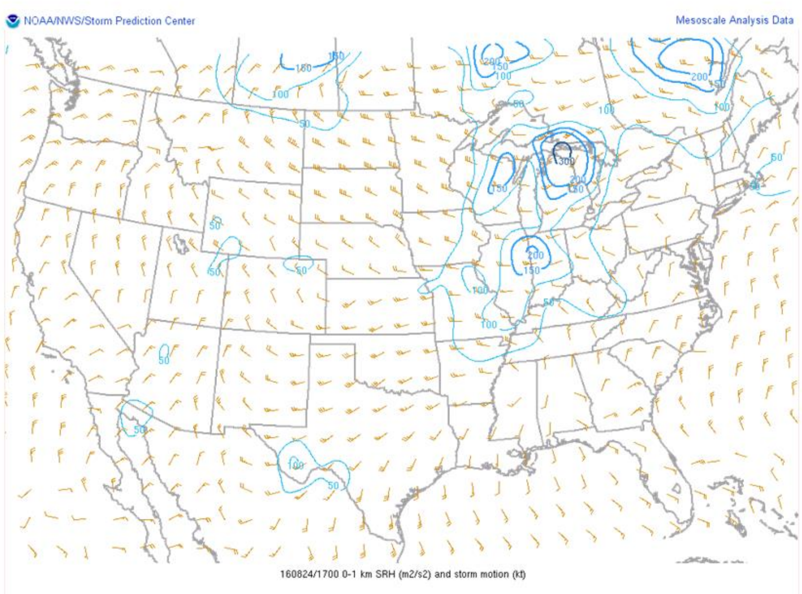
0-6 km Bulk Shear – 1700 UTC



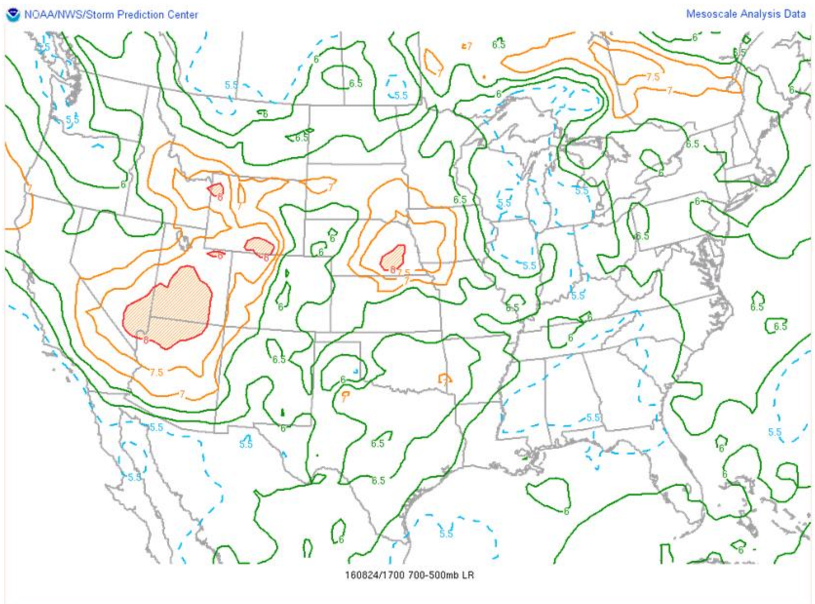
0-3 Storm-Relative Helicity/Stm Motion – 1700 UTC



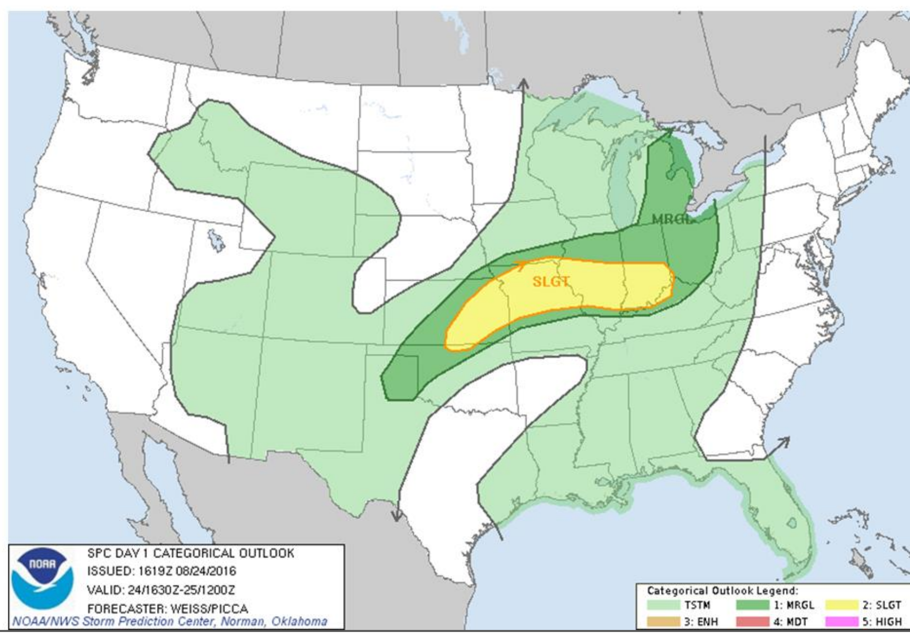
0-1 Storm-Relative Helicity/Stm Motion – 1700 UTC



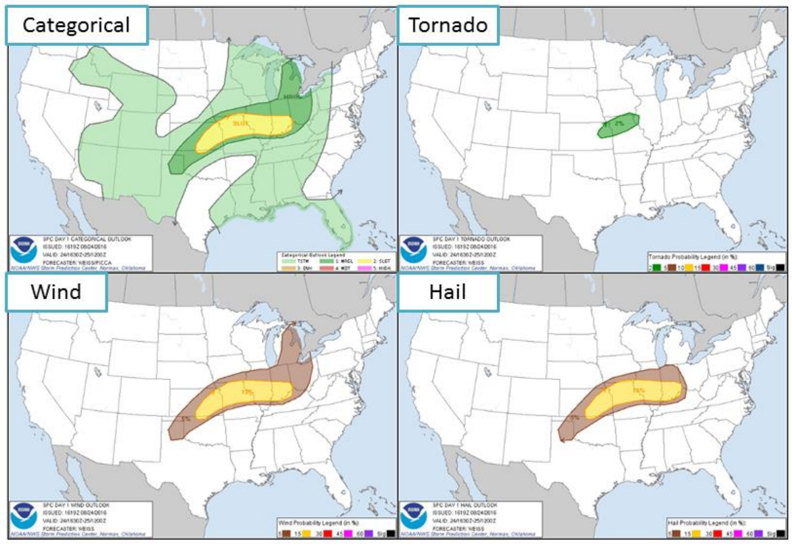
700-500-mb Lapse Rates – 1700 UTC



Current SPC Day 1 Outlook – 1630 UTC



SPC Day 1 Hazards Outlook– 1630 UTC



Supplementary Information: Exercise 1

- **You will be localized as IND.**
- **You will be working individually.**
- **Available Data:**
  - **Radar: KIND, KILX, KIWX**
  - **Satellite: GOES-13 VIS, IR, WV**
  - **Surface Observations**
  - **Model Output: RAP and HRRR**
  - **Near-Storm Environment Awareness (NSEA) application and cursor readout**
- **Primary Task: Monitor for severe convection. Issue convective warnings as necessary.**
- **This simulation begins at 17:25 UTC or 1:25 p.m. local time.**