6A.2 The testing of NSSL multi-sensor applications and data from prototype platforms in NWS forecast operations

Kevin A. Scharfenberg* and Travis M. Smith
Cooperative Institute for Mesoscale Meteorology Studies, University of Oklahoma;
also affiliated with NOAA/National Severe Storms Laboratory, Norman, OK

Gregory J. Stumpf
Cooperative Institute for Mesoscale Meteorology Studies, University of Oklahoma;
also affiliated with NOAA/National Weather Service Meteorological Development Laboratory, Silver Spring, MD

1. Introduction

The National Severe Storms Laboratory (NSSL) has delivered experimental data, applications, and decision support systems to National Weather Service (NWS) forecast offices for many years. The products recently under evaluation by NWS forecasters include those from prototype platforms, such as bulk hydrometeor classification provided by dual-pol radar and three-dimensional lightning information from the Oklahoma lightning mapping array. Experimental severe weather diagnostic tools are also being tested, including quantitative precipitation estimates derived from multiple sensors, low-level rotation track maps, and multi-radar hail analysis tools which incorporate near-storm environment (NSE) model data. Many of these experimental data sets are being viewed with the NSSL's Warning Decision Support System - Integrated Information (WDSS-II), which allows four-dimensional data visualization in real-time and the automated processing of data from multiple platforms (Hondl 2002).

Many of these applications and platforms are now beginning their operational implementation phase (e.g., dual-polarization radar, terminal Doppler radar) and others are approaching periods of intense operational testing (e.g., phased-array radar, three-dimensional lightning sensing). With this in mind, NSSL-NWS experience with these platforms may be useful in planning future operational concepts and proposed national testbeds. Formal feedback was collected from forecasters at NWS forecast offices in Jackson, MS (Stumpf et al. 2003), Norman, OK (Scharfenberg et al. 2004; Adrianto et al. 2005), St. Louis, MO, and Wichita, KS. This manuscript summarizes results from all of these proof-of-concept tests and touches upon implications to the future of experimental and operational hazardous weather forecasting.

2. Warning Decision Support System – Integrated Information (WDSS-II)

WDSS-II is the second generation of a suite of algorithms and displays for severe weather analysis, warnings and forecasting. WDSS-II has been developed jointly by engineers at the NSSL and the Cooperative Institute for Mesoscale Meteorological Studies (CIMMS) at the University of Oklahoma. WDSS-II allows 4-dimensional display, interrogation, and manipulation of data sets from operational and experimental sources (in Earth-relative, time synchronized coordinates).

Using OpenGL visualization technology and off-the-shelf Linux workstations, three-dimensional data in WDSS-II can be displayed as shown in Fig. 1 (Stumpf et al. 2005). The vertical and horizontal cross-sections can be manipulated and dynamically updated on the fly. For example, the cross-section line shown in Fig. 1 could be "dragged" across the storm of interest, with the vertical display dynamically updating as the user drags the line.

Initial experiences in operational settings suggest 4-D visualization (the described 3-D visualization with time animation capability) allows for the rapid diagnosis of storm structure that might not be possible by looking at multiple individual elevation angles from individual radars. This opens up the possibility of improved warning services and greater skill through better forecaster situation awareness.

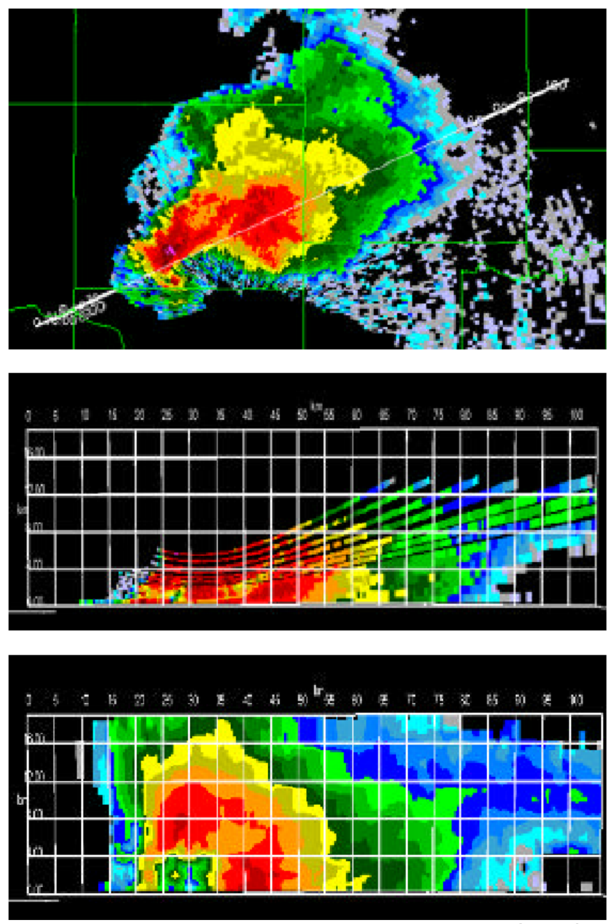

Fig. 1. Horizontal cross-section at 1 km AGL of a tornadic supercell (top). Vertical cross-section along the line shown in the top figure is shown for a single radar (middle) and for multiple radars (bottom).

* *Corresponding author address:*
Kevin A. Scharfenberg, National Severe Storms Laboratory, 1313 Halley Circle, Norman, OK 73069;
e-mail: Kevin.Scharfenberg@noaa.gov

WDSS-II also allows the rapid development of experimental applications by NSSL scientists through an intuitive application programming interface (API) (Lakshmanan 2002). This allows seamless integration of data from a variety of existing sources (polar and Cartesian) into one application without the need for repetitive coding.

3. Multi-Radar/Multi-Sensor Applications

Quality-controlled reflectivity data from all radars in the lower 48 United States are "merged" in near-real-time onto a three-dimensional Cartesian grid (Lakshmanan 2003). Each grid voxel value is determined by a distance-weighting scheme, and the data are updated in a virtual-volume manner (Lynn et al. 2002). Older data are advected to the merger product's valid time (Lakshmanan et al. 2003).

Numerical weather prediction model outputs are being used to incorporate NSE data into algorithms and applications (Stumpf et al. 2004a). Fig. 2 shows a plot of reflectivity at the altitude of the -20°C isotherm, where the reflectivity values were determined from the multiple-radar reflectivity merger, and the temperature information from the latest RUC model zero-hour forecast. In the case shown in Fig. 2, an area of reflectivity as high as 65 dBZ at the -20°C altitude preceded a report of hail greater than 12 cm in diameter. This allows forecasters to quickly combine reflectivity and thermodynamic data, saving time compared to the "stare and compare" technique – looking at data from one source on one screen and from the other on another screen.

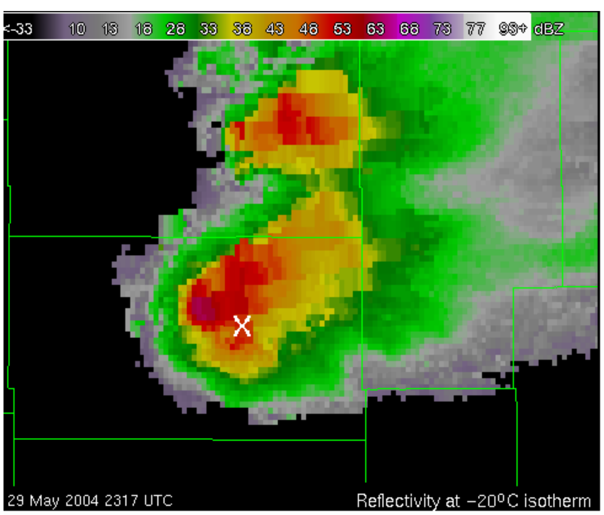

Fig. 2. Reflectivity at the -20°C isotherm, 2317 UTC on 29 May 2004. Maximum values near 65 dBZ are observed. The "X" marks the location of a report of hail more than 12 cm in diameter at 2325 UTC.

To produce a "hail swath" product, as shown in Fig. 3, the maximum value from the multiple-radar gridded hail product is plotted over the time period of interest. Such a plot allows the forecaster to have a "quick look" at the trends in direction and severity of the hail swath. In addition, verification efforts can be better focused on areas where hail was most likely to be observed at the ground (Stumpf et al. 2004b).

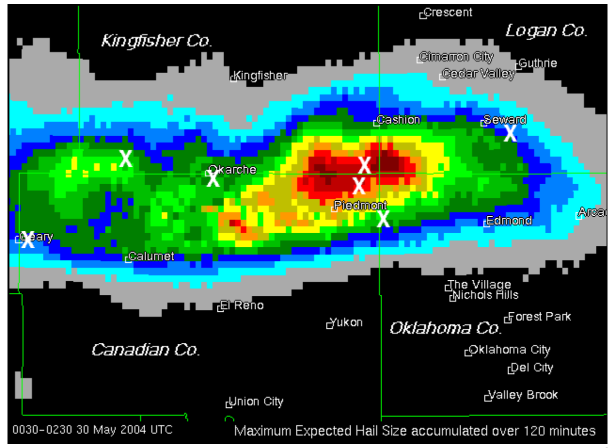

Fig. 3. 120-minute multiple-radar accumulation of maximum hail size, from 0030 to 0230 UTC on 30 May 2004. Each "X" marks the location of a hail report during the time period.

Other grid products can be accumulated over time to produce "swaths" for moving weather systems. Fig. 4 shows tracks of low-level rotation observed by multiple radars ("rotation tracks"). Because Doppler velocity information depends on radar viewing angle, a linear-least squares derivative (LLSD) of velocity algorithm was developed (Elmore et al. 1994) and tested in WDSS-II so that the radar-centric nature of velocity information could be removed and the data could be merged into a multi-radar grid. As in the case of the "hail swath" product, the "rotation track" product allows forecasters to quickly assess the changes in intensity and direction of low-level mesocyclones, and has been frequently used after tornadic events to assist in directing ground survey teams to areas of damage.

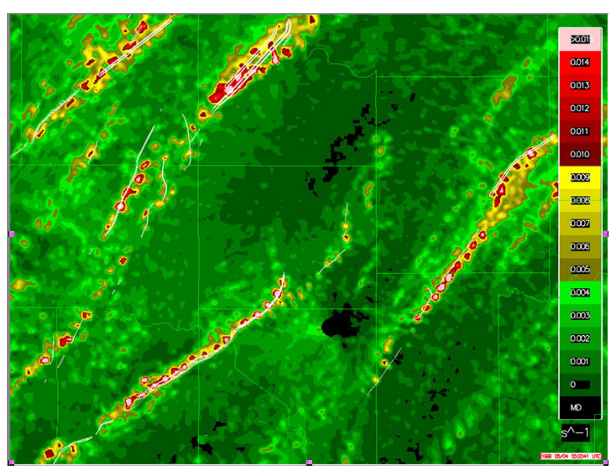

Fig. 4. Eight-hour gridded accumulated shear (LLSD-rotation) field for the 3 May 1999 tornado outbreak in Central Oklahoma. Overlaid thin white lines are the tornado track locations from NWS damage surveys.

4. Experimental/Non-operational Platforms

The tools available to forecasters and developers in WDSS-II allow for easy visualization, interrogation, and manipulation of data from test and experimental platforms. Instead of being written “hard-wired” to expect certain volume coverage patterns (VCPs) of WSR-88D, WDSS-II can display any Cartesian or polar data source. This allows rapid integration of data from new platforms, such as three-dimensional lightning detection systems, polarimetric radars, phased-array radars, and terminal Doppler weather radar (Miller and Burgess 2003).

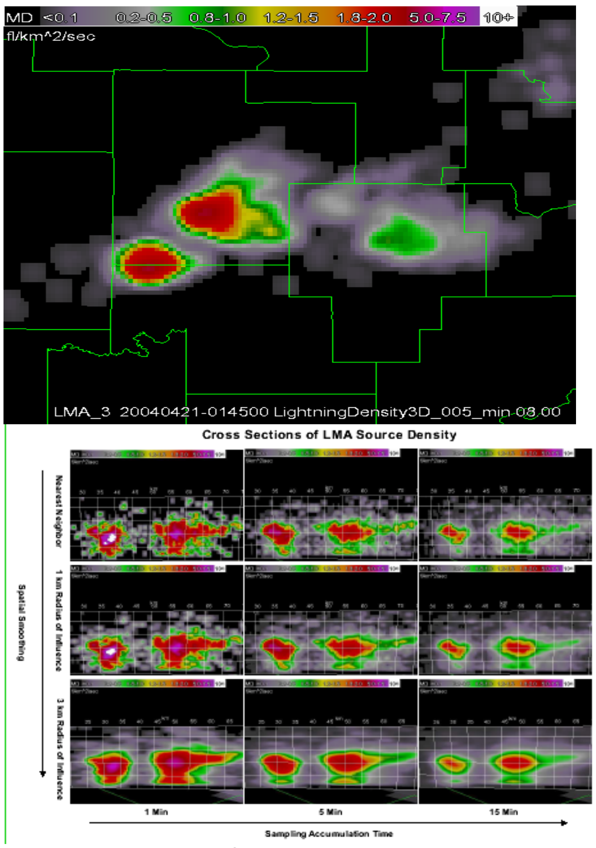

Fig. 5. Examples of lightning mapping array source density plots displayed in WDSS-II. Constant-altitude plan view (top) and cross-sections (bottom).

Three-dimensional data from the Oklahoma Lightning Mapping Array (LMA) (MacGorman 2005) are displayable in near-real-time in WDSS-II. Beginning in the summer of 2005, these data are being delivered to the NWS office in Norman, OK for evaluation by forecasters. Fig. 5 shows an example of LMA output. Data can be displayed in plan-view at 1-km intervals or cross-sections can be created, allowing users to determine the three-dimensional charge structure of thunderstorms. In addition, “vertically-integrated” lightning products are available, allowing forecasters to quickly assess three-dimensional lightning intensity trends.

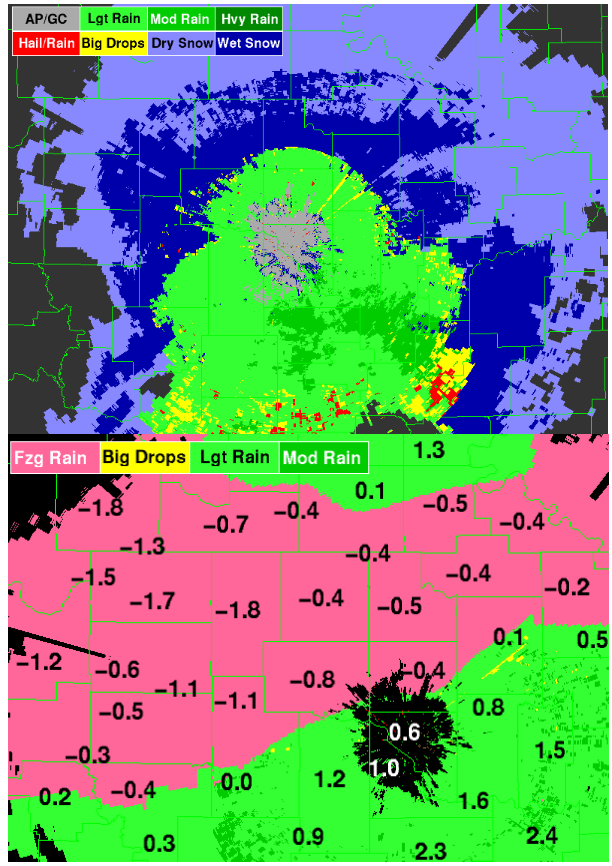

Fig. 6. Output from the polarimetric hydrometeor classification algorithm (HCA) from data collected during a winter storm on 4 December 2002 (top). Surface precipitation type algorithm output using dual-pol radar HCA data and surface mesonet temperature data in degrees Celsius (bottom).

WDSS-II was used as a display and application development program during the Joint Polarization Experiment (Ryzhkov et al. 2005), which demonstrated the operational utility of the polarimetric WSR-88D in NWS operations. Forecasters were able to view and evaluate hydrometeor classification algorithm output (top of Fig. 6), providing important feedback for the product’s developers. Additionally, new products could be developed to use polarimetric radar data. One such product incorporated polarimetric radar, numerical model, and surface temperature data to determine likely areas for freezing rain at the surface (Fig. 6, bottom).

5. WDSS-II Products Displayed By Other Software

Beginning in the spring of 2005, a selection of WDSS-II application outputs were made available for near-real-time viewing in AWIPS D2D (Fig. 7) at NWS forecast offices in Norman and Tulsa, Oklahoma and in Fort Worth, Texas. This allows more frequent forecaster interaction with these products, yielding greater feedback for developers. The NetCDF-format products are prepared at NSSL, and routed through NWS

Southern Region Headquarters to field offices over the internet via local data manager (LDM) servers at each site.

This demonstration concept allows NSSL scientists to develop products and applications in WDSS-II, which is also used as a display for preliminary feedback from forecasters. Products that show promise for long-term implementation in NWS operations can be more intensely evaluated via direct ingest into AWIPS. It is hoped that as AWIPS storage capacity and communication infrastructure are improved over time, more applications developed in WDSS-II can be tested in AWIPS.

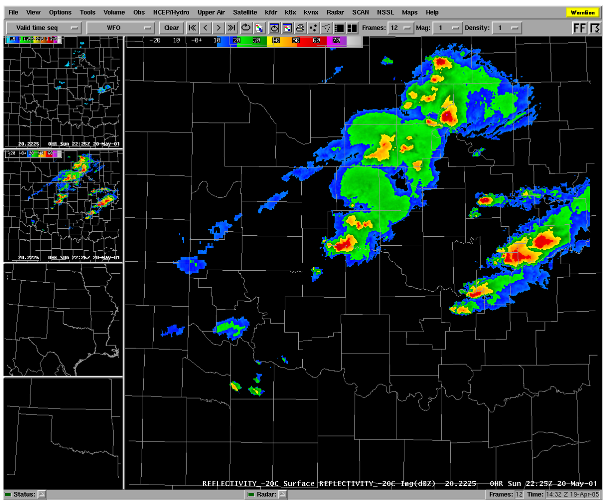

Fig. 7. Example of output from the WDSS-II reflectivity at the -20°C isotherm algorithm displayed in AWIPS D2D.

Additionally, some WDSS-II applications can be displayed in near-real-time as overlays in a popular internet GIS program. This will allows a variety of users to be exposed to these developmental products. Please refer to http://cimms.ou.edu/~smith/wdssii for further information.

6. Discussion and Conclusions

NSSL is using the Warning Decision Support System – Integrated Information (WDSS-II) for multiple purposes, such as rapid development of prototype multiple-radar/multiple-sensor applications, display and manipulation of data from experimental platforms, and testing of 4-dimensional dynamic data interrogation. Many of these concepts have already been successfully tested in operational environments at several National Weather Service field offices.

The 4-D visualization concepts in WDSS-II are designed to help forecasters better manage the rapidly increasing volume of information used in operational hazardous weather detection and prediction. The multiple-radar/multiple-sensor concepts also help eliminate the need for the forecaster to “stare and compare” sensor data and “near-storm environment” information.

The authors believe more effective data management tools will become increasingly crucial as more observing platforms are deployed and the information load on forecasters continues to grow. 4-dimensional visualization and multiple-radar/multiple-sensor merged data sets are key components to effective data management. These concepts should be tested and refined through their use in hazardous weather testbeds.

7. Acknowledgments

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