P10.5 THE NOAA HAZARDOUS WEATHER TESTBED 2008 SPRING EXPERIMENT: TECHINCAL AND SCIENTIFIC CHALLENGES OF CREATING A DATA VISUALIZATION ENVIRONMENT FOR STORM-SCALE DETERMINISTIC AND ENSEMBLE FORECASTS

Jason J. Levit*[1], Gregory W. Carbin[1], David R. Bright[1], John S. Kain[2], Steven J. Weiss[1], Russell S. Schneider[1], Michael C. Coniglio[2], Ming Xue[3], Kevin W. Thomas[3], Matthew E. Pyle[4], Morris L. Weisman[5]
[1]NOAA/NWS Storm Prediction Center
[2]NOAA National Severe Storms Laboratory
[3]Center for Analysis and Prediction of Storms and University of Oklahoma
[4]NOAA/NWS Environmental Modeling Center
[5]National Center for Atmospheric Research

1. INTRODUCTION

The 2008 NOAA Hazardous Weather Testbed (HWT; http://hwt.nssl.noaa.gov) Spring Experiment was a seven-week experiment in April, May, and June of 2008 that focused on examining high-resolution numerical weather prediction forecasts, for use in operational convective weather forecasting (Coniglio et. al. 2008). Both deterministic and ensemble forecasts were generated, by several research centers and NOAA, and evaluated using a variety of new and innovative techniques. Visualizing these data sets in an experimental sense required a large software design effort to not only create images for data investigation, but also to technically manage the diverse data ingest systems and data archival. The NOAA Storm Prediction Center (SPC) and the National Severe Storms Laboratory (NSSL) worked together to create an environment where experiment participants could view and discuss these detailed model data, and collaborate on generating experimental forecasts, in a laboratory-like setting.

2. EXPERIMENT DESIGN

Several different model forecasts were produced for the HWT spring experiment, generated by different modeling centers around the country. All forecasts used in the experiment had an initialization time of 00 UTC.

The Center for Analysis and Prediction of Storms (CAPS), located at the University of Oklahoma, created a 10-member 4km high-resolution WRF-ARW ensemble (mixed physics and initial condition perturbations) forecast using the WRF-ARW model, and a single 2km deterministic forecast. The National Center for Atmospheric Research (NCAR) generated a 3km WRF-ARW forecast; the National Severe Storms Laboratory (NSSL) produced a 4km WRF-ARW deterministic forecast, and finally, NOAA's Environmental Modeling Center created a WRF-NMM 4km deterministic run.

Generally, the 2008 experiment attempted to answer these questions: what impact would high resolution ensemble and deterministic model forecasts have on human generated convective storm forecasts? Would forecasts be improved using the model data (Kain et. al., 2008), and what impact would radar data assimilation have on the forecasts (Xue et. al. 2008)? To explore that question, customized software was created to ingest the large data sets created and to visualize the unique output fields.

3. PROJECT DATAFLOW

With many different model data sets flowing into the HWT, ingesting and managing these in real-time was a large focus of the "behind-the-scenes" software development. Given that most of the model forecasts were purely experimental and were not necessarily supported in an operational 24x7 environment, a "grass-roots" type effort of software development was employed at SPC that generated customized, "from-scratch" software programs for data ingest, data flow monitoring, image creation, dynamic web page content, experimental forecast creation, participant survey evaluations, and data archival, all while ensuring IT security. To create a seamless environment that provided the maximum opportunity for participants to evaluate and discuss each experimental forecast, several specific problems had to be addressed and solved, requiring a highly collaborative and orchestrated effort by both the hosting agencies of the HWT (SPC and NSSL) and external organizations providing experimental data. *Effective communication and collaboration is important for performing a successful experiment such as this*. Specific problems that had to be addressed with custom software are described below.

All of the high resolution forecasts and graphics generated for their evaluation were performed overnight, usually between midnight and 6am CDT. Therefore, the software that ingested the data had to be robust, recover from significant errors in dataflow (e.g., missing data files) and create detailed logs for problem troubleshooting, while executing automatically overnight. Additionally, each forecast was created by a different center and the data generation was not centralized in one location. Therefore, this problem was solved by generating customized ingest scripts, using the Practical Extraction and Reporting Language (Perl) and C-shell scripts (csh) to ingest the data in real-time, via cronjobs on data servers at both the SPC and the NSSL. Each forecast model used a separate ingest script (including each member of the CAPS ensemble).

* *Corresponding author address*: Jason J. Levit, NOAA, NWS Storm Prediction Center, 120 David L. Boren Blvd., Suite 2300, Norman, OK 73072 e-mail: jason.levit@noaa.gov

4. DATA ANALYSIS AND VISUALIZATION

Creating displays for the analysis and visualization of these large and data rich model forecasts is challenging. Traditional methods of displaying model data (using existing tool sets) are usually pushed to the limit or are wholly inadequate because of the model grid size, or because data at these high resolutions require large amounts of computing power to display.

High resolution model data can be thought of, in a general sense, as "enhanced" radar data since these models are capable of resolving phenomena that are typically observed near the radar scale (~few kilometers). Model output fields that are meaningful on that scale, such as simulated radar reflectivity, become very important to visualize and compare with real data for evaluation. Therefore, most of the HWT spring experiment data were visualized with this concept in mind, such that the model data would be characterized and examined at these scales, and that traditional output fields of (for example) 500mb height would either be too noisy or would eventually become synoptically meaningless once convection was initiated. This idea, that one of the core strengths of these models is producing "radar-like" data, formed the basis for many of the display vehicles used to examine them.

Two main software tools were used to view the model data. The first consisted of ingesting the raw gridded data into N-AWIPS, the NCEP national center version of AWIPS, by using pre-configured macro-like tools to load specific model fields into a single looping frame. This tool was also used to view real-time data during the experiment.

The other tool consisted of customized, dynamic web pages with pre-generated images using several scripting languages and GEMPAK. Since N-AWIPS allows data browsing in a single loop (however, users can flip between loops containing different data, but only one loop per screen is possible), the web page images needed to be created to show side-by-side comparisons of different model fields (Figure 1), and verification data, for more efficient evaluation. Here, especially, software reusability was very important, because some image combinations that were created during the experiment were "on-demand", as needs to examine different data sets were recognized upon model data evaluation. The scripting languages used to generate the images consisted of (as before with the ingest scripts) Perl and csh, while the dynamic web pages were created with PHP. Software modularity allowed for rapid, on-the-fly redesigns of image combinations and web pages to accommodate the changing needs of the experiment from week-to-week. This was important because it allowed the experiment designers and software developers to focus on content creation, rather than software design, and participate more directly in the day-to-day evaluation of meteorological data. Modular software, with standard file naming conventions and subroutine duplication, helped maintain this environment. For example, during the first few days of the experiment, a need arose to examine the differences between the CAPS ensemble forecasts initialized with and without NEXRAD radar data. Given the modularity of the web-based display software, creating new images was very straightforward.

Traditional methods of viewing synoptic-scale deterministic and ensemble forecast data, such as spaghetti diagrams for ensembles and 2-d contoured plan views of height fields for deterministic forecasts, are usually not asbuseful with high resolution data. Therefore, imagery comparisons between models mainly focused on plots of surface, or near-surface, fields of reflectivity, surface wind speed and gusts, updraft helicity (a rough measure of updraft rotation), and probability exceedance values (Figure 3). In addition, "postage stamp" style views of ensemble data were also created. These fields were compared to observations, storm reports, radar-detected mesocyclones (Figure 2), and some derived fields (such as the supercell composite index), and evaluated subjectively by experiment participants.

Throughout the duration of the experiment, the participants were divided into two teams each day to create an experimental convective weather outlook. This outlook focused on a region of the country where the most severe weather was expected (Figure 4). Participants used internal product generation software to create graphics highlighting forecast areas, and to generate text discussions.

Beyond the customized software that was created, some off-the-shelf software was used for the daily experiment evaluation forms used by project participants. Since these forms needed to be accessed by numerous project personnel before, during, and after the experiment, the web-based software "Survey Monkey" was used to create a total of eight separate survey forms. Participants simply logged into the web page created by Survey Monkey (hosted by the company's web site) and answered either multiple choice or short essay questions concerning both model evaluation and experimental forecast evaluation. These subjective evaluation surveys were created mainly before the start of the experiment, but some were created on-demand as participants provided real-time feedback. The pre-packaged survey creation interface allowed for rapid changes and creation of new content on-the-fly, which was needed in the evolving environment of the experiment.

5. CONCLUSIONS AND FUTURE EXPERIMENTS

Perhaps the most important lesson learned concerning software development for this type of experiment was that software reusability and modularity is the key to its success, because of the desire for the rapid creation of new web imagery content on-the-fly as the experiment evolves. Investigation of off-the-shelf software such as Survey Monkey was important, because development of such a large survey system was beyond the scope of the software developers, and its use became very cost effective. It is important to indentify what software needs to be created locally and customized, versus what can be purchased or licensed that meets the needs of the experiment without compromising its focus. Additionally, web pages are a good display vehicle, allow for fast animations of content and images that can be used in publication or referenced later by experiment participants (requests to view the data at home institutions have increased). In the future, software from this past experiment will be re-organized to be even more efficient and flexible for image and content creation.

6. ACKNOWLEDGEMENTS

The authors would like to thank all of the personnel that participated in the 2008 Spring Program, from the visiting scientists and students, to the SPC forecast staff, and technical staff assistance at all participating centers. Key assistance from Jay Liang and Joe Byerly (SPC), Doug Kennedy and Steve Fletcher (NSSL), and Kevin Thomas (CAPS) was especially appreciated.

7. REFERENCES

Coniglio, Michael C., J. S. Kain, S. J. Weiss, D. R. Bright, J. J. Levit, G. W. Carbin, K. W. Thomas, F. Kong, and M. Xue, 2008: Evaluation of WRF model output for severe-weather forecasting from the 2008 NOAA Hazardous Weather Testbed Sping Experiment. Preprints, 24th Conference on Severe Local Storms, 27-31 October, Amer. Meteor. Soc., Savannah, Georgia, CD-ROM.

John S. Kain, NOAA/NSSL, Norman, OK; and S. J. Weiss, S. R. Dembek, J. J. Levit, D. R. Bright, J. L. Case, M. Coniglio, A. R. Dean, R. Sobash, and C. S. Schwartz, 2008: Severe-weather forecast guidance from the first generation of large domain convection-allowing models: Challenges and opportunities. Preprints, 24th Conference on Severe Local Storms, 27-31 October, Amer. Meteor. Soc., Savannah, Georgia, CD-ROM.

Xue, M., F. Kong, K. Thomas, J. Gao, Y. Wang, K. Brewster, K. Droegemeier, J. S. Kain, S. J. Weiss, D, Bright, M. C. Coniglio, and J. Du, 2008: CAPS Realtime Storm-scale Ensemble and High-resolution Forecasts and Part of the NOAA Hazardous Weather Testbed 2008 Spring Experiment. Preprints, 24th Conference on Severe Local Storms, 27-31 October, Amer. Meteor. Soc., Savannah, Georgia, CD-ROM.

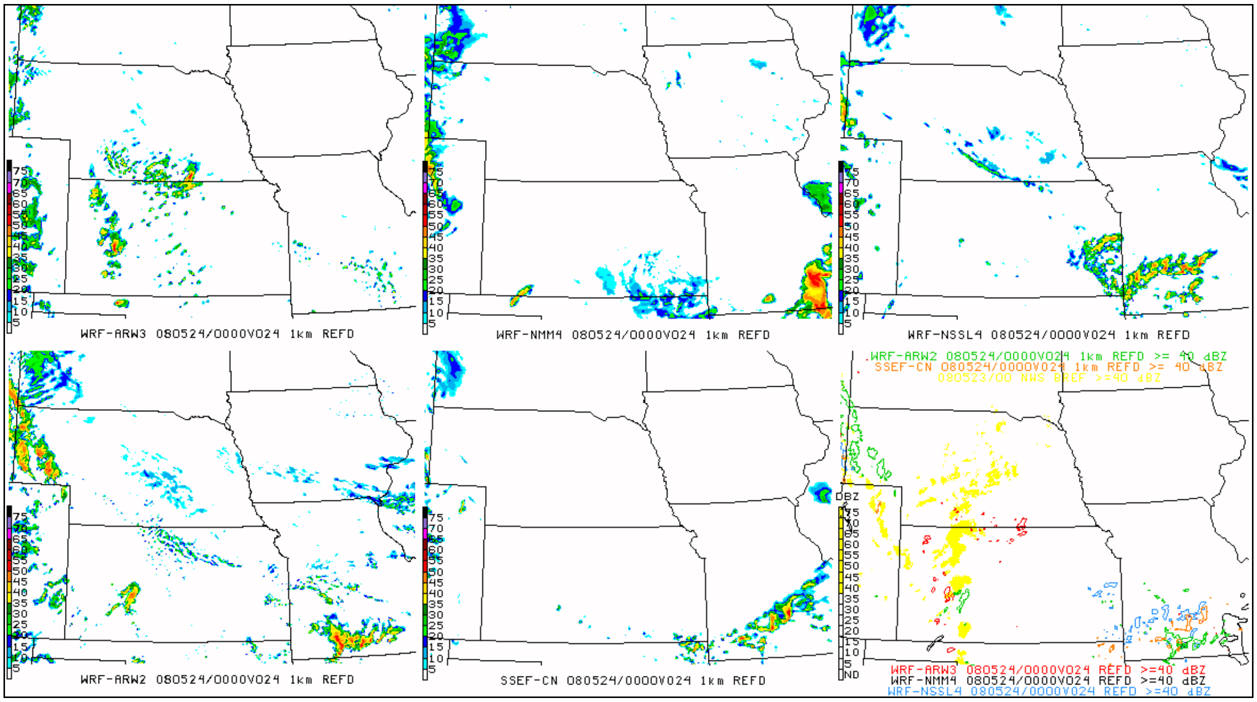

Figure 1: Comparison between the NCAR WRF-ARW 3km (upper left), EMC WRF-NMM 4km (upper middle), NSSL WRF-ARW 4km (upper right), CAPS WRF-ARW 2km (lower left), and CAPS 10-member 4km control (lower middle) forecasts and observed reflectivity above 40dBZ (lower right) valid 00 UTZ 24May 2008.

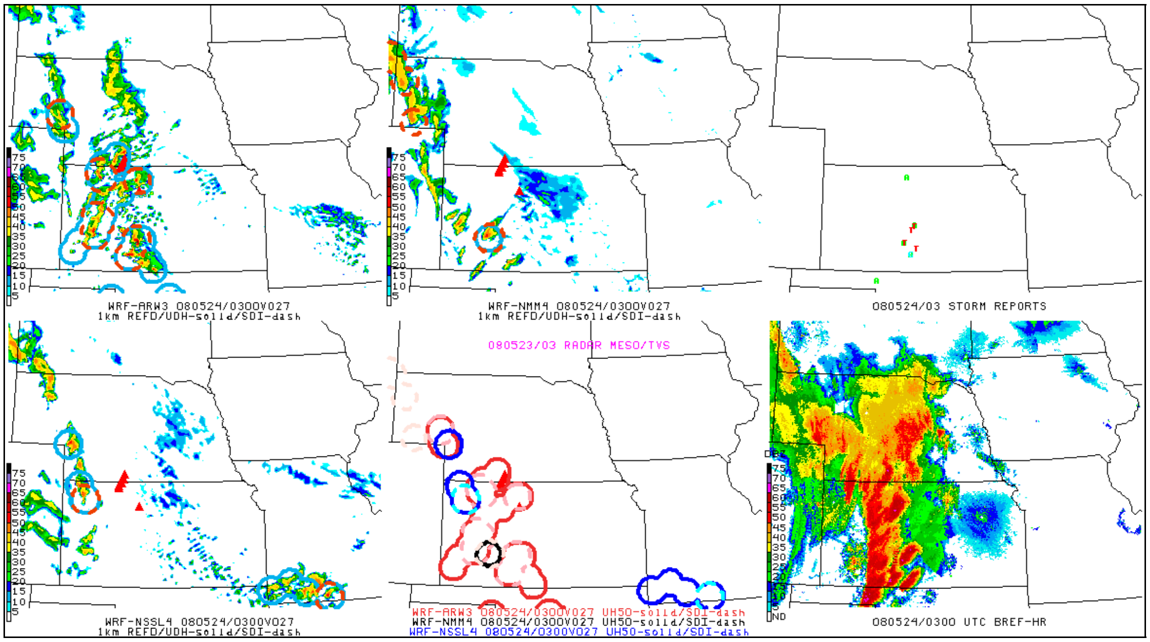

Figure 2: Comparison between the NCAR WRF-ARW 3km (upper left), EMC WRF-NMM 4km (upper middle), NSSL WRF-ARW 4km model (lower left) forecasts, observed storm reports (upper right), observed NEXRAD mesocyclone/TVS detections (lower middle), and maximum reflectivity at a point for the prior hour (lower left), valid 03 UTC 24 May 2008.

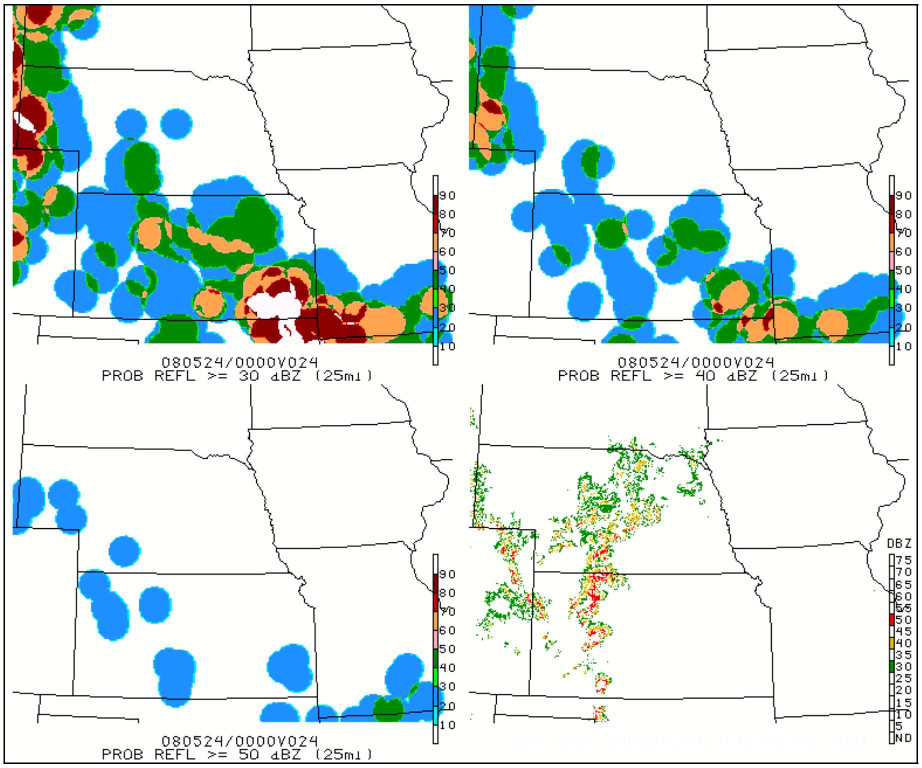

Figure 3: Comparison between the 24 hour forecast of reflectivity at 30, 40, and 50dBZ for the CAPS 10 member 4km ensemble and observed radar reflectivity valid at 00 UTC 24 May 2008.

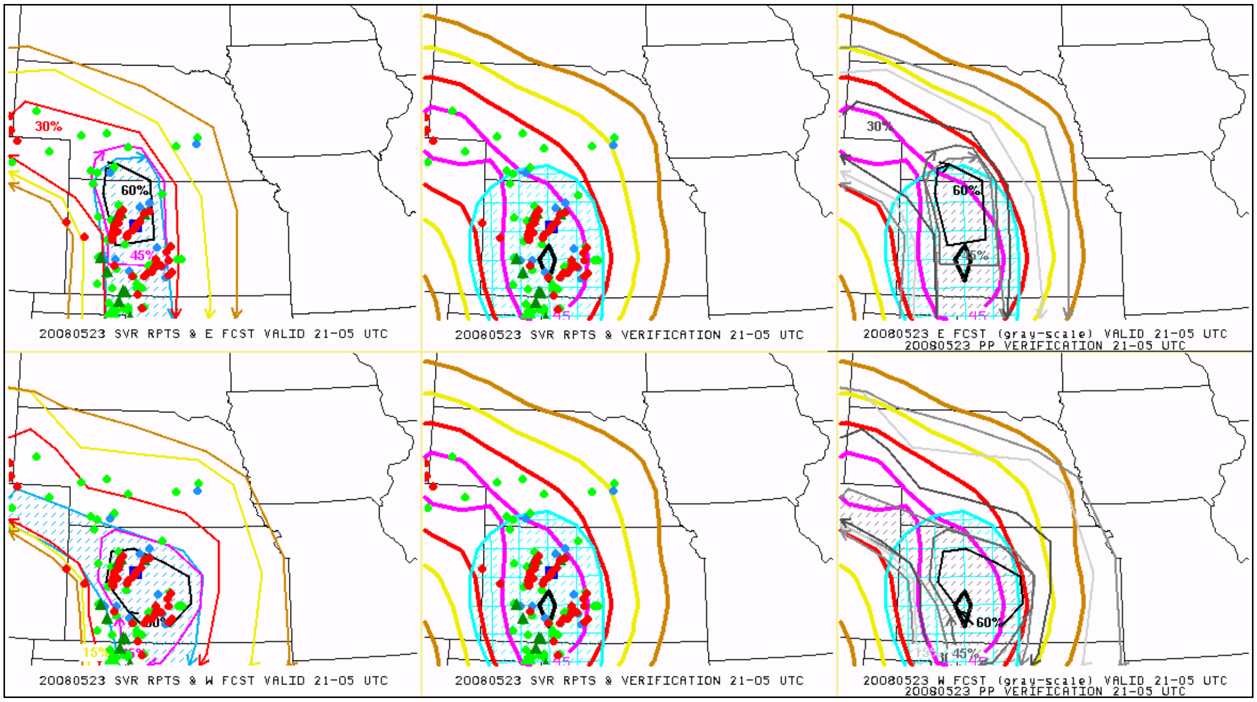

Figure 4: Comparison between observed storm reports, perfect prog verification, and experimental team forecasts for May 23rd, 2008.