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ADVANCING OPERATIONAL FORECASTING THROUGH COLLABORATIVE APPLIED RESEARCH PROGRAMS AT THE STORM PREDICTION CENTER AND NATIONAL SEVERE STORMS LABORATORY

by

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1. INTRODUCTION

Co-location of the Storm Prediction Center (SPC) with the National Severe Storms Laboratory (NSSL) and other agencies in the Norman, Oklahoma Weather Center has facilitated interaction and collaboration on a variety of experimental forecast and other operationally relevant research programs. A cross section of local and visiting forecasters and researchers have participated in a variety of programs over the past several years. These include forecasting support for field programs, establishing the SPC winter weather mesoscale discussion product, evaluating operational and experimental NWP model guidance, and integrating new observational data, objective analyses and display tools into forecast operations. A key goal of these programs is to improve forecasts meteorological phenomena by speeding up the transfer of new technology and research ideas into forecast operations at the SPC, and sharing new techniques, skills, and results of applied research more freely. Issues addressed in these programs include, but are not limited to: data overload concerns in operations, testing and evaluation of new analysis or predictive (NWP) models, better understanding of operational forecast problems, development and evaluation of diagnostic conceptual models, and new product development and display strategies.

During the Spring of 2000 and 2001 the collaborative programs focused on critical SPC operational problems including the short term predictability of severe and non-severe thunderstorms and potential impact on operational convective watch projection time (where projection time is typically defined as the time period between watch issuance and the time of the first severe event). In order to conduct these exercises, access to real time operational and experimental data was made via N-AWIPS workstations and the world wide web in the Science Support Area (SSA), located adjacent to the SPC Operations Area. This allowed for collaboration between program participants and operational forecasters with limited impact on SPC operational responsibilities.

2. SPRING PROGRAM MOTIVATION, GOALS, AND OBJECTIVES

Given that the primary mission at the SPC is related to mesoscale forecasting of severe and/or hazardous weather, it is not only prudent but necessary to place a strong emphasis on diagnostic analysis using real-time observational data as well as a range of predictive guidance from numerical weather prediction models. However, owing to insufficient sampling of the mesoscale environment (especially when the distribution of water vapor is considered) coupled with limited scientific knowledge of important mesoscale and storm-scale processes, considerable uncertainty still exists in the short-term prediction of convection. As a result, it is in our best interests to more fully explore the potential use of operational and experimental mesoscale model guidance to see if and what information is available from them to help forecasters more confidently predict when and where convection will develop several hours in advance. Over the past two years, collaboration between SPC and NSSL during the Spring Program has expanded to include participation from NOAA's Forecast System Lab (FSL), National Centers for Environmental Prediction Environmental Modeling Center (NCEP/EMC), Iowa State University, University of

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Oklahoma, and National Weather Service Forecast Office, Norman, OK (WFO/OUN). Collaboration with this wide cross section of participants has allowed us to examine important issues related to mesoscale model performance, use of new model-based prediction systems, and information transfer from models to forecasters, that can be directly related to forecaster decision making and potential improvements in convective watch projection time

In support of this primary goal, several sub-objectives were also defined. These include:

1. Evaluation of increased computational and display resolution of operational Eta model data,
2. Comparison of Eta-BMJ and EtaKF convective schemes (Kain, et al., 2001)**,**
3. Comparison of operational 40 km RUC and experimental 20 km RUC models
4. Examination of short range ensembles on convective forecasting.
5. Evaluation of the impact of new analysis and display software on convective forecasts.

A full description of all program objectives, types of model output, forecast products, evaluation and verification forms, daily weather summary, and other related links are available at the Spring Program web site:

http://www.spc.noaa.gov/exper/Spring_2001

3. PLANNING, PARTICIPANTS, AND DAILY OPERATIONS

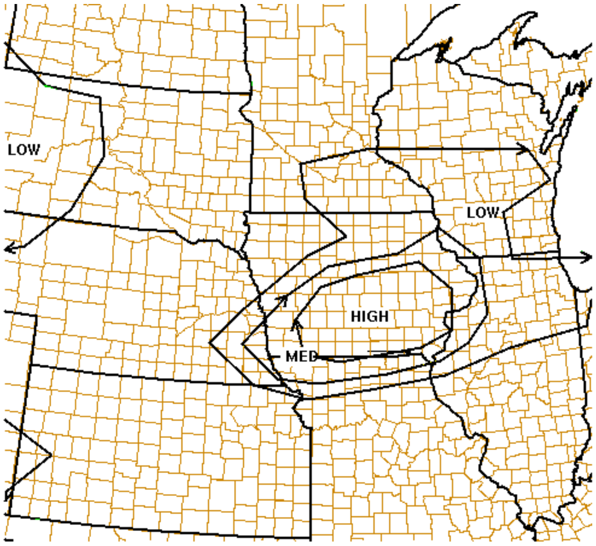
Due to limited resources and participant availability, planning for collaborative applied research programs with operational forecast centers (such as SPC, WFO/OUN, etc.) requires nine months to a year of advance work to ensure that participants can be made available without negative impact to operational work schedules and that program objectives can be adequately addressed. Planning must include establishing a real time data flow (including post processing of experimental model data for access and display independent of forecast operations), graphical displays of forecast data consistent with the needs of the forecast/model evaluation team, design of appropriate forecast products and unbiased model/forecast evaluation forms, creation of interactive/automated product generation, discussion, and evaluation software for participants to conveniently enter forecast and other relevant information (data) to create a comprehensive database for post-analysis, creation of operations plan and instructions/training for use of workstations and software, archive of data and forecast products, establishment of real time and objective verification procedures, and coordination with external participants. Recent efforts have focused on operational forecast issues in lieu of support of real-time field operations such as VORTEX-95 (Brooks et al., 1996) and expand upon the findings of Howard et al., (1986) and Doswell et al.,(1986).

During Spring Program 2001, real time operations were conducted M-F from 16 April through 8 June 2001. Due to the spin-up and training required of participants, each full time participant worked a minimum of one week with a few visiting scientists participating in an observational role for a 2-3 day period. Full time participants made up a forecast team consisting of 3-4 forecasters and/or scientists to complete daily forecasts and participate in evaluation/verification exercises. Staffing included one SPC forecaster, one NSSL scientist and one or two visiting scientists from other organizations. Visiting participants were invited to incorporate their ideas into the evaluation portion of the program as well as present a seminar during their visit. This helped increase a sense of "ownership" in the program beyond that of SPC and NSSL exclusively.

The forecast team created forecast products, conducted evaluation exercises, and participated in a daily weather discussion in the SSA from 8am-4pm M-Th. Operations on Friday's ran from 8am-2pm and served to verify the previous day's forecast as well as document findings by the forecast team during that week. Although participants had varied levels of expertise and interest, collaboration on the creation of the forecast product and evaluation of numerous model forecasts was highly encouraged.

4. FORECAST PRODUCT AND MODEL EVALUATIONS

In order to examine the ability of forecasters to issue short-term convective forecasts (initiation of severe and non-severe convection) with up to a 4 hour lead time, an experimental forecast product was created. It consisted of two graphical products and a short written discussion explaining the rationale of the forecast, with emphasis on the role of the model guidance in the decision-making process. To maximize the amount of data (NWP guidance), the forecast team was able to examine for each forecast, the domain of the experimental product was limited to roughly a 10 x 10 degree latitude/longitude area centered on a severe thunderstorm "risk" area defined by the 1300 UTC SPC Day 1 Convective Outlook and in consultation with the SPC operational lead forecaster. Separate forecasts of "confidence", within the prescribed domain, were made for: 1) the occurrence of thunderstorms, and 2) the occurrence of severe thunderstorms. These forecasts were verified by CG



10 May 2001 - 21Z SEVERE Thunderstorm Forecast

Fig. 1. Example of Experimental Severe Thunderstorm Confidence Forecast issued 2000 UTC 10 May 2001 (valid 2100 UTC 10 May - 0000 UTC 11 May).

lightning strike data and severe storm reports, respectively. Since primary interest was on timing/ location of the initiation of new convection and severe storms, rather than the continuation of existing convection, these considerations affected the choice of forecast domain.

Experimental forecasts were issued twice daily and were valid for a 3-h period (as described below).

Issue Time	Valid Period
1700 UTC	1800-2100 UTC
2000 UTC	2100-0000 UTC

The graphical forecasts delineated areas of thunderstorm and severe thunderstorm potential for each 3 hour period. The forecast team had a choice of up to three contours (Low, Medium, High) which represented discrete levels of forecaster confidence of convective initiation and development of severe convection (Fig. 1). For severe convection, this level of confidence is a key part of the convective watch decision making process. Although other factors (both meteorological and non-meteorological) also influence whether or not a watch is required, this particular assessment is expected to play an important role in identifying situations when watches can successfully be issued with extended projection times.

The emphasis on issuing explicit convective initiation forecasts with as much as a 4-h lead time was intended to expand the use of NWP guidance in the forecast process. This was not intended to diminish the importance of observational data in actual forecast operations, but to see if model output (operational and experimental) contained information which allowed forecasters to develop an early conceptual model of how convection would develop and assign a level of confidence to that scenario.

Coincident with the issuance of each experimental forecast product, other members of the team completed a multiple choice evaluation form, questionnaire, and log intended to document the usefulness of various sources of model information and displays in the forecast decision-making process. A numerical and text database was created from these entries for post-analysis. The completion of these forms also helped facilitate discussion, note strengths and weaknesses of model forecasts in real time, and allowed for subjective testing of hypotheses in subsequent weeks.

5. DATA FLOW

In addition to operational data, new analysis displays and non-operational (experimental) NWP model data was incorporated into the forecast process during the Spring Program. Considerable post-processing of the data was required for it to be viewed on operational workstations in the SSA. As forecasters became familiar with new/ experimental data sets, reliability of the data in various SPC operational products increased through a proof-of-concept process, which allowed information to be more efficiently integrated into SPC operations.

NWP model data available during the Spring Program included the following (model run resolution / model display grid):

20km/80km Operational Eta Model (00Z and 12Z)
20km/40km Operational Eta Model (00Z and 12Z)
20km/20km Operational Eta Model (00Z and 12Z)
10km/10km Experimental Nested Eta Model
(00Z and 12Z; as available for forecast area)
20km/40km Experimental EtaKF Model (00Z and 12Z)
20km/20km Experimental EtaKF Model (00Z and 12Z)
40km/40km Operational RUC Model (12Z, 15Z, and 18Z)
20 km/20km Experimental RUC Model (12Z, 15Z, and 18Z)
Short Range (ETA/RSM) EMC Ensembles (SREF - 00Z only)
Mesoscale Short Range Ensemble
(MM5, Eta, EtaKF, RUC20; 00Z only)
WRF Model (Kain-Fritsch Parameterization - 00Z only)
Cloud Model Ensemble Predictions (Elmore - 00Z only)

Italicized fields were experimental data not initially available to SPC forecasters

In addition to NWP data, several experimental analysis displays were available for Spring Program participants to use. These included the ability to create point forecast (PFC) sounding loops, web based sounding comparison and difference computations for PFC and observed soundings, and displays of 1-D output for the Kain-Fritsch and Betts-Miller-Janjic convective paramerterization schemes. These routines helped forecasters better diagnose model forecasts and integrate them into the forecast product more efficiently.

6. VERIFICATION AND DAILY WEATHER DISCUSSION

During the first two hours each day, the forecast team conducted a subjective verification of the previous day's forecast and evaluation of specific model parameters used in creating the forecast. This included a web based verification/evaluation form intended to solicit specific information regarding the quality of the forecast, utility of model data, and what data had the highest impact on the forecast. Verification was done collaboratively with all members of the forecast team participating. Since no forecasts were made on Sunday, participants used the first two hours on Monday morning for orientation and familiarization. Forecast verification was made by comparing severe reports and C-G lightning displays with forecasts made the previous day. A variety of verification data and displays (models, satellite/radar image data, soundings, observed data, severe reports, etc.) were also available.

Each day at 1800 UTC, a thirty minute weather discussion was presented for interested forecasters/ scientists in the local weather center. Findings during the verification exercises were presented in the first half of the discussion while the first period forecast and other relevant issues were discussed during the last half of the period. The discussion ended promptly at 1830 UTC to allow sufficient time for the forecast team to prepare and issue the second period forecast by 2000 UTC.

7. DISCUSSION

Increased spatial and temporal skill in forecasting the initiation of severe and non-severe thunderstorms is central to efforts to increase convective watch projection time without substantial degradation in their accuracy. Beginning in the 1980s operational forecasters became more reliant on new sources of real-time observational data, particularly from satellite and radar, to monitor the life cycle of thunderstorms. Most notable was the discovery that they could often wait until they saw signs of convective initiation before issuing a convective watch. This new operational methodology resulted in more accurate placement of watches in time and space, but also changed the character of the convective watch from a pure forecast product to a hybrid nowcast/forecast product. Increases to watch projection time will likely require a shift from primary reliance on observational data to a better integration of observational data with improved guidance and interpretation of short range NWP output.

By conducting forecast evaluation and verification exercises on a daily basis, the Spring Program forecast team often had different interpretations of model guidance before and after a forecast was issued. In many cases, forecast guidance was discarded because the model solution did not fit a particular conceptual model, or a specific parameter (e.g. surface dewpoint) appeared to be in error which biased forecaster acceptance of other fields (e.g. QPF) in a particular model run. However, forecaster decisions to accept or reject model forecast data were not always correct, partly due to misinterpretation of important processes occurring in the model atmosphere and/or with a particular convective parameterization scheme.

While forecasters may look at QPF guidance as a proxy for initiation of convection in a model forecast, there are often other signals in model fields which may suggest initiation is imminent. High resolution plots of the character and intensity of model derived upward vertical motion may often preclude the development of precipitation (QPF) by several hours in the model atmosphere. These changes are best observed by comparing or looping model point forecast soundings at a location of interest rather than examining a constant level chart which has been an operational standard for many years.

It became evident during the program was that it is vitally important to understand the character of precipitation in the model QPF. In many cases, elevated convection, developing above the boundary layer, resulted in a misinterpretation of surface based convective initiation. Extraction of model specific parameters such as the Updraft Mass Flux or Updraft Source Layer (Kain and Baldwin, 2000) can result in improved interpretation of model guidance and better integration with observational data in the forecast process.

There were several events in which forecasters expressed a high confidence of severe convection initiating with several hours of projection time. However, while these were often situations where operational and experimental model guidance provided convergence on a particular solution, there were several cases, especially in weakly forced environments, where confidence was very low and yet the forecast was highly conditional (e.g. if thunderstorms developed, they would likely become severe very rapidly). As a result, improved skill in forecasting convective initiation or severe convection over the next few years should not be expected to be universal, but rather incremental and on a case by case basis, gradually improving as high resolution model guidance becomes increasingly reliable.

The structure of the 2001 Spring Program was set up to allow an SPC forecaster to work with NWP model experts or research scientists. This arrangement provided stimulating interaction and discussion during the forecast process and allowed SPC forecasters to integrate a mesoanalysis of observational data with explicit model interpretation. A comprehensive examination of full vertical resolution point forecast soundings, loops of model point forecast soundings and their time evolution combined with diagnostics illuminating model processes (such as shallow convection, etc.) are critical in understanding the evolution of model parameters and what processes are most important in changing a thermodynamic profile from one which will likely inhibit convection to one in which convection is able to initiate.

Over the past several years, collaborative/applied research programs at SPC and NSSL have continued to expand and now involve a wide range of participation from several internal and external agencies. The value of the collaborative interaction, applied research, and ability to transfer new scientific ideas more efficiently into operations is greatly enhanced by this annual program. Similarly, researchers/modelers benefit by gaining a better understanding of how severe weather forecasters use model data in an operational environment characterized by time constraints, data overload issues, and limitations in mesoscale/stormscale knowledge. In addition, the value of subjective evaluations of model performance becomes readily apparent, which can compliment traditional objective measures such as equitable threat/bias scores. It is likely that future programs will continue to focus on convective initiation and convective mode as they remain amongst the most challenging problems facing SPC forecasters and mesoscale researchers today.

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