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## 1. INTRODUCTION

During the spring of 2003, the NOAA Storm Prediction Center (SPC) and National Severe Storms Laboratory (NSSL) conducted their annual "Spring Program" (Kain et al. 2003). The goal of these annual experiments, which started in the mid-1990s, is to infuse new forecasting techniques and state-of-the-art meteorological science into SPC forecast operations. The 2003 experiment focused on two topics: evaluating a) short-range ensemble forecasts (SREF), and b) high-resolution numerical model forecasts (Kain et al. 2004, this volume) for severe weather forecasting.

The SREF portion of the experiment was delineated into two components, and its primary goal was to evaluate SREF data for use in an experimental day-2 severe weather outlook for the United States. The first part evaluated a 15-member ensemble generated by the Environmental Modeling Center (EMC) of the National Centers for Environment Prediction (NCEP). This ensemble consisted of five members each of an Eta, Eta-KF, and the RSM (Regional Spectral Model) model 63-hour forecast, initialized at 09Z (these SREF members are also generated at 21Z, but were not used in this experiment). The other part of the experiment involved forecaster participation in generating a 32-member, 48-hour MM5 model ensemble forecast, using the MM5 adjoint (Xu et al, 2001).

The 2003 experiment ran five days per week from April 14<sup>th</sup> – June 6<sup>th</sup>, with April 14<sup>th</sup> – 25<sup>th</sup> consisting of an internal "shake-down" period. Several SPC forecasters and outside personnel (explained further in the results section) participated on forecast teams to examine the ensembles and generate the experimental Day 2 outlook. Since the results from the experiment are still being analyzed at the time of this writing, the following sections will focus on the experiment design, daily data evaluation methods, and some general discussion of the preliminary results.

## 2. EXPERIMENT DESIGN

The SREF component of the 2003 Spring Program focused on using the NCEP SREF and a locally produced MM5 SREF for creating an experimental Day 2 severe weather outlook. The initial experimental day 2 outlook was created by SPC forecasters using traditional deterministic model guidance (e.g., operational Eta, Eta-KF and GFS), in order to emulate

current operational practice. The afternoon update incorporated new guidance from both SREF systems, and was designed to assess the impact of SREF information to enhance forecaster assessment of confidence/uncertainty.

One of the most unique aspects of this experiment was the involvement of the forecast teams in generating the perturbations for the 32-member MM5 ensemble. Rather than use a mathematical method such as breeding (Tracton 1993), the forecast teams, for each day of the experiment, highlighted sixteen areas of interest via an interactive Java applet (see figure 2) that, when coupled with the MM5 adjoint, created 32 separate perturbations. The Java applet allowed forecasters to select various fields at six hour increments (e.g., 500mb height, 250mb isotachs, surface-based CAPE, etc.) from the NCEP 12Z ETA run, and draw a polygon around a feature of interest (e.g., trough, dryline, jet core, etc.). Custom designed software determined the MM5 grid points located inside the polygon, and subsequently determined the appropriate configuration for the MM5 adjoint to run (forward and backward models) and produce initial condition perturbations for the MM5 full-physics forecast. The results from the MM5 adjoint were scaled to prevent unreasonable values from producing unrealistic forecasts, and a positive and negative perturbation were created as well (each forecast field had the same magnitude, but a different sign). The MM5 adjoint was computed at a horizontal resolution of 90km, while the full-physics SREF run was computed at 30km.

The MM5 ensembles were produced on a Linux supercomputer managed by the Oklahoma Supercomputing Center for Education and Research (OSCER), located at the University of Oklahoma. The forecasts utilized 32 two-way nodes (64 processors total), and OSCER graciously provided a grant that allowed the MM5 ensembles to be generated on a daily basis, in real-time, so the forecast teams could have access to the data for the update of the Day 2 severe weather outlook. Running the adjoint and the full MM5 forecast model took approximately 3 hours of wall-clock time, from 11:30am – 2:30pm.

The overall goal of this experiment design was to expose SPC forecasters and Spring Program participants not only to SREF analysis techniques, but to also explore the usefulness of forecaster interaction with an ensemble modeling system and the creation of customized perturbations. The main research interests with the MM5 SREF system were to determine if forecasters could provide more accurate information to the ensemble system compared to a method that is strictly mathematical, and to identify relevant

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atmospheric features that were used by the MM5 adjoint to generate perturbations.

### 3. RESULTS

The ensembles were evaluated on a daily basis by a team of four forecasters that consisted of SPC forecasters, NSSL research scientists, and visiting meteorologists from across the world. The visiting personnel ranged from National Weather Service forecasters to university professors and research scientists. Both the NCEP SREF and MM5 SREF were examined via GEMPAK files produced locally at the SPC, through N-AWIPS software. The fields examined consisted of mean/spread charts, probabilities, and "spaghetti" plots. Also available were custom-generated "postage stamp" style plots (figure 1) via NCAR Command Language (NCL) scripts. While the NCL scripts were not used operationally in real-time, they were utilized on a "per request" basis to illustrate the broad scope of particular ensemble fields. Additionally, these forecast teams evaluated the ensembles via the following questions through a web-based form:

1. Overall, how useful did you find the SREF output in assessing severe weather potential?
2. How useful did you find the NCEP SREF output?
3. How useful did you find the MM5 SREF output?
4. Text box for general comments.
5. How useful were the following SREF display output techniques? (a. Spaghetti charts, b. mean/spread charts, c. probability charts).
6. If you looked at spaghetti charts, which meteorological fields were best displayed in this chart format? (Check all that apply: 250mb: height, isotachs; 500mb: height, vorticity, temperature, isotachs; 700mb: height, temperature, dewpoint, isotachs, vertical velocity; 850mb: height, temperature, dewpoint, isotachs; surface: pmsl, temperature, dewpoint, isotachs; precipitation: 3hr, 6hr, 12hr, 24hr; instability: CAPE, CIN; shear: SRH, 0-6km shear; composites: supercell composite parameter, stp).
7. If you looked at mean/spread charts, which meteorological fields were best displayed in this chart format? (Check all that apply: *same as question 6*).
8. If you looked at probability charts, which meteorological fields were best displayed in this format? (Check all that apply: *same as question 6*).
9. Did you find other SREF data displays useful? (yes/no).
10. If "yes", please describe.
11. Other comments about the SREF or the MM5.

Results from these surveys, as well as numerical results from the forecasts, were evaluated and results indicate that use of the SREF data slightly improved the experimental Day 2 severe weather outlook. However, one can also argue that the teams had additional time between the initial Day 2 outlook and the updated afternoon outlook to think more about the forecast, rather than only use the SREF data to adjust the

outlook. This issue is being considered within the context of the overall experiment analysis. Additionally, we are formulating a plan to analyze the 270+ GB of data generated by the MM5 ensembles, and this will likely include verification of the MM5 data against the NCEP SREF model data, to determine if the forecaster-generated perturbations increased the skill of the model forecasts. Also, we plan to perform some cluster analysis techniques (Alhamed 2002) with the MM5 data.

### 4. CONCLUSIONS

The 2003 Spring Program was considered a success, due to the knowledge gained from the evaluation of the short-range ensembles and the use of SREF data for the experimental Day 2 outlook. SPC benefited from the experiment in several ways, which included: 1) transfer of SREF ensemble analysis knowledge to SPC forecasters, 2) development of N-AWIPS graphics displays of ensemble fields for SPC operations, and 3) ongoing interaction with visiting scientists on ensemble forecasting techniques.

### 5. ACKNOWLEDGEMENTS

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### 6. REFERENCES

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MM5 Surface Temperature (K) valid 20030508/00

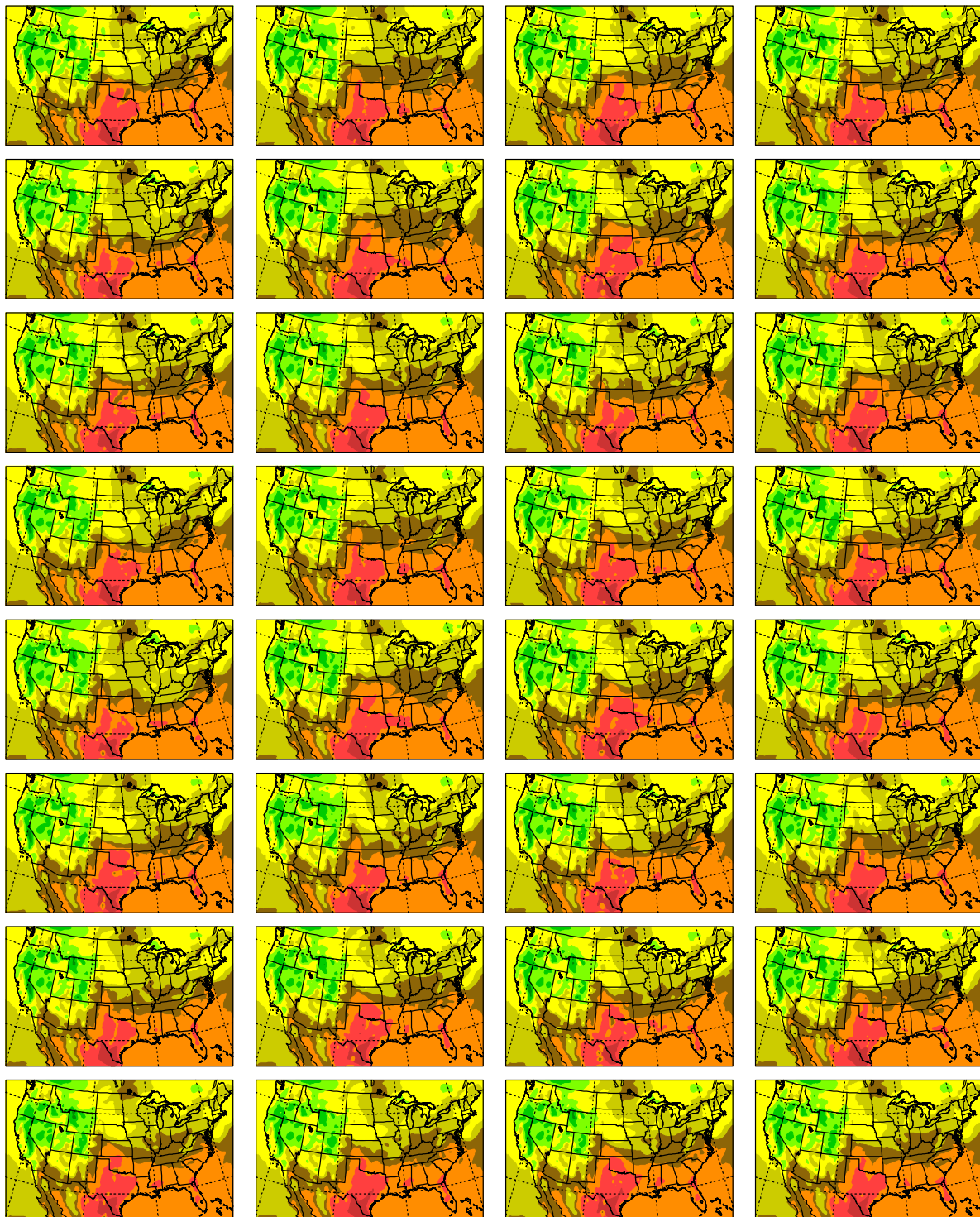


Figure 1: An example of a “postage stamp” plot from a 32-member MM5 forecast valid at 00Z on May 8<sup>th</sup>, 2003 (an F4 tornado damaged Moore, Oklahoma on this day).

# Perturbation Generation

Forecaster chooses level, field, and time

A box is drawn around interest area, process continues until counter is at zero

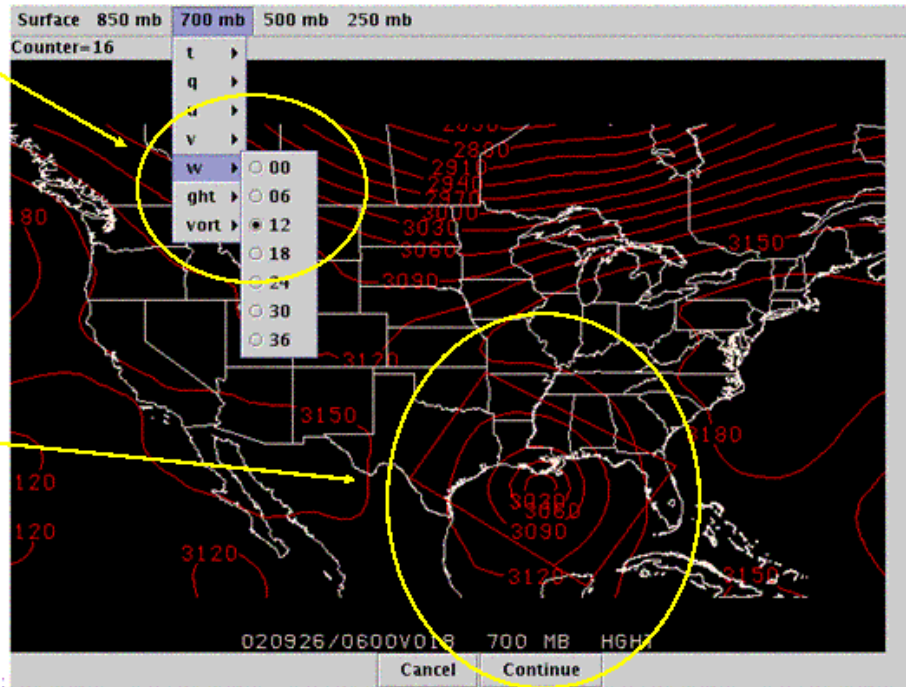


Figure 2: Snapshot of the interactive Java applet graphical user interface. This program was used by the 2003 Spring Program forecast teams, to identify important atmospheric features that were used to generate perturbations for the MM5 ensemble forecast system.