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SAMEX '98: THE 1998 STORM AND MESOSCALE ENSEMBLE EXPERIMENT

SAMEX Work Group

[Editor's Note: Technical Attachment (TA) 98-16 is a reprint of Southern Region's TA 98-7 (3/1/98) of the same title. This document provides a detailed description of the proposed goals and methodology of SAMEX '98 (Storm and Mesoscale Ensemble Experiment, spring 1998)]

Technical Attachment

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1. Introduction and Project Overview

One of the most critical and highly debated topics in numerical weather prediction today concerns the data requirements, analysis and assimilation strategies, and spatial resolution and physics parameterizations needed to accurately predict the initiation, evolution, and decay of intense meso-β and meso-γ weather systems. The practical importance of these issues is underscored by the fact that economic losses due to "extreme weather" associated with such systems are believed to exceed $300 million *per week* in the US (Pielke, 1997). As the scientific and operational communities explore strategies for dealing with the detailed short-range prediction of intense weather systems, a question of fundamental importance has arisen: can an ensemble of relatively coarse-resolution (20 to 30 km grid spacing) forecasts provide guidance superior to a much smaller number of forecasts run at considerably higher resolution (1 to 3 km)? The answer to this question has far-reaching implications for the manner in which the US invests in future scientific research and technology acquisition, and efforts must be directed toward providing an answer as quickly as possible so as to maximize available resources.

During the past decade, a number of groups in the US and abroad have begun to experiment with mesoscale and short-range forecast ensembles (e.g., Stensrud et al., 1998; Tracton et al., 1998) as well as forecasts that seek to resolve explicitly, using high spatial resolution model grids and observational data, the most important processes associated with intense convective and winter precipitation systems (e.g., Weygandt et al., 1998; Crook and Sun, 1998; Gao et al., 1998; Zong et al., 1998). In many cases, the associated forecast systems have been run in a realtime, quasi-operational mode in order to collect stable statistics and provide an assessment of forecast value under the rigorous constraints of an operational environment (e.g., Carpenter et al., 1997, 1998; Droegemeier, 1997; Szoke et al., 1998; Herbster and Watson, 1998).

In an attempt to build upon these many activities and begin addressing the questions noted above in a collaborative manner, we propose here an *initial* multi-institutional numerical weather prediction experiment scheduled for the spring, 1998 convective season over the central US. Known as SAMEX '98 (Storm and Mesoscale Ensemble Experiment, spring 1998), this effort involves a realtime comparison of approximately 30 ensemble forecasts, run at 30 km resolution using 3 models, against a much smaller number of forecasts run at both intermediate (10 km) and high (2-3 km) resolution over sub-sets of the ensemble domain.

Coordinated by the Center for Analysis and Prediction of Storms (CAPS) at the University of Oklahoma, SAMEX presently represents a collaboration among the National Severe Storms Laboratory (NSSL), Air Force Weather Agency (AFWA), National Center for Atmospheric Research (NCAR), and the National Centers for Environmental Prediction (NCEP). Additionally, a number of other groups will participate in the realtime forecast evaluation process, including several National Weather Service Forecast Offices (NWSFOs), the Storm Prediction Center (SPC), Tinker Air Force Base, and the Aviation Weather Center (AWC). Following the initial experiment in spring, 1998, SAMEX is envisioned to expand in 1999 and beyond to include other models and evaluators, as well as cold-season campaigns and an expanded forecast period.

This document provides a detailed description of the proposed goals and methodology of SAMEX '98. Although SAMEX was conceived only a short time ago (October, 1997), considerable progress has been made in designing the forecast experiment. A working group of more than 20 scientists representing all participants has assembled three times (twice by phone conference and once in person at the 1998 AMS Annual Meeting) to discuss plans, and a specific project timetable has now been established (see section 6). The level of enthusiasm for SAMEX continues to be extremely high, particularly among the leaders of the participating agencies/centers, and we are confident that this project will continue to grow and be of substantial benefit to the meteorological community world-wide.

2. Scientific Goals and Expected Impact/Benefits

Five principal goals underpin the spring 1998 SAMEX campaign. Specifically, this program seeks to:

- provide an initial quantitative assessment of the value of coarse (30 km) resolution ensemble forecasts relative to a few intermediate (10 km) and high (2-3 km) resolution forecasts;
- apply short range ensemble forecasting techniques and related statistical verification strategies to multi-model mesoscale ensemble forecasts;
- develop and apply strategies for verifying numerical predictions of individual convective storms with emphasis on quantitative precipitation forecasting;
- expose operational forecasters in a variety of settings to mesoscale ensemble and explicit cloud-resolving numerical predictions;
- provide the scientific community with initial datasets appropriate for assessing the predictability of the small-scale atmosphere with emphasis on the observations, model physics, and model spatial resolutions needed for generating quality numerical forecasts of meso- and storm-scale phenomena.

These goals fit nicely with the current themes of the US Weather Research Program, as well as with plans by the NCEP to implement a 4-5 km resolution operational model over the US early in the next century. Indeed, although the historical trend at operational centers has been toward higher spatial resolution, the point of diminishing return has never been identified. SAMEX seeks to utilize new techniques in ensemble forecasting, along with the ubiquity in the US of storm-scale observations provided by the WSR-88D radar, as a first step in that direction.

Datasets produced by SAMEX '98 will be made available to the entire community, and are envisioned to be of considerable value for addressing issues such as the fundamental predictability of the small-scale atmosphere and the specification of initial perturbations for meso- and storm-scale ensemble forecasts. Lessons learned from the spring, 1998 experiment will be used to optimize strategies for the 1999 spring and winter campaigns, and to provide a mechanism for involving other groups, possibly from other countries.

SAMEX '98 is poised to make a significant impact on a number of major programs currently underway in the United States, most notably the Weather Research and Forecasting (WRF) model development project being organized by NCAR, NCEP, and the FSL (Dudhia et al., 1998). SAMEX '98 also represents a mechanism for coordinating the many, currently independent realtime forecast experiments being conducted nationwide, and perhaps serve as the forerunner of a National NWP Test Facility. Finally, SAMEX '98 could become a strong component of the US Weather Research Program, leading to subsequent tests of expanded scope and duration, eventually within an international framework.

3. Experiment Design

a. Forecast Period

SAMEX '98 is scheduled to begin on 15 April 1998 and continue through the first week of June in order to provide a sufficient number of cases for evaluation, and to coincide with spring data collection experiments planned by the National Severe Storms Laboratory and the University of Oklahoma. A one- or two-week extension of this period may be possible depending upon available resources, particularly computer time. It is important to recognize that SAMEX '98 is envisioned as an *initial testbed* for the goals outlined in section 2, and that a more formal experiment, based on lessons learned in 1998, is being planned for 1999.

b. Participating Models and Their Configurations

In order to ensure the success of this initial effort, the number of participating organizations and models have intentionally been limited to the following:

- Advanced Regional Prediction System (ARPS; Center for Analysis and Prediction of Storms)
- NCAR-Penn State Model (MM5; National Severe Storms Laboratory)
- NCAR-Penn State (MM5; NCAR)
- NCAR-Penn State Model (MM5V2; Air Force Weather Agency)
- Meso-Eta and Eta-10 Models (National Centers for Environmental Prediction)

Although three groups will be running MM5, the variety of physics and computational options to be used, particularly with respect to the ensembles, is expected to yield a sufficiently diverse set of forecasts. The inclusion of other models in 1999 will provide a more balanced configuration.

As shown in Table 1, three sets of forecasts will be run *in realtime* during each day of the experiment using the domains shown in Figure 1.

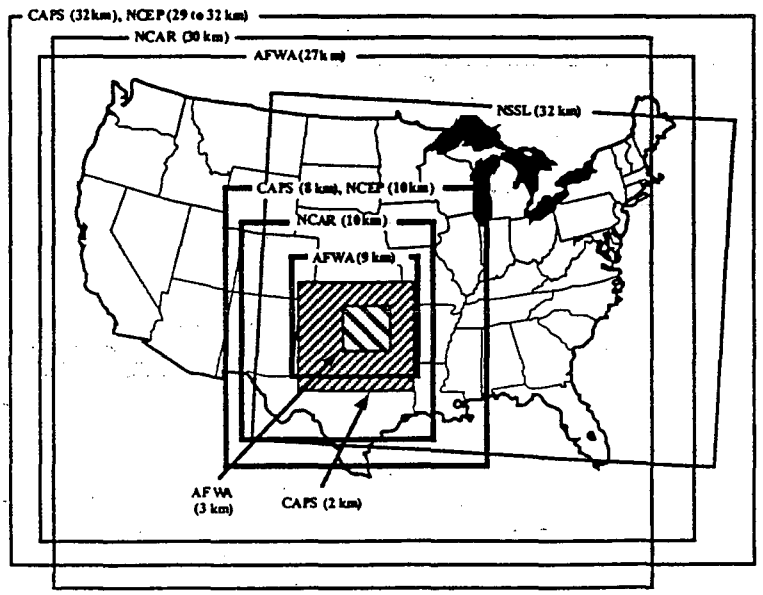

Figure 1. Domains to be used for SAMEX '98. Shown is the acronym for each model, with the spatial resolution in parentheses. See Table 1 for further details.

Table 1. Forecast Strategy for SAMEX '98

Description	# Fcsts/Day	Duration	Start Time	Models & Resolutions
Low-Res Ensembles	10	36 h	00Z	ARPS (32 km) MM5-NSSL (32 km) Meso-Eta (29 km) †MM5-NCAR (30 km) §RSM-AFWA (27 km)
Intermediate Res Single Runs	1	12 h	12Z	ARPS (8 km) MM5-NCAR (10 km) MM5V2-AFWA (9 km) Eta-NCEP (10 km)
High Res Single Runs	1	6 h	18Z	ARPS (2 km) MM5V2-AFWA (3 km)

† One run per day
§ Possibly one run on some days

c. Model Initialization and Execution

Each participating organization is responsible for all aspects of model initialization, execution, and data post-processing, and each will use all data available to them. (In 1999, we hope to consolidate the effort at one or a few national supercomputing centers, and provide a unified set of observations including realtime base Level II data from several WSR-88D radars). The strategy for the ensemble forecasts also will be left to the discretion of each organization, with some groups (e.g., NSSL, CAPS) constructing ensembles through variations in model physics parameterizations, and others (e.g., NCEP) using carefully-defined initial and boundary condition perturbations. The suitability of this strategy will be examined as part of the SAMEX '98 post-mortem, and changes will be implemented as necessary for the 1999 campaign.

d. Ensemble Product Generation and Display

The ensemble forecasts are viewed as the centerpiece of SAMEX '98, and thus considerable effort is being expended to ensure their ready availability to the realtime evaluators. Given the size of the combined datasets to be produced for the ensembles, as well as the fact that operational forecasters will be seeing this type of ensemble information for the first time, a limited but carefully selected set of products will be generated for realtime evaluation (as discussed below, archived data will be available for more complete subsequent analysis). They include:

- mean sea level pressure
- 500 mb height

- 250 mb height
- vector winds at 850 and 250 mb
- 850 mb temperature
- 1000 to 500 mb thickness
- 700 mb relative humidity
- 700 mb vertical velocity
- 2 m temperature
- accumulated precipitation
- lifted index
- CAPE
- bulk Richardson number
- convective inhibition\
- low-level convergence
- precipitable water

Each group running ensemble forecasts will generate the above subsets of information at 3-hourly intervals on a standard uniform grid using the GRIB data format. It is important to note that a single common method will be used for computing derived quantities (e.g., the lifted index). These data files, small in size because of their 2-D format, will be transferred to CAPS as soon as they become available, and ensemble statistics will be created, including:

- ensemble mean and spread
- spaghetti diagrams of selected quantities (e.g., surface isodrosotherms at 5 deg intervals from 50 to 70 F)
- ensemble clusters
- conditional probabilities (e.g., QPF, stability indices)

The World Wide Web has been chosen as the mechanism to deliver forecast information because of its wide availability (not only to the groups listed, but also to universities and other organizations both in the US and abroad) and ease of use. CAPS will create and manage a new Web site specifically for the ensemble forecasts, from which the realtime evaluators will submit their formal comments (see section 4 below). Ensemble statistics will be generated using all forecasts within the NSSL domain (i.e., the domain common to all participating models at the coarsest resolution -- see Figure 1), as well as for each model individually. This will allow for a statistical comparison *among* individual models as well as for *all models combined.*

e. Other Forecast Product Generation and Display

The intermediate and high-resolution forecasts will be displayed on each group's existing Web site, with links provided from the central ensemble Web page. To facilitate usage of these other forecasts, a set of common products is being identified and will include those listed above for the ensembles as well as other information more suited to high-resolution models (e.g., radar reflectivity, hourly accumulated precipitation, precipitation type based on explicit microphysical schemes). Even though the number of intermediate resolution experiments is quite small, the same ensemble statistical procedures used for the 30 km resolution experiments will likely be applied in an effort to provide some basis for comparison.

4. Realtime Operational Forecast Evaluation

An important element of SAMEX is the formal realtime evaluation of all forecasts by operational users, including forecasters at the Storm Prediction Center, the Aviation Weather Center, and several National Weather Service Forecast Offices throughout the US. To facilitate this effort while minimizing any deleterious impact on forecast operations, SAMEX will utilize an electronic Web-based evaluation form and associated on-line archival/display system (e.g., as is now being used in Project Hub-CAPS at the University of Oklahoma). In order to focus the evaluation, forecasters will be asked to comment on specific aspects of the predictions, including the following:

- advantages of ensemble guidance relative to explicit predictions at the same or higher resolution;
- identification of those fields deemed most useful from both the ensemble and explicit predictions;
- identification of *unique* information that can be obtained from ensembles versus other types of forecasts at both similar and higher resolution;

For the explicit predictions, specific attention will be given to the following:

- identification of mesoscale boundaries and their role in convective initiation and morphology;
- ability to discriminate between active and non-active boundaries;
- role, initialization, and generation of meso-beta and convection-induced outflow boundaries and boundary-boundary interactions;
- QPF (amount, location, timing);
- details of the low- and mid-level wind and moisture fields;
- quality and reliability of reflectivity forecasts;
- point sounding forecasts

About one month prior to the start of the experiment, a training session will be held for all participating forecasters to acquaint them with the goals of SAMEX, the characteristics of the models to be used, the types of output to be delivered, and the manner in which this output should be used in the forecast process. Efforts will be directed toward using tele-conferencing and other distance learning tools for this activity.

5. Data Archival and Post-Experiment Analysis

The value of SAMEX to the broader meteorological community lies in the availability of both the data/analyses used to initialize the models as well as the forecasts themselves. To maximize this value, we propose to archive the model codes, all initial datasets, and forecast output at selected times at the NCAR JOSS. We seek herein support for this aspect of the program, and note that each participating group also will archive selected datasets at their local computing sites.

Participants of SAMEX, as well as other groups, will conduct detailed analyses of the forecasts at the conclusion of realtime operations. As an example, the Center for Analysis and Prediction of

Storms is supporting a new graduate student, supervised by Prof. E. Kalnay, to synthesize information from the ensembles, validate the associated forecasts, and determine their value relative to conventional products as well as output from the higher-resolution runs. Additionally, NCEP plans to use its extensive expertise in forecast verification to perform detailed statistical analyses and objective scoring of all forecasts.

6. Progress to Date and Project Timetable

The core scientists involved with SAMEX '98 (see section 9) have met three times to date -- twice via conference calls and once in person at the 1998 AMS Annual Meeting. A detailed set of notes has been prepared from each meeting, and most of the key decisions already have been made, as explained above. Other details (e.g., the forecaster training briefing) are being addressed by e-mail . At the AMS Annual Meeting, a tentative timetable for SAMEX '98 was established and is shown below. While clearly ambitious, we believe the milestones are achievable provided that funding can be secured for the needs outlined in the previous section.

Mid-January

- Finalize forecast domain sizes and locations
- Finalize forecast start times and durations
- Determine the "standard" products to be created for all 3 sets of forecasts
- Determine the common domain for the ensemble statistics
- Determine the data format for the ensemble output
- Submit proposal to fund SAMEX '98
- Finalize strategies for creating the ensembles

Early February

- Bring ensemble processing code to OU
- Finalize the groups involved with the formal forecast evaluations

Mid-February

- Bring new-hire on board and begin work on ensemble processing
- Determine forecast evaluation topics
- Begin to develop the central web site
- Finalize products for the intermediate and high-resolution forecasts
- Begin work on forecast evaluation system

Mid-March

- Each group makes a full test run using each of its model configurations
- Ensemble processing system ready for testing
- Test the data archive
- Create user training program and schedule training
- Test all web pages
- Test the electronic forecast evaluation system

Early April

- Conduct user training
- Put sample products on Web for testing

Early- to Mid-April

- Each group conducts 3 or 4 days of trial runs

15 April 1998

- Begin operations

Early June 1998

- Conclude operations

7. Plans for 1999 and Beyond

As described throughout this document, SAMEX '98 is envisioned as a relatively small, prototype experiment from which lessons can be learned in planning a much larger and formal campaign for the spring and winter severe weather seasons of 1999. Specifically, the forecast strategies and products generated in 1998 will be refined and improved for 1999, and other groups and models (e.g., CSU/RAMS, Navy/COAMPS, Canadian, UK Met Office) will be invited to participate. Further, we hope to consolidate the computing and data acquisition efforts to some extent in 1999, and make available - to groups running at high spatial resolution - realtime base Level II data from a number of WSR-88D radars in the central US. At this time, the SAMEX '99 storm-resolving domains are envisioned to be centered over the southern Great Plains, though perhaps cover a larger area than in 1998 pending the availability of adequate computing resources.

If SAMEX '99 proves successful, we will propose to focus subsequent experiments over other parts of the country, emphasizing, for example, coastal regions, mountainous terrain, and the Great Lakes in winter. As data acquisition systems continue to mature, these experiments could include targeted observation programs and support field data collection efforts.

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