NOAA HAZARDOUS WEATHER TESTBED

EXPERIMENTAL FORECAST PROGRAM SPRING EXPERIMENT 2008

http://hwt.nssl.noaa.gov/Spring_2008/

HWT Facility – National Weather Center
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Program Overview and Operations Plan

5/6/08 Version

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I. The NOAA Hazardous Weather Testbed

NOAA's Hazardous Weather Testbed (HWT) is a joint facility managed by the National Severe Storms Laboratory (NSSL), the Storm Prediction Center (SPC), and the NWS Oklahoma City/Norman Weather Forecast Office (OUN) within the National Weather Center building on the University of Oklahoma South Research Campus. The HWT is designed to accelerate the transition of promising new meteorological insights and technologies into advances in forecasting and warning for hazardous mesoscale weather events throughout the United States. The HWT facilities include a combined forecast and research area situated between the operations rooms of the SPC and OUN, and a development laboratory also located nearby on the second floor. The facilities support enhanced collaboration between research scientists and operational weather forecasters on specific topics that are of mutual interest.

The HWT organizational structure is composed of two primary overlapping program areas (Fig. 1). The first program area focuses on forecast-scale activities under the auspices of the Experimental Forecast Program (EFP), and the second program tests research concepts and technology specifically aimed at short-fused warnings of severe convective weather under auspices of the Experimental Warning Program (EWP). A key NWS strategic goal is to extend warning lead times under the concept of "Warn-on-Forecast" through the development and application of convection-allowing numerical models to extend short-term predictability of hazardous convective weather. This provides a natural overlap between the EFP and EWP activities as the distinction between warnings and short-term forecasts of convective weather gradually diminishes. Both programs reside beneath the overarching HWT organization and facility with a focus on national hazardous weather needs.

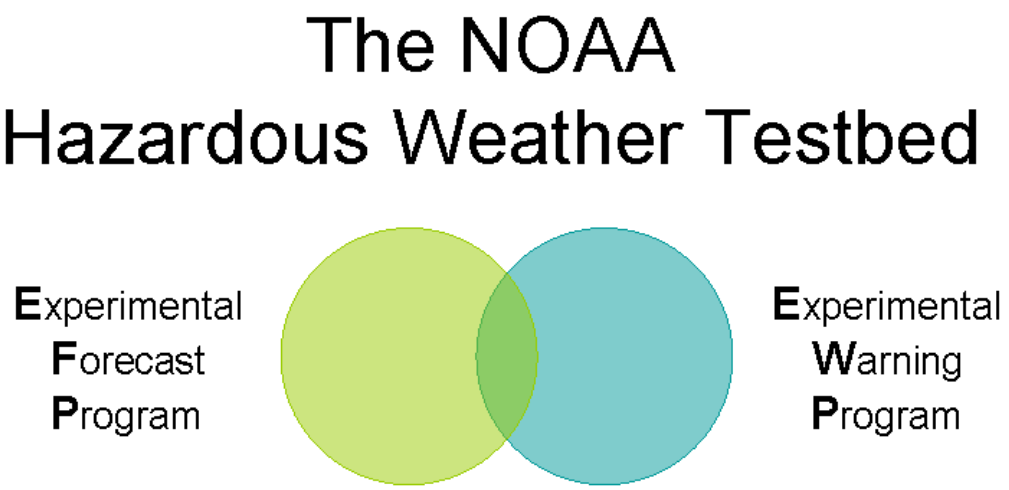


Figure 1: The umbrella of the NOAA Hazardous Weather Testbed (HWT) encompasses two program areas: The Experimental Forecast Program (EFP) and the Experimental Warning Program (EWP).

The specific mission of each HWT program branch is:

The Experimental Forecast Program - EFP

The EFP branch of the HWT is focused on predicting hazardous mesoscale weather events on time scales ranging from a few hours to a week in advance, and on spatial domains ranging from several counties to the CONUS. The EFP embodies the collaborative experiments and activities previously undertaken by the annual SPC and NSSL Spring Experiments.

The Experimental Warning Program – EWP

The EWP branch of the HWT is concerned with detecting and predicting mesoscale and smaller weather hazards on time scales of minutes to a few hours, and on spatial domains from several counties to fractions of counties. The EWP embodies the collaborative warning-scale experiments and technology activities previously undertaken by the OUN and NSSL. See http://ewp.nssl.noaa.gov/ for more information about the EWP.

Rapid science and technology infusion for the advancement of operational forecasting requires direct, focused interactions between research scientists, numerical model developers, information technology specialists, and operational forecasters. The HWT provides a unique setting to facilitate such interactions and allows participants to better understand the scientific, technical, and operational challenges associated with the prediction and detection of hazardous weather events. The HWT allows participating organizations to:

- Refine and optimize emerging operational forecast and warning tools for rapid integration into operations
- Educate forecasters on the scientifically correct use of newly emerging tools and to familiarize them with the latest research related to forecasting and warning operations
- Educate research scientists on the operational needs and constraints that must be met by any new tools (e.g., robustness, timeliness, accuracy, and universality)
- Motivate other collaborative and individual research projects that are directly relevant to forecast and warning improvement

For more information about the HWT, see http://www.nssl.noaa.gov/hwt/

II. Historical Perspective

Co-location of the Storm Prediction Center (SPC) with the National Severe Storms Laboratory (NSSL), the Oklahoma City/Norman Weather Forecast Office, and many University of Oklahoma meteorological organizations in the National Weather Center in Norman provides a unique opportunity to enhance long-standing community interactions and

collaboration on a variety of experimental forecast and other operationally relevant research programs. Since the re-location of the SPC to the previous NSSL facility Norman in early 1997, a wide cross section of local and visiting forecasters, research scientists, and model developers has participated in a number of experimental programs since the late 1990s. These include forecasting support for field programs such as the International H2O Project (IHOP), establishing the SPC winter weather mesoscale discussion product, evaluating operational and experimental NWP models for application in convective forecasting including Short Range Ensemble Forecast (SREF) systems and convection-allowing Weather Research and Forecasting (WRF) models, and integrating new observational data, objectives analyses, and display tools into forecast operations. A key goal of these programs is to improve forecasts of hazardous meteorological phenomena by accelerating the transfer of new technology and research ideas into forecast operations at the SPC and other NWS offices, and by sharing new techniques, skills, and results of applied research more freely with others in the operational forecasting community. Typical issues addressed in these activities include, but are not limited to: optimizing use of vast and ever increasing quantities of observational and model data in operational forecasting, testing and evaluation of new NWP models, better understanding of operational forecast problems, development and evaluation of diagnostic conceptual models, and new product development and display strategies utilizing operational workstations.

Each spring during the climatologically most active severe weather periods, multi-agency collaborative forecasting experiments known as the HWT EFP Spring Experiment (formerly called the SPC/NSSL Spring Program) have occurred since 2000. The only exception was in 2006 when the physical move to the new National Weather Center building precluded a large collaborative experiment. During that spring SPC conducted a focused internal pre-implementation evaluation of the NCEP NAM-WRF model.

Summaries about earlier Spring Experiments are available at:

http://www.nssl.noaa.gov/projects/hwt/sp2000.html
http://www.nssl.noaa.gov/projects/hwt/sp2001.html
http://www.nssl.noaa.gov/projects/hwt/sp2002.html
http://www.nssl.noaa.gov/projects/hwt/sp2003.html
http://www.nssl.noaa.gov/projects/hwt/sp2004.html
http://www.nssl.noaa.gov/projects/hwt/sp2005.html
http://www.nssl.noaa.gov/projects/hwt/sp2007.html

The following sections provide additional background information about the SPC national severe weather forecasting mission, an overview of the scientific goals of the experiment and its relevance to operational forecasting, the schedule of daily forecasting and evaluation activities, and a list of weekly participants for the 2008 Spring Experiment.

III. Spring Experiment Background and Motivation

The prediction of convective weather is important from both meteorological and public service/societal impact perspectives. Since a primary mission of the National Weather Service is the protection of life and property from hazardous weather phenomena, applied

research aimed at improving the prediction of impact weather such as severe thunderstorms and tornadoes is a critical activity at the SPC, NSSL, OUN, and other NWS offices.

The SPC is responsible for the prediction of severe convective weather over the contiguous United States on time scales ranging from several hours to eight days. To meet these responsibilities, the SPC issues Convective Outlooks for the Day 1, Day 2, Day 3, and Day 4-8 periods to highlight regions with enhanced potential for severe thunderstorms (defined as thunderstorms producing hail $\geq$ 3/4 inch in diameter, wind gusts $\geq$ 50 kt or thunderstorm induced wind damage, and/or tornadoes). These outlooks are issued in both categorical (slight, moderate, or high risk) and probabilistic formats, and are issued with increasing frequency as the severe weather time frame draws nearer. In addition to the scheduled Outlooks, Severe Thunderstorm and Tornado Watches are issued on an as-needed basis to provide a higher level of alert over smaller regions in time and space when atmospheric conditions are favorable for severe thunderstorms and/or tornadoes to develop. The SPC also issues short-term Mesoscale Discussion products that emphasize hazardous weather on the mesoscale and often serve to fill the gap between the larger scale Outlooks and smaller scale Watches. These specialized hazardous weather forecast products depend on the ability of SPC forecasters to assess the current state and evolution of the environment over varied time frames, and to synthesize a wide variety of observational and numerical model data sources. In general, observational data play a dominant role in diagnostic assessment for short-term forecasting, however, the development of more accurate and higher resolution models in recent years has allowed model information to influence the short-term prediction of convection as well. This is especially evident in the use of the hourly Rapid Update Cycle model, which forms a foundation for the SPC Mesoscale Analysis fields.

An effective NWS severe weather forecast and warning program should provide the public and others specialized users with sufficient advance notice of impending hazardous weather. Human response studies have shown that when a severe thunderstorm or tornado warning is issued, people are more likely to seek safe shelter if they have been made aware of the severe weather threat prior to the issuance of the warning. However, if they have not been "pre-conditioned" to the threat prior to hearing a warning, their first response is often to seek confirmation of the threat, rather than to seek shelter. This can result in the loss of critical reaction time when life and property are at immediate risk. Thus, there is a substantial need for the SPC to issue severe weather watches prior to the issuance of warnings by local NWS Weather Forecast Offices (WFOs), in order to allow WFO staffs, emergency managers, broadcast media, etc. sufficient time to implement contingency plans prior to the onset of severe weather. In recent years the SPC has embarked on a program to increase the lead time of convective watches while continuing to improve forecast accuracy.

This goal places additional requirements on SPC forecasters to determine in advance the characteristics of potential severe thunderstorm activity. Operational experience and research studies suggest that the type of severe weather that occurs (tornadoes, hail, or damaging winds) is often closely related to the convective mode (or morphology) exhibited by storms, such as discrete cells, squall lines (or quasi-linear convective systems (QLCS)), and multi-cellular convective systems. A disproportionate number of intense tornado and widespread straight-line wind damage events appear to be associated with two dynamically unique classes of thunderstorms: supercells and bow echoes. Thus, accurate severe weather watches are dependent on forecasters being able to properly predict not only where and when severe

thunderstorms will develop and how they will evolve over the next 4 – 8 hours, but also the convective mode(s) that are most likely to occur.

Given the SPC's primary mission of mesoscale forecast responsibility, we continue to place a strong emphasis on assessing the current state of the atmosphere by using real-time observational data and derived diagnostic parameters for short-term thunderstorm prediction. However, owing to insufficient sampling of the mesoscale environment (especially when the horizontal and vertical distribution of water vapor is considered) coupled with limited scientific knowledge of important mesoscale and storm-scale processes, considerable uncertainty exists in the prediction of convection. While traditional operational models such as the NAM and GFS often can predict broader regions of precipitation resulting from parameterized convection, they are not capable of resolving important details of the smaller scale convective structure that is critical to severe weather forecasters. Furthermore, various proximity sounding studies using observed radiosondes and RUC model analyses indicate that the relationship between environmental characteristics (such as CAPE and shear) and storm mode is not unique; rather it is found that similar storm types occur within different parts of the CAPE-shear parameter space, and different storm types occur within similar parts of parameter space.

Earlier research studies using idealized cloud resolving models to simulate convective storms at the National Center for Atmospheric Research (NCAR) and the University of Oklahoma Center for Analysis and Prediction of Storms (CAPS), among others, indicated that in some cases the models could replicate severe storm structures including supercells and bow echo systems. However, it was not until recently that sufficient computer resources, communications bandwidth, and workstations were available to facilitate the testing of convection-allowing WRF models over large domains in a semi-operational forecasting environment, and to assess their potential utility for severe weather forecasting. It has been demonstrated over the last five years in Spring Experiments, field programs such as BAMEX, and daily use by SPC forecasters of experimental 4 km WRF models from the NCEP Environmental Modeling Center (EMC) and NSSL that near-cloud resolving configurations of the WRF model can predict convective storms that, at times, appear remarkably similar to actual storms as seen on radar. Experiments with different WRF model configurations also indicate that it is not uncommon for each of the models to produce a variety of convective solutions for initiation, mode, and evolution, especially within more weakly forced environments. Thus, the model forecasts appear to reflect various uncertainties associated with real-world convective forecasting. These uncertainties arise from: 1) the need to better sample and predict the pre-convective and near-storm environments, as convection can be sensitive to small variations in the environment, and 2) limits in our understanding of smaller scale physical processes relevant to convection, which are modulated by mesoscale and stormscale forcing that are difficult to assess in the actual atmosphere.

Our experience has shown that variations in WRF model convective storm predictions are at times difficult for operational forecasters to reconcile, in part because all solutions may appear to be plausible for a given mesoscale environment. Thus, the forecaster must determine how much confidence to place in specific model solutions, which is often difficult to assess because very high resolution models will attempt to predict phenomena (such as thunderstorms) on scales that are inherently unpredictable. The uncertainty in thunderstorm prediction suggests at least several possible research approaches to explore: 1) development

of appropriate data assimilation systems for convection-allowing models to better resolve the initial conditions, and 2) improvement in the model itself with more realistic physics and increased resolution. However, inherent limits to the predictability of thunderstorms further suggest that application of ensemble forecasting concepts, currently used operationally for synoptic scale and mesoscale forecasting, may also be applicable to address challenges of convective-scale forecasting.

Finally, a key component of the annual experiments is the participation of operational forecasters from the SPC, other NCEP Centers, NWS WFOs, Environment Canada, and several private sector companies. Their insights and experience provide a real-world severe weather forecasting perspective when assessing the usefulness of convection-allowing WRF modeling systems, provide them with opportunities to become familiar with cutting-edge science and technology applications before they are implemented operationally, thus increasing the likelihood that HWT activities will result in improved severe weather forecasts and better public service. Their interactions with model developers, research scientists, university faculty, and graduate students create a unique forum where a diverse mix of scientific backgrounds and insights work together to advance operationally relevant research and improve forecasts of hazardous convective weather.

IV. Experimental Models

The 2008 Spring Experiment will benefit from the continued participation and large contributions from CAPS, EMC, and NCAR. In support of the experiment, each of these collaborators (along with NSSL) will generate high resolution, convection-allowing WRF-based model guidance initialized at 0000 UTC. Model domains will vary somewhat, but all will cover roughly the eastern two-thirds to three-fourths of the CONUS and all forecasts will extend to at least 30h.

CAPS Models – 4 km Storm Scale Ensemble, 2 km WRF-ARW, and "On Demand" Runs

As in 2007, the CAPS contribution will be in the form of a *10-member WRF Storm Scale Ensemble Forecast (SSEF) system* with grid spacing of 4 km, along with a single deterministic run using 2 km grid spacing, utilizing the resources of the Pittsburgh Supercomputing Center (PSC). The ensemble will draw diversity from a combination of initial-condition and model-physics perturbations. In all members, the background initial condition will come from interpolation of the 12 km NAM analysis. Mesoscale atmospheric perturbations will be introduced in the initial and lateral-boundary conditions of 8 members by extracting four pairs of positive/negative perturbations from EMC's operational Short Range Ensemble Forecast (SREF) system and applying them separately to the 8 members. In addition, convective-scale perturbations will be introduced in the initial conditions of these 8 members by assimilating reflectivity and velocity data from radar using a CAPS 3DVAR system. For the remaining two members, identical model configurations will be used and there will be no SREF-based perturbations. Radar data will be assimilated into one of these members (the control member), but not the other. Comparison of output from these two members will allow us to isolate the impact of the radar data from other sensitivities at 4 km grid spacing. Overall, the SSEF configuration builds upon lessons learned from the initial SSEF tested during the 2007 Spring Experiment, and is expected to be more robust and contain improved statistical performance. For operational forecasting applications, it is

anticipated the SSEF will provide improved probabilistic guidance on high impact convective weather events by quantifying aspects of uncertainty and offering insights about a possible range of solutions. *In the 2-km forecast*, there will be no SREF-based perturbations but radar data will be assimilated, allowing a direct comparison with the SSEF control member and a clean measure of sensitivity to 2 versus 4 km grid spacing when radar data is assimilated. The CAPS computational domain for the SSEF and 2 km WRF is shown in Fig. 1, and the SSEF member configuration is provided in Table 1.

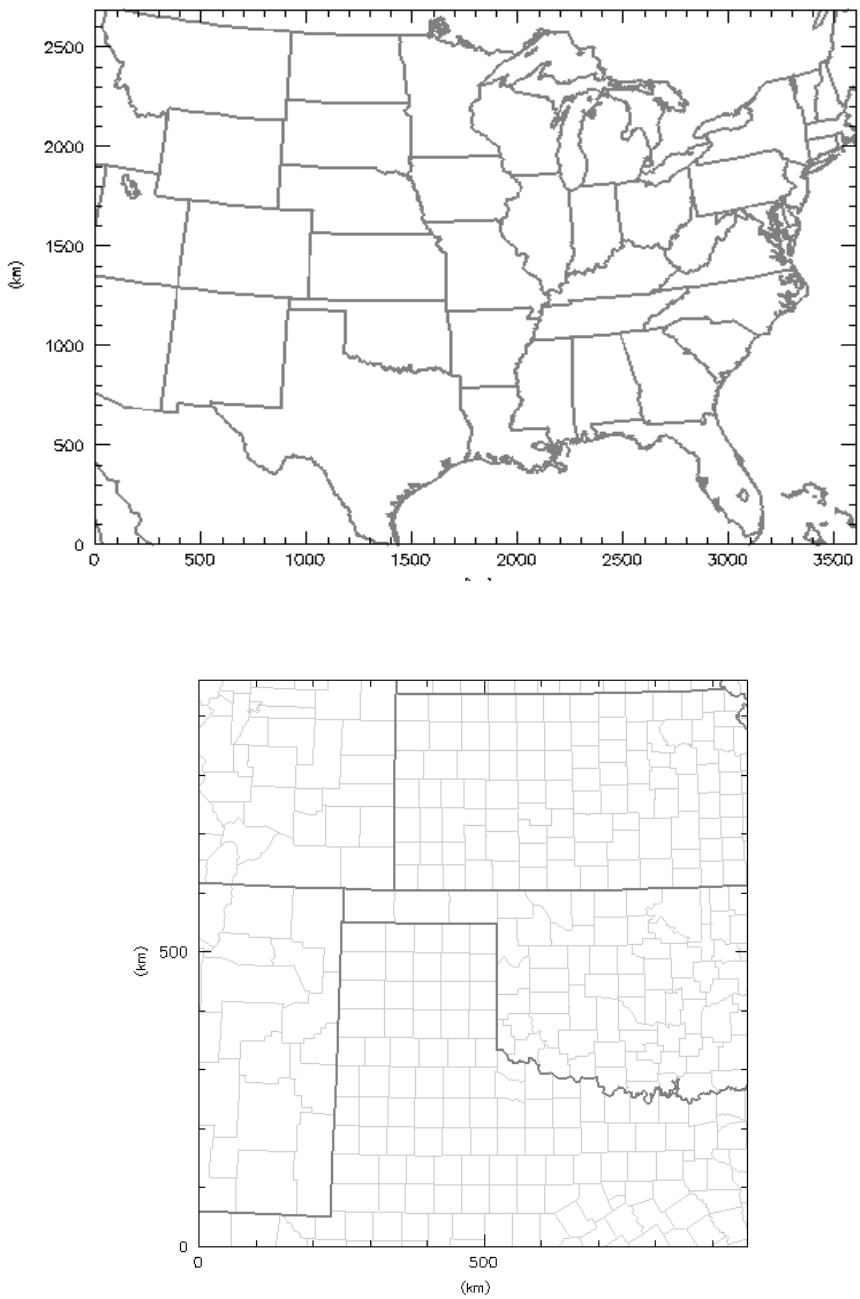


Fig. 1. CAPS domain for SSEF and 2 km WRF(top); example of "On Demand" domain (bottom).

member	IC	LBC	Radar data	mp_phy	sw-phy	pbl_phy
Cntl	**00Z NAMa**	**00Z NAMf**	**yes**	**Thompson**	**Goddard**	**MYJ**
C0	**00Z NAMa**	**00Z NAMf**	**no**	**Thompson**	**Goddard**	**MYJ**
N1	**Cntl – em_pert**	**21Z SREF em_n1**	**yes**	**Ferrier**	**Goddard**	**YSU**
P1	**Cntl + em_pert**	**21Z SREF em_p1**	**yes**	**WSM 6-class**	**Dudhia**	**MYJ**
N2	**Cntl – nmm_pert**	**21Z SREF nmm_n1**	**yes**	**Thompson**	**Goddard**	**MYJ**
P2	**Cntl + nmm_pert**	**21Z SREF nmm_p1**	**yes**	**WSM 6-class**	**Dudhia**	**YSU**
N3	**Cntl – etaKF_pert**	**21Z SREF etaKF_n1**	**yes**	**Thompson**	**Dudhia**	**YSU**
P3	**Cntl + etaKF_pert**	**21Z SREF etaKF_p1**	**yes**	**Ferrier**	**Goddard**	**MYJ**
N4	**Cntl – etaBMJ_pert**	**21Z SREF etaBMJ_n1**	**yes**	**WSM 6-class**	**Goddard**	**MYJ**
P4	**Cntl + etaBMJ_pert**	**21Z SREF etaBMJ_p1**	**yes**	**Thompson**	**Dudhia**	**YSU**

For all members: ra_lw_physics= **RRTM**; sfc_physics= **Noah**; cu_physics= **NONE**

Table 1. SSEF member configuration.

Finally, CAPS will run so-called *"on demand" updated versions of the 2 km WRF-ARW* over a movable regional domain (960 x 960 km) each day (Fig. 1). Two versions of the model will be initialized at 15 UTC and integrated 15 hours through 06 UTC. One is initialized from a 3-hour forecast of the operational 12 UTC NAM model, and the other from an interpolation of a 10 km ADAS analysis using standard data (e.g., surface METAR, selected mesonet, aircraft observations) plus GOES satellite and NEXRAD reflectivity data. Lateral boundary conditions for both runs will come from the 12 UTC NAM. These runs allow a comparison of later WRF forecasts with those from the 00 UTC model runs to examine the effects of initializing with later data during the start of the current diurnal heating cycle.

NCAR 3 km WRF-ARW Model

The unique contribution from NCAR this year will focus on the new cycled WRF 3DVAR system. They will use this assimilation system to cycle continuously a relatively large domain forecast system with 9 km grid spacing. They will initialize a 3 km nest (one way nesting) within this domain every day at 0000 UTC and run a 36h forecast. Lateral boundary conditions for the 3 km nest come from a parallel 9 km run initialized at 12 UTC, and boundary conditions for the 9 km run come from the operational GFS

model. The data sources used for the 3DVAR cycling include standard soundings, profilers, multi-level satellite winds, SYNOP and METAR surface observations, ships and buoys, various aircraft observations, and a variety of satellite observational data (GPSRF (COSMIC), GSCAT, GPSPW). Satellite radiances and radar data are not being used this year. Of note is that explicit precipitation from the 9 km cycled forecast is now included in the 00 UTC initialization, so the run is not considered to be a pure ``cold'' start. This system will provide the first extensive real-time test of the WRF 3DVAR system. Examination of the NCAR 3 km output should provide interesting insights into the performance of the assimilation package and provide developers with valuable information for continued improvements.

EMC and NSSL 4 km WRF Models

An important third component of the experimental modeling effort will involve 4 km WRF forecasts from EMC and NSSL. The EMC runs will use the NMM dynamic core while the NSSL forecasts will be based on the ARW core. Both of these forecasts have been available to, and used by, SPC forecasters on a daily basis for more than a year. A recent review of the performance of these models during selected severe weather episodes revealed numerous strengths, but also many unexplained weaknesses in these forecasts. The 2008 Spring Experiment will provide us with an opportunity to combine the analysis skills and insights of model developers and forecasters in a detailed examination of daily forecasts from these two WRF configurations. This examination will focus on the evolution of the pre-convective environment, mechanisms responsible for convective initiation, and representation of the various forms of convective mode. It is anticipated that these analyses will provide important fundamental insights to model developers as well as forecasters, leading to improvements in both WRF configurations and ultimately benefitting WRF-based ensemble and higher-resolution forecast systems.

The configuration of the WRF deterministic models is shown in Table 2, and geographic domains of the models are shown in Figs. 2-3.

	EMC-NMM4	**NCAR-ARW3**	**NSSL-ARW4**	**CAPS-ARW2**
Horiz. Grid (km)	4.0	3.0	4.0	2.0
Vertical Levels	35	39	35	51
PBL/Turb. Param.	MYJ	MYJ	MYJ	MYJ
Microphysical Param.	Ferrier	Thompson	WSM6	Thompson
Radiation (SW/LW)	GFDL/GFDL	Dudhia/RRTM	Dudhia/RRTM	Dudhia/RRTM
Initial Conditions	32 km NAM	WRF-3DVAR	40 km NAM	CAPS-3DVAR

Table 2. Configurations of deterministic WRF models. EMC NMM, NSSL ARW4, and NCAR ARW3 start at 00z and run through 36 hrs; CAPS ARW2 starts at 00z and runs through 30 hrs.

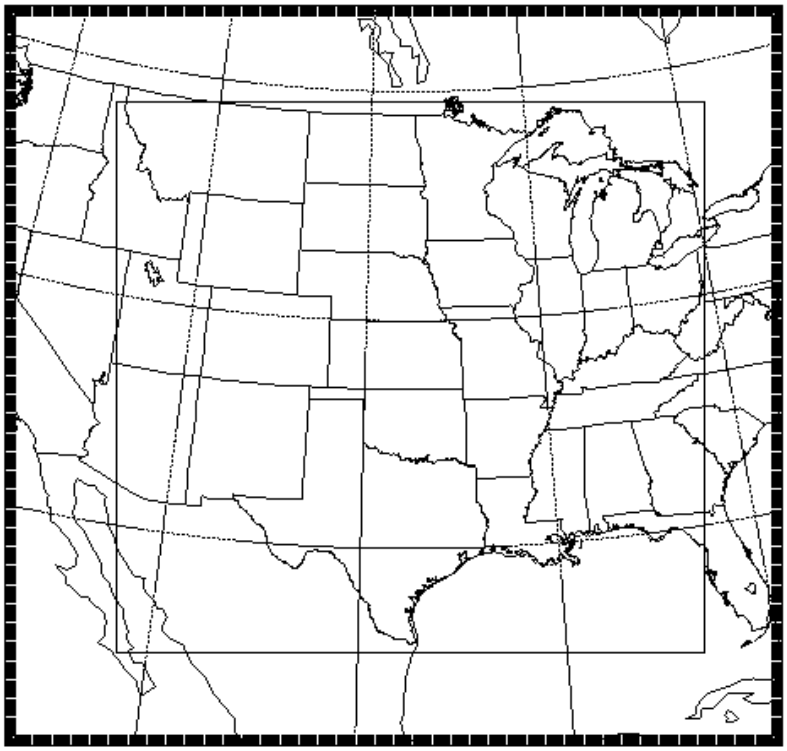


Fig. 2. NCAR 3 km WRF-ARW showing 9 km domain (thick outer box) and 3 km nest (thin inner box)

Fig. 3. NSSL 4 km WRF-ARW domain. This geographic area closely approximates the EMC 4 km WRF-NMM domain.

V. New Objective Verification Approaches *(Starting in May 2008)*

Subjective verification of model forecasts has been a cornerstone to HWT activities in previous years. This approach provides valuable insights into how forecasters use numerical models, and facilitates the gathering of information about the value of new guidance tools from the perspective of a forecaster. In addition, traditional verification measures (e.g., Equitable Threat Score or ETS) used for synoptic scale and mesoscale model forecasts of discontinuous variables such as precipitation typically provide less useful information (and even misleading information) about forecast accuracy as the scale of the phenomena being evaluated decreases. This is because the ETS is proportional to the degree of grid scale overlap in space and time between the forecasts and observations, and there is typically low predictability on convective scales. Despite these limits, operational severe weather forecasters have often found value in WRF forecasts of thunderstorms and convective systems, since they can provide unique information about convective mode, coverage, and evolution that is not resolved by mesoscale models using parameterized convection. In recent years, we have found that subjective evaluation has great potential to serve as a comparative benchmark for assessing new objective verification techniques designed for high resolution NWP, and has had a significant positive impact on model development strategies.

In order to better utilize subjective and objective verification techniques in a complementary manner, simulated reflectivity and QPF output from the EMC-NMM and NSSL-ARW models will be evaluated using subjective visual comparisons and objective measures produced by the NSSL National Mosaic and Multi-Sensor QPE (NMQ) project's Quantitative Verification System (QVS). The QVS produces state-of-the-science high resolution multi-sensor Quantitative Precipitation Estimates (QPE) and three-dimensional radar reflectivity data bases, which will be used to produce traditional objective verification scores for the EMC and NSSL models. See http://www.nssl.noaa.gov/projects/q2/ for more information about the NMQ.

In addition, the WRF Developmental Testbed Center's Meteorological Evaluation Toolkit (MET) will play a role in evaluating WRF model performance. MET is designed to be a highly-configurable, state-of-the-art suite of verification tools. We will focus on the use of the object-based verification called Method for Object-based Diagnostic Evaluation (MODE) that compares gridded model data to gridded observations for the QPF and simulated reflectivity forecasts from the EMC-NMM and NSSL-ARW models. MODE output will be tested to evaluate its ability to diagnose different types of convective modes considered important in forecasts and observations of convective weather, such as linear systems, discrete cells, and MCS's. More information about the DTC MET system is at http://www.dtcenter.org/met/users/ .

VI. Objectives and Expected Outcomes

The primary objectives of Spring Experiment 2008 are to:

- Continue testing and refining a real-time, large domain convection-allowing Storm Scale Ensemble Forecast (SSEF) system during the prime severe weather season to gauge high performance computing, networking, data transfer and processing, product creation, and workstation display requirements for future high impact weather forecasting initiatives associated with the Warn-on-Forecast concept.

- Explore the relative impact of assimilating radar reflectivity and velocity data into SSEF members on short-term forecasts of hazardous convective weather, as well as possible impacts in forecast performance later in the forecast period.

- From real-time and post analyses of the SSEF, determine strengths and limitations of the ensemble configuration and consider appropriate modifications that will lead to improved ensemble performance in subsequent years.

- Identify and test innovative ways to extract useful information from the SSEF and deterministic WRF models, and develop new product display techniques that provide forecasters with meaningful probabilistic guidance on high impact convective weather events, including severe convective weather, heavy rain, and aviation applications.

- Transfer selected SSEF guidance products to SPC forecaster workstations to expand opportunities for real-world operational testing during prime severe weather season.

- Assess the utility of higher resolution convection-allowing deterministic WRF models to provide more detailed and useful forecast guidance to forecasters on the initiation, mode and evolution of severe thunderstorms, including supercells.

- For the WRF-NMM and WRF-ARW cores, explore in more detail the relationship between model forecasts of convective storms and model predictions of the mesoscale environment, focusing on surface boundaries, airmass characteristics, and sounding structure.

- Conduct an initial test of the NCAR-WRF-3DVAR data assimilation system to assess its impact on WRF-ARW analyses and forecasts.

- Expand previous subjective model evaluation approaches to include traditional and new objective verification measures and test their utility to provide unique and meaningful information about convection-allowing model performance.

- Provide focused feedback to model developers on the performance of the experimental SSEF and deterministic models during severe thunderstorm episodes.

The experiment expected outcomes include:

- Documentation of statistical verification properties of the SSEF, leading to improvements in the configuration of the 2009 ensemble.

- Documentation of the utility of a SSEF to quantify uncertainty and provide probabilistic guidance for high impact convective weather events, including severe storms, heavy rain, and applications for aviation .

- Documentation of the impacts of incorporating data assimilation systems to initialize convection-allowing WRF models and the SSEF, including radar reflectivity and velocity data.
- Confirmation and clarification of the ability of convection-allowing WRF models to provide unique information on convective mode and how operational severe weather forecasters utilize this guidance in daily forecasting.

- Documentation of the evolving complimentary relationship between operational mesoscale deterministic models, the current mesoscale SREF, and convection-allowing WRF models including the SSEF in quantifying uncertainty in high impact convective weather forecasts.

- Documentation of the ability of traditional and new objective verification approaches to provide needed information about high resolution convection-allowing model performance.

- Internal NWS documentation of challenges to the real-time display and utilization of very high resolution NWP output in an operational forecast setting.

- Enhanced communication and collaboration between forecasters and model developers leading to enhancements in the transfer of research to operations.

- Continued effective collaboration between research scientists, model developers, and forecasters during the Spring Experiment with high participant satisfaction (greater than 70% very good to excellent collaboration assessment) as measured by responses to a survey form given to all participants.

VII. Spring Experiment Web Site

A full description of all program objectives, types of model output, forecast products, evaluation and verification forms, a data archive, and other related links are available at the Spring Experiment web site:

http://hwt.nssl.noaa.gov/Spring_2008/

This web site is intended to support real time activities as well as additional research and reference after the conclusion of the program.

VIII. Dates of the Spring Experiment

Spring Experiment 2008 will run Monday-Friday 8 am – 4 pm from April 21 through June 6, 2008. **On each Monday, participants are asked to arrive by 7:30 am for a brief orientation session.** During the first week, final spin-up activities will be tested with in-house participants only. Beginning April 28, a full range of in-house and external participants will staff the program. Full time participants will work shifts of one week, with part-time visiting scientists and forecasters participating on a 2-3 day basis (schedule permitting). Program operations will be conducted in the Hazardous Weather Testbed facility (Room 2380) located on the second floor of the NWC between the SPC and WFO Norman operations areas. The full time forecast team will complete daily experimental forecasts and participate in evaluation and verification activities; part-time visitors can participate in daily activities at levels appropriate with their interest and expertise. Staffing typically will include one SPC forecaster, one or more NSSL scientists, and a number of visiting scientists, model developers, forecasters, and university faculty. A list of weekly participants is found in Appendix A.

IX. Daily Operations Schedule

Participants in the experiment will create experimental forecast products and conduct subjective evaluation activities in the HWT from 8 am - 4 pm on Monday-Friday. Occasional seminars by visiting scientists will be scheduled for 4 pm in the David L. Boren Auditorium on the first floor of the NWC upon completion of daily experimental activities.

Participants are expected to perform evaluation activities in a collaborative manner, such that results reflect a consensus decision. Participants may eat lunch while conducting program activities or at their discretion any time during the day. Visitors may purchase lunch at a food court located on the south side of the first floor of the NWC. Below is an outline of the daily schedule for activities during the experiment; a more detailed description is listed below the table.

Monday-Friday:

7:30 am	-	8:00 am	-	Orientation (Monday only)
8:00 am	-	8:30 am	-	Subjective verification of yesterday's experimental severe weather forecasts
8:30 am	-	9:45 am	-	Detailed subjective evaluation of yesterday's 4 km WRF-NMM and WRF-ARW model forecasts
9:45 am	-	10:00 am	-	Select today's 8-hour valid period and forecast/evaluation domain valid 21-05 UTC Subjective evaluation of yesterday's forecasts of simulated reflectivity from additional WRF model forecasts
10:00 am	-	10:30 am	-	Subjective evaluation of data assimilation impacts on yesterday's CAPS and NCAR model forecasts of simulated reflectivity
10:30 am	-	11:30 am	-	Subjective evaluation of yesterday's SSEF products
11:30 am	-	12:30 pm	-	Lunch and meteorological chart analysis to set the stage for today's experimental severe weather forecasts
12:30 pm	-	3:00 pm	-	Break into two forecast teams and formulate experimental probabilistic severe weather forecasts for selected regional domain valid 21-05 UTC.
3:00 pm	-	3:15 pm	-	Prepare for end of day summary and wrap-up
3:15 pm	-	4:00 pm	-	Discussion summarizing today's evaluation and forecast activities and daily wrap-up

Spring Experiment 2008
Daily Schedule and Order of Activities
(Subject to Modification)

Monday only
7:30-8:00 am: Weekly orientation. Introduction to SPC and NSSL (powerpoint - Russ), followed by individual introductions, experience and interests; purpose and goals of HWT and Spring Experiments; collaborative daily activities

Monday-Friday
Morning activities primarily focus on evaluation of previous day human and model forecasts

1. 8:00 – 8:30 am: Human forecast evaluation (Leader: Weiss and Kain)

Subjective verification of the previous day probabilistic severe weather forecasts issued by both forecast teams for 21-05z period over the selected regional domain. Formulate an overall rating by averaging the accuracy of different forecast areas when necessary. Areas with greater severe storm occurrence, higher forecast probabilities, and the forecast or occurrence of significant reports should be given more weight in the rating process.

Numerical ratings of 0-10 and descriptive text information are entered into internal web page survey form.

Primary data sources: Web page displays of probability forecast graphics and corresponding plot of severe reports with "practically perfect" forecast contour overlays. (Information about the "practically perfect" forecast concept is found in Appendix C.) Forecasts display contours of standard SPC probability values for all severe storms (less than 5%, 5, 15, 30, 45, 60%) and 10% or greater probability of significant severe (hatched area) if needed.

2. 8:30 – 9:45 am: 4 km WRF-NMM and WRF-NSSL forecast evaluation

2a: Evaluation of 1 km AGL simulated reflectivity forecasts (Leader: Kain)

Subjective verification of 1 km AGL simulated reflectivity forecasts from the two models during 21z-05z forecast period over the same regional domain. Assessment includes how well model reflectivity forecasts corresponded to observed reflectivity, including convective initiation, direction and speed of system movement, areal coverage, configuration and orientation of mesoscale features, and convective mode. Numerical ratings of 0-10 and descriptive text information are entered into internal web page survey form.

Primary data sources: Web page 3-panel display showing hourly model reflectivity forecasts and observed BREF images from 18-06z. *(Time period covers before and after forecast period to assess possible timing errors.)*

2b: Assessment of model QPF using NSSL QVS (QPF Verification System) (Leader: Kain)

Subjectively compare model QPF forecasts with QVS graphics and objective statistics valid for the 21-05z forecast period over the same regional domain. Assessment includes how well model QPF corresponded to NSSL QPE and perceived validity of objective scores. Descriptive text information is entered into internal web page survey form.

Primary data sources: NSSL QVS web page containing model QPF images and objective verification statistics.

2c. Assessment of model predictions of convective mode using DTC-MET-Mode system (Leader: Coniglio)

Subjectively assess model 1-hr QPF and reflectivity forecasts over selected regional domain focusing on precipitation/convective structure (mode) and compare with object-oriented analysis results produced by MET-Mode. Assessment includes how well the MET-Mode results compare to subjectively perceived mode. Descriptive text information is entered into internal web page form.

Primary data sources: Special DTC webpage displaying raw model forecasts and MET-Mode object-oriented structure analysis for different scales.

2d. Model generated storm development and its relationship to model environment (Leaders: Kain and Coniglio)
**** Now Break into NSSL and NMM Evaluation Teams ****

Each team will examine over the selected regional domain the initiation and maintenance of the primary model generated convective storms and their relationship (if any) to model surface boundaries/convergence lines, and the pre-convective and near-storm environment characteristics of CAPE/CIN and vertical shear, as indicated by plan views of model forecast parameters and point soundings. Descriptive text information is entered into internal web page form.

Primary data sources: NMAP displays of model 10 m winds and convergence (NCF), 1 km AGL simulated reflectivity, 2 m temperature and dewpoint, SBCAPE/CIN, and Supercell Composite (CAPE, 0-6 km bulk shear, 0-3 km SRH). N-SHARP displays of model point soundings, and web page of model sounding comparisons including with observed raobs.

Team Discussions: After completion of the NSSL and NMM assessments, each team will discuss their findings with the group. The participants will then reconvene as a single group.

3. 9:45-10:00 am: Selection of current day regional forecast domain, and Evaluation of multiple WRF model forecasts of 1 km simulated reflectivity

3a. Selection of current day regional forecast domain. (Leaders: Weiss, Kain)

The upcoming afternoon experimental severe weather forecast will be valid for the 4 pm - midnight "swing" shift time period (21-05z), and a regional domain will be selected for the forecast. The forecast area will be restricted to fall within the common domain of all WRF model guidance, and is typically placed where the most intense severe storms are expected to occur. However, areas where the forecast is considered to be particularly difficult can also be considered in the domain selection process. The domain is selected by entering a three letter METAR station ID centered on the domain into an internal web page.

Primary data sources: 13z SPC Day 1 Convective Outlook available on SPC web page, discussion with SPC forecasters, and early examination of observational and model data.

3b. Evaluation of multiple WRF model forecasts of 1 km simulated reflectivity

Subjective verification of 1 km AGL simulated reflectivity forecasts from 4 km CAPS control member (radar), 2 km CAPS, 3 km NCAR, NSSL, and NMM models during 21z-05z forecast period over the selected regional domain. Assessment includes how well

model reflectivity forecasts corresponded to observed reflectivity, including convective initiation, direction and speed of system movement, areal coverage, configuration and orientation of mesoscale features, and convective mode. **Since the NMM and NSSL models have already been evaluated in activity 2a, this evaluation is to determine if the three other models are noticeably different from the NMM and NSSL.** Numerical ratings of 0-10 and descriptive text information are entered into internal web page survey form.

Primary data sources: Web page 6-panel display showing hourly model reflectivity forecasts and observed BREF images from 18-06z. (Time period covers before and after forecast period to assess possible timing errors.)

4. 10:00-10:30 am: Comparison of CAPS 4 km control members with/without radar and NCAR 3 km ARW (Leader: Levit)

Subjective verification focusing on impacts of CAPS arps3dvar radar data assimilation and NCAR WRF3dvar on model analyses of 00hr reflectivity, short term model spin up and maintenance of coherent reflectivity fields, and possible effects of data assimilation on next afternoon forecasts. Descriptive text information is entered into internal web page survey form.

Primary data sources: Web page 4-panel display showing hourly model reflectivity forecasts and observed BREF images from 00z through 06z (30 hour period).

5. 10:30 – 11:30 am: Storm Scale Ensemble Forecast (SSEF) system evaluation (Leader: Bright)

Subjective comparison of SSEF post-processed output fields with observed radar reflectivity, NSSL QPE, and severe reports over the selected regional domain for the 21-05z forecast period. The evaluation explores the correspondence between various SREF products and the occurrence/location of severe weather reports and QPE. Two post-processing techniques for computation for exceedance probabilities will be used: 1) exceedance probability within 25 mi of a grid point, and 2) temporal/spatial neighborhood exceedance probability approach using 25 mi radius and +/- 1 hour scale configuration.

The following parameters will be examined: Reflectivity $\geq$ 40 dBz, UH $\geq$ 50 m2/s2 (supercell indicator), LML wind $\geq$ 40 kt and $\geq$ 50 kt (severe wind indicator), maximum UVV $\geq$ 10 m/s and 14 m/s (hail indicator), linear mode $\geq$ 200 mi, and QPF $\geq$ 1 in/hr. Hourly and 8 hour probabilities will be computed, with the latter corresponding to the length of the forecast period. Descriptive text information is entered into internal web page survey form describing relationship of variables to severe reports (or QPE).

Primary data sources: Web page 3-panel displays that show SSEF hourly and 8 hour exceedance probability using both post-processing techniques (25 mi radius and

neighborhood approach) and map of severe reports (or accumulated QPE for the QPF) over the selected regional domain for the 21-05z forecast period.

6. 11:30 am – 12:30 pm: Lunch and meteorological chart analysis (Leader: Weiss)

Participants will break to obtain lunch, and they are encouraged to bring food back to the HWT and eat during the chart analysis period. Standard SPC 12z upper air (250 mb, 500 mb, 700 mb, and 850 mb) and the latest surface charts will be provided for subjective hand analysis to determine the synoptic and mesoscale observational background setting for the afternoon experimental forecasting activity.

A brief discussion of the analysis findings will take place focusing on the relationship of specific features (jet streaks, short-wave troughs, surface boundaries) and kinematic/thermodynamic ingredients (vertical shear, moisture), and relevant observed soundings.

7. 12:30 – 3:00 pm: Formulation of experimental severe weather forecasts (Forecast leaders: SPC Forecaster and Team 2 Coordinator (Weiss, Carbin, Coniglio, or Bright); SSEF resource: Bright; WRF resource: Kain))

The participants will then break into "East" and "West" forecast teams, which will be randomly chosen each day. One team will be lead by the weekly SPC forecaster, and one by a Spring Experiment coordinator with severe weather forecasting background and familiarity with N-AWIPS data and functionality. The forecast teams will use N-AWIPS to examine a wide variety of observational data (e.g., METAR, satellite, radar including wind profilers, sfcoa fields (hourly SPC Mesoscale Analysis), and both operational (e.g., NAM, RUC, SREF, WRF-NMM) and experimental (NCAR WRF, NSSL WRF, CAPS SSEF) numerical model output. Forecasts will be created in N-AWIPS which consist of probability contours of all severe events (combined tornado, hail, and wind events) and significant severe events over the regional domain from 21-05z, using standard SPC outlook product probability conventions (less than 5%, 5%, 15%, 30%, 45%, 60% and $\geq$10% significant severe). Descriptive text information is entered into internal web page survey form describing the role of model data, especially the convection-allowing WRF models and SSEF, in the forecast decision making process, including identification of specific specialized products considered to be useful for impact weather forecasting. A lengthy "SPC-style" outlook synopsis and forecast discussion will not be done. Instructions for electronically creating and submitting the experimental forecast products, and a table showing the relationship between the probabilistic forecasts and SPC categorical outlooks (Slight, Moderate, High Risk) is contained in Appendix B.

8. 3:15 – 4:00 pm: Forecast discussion and daily wrap-up

Each forecast team will discuss their severe weather forecast emphasizing what steps they took to assess the current severe weather environment and ongoing convection, and key inputs to determine the evolution of ongoing storms as well as expected development of new convection. A focus will be placed on the use and interpretation of WRF and SSEF

model data as they relate to convective initiation, evolution, and mode, and the likelihood of specific convection details, is of particular importance to the experiment.

The daily wrap-up will solicit input from all participants to identify key results from morning evaluation and afternoon forecast activities, plus new questions we should explore on subsequent days. In short, what do we think we learned today, what questions came up that we can't answer at this time, and what specific topics should we explore further in the coming days. Key findings will be documented and saved in the online data archive.

X. Acknowledgments

Special thanks and appreciation is extended to many people for their creative insights and assistance in Spring Experiment preparations, planning, and execution of numerous complex and ground-breaking technical and scientific activities. Without the combined efforts of many SPC and NSSL staff, the Spring Program could not be conducted. In particular, special thanks go to SPC's Phillip Bothwell for providing access to severe storm report verification data; Gregg Grosshans for establishing model data flow and configuring the experimental forecasts for transmission and archival, and for helping to organize model display files, Andy Dean for data processing and graphics display support, and Jay Liang and Joe Byerly for expertise in configuring and upgrading hardware/software, network and workstations in the HWT. Expert NSSL technical support was provide by Doug Kennedy, Brett Morrow, Jeff Horn, Steve Fletcher and Brad Sagowitz to address networking, data flow, hardware, and archive requirements. Linda Crank (SPC), Peggy Stogsdill (SPC), and Linda Foster (NSSL) ably assisted with logistical and budget support activities. J. J. Gourley's assistance in organizing the NSSL Seminar Series for visiting scientists during the experiment is also greatly appreciated.

The experimental activities could not take place without the dedicated collaborative efforts of many people at CAPS, EMC, and NCAR who are working to enhance community efforts to improve severe weather forecasting. We acknowledge the expertise of CAPS scientists Ming Xue, Kelvin Droegemeier, Fanyou Kong, Kevin Thomas, Yunheng Wang, Jidong Gao, and Keith Brewster for outstanding efforts to develop and run the convection-allowing SSEF and WRF-ARW2 runs; the Pittsburgh Supercomputing Center and David O'Neal in particular for providing technical support and computer facilities for the CAPS model runs; NCAR scientists Morris Weisman, Greg Thompson, Jimy Dudhia, and Wei Wang for developing the WRF-ARW3 runs and offering technical support and advice on the ARW system and configuration of the WRF ensemble; EMC scientists Matt Pyle, Zavisa Janjic, Brad Ferrier, Jun Du, Zoltan Toth, and Geoff DiMego for developing and contributing the WRF-NMM models and for scientific input and infrastructure support for the WRF ensemble. We further wish to recognize the full support of SPC and NSSL management; and the numerous contributions and insights provided by the many participants who clearly demonstrated the value of collaborative experiments involving the research, academic, and forecasting communities, and whose presence and enthusiasm resulted in a positive learning experience for everyone.

Appendix A: Spring Experiment Participant Schedule

Weekly Calendar of EFP Spring Experiment Participants – 2008

Mon April 21	Tue April 22	Wed April 23	Thu April 24	Fri April 25
(Spin-Up Week) Steve Goss Jack Kain Mik Coniglio Jason Levit David Bright	*(Spin-Up Week)* Steve Goss Jack Kain Mik Coniglio Jason Levit Steven Weiss	*(Spin-Up Week)* Steve Goss Jack Kain Mik Coniglio Jason Levit Steven Weiss	*(Spin-Up Week)* Steve Goss Jack Kain Mik Coniglio Jason Levit Steven Weiss	*(Spin-Up Week)* Steve Goss Jack Kain Mik Coniglio Jason Levit David Bright
Mon April 28	**Tue April 29**	**Wed April 30**	**Thu May 1**	**Fri May 2**
Corey Mead Ernani Nascimento Victor Homar Scott Overpeck Stephen Jascourt Don Burgess Bill Bua	Corey Mead Ernani Nascimento Victor Homar Scott Overpeck Stephen Jascourt Don Burgess Bill Bua Peter Manousos Andy Edman Ken Cook	Corey Mead Ernani Nascimento Victor Homar Scott Overpeck Stephen Jascourt Don Burgess Bill Bua Peter Manousos Andy Edman Dave Stensrud	Corey Mead Ernani Nascimento Victor Homar Scott Overpeck Stephen Jascourt Don Burgess Bill Bua Peter Manousos Andy Edman Dave Stensrud	Corey Mead Ernani Nascimento Victor Homar Scott Overpeck Stephen Jascourt Don Burgess Dave Stensrud
Mon May 5	**Tue May 6**	**Wed May 7**	**Thu May 9**	**Fri May 10**
Jeff Peters Suzanne Van Cooten Mike Vescio Mike Johnson Morris Weisman Catherine Mavriplis Kenneth Crawford John Huhn Kelly Mahoney	Jeff Peters Suzanne Van Cooten Mike Vescio Mike Johnson Morris Weisman Catherine Mavriplis Kenneth Crawford John Huhn Kelly Mahoney	Jeff Peters Suzanne Van Cooten Mike Vescio Mike Johnson Morris Weisman Catherine Mavriplis Kenneth Crawford John Huhn Richard Johnson	Jeff Peters Suzanne Van Cooten Mike Vescio Mike Johnson Morris Weisman Catherine Mavriplis Kenneth Crawford John Huhn Richard Johnson Ria Alsen	Jeff Peters Suzanne Van Cooten Mike Vescio Mike Johnson Morris Weisman Catherine Mavriplis David Schmidt Kenneth Crawford
Mon May 12	**Tue May 13**	**Wed May 14**	**Thu May 15**	**Fri May 16**
Jon Racy Craig Schwartz Brad Zavodsky Nelson Seaman Tom Hultquist Bruce Entwistle Geoff Manikin Alan Coldwells Bill Gallus Scott Dembek	Jon Racy Craig Schwartz Brad Zavodsky Nelson Seaman Tom Hultquist Bruce Entwistle Geoff Manikin Alan Coldwells Bill Gallus	Jon Racy Craig Schwartz Brad Zavodsky Nelson Seaman Tom Hultquist Bruce Entwistle Geoff Manikin Alan Coldwells Bill Gallus	Jon Racy Craig Schwartz Brad Zavodsky Nelson Seaman Tom Hultquist Bruce Entwistle Geoff Manikin John Jarboe	Jon Racy Craig Schwartz Brad Zavodsky Nelson Seaman Tom Hultquist Bruce Entwistle Geoff Manikin

Mon May 19	Tue May 20	Wed May 21	Thu May 22	Fri May 23
Jared Guyer Mike Baldwin Patrick Marsh Lance Bosart Tom Galarneau Jack Settelmaier Barb Brown Dustan Wheatley (v) Bobby Prentice John Jarboe Dan Lindsey Fred Carr Brad Colman (v)	Jared Guyer Mike Baldwin Patrick Marsh Lance Bosart Tom Galarneau Jack Settelmaier Barb Brown Dustan Wheatley (v) Bobby Prentice John Jarboe Dan Lindsey Fred Carr	Jared Guyer Mike Baldwin Patrick Marsh Lance Bosart Tom Galarneau Jack Settelmaier Barb Brown Dustan Wheatley (v) Bobby Prentice John Jarboe Dan Lindsey	Jared Guyer Mike Baldwin Patrick Marsh Lance Bosart Tom Galarneau Jack Settelmaier Barb Brown Bobby Prentice John Jarboe	Jared Guyer Mike Baldwin Patrick Marsh Lance Bosart Tom Galarneau Jack Settelemaier Barb Brown
Mon May 26	**Tue May 27**	**Wed May 28**	**Thu May 29**	**Fri May 30**
Holiday-No Operations	Jeremy Grams Brian Colle Kelly Lombardo Dave Novak Evan Kuchera Isadora Jankov Steve Koch Paul Janish Ryan Knutsvig	Jeremy Grams Brian Colle Kelly Lombardo Dave Novak Evan Kuchera Isadora Jankov Steve Koch Paul Janish Ryan Knutsvig	Jeremy Grams Brian Colle Kelly Lombardo Dave Novak Evan Kuchera Isadora Jankov Steve Koch Paul Janish Ryan Knutsvig	Jeremy Grams Brian Colle Kelly Lombardo Dave Novak Evan Kuchera Isadora Jankov Steve Koch Paul Janish Ryan Knutsvig
Mon Jun 2	**Tue Jun 3**	**Wed Jun 4**	**Thu Jun 5**	**Fri Jun 6**
Greg Dial Ryan Sobash Andrew Molthan Steve Mullen Chris Smallcomb John Brown Bob LaPlante Lacey Holland Rebecca Morse	Greg Dial Ryan Sobash Andrew Molthan Steve Mullen Chris Smallcomb John Brown Bob LaPlante Lacey Holland Rebecca Morse Chris Landsea Jun Du	Greg Dial Ryan Sobash Andrew Molthan Steve Mullen Chris Smallcomb John Brown Bob LaPlante Lacey Holland Rebecca Morse Chris Landsea Jun Du	Greg Dial Ryan Sobash Andrew Molthan Steve Mullen Chris Smallcomb John Brown Bob LaPlante Lacey Holland Chris Landsea Jun Du	Greg Dial Ryan Sobash Andrew Molthan Steve Mullen Chris Smallcomb John Brown Bob LaPlante Lacey Holland

EFP Spring Experiment 2008 Participants and Affiliations

Week of April 21 (Internal Spin-Up Week)
Steve Goss (NOAA/NWS/NCEP SPC)
Jack Kain (NOAA/OAR NSSL)
Mike Coniglio (NOAA/OAR NSSL)
Jason Levit (NOAA/NWS/NCEP SPC)
David Bright (NOAA/NWS/NCEP SPC)
Steven Weiss (NOAA/NWS/NCEP SPC)

Week of April 28
Corey Mead (NOAA/NWS/NCEP SPC)
Ernani Nascimento (Meteo-France, Toulouse)
Victor Homar (University of Balearic Islands, Spain)
Scott Overpeck (NOAA/NWS Houston TX)
Stephen Jascourt (COMET, Silver Spring MD)
Bill Bua (COMET, Boulder CO)
Peter Manousos (FirstEnergy Corp., Akron OH)
Andy Edman (NOAA/NWS/WRH, Salt Lake City UT)
Ken Cook (NOAA/NWS Wichita KS)
Don Burgess (CIMMS/NSSL)
Dave Stensrud (NOAA/OAR NSSL)

Week of May 5
Jeff Peters (NOAA/NWS/NCEP SPC)
Suzanne Van Cooten (NOAA/OAR NSSL)
Mike Vescio (NOAA/NWS Pendleton OR)
Mike Johnson (NOAA/NWS Amarillo TX)
Morris Weisman (NCAR, Boulder CO
Catherine Mavriplis (CIMMS/NSSL)
Kenneth Crawford (Oklahoma Climate Survey and University of Oklahoma, Norman)
John Huhn (Mitre Corp/FAA, McLean VA)
Kelly Mahoney (North Carolina State University, Raleigh)
Richard Johnson (Colorado State University, Fort Collins)
Ria Alsen (Environment Canada, Toronto)
David Schmidt (Environment Canada, Edmonton)

Week of May 12
Jon Racy (NOAA/NWS/NCEP SPC)
Craig Schwartz (University of Oklahoma, Norman)
Brad Zavodsky (NASA-NSSTC, Huntsville AL)
Nelson Seaman (Penn State University, State College)
Tom Hultquist (NOAA/NWS Chanhassen-Minneapolis MN)
Bruce Entwistle (NOAA/NWS/NCEP AWC, Kansas City)
Geoff Manikin (NOAA/NWS/NCEP EMC, Camp Springs MD)
Alan Coldwells (Environment Canada, Vancouver)
Bill Gallus (Iowa State University, Ames)
Scott Dembek (NASA-NSSTC Huntsville)

Week of May 19
Jared Guyer (NOAA/NWS/NCEP SPC)
Mike Baldwin Purdue University, West Lafayette IN)
Patrick Marsh (University of Oklahoma, Norman)
Lance Bosart (University at Albany-SUNY)
Tom Galarneau (University at Albany-SUNY)
Jack Settelmaier (NOAA/NWS/SRH, Fort Worth)
Barb Brown (NCAR, Boulder CO)
Dustan Wheatley (NOAA/OAR NSSL)
Bobby Prentice (FAA Training Academy, Oklahoma City)
John Jarboe (FAA Training Academy, Oklahoma City)
Dan Lindsey (CIRA/NESDIS, Fort Collins CO)
Fred Carr (University of Oklahoma, Norman)
Brad Colman (NOAA/NWS Seattle)

Week of May 27
Jeremy Grams (NOAA/NWS/NCEP SPC)
Brian Colle (University at Stony Brook-SUNY)
Kelly Lombardo (University at Stony Brook-SUNY)
Dave Novak (NOAA/NWS/ERH, Bohemia NY)
Evan Kuchera (AFWA Offutt AFB, Bellevue NE)
Isadora Jankov (NOAA/OAR/ESRL/GSD, Boulder CO)
Steve Koch (NOAA/OAR/ESRL/GSD, Boulder CO)
Paul Janish (Merrill-Lynch Global Commodities, Houston TX)
Ryan Knutsvig (NOAA/NWS Elko NV)

Week of June 2
Greg Dial (NOAA/NWS/NCEP SPC)
Ryan Sobash (University of Oklahoma, Norman)
Andrew Molthan (NASA-NSSTC and University of Alabama-Huntsville)
Steve Mullen (University of Arizona, Tucson)
Chris Smallcomb (NOAA/NWS Reno NV)
John Brown (NOAA/OAR/ESRL/GSD, Boulder CO)
Bob LaPlante (NOAA/NWS Cleveland OH)
Lacey Holland (NCAR Boulder CO
Rebecca Morse (NCAR Boulder CO)
Chris Landsea (NOAA/NWS/NCEP TPC, Miami)
Jun Du (NOAA/NWS/NCEP EMC, Camp Springs MD)

Appendix B: Instructions for Creating and Submitting Experimental Forecast Products

1. Forecast Graphics

The **severe weather forecast** graphics will be very similar to operational SPC outlooks, except only total severe storm probability contours will be formulated (no categorical outlook, and no general thunderstorms will be forecast). The same probability contours used in the operational outlooks will be used for the severe forecasts (5, 15, 30, 45, and 60 %); an area delineating potential for significant severe storms will be included when the probability for significant severe is 10% or greater. Probability-to-Categorical conversion for total severe is identical to that used for the SPC Day 2 Outlook, and is shown below in tabular form.

2. Saving the Forecasts in NMAP

a. The forecaster will draw/save probability contours in NMAP, and save the forecast in the same manner as for operational outlooks. The time period will be valid from 21-05z.

1) In the format outlook box, ***manually change valid time to 2100z until 0500z***
2) In the product save box, ***manually replace "outlook"with "west" or "east" (team name)***.

b. Enter command in xterm window: sp08bg STN team name # (such as sp08bg OKC east 2)

(**STN** is METAR centerpoint site ID**, team name** is "east" or "west", and **#** is NAWIPS workstation number**).** This archives the severe weather forecast, attaches date/time to the graphics file, and sends graphics to the web page.

3. Completing Model Discussion Section on Internal Web Page

a. Go to HWT Spring Experiment home page and click on Experiment Product Generation (East or West)
b. Click on "Copy Graphics and Begin Forecast"
c. Complete Discussion Text Box and when finalized, click on Submit.

Probability to Categorical Outlook Conversion

(SIGNIFICANT SEVERE area needed where denoted by hatching - otherwise default to next lower category)

Outlook Probability	Combined TORN, WIND, and HAIL
5%	SEE TEXT
15%	SLGT
30%	SLGT
45%	MDT
60%	HIGH

Appendix C: Practically Perfect Forecasts

(From Brooks, H. E., M. Kay, and J. A. Hart, 1998: Objective limits on forecasting skill of rare events. *Preprints*, 19th Conference on Severe Local Storms, Minneapolis, Minnesota, American Meteorological Society, 552-555.)

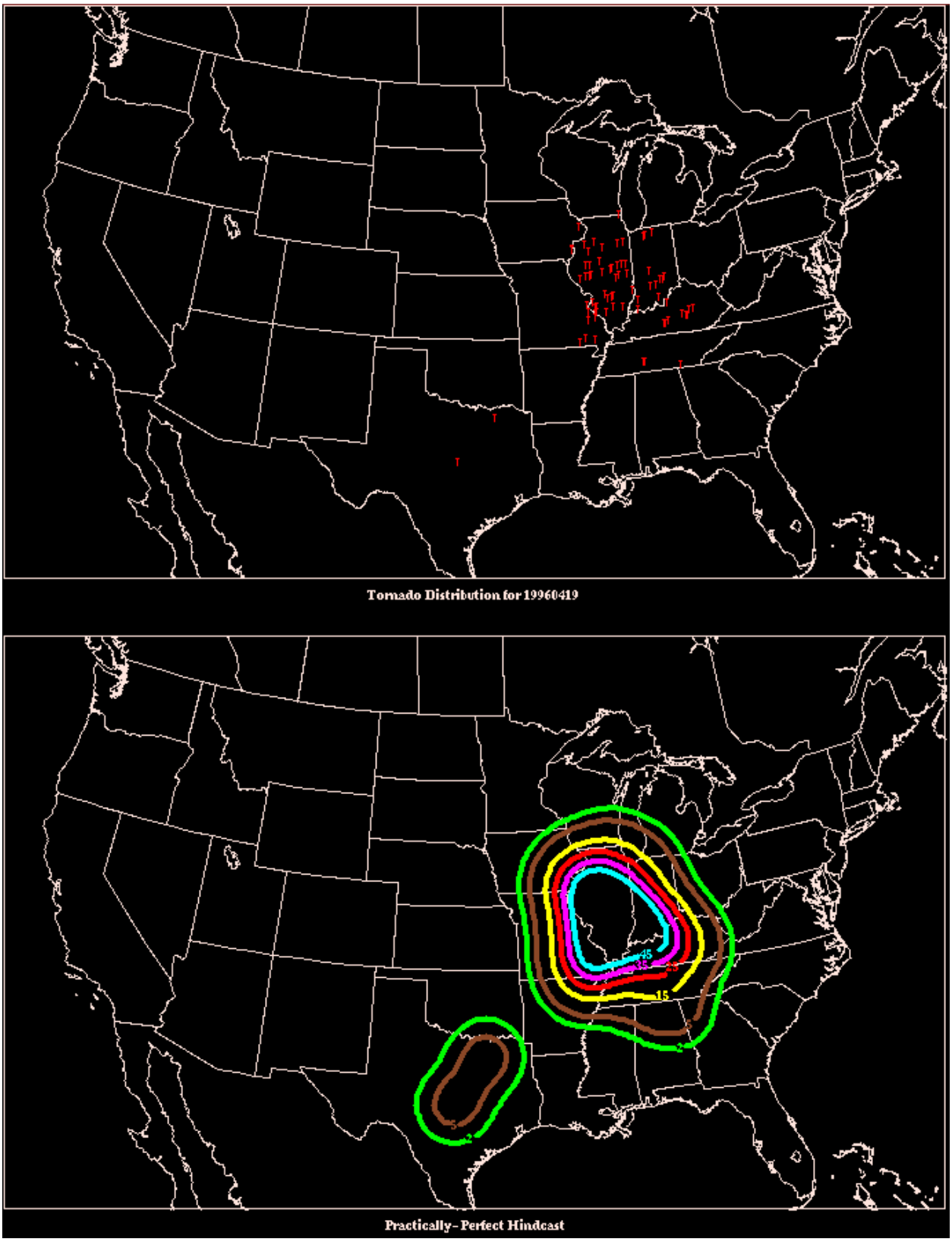
Severe weather forecasts such as SPC outlook and watch products are issued with the explicit expectation that there will be "false alarms" (parts of the forecast for which there are no events) and "missed detections" (events which are not included in the forecast). Thus, the expected range of values of the probability of detection (POD) or false alarm rate (FAR), for example, does not run from 0 to 1 in practice. The concept of a "practically" perfect (PP) forecast can then be used to estimate the minimum and maximum scores that a forecaster could reasonably be expected obtain given real world distributions of severe weather reports and the low predictability of specific severe convective storms in advance. In general, that range will be much smaller than the absolute minimum and maximum, but will provide a range over which meaningful forecast performance can be judged.

To compute the PP forecast, reports of severe weather are recorded on a grid with each grid box representing an area 40 x 40 km. All severe weather reports are considered equal and the computation considers only whether a box has had an event or not. The PP forecast is then created by smoothing the events using nonparametric density estimation with a two dimensional Gaussian kernel. Specifically, at each grid point in the domain, the PP forecast value, *f*, is given by

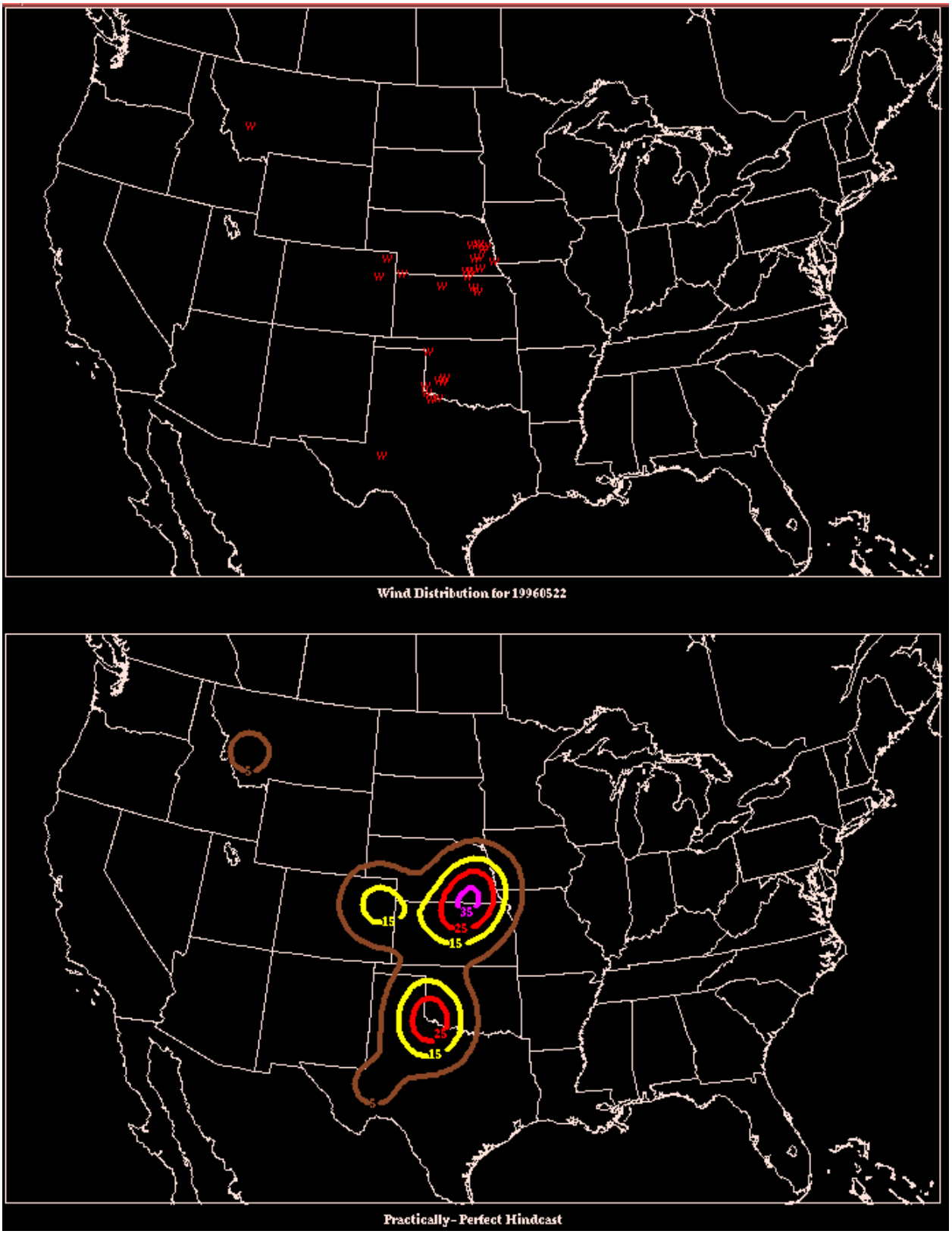
$$f = \sum_{n=1}^{N} \frac{1}{2\pi\sigma^2} \exp\left(-\frac{1}{2}\left[\frac{d_n}{\sigma} \right]^2 \right)$$

where *dn* is the distance from the forecast grid point to the *n*-th location that had an event occur, *N* is the total number of grid points with events, and σ is a weighting function that can be interpreted as the confidence one has in the location of the forecast event. Increasing σ is
is equivalent to increasing the uncertainty associated with the forecast as one would do with increasing lead time of the forecast. That is, in the context of severe weather forecasting, very small σ can be thought of as being associated with the warning stage, while larger σ is associated with the watch or convective outlook stages. For SPC forecasts a value of 3 used.

Examples of practically perfect forecasts based on actual severe weather reports are shown on the next two pages.



19 April 1996 tornado reports (top) and PP forecast (bottom) based on tornado reports



22 May 1996 wind damage reports (top) and PP forecast (bottom) based on the wind reports only

Appendix D: WRF Model Identification of Convective Storms with Rotating Updrafts – Computation of Updraft Helicity

1. Storm Relative Environmental Helicity

Helicity, H, is a scalar measure of the potential for helical flow (i.e., the pattern of a corkscrew) to develop in a moving fluid defined by

$$H = \vec{V} \bullet \nabla \times \vec{V} .$$

Expressed in its component form,

$$H = u(\frac{\partial w}{\partial y} - \frac{\partial v}{\partial z}) + v(\frac{\partial u}{\partial z} - \frac{\partial w}{\partial x}) + w(\frac{\partial v}{\partial x} - \frac{\partial u}{\partial y}) .$$

The portion of helicity associated with the *storm relative streamwise component* is that along the ambient horizontal velocity vector, or

$$H_s = -(u - c_u)(\frac{\partial v}{\partial z}) + (v - c_v)(\frac{\partial u}{\partial z}) ,$$

where is the storm motion and terms involving w neglected. Integrating H_s vertically through the thunderstorm inflow layer, z, yields the *storm relative environmental helicity*, SREH,

$$SREH = -\int_{z_o}^{z} [(u - c_u)(\frac{\partial v}{\partial z}) - (v - c_v)(\frac{\partial u}{\partial z})]dz .$$

SREH is a commonly used parameter to assess the severe thunderstorm potential of the environment and is often integrated from the surface to 1 - 3 km AGL. Order of magnitude values of SREH are ~ O(50) to O(300) m^2/s^2 in environments that tornadic storms.

2. Updraft Helicity

With the availability of numerical models containing sufficient resolution to resolve convective processes explicitly, it is now possible to calculate a *vertical component of helicity* associated with the convective updraft. This is the vertical integral of the third term in equation (2) and referred to as *updraft helicity*, U_H. Thus,

$$U_H = \int_{z_o}^{z} [w(\frac{\partial v}{\partial x} - \frac{\partial u}{\partial y})]dz = \int_{z_o}^{z} [w\zeta]dz$$

where is the vertical component of the relative vorticity at grid points where w > 0. In post processing the WRF members for the SPC/NSSL Spring Program, equation (5) is integrated vertically from z_o = 2 km to z = 5 km AGL using a midpoint approximation. Data are available every 1000 meters AGL, so equation (5) is computed as

$$U_H = \int_{z_o}^{z} [w\zeta]dz \approx \sum_{z=2000m}^{z=5000m} (\overline{w\zeta}\Delta Z) = (\overline{w\zeta}_{2,3} + \overline{w\zeta}_{3,4} + \overline{w\zeta}_{4,5}) \times 1000 \ ,$$

where the over bar indicates a layer average and the subscripts indicate the bottom and top of the layer in kilometers. Early experience indicates that typical values of U_H associated with WRF predicted supercell thunderstorms are have U_H of at least ~O (50) m^2/s^2 and that significant supercells have U_H ~O (150) m^2/s^2.