Collaboration between forecasters and research scientists at the NSSL and SPC

by

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ABSTRACT

Collaborative activities between operational forecasters and meteorological research scientists have the potential to provide significant benefits to both groups and to society as a whole, yet such collaboration is rare. An exception to this state of affairs is occurring at the National Severe Storms Laboratory (NSSL) and Storm Prediction Center (SPC). Since the SPC moved from Kansas City to the NSSL facility in Norman, OK in 1997, collaborative efforts between researchers and forecasters at this facility have begun to thrive. This article presents an historical background for this interaction and discusses some of the factors that have helped this collaboration gain momentum. It presents the 2001 Spring Program, a collaborative effort focusing on experimental forecasting techniques and numerical model evaluation, as a prototype for organized interactions between researchers and forecasters. In addition, the many tangible and intangible benefits of this unusual working relationship are discussed.

1. Introduction

Collaboration between operational weather forecasters and research meteorologists provides a unique opportunity to advance the science of meteorology by promoting better understanding and improved prediction of atmospheric processes, yet sustained collaborations between these two groups are relatively rare. Forecasters perform an in-depth analysis of atmospheric conditions nearly every day and they often observe processes or phenomena that are not well understood, yet are critically important to forecasting accurately weather that can threaten life and property. Many forecasters have a keen insight into the weather and an interest in doing applied atmospheric research, but often they are provided little in the way of appropriate guidance or mentoring, diagnostic tools, or time for independent research projects (Doswell 1986; Auciello and Lavoie 1993). On the other hand, many meteorological research scientists have at their disposal a vast array of diagnostic tools, numerical models, theoretical knowledge, and experience in formal research efforts. Yet, most meteorological research does not have direct implications for improving weather forecasts, despite the obvious societal benefits of applied research (Serafin et al. 2002). The failure of meteorological researchers and forecasters to collaborate on a consistent and widespread basis appears to be a serious impediment to solving many of the science's most accessible problems (Doswell et al. 1981).

One way to promote collaboration between the two groups is to make their physical environment and proximity conducive to interactions. In early 1997 the National Weather Service (NWS) moved the Storm Prediction Center (SPC) into the National Severe Storms Laboratory (NSSL) building in Norman, Oklahoma, combining the scientific staff of NSSL and the forecasting expertise of the SPC under one roof. Prior to the arrival of the SPC, a "Science Support Area" (SSA – see below) was established adjacent to the SPC operational forecasting area. This area was designed to mirror the operational forecasting environment without interfering in daily forecast operations, so that the operations could be simulated realistically. A small group of NSSL scientists with an interest in applied research problems was assigned to work with the SPC to pursue operationally relevant research and to facilitate interactions between the SPC and the larger NSSL scientific community. After the arrival of the SPC, a routine of daily interactive map discussions was initiated in the SSA, in part to provide a forum where the common interests and concerns of forecasters and researchers could draw the two groups together and cultivate collaborative research efforts.

The combination of this unique work environment and a favorable evolution of the "human element" (Doswell 1986; Howard et al. 1986) has fostered a productive interaction at the NSSL/SPC facility. Numerous collaborative research studies have been brought to fruition in recent years (e.g., Baldwin et al. 2002; Evans and Doswell 2001; Kain et al. 2000, 2002) and others are underway. Organized interactions on a larger scale have matured as well, and in recent years the cornerstone of the collaboration has become intensive multi-week research efforts conducted during the peak severe weather season each spring, known as the "Spring Program".

These programs are designed to combine objectives that are mutually beneficial to the participating operational and research organizations. For example, the 2001 Spring Program focused on detailed examination of experimental and operational numerical model output, use of this output to create experimental forecast products, and validation and verification of both the models and the forecast products, with the overriding goal of improving forecasts of thunderstorm initiation.

Conducting real-time research and forecast verification exercises requires a considerable commitment in planning, preparation, and execution from all organizations involved. These programs have received strong support from SPC, NSSL, and other participants because project goals are carefully designed to address mission-critical interests of all organizations represented, as well as the broader research and forecasting communities. Furthermore, support has been forthcoming because managers at SPC and NSSL recognize the numerous benefits to collaborative projects of this nature. For example, research scientists benefit from working closely with forecasters by developing an appreciation for operational constraints and the practical limitations of various research products. In turn, forecasters benefit by learning more about various research tools and products that are being tested for possible operational implementation. In short, *a major benefit of the program is that forecasters are empowered to address operational forecast challenges from a more scientific perspective while researchers become better equipped to develop research projects that have operational relevance*.

The purpose of this paper is to provide an overview of the growing collaborative research efforts at the SPC and NSSL, with an emphasis on the 2001 Spring Program. The next section outlines the brief history of operational/research interactions at the Oklahoma Weather Center, followed by descriptions of current facilities and the evolution of collaborative efforts that have been carried out in these facilities. A section on the 2001 Spring Program details our most involved effort to date. The paper concludes with a summary of the benefits of this unique collaboration.

2. Historical Perspective

Interest in collaboration between research scientists at NSSL and operational forecasters in the Norman, OK Weather Center dates back to the 1980s. During 1984-1985, forecasters and researchers collaborating at the Norman, OK National Weather Service Forecast Office (WFO) participated in data collection and forecasting for mesoscale convective systems (MCSs) during the PRE-STORM program (Preliminary Regional Experiment for STORM-Central, see Cunning 1986). The experience gained through a positive exchange of ideas, support of field operations, and real-time data collection in this experiment were paramount to the success of future collaborative programs (Doswell et al. 1986). In 1987, NSSL and the Norman, OK WFO participated in real-time operational testing and evaluation of Doppler radar during DOPLIGHT ›87 (Doswell and Flueck 1989). The fundamental success of this effort contributed to the nationwide implementation of the NEXRAD/WSR-88D radar network, a key component of the NWS Modernization. The NEXRAD program has resulted in a significant advancement in understanding storm structure, improvements in severe storm detection and increased lead-time on severe thunderstorm and tornado warnings for the public (Bieringer and Ray 1996). Other successful collaborative exercises during this time included the Mesoscale Applications Project (MAP) 1988-1989 (Jincai et al. 1992) and STORMTIPE (Brooks et al. 1993; Wicker et al.1997) which helped introduce forecasters to future applications and limitations of evolving high resolution mesoscale and storm scale numerical weather prediction models.

Inspired by the early success of these programs, plans were made for creation of a collaborative research and forecast facility in Norman known as the Experimental Forecast Facility (EFF, see Howard et al. 1986; Subcommittee on Atmospheric Research 1992; Auciello and Lavoie 1993). This facility, located adjacent to the forecast operations floor in the Norman, OK WFO, was supported/staffed by NSSL, Norman, OK WFO, and WSR-88D Radar Operations Center (ROC) [formerly known as the Operational Support Facility; OSF]. The first large scale program conducted in the Norman EFF was STORMFEST (Storm-scale Operational Research Meteorology Fronts Experiment Systems Test) in 1992. Activities in subsequent years focused on applications of new operational data sets, interrogation of numerical model guidance, and technology transfer from research into forecast operations (Janish et al. 1995).

During 1994 and 1995 SPC forecasters in Kansas City were invited to provide forecasting support for the Verification of the Origin of Rotation in Tornadoes Experiment (VORTEX -94/95) at the EFF and NSSL (Brooks et al. 1996). It was one of the first attempts to incorporate SPC mesoscale and severe storm forecasting experts into a real-time/multi-agency data collection and research program. SPC forecasters were able to explore new applications of data analysis and utility of experimental numerical model output in the forecast process while discussing the daily operational forecast challenges and limitations with leading scientific experts in an informal setting. While this interaction proved beneficial to both groups, SPC forecaster participation was limited to forecasting/nowcasting with little involvement in scientific study or post-analysis of data. In order to enhance scientific participation, collaboration, and technology transfer between SPC forecasters and researchers at NSSL, the University of Oklahoma, and the local Norman meteorological community, the NWS moved SPC operations from Kansas City to the NSSL building in Norman in early 1997.

3. The Science Support Area (SSA)

The SSA was included in the blueprints to integrate the SPC into the NSSL facility. This area was created to ensure that physical space, data flow, and equipment would be available to facilitate real-time applied research programs and stimulate collaboration between SPC forecasters, NSSL scientists, and other researchers and forecasters. NSSL embraced the concept of organized interactions by creating a Mesoscale Applications Group (MAG), staffed by a cross section of numerical modelers, observational specialists, and mesoscale meteorologists, all with an interest in operational issues. The goal of the MAG was to build on the collaborative experiences with the Norman, OK WFO in the 1980s and early 90s and create a synergistic relationship between local researchers and the SPC's mesoscale forecasting experts. The SSA provided MAG scientists with unprecedented access to real-time data, the insight of operational forecasters, and an environment conducive to testing, exploring, and developing operationally relevant applications of their scientific research.

The SSA (Fig. 1) was designed to be flexible for use in support of field research programs, testing of experimental products/techniques, and for conducting other collaborative research/testing efforts. Ample computer networking, telephone connections, and electrical power supplies (including generator back-up) were incorporated into the design of the SSA to ensure continuous accessibility of systems during real-time operations. The SSA contains workspace for up to 5 meteorologists during operations or 15-20 people participating in map discussion and/or program related briefings. The facility contains AWIPS (Advanced Weather Interactive Processing System) workstations and several unix/Linux workstations capable of running N-AWIPS (for National centers) similar to those used in SPC operations. In addition, these workstations have access to an alternate data flow intended to back-up SPC operations in the event of a systems failure. This enables the SSA to access the full operational data stream as well as experimental data for testing and evaluation. Other equipment includes internet connected PCs supporting Windows and Linux for text processing and additional workstation functionality, a flash-by-flash National Lightning Detection Network (NLDN) display, color and standard laser printers, four large monitors to facilitate map discussion and program briefings, and additional test equipment in support of other NSSL and SPC collaborative projects.

A key component to the success of Spring Program operations is the similarity in workstation design, data flow, and display capability to that of the SPC operations area. Local forecasters and researchers who participate in SSA activities are familiar with equipment; visitors are provided documentation and training in a timely manner thereby limiting technological hurdles so they can quickly focus on meteorological objectives. The SSA is the facility where Spring Program activities take place each year.

4. Establishing working partnerships in the SSA

One of the primary goals for programs conducted in the SSA is to develop working partnerships through collaboration on applied research. Agreement on mutually beneficial goals and objectives has been a fundamental component in the planning and operations of each program since VORTEX. Making this a priority has resulted in productive and professional interaction as well as mutual respect among participants, establishing a synergy and enthusiasm that has carried through the planning stages and subsequent execution of each program.

The first organized effort involving NSSL/MAG and SPC focused on winter weather (WIN-

WEX - WINter WEather EXperiment) in early 1996 and 1997. Participants from both agencies worked together to develop and test an experimental hazardous winter weather forecast product. The results of this effort were a more systematic and scientific approach in evaluating mesoscale conditions associated with hazardous winter weather and the creation of an ingredients based approach toward winter forecasting (Janish et al. 1996). The experimental forecast product was evaluated at select WFOs. They provided feedback that was instrumental in the development of an event-driven winter weather mesoscale discussion product that was incorporated into the SPC's operational product suite in 1997. This activity provided a catalyst for several other collaborative research projects focused on mesoscale aspects of winter weather in subsequent years (Kain et al. 2000; Cortinas 2000; Robbins and Cortinas 2002).

The focus shifted from winter weather to convective weather in 1998 as NSSL hosted the MCS Electrification and Polarimetric Radar Study (MEaPRS) field project from May 15 through June 15, 1998 (Jorgensen et al. 2000). The two primary objectives of MEaPRS were 1) to investigate MCS electrification processes, and 2) improve understanding of polarimetric radar measurands. All forecasting and nowcasting operations for MEaPRS were conducted in the SSA through collaboration with NSSL/MAG and SPC forecasters. The forecast team prepared probabilistic outlooks of MCS activity and forecast the position of the LLJ across the MEaPRS domain.

After a year with no organized program (1999), NSSL and SPC organizers sought to establish a more independent effort in 2000. In particular, it was decided to develop a program that could take on a life of its own, one that was motivated by the mutual scientific and strategic interests of participants rather than imposed by external interests, such as field programs or new forecasting responsibilities. The Spring Program 2000 was designed to evaluate operational and experimental numerical models as well as various diagnostic tools used in SPC operations, such as objective analysis routines and hail forecasting algorithms. Each component of the program had a "sponsor", a scientist or forecaster who developed and/or promoted one of the tools. Each sponsor played an active role in designing specific evaluation procedures to be followed during the program. This provided a sense of "ownership" and extra motivation for each contributor. In addition, numerical modelers from both the Environmental Modeling Center (EMC) and the Forecast Systems Laboratory (FSL) participated and provided input for the design of numerical model evaluation procedures.

During the 2000 Spring Program interactions between forecasters and numerical modelers were particularly satisfying. Forecasters who participated became more skillful at interpreting model output and modelers developed new insights into the ways that models are utilized at the SPC. External visitors provided very favorable feedback based on their experiences in the program. However, the tangible benefits were more difficult to grasp. Models and diagnostic tools were evaluated using web-based forms and most of the information collected was in "short-answer" format. This format maximized the information content for individual events, but made it very difficult to compile statistical data over the many cases of the 6-week program. Nonetheless, it became obvious to organizers the general framework of the program held significant potential. Organizers took careful inventory of the external feedback and internal assessments. They capitalized on the enthusiasm and momentum that carried over from 2000 and planned a more refined and focused program for 2001.

5. 2001 Spring Program

The primary goal of the 2001 Spring Program was to investigate whether operational and experimental mesoscale numerical weather prediction models could be used more effectively to enhance the accuracy of convective initiation and evolution predictions. It was hypothesized that more effective use of the numerical models would come from having modeling experts work side-by-side with forecasters to provide additional insight into model behavior and performance. There were certainly situations during the 2001 Spring Program in which one or more models provided very accurate predictions of convective initiation and evolution. The working goal was that if SPC forecasters could determine *in advance* when they could have more trust in model solutions, they could issue severe thunderstorm and tornado watches earlier and with more confidence. A primary objective of the 2001 Spring Program was to gather information to help identify those situations when numerical guidance is more reliable – and when it is likely to be less reliable. For the foreseeable future, it seems likely that SPC forecasters will rely more heavily on observations than numerical models for short-term convective forecasts, as they should. But improving their ability to interpret and utilize numerical model output can be very beneficial (Baldwin et al. 2002).

Two fundamental changes were introduced in 2001. First, experimental forecast products became a major part of the program activities. The forecasts provided a focal point and motivating factor for operational forecasters who participated, plus they provided the basis for tangible benefits to the SPC in their quest to optimize the lead-time for severe weather watches. Second, model evaluation forms were designed to emphasize quantitative information in a survey format rather than descriptive narratives (Kain et al. 2003). This allowed for efficient post-processing and tabulation of subjective verification statistics for numerous model parameters.

The 2001 Spring Program was conducted during an eight-week period, from 16 April through 8 June. Program activities are highlighted below. Additional details can be found at http://www.spc.noaa.gov/exper/Spring_2001/.

a. Personnel, equipment, and data

EMC and FSL renewed their commitment to the program in 2001, and the list of participating agencies expanded to include the Norman WFO and Iowa State University. A complete list of participants and affiliations is given in Appendix A. Full-time participants were required to spend an entire week (M-F) in the program. Previous experience with this type of program has convinced us that a weekly turnover of personnel is close to optimal for this type of experiment. Bringing in a new “team” at least once a week introduces diversity of experience, perspective, and sense of continuing enthusiasm to the program, all of which are essential. On the other hand, requiring team members to stay for no less than a full week is quite important for several reasons. It helps to ensure that participants will become comfortable and confident with their required tasks, limits the number of orientation and training sessions that organizers must conduct to a tolerable number, and promotes a sense of day-to-day continuity.

The primary criterion for staffing the experiment was to ensure that each working group would have expertise in forecasting *and* numerical model interpretation. Each shift had three full-time participants, including one SPC forecaster, a modeling expert from NSSL, EMC, or FSL, and a third forecaster or researcher with expertise in related areas. In addition, a number of scientists who were unable to commit an entire week to the program served as part-time "visitors" for shorter time periods. All out-of-town visitors were encouraged to incorporate their interests into the evaluation portion of the program and to present a seminar during their visit. This helped increase the sense of unique contribution for all participants.

Each full-time participant had access to a fully configured N-AWIPS workstation in the SSA, including the complete operational data stream that is available to operational SPC forecasters. This included high-resolution satellite and radar data, surface and upper air observations, operational NWP models from EMC, and various other types of data. In addition, output from several experimental forecast models (typically *not* available in routine operations) was accessible from these workstations.

A complete list of the models utilized during the program is summarized below. The operational Eta (Black 1994) output, the regional high resolution Eta Threats (now called HiRes Window; G. DiMego, personal communication), and the RUC-2 (Benjamin et al. 1999) forecast were available as part of the normal real-time data stream at the SPC. The EtaKF was a version of the Eta model configured at NSSL and run daily in parallel with the operational Eta (Kain et al. 2002). The RUC-20 was a "beta" version of the modified, higher resolution version of the RUC that evolved into the new operational RUC in the spring of 2002 (Benjamin et al. 2001). The EMC mesoscale ensemble was a 10-member ensemble composed of 5 members from the Eta and 5 from EMC's regional spectral model (Du and Tracton 2001). The NSSL ensemble was a multi-model ensemble created at NSSL by M. Baldwin by combining all available (operational and experimental) mesoscale models. The WRF run was from a beta version of the WRF model (Skamarock et al. 2001), integrated once per day at NSSL using 0000 UTC data. All model output was presented in a common format on N-AWIPS workstations, with the exception of the WRF forecasts, which were only available via the world-wide web.

MODEL	INITIALIZATION TIMES (UTC)	GRID SPACING (km)	
		NATIVE	OUTPUT
Eta	00,12	22	40
EtaKF*	00,12	22	20/40
Eta Threats run	12	10	10
RUC-2	12, 15, 18	40	40
RUC-20*	12, 15	20	20
EMC mesoscale ensemble	00	48	48
NSSL ensemble	00+12	Various	40
WRF*	00	34	34

* indicates experimental models

A Spring Program data archive was produced daily to assist in model verification and post event analysis. The web-based “event pages” were created in a calendar format and were linked from the main Spring Program website at URL http://www.spc.noaa.gov/exper/Spring_2001. Through the event web pages, experiment participants could access surface and upper air analyses, radar, lightning, and storm report loops from the previous day, as well as selected model-output loops. This data remains online for continued study.

b. Daily schedule

Complete daily operations were conducted from 8 a.m. to 4 p.m. (1300-2100 UTC) Monday through Thursday, according to the following schedule:

TIME (UTC)	ACTIVITY
1300 – 1500	Perform verification of both forecast and model output from previous day.

1500 – 1630 Analyze model data and available observations in preparation for first experimental forecast.

1630 – 1700 Prepare first experimental forecast and begin first formal model evaluation

1700 – 1800 Issue first forecast (1700 UTC), finish first model evaluation, and prepare to lead daily NSSL/SPC map discussion.

1800 – 1830 Lead daily map discussion

1830 – 1930 Analyze model data and available observations in preparation for second experimental forecast.

1930 – 2000 Prepare second experimental forecast and begin second formal model evaluation.

2000 – 2100 Issue second forecast (2000 UTC), finish second model evaluation.

On Mondays, the verification time slot (1300 – 1500 UTC) was used for orientation and training. After verification activities were completed on Fridays the remainder of the day was reserved for NSSL/SPC seminars by visiting scientists (six participants provided scientific seminars for the Norman meteorological community) and weekly wrap-up activities. The latter focused on soliciting feedback from participants and summarizing relevant meteorological events and observations from that week.

c. Forecast product

The forecast product was designed to assess forecaster skill in issuing short-term convective forecasts (initiation of severe and non-severe convection) with up to a 4 hour lead time. It consisted of two graphical displays and a written discussion explaining the rationale of the forecast (*e.g.*, Fig. 2). The forecast domain was limited to an area approximately 10 x 10 degree latitude/longitude so that forecasters would have sufficient time to examine multiple sets of NWP guidance. Domain placement was guided primarily by the 1300 UTC SPC Day 1 Convective Outlook and consultation with the day shift SPC operational lead forecaster. Since our primary interest was on the timing and location of the initiation of new convection and severe storms, rather than the continuation of existing convection, these considerations also affected the choice of forecast domain.

Experimental forecasts were issued twice daily and each were valid for a 3-h period:

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

Within the prescribed domain, separate forecasts of "confidence" were made for the occurrence of: 1) thunderstorms, and 2) severe thunderstorms. The forecast team had a choice of up to three contours (Low, Medium, High), representing discrete levels of forecaster confidence of convective initiation and development of severe convection during each three-hour period. For severe convection, this level of confidence is a key part of the convective watch decision-making process. Although other factors (both meteorological and non-meteorological) also influence whether or not a watch is issued, detailed evaluation of these experimental products is expected to play an important role in identifying situations when watches can successfully be issued with extended lead times.

An example of a forecast product is shown in Fig. 2. In this forecast, issued 2000 UTC on 10 May 2001 forecasters, had "medium" confidence that thunderstorms would develop over a large area from southeastern Minnesota into southern Wisconsin and northern Illinois, then southwestward across all but the northwest corner of Iowa and into southeastern Nebraska and northern Missouri. Within this area, they expressed high confidence that development would occur over the southeastern half of Iowa. Furthermore, they expressed high confidence that convection would be severe over south-central and southeastern Iowa. The discussion portion of this forecast provides a broad synoptic overview, then a more detailed description of specific concerns. Note also that specific information relevant to the SPC watch program is given on timing, character, and probability of activity. In addition to this information, a separate web-based form (not shown) was used to compile a brief overview of the broad-scale flow regime and to quantify the magnitude of dynamic forcing, CAPE (Convective Available Convective Energy), and 0-6 km wind shear over the area of interest.

d. Model evaluation

While the SPC forecaster prepared the experimental forecast product, other members of the team began a formal *evaluation* of the models that were utilized in the formulation of the forecast. For each model, information was gathered in survey format relative to 1) forecaster impressions of how favorable individual model solutions were for development of severe weather, 2) forecaster confidence in various model solutions, and 3) forecaster impressions of the overall utility of individual models. Details of the model evaluation can be found in Kain et al. (2003).

e. Forecast verification

Experimental forecasts for the prediction of general (without regard to severity) thunderstorms were verified by comparison with NLDN cloud-to-ground lightning data, while the occurrence of severe convection was verified by local storm reports (LSRs). In addition, radar and satellite data were used to corroborate the NLDN and LSR data and to provide additional information on timing and the specific character of convective activity. Separate measures of forecast error were computed for 1) timing, 2) areal coverage, and 3) displacement based on comparisons with the available verifying data. A graphic display of LSRs corresponding to the 10 May severe thunderstorm forecast discussed above is show in Fig. 3. The experimental forecast was quite good on this day. Almost all of the LSRs were contained within the "medium confidence" area and most came from within the "high confidence" region. Areal coverage corresponded well with the area of highest confidence, although the center of activity was displaced slightly to the north. A complete summary of forecast evaluation statistics is currently being compiled.

f. Model verification

The forecast team that performed a subjective *evaluation* of model output at the time of forecast preparation was responsible for a subjective *verification* of the previous day's model output the next morning. These verification data were later used not only to gage the relative performance of the models, but also to compare with the previous day's model evaluation statistics. The latter comparison provided insight into forecaster decisions and was used to evaluate whether forecasters had skill in favoring or rejecting one model over another. A detailed discussion of the model evaluation and verification component of the program can be found in Kain et al. (2003).

g. Future programs

The 2001 Spring program was our most successful program to date. We intend to maintain the momentum gathered in the years leading up to 2001 by hosting organized collaborative programs nearly every year. During some years, the program will be held in conjunction with larger projects, such as observational field programs. When this happens, the objectives of the Spring Program will be dictated to some extent by the goals of the larger program. For example, in 2002, the Spring Program was conducted in collaboration with IHOP (International H_2O Project, see http://www.atd.ucar.edu/dir_off/projects/2002/IHOP.html). Consequently, a significant amount of effort was devoted to providing forecasting support for IHOP field operations. Nonetheless, Spring Program organizers still managed to incorporate a subjective verification component for both numerical guidance and experimental IHOP forecasts in their daily routine in 2002. It is anticipated that *internal* research objectives will normally have to be scaled back when future Spring Programs are entrained into larger external programs, but they can be expanded in other years when local applied research activities take precedence.

6. Summary and Concluding Remarks

Collaboration between operational forecasters and research scientists has the potential to stimulate significant advances in weather forecasting and applied meteorological research. Yet, sustained collaborations between these two groups are quite rare. In order to promote collaborative efforts between forecasters at the SPC and like-minded research scientists at the NSSL, the NWS relocated the SPC (formerly the Severe Local Storms unit of the National Severe Storms Forecast Center) from Kansas City to Norman in the mid 1990s (McPherson 1994). The NSSL created space in its building for the SPC, and complete forecast operations were officially transferred to Norman in early 1997.

Since that time, collaborative research between the SPC and the MAG of NSSL has begun to thrive. Significantly, an important component of the NSSL/SPC interaction has occurred at a grassroots level. During the first couple of years after the transfer, forecasters and research scientist from the two organizations developed a comfortable working relationship through casual interactions, daily map discussions, and a mutual interest in the weather. Additional interactions came from sharing responsibilities during organized, externally driven programs. These interactions catalyzed a number of smaller research efforts.

Beginning in 2000, the SPC and NSSL/MAG took an important step by designing a collaborative multi-week experiment driven by *internal* research objectives. This was the first experiment that was officially called the SPC/NSSL "Spring Program". This program, involving NSSL and SPC as well as EMC and FSL, was very successful and inspired a more refined and focused Spring Program in 2001, with additional participation from the Norman WFO and Iowa State University. The 2001 Spring Program is highlighted herein.

Enthusiastic support for the 2001 Spring Program was inspired by several factors. Fundamentally, it was the complementary objectives of the forecasting and research elements that cultivated mutual interest in the program. The primary goal of the forecasting element was to investigate whether forecasters, working in conjunction with numerical modeling experts, could extract enough information from operational and experimental NWP models to predict convective initiation earlier than current approaches allow. If successful, the methods used in this study could enable SPC forecasters to identify situations when they could issue convective watches with increased lead-time. The research objectives were to develop a better understanding of how forecasters use NWP model output and to gather subjective impressions of model forecasts for comparison with current objective verification metrics. These objectives overlapped to a large degree and allowed the mission-critical goals of both operational and research interests to be addressed effectively in a relatively short period of time.

Several tangible benefits have been generated as a direct result of the 2001 Spring Program. Examination and interrogation of model-forecast soundings from the Eta model allowed us to document common irregularities in sounding structure associated with the model's convective parameterization scheme. This documentation was recently compiled in a paper designed to provide forecasters with guidance in interpreting Eta-model soundings (Baldwin et al. 2002). Parameterized updraft mass flux, a unique predictor of convective intensity from the Kain-Fritsch convective scheme (KF - Kain and Fritsch 1993), earned the confidence of forecasters during the program. This output parameter is described in Kain et al. (2002). Subjective evaluations and verifications of model forecasts from the program have been summarized and compared to objective verification measures. Summary statistics for precipitation fields are provided in Kain et al. (2003). In addition, sounding analysis programs in SPC operations have recently been modified to include diagnostic versions of the Betts-Miller-Janjic (Janjic 1994) and Kain-Fritsch (Kain and Fritsch 1993) convective parameterizations. This software infusion came about because significant differences between Eta and EtaKF model soundings have been documented during Spring Programs and daily map discussions. SPC forecasters rely quite heavily on model forecast soundings in assessing the potential for convective initiation and intensity. The diagnostic versions of the schemes have proven to be very helpful in facilitating educated interpretations of model soundings and the behavior of the two convective schemes.

The Spring Program has also produced many intangible benefits, which are more difficult to measure. Model developers have worked side by side with the end users of their product – operational forecasters. They have gained valuable insight into how their products are being used and how they might be improved to meet the needs of forecasters more effectively. At the same time, forecasters have been given a rare opportunity to discuss various applications and interpretations of NWP models with model developers in the context of a simulated operational forecasting environment. Thus, participating forecasters have became more confident and educated users of one of their primary guidance tools. Perhaps most importantly, the organizational environment of the program has promoted solid working relationships between the operational and research communities. These relationships will form the foundation for expanding collaborative efforts in coming years.

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Appendix

List of participants for Spring Program 2001 by Affiliation:
(v) - Visiting Scientist

SPC:	Paul Janish
	Steve Weiss
	Jeff Evans
	Greg Carbin
	Steve Corfidi
	Jeff Peters
	Dan McCarthy
	Bob Johns
	John Hart
	Russ Schneider (v)
	Dave Imy (v)
NSSL:	Jack Kain
	Mike Baldwin
	Harold Brooks
	Don Burgess
	Matt Wandishin
	Kim Elmore
	Lou Wicker (v)
	Dave Stensrud (v)
NCEP/EMC:	Geoff Manikin
	Tom Black (v)

FSL: Stan Benjamin (v)
Tracy Smith
Steve Weygandt
Barry Schwartz
John Brown (via telephone)

WFO/OUN: Mike Foster (v)
Kevin Brown
Doug Speheger
Dave Floyd

ISU: Bill Gallus

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Figure Captions

Fig. 1. A scene from the 2001 Spring Program in the SSA. Pictured from left to right are Don Burgess (NSSL), Lou Wicker (NSSL), Greg Carbin (partially hidden - SPC), Paul Janish (SPC), and Mike Foster (Norman WFO). Note that the SPC forecasting area can be seen through the doorway.

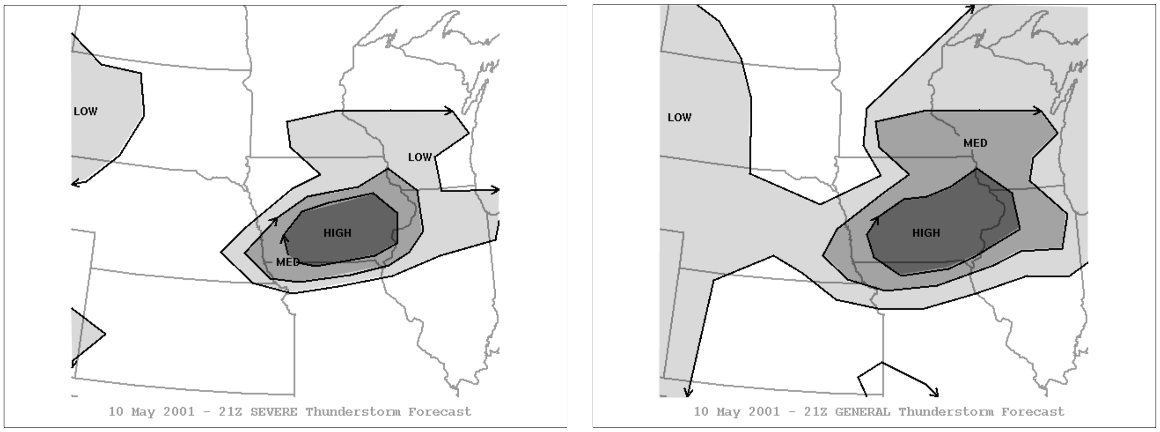
Fig. 2. Experimental forecast product from the 2001 Spring Program, issued 2000 UTC 10 May 2001, valid for the time period 2100 UTC - 0000 UTC 11 May.

Fig. 3. Verification data for the experimental forecast shown in Fig. 2. Severe weather reports are marked on the map according to $\mathrm{hail} \geq 0.75$ in. diameter (**a**), $\mathrm{windgusts} \geq 58$ mph (**g**), or tornado (**t**)

Fig. 1. A scene from the 2001 Spring Program in the SSA. Pictured from left to right are Don Burgess (NSSL), Lou Wicker (NSSL), Greg Carbin (partially hidden - SPC), Paul Janish (SPC), and Mike Foster (Norman WFO). Note that the SPC forecasting area can be seen through the doorway.

SPC/NSSL Experimental Forecast for 20010510 Valid 2100-0000 UTC

Severe Thunderstorm Forecast **General Thunderstorm Forecast**



Forecast Issue Date: 20010510
Forecast Period: 2100-0000 UTC
Forecast Team: Corfidi/Gallus/Smith
Visiting Scientist(s): STENSRUD

Forecast Area: WESTERN PLAINS THROUGH THE WESTERN GREAT LAKES

..Synopsis..

A COLD FRONT ASSOCIATED WITH A LOW AMPLITUDE DISTURBANCE IN FAST ZONAL FLOW ACROSS THE NRN TIER OF STATES WILL CONTINUE TO MOVE SLOWLY ESE ACROSS THE LWR MO/MID MS VLYS THIS PERIOD. THUNDERSTORMS NOW FORMING ON THIS BOUNDARY...AND ON A WEAK OUTFLOW BOUNDARY ASSOCIATED WITH AN EARLIER CLUSTER OF CONVECTION...EXPECTED TO INCREASE IN COVERAGE AND INTENSITY DURING THE NEXT SEVERAL HOURS. INCREASING DEEP LAYER SHEAR ASSOCIATED WITH THE APPROACHING UPPER IMPULSE, COUPLED WITH CONTINUED SURFACE HEATING AND BOUNDARY LAYER MOISTURE INFLUX, SUGGEST GOOD LIKELIHOOD FOR A FEW SUPERCELLS WITH LARGE HAIL AND PERHAPS SMALL SCALE BOWS.

..Discussion..

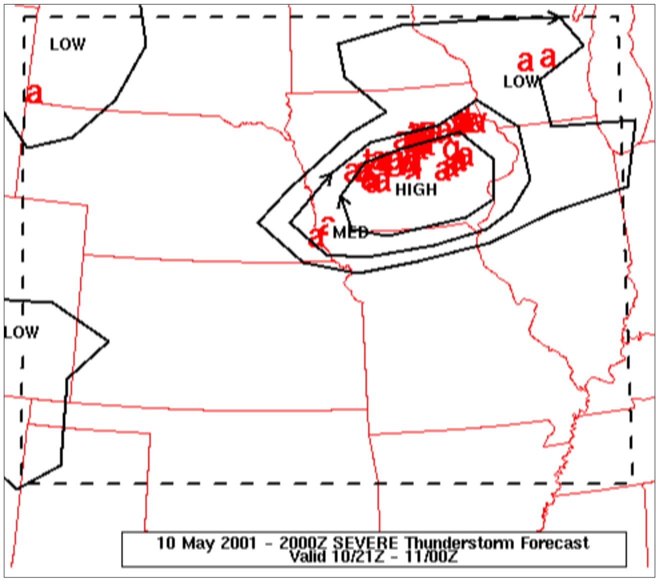
N/S BAND OF THUNDERSTORMS DEVELOPING ATTM OVER CNTRL IA APPEARS TO BE ASSOCIATED WITH WEAK WARM ADVECTION ON THE BACK SIDE OF RETREATING COOL POOL ASSOCIATED WITH DISSIPATED OVERNIGHT MCS. THESE STORMS APPEAR TO BE SLIGHTLY ELEVATED PER RADAR AND VISIBLE SATELLITE DATA. OTHER SHOWERS/WEAK THUNDERSTORMS HAVE DEVELOPED IN THE PAST 90 MINUTES ALONG E/W OUTFLOW BOUNDARY ASSOCIATED WITH MID MORNING CONVECTIVE CLUSTER IN THE NORTH CENTRAL PART OF THE STATE.

THE LOWER TROPOSPHERIC FLOW HAS VEERED TO WEST SOUTHWESTERLY ACROSS MOST OF IA IN THE PAST 2-3 HOURS. THIS APPEARS TO BE AT LEAST PARTIALLY RESPONSIBLE FOR THE DEVELOPMENT OF THE N/S CONVECTIVE BAND NEAR DSM. THE VEERING HAS, HOWEVER, LIMITED THE DEGREE OF LOW LEVEL CONVERGENCE ALONG THE COLD FRONT IN EASTERN NEBRASKA AND FAR WESTERN IA. POSSIBLY AS A RESULT, THE BOUNDARY LAYER CU/SC FIELD OVER THIS REGION APPEARS TO STILL BE RATHER STRONGLY CAPPED. COMBINATION OF CONTINUED SURFACE HEATING, BOUNDARY LAYER MOISTURE INFLUX, FRONTAL/ OUTFLOW BOUNDARY ASCENT AND INCREASING UPPER DIVERGENCE ASSOCIATED WITH APPROACHING TROUGH EXPECTED TO RESULT IN INCREASED CONVECTIVE COVERAGE AND INTENSITY OVER TARGET AREA IN THE NEXT HOUR. LARGELY UNIDIRECTIONAL DEEP LAYER WESTERLY SHEAR /ON THER ORDER OF 50 KTS/ ROUGHLY PARALLEL TO COLD FRONT/OUTFLOW BOUNDARY SUGGESTS POTENTIAL FOR A FEW EMBEDDED SUPERCELLS WITHIN DEVELOPING MCS. THE MAIN SEVERE THREATS SHOULD BE LARGE HAIL AND LOCALLY DAMAGING WINDS.

ELSEWHERE,
MORE ISOLATED WIND/HAIL POTENTIAL MAY EXTEND EWD INTO ENVIRONMENT OF MODERATE WLY SHEAR AND INSTABLITY ACROSS WI/NRN IL. OTHER LOCALLY SEVERE STORMS MAY DEVELOP IN "INVERTED-VEE" ENVIRONMENT OVER THE SOUTHERN HIGH PLAINS, AND IN REGION OF STRONG /40-50 KT/ DEEP LAYER SHEAR, BUT LIMITED INSTABLITY/CONVERGENCE OVER SOUTHEAST MT/NORTHEAST WY/WRN SD.

Expected Hour of First Report: 2100 UTC
Expected Primary Report Type: HAIL
Probability of Convection Within Forecast Area: 99
Probability of Severe Convection Within Forecast Area: 90
Possible Watch Type: SEVERE THUNDERSTORM

Fig. 2. Experimental forecast product from the 2001 Spring Program, issued 2000 UTC 10 May 2001, valid for the time period 2100 UTC - 0000 UTC 11 May.



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