2009 Community Review of the

NCEP Storm Prediction Center

Carried out by the

University Corporation for Atmospheric Research

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Executive Summary

The University Corporation for Atmospheric Research (UCAR) was requested in November 2008 by the National Centers for Environmental Prediction (NCEP) to facilitate a thorough and thoughtful community review of the nine centers that comprise NCEP, as well as the NCEP Office of the Director. This report summarizes the review of the Storm Prediction Center (SPC) and was conducted by the panel that also reviewed the Aviation Weather Center (AWC).

The SPC is an effective Center with balanced operational and research transition activities. SPC staff members are motivated and energetic with respect to both their defined operational duties and the Center's culture of science awareness and exploitation. SPC's co-location with the Norman Weather Service Forecast Office, National Severe Storms Laboratory, and University of Oklahoma academic and research organizations is clearly a key factor in establishing this dual identity. The Hazardous Weather Test Bed Spring Experiment, in which forecasters from around the world gather at SPC to exercise state-of-the-art models in an operational environment, epitomizes the center's commitment to advancing severe weather forecasting capabilities.

To maximize its success going forward, SPC should do the following:

- Seek sufficient levels of staffing for product development and creation and identify alternative strategies for meeting needs if additional resources are not forthcoming. Paths that could be pursued for the latter include greater automation of forecast responsibilities, obtained for example through collaboration with outside researchers; greater collaboration with other NCEP centers to share responsibility for generating certain products; and clarification, both internally and externally, that the frequency of certain products will be reduced in a manner consistent with staffing levels.

- Leverage SPC capability with other organizations, particularly the Environmental Modeling Center (EMC), Tropical Prediction Center(TPC)and the Hydrometeorological Prediction Center (HPC), and coordinate more effectivelywith the National Weather Service(NWS) Forecast Offices. For example, it is clear that SPC resources and culture could be more strongly leveraged to help AWC meet aviation weather needs, particularly with regard to the evolving Aviation Weather Test Bed.

- Continue working with the social sciences research community to better understand how severe weather information can best be packaged and communicated, and the response to it understood and thus managed. It is no longer appropriate for meteorologists alone to address these issues, particularly with the advent of instant communication via mechanisms such as social networking. SPC could play a leadership role in this arena among all NCEP centers.

1. Introduction

1.1. Purpose: Context and Summary of Charge

The University Corporation for Atmospheric Research (UCAR) was requested in November 2008 by the National Centers for Environmental Prediction (NCEP) to facilitate a thorough and thoughtful community review of the nine centers that comprise NCEP, as well as the NCEP Office of the Director. NCEP is organized under the National Weather Service (NWS) of the National Oceanic and Atmospheric Administration (NOAA). The nine Centers include:

- Aviation Weather Center (AWC; Kansas City, MO)
- Climate Prediction Center (CPC; Camp Springs, MD)
- Environmental Modeling Center (EMC; Camp Springs, MD)
- Hydrometeorological Prediction Center (HPC; Camp Springs, MD)
- NCEP Central Operations (NCO; Camp Springs, MD)
- Ocean Prediction Center (OPC; Camp Springs, MD)
- Space Weather Prediction Center (SWPC; Boulder, CO)
- Storm Prediction Center (SPC; Norman, OK)
- Tropical Prediction Center (TPC; Miami, FL)

This report concerns the Storm Prediction Center (SPC) and was conducted by the panel that also reviewed the Aviation Weather Center (AWC). The last UCAR review of SPC was held in 1999.

The 2009 review of NCEP was undertaken because the centers of NCEP are viewed collectively as a critical national resource that delivers national and global weather, water, climate and space weather guidance, forecasts, warnings and analyses to its partners and external user communities. These products and services respond to user needs to protect life and property, enhance the Nation's economy and support the Nation's growing need for environmental information. As the centerpiece of the National Weather Service's science-based forecast enterprise, NCEP serves as the focal point for weather, climate and space weather modeling, analysis and dissemination of forecast products and services. As such, it is essential that NCEP be held to a set of high standards that define the quality, quantity, timeliness, impact and improvement over time of its products and services. An independent, external evaluation of the effectiveness with which NCEP is accomplishing its mission and realizing its vision was deemed necessary.

It has been over a decade since most centers have been assessed, as external reviews of each center occurred independently most recently during the period 1996 – 2001. In particular, the complementary roles and interactions among the Centers were not comprehensively reviewed. The goal of the current review is to evaluate the entire range of NCEP activities, with particular emphasis on the way in which the various Centers interact with each other, and in some cases rely upon each other, and with other NOAA, federal, academic and non-governmental entities.

This is a particularly appropriate time to conduct such a review insofar as many national and international challenges have arisen that require NCEP to operate at the highest possible level of

scientific and technological excellence. Examples of challenges facing the Nation for which NCEP's products and services are essential include the following:

- The growing threat of hazardous weather reached a new and staggeringly high level of severity in the 2005 hurricane season during which 28 named storms threatened the U.S. Atlantic and Gulf of Mexico coastlines, including Hurricane Katrina that caused massive damage and loss of life in New Orleans and along the Gulf coast.

- The 2007 Intergovernmental Panel on Climate Change released its fourth assessment report, stating unequivocally that the Earth's climate is changing at an unprecedented rate as a result, in part, of human activities. This recognition, along with the growing predictive understanding of the influence of El Niño and the Southern Oscillation, and a host of other climate factors and conditions, on climate-sensitive sectors of the U.S. population and economy, has led NOAA to begin planning for a suite of National Climate Services.

- Adverse weather continues to strongly affect the aviation industry, and the NWS' pledge of support to satisfy the weather requirements of the Federal Aviation Administration's (FAA's) new Next Generation Air Transportation System (NextGen) will place increased demands on NCEP services.

- Solar activity, in the form of flares and coronal mass ejections, has a profound influence on the Earth's atmosphere (causing beautiful auroral displays) and can project fluxes of high energy particles that can disrupt communications, navigation, satellites, electric power grids, and human space flight. Solar activity has an approximately 11-year cycle and has been at a minimum for the past few years, and is expected to rise to its next maximum in 2013. Given the increasing dependence of the U.S. and world economies on aviation, telecommunications, and the Global Positioning System (GPS), the coming Solar Maximum has the potential to be highly disruptive.

Because the threat to life and property from weather, climate and space weather anomalies has never been higher and continues to rise, the products and services of NCEP must be of the highest quality, timeliness and impact.

In order to provide a review that could be most useful to NCEP, the UCAR review was organized into five panels, each of which was asked to review two NCEP centers both individually and as a complementary pair. The five panels were asked to review:

- AWC and SPC
- CPC and HPC
- EMC and NCO
- OPC and TPC
- SWPC

In each case, the pair of centers was chosen specifically because the two centers in each pair are expected to work more closely together, having affinities of mission and/or stakeholder communities.

Each panel was asked to review the centers' vision and mission to determine its relevance, appropriateness and alignment with NCEP's strategic plan. The review also assessed the productivity and quality of the scientific activities, and the quality, relevance and impact of operational products and services. Special emphasis was placed on the ability to gauge and meet customer demand and emerging requirements, the effectiveness of activities intended to support technology transfer based on research conducted either within or outside NOAA, and the effectiveness of collaboration with the academic research community or the private sector. The review evaluated the balance between operations and research and development and assessed the plans for evolving the suite of products and services. Finally, as indicated above, the interactions of each center with its "sister" center (except SWPC) and the outside community were evaluated. The full charge to the review panels is provided in Appendix A.

1.2 Procedure

The review panel conducted its site visit to SPC on 3-4 August 2009. To prepare for the visit, a set of questions was provided to SPC leadership. In return, a comprehensive binder of material was provided to the review panel. This included responses to the panel's questions; SPC overview documents;and information on customers, products, and services, transition of research to operations, performance measures, budgets, and strategic planning. A web-based surveyalso was distributed to a variety of stakeholders.

At the site visit, SPC Director Joseph Schaefer presented highlights of the center, including successes and challenges. Other presentations were given on topics including the Forecast Program, Products and Services, Outreach, and the Science Program. Considerable time was spent conducting interviews with staff on topics including administration, information technology and facilities, forecasting, science/research, and outreach/engagement. Additionally, a lunch was held during the first day of the visit during which leaders of other local NOAA organizations discussed their organization's interactions with SPC. A tour was provided of operations and the Hazardous Weather Test Bed (HWT), and the visit concluded with a briefing of initial findings and recommendations to SPCleadership and NCEP Director, Dr. Louis Uccellini.

2. Overview of the Storm Prediction Center

2.1 Mission and Vision

The SPC is part of the National Weather Service (NWS) and one of seven NCEP service centers. According to the SPC Five-Year Implementation and Operations Plan (2009-2013) draft document dated 20 August 2008, the mission of SPC is as follows:

> *The Storm Prediction Center exists solely to protect life and property of the American people through the issuance of timely and accurate watch and forecast*

products dealing with tornadoes, wildfires and other hazardous mesoscale weather phenomena.

Likewise from the same document, the vision of SPC is as follows:

A team of world-class Applied Meteorologists, Computer Scientists, and Administrative Professionals that works to protect the American people from hazardous weather. This is accomplished by the use of state-of-the-art science and technology to issue timely and accurate watch and forecast products for high-impact mesoscale weather including tornadoes, severe thunderstorms, wildfires, hazardous winter weather, and excessive rainfall.

SPC uses a broadsuite of productsand services to develop and disseminate forecasts of organized severe weather, and conditions favorable for wildfires, as much as eight days ahead of time, and continually refines the forecast until the event has concluded. All products issued by SPC are available on the Internet and are commonly used by local NWS Forecast Offices (WFOs), emergency managers, TV and radio meteorologists, private weather forecasting companies, commercial, general and private aviation, storm spotters, agriculture interests, educational institutions and many other groups.

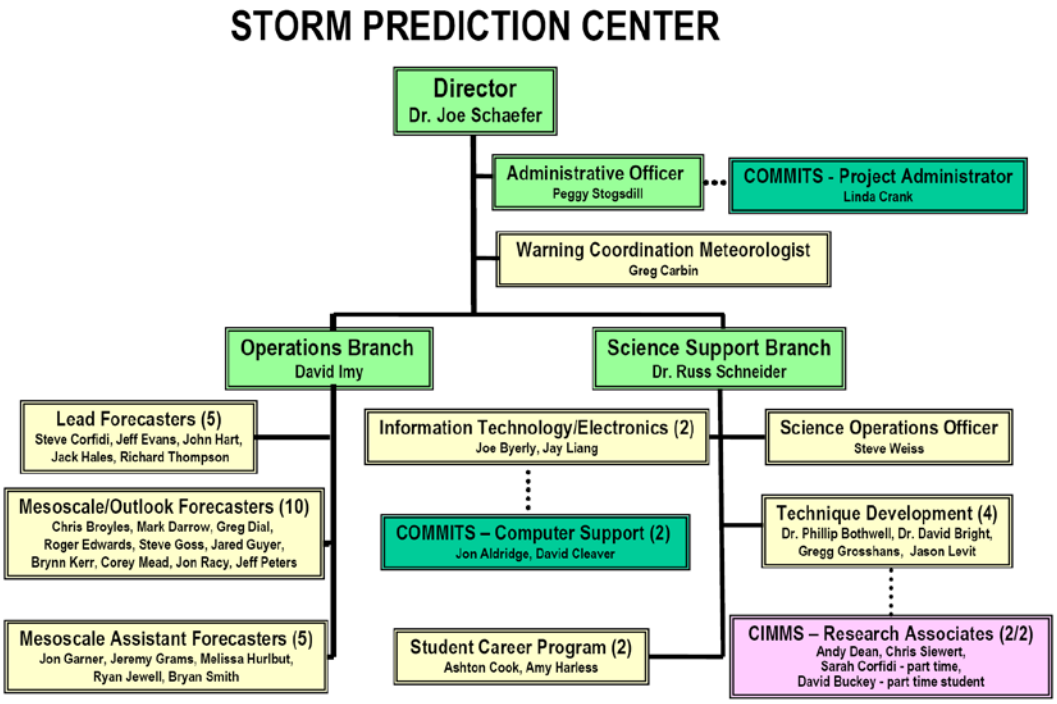
SPC's specialized mission requires meteorologists with a high level of expertise in convective storm and heavy precipitation forecasting, as well as winter weather and conditions leading to high fire danger. SPC staffmembers also are active in scientific researchin severe and dangerous weather, and all SPC forecasters have at least a Bachelor of Science degree in atmospheric science. More than 25% have done graduate-level workand 35% of full-time SPC forecasters hold a Master of Science degree. Most forecasters have at least five years of specialized experience, with veteran forecasters having over 20 years of experience. SPC has participated in several major scientific experiments and field programs, including most recently the second Verification of the Origins of Rotation in Tornadoes Experiment (VORTEX-II) project.

2.2 Brief History

In 1995, the Severe Local Storms Unit (SELS) of the National Severe Storms Forecast Center in Kansas City, MO was renamed SPC, with Dr. Joseph Schaefer its new director. In 1997, SPC completed itsrelocation to Norman, Oklahoma, which is home to the NOAA National Severe Storms Laboratory (NSSL), Radar Operations Center, Warning Decision Training Branch, Oklahoma City Area National Weather Service Forecast Office, University of Oklahoma (OU) School of Meteorology, and other weather organizations. In summer 2006, most of the NOAA organizations in Norman, including SPC and all of the University's weather-related research, service and educational organizations, moved into the new National Weather Center (NWC) building on the University of Oklahoma Research Campus.

2.3 Organizational Structure

As shown in the figure below, SPC is organized into an Operations Branch and a Science Support Branch. The former contains lead, mesoscale, outlook and assistant forecasters, with the lead forecaster serving as the "team leader," overseeing duties among other forecasters on shift and making sure each product issued is of the highest quality possible. The main operational duty of the lead forecaster is to issue tornado and severe thunderstorm watches as necessary, coordinating with numerous local NWS offices in threat areas. The lead forecaster also composes Public Severe Weather Outlooks (PWOs) when major severe weather outbreaks threaten, and provides direct assistance and guidance in the preparation of all other forecasts at SPC.



Mesoscaleforecasters specialize in forecasting dangerous weather on the "mesoscale," which comprises a time frame of ~ 6 hours and areasranging from 5,000 to 100,000 square miles. These activities require extensive knowledge of weather processes that lead to severe thunderstorms, tornadoes, heavy rain, hazardous winter weather, and fire weather. The primary responsibility of the mesoscale forecaster is to provide short-term guidance on the formation and evolution of severe thunderstorms, tornadoes, heavy precipitation, and winter weather events.Mesoscale forecasters compose concise short-term guidance messages called Mesoscale Discussions (MDs) that address areas of current or expected hazardous weather. The mesoscale forecaster also writes formal Status Reports for every severe weather watch in effect. The outlook forecaster prepares forecasts of thunderstorm activity, both severe and non-severe, within the contiguous United States.

The Science Support Branch maintains an extensive array of computer hardware and software, develops new software in support of forecast operations, and ensures that forecast products and services have a strong science foundation. Within Science Support, the Science and Operations Officer (SOO) is in charge of in-house meteorology training and integrating the latest atmospheric science discoveries into SPC forecasting. The SOO also oversees all SPC research projects and scientific publications. The Science Support Branch leads efforts to extract SPC specific guidance from observational and numerical model data, to develop tools to support new forecast techniques, and to support both the creation and verification of SPC forecasts. Science Support Branch personnel also assist visiting scientists as well as contract staff who deal with various types of computer programming, numerical modeling, and network maintenance activities. Finally, it is important to recognize that the Science Support Branch also supports two computer hardware experts, a software engineer, three Techniques Development Meteorologists, two full-time meteorologist consultants (both with MS degrees), and two electronics contractors.

SPCadministrative staff oversee all SPC functions, and the Director reports to the Directorof NCEP. The Director is active in administrative areas, diversity, equal employment opportunity (EEO) compliance, broadcast and print media relations, NWS outreach both internal and external, strategic planning, tactical planning, resource management, and severe reports data base management. The Warning Coordination Meteorologist (WCM), who reports to the Director, serves as SPC's point of contact to NWS field offices, emergency managers, private sector meteorologists and broadcast and print media. The Administrative Officer (AO) has a wide variety of managerial responsibilities including human resource management, diversity enhancement, budgeting, acquisitions, tours, broadcast media scheduling, and international activities. The Project Administrator, a contractor, supports a wide variety of administrative activities and is SPC's travel coordinator. The Operations Branch Chief and Science Support Branch Chief direct daily supervisory/ management duties of forecasters and support staff, respectively.

3. Progress Since the Previous Review

SPC has made considerable progress since the previous review held in 1999. Some actions stem from explicit recommendations from the review panel while others were stimulated by the external community or resulted from internal initiatives. Perhaps the most obvious and significant change has been in physical location and facilities, as described in the preceding section. This consolidation of organizations with similar and complementary missions has strengthened SPC by stimulating collaboration and providing a modern, well-designed workspace.

Acting on a recommendation by the 1999 review panel, SPC now provides probabilistic information on many of its products including convective outlooks and watches. Mesoscale Discussions now include information regarding severe thunderstorm potential, and the likelihood of winter weather (blizzard, heavy snow, freezing rain, and winter mixed precipitation) and heavy precipitation. Formats have been changed to facilitate interpretation and parsing.

Another major change at SPC is the inclusion of fire weather products. Fire Weather Outlooks are prepared for the day 1, day 2, and day 3-8 periods and include both text and graphical presentations. Guidance lightning forecasts are now generatedusing a probabilistic format via a perfect-prognostic regression technique. All SPC products, both official and experimental, are now posted in real time on the Internet. SPC's website is considered one of the best among all NCEP centers.

Many new efforts have been initiated to expand collaborative research among SPCandNOAA laboratories, universities, and other institutions. The most prominent of these is the Hazardous Weather Testbed (HWT), which operates a Spring Program that includes participants from NWS, other NOAA agencies, academia, international organizations, and the private sector. HWT has been particularly helpful in the evaluation and implementation of ensemble storm-resolving models.

On the administrative side, the SPC Strategic Plan was revised since the previous review, along with the SPC Strategic Implementation Plan, to include milestones extending to 2013. A WCM position was established and staffed in response to the 1999 review recommendations. SPC also has developed an equipment replacement plan whereby new workstationsare purchased annually for critical forecast positions and the old workstations made available to progressively less critical positions. This insures that all SPC workstations are relatively current with no large one-time procurement needed to cure simultaneous obsolescence.

Finally, SPC has successfully increasedstaff diversity. Career ladder positions were established to allow hiring of assistant forecasters at the GS-5 level, where females and minorities are more readily available in the NWS labor pool.

An Asian-American was hired as a federal System Administrator, as was a Native-American contract computer technician. The SPC has two Student Career Experience Program employees, one is an African-American male and the other is a white female. Also an African-American SPC forecaster is working with Langston University, a minority-serving institution in Oklahoma, to heighten interest and awareness among prospective students and recent graduates regarding NOAA career opportunities.

4. Summary of Stakeholder Survey

An invitation was distributed to a wide spectrum of potential users of SPC weather information and products, requesting that they respond to an on-line questionnaire.These customers includedWFO Meteorologists in Charge, SOOs, and WCMs; numerousprivate weather providers, airlines, government research laboratories, media outlets, energy companies, the military, insurance and safety organizations, academic institutions, storm spotters and chasers, and various American Meteorological Society listserves. Responses were obtained from 151 users. Of those indicating a profession, 55.5% were weather forecasters. Other users included researchers, the media, those with hobby or professional interests, emergency managers, teachers, and others. Eighty-eight of the respondents replied to all of the questions.

Feedback from the user community was predominantly positive, with a few responses indicating suggestions for improvement. In analyzing the data, responses in the "agree or strongly agree" categories were used as positive in the summary statistics below.

- SPC is the preferred source of severe storm information for 63.6% of survey respondents. Confirming the widespread use of SPC information, the SPC web site received 140 million to 450 million hits per month during the period 2008-2009, according to data supplied by SPC.

- 77% of survey respondents consider SPC products to be state-of-the-art, and 78% consider the rate of SPC product improvement to be appropriate. Importantly, 85% consider product quality to be consistent from day to day and from shift to shift.

- Survey respondents find SPC information to be both important and useful for their own tasks. 81% of survey respondents indicate that their organizations would suffer without access to SPC products. With the exception of fire weather products, at least 79% of respondents find that each SPC product was somewhat important or very important and useful to them. Watches are by far the most important and useful product for users, with 98% of respondents providing positive responses.

- 97% of respondents find SPC products to be accessible and timely, and 90% find the presentation style to be useful and understandable.

- Survey respondents find fire weather products to be the least useful among those on the SPC suite, with only 59% judging them to be important. Some respondents also wonder whetherfire weather forecasting responsibilityrightly belongs within SPC.

Users expressed some concern that interaction with SPC about web products is not as effective as desired, though evidence does exist that many users felt little need for it. Only 53% of respondents indicate that SPC has an effective mechanism for requesting external feedback, while 20% did not respond because they did not have a basis for replying. Of those with a basis to judge, 72% feel that SPC satisfactorily responds to requests for changes or new products and 76% feel that SPC satisfactorily responds to questions and problems. Although 85% of respondents indicate that SPC effectively communicates information about new products and changes in existing products, several respondents suggest the need for a pro-active "mailing list" to inform users of such changes.

5. General Observations and Overarching Issues

Overall, the review panel found SPC to be an effective, well-managed center with balanced operational and research-transition activities. SPC staff members are motivated and energetic with respect to both their defined operational duties and the center's culture of science awareness and exploitation. SPC's co-location with the Norman WFO and NSSL is clearly a key factor in establishing this dual identity. The HWT Spring Experiment, in which forecasters from around

the world gather at SPC to exercise state-of-the-art models in an operational environmental, epitomizes the center's commitment to advancing severe weather forecasting capabilities.

Based on discussions at the site visit and follow-on analysis, the panel identified three overarching issues: (i) operational product delivery requirements that are not adequately resourced; (ii) an opportunity to leverage SPC capability to augment activities at other centers, in particular the Aviation Weather Test Bed (AWT); and a widespread belief that center staffing levels are lower than at other NCEP centers in spite of good performance in meeting operational objectives. We briefly discuss each of these issues below.

Under-Resourced Product Delivery Requirements: In at least two areas, the review panel noted SPC is required to issue products that management is not able to adequately staff given current full time equivalent (FTE) constraints. The mesoscale heavy precipitation discussion, although valued by external users, must be treated as secondary to the creation of severe thunderstorm and tornado products. Even more problematic are fire-weather related forecast products, for example those dealing with "dry" thunderstorm threats. Staffing limitations only allow the fire weather product to be generated during the nighttime shift; as a result, the product may be outdated by the time it is needed operationally the next day.[1]

The panel is sympathetic to the frustrations of SPC staff in this area but, given the likelihood that FTE levels will remain constrained, it believes that a more strategic process for dealing with these and other "unfunded mandates" is in order. Paths that could be pursued include:

- Greater automation of current forecast products and services, obtained for example through collaboration with outside researchers;
- Collaboration with other NCEP centers to share responsibility for generating certain products;
- Clarification, both internally and externally, that the frequency of certain products will be reduced in a manner consistent with staffing levels.

Whatever the course of action, the panel members believe that time spent at the management level considering strategic alternatives, and coordinating these with SPC staff and external stake-holders, will be valuable in addressing product challenges.

Leveraging SPC Capability: SPC leadership reported good working relationships with EMC, TPC and HPC and effective coordination with NWS WFOs. Given the review panel's charge of reviewing both AWC and SPC, however, it is clear that SPC resources and culture could be more strongly leveraged to help AWC meet aviation weather needs. As an example, AWC management has proposed the development of an Aviation Weather Testbed (AWT) as a focus for NWS engagement in the Next Generation Air Transportation System (NextGen) initiative. This vision could be jump-started by exploiting SPC experience, culture and infrastructure

[1] Since the site visit, NWS has provided two additional forecasters for the express purpose of adding a daytime fire weather forecast shift.

associated with the analogous HWT at SPC.[2] The review panel recommends that SPC and AWC leadership continue working together to develop a strategic plan for exploiting NCEP advanced severe weather modeling and human forecasting capabilities that includes concrete objectives and implementation plans for AWT. This effort should be phased, beginning with aviation-focused product exploration at HWT that would expand to AWT when physical infrastructure at AWC is in place. Exploitation of advanced modeling capabilities at SPC (such as those demonstrated during the Spring Experiment) should be continued even after the aviation-focused demonstrations switch to AWC.

More broadly the panel believes that operations-focused collaboration between SPC and AWC could be strengthened and encourages the leadership to strategize on processes for achieving this goal.

Staffing Shortage Frustration: Staff and management voiced the belief that SPC might, in fact, be getting penalized in FTE allocation because of its excellent performance in meeting operational objectives. The sentiment was that NCEP leadership views SPC's performance as evidence that staffing is adequate and therefore continues to reject requests for additional FTEs. Further, it did not appear that SPC management provided feedback to staff on their interactions with NCEP leadership regarding FTE issues.

The panel believes that such speculation is counter-productive and largely unnecessary. Although SPC staff resources are clearly constrained, such constraints are, to the best of the panel's knowledge, equitably shared across NCEP centers. SPC management should work to develop clear explanations for the processes that limit FTE levels at the Center and put in place mechanisms for regularly sharing these explanations with Center staff. In turn, it should be clear to SPC staff that their concerns and frustrations are being conveyed up the chain of command, even if NCEP does not have the flexibility to address them.

6. Findings and Recommendations

6.1 Mission and Vision

The wording of SPC's mission statement could be made less ambiguous by referring to residents of the United States rather than "American people." As presently constructed, SPC's role in protecting the life and property of the American people could imply giving such protection to individuals regardless of their physical location, e.g., if visiting overseas. Although obviously not the intent, this review provides an opportunity for clarification. Additionally, and somewhat oddly, the mission statement, unlike the vision statement, contains no reference to severe thunderstorms but does include the word tornadoes. In light of SPC's role in issuing severe thunderstorm and tornado watches, we suggest addition of the reference to severe thunderstorms.

[2] The review panel notes with great satisfaction that such linkages are now being developed, in part as the result of this evaluation and preliminary recommendations conveyed to Center leadership during the site visit out-brief.

A point similar to that made above with regard to "American people" is valid for the vision statement. Additionally, the vision statement is not as compelling as it might be. For example, it no doubt is the vision of NCEP for SPC to provide the best services and protection possible. The present wording "works to protect" could be made by any organization. We therefore suggest a more compelling statement that truly reflects the vitality of the SPC mission and the dedication of its staff.

6.2 Customers and Partners

SPCplays a critical role in supporting the service, delivery and improvement goals of NOAA's Strategic Plan. Its highly trained forecasters focus on hazards related to severe weather in order to ensure that NWS field offices, other government agencies and the private sector have the information necessary to adequately prepare for potentially severe weather events whenever and wherever they occur. SPC's tornado and severe weather outlooks and watches for the contiguous United States, in addition to their suite of hazardous weather and mesoscale products, are widely used by the emergency management community, broadcast meteorologists, private sector users (including energy, insurance, agriculture, aviation, surface transportation, and disaster recovery firms, among others), private sector service providers, NWS WFO meteorologists, other NCEP Centers, academia and the general public. It is very apparent, based on the quality of feedback from this broad base of users via the web survey, that SPC is effectively meeting its goals.

SPC staff are to be commended for their efforts in reaching out to the research and academic communities and engaging with customers and partners using a wide variety of mechanisms including workshops, tours, job shadowing, Research Experiences for Undergraduates mentoring, and special events that leverageSPC strengths and exploitits close connection with on-site NOAA Public Affairs staff. SPC staffmembers have a welcoming, accepting attitude that fosters collaboration and discovery among participants in workshops and external research activities. They also have built databases and tools designedfor use with archived events, which opens opportunities forcollaboration with remote colleagues who use such tools for research and education. Equally important is the constant flow of visitors, school age and above, who tour SPCand emerge with an appreciation for the commitment and professionalism of itsstaff and the importance of NOAA's mission.

It is also important to note that moving to the new NWC building with its spacious, well-designed configuration has been an enabler of these customer and partner outreach activities. The annual National Severe Weather Workshop has become a major event based on sustained attendance over the years, and the National Weather Festival, which draws more than 3000 visitors over a four-hour period and is sponsored in part by the Norman Chamber of Commerce Weather Committee, likewise is an important outreach mechanism. SPC's close connection with NSSL, the Norman WFO, private companies located on the OU Research Campus, and the OU academic community has yielded substantial benefits to all involved. Unfortunately, however, funding and staff time needed to support these crucial activities is becoming increasingly constrained.

6.2.1 Findings

Finding CP1: Significant progress has been made in addressing recommendations from the 1999 review.SPC also has leveraged the Internet to develop linkages with customers, partners and the public as requested in the 1999 review. The review panel found SPC's use of the Internet to be a valuable part of itsoutreach and education strategy, and its outstanding web site and effective graphical capabilities are to be commended.

The move of SPC to the NWC building in 2006 was completed as planned and has proven to be an important asset for engaging partners and customers in a more collaborative and productive research environment and training forum. Locating HWT in the center of the facility between WFO and SPC forecasters, and in close proximity to OU organizations, has facilitated and fostered ideas and techniques to improve the quality and communication of SPC forecasts. Additionally, SPC was found to have a healthy, productive relationship with the emergency management community, with whom they engage regularly in outreach activities.

Finding CP2: SPC is fortunate to be co-located with NSSL, the Oklahoma City Area WFO, the OU School of Meteorology, and other organizations (Oklahoma Climatological Survey (OCS), the Cooperative Institute for Mesoscale Meteorological Studies(CIMMS), the Center for Analysis and Prediction of Storms (CAPS) and the Warning Decision Training Branch(WDTB)), providing an intellectually stimulating work environment that fosters collaboration.The importance and impact on the success of SPC outreach activities of co-location with other organizations cannot be overstated. The review panel found SPC staff invigorated by opportunities to interact with critical members of the weather community in an environment that enables and encourages open discussion, educational opportunities and partner and customer feedback. SPC alsois to be commended for making good use of the NWC facility in light of budgetary limitations.

Finding CP3: SPC leadership reports good working relationships with EMC, TPC and HPC among the other NCEP centers, as well as effective coordination with WFOs.SPC's engagement with other centers critical to its mission is appropriate and effective. The coordination of activities related to EMC's model plans and releases on a frequent basis, the sharing of test bed best practices with TPC and warning situational awareness with HPC are to be commended. SPC also workseffectively with WFOs in managing watches within the capabilities of the current "watch by county" schema.

Finding CP4: SPC is heavily involved in meaningful outreach activities at all levels, e.g., tours to the general public, high school job shadowing, Research Experiences for Undergraduates (REU) mentoring, career experience programs, etc.With support from on-site NOAA Public Affairs staff and OU's NWC staff, SPC sponsors and supports a multitude of outreach programs and activities. The review panel found SPC staff to be actively engaged in opportunities to expand the visibility to stakeholders at all levels of NOAA and NWS activities. Reaching high school and college students through job shadowing and mentoring programs, the science community through workshops, and the general public through tours and media events requires a commitment in time and energy that SPC staff willingly make despite their demanding schedules. This model, entailing a mixture of people/facility/location, works extremely well and

should be studied carefully and considered for other centers within NOAA for the benefit of all stakeholders.

Finding CP5: The severe thunderstorm report database, event summaries, and forecast tools are valuable and heavily used by the community, representing an important outreach function.A valuable outcome of close collaboration with stakeholders is a better understanding of their needs. SPC staff members have applied their understanding of stakeholder needs in a unique way that can be leveraged and exploited by the weather community for years to come. The severe thunderstorm report database is such an effort. SPC has captured information that will help not only them but also others improve warning forecasts and techniques that yield benefits for all stakeholders. SPC is to be commended for their creativity and strategic planning in using information acquired from close collaboration with stakeholders and partners.

Finding CP6: A formal process exists for determining user needs and priorities at the agency level, and another, much more informal process occurs at the SPC level of engagement with users. The balance and connection between these two processes is unclear.Capturing user needs and priorities from the bottom up is very effective in providing useful products and services. However, it may not be the most cost effective or efficient approach from an agency perspective. The review panel recognizes SPC staff accomplishments in informally engaging stakeholders; however, linkages to NOAA's formal requirements gathering process are unclear. Perhaps a more formal coordination process is needed between NOAA and SPC to ensure effective planning of user input provided both formally and informally. We do not make such a formal recommendation here but rather suggest NOAA and NWS leadership discuss the issue.

6.2.2 Recommendations

Recommendation CP1: SPC is to be commended for engaging social scientists in HWT and we encourage broader and deeper interactions with the Social Science Woven into Meteorology (SSWIM) effort at OU, related activities at NCAR (National Center for Atmospheric Research) and the National Severe Weather Workshop, and with others.Advancing SPC outreach activities to the next level will require considerably more interaction with social scientists, especially within HWT. We wish to make clear that by "social scientists," we mean scholars in the field of social, behavioral, and economic sciences who bring expertise not available to meteorologists, even those who have been working for lengthy periods on social science problems. The SSWIM effort at OU seeks to bring social scientists into the meteorological domain, but equally important is bringing meteorologists into the social sciences domain, where research methodologies, problem conceptualization, and tools for analysis differ markedly from those used by physical scientists and engineers. By working together, these groups can begin to mutually address many of the key challenges related to stakeholder interpretation, planning, and reaction to a wide variety of weather information as well as strategies for effective communication.

Recommendation CP2: A plan should be developed for more effective interactions at the interface between AWC and SPC, e.g., utilizing HWT and the nascent Aviation WeatherTest

Bed for NextGen-related activities.[3]To capitalize upon the success of HWT, the review panelstrongly urgesthat SPC and AWC work more closely to address NWS NextGen requirements. Sharing best practices with respect to AWT design and execution, ensuring effective use of AWT for workshops and outreach, and engaging commercial customers in AWC activities should be given high priority. The intent is to spread the infectious enthusiasm and collaborative attitude of SPC staff throughout other NCEP Centers, with AWC first and potentially the rest to follow.

Recommendation CP3: SPC outreach activities are excellent and play a positive role in research. We encourage SPC to ensure an appropriate balance between the staff time required for such activities and the benefits wrought by them.The review panel recognizes limitations in expenditures of both funding and human resources for outreach at SPC, and that these limitations are likely to continue based on current economic conditions. It also recognizes difficult decisions SPC management must make to satisfy stakeholders, partners, NOAA management and SPC staff. Identifying the benefits from outreach efforts will be a critical task going forward in order to best utilize the resources available.

6.3 Products and Services

SPC provides a variety of products and services in the form of forecasts and discussions that help fulfill the NOAA mission of serving society's needs for weather and water information, and the NWS mission of protecting life and property. Products and services include but are not limited to timely and accurate watch and forecast guidancefor tornadoes, wildfires, and other hazardous phenomena, including severe thunderstorms, heavy precipitation, and hazardous winter weather.

SPC's origins date to the early 1950s when the first official tornado and severe thunderstorm forecasts were issued by the U.S. Weather Bureau. Products for many years included severe thunderstorm and tornado watches and outlooks detailing expected area(s) of severe thunderstorms and tornadoes including discussions ofcontributing factors. That basic but important product suite has been enhanced considerably and now includes quantitative estimates of severe thunderstorm and tornado probability out to as many as eight days in advance; status statements regarding current watches; and mesoscale discussions used to provide background information on upcoming changes to outlooks, areas where watches may be issued, areas where a severe threat is deemed to be too limited to warrant a watch, and discussions of existing watch threats beyond those described in status statements. Prior to the issuance of watches, extensive collaboration and coordination occurs between SPC and local WFOs. Watches are now officially issued on a county basis, as opposed to a parallelogram. However, the aviation industry expressly asked that a parallelogram approximating the watch still be issued for aviation purposes. The expansion of outlook products to eight days, and the creation of probability products pertaining to outlooks and watches, has met the major recommendations of the 1999review.

[3] The review panel notes with great satisfaction that such linkages are now being developed, in part as the result of this evaluation and preliminary recommendations conveyed to Center leadership during the site visit out-brief.

In addition to these "traditional" products, SPC in recent years has been tasked with generating mesoscale discussions regarding areas of potentially heavy precipitation rates – not only from warm season convection but also for cool season precipitation; fire weather forecast products; and enhanced thunderstorm probability forecasts for use by AWC. SPC also has generated an extensive suite of automated analysis, diagnostic and prognostic products that are useful in generating each of the forecast and discussion products listed above. This includes Short Range Ensemble Forecast (SREF) products, which are numerical model-based guidance products used to help generate probabilistic forecasts. Additional products are under development, such as enhanced thunderstorm forecasts for 4-hour periods. Some of these new activities have addressed recommendations in the 1999review.

SPC has developed an extensive and highly functional web page that provides access to all of the above products, plus additional products for use by SPC meteorologists, NWS meteorologists, and others. These include real-time analysis (forecast tools) products; severe thunderstorm and tornado report mappings and raw data; collections of observations and analyses for severe weather events since 1999; and frequently asked questions (FAQ) pages. Combined, these new resources meet several recommendations of the 1999 review.

6.3.1 Findings

Finding PS1: SPC has responded well to recommendations regarding products and services made during the 1999 review. Outlooks have been extended to eight days, outlooks and watches have been amended to include probabilities, new products have been generated, and a very effective web page has been created.

Finding PS2: SPC forecasts and products are of high quality and verification scores show steady improvement over time. SPC staff members understand and rely upon rigorous verification techniques to ensure product quality and consistency. More than 70% of significant or extreme events (Enhanced Fujita index 2, EF2, or stronger tornadoes; 2" or larger diameter hail; 65 mph or greater gusts) now occur within watches, while more than 90% of significant tornadoes do so. For Day 1 outlooks, despite areal coverage showing a slight decrease over the years, the percentage of severe weather reports occurring outside of outlook areas has decreased while the percentage of areas having no reports also decreased. Day 2 and Day 3 outlooks have shown an overall decrease in areas containing no reports of severe weather, while the percentage of severe weather reports occurring outside outlook areas generally has been steady though of course variable from year to year.

Finding PS3: SPC products and services are widely used and generally much appreciated by users. The SPC web site received 140 million to 450 million hits per month during the period 2008-2009, and results from the survey, described above, clearly demonstrate the value placed by the community on SPC products.

Finding PS4: Many SPC products have been converted to a probabilistic framework, including watches and outlooks. Experimentation with new capabilities continues, fulfilling a major recommendation of the 1999 review. Verification statistics indicate that SPC probabilistic forecasts are highly reliable, and the significance of this achievement cannot be overstated.

Finding PS5: SPC now indicates low, medium, and high threats of tornadoes, large hail, and damaging winds in association with its watches and outlooks and is testing of the use of new wording to convey these relative risks. Criteria have been set regarding phenomena associated with this wording.

Finding PS6: Watch decentralization, or the reversion from SPC control to WFO control once a watch is issued, continues to be a source of frustration for SPC forecast staff.Whereas watch issuance is a collaborative process between SPC and WFO staff, subsequent watch modification appears to occur in many cases without SPC input.

Finding PS7: SPC has developed many forecast tools including those used for sounding analyses, Rapid Update Cycle (RUC) model analysis, and probabilistic guidance using the SREF numerical model. SPC is to be commended for its leadership role in the development and application of mesoscale ensemble and advanced diagnostic products in weather forecasting, and for making them publicly available on their web site.

Finding PS8: SPC has developed an effective formal procedure for transitioning new products from experimental to operational status. This includes requesting and considering feedback from users.

Finding PS9: As noted in the survey discussion, users expressed some desire for greater interaction with SPC regarding existing products and services and/or information, for suggesting changes or new products, and for strategies in effectuating SPC-user interactions.

Finding PS10: SPC tools are very creative, especially in the area of forecast verification, and include a database useful for comparing current weather situations to historical cases. The relational database now under development shows great promise as a tool for improving situational awareness and context-based forecasting.

Finding PS11: SPC provides an excellent web site with an outstanding suite of products. The site is useful to SPC and NWS forecasters, other meteorologists, and the public, and because of quality graphics and layout, the site is especially appropriate for educational purposes.As indicated previously, respondents found SPC products to be highly useful and did not identify significant problems.

Finding PS12: The mesoscale heavy precipitation discussion product is largely an unfunded mandate.Issued for both warm and cool-season precipitation, the mesoscale heavy precipitation discussion is not issued as consistently as desired because of staffing limitations and because the product topicis treated as secondary to SPC's primary mission of severe thunderstorm and tornado forecasting. SPC forecasters and NWS and other users express a desire for more mesoscale discussions, and SPC forecasters are somewhat frustrated by a lack of time to devote to them, particularly during the warm season. In addition, the nature of some cool season heavy precipitation is rather different from convective precipitation and thus requires a different set of skills and diagnostic products.

Finding PS13: Despite limited resources and in light of other challenges, SPC has developed a credible fire weather product. Staffing limitations only allow the fire weather product to be

created overnight, and it can become outdated by the following afternoon. Staffing limitations[4] also preclude SPC forecastersfrom interacting with fire managers during the daytime and evening hours when such interactions are most valuable. Limited interest and background knowledge of fire weather by already heavily tasked SPC personnel hamper developmental efforts that have been so outstanding with regard to severe thunderstorm and tornado forecasting products.Most importantly, the fire weather burden can harm morale and the culture of excellence SPC has so effectively created.

Fire weather outlooks show improvement as probability of detection values have increased while false alarm ratios have decreased. However, SPC forecasters recognize that time does not permit an appropriate level of commitment to this activity, leading to frustration because of the SPC culture of product excellence. Some forecasters may be more qualified or interested in fire weather than others, and some question whether it belongs within SPC.

Finding PS14: Dry thunderstorm research vis-à-vis lightning is an example of how SPC has leveraged its expertise in thunderstorm forecasting to help meet other (fire weather) requirements, and is another example of SPC's creative development of useful products.Fire modeling is being performed within other organizations, focusing heavily on fuels and fire-scale processes, whereas SPC focuses mainly on large-scale and convective forcing factors. This suggests that collaborative efforts between SPC and other groups could be fruitful if NWS and other interests wish to see fire weather products have commensurate quality and value to others in the SPC suite.

Finding PS15: SPC generates enhanced thunderstorm probability forecasts for use by AWC and is working on a 4-h version of this product.As is the case for the fire weather product, the enhanced thunderstorm probability product appears to be largely another unfunded mandate which - in light of the importance of accurate weather information to aviation – is one for which SPC could be a valuable resource. Both the opportunity and desire appear to exist for greater collaboration between SPC and AWC on the enhanced thunderstorm probability and other products, and especially on issues pertaining to NextGen.

6.3.2 Recommendations

Recommendation PS1: SPC should continue working toward higher time and space resolution forecasts, outlooks, and watches, and implement daily outlooks to replace the current day 4-8 day map and discussion.

Recommendation PS2: The SPC is encouraged to continue its outstanding efforts to improve forecast skill through the use of relational databases, context-based forecast and verification approaches, and other means.

[4] Information available following the site visit suggest that additional FTE positions are being or soon will be made available to support the fire weather forecasting effort.

Recommendation PS3: Additional expertise, and a change in the timing of operational processes, is needed to fully implement quality fire weather forecasts.As this occurs and as resources allow, fire weather products should be converted to a probabilistic framework.

Recommendation PS4: SPC should continue to add Geographic Information Systems (GIS) and interactive analysis capabilities for application to forecast and data base products in its web environment.

Recommendation PS5: Continued efforts should be directed toward improving probabilistic guidance.Care should continue to be taken to ensure that users understand the proper use of probabilities and the extent to which they are statistically reliable. This becomes increasingly important in the context of appropriately calibrated ensemble model output and risk-based decision support systems of the type to be used in NextGen.

Recommendation PS6: SPC should collaborate with social scientists regarding appropriate thresholds for low, medium, and high threat wordings; public perception and response, and "cry-wolf" issues possibly associated with low-probability watches; and optimal values of probability of detection, false alarm rate/ratio, and lead time/duration for severe thunderstorm and tornado watches.

Recommendation PS7: SPC, NCEP and NWS leadership should work together to ensure adequate understanding of, and develop more effective mechanisms of communication among, all operational personnel regarding watch decentralization philosophy and procedures.

Recommendation PS8: SPC should continue to update its excellent web site with additional forecast tools and products as they become available, including short "primers" regarding the nature of such products and how they might best be applied.SPC should consider including on its web site a more prominent link through which users can make inquiries and offer suggestions regarding the web environment and SPC products.

Recommendation PS9: NWS and SPC should re-examine the desirability of SPC issuing cool season heavy precipitation mesoscale discussions and evaluate ramifications for staffing, guidance products and training.Manpower limitations should be considered in deciding whether SPC should continue to be tasked with issuing warm season heavy precipitation mesoscale discussions.

Recommendation PS10: A multi-agency effort (at a minimum, NOAA and the Department of the Interior) should be initiated to re-visit the fire weather forecast challenge to determine the most appropriate way forward.Failure to do so could have important long-term negative consequences on the SPC mission and the perception of its effectiveness.

6.4 Information Systems

SPC information systems (hereafter IS) staff are part of the Science Support Branch, which includes two NCEP IS/electronics specialists and two contractor support positions. IS support at SPC includes management of hardware, software, networking and data flow. SPC maintains

24x7 operations,requiring that critical products and services (e.g., NCEP Advanced Weather Interactive Processing System (N-AWIPS), SPC Product Generator (Prodgen), AWIPS, NCEP Skew-T/Hydrograph Analysis and Research Program (N-SHARP)) be available continuously. IS staff strive to minimize maintenance costs, leverage national support for software and services, develop code using common and modern languages, and exploit national software when possible. Innovation is strongly encouraged among IS staff.

SPC maintains a tiered backup plan for loss of power or communications at the NWC building. For short-duration outages (<24 h), the US Air Force Weather Agency(AFWA) 15th Operational Weather Squadron at Scott Air Force Base (AFB) backs up critical SPC forecasts. For longer-term disruptions, Offut AFB is used as a backup facility, with SPC forecasters deployed to Offut to issue the products. This backup plan is testedquarterly with a team from the SPC observing AFWA operations to provide real-time training to the AFWA personnel when necessary.

The workload of SPC forecasters has increased significantly since the last review in 1999, as mentioned elsewhere in this report, yet the number of support staff, excluding contract computer maintenance technicians, has decreased. It is very much to the credit of IS staff members that additional tasks have been added with no apparent breakdown in quality or timeliness. Good communication exists between forecasters and information systems staff regarding support activities (e.g., automation of processes, development of forecast aids), which improves efficiency and, most importantly, allows forecasters to apply scientific knowledge rather than struggle with computer technology inthe production ofproducts.

SPC IS staff members have more than achieved the goals put to them in the 1999 review. Specifically, they have developed an outstanding web site with effective graphical capabilities including educational applications. Some survey respondents suggested specific enhancements to the website, as noted in more detail below.

6.4.1 Findings

Finding IS1: SPC has produced an outstanding web site with effective graphical capabilities including information for education. A web design philosophy that embodies breadth, followed by depth, makes the site easy to navigate. The site well reflects SPC forecast services and scientific expertise and allows for in-depth exploration of product details, data archives, and forecast tools.

Finding IS2: SPC's severe thunderstorm report database, event summaries, and forecast tools are valuable and heavily used by the community, representing an important outreach capability. The stakeholder survey included several positive comments regarding these resources, and the value of the database for teaching was especially prominent.

Finding IS3: The upgrade of AWIPS/N-AWIPS to the Second Generation Advanced Weather Interactive Processing System (AWIPS-II) could have a major impact on IS and other operations, especially given that many of the tools used by SPC and others in NCEP, including those in N-AWIPS, were developed and implemented by SPC.The AWIPS-II migration plan is a good start on minimizing impacts to SPC and other service Centers.

Finding IS4: IS security implementation of the Federal Information Security Management Act (FISMA) and certain administrative functions (e.g., NOAA's Planning, Programming, Budgeting and Execution System - PPBES) are consuming a substantial and increasing portion of staff time and encroaching on other important duties.

Finding IS5: A notable diminution of staff professional training has occurred during the past 3-4 years, especially in critical IS areas. Classes in Java, scripting languages, etc. are desired by IS staff, and management should realize that providing the staff with time to attend professional training courses (as opposed to taking online courses at their desks, subject to interruption and distraction) will pay off several-fold in more efficient use of staff time to perform critical programming and system management duties

6.4.2 Recommendations

Recommendation IS1: IS staff should place a high priority on maintaining the schedule for AWIPS-II transition. Failure to do so could lead to increases in the already large amount of time and effort required for a smooth transition.

Recommendation IS2: IS staff and SPC management should seek common security and AWIPS-II solutions with other NCEP centers, including NCO. IS staff members are concerned that security issues are taking up a considerable amount of time, currently estimated at more than one FTE. This is not likely to decrease in the future, and other NCEP centers have similar issues. NWS and NCEP leadership must ensure that adequate IS staff time is directed toward the AWIPS-II transition, particularly because many of the tools presently used within N-AWIPS were developed by SPC and need to be transitioned to AWIPS-II.

Recommendation IS3: SPC management should insure that IS staff members receive sufficient opportunity for training and professional development.

6.5 Science and Technology

One important mission of NCEP centers is to accelerate science and technology infusion to enhance the value of NCEP guidance, analyses, forecasts, and warnings over all spatial and temporal scales. This includes development and implementation of the next generation unified numerical forecast system, as well as infusion of science and research into operational systems through partnerships and knowledge transfer with the scientific community both within and outside NOAA. The test bed concept is an important part of this research-to-operations (R2O) and operations-to-research (O2R) exchange.

At SPC, R2O and O2R activities flow naturally at all levels. In this sense, SPC is truly a refreshing and stimulating environment. This can be attributed in part to a management team that values both research and operations and to a forecast team that is sincerely interested in the betterment of their products such that they have a natural interest in validation as well as furthering the understanding of the processes underlying the phenomena they forecast.

Despite limited time, SPC staff members produce an impressive array of publications. HWT is a shining example among NCEP test beds, bringing together the research and operational communities in a non-threatening atmosphere for evaluating high-resolution models and associated new forecasting techniques. It is important that the SPC intellectual environment be preserved and nurtured. For example, the addition of new required products has placed increased stress on SPC staff, decreasing the time available for forecasters to conduct research and forcing many of them to complete research projects on their own time. This is unfortunate and sends a negative message both to them and to those with whom they collaborate. Thus, care must be taken to prevent erosion of the high morale and intellectual energythat drive this very dedicated staff.

6.5.1 Findings

Finding ST1: SPC is leading the application of meso- and storm-scale ensemble numerical prediction in operational forecasting. Ensemble guidance has played a critical role in SPC forecast advances, including SREFoutput in the production of the Calibrated Thunderstorm Forecast, which is shared with AWC to aid preparation of the Collaborative Convective Forecast Product (CCFP). Additionally, SPC post-processing of SREF output yields environmental guidance to forecasters in the production of severe, fire, and winter weather products. Evaluation of experimental storm-scale ensemble forecasts (SSEF) has since 2004 been an integral part of the HWT Spring Experiment. Thus, SPC has sought to push the envelope with regard to operational use of ensemble forecasts and has done so with great success through extensive collaborations made possible largely by HWT.

Finding ST2: SPC is using innovative verification techniques to investigate at a deeper level the skill of its forecasts in the context of the overall environmental conditions. SPC uses traditional forecast verification metrics (e.g., probability of detection) but also is exploring context-based verification using a unique severe storm environment relational database developed in house. The latter allows forecasters to parse previous forecasts according to environmental conditions to produce verification statistics valid for particular environments. By doing so, they and other researchers are able to identify and focus on atmospheric conditions that represent the greatest forecast challenges and subsequently focus research efforts more sharply. This extra effort at verification is a testament to the pride taken by SPC staff in producing the best possible analyses and forecasts.

Finding ST3: SPC is the undisputed “go-to” place among remote NCEP service centers for the creation of forecaster tools. Examples include the N-SHARP model sounding program and hourly mesoscale analysis fields produced by supplementing observational data with model data. Other centers have benefitted from these SPC developments.

Finding ST4: HWT is very successful in multiple ways.This is particularly true for R2O, O2R, education and community engagement programs, multiple-agency interaction, and HWT serving as an “honest broker” to bring disparate communities together for mutual benefit. HWT has become a role model for other test beds and has tremendous potential for fostering work at interfaces with other NCEP Centers.

The HWT Spring Experiment provides fertile ground for the sharing of ideas among researchers, academics, private industry and forecasters. Through honest and open discussion of results from competing model formulations, model development is able to proceed in the most effective directions possible. HWT has been instrumental in pushing forward short-range ensemble forecasting and providing SPC with a mechanism to forge strong outside collaborations. HWT also is serving as a proving ground for the Geostationary Operational Environmental Satellite (GOES-R) products.

Finally, HWT has been funded "out of hide" from resources made available by NSSL and SPC, indicating not only a fruitful partnership between an Office of Atmospheric Research (OAR) lab and a NWS operational center but also a compelling need for stable, base funding commensurate with test beds at other NCEP service Centers. In HWT, NCEP has a tremendous resource having substantially greater potential than now is being realized (see Finding ST5).

Finding ST5: Despite its notable success, the HWT facility and related infrastructure could be used more effectively if additional resources were made available (e.g., via leveraging, linking with other programs like NextGen). Given the impressive facilities at HWT and their effective use during the SPC Spring Experiment, it is somewhat disappointing that the facilities sit relatively idle during the remainder of the year. This is through no fault of the SPC, which has very little funding for HWT, but represents an overlooked opportunity for NCEP as a whole.

6.5.2 Recommendations

Recommendation ST1: SPC is to be commended for engaging social scientists in HWT activities and we encourage broader and deeper interactions with the SSWIM effort at OU, related activities at NCAR and the National Severe Weather Workshop, and with others. As the border between watches and warnings becomes increasingly blurred and the public is supplied with forecast probability information in ways different from those in the past, social scientists must be engaged in research that helps determine optimal waysfor presentingforecast information. Social scientists also could be very useful in new risk forecasts being explored by SPC, which combine population density data with forecast information. Complementary to the SSWIM approach, which brings social science into meteorology, we recommend SPC also take meteorology into the social sciences.

Recommendation ST2: With support of NCEP headquarters, a plan should be developed mutually by SPC and AWC to ensure more effective interactions at the interface between severe weather and aviation operations, e.g., utilizing HWT and the nascent AWT for NextGen-related activities. Convection is the clear binding tie that lies at the interface between the AWC and SPC missions, and greater collaboration between the two centers would prove beneficial, particularly with regard to preparing for NextGen. However, this must be done with sensitivity to IS and other staff at both AWC and SPC so they are not unduly burdened by supporting these efforts. NCEP leadership should consider appropriate similar interfaces with other service Centers.

Recommendation ST3: A strategic plan for HWT should be developed that builds upon its unique strengths and potential and takes advantage of emerging capabilities in high performance computing. The latter includes the availability in 2011 of sustained petascale computing

capability within the National Science Foundation (NSF) suite of supercomputing facilities, opportunities in education and outreach, and engagement of other interests in business. Given the proper resources, the already successful HWT could be used to address a plethora of pressing problems within NCEP, and we encourage NCEP and SPC leadership to consider extending HWT's vibrant intellectual capability into new research areas.

6.6 People and Organizational Culture

SPC staff and leadership exhibit high morale and productivity. The organization's work processes seem well structured, and SPC's co-location with NSSL, the Oklahoma City Area WFO, and University of Oklahoma – all within the National Weather Centerbuilding – provides unique opportunities for SPC staff.

6.6.1 Findings

Finding POC1: SPC staff productivity is high, both in terms of operational product generation and associated O2R activities.In addition to a heavy shift workload (which has increased as SPC assumed additional tasks pertaining to fire weather, heavy precipitation, and enhanced thunderstorm probabilities), SPC personnel continue to perform research and write a substantial number of papers for conferences and even archive journals. As noted previously, some of this work is performed during staff spare time, which is a testament to staff passion for and devotion to the SPC mission of protecting life and property. Since 1993,the annual average number of refereed and non-refereed conference publications having SPC staff as authors or co-authors has beenfour and 30, respectively.

Finding POC2: Significant attention has been given toward improving workforce diversity.Thirteen percent of permanent SPC Federal staff members are women or underrepresented minorities while 38% of SPC contractors have the same designation. The two most recent SPC Student Career Employment Program (SCEP) students have been female or underrepresented minorities. This brings the most recent total SPC staff to 20% female/minority.

Finding POC3: Although NCEP's seven service centers are not in competition with one another but in fact work collaboratively, comparisons between centers among staff are unavoidable, particularly given the varying missions of the centers. It is in this context, and considering its mission, we note that SPC has fewer FTEs than several of the other NCEP centers. Specifically, despite increased tasking (e.g., fire weather, mesoscale discussions on heavy precipitation), the only net staff increase in the number of Operations Branch personnel during the past several yearshas been the addition of the WCM. As a result, SPC forecasters are concerned that increasing workloads will ultimately endanger their standards for excellence in product quality and timeliness. The workforce is aware that SPC leadership has requested additional FTE's but has not been informed as to why these requests were denied. This may lead to non-productive speculation regarding motives. Frustration was expressed during the site visit over the fact that the notably successful HWT was being funded "out of hide" while other startup testbeds apparently received substantial new funds. A lack of NOAA support in this regard also threatens morale and limits a greater exploitation of this excellent testbed.

Finding POC4: Significant cross-functionality is built into the SPC organization.Examples include shadowing among lead forecasters, mesoscale and outlook forecasters and assistant mesoscale forecasters. The chiefs of the Operations Branch and Scientific Support Branch, the SOO, and the WCM frequentlyfill operational forecast shifts, working a combined 175 and 179 operational shifts in 2007 and 2008, respectively. Although this is importantfor keeping management in touch with operational shift reality and builds a comfort level between staff and supervisors, the frequency with which management performs floor forecast functions suggests that FTE levels may be too low in relation to the SPC's operational responsibilities. Additionally, limitations in how various General Scale (GS) grade positions are used to accommodate substitutions due to forecaster illness or other circumstances may be limiting short-term accommodation of staffing shortages.

Finding POC5: SPC staff members appear to trust management and consider themselves to be empowered to determine the success of their organization.Management relationships with the NWS Employee Organization (NWSEO) appear very sound, and it was clear during on-site interviews that workforce personnel ideas and concerns are respected.

Finding POC6: The effectiveness of interactions between SPC and other NCEP centers, outside research organizations and other Federal agencies is variable. Although SPC makes available to AWC the enhanced thunderstorm probability forecast, little daily interaction appears to occur between forecasters from the two centers. Some collaboration occurs between SPC and HPC and between SPC and TPC when tropical cyclonesnear the US coastline. Discussions with SPC leadership during the site visit revealed inconsistencies regarding the importance of such collaborations. Additionally, a degree of rivalry and/or mistrust was evident in some cases.

Finding POC7: The SPC Director has announced his intention to retire effective 2 January 2010 and no SPC Deputy Director presently exists.

6.6.2 Recommendations

Recommendation POC1: SPC leadership should evaluate its operational responsibilities and current staffing levels and formally communicate to NCEP leadership recommendations for increased staffing and/or reduced operational responsibilities.Although this recommendation may seem odd in light of the structured NCEP strategic planning process, the review panel wishes to highlight the importance of staffing issues and suggest that SPC leadership and staff evaluate current work practices to determine whether opportunities exist to increase efficiency, for example, via increased automation of product generation. The review panel inquired as to this possibility and was told that all options for increasing efficiency had been exhausted. No substantiation for this statement was provided, however.

Recommendation POC2: SPC leadership should keep staff fully informed of staffing plans, the status of requests for increased staffing and reasons that such requests are not granted. In addition, leadership should incentivize staff to improve efficiency where possible, either through improved work-practices or additional automation.

Recommendation POC3: SPC leadership should re-evaluate its policy on GS-level substitution to ensure maximum flexibility in dealing with personnel substitutions.Current SPC policy does

not allow a GS-13 forecaster to substitute for a Lead Forecaster, though GS-13 forecasters can assist Leads, including with the issuance of watches, though never issue watches on their own if a Lead Forecaster is not present. Likewise, GS-12 forecasters cannot substitute for GS-13 forecasters. A number of reasons exist for this policy, e.g., to avoid perceived pre-selection of individuals for promotion, to ensure proficiency, to avoid the challenge of an individual supervising someone in his or her own grade. The SPC Union does not agree with this policy and believes that GS-13 forecasters should be utilized when Lead Forecasters are not available. We therefore recommend that SPC leadership continue discussing these issues with staff, and the NWS Union Steward, to ensure that fill-in policies are as effective as possible.

6.7 Business Processes

A commitment to sound business practices is important to the success of every organization, while a more casual view of these practices can easily undermine the very foundation of a business. This area of the review crosscuts other sections, and while it could easily be justified, we will not attempt to apply every finding or recommendation from those sections to business practices. However, several are foundational and therefore will be listed here.

6.7.1 Findings

Finding BP1: The 360 performance evaluation, developed by SPC, has been useful for identifying and addressing issues.This annual process was put in place several years ago and both management and the NWSEO believe it has resulted in effective working relationshipsamong all SPC employees.

Finding BP2: The relationship between SPC management and local labor (NWSEO) is quite good.Both groups noted that most issues are resolved quickly and equitably and to everyone's satisfaction.

Finding BP3: Although SPC leadership appears to have meaningful working relationships with their counterparts at a few of the other service Centers, the same does not appear to be true for staff.Indeed, some staff members do not appear to have the expected level of familiarity with the mission and operational frameworks of other NCEP service Centers. This has led to feelings of resentment by some staff towardtheir sister Centers, along with a perception of favoritism by NCEP headquarters owing of differential staffing levels among Centers.

Finding BP4: Insufficient communication appears to be occurring between management and staff in some areas, even when factoring in the challenges of a 24/7 operational environment and especially concerning resource allocation and other decisions made at the NWS, NOAA and Department of Commerce levels. SPC staff members conveyed to the review team that they often do not receive information from leadership in a timely manner, and sometimes not at all, regarding key SPC strategies and issues. For example, although staff members are aware of ongoing discussions between SPC and NCEP leadership regarding additional personnel to supportfire weather forecasts, they are not apprised of reasons why such requests go unfulfilled.

*Finding BP5:*Information Technology (IT) security (FISMA) implementation and certain administrative functions (e.g., PPBES) are consuming a substantial and increasing portion of staff time, encroaching on other important duties.Cybersecurity has become an essential part of doing business and this is especially true in the US government. Similarly, standardizing procedures is critical to any organization. However, both have become burdensome and have resulted in an ineffective use of precious time and resources such that they seem counterproductive to Center staff and management.

Finding BP6: A notable diminution of staff professional training has occurred during the past 3-4 years, especially in critical IT areas.This has occurred as a result of increased time spent by management in operational forecasting. Althoughmanagement understandsand appreciates the need to stay proficient on operational procedures,and that situations exist in which they will be required to work more operational shifts than normal, it seems to them that the elevated level of shift work has become the norm rather than the exception. The result has been less time for staff training.

Finding BP7: Despite its notable success, HWT and related infrastructure could be used far more than now is the case if resources were made available (e.g., via leveraging, linking with other programs such as NextGen).As noted elsewhere in this report, the budget for HWT is taken entirely "out-of-hide" at SPC and NSSL. That is commendable but not sustainable. Other optionsshould be considered to ensure that HWT remains an outstanding program that delivers value to NCEP and the broader community.

Finding BP8: A formal process exists for determining user needs and priorities at the agency level, and another, much more informal process occurs at the SPC level of engagement with users. The balance and connection between these two processes is unclear. NCEP and NOAA receive requests for new services and after due consideration pass them to SPCleadership. Operational staff members also are approached by users with requests for new services but frequently, these requests are not coincident. The official process of soliciting user input generally works well because resource issues are addressed upfront and the political implications also are considered. Conversely, operations staff understandably desire to provide services requested directly by customers. The lack of coordination with the two approaches causes confusion and wasted effort, especially because of the difficulty associated with discontinuing existing services to make room for new ones.

6.7.2 Recommendations

Recommendation BP1: A plan should be developed for more effective interaction at the interface between AWC and SPC, e.g., utilizing HWT and the nascent AWT for NextGen-related activities.Although SPC leadership reports good working relationships with other relevant NCEP centers, the same does notappear true at the level of operations staff. Additionally, the absence of a programmatic budget for HWT limits the extent to which it can be used as a mechanism for interacting with other centers. These issues may be ameliorated to a great extent by focusing on HWT as a vehicle to move forward several important and timely initiatives, e.g., spin-up of the AWT.

Recommendation BP2: Attention needs to be given to more effectively capturing and communicating user needs at multiple levels into SPC product road maps.A number of areas exist where SPC and NCEP need to coordinate communication between operations staff and management, operations staff and customers, management staff and NCEP management, and NCEP and other service Centers. This issue is especially critical due to current and likely future resource constraints, and as a mechanism to provide optimum customer service.

Recommendation BP3: Consideration should be given to more frequent meetings between management and staff, not only to communicate information to staff but also to obtain their input on emerging activities, milestones and products.It is apparent that staff members believe updates from management about issues that impact them are too infrequent. Similarly, the current meeting frequency fails to provide staff anadequate opportunity to share with management their ideas about products, services and research. Staff members do recognize the challenges of meeting this goal in the context of an event-driven 27x7 environment. However, a higher frequency of meetings should result in operations staff feeling more connected to the SPC team, and empowered to provide input that no doubt will be valuable to SPC leadership.

Recommendation BP4 To be more effective in collaborating and especially working at organizational interfaces, mechanisms should be developed and implemented to provide SPC staff with opportunities to become familiar with, and have greater direct interaction with, appropriate sister NCEP service centers.It is in the interest of SPC, NCEP, NWS and NOAA to engender as much inter-organizational cohesiveness as possible. Budget concerns alone should be sufficient to force collaboration; however, it is apparent from discussions with SPC staff and management that a strong desire exists to make SPC an even more vital part of NCEP.

Two possible impediments to full and open collaboration are the feeling that other centers receive more direct credit in the public eye for their work than does SPC, and that other centers also receive preferential treatment in staffing levels. Assuming these to be the case, it is understandable why SPC staff and management fail to initiate interaction with other centers except on anas-required basis. Further, this feeling leads to distrust of NCEP more broadly. These issues point to a lack of clear communication within NCEP that must be addressed.

Recommendation BP5: NCEP needs to review IT security mandates and administrative processes within SPC, especially those that seem to act as a roadblock to desired productivity improvements.A seemingly inordinate amount of time is spent at SPC addressing IT security and PPBES issues. Although necessary, these two systems have a noticeable negative impact on staff workload, especially in an already resource-constrained environment which. Itwould seem logical for NCEP and/or NOAA to streamline these processes/systems as much as possible and deploy them within all Centers in a manner that minimizes duplication of effort and cost.

Recommendation BP6: Serious consideration should be given to formalizing regularly scheduled training for all SPC personnel. While the type and audience for training will vary, the frequency and amount of training should be relatively consistent among NCEP service centers.Training, both initial and recurring, is a critical component of any organization but often is given lower priority in times of constrained budgets and limited personnel. Although deferring staff professional development may result in short-term gains, long-term impacts can be highly negative in multiple ways.

First, employees who fail to remain current on the latest techniques in their profession and utilization of work productivity tools (e.g. web design, modern scripting languages, graphical tools) are unable to produce the best results. Second, morale is negatively impacted because employees view themselves falling behind professional colleagues elsewhere. Neither of these is desirable. Training should be given a high priority by NCEP and SPC management in the development of budgets and work schedules. Third, limited opportunities exist for professional advancement of IS personnel because the top-level employee in this bracket holds a GS-13 classification.

Appendix A

National Centers for Environmental Prediction Review
Charge to the Review Panels

Charge

The University Corporation for Atmospheric Research (UCAR) will carry out a review of the National Centers for Environmental Prediction (NCEP) in 2009 through a series of panels that will assess the individual Centers, their interaction with each other and with other NOAA, federal, academic and non-governmental entities to determine how effectively NCEP is accomplishing its mission and realizing its vision. In particular, for each Center and NCEP as a whole, the Review will assess:

- Statements of mission, vision and five-year plans.

- Productivity and quality of scientific activities and/or operational products and services with an emphasis on the progress since the most recent review.

- Relevance and impact of the researchand/or products. Ability to meet customer demand and emerging requirements.

- Effectiveness of activities or specific plans for transition of research to operations (R2O), including research conducted outside NCEP within NOAA, within the federal research enterprise, and in academia or the private sector.

- Effectiveness of activities or specific plans for support of research by and/or joint efforts with program elements within NOAA that provide support for or conduct research as their primary mission and also with outside entities (academia; research laboratories) via the provision of operational products, services and in-house support (operations-to-research - O2R).

- Balance between operational responsibilities and research and development initiatives.

- Programmatic plans for new scientific activities and operational products and services, including plans for continuations and terminations.

In addition, the Review will address any specific other issues or questions raised in the course of the review.

Procedure

1. The Review will be organized under the leadership of an Executive Committee composed of two co-chairpersons, representatives of the operational environmental prediction and NCEP user communities, and each of the chairpersons of the individual Center Review Panels. Each Center Review Panel will have 5-6 members with diverse representation from academia, federal labs and users. The Executive Committee will develop a slate of panel members in consultation with the Director of NCEP. The Executive Committee will recommend a panel review slate to the President of UCAR, who will appoint the Review Panels.

2. The following documentation will be requested from each Center and NCEP:
   - Vision and mission statement (strategic plan, if extant)
   - Organization chart and list of present staff and visitors (staff turnover since last review)
   - Summary narrative of recent highlights and accomplishments
   - Summary narrative of R2O and O2R activities
   - Summary narrative of collaborative work
   - List of publications and/or reports since last review (with sample of reprints)
   - List of products and services, along with selected samples
   - Summary of budget, sources of support and expenditures
   - The NCEP and/or individual Center responses to the reviews conducted between 1996 and 2001.

3. Each Center will be asked to submit documentation, at least one month before the on-site visit, to UCAR for distribution to Review Panel members before the on-site visit.

4. An on-site review (typically 1.5-2 days) will be conducted at each Center. The date for each review will be fixed in consultation with the Center Director and the Director of NCEP.

5. Each Review Panel will provide a preliminary briefing to the Director of NCEP at the conclusion of each on-site review.

6. Each Review Panel will write a report of its findings. A draft of the review report for each Center will be shared with the Center Director to correct any factual errors.

7. The Executive Committee will write a final report, directed to the President of UCAR, that summarizes the findings of the reviews of the individual Center as well as NCEP as a whole, and will make recommendations for improvements.

UCAR will provide administrative help for the preparation of the individual Center Review Panel reports and the final report of the NCEP Review.

Appendix B

SPC Review Panel Membership

Kelvin K. Droegemeier (Chair)
University of Oklahoma

Greg Forbes
The Weather Channel

Maria Pirone
Atmospheric and Environmental Research, Inc.
(subsequently joined Harris Corporation during the review)

Marcia Politovich
National Center for Atmospheric Research

Warren Qualley
Harris Corporation

Yvette P. Richardson
The Pennsylvania State University

Mark Weber
MIT Lincoln Laboratory

NCEP Review Executive Committee Members

Frederick Carr (Co-chair)
University of Oklahoma

James Kinter (Co-chair)
Center for Ocean-Land-Atmosphere Studies

Gilbert Brunet
Environment Canada

Kelvin K. Droegemeier
University of Oklahoma

Genene Fisher, Panel Chair
American Meteorological Society

Ronald McPherson
American Meteorological Society (Emeritus)

Leonard Pietrafesa
North Carolina State University

Eric Wood
Princeton University

Appendix C

List of Acronyms

AFB	Air Force Base
AFWA	Air Force Weather Agency
AO	Administrative Officer
AWIPS	Advanced Weather Interactive Processing System
AWIPS-II	Second Generation Advanced Weather Interactive Processing System
AWC	Aviation Weather Center
AWT	Aviation Weather Test Bed (at the Aviation Weather Center)
BP	Business Processes
CAPS	Center for Analysis and Prediction of Storms
CCFP	Collaborative Convective Forecast Product
CIMMS	Cooperative Institute for Mesoscale Meteorological Studies
CP	Customers and Partners
CPC	Climate Prediction Center
EEO	Equal Employment Opportunity
EMC	Environmental Modeling Center
FAQ	Frequently Asked Questions
FISMA	Federal Information Security Management Act
FTE	Full Time Employee
GIS	Geographic Information Systems
GOES-R	Geostationary Operational Environmental Satellite
GPS	Global Positioning System
GS	General Scale
HPC	Hydrometeorological Prediction Center
HWT	Hazardous Weather Test Bed (at the Storm Prediction Center)
IT	Information Technology
IS	Information Systems
MD	Mesoscale Discussion
N-AWIPS	NCEP AWIPS
NCAR	National Center for Atmospheric Research
NCEP	National Centers for Environmental Prediction
NCO	NCEP Central Operations
NextGen	Next Generation Air Transportation System
NOAA	National Oceanic and Atmospheric Administration
NSF	National Science Foundation
N-SHARP	NCEP SHARP
NSSL	National Severe Storms Laboratory
NWC	National Weather Center building
NWS	National Weather Service
NWSEO	NWS Employees Organization
O2R	Operations-to-Research

OAR	Office of Atmospheric Research
OCS	Oklahoma Climatological Survey
OPC	Ocean Prediction Center
OU	University of Oklahoma
POC	People and Organizational Cuture
PPBES	Planning, Programming, Budgeting and Execution System
PRodgen	SPC Product Generator
PS	Products and Services
PWO	Public Severe Weather Outlook
R2O	Research-to-Operations
REU	Research Experiences for Undergraduates
RUC	Rapid Update Cycle (Model)
SCEP	Student Career Employment Program
SELS	Severe Local Storms Unit
SHARP	Skew-T/Hodograph Analysis and Research Program
SOO	Science and Operations Officer
SPC	Storm Prediction Center
SREF	Short Range Ensemble Forecast
SSEF	Storm-Scale Ensemble Forecast
SSWIM	Social Sciences Woven Into Meteorology
ST	Science and Technology
SWPC	Space Weather Prediction Center
TPC	Tropical Prediction Center
UCAR	University Corporation for Atmospheric Research
VORTEX-II	Verification of the Origins of Rotation in Tornadoes Experiment II
WCM	Warning Coordination Meteorologist
WDTB	Warning Decision Training Branch
WFO	(US National Weather Service) Weather Forecast Office