

2009 Community Review of the NCEP Office of the Director

**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 Office of the Director (OD).

The vision of “NCEP as a whole” being greater than the sum of its parts is being realized but is also a work in progress. NCEP is performing well in its primary mission of providing products and services in support of protecting life and property in a timely manner. Many of its service centers are recognized as world leaders in their particular missions. The interactions between centers are increasing, although improvement is needed in this area. The Review Panel commends the strong leadership of the NCEP Director and his staff members for the significant progress NCEP has made over the past decade. NCEP’s mission is unique in the U.S., and has been noted as a “national resource”; as such, it has the opportunity to leverage this leadership and respect to achieve higher goals.

This is a very crucial, perhaps watershed, moment for NCEP in which effective leadership and resources are essential if NCEP is to regain/retain its competitive advantage in the world. Important decisions are imminent on how to lead and resource a large number of key initiatives, possibly in competition with other agencies or even other National Weather Services (NWS) and National Oceanic and Atmospheric Administration (NOAA) programs.

The fundamental challenge within NCEP is that it is under-resourced for its mission. Each center reported that it is providing more services and products, with additional requests in the pipeline, with roughly the same number of personnel since the last review. At the Environmental Modeling Center (EMC) of NCEP, the numerous additional demands for improved or new modeling and data assimilation systems added to an already broad mission has precluded any one system from being considered “world-best”.

There is sentiment in the community that EMC is not equipped to fulfill its mission or realize its vision, i.e., it cannot deliver world-leading models with its current structure and broad mission, for which it is under-resourced. The EMC mission should be carefully evaluated and either reduced in scope to align with the resources or the resources should be increased to align with the broad mission. This should be done in combination with a comprehensive plan to initiate partnerships with other modeling groups within NOAA, other federal agencies and the academic community. The latter is recommended owing to EMC’s reputation for being unreceptive to external collaboration, a perception that often (unfairly) characterizes NCEP as a whole. NCEP personnel are correct to note that the research community has a lack of appreciation of the constraints that are imposed by the requirements for timeliness, dependability and accuracy on any operational center. Nevertheless, better understanding and cooperation between operational and research scientists are absolutely essential for NCEP to fully achieve its mission.

For the NOAA numerical weather and climate prediction endeavor to serve the nation adequately and be comparable to those that are the best in the world, NCEP must:

- Create a culture and work environment that attracts an extraordinary cadre of talented scientists skilled in various aspects of numerical weather and climate prediction. This will require innovative personnel policies, a much greater fraction of civil service positions, opportunities for advancement based on scientific and technological contributions, and systematic mechanisms and commitments for ensuring cooperation and collaboration with the national and international modeling communities.
- Deploy computer capabilities that are comparable to or better than those of other major international centers. This will require a substantial increase in computer power and data management and storage facilities.
- Provide adequate human resources to meet the stated operational mission.
- Embrace an entirely new approach to model development and implementation. This will require a substantial effort to focus on creating a single, powerful, flexible, multi-scale atmosphere-ocean-land-surface modeling approach that can be specialized to specific resolutions and time scales. It should be an effort that involves the entire national weather modeling community and engages partners from other agencies, academia, and the private sector.

In addition to taking these steps toward achieving excellence, the Office of the Director should consider the following critical issues:

1. External Advice

The National Centers for Environmental Prediction needs external advice on both scientific aspects of its mission and the further development of its products and services. To enhance its linkage to both the research and private sector communities, NCEP should request from NOAA Headquarters that a science and services advisory board be established.

2. Administrative Workload

The large workload associated with the Office of the Director has grown significantly along with the NCEP mission and budget over the past decade. NCEP requires a Deputy Director who can handle the day to day operations of NCEP as well as many other internally-directed duties, freeing up the Director to think more strategically and forge new collaborations and partnerships within NOAA, the federal government, the US academic community, the private sector and abroad. Also, the vacancy in the position of NCEP Chief Operations Officer should be filled.

3. Future Reviews

In order to preclude large periods of time transpiring before the next set of reviews, NCEP should formalize a periodic review process, to occur every 5-6 years.

These issues are more fully developed in section 5 of this report, and a detailed set of findings and recommendations that address the points above are given in section 6.

1. Introduction

1.1 Purpose – Context and Summary of Charge

The University Corporation for Atmospheric Research (UCAR) was requested in 2009 by the National Centers for Environmental Prediction (NCEP) to conduct a thorough and thoughtful 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 is focused on the Office of the Director of NCEP.

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 NWS'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 that the nation must meet 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 new Next Generation Air Transportation System (NextGen) of the Federal Aviation Administration (FAA) 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 aurora 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 been at a minimum for the past few years, and is expected to rise to its 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 Procedures

The Executive Committee of the NCEP review panel (see Appendix B for membership) conducted its site visit to the Office of the Director (OD) on 6-7 October 2009. To prepare for the visit, a set of questions was provided to the NCEP Director, Dr. Louis Uccellini. Additionally, a set of questions, developed by the NCEP Review Executive Committee, was sent separately to the NCEP center directors and to a group of high-level stakeholders in NCEP, including members of the NWS corporate board, program directors from agencies other than NOAA, and representatives of the private sector. The survey responses were received by the Executive Committee and will be held in confidence. The responses helped in the development of the site review and in the writing of this report.

During the site review, Dr. Uccellini presented an update on NCEP and responded to the questions provided in advance by the Executive Committee. The questions and answers provided a basis for much of the discussion on the first day of the review. The members of the staff of the Office of the Director were interviewed separately. In addition, Wayman Baker was interviewed by telephone prior to the site review (25 September), in advance of

his imminent retirement, by members of the Executive Committee. The visit concluded with a briefing of initial findings and recommendations to Dr. Uccellini.

2. Overview of the National Centers for Environmental Prediction

2.1 Mission and Vision

Vision:

NCEP seeks to be “the Nation’s trusted source, first alert and preferred partner for environmental prediction services.”

Mission:

“NCEP delivers science-based environmental predictions to the Nation and the global community. We collaborate with partners and customers to produce reliable, timely and accurate analyses, guidance, forecasts and warnings for the protection of life and property and the enhancement of the national economy.”

In fulfillment of its mission, the NCEP product suite includes regional, national and global weather, water, climate and space weather analyses, forecasts, warnings and guidance.

2.2 Strategic Plan

In 2008, NCEP, with its stakeholders, developed a Strategic Plan to guide its activities for the years 2009-2013. The NCEP Strategic Plan articulates the following six strategic goals:

- *Customers and Partners* – Ensuring the value, usability, and relevance of NCEP products and services
- *Products and Services* – Improving decision support capability to meet the widest spectrum of user and partner needs
- *Information Systems* – Enhancing the real-time, on-time, all the time access, display and delivery of NCEP products and services
- *Science and Technology* – Accelerating science and technology infusion to enhance the value of NCEP guidance, analyses, forecasts and warnings over all spatial and temporal scales
- *People and Organizational Culture* – Developing, valuing and sustaining a highly skilled and flexible workforce that excels in service, teamwork and innovation
- *Business Processes* – Strengthening and integrating business processes that encourage innovation, manage change, promote efficiency, and hold individuals accountable for results at all levels.

The NCEP Review Panel organized this and all center reports within the framework of each center's mission, vision and these strategic goals. Thus the attributes to be assessed as enumerated in the charge in Appendix A are incorporated into this framework.

2.3 Brief History

NCEP was formed from existing components of NOAA in 1995. The principal initial components were the National Hurricane Center in Miami, the National Severe Storms Forecast Center (NSSF) in Kansas City, and the National Meteorological Center in Camp Springs, Maryland. Prior to the official formation, the Space Environment Laboratory (SEL) of NOAA's Office of Oceanic and Atmospheric Research (OAR) was added, in a somewhat tentative way: SEL remained partly in OAR, and partly in NWS, but its funding came from OAR. It was not until 2005 that what is now the Space Weather Prediction Center was fully transferred to the NWS.

The Aviation Weather Center was formed from a convective weather advisory unit of the NSSF, and an aviation unit of the National Meteorological Center (NMC). The Climate Prediction Center began in the 1970s as the Climate Analysis Center, attached to the NMC. The Ocean Prediction Center was to be formed jointly with the NWS contributing the operational component, and the National Ocean Service contributing a development component. That did not come to fruition, and for more than a decade the OPC shared a leader and several of the administrative staff members with the Hydrometeorological Prediction Center, which came from the NMC's Meteorological Operations Division.

The Storm Prediction Center has its origin in the Severe Local Storms unit of the NSSF. It was moved to Norman, OK, in order to reunite it with the National Severe Storms Laboratory of OAR.

These components all had their own histories and cultures, and integrating them into an organization in which "the whole is greater than the sum of its parts" was, and continues to be, a challenge.

2.4 Organizational Structure

The NCEP organization is represented (Fig. 1) in a concentric configuration with EMC at the heart of the organization, developing models and data assimilation methods that are used operationally by NCO to provide the analyses and numerical guidance for practically all the products that are generated by the NCEP service centers (AWC, CPC, HPC, OPC, SWPC, SPC, and TPC). The Office of the Director is a small organizational unit that sits atop this organizational schema, providing administrative, managerial, budgetary and strategic support for the nine centers.

The NCEP is a large component of the NWS, with an annual budget of approximately \$100 million, 430 civil service employees, 8 of whom are in the Office of the Director, as

well as 167 contract employees, 5 NOAA Corps officers, and a varying complement of 40-60 outside visitors. The products and services provided by NCEP are intended to be a seamless suite that extends from lead times of a few minutes to about a year and serves a broad range of stakeholders including aviation interests, marine interests, space weather- and fire weather-sensitive operations, emergency management, energy, agriculture, and recreation. NCEP seeks to collaborate with a wide range of partner organizations within NWS, within NOAA, in other federal agencies, in the academic community and in the private sector. To enhance collaboration and accelerate the transition from research to operations, NCEP has established testbeds in all of its service centers (except OPC, which has external partnerships for the transition from research to operations (R2O)).

NATIONAL CENTERS for ENVIRONMENTAL PREDICTION

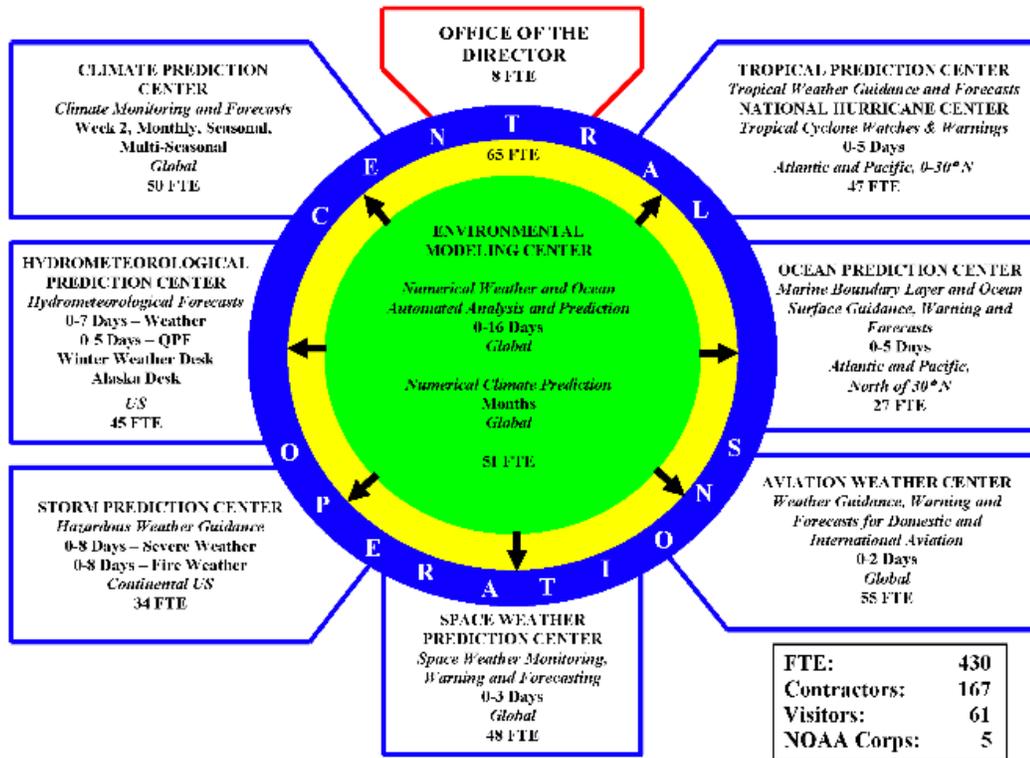


Figure 1. Representation of NCEP organization provided by NCEP Director. Staff numbers are current as of 6 October 2009.

As mentioned above, this report is organized around the vision, mission and NCEP Strategic Plan goals. First, developments since the last review, and a summary of stakeholder responses are presented in Sections 3 and 4. Section 5 will provide general observations and overarching concerns arising from the review, for both the Director’s Office and the nine centers. Section 6 contains findings and recommendations for the Office of the

Director mapped into the Strategic Plan. The charge to the Review Panel in Appendix A is within these findings and recommendations.

3. Developments Since Last Review

Several of the NCEP centers have been reviewed at some point in the decade preceding this review. NCEP as a whole was reviewed by the NCEP Advisory Panel (NAP) in 1999. At that time, the review panel focused on the (then) draft NCEP strategic plan, the balance of funding for EMC between base funding and “soft money”, and the potential move of NCEP to a new facility on the campus of the University of Maryland. Since that review, NCEP has made several important achievements.

- Finalized its Strategic Plan and established a strategic planning process to evaluate progress and update the strategic plan. The latest NCEP Strategic Plan is for the period 2009 – 2013.
- Established a partnership with the University of Maryland and initiated construction of a new building to house several centers of NCEP.
- Added a backup computer for failsafe operations.
- Improved management processes and strengthened the partnership with the NWS employee’s organization.
- Fostered increased collaborations among centers, and between World Forecast Offices (WFO) and centers.
- Began building multi-model ensembles across the seamless suite of forecast products.
- Established testbeds for aviation, climate, hurricane, hydrometeorology, satellite data assimilation, severe weather, space weather; and a Developmental Test Center in Boulder.
- Provided reliable, on-time delivery of products and formalized the customer requirements process.
- Organized its products around a seamless suite of operational environmental analysis, diagnostics and forecasts integrated across time and space and forecast applications.
- Extended forecasts and outlooks for extreme events.

Despite these significant advances, NCEP still faces several difficult challenges:

- Computing resources remain far below what is needed - NCEP does not have sufficient computing resources for its current mission, much less the prospectively expanded mission envisioned in the future (e.g. space weather, ocean prediction, increased resolution models, ensembles, four-dimensional variational data assimilation (4DVar), etc.).
- Entraining the best understanding, techniques and practices from the research community is slow and not as effective as it could be.
- Its mission portfolio is very large, and there are pressures to increase the portfolio due to the advent of NextGen (advanced, GPS-based aviation systems), potential requirements for decadal prediction of climate and climate change, and expanding forecast challenges in space weather, ecosystems, air quality, and other areas that are beyond the traditional meteorological domain.
- The move to the new building has been significantly delayed, yet again, most recently by economic factors associated with the national recession that are well beyond the control of NCEP, NWS, or NOAA. This additional delay has had a serious negative effect on staff morale, budgeting, and the ability to address long-standing issues such as building a more effective visitor program or enabling a richer set of collaborations.

Meeting these challenges and accelerating progress to achieve the vision remain the largest difficulties facing NCEP.

4. Summary of Stakeholder Survey

A survey of NCEP stakeholders was performed prior to the site visit. The survey consisted of seven questions and was done by e-mail. The survey was sent to all nine Center Directors (internal stakeholders) as well as external stakeholders. The latter included NWS Corporate Board members, NOAA OAR laboratories, leaders from the National Environmental Satellite, Data and Information Service (NESDIS), the National Aeronautics and Space Administration (NASA) and the National Center for Atmospheric Research (NCAR), and selected representatives of the private sector. All nine Center Directors responded to the questions, but only five responses were received from the external stakeholders. This section will summarize the strengths and weaknesses of “NCEP as a whole” as well as suggestions for improvement, as determined from stakeholder responses. In some instances, the Center Director (CD) responses will be noted specifically.

All stakeholders considered NCEP to be meeting its fundamental obligations to provide products and services to protect life and property. The CDs felt that the return on investment was remarkable and that NCEP’s performance could be even better with more resources. The seven forecast centers received higher praise than the EMC and NCO units, which is consistent with the mission over-extension discussed elsewhere in this report. Suggestions included expanding the product suite (especially probabilistic guidance), increasing coupled-

model prediction, improving integration of NCEP products within the National Weather Service as a whole, quantifying the value and economic benefits of NCEP forecasts, and improving the quality of quantitative precipitation forecast products.

Most respondents felt that NCEP is a world leader, but not at the top. Lack of sufficient computer resources and human capital in model development were cited as reasons, as was NCEP's broad portfolio and the less-than-ideal interactions with OAR and the academic community. The latter issue could be addressed through better coordination within NOAA and partnering with the U.S. research enterprise. Other suggestions included running and disseminating products at higher resolution (i.e., network bandwidth needs attention), and improving and automating the model assessment process.

The effectiveness of NCEP in technology transfer received mixed reviews. All service centers have individual success stories but progress in technology transfer for the primary modeling and data assimilation missions of NCEP was deemed weaker. The many testbeds were mentioned but they all operate differently, with varying degrees of success, and could be utilized more effectively. There are some successes in interaction with the research community, but much more could be done with improved visitor programs and an independent funding mechanism that would concentrate on projects rather than organizations. NCEP was noted as responsive to problems identified by NWS Forecast Offices, but also for having user-unfriendly and undocumented code. Suggestions included having an independent verification/evaluation group, providing workstation versions of its modeling systems for community use, and establishing an overall technology infusion team to provide guidance on responding to technology opportunities.

The survey assessed a related issue on how well NCEP is integrated into the weather research communities. While some CDs noted that they are in communication with the research community or aware of its recent developments, most noted that full integration could not occur without a grants program. Also, since the operational side of their organizations has highest priority, the latter could not be done without some of the resources being directed toward the centers as well. Suggested resource mechanisms included enhancements of the CSTAR program, increased testbed funding, a NOAA grants program, an enhanced visiting scientist program, and the creation of a Model Test Facility. Long-range development projects should consist of teams comprised of NCEP and external community members.

A goal of NCEP is that the "whole is greater than the sum of the parts" and the survey revealed that stakeholders believe that this aspect is better than in the past but can still be improved. Interaction between the service centers was viewed as being better than between those centers and NCO/EMC, and between NCO and EMC. For example, "mission creep" within EMC was seen as limiting the ability of service centers to excel. Some CDs noted that provision and integration of information technology (IT) services were better within the co-located centers at Camp Springs than for the external service centers, but others noted that this could still be improved even within the World Weather Building. NCEP-wide projects are still difficult to achieve and more interaction and teamwork is needed among CDs and the OD. Expanding the Joint Center for Satellite Data Assimilation (JCSDA) to study all

possible data solutions was suggested. Cited under-resourced efforts included space weather, land-surface modeling and efforts with the hydrologic community. Some CDs gave credit to strong NCEP leadership in promoting an integrated rather than stovepipe approach, but also noted that the Director's Office is quite understaffed given its mission.

Respondents' suggestions for issues to be raised in the OD review were incorporated into the questions sent to the OD in advance. Most CDs respect the quality, level of effort, and integrity of the Director's Office. They again noted that the OD office is understaffed, with the addition of a Deputy Director and a Chief Operations Officer being common suggestions. Excellent communication, management and leadership were noted.

5. General Observations and Overarching Issues

5.1 Office of the Director

The Review Panel found that NCEP is performing well in its primary mission of providing products and services in support of protecting life and property in a timely manner. Many of its service centers are recognized as world leaders in their particular missions. The interactions between centers are increasing, although improvement is needed in this area. Thus the vision of "NCEP as a whole" being greater than the sum of its parts is being realized but is also a work in progress. The Review Panel commends the strong leadership of the NCEP Director and his staff members for the significant progress NCEP has made over the past decade. The NCEP mission is unique in the U.S., and has been noted as a "national resource"; as such, it has the opportunity to leverage this leadership and respect to achieve higher goals.

The fundamental challenge within NCEP is that it is under-resourced for its mission. Each center reported that it is providing more services and products, with additional requests in the pipeline, with roughly the same number of personnel since the last review. However, the problem is most evident in EMC and NCO, the latter primarily because of the shortage of hardware capabilities to serve the mission (see 4. below). At EMC, the numerous additional demands for improved or new modeling and data assimilation systems added to an already broad mission has precluded any one system from being considered "world-best". The vision of a community model approach is not fully embraced at EMC, which has created an impression of being unfriendly to external collaboration, a perception that often (unfairly) characterizes NCEP as a whole. It must be noted that this impression arises partly from a lack of appreciation on the part of researchers of the constraints that are imposed by the requirements for timeliness, dependability and accuracy on any operational center. Nevertheless, better understanding and cooperation between operational and research scientists is absolutely essential for NCEP to fully achieve its mission.

This review is timely as this is a very crucial, perhaps watershed, moment for NCEP in which effective leadership and resources are essential if NCEP is to regain/retain its competitive advantage in the world. It currently has the opportunity to exert national

leadership on pressing weather, climate and environmental issues. Some of these issues include:

- The growing importance of and NOAA's emphasis on providing climate services
- NCEP's role in NextGen
- Expansion into forecasting ecosystems, decadal climate, air and water quality, space weather
- Improving high-performance computing, information technology (IT) security, storage and bandwidth
- Multi-model ensembles and probabilistic forecasting on all scales
- Advent of the National Polar-Orbiting Operational Environmental Satellite System (NPOESS) era
- Warn-On-Forecast and Hurricane Forecast Improvement Program initiatives
- Need for improved data assimilation and linkages to observing systems
- The transitions to Second Generation Advanced Weather Interactive Processing System (AWIPS2) and National Environmental Modeling System (NEMS).
- New Global Forecast Systems (GFS) and Climate Forecast System (CFS) models, and associated reanalysis/reforecast efforts.

Important decisions are imminent on how to lead and resource these initiatives, possibly in competition with other agencies or even other NWS and NOAA programs.

In reviewing the Office of the Director, several specific overarching issues were identified that are enumerated below. In each case, we provide Findings and make specific Recommendations.

1. Leadership

Finding: There is a serious lack of cooperation between the Directors of EMC and NCO, which is damaging to NCEP as a whole. The site review panel perceives that this is due in large part to the NCEP Director's decision to introduce more disciplined processes with respect to the implementation and improvement of the operational model suite and with respect to information technology (IT) activities. The site review panel recognizes and supports this decision as necessary and important, and the role of NCO in leading and managing this process.

Each of the two leaders (EMC Director and NCO Director) has very strong, positive characteristics. The EMC Director is an outstanding scientist and expert in numerical weather prediction (NWP), widely known in the community. He is protective of and respected by the EMC staff. The NCO Director has brought stability, discipline and purpose to the operational arm of NCEP. The Director and staff of EMC, whose mission exceeds the resources provided to accomplish it, view the additional strictures imposed by IT organization and discipline as onerous. Possibly as a result of the stresses inherent in this situation, neither the EMC Director nor the NCO Director seems able or willing to cooperate with the other, although the new Deputy

Directors of EMC and NCO have taken positive steps to reduce this tension. The site review panel views this as a serious managerial problem.

Recommendation: The NCEP Director must resolve this problem in the near future.

2. External Advice

Finding: NCEP needs external advice on both scientific aspects of its mission and the further development of its products and services.

Recommendation: To enhance its linkages to both the research and private sector communities, NCEP should request from NOAA Headquarters that a science and services advisory board, linked to the testbeds, be established under the auspices of the NOAA Science Advisory Board. Also, the newly formed Environmental Information Services Working Group (EISWG) of the NOAA Science Advisory Board, using its charge to improve two-way communications between the public sector and America's weather enterprise, could examine the collaborations between NCEP and the external community. Furthermore, while some NCEP service centers have begun to work with the social sciences research community, all service centers require access to social science expertise to help them understand how better to package and deliver weather and climate information.

3. Administrative Workload

Finding: There is a very large workload associated with the Office of the Director that has grown significantly along with the NCEP mission and budget over the past decade. In particular, there are full-time operational, strategic planning, research-to-operations transition, international support, labor relations and public affairs duties that significantly overstretch the capability of one person to fulfill them.

Recommendation: The NCEP requires a Deputy Director who can handle the day to day operations of NCEP as well as many other internally-directed duties, freeing up the Director to think more strategically and forge new collaborations and partnerships within NOAA, the federal government, the US academic community, the private sector and abroad.

4. Computing Capability

Finding: The NCEP computing resources are not commensurate with the scope of the mission. The Central Processing Units (CPU), disk storage, and long-term archival systems are each at least an order of magnitude under-powered relative to the requirement.

Recommendation: The NCEP requires a significant increase in its computing capability, with at least an order of magnitude increase in capability over the next five years.

5. World-class Model Development

Finding: There is sentiment in the community that EMC is not equipped to fulfill its mission or realize its vision, i.e., it cannot deliver world-leading models with its current structure and broad mission, for which it is under-resourced.

Recommendation: The EMC mission should be carefully evaluated and either reduced in scope to align with the resources or the resources should be increased to align with the broad mission. This should be done in combination with a serious plan to initiate partnerships with other modeling groups within NOAA, other federal agencies and the academic community. ‘Partnership’ here means all sides “putting skin in the game” and being held accountable, which may be more substantial than the testbed model of organization. NCEP and NWS leadership are urged to follow a path in which the EMC scientists are involved in the development with a team of partners from the beginning, instead of being relegated to transitioning to operations a model developed elsewhere without their involvement. To do otherwise will result in the EMC scientists not having a sense of ownership, impairing the transition. In the long run, it will also result in an inability to recruit world-class modelers to the EMC.

6. Ongoing Periodic Review

Finding: The NCEP Review charged in November 2008 and conducted in 2009 has been valuable in providing an opportunity for introspection on the parts of the NCEP centers and NCEP as a whole and in making a number of recommendations that are likely to lead to changes and improvements in NCEP’s products and services, interactions with stakeholders, and organizational culture.

Recommendation: In order to preclude large periods of time transpiring before the next set of reviews, NCEP should formalize a periodic review process, to occur every 5-6 years.

5.2 NCEP Centers

In this section, we provide the overarching issues and recommendations for each of the nine NCEP centers. Much more detail is provided in the individual center reports.

1. Aviation Weather Center

Among all NCEP service centers, AWC is unique in that its mission is driven principally by the requirements of a Federal agency different from the one by which it is administered. The review found that AWC provides quality services and has achieved important product innovations. However, AWC is entering a time of great change and its response to and engagement in that change must be carefully planned. To be successful going forward, AWC must: (1) Become more directly involved with planning for the Federal Aviation

Administration's (FAA's) NextGen initiative, which will fundamentally change the way aviation stakeholders interact with the air traffic infrastructure as well as how decisions are made with aviation weather products and services. It is critical that AWC establish itself as a major player on the NWS team supporting NextGen because AWC's role, products and operational strategy likely will be profoundly different in the NextGen era. (2) Establish the Aviation Weather Test Bed as a vibrant environment for intellectual activities and the development of partnerships throughout the aviation weather community. (3) Explore additional mechanisms for automating the creation and delivery of products and services. With programs like NextGen on the horizon, many AWC forecast products will become obsolete unless they are re-tailored into tools for the NextGen decision support framework. Additionally, legacy products need to be carefully examined in collaboration with FAA and users with a view toward eliminating those that are of marginal value or have relatively few users.

2. Climate Prediction Center

The Climate Prediction Center (CPC) serves, as it has done for some time, as a national and global asset for providing climate predictions, analyses and assessment products. The CPC products and services target time scales ranging from weeks to about a year and are vital for NOAA's stewardship of life, property, and the economy. The CPC is recognized as a global leader in climate monitoring, development and dissemination of reanalysis products and intra-seasonal prediction, and CPC stakeholders see CPC as an 'honest broker' of climate information. The vibrancy, commitment and talent of the staff members are clearly evident and contribute to the productivity, value and relevance of CPC. The CPC mission is clearly articulated with its products vital to a NOAA Climate Service (NCS) activity and to the nation. The review panel is concerned that CPC appears to have a low priority in NWS mission planning and in NOAA Climate Service (NCS) initiative, which manifests in a sense of uncertainty about the Center's future mission. The CPC must play a critical and essential role in any future NCS activity, and recommends that ongoing NCS planning fully engage and involve CPC management.

Among NCEP Centers, CPC is among the most interactive and collaborative with a wide variety of other institutions and individuals in the government and academia, which is a necessary consequence of its mission. Within NCEP, CPC interacts productively with HPC, but the relationships between CPC and EMC and CPC and NCO need to be improved. To further enhance CPC's interactions within NCEP, CPC should (1) Develop effective mechanisms that address center roles, mission priorities, and intra-center activities and responsibilities. These are needed in order to build a true partnership between EMC and CPC in facilitating needed improvements to CFS and the development of a National Multi-Model Ensemble (NMME) system. It will also foster a closer relationship between NCO and CPC in R2O transition of CPC products and services that are ready to be made operational. (2) Work with HPC to create a week-2 development team (W2DT) to develop and evaluate a unified (CPC-HPC) forecast product for improved forecast skill at week 2. (3) Establish policies, processes, and practices that will foster interoperability among products and tools within CPC, NCEP, NWS, NOAA, and beyond. (4) Clarify the current structure of the Climate Test

Bed (CTB) to make sure that it addresses its needs for research, product development and R2O transition in support of CPC's (hence NOAA's) mission and strategic plan goals.

3. Environmental Modeling Center

The heart of NCEP's operation is EMC's development of data assimilation methods and models whose products are used in all the service centers. EMC accomplishes much, considering the scarcity of resources available to the Center. The staff is significantly overstressed and computer capabilities and data storage capacities are woefully inadequate. While EMC strives to be the "best in everything," it is falling behind the European Center for Medium Range Weather Forecasts (ECMWF) and other forecast centers because it is working on too many models, exhibits a lack of openness to the research community, and does not promote close proximity of researchers and forecasters.

The review panel recommends that EMC undertake 6 changes to address these critical problems: (1) Create a culture and work environment that attracts extraordinarily talented scientists through innovative personnel policies with a much greater fraction of civil service positions and opportunities for advancement based on scientific and technological contributions. (2) Develop systematic mechanisms and commitments to ensure cooperation and collaboration with the national and international modeling communities. (3) Work closely with NCO to deploy computer capabilities that are comparable to or better than those of other major international centers, which will require a substantial increase in computer power and data management and storage facilities. (4) Provide adequate human resources to meet the stated operational mission. (5) Carefully examine and consider employing new data assimilation capabilities that are significantly advanced beyond those now used. (6) Embrace an entirely new approach, involving the entire national weather modeling community, to model development and implementation with a substantial effort to focus on creating a single, powerful, flexible atmosphere-ocean-land-surface model that can be specialized to specific resolutions and time scales.

4. Hydrometeorological Prediction Center

The HPC provides a valuable service to the nation through quantitative precipitation forecast (QPF) guidance, model diagnosis and interpretation, medium-range prediction and surface analyses. The HPC products and services are widely used and are considered to be of very good quality. The review panel found the HPC staff members to be hard working and dedicated. HPC has a very effective and widely praised international training activity. The HPC has fostered a productive relationship with CPC and works well with NCO, resulting in an effective day-to-day delivery of their guidance products and services. The review panel identified three overarching issues that cut across center activities and affect many of its functions, as well as those of stakeholders outside NCEP: (1) Strategic planning, as evidenced by the Implementation Plan, is insufficient and lacking the necessary information needed to guide HPC's development and evolution over the next five years. (2) As a more specific item to the above, advances in model forecasts (especially as multi-model ensemble (MME) systems evolve), data systems and internet technology will inevitably lead to mission evolution. The HPC must engage their stakeholders and NCEP partners to assess and respond to this evolution. (3) HPC should seek improved and expanded engagement with the

research and development community. New HPC products and services are dependent on this infusion of science and technology.

5. NCEP Central Operations

It is the responsibility of NCO to acquire, deploy, operate and support the requisite computational and data resources and deliver digital products to users in NOAA, other agencies, and the private sector. It is also NCO's responsibility to maintain the flow of a colossal amount of information about the present and future state of the atmosphere that affects decisions about public safety, national defense, corporate actions, and environmental management. Significant challenges lie ahead as observation systems increase in capability and information density, as the conceptual and software frameworks of the computer forecast systems become more complex and powerful, and as users demand forecast products of increasing skill at increasing resolution. NCEP Central Operations has been successful in creating a more rigorous process to manage computation and delivery of products, but the process-oriented management perspective of NCO has not been fully cognizant of the model development perspective of EMC, and thus a fully integrated set of processes composing the requirements of both EMC and NCO are completely absent. This, along with the fact that the present computational and data storage resources are woefully inadequate, has led to tensions and associated efforts to protect perceived prerogatives. Furthermore, NCO, like EMC, is too insular: it is not sufficiently engaged with other operational or research supercomputer centers on the national or international level to take advantage of community advances in development of concepts and implementation of processes for successful management of complex computer systems.

To address the large challenges ahead and reduce the tension between NCO and EMC, the two organizations must (1) Delineate their missions and responsibilities more precisely, integrate their cultures, and work toward the future. (2) Develop a better understanding of the requirements and advantages of creating a more formal and optimal approach to managing their collaboration. (3) Create an effective forecast system scaled to the available resources. (4) Deploy computer capabilities that are comparable to or better than those of other major international centers, which will require a substantial increase in computer power and data management and storage facilities. (5) Foresee future scientific and technological trends and opportunities and seek the computational and human resources to take advantage of them.

6. Ocean Prediction Center

The Ocean Prediction Center, which evolved from the Marine Prediction Group and was established in 1995, was one of the original six service centers of NCEP. The OPC delivers atmospheric and oceanographic warning, forecast, analysis and guidance products and services to all marine-based users and strives to be recognized as the mariner's weather lifeline and the center where NOAA's physical oceanographic observations, modeling research and operational services come together. Based on the site review and the stakeholder survey, the OPC staff members, who are enthusiastic and highly capable, are providing an excellent set of marine weather products and services that are serving the community well. There is an expectation that OPC's mission will expand to include a wider variety of

oceanographic and marine ecosystem products and services to meet the growing demand. The review panel noted that the absence of physical or chemical oceanographers, statisticians and ecosystems specialists on the OPC staff makes meeting this demand challenging. Natural partners are NOAA's National Ocean Service (NOS) and National Marine Fisheries Service (NMFS). In particular, the OPC and NOS should look for areas of mutual interest and responsibility and consider developing a joint center. The NWS has an opportunity to capitalize on the still fledgling Integrated Ocean Observing System (IOOS) observing network in order to enhance the existing marine buoy network and to provide context to the optimal sites of the array elements. There is a trend toward model-based products, which engenders a growing reliance on EMC for product generation. To ensure future success, OPC should: (1) Clearly delineate its requirements to EMC for high quality numerical model output, and a suite of multiple state-of-the-science physics-based models. (2) Consider ensemble forecasting capabilities to address the requirement for probabilistic information. (3) Work with EMC to develop a robust data assimilation capability using modern methodologies.

7. Storm Prediction Center

The Storm Prediction Center is an effective center with balanced operational and research transition activities. The SPC staff members are motivated and energetic with respect to both their defined operational duties and their culture of science awareness and exploitation. The 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 Testbed (HWT) Spring Experiment, in which forecasters and researchers 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. To maximize its success going forward, SPC should: (1) Seek sufficient levels of staffing for new product development and creation; strategies for meeting such needs include greater automation of forecast responsibilities, greater collaboration with outside researchers and other NCEP Centers, and clarification, both internally and externally, that the frequency of certain products will be consistent with staffing levels. (2) Leverage SPC HWT capability with other organizations, particularly AWC, EMC, TPC and HPC, and coordinate more effectively with NWS Weather Service Forecast Offices. (3) 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.

8. Space Weather Prediction Center

The Space Weather Prediction Center is the Nation's official source of space weather alerts, watches, and warnings. Since joining NWS in 2005, SWPC should be commended for many accomplishments amid a reorganization and recruitment of a new Director. SWPC leadership has created several new "partnerships for progress" with other federal agencies, commercial service providers, and international organizations to benefit their customers. They have identified a plan to modernize the Space Weather Forecast Office (SWFO) and create the Space Weather Prediction Testbed (SWPT). Additionally, the Director has

successfully made the case to NOAA on the need for an appropriate budget to carry out their mission, and it is expected the Center will see a budget increase in the coming years. Since its name was changed from the Space Environment Center in 2007, SWPC has been redirecting efforts towards an operational focus and aligning with a reduced scope of its purview to focus on customer products and services.

The review panel fully supports SWPC's mission as an operational center. The SWPC needs to leverage the significant advances in domestic and international space science research funded by agencies such as NASA, National Science Foundation (NSF), Office of Naval Research (ONR), Air Force Office of Scientific Research (AFOSR), Department of Energy (DoE), and the European Space Agency. The panel also supports the transfer of the satellite data activities from SWPC to NESDIS, which allows SWPC to focus on space weather prediction. However, the panel cautions that an overemphasis on operational products with under- (or no) emphasis on involvement with the science will ultimately lead to intellectual stagnation. Interaction with the Cooperative Institute for Research in Environmental Sciences (CIRES) is an area that needs major improvement. SWPC needs to clarify its expectations and requirements for the activities of the CIRES researchers. This is particularly important as parties prepare for the upcoming contractual competition.

An important challenge facing SWPC is the preparation needed for the upcoming Solar Maximum, now projected for 2013. Given our Nation's increasing reliance on space-based assets to perform multiple missions for commerce, resource protection, and military operations, it is imperative that SWPC be postured to provide the best possible space weather impact products. The upcoming Solar Maximum will stress SWPC operations and impose a timeline for addressing issues. In order to prepare for Solar Max, SWPC should: (1) modernize the Space Weather Forecast Office, (2) modernize and ensure certification and accreditation of the SWPC IT system, (3) develop the Space Weather Prediction Testbed, and (4) attract the best possible talent for its workforce and provide as much realistic training to new forecasters as soon as possible.

9. Tropical Prediction Center

The NHC-TPC mission is focused entirely on "hazardous tropical weather". This singular focus on highly recognizable, life-threatening weather, and the overall skill in which the center performs its mission makes the NHC-TPC arguably the most publically visible and well-regarded NCEP center. This public respect and good will can be leveraged to further enhance their already excellent engagement with the Federal Emergency Management Agency (FEMA), Department of Homeland Security (DHS), state/local emergency managers and public outreach. The review panel found that NHC-TPC responded well to the Turner report recommendations. The current leadership deserves credit for improved staff moral and successful administrative changes.

The NHC-TPC has a balanced forecast and research mission. Most hurricane forecasters participate in research during the off-season. The Joint Hurricane Testbed (JHT) has implemented over 2 dozen research projects into operations over the last 10 years. The NHC-TPC should play an important role in the Hurricane Forecast Improvement Project,

especially on intensity forecast research and use of ensemble information. The recognition, that the main driving force behind the significant increase in track forecasting skill over the years has been advances in environmental modeling, suggests that continued increases in skill are possible through higher resolution, increased observations, improved model physics and advanced data assimilation methods. Thus the report recommends that a team be constructed involving NHC-TPC, the Environmental Modeling Center (EMC), the Ocean Prediction Center (OPC), the National Weather Service (NWS), the National Oceanic and Atmospheric Administration's (NOAA) National Ocean Service, the Navy, the research community (both national and international), as well as selected stakeholders, to develop a strategic plan for an advanced, collaborative approach to coastal, surge and ocean observations and forecasting. Because the NHC-TPC has earned respect for its operational reliability, it should continue to leverage its high public visibility and positive image to improve public preparedness.

Conflicting pressures exist from the emergency management community (which wants extended forecast lead times) and the reality of current forecast skill, especially of intensity. As forecast skill continues to improve, however, opportunities to further increase lead times should be strongly considered. Additional recommendations and issues connected to the future success of NHC-TPC include: (1) adding more oceanographic expertise; (2) increasing visibility and products for storm surge and inundation; (3) employment of more Spanish and French-speaking personnel; (4) possible realignment of OPC and NHC-TPC responsibilities; (5) working with the FEMA and DHS on joint national level training and exercise units; (6) improving communication with the World Meteorological Organization (WMO) Regional Association IV (RA-IV) countries in its area of responsibility; and (7) increasing real-time verification and feedback efforts as well as case studies of failed and successful forecasts.

6. Findings and Recommendations

6.1 Mission and Vision

Finding MV1: The site review panel finds that the organization of the nine centers that comprise NCEP are, on the whole, well-managed and interoperating at a level that provides significant benefit over and above what could be achieved by the individual centers if they were not coordinated. In other words, the whole of NCEP is greater than the sum of its parts.

Finding MV2: The current NCEP Director's efforts to make collaboration among the NCEP service centers a strategic basis for improvement are good.

Finding MV3: Considerable work remains to be done, specifically in breaking down barriers among service centers, between EMC and NCO, and between EMC/NCO and several of the service centers.

Recommendation MV1: To facilitate the improvement, the NCEP Director needs to engage continuously the service center directors in strategic planning (in addition to planning associated with the Annual Operating Plan - AOP - and NCEP Technical Operating Plan - NTOP).

Finding MV4: The site review panel recognizes and commends the NCEP Director for strong leadership. Due in part to his leadership, there has been considerable progress made in NCEP as a whole since last set of reviews.

Finding MV5: All NCEP service centers have met or exceeded their Government Performance and Results Act (GPRA) performance measures.

Finding MV6: Partly as a result of the large loss of civil service human resources in the 1990s without a commensurate reduction in mission, and also as a result of its expanding mission, NCEP, particularly EMC, has become overly reliant over time on soft money support. This is a risk to the NCEP mission.

Finding MV7: NCEP is under-resourced with respect to its scope and the vision of its future.

Recommendation MV2: The ratio of funds from the NOAA base to funds from soft NOAA and non-NOAA sources needs to be increased, in order to mitigate risk to the execution of current and future core mission components. One way to effect this change is by increasing collaboration with partners to offload the non-mission-critical activities, for which partnership agreements to jointly manage resources and jointly develop and monitor annual operating plans are critical.

Finding MV8: The NCEP mission portfolio is very large, and there are pressures to increase the portfolio due to the advent of NextGen, potential requirements for decadal prediction of climate and climate change, and expanding forecast challenges in space weather, ecosystems, air quality, and other areas that are beyond the traditional meteorological domain.

Finding MV9: The evaluation and implementation of changes to the NCEP modeling suite is an important process that involves all NCEP centers. However, the process appears to be contentious and often ineffective.

Recommendation MV3: The Director of NCEP needs to work with all center directors, particularly EMC and NCO, to design a thorough, standardized and competent evaluation and implementation process. The design of this process should take into consideration the possibility of involving an independent evaluation entity. At the same time, it can not be so burdensome as to preclude steady implementation of necessary improvements.

Recommendation MV4: To address the issues of the provision of weather services and interaction with the research community more holistically, NCEP, or more properly NOAA, should consider requesting the National Academy of Sciences (NAS) to conduct a study on how NCEP, NWS (field offices), NOAA, the academic community and interested stakeholders could engage more effectively.

Finding MV10: The NCEP service centers are beginning to work and/or communicate well together on some activities. For example, the new sharing of testbed resources between SPC and AWC, and the ongoing effort to collaborate on the development of week-2 forecast products between CPC and HPC, are encouraging. Given the many areas of common interest among the service centers, many potentially beneficial collaborations could be enhanced or initiated.

Recommendation MV4: The NCEP Director should look across the organization for potential new or enhanced collaborative opportunities among the service centers and with outside entities.

Finding MV11: Connecting annual evaluations to the quality of collaborative efforts is an excellent practice that is already proving to be effective.

6.2 Customers and Partners

Finding CP1: NCEP has taken strides toward openness and collaboration within NOAA, with other US institutions, and with international partners. The establishment of testbeds in several of the service centers has been useful and valuable and has the potential to entrain research results from other NOAA laboratories and the academic community and to enable the transition from research to operations in an effective way.

Finding CP2: Despite the progress in this area, the effectiveness and impact of the testbeds has varied considerably from center to center, and NCEP remains insufficiently engaged with the community. The visiting scientist program at NCEP has waxed and waned over the years and is currently in a relatively low state of activity and integration across NCEP.

Finding CP3: Despite active participation in international programs, NCEP does not have as strong an international leadership role as it should.

Recommendation CP1: A multi-faceted plan is needed that builds on the organizational strengths of NCEP and the early successes and lessons learned from the testbeds to enhance engagement with the rest of the community.

Recommendation CP2: A more vigorous visiting scientist program is needed that is tightly linked to programs in the academic community and driven both by scientific issues and mission demands.

Finding CP4: Outreach to partners and stakeholders deserves praise. For example, all NCEP centers are working hard to improve data/product dissemination (e.g. web services).

Finding CP5: While the surveys and the review panel found that NCEP responded well to Forecast Office problems with model guidance, increased dialog with other organizations within the National Weather Service is desirable; e.g., with the Office of Hydrology,

forecast/climate services in the Office of Climate, Water and Weather Services (OCWWS), Regional Offices, and the Office of Science and Technology.

Recommendation CP3: NCEP should solicit feedback, and suggestions for improved products and services from partners and stakeholders within the NWS.

6.3 Products and Services

Finding PS1: NCEP is among the world leaders in making real-time weather and climate data, codes, and other products freely available.

Finding PS2: The staff members of the OD provides a highly professional and timely suite of administrative services to the rest of the NCEP organization.

Finding PS3: The suite of products and services is expected to evolve over the next few years in response to increasing demands in areas that have traditionally been served by NCEP (aviation, seasonal climate, severe weather, oceanic and coastal areas, fire weather, and space weather), areas that are expected to emerge in the future (ecosystem prediction, NextGen, National Climate Service, air and water quality, homeland security and others), and possible new directions that will be defined as part of the new NWS strategic plan that will be released in April 2010.

Finding PS4: While the NTOP process helps identify redundancies across NCEP centers, there is no provision for discontinuing products or services.

Recommendation PS1: The Office of the Director will need to manage a growing portfolio of activities spread across the Centers to meet the growing and emerging demands for products and services. Such management should include a rational process for periodic identification and discontinuation of products that are obsolete or low in demand.

6.4 Information Systems

Finding IS1: The entire NCEP enterprise depends critically on information systems and information technology (IT). NCEP has a requirement to stay abreast of the latest developments in high-end computing (HEC), data transmission, storage and management, data analysis and visualization, and web services. More transformative improvements in product generation and delivery capabilities will require a more expansive paradigm in the design of products, the interface by which users access products, and the underlying technological systems for delivering products.

Recommendation IS1: NCEP should establish policies, processes, and practices that will allow users to create (1) customized interactions with its information systems, including dynamic process initiation, so that users can perform customized analyses and generate customized products on demand; (2) user accounts and registration that allow maintenance

of choices and portfolios across sessions; and (3) implementation of new methods for providing information and engaging with users (e.g., podcasts, webinars). These policies, processes, and practices should foster interoperability among products and tools within NCEP, NWS, NOAA, and beyond. This includes a process of active engagement with external groups that are developing new tools for users (public, academic, and private sector), and easy access to explicit technical information, e.g., meta-data.

Finding IS2: Centers are not using NCO effectively. Each center has a different balance between in-house and NCO-managed systems.

Finding IS3: NCEP is striving toward a unified system of cyberinfrastructure and information technology (IT) activities, including cyber-security, in line with overall NOAA direction.

Recommendation IS2: The review panel affirms its support for a more unified system of cyberinfrastructure and IT activities, taking advantage of efficiencies of centralization and economies of scale. NCO should establish policies, processes, and practices that will foster interoperability among products and tools within NCEP, NWS, NOAA, and beyond.

Recommendation IS3: NCEP should clearly delineate NCO's responsibilities and those of the NCEP service centers to clarify roles and responsibilities and to identify the IT services that will and will not be provided centrally to the different service centers. For example, NCO could provide centralized support for IT security, hardware and software procurement and system and system-software maintenance, certification and accreditation audits, and other services to be agreed upon, with an eye toward mitigating unnecessary duplication between NCO and the NCEP organizations that it supports. Code for products and services developed locally could be maintained by the service centers. This would require that they be permitted to hire expertise in such software.

Finding IS4: NCEP computing resources are not commensurate with the scope of the mission. The HEC, disk storage, and long-term archival systems are each at least an order of magnitude under-configured relative to the requirement.

Recommendation IS4: The NCEP requires a significant increase in its computing capability, with at least an order of magnitude increase in capability over the next five years.

6.5 Science and Technology

Finding ST1: The establishment of testbeds in the service centers is a critical element of the process to support the transition from research to operations. Establishing testbeds in each of the service centers is an excellent idea.

Finding ST2: The maturity, effectiveness and impact of the testbeds, and their funding models, vary widely across the service centers.

Finding ST3: The service centers don't all have a clear vision of how to utilize the testbeds to move their missions forward.

Finding ST4: Entraining the best understanding, techniques and practices from the research community remains slow and largely ineffective.

Finding ST5: Data assimilation is a critical component of all NCEP analysis and modeling activities. The methods used for data assimilation are being vigorously researched and developed both at EMC and by the research community, and many exciting new developments have recently emerged. Investments in data assimilation methods and model development are increasingly linked, both because some methods have a technological dependence on the model code (e.g. the 4DVAR method depends on the adjoint of the dynamical model), and because the results of data assimilation are dependent on the choice of model (e.g. error covariance calculations).

Recommendation ST1: NCEP should require that every service center has strategic and implementation plans that describes how its testbed advances the center's mission.

Recommendation ST2: The NCEP Director needs to be more proactive in

- a. overseeing the centers' development of the testbed strategic and implementation plans;
- b. helping the center directors to identify funding for their testbed activities.

Recommendation ST3: NCEP, in cooperation with external experts, should develop a strategic plan for atmospheric and oceanic data assimilation to guide the way forward over the next five years.

6.6 People and Organizational Culture

Finding POC1: The OD staff members work very hard and very well together, and staff morale is very high.

Finding POC2: During 1958-1996, NCEP had a deputy director, but it has had no deputy director since 1996.

Finding POC3: There is a very large workload associated with the Office of the Director that has grown significantly along with the NCEP mission and budget over the past decade. In particular, there are operational, strategic planning, transition from research-to-operations, international support, labor relations and public affairs duties that significantly overstretch the capability of one person to fulfill them.

Recommendation POC1: NCEP requires a Deputy Director who can handle the day to day operations of NCEP as well as many other internally-directed duties, freeing up the Director to think more strategically and forge new collaborations and partnerships within NOAA, the federal government, the US academic community, the private sector and abroad.

Recommendation POC2: The vacancy in the position of NCEP Chief Operations Officer should be filled.

Finding POC4: The move to the new building has been significantly delayed, yet again, most recently by economic factors associated with the national recession that are well beyond the control of NCEP, NWS, or NOAA. This additional delay has had a serious negative effect on staff morale, budgeting, and the ability to address long-standing issues such as building a more effective visitor program or enabling a richer set of collaborations.

Recommendation POC3: The NCEP Director, working with NWS, NOAA and DOC, should continue and redouble efforts to ensure that the National Center for Weather and Climate Prediction (NCWCP) becomes a reality and the move to the new building is made as efficiently and expeditiously as possible.

Finding POC5: The NCEP in-house culture has evolved over the past 20 years from a relatively informal research-oriented collegial atmosphere to a more process-oriented, mission-driven culture.

Finding POC6: As an operational organization, with on-time delivery of products and services as a high priority, NCEP needs to emphasize mission and process (terms of reference, metrics of success, accountability, IT security, etc.).

Finding POC7: As a science organization, NCEP needs to foster innovation and creativity.

Recommendation POC4: NCEP needs to strive for balance between operational strictures and fostering innovation, adopting a proper level of structure and process without suppressing a creative research environment.

Finding POC8: Forecaster involvement in research is non-uniform among centers (this situation is variously characterized as a “sweatshop mentality”, “intellectual stagnation”, a “two-class system”).

Recommendation POC5: The NCEP Director should work with service center directors to be more proactive about professional development for their staff members, including research components of their activities and linkages to testbeds.

6.7 Business Processes

Finding BP1: There is a good level of communication between the OD and the NCEP centers, especially on financial matters and planning processes (e.g. the NCEP Technical Operating Plan - NTOP – and Annual Operating Plan - AOP – processes).

Finding BP2: The NCEP budget is determined by a somewhat byzantine combination of inputs from the NOAA Planning, Programming Budgeting and Execution System (PPBES)

process, NWS/NOAA mandates, and the Director's Office allocations. Although the Director supports the PPBES process, because it gets NCEP more engaged in NOAA beyond the NWS, new full time employee (FTE) positions are very difficult to obtain.

Finding BP3: Reaching NCEP's goal of becoming a world leader in environmental prediction is hindered by the lack of flexibility in the hiring process.

Finding BP4: The need to streamline burdensome hiring, promotion, budgeting, etc. processes is recognized by NCEP management, and they are working with higher level people in NWS and NOAA.

Recommendation BP1: At a level above NCEP, NOAA/NWS should conduct a review of the constraints on hiring highly-qualified talented scientists, which are often imposed by overly-burdensome bureaucratic rules from other organizations (Chief Information Officer - CIO, Department of Commerce - DOC, Office of Personnel Management - OPM) that may not fully appreciate the negative impact.

Finding BP5: A more concerted application of communications technology and less restrictive travel budgets would allow more staff interactions among centers, and greater interaction with the research community,

Recommendation BP2: NCEP should consider more creative business processes to increase interactions that would enhance the integration and synergy that could be achieved.

Finding BP6: The NCEP Review, charged in November 2008 and conducted in 2009, has been valuable in providing an opportunity for introspection on the parts of the NCEP centers and NCEP as a whole and in making a number of recommendations that are likely to lead to changes and improvements in NCEP's products and services, interactions with stakeholders, and organizational culture.

Recommendation BP3: In order to preclude large periods of time transpiring before the next set of reviews, NCEP should formalize a periodic review process, to occur every 5-6 years.

Recommendation BP4: To incorporate new research and technology into its suite of products and services, without compromising forecast integrity, NCEP must further embrace public and private partnerships and consider creating a research and development new product cell to test, review and recommend ideas. NCEP could work with academia, other government labs and/or private industry to create a mechanism to introduce and test new products.

Appendix A

National Centers for Environmental Prediction Review Charge to the Review Panels

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 research and/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 members 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

NCEP Review Executive Committee Members

The following are members of the NCEP Review Executive Committee, composed of two co-chairs, two external experts, and the chairs of the seven Center review panels.

Frederick Carr, Co-chairperson
University of Oklahoma

James Kinter III, Co-chairperson
Center Ocean Land Atmosphere Studies

Gilbert Brunet
Environment Canada

Kelvin Droegemeier
University of Oklahoma
AWC/EMC/NCO/SPC Review Chairperson

Gene Fisher
American Meteorological Society
SWPC Review Chairperson

Ronald McPherson
American Meteorological Association (Emeritus)

Leonard Pietrafesa
North Carolina State University
TPC/OPC Review Chairperson

Eric Wood
Princeton University
CPC/HPC Review Chairperson

Appendix C

Acronyms and Terms

4DVAR	Four-dimensional Variational Data Assimilation
AFOSR	Air Force Office of Scientific Research
AOP	Annual Operating Plan
AWC	Aviation Weather Center
AWIPS2	Second Generation Advanced Weather Interactive Processing System
BP	Business Processes
CD	Center Director
CFS	Climate Forecast System
CIO	Chief Information Officer
CIRES	Cooperative Institute for Research in Environmental Sciences
CP	Customers and Partners
CPC	Climate Prediction Center
CPU	Central Processing Unit
CTB	Climate Test Bed
DHS	Department of Homeland Security
DOC	Department of Commerce
DoE	Department of Energy
ECMWF	European Center for Medium Range Weather Forecasts
EISWG	Environmental Information Services Working Group
EM	Emergency Managers
EMC	Environmental Modeling Center
FAA	Federal Aviation Administration
FEMA	Federal Emergency Management Agency
FTE	Full Time Employees
GFS	Global Forecast System
GPRA	Government Performance and Results Act
GPS	Global Positioning System
HPC	Hydrometeorological Prediction Center
HEC	High End Computing
HWT	Hazardous Weather Testbed
IOOS	Integrated Ocean Observing System
IS	Information Systems
IT	Information Technology
JCSDA	Joint Center for Satellite Data Assimilation
JHT	Joint Hurricane Testbed
MME	Multi-model Ensemble
MV	Mission and Vision
NAP	NCEP Advisory Panel
NAS	National Academy of Sciences
NASA	National Aeronautics and Space Administration
NCAR	National Center for Atmospheric Research
NCEP	National Centers for Environmental Prediction

NCS	NOAA Climate Services
NCO	NCEP Central Operations
NCWCP	National Center for Weather and Climate Prediction
NEMS	NOAA Environmental Modeling System
NESDIS	National Environmental Satellite, Data and Information Service
NextGen	Next Generation Air Transportation System
NMC	National Meteorological Center
NMFS	National Marine Fisheries Service
NMME	National Multi-Model Ensemble
NOAA	National Oceanic and Atmospheric Administration
NOS	National Ocean Service
NPOESS	National Polar-Orbiting Operational Environmental Satellite Systems
NSF	National Science Foundation
NSSFC	National Severe Storms Forecast Center
NTOP	NCEP Technical Operating Plan
NWP	Numerical Weather Prediction
NWS	National Weather Service
O2R	Operations-to-Research
OAR	Office of Oceanic and Atmospheric Research
OCWWS	Office of Climate, Water and Weather Service
OD	Office of the Director (NCEP)
ONR	Office of Naval Research
OPC	Ocean Prediction Center
OPM	Office of Personnel Management
POC	People and Organizational Culture
PPBES	Planning, Programming, Budgeting and Execution System
PS	Products and Services
QPF	Quantitative Precipitation Forecasting
RA-IV	Regional Association IV
R2O	Research-to-Operations
SEL	Space Environment Laboratory
SPC	Storm Prediction Center
ST	Science and Technology
SWFO	Space Weather Forecast Office
SWPC	Space Weather Prediction Center
SWPT	Space Weather Prediction Testbed
TPC	Tropical Prediction Center
UCAR	University Corporation for Atmospheric Research
WFO	Weather Forecast Office
W2DT	Week-2 Development Team
WMO	World Meteorological Organization