2009 Community Review of the NCEP Climate Prediction Center

Carried out by the University Corporation for Atmospheric Research

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Executive Summary

A review of the National Oceanic and Atmospheric Administration (NOAA) Climate Prediction Center (CPC) was conducted in June 2009 as part of a comprehensive review of the National Centers for Environmental Prediction (NCEP). The CPC review panel was asked to examine the Center's mission to determine its relevance, appropriateness and alignment with NCEP's strategic plan, in addition to assessing the quality, relevance and impact of its operational products and services, and the productivity and quality of its scientific activities.

The review found that the Climate Prediction Center continues to serve as a national and global asset for providing climate predictions, analyses and assessment products. CPC's 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. 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 are clearly evident and contribute to the productivity, value and relevance of CPC.

Below are the key findings and recommendations as arranged by the themes of NCEP's Strategic Plan. These findings and recommendations are related to each other and should not be considered in isolation. Additional findings and recommendations are in the body of the report.

Mission and Vision

CPC's mission is clearly articulated with its products vital to the NOAA Climate Services (NCS) activity and to the nation. Under its current director, CPC has embraced strategic planning, and its implementation plan is wholly consistent with the NCEP strategic plan. Overall, the shared strategic planning and vision by CPC provides a consistent framework for the Center personnel to carry out research and development that should allow for an evolution of its products and services over time.

The panel is concerned that CPC appears to have a low priority in the National Weather Service (NWS) mission planning and in the NCS initiative, which manifests in a sense of uncertainty about the Center's future mission. This is similar to the situation found in the 1998 CPC review ("It is a consensus concern of the Panel that CPC and its components of Climate Studies and operational Products and Services are vital but appear to be a low priority for the National Weather Service.")

Recommendation: The panel believes that 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. This will ensure that CPC's mission objectives, products and services, and expertise are represented.

Customers and Partners

CPC has a long history of proactively reaching out to the research community, e.g. hosting the annual Climate Diagnostics and Prediction Workshop, and interacting with the community in its scientific developments. By necessity, CPC also interacts with other NCEP centers, groups

within NWS and NOAA (examples include the NWS/Office of Hydrologic Development (OHD), the NOAA/Office of Oceanic and Atmospheric Research (OAR)/Climate Program Office (CPO), and the Regional Integrated Sciences and Assessments (RISA) centers). This reflects the quality of CPC scientists and the importance of their work to the community.

By necessity, they also have collaborations and relationships with other NCEP Centers. While CPC and the Hydrometeorological Prediction Center (HPC) appear to have a mutually productive relationship, the panel is concerned that there is an apparent lack of balanced, mutually respectful and productive relationships with some centers within NCEP. This situation is impeding CPC from better executing its mission and developing its products and services. Specifically, the relationships between CPC and the Environmental Modeling Center (EMC) and CPC and the NCEP Central Operations (NCO) need to be improved if NCEP is to reach its potential in climate products and services. CPC requires cooperation with EMC for necessary Climate Forecast System (CFS) model improvements and the development of a National Multi-Model Ensemble (NMME) system, and CPC is dependent on NCO in transitioning to operations forecast products and services developed at CPC. The panel is aware of examples of successful EMC-CPC collaborations, including the recent work on high-resolution CFS-based seasonal hurricane outlooks and monitoring of the production of CFS Reanalysis in real-time. Such successes must be expanded. This means having an effective mechanism whereby EMC and NCO establish relationships with CPC in which roles, mission priorities, and intra-center roles and responsibilities must be clarified and clearly articulated.

Given CPC's critical dependence on CFS for many of its key products, and its unique role with respect to EMC, it is to the benefit of both organizations that it play a more integral role in the development of CFS – this includes (as examples) access to intermediate model versions for assessing and diagnosing climate variability and predictability, and the capability to do sensitivity experiments that can provide feedback to EMC regarding model development priorities, which could be facilitated by having CPC rotators in EMC and vice-versa.

Recommendation: It is recommended that effective mechanisms be developed that address center roles, mission priorities, and intra-center activities and responsibilities. This will lead to true partnerships between EMC and CPC in facilitating needed improvements to CFS and the development of a NMME system, and between NCO and CPC in the transition from research to operations (R2O) of CPC products and services that are ready to be made operational.

Products and Services

CPC has established itself as a world leader in the development of climate products. As examples, CPC has had a pioneering role in the development and dissemination of reanalysis products for climate monitoring and analysis, they have a leadership role in El Niño Southern Oscillation (ENSO) monitoring and prediction as well as for drought assessment and prediction products. CPC, in collaboration with EMC, is also taking a leading role in the development of new high-resolution CFS-based seasonal hurricane forecast products. The number of CPC products has greatly expanded over the years, and it's a testament to CPC and its scientists of their wide usage. But the review found that CPC faces the challenges of maintaining its current portfolio of products, and developing new, desired products and services, within its budget. CPC needs to determine what its essential climate products and services are, and what

information is needed by the nation and decision makers, so CPC can generate and deliver its essential products and climate information effectively.

Recommendation: CPC needs to implement formal mechanisms for assessing its products and services with the goals of identifying those that are essential and must be maintained, those which can be retired, with their users transitioned to similar products that fulfill their needs, and those that need to be improved or developed.

Advancement and improvement of seamless weather-to-climate forecast products is an important example where product development is needed and can be achieved by partnering with HPC in developing unified week 2 and weeks 3-4 forecast and guidance products. Week-2 prediction is a major challenge for techniques traditionally associated with deterministic weather prediction. Similarly, the probabilistic techniques traditionally employed by climate science contribute to forecast skill at week 2. Providing a consistent, unified week-2 product would be useful for both CPC and HPC stakeholders (as discussed in section 5.3). A joint HPC-CPC effort, in consultation with EMC, stands a far better chance to generate products and services of importance and relevance to a wide range of stakeholders in need of information at this range. Similarly, at climate scales, there are opportunities to partner with the Geophysical Fluid Dynamics Laboratory (GFDL) modeling developments to evaluate climate products at the decadal-to-century scales that would be responsive to user needs identified in the NCS vision.

Recommendation: It is recommended that the development of improved forecast skill at week 2 be a high priority for NCEP. Thus, CPC and HPC should create a week-2 development team (W2DT) to develop and evaluate a unified CPC-HPC forecast product. As recognized by co-sponsorship of the Observing System Research and Predictability Experiment (THORPEX) Program by the World Meteorological Organization (WMO) and the World Climate Research Program (WCRP), W2DT should apply the methodologies and metrics of the extended range weather prediction community together with sub-seasonal predictions of the short-range climate community.

Information Systems

Over the last decade CPC has recognized and has been proactive and effective in developing web-based product delivery systems (e.g., Extensible Markup Language (XML), Geographic Information Systems (GIS) and KML (formerly Keyhole Markup Language) outputs), and must be commended for these developments, which will likely continue with their website redesign. However, more transformative improvements in product generation and delivery capabilities will require a more expansive paradigm in the design of products, the interface for user access, and the underlying technological systems for delivering products. CPC relationships with NCO and the inability of CPC to hire information technology (IT) software personnel can hinder its plans for R2O transitions and product delivery mechanisms. A current “valley of death” even exists now between the CPC development and operations branches.

Recommendation: NCEP should establish policies, processes, and practices that will foster interoperability among products and tools within CPC, NCEP, NWS, NOAA, and beyond. This includes a process of active engagement with NCO and other external groups that are developing new tools for users (public, academic, and private sector), and having easy access to explicit

technical information, e.g., metadata. Engagement with the Earth Science Information Partners (ESIP) Federation, Earth Observing System Clearinghouse (ECHO), and similar groups is encouraged, with participation by CPC IT staff. CPC needs full access to IT software engineering personnel and an approach to R2O that prioritizes entrainment of software developed elsewhere rather than redevelopment of functionalities in-house.

Science and Technology

CPC maintains a world-class research and development program, with outstanding scientists that have a successful track record in attracting extramural, competitive funding and actively publishing in high-quality, refereed scientific journals. CPC has a very good track record of developing and providing important climate products and engaging the climate research community. The Climate Test Bed (CTB) was established as a mechanism for science and technology infusion related to model improvements, NMME development, forecast product development and R2O transition by leveraging resources in coordination with the CPO and through additional partnering with outside researchers. This has largely failed because of resource limitations and organizational issues documented by its Science Advisory Board (SAB). The CTB, while organizationally part of the Development Branch (DB), does not have an integrated relationship with DB and is relatively autonomous without clear lines of authority as discussed in the report (see sections 5.2 and 6.5). The roles of CTB and DB can and should function in a harmonious and mutually reinforcing manner, including complementary activities, undertaken by design. The current structure of the CTB hinders CPC in developing a unified organizational culture needed to meet its mission and strategic plan goals. Additional partnering with the other research agencies and universities (the National Science Foundation (NSF), the Department of Energy (DOE), and the National Aeronautics and Space Administration (NASA)) would bolster science infusion by leveraging resources.

Recommendation: CPC needs to clarify the current structure of the 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. As part of this effort, CPC should move forward with plans to establish a model test facility, presumably as an effort that combines activities of the CTB, NCEP and CPO that gives the external research community (and CPC) access to the CFS with the aim of influencing and accelerating improvements to CFS, as discussed earlier.

People and Organizational Culture

The personnel of the CPC are very talented and committed people who are well versed with the current state of the science. They have exhibited an extraordinary amount of activity and passion for their work. Under its current Director, CPC has gained an appreciation for the value and need for strategic and implementation planning. This has led to an overall appreciation of staff roles and the contribution of CPC to NCEP.

Within CPC, the roles of the DB and the Operations Branch (OB) in the research and development of new products and services, which appears to occur in both branches, are unclear, resulting in overlapping development activities. The panel found insufficient coordination and interaction between the branches leading to less effective transitioning of DB research products

to operations. A contributing factor may be CPC's organizational structure that relies heavily on contractors and "soft money" for the generation of its products and services. In part, this is a resource issue, and the observation about resource constraints is similar to that found in the 1998 review.

Development Branch personnel should be familiar with the challenges involved with operational product generation, and devote energy towards research that improves the operational product suite as called for earlier. An example of a mechanism for enhanced interactions would be to include in each research project an operational liaison who would provide suggestions and feedback. Also, the CTB must provide a more effective bridge between the operational and developmental activities at CPC.

Recommendation: Mechanisms must be developed for clearly delineating research and development activities for the two branches, increasing the coordination of activities between the DB and OB, and minimizing overlapping activities. Additionally, mechanisms are needed for reducing the reliance on contract personnel for mission-critical operational product generation (perhaps by reducing the number of products as called for in the 'Products and Services' recommendation and / or by establishing more formal decision making processes involving NWS Headquarters), while at the same time creating opportunities for enhanced interactions between the Operations and Development branches.

1. Introduction

1.1 Purpose 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 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 Climate Prediction Center.

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 reviews 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 (IPCC) 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) new Next Generation Air Transportation System (NextGen) air traffic control system 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 projecting fluxes of high-energy particles that can disrupt communications and Global Positioning Satellites (GPS). Solar activity has been at a minimum for the past few years, and is expected to rise to its maximum in the next few years. Given the increasing dependence of the U.S. and world economies on telecommunications and 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 communities were evaluated. The full charge to the review panels is provided in Appendix A.

1.2 Procedures

The Review Panel consisted of six members (Appendix B), who were appointed by the President of UCAR. The review panel carried out a site visit to CPC on June 29, 2009, and the morning of June 30. They met in executive session July 2 to develop preliminary findings and recommendations, and to debrief the CPC center director as well as the Director of NCEP on the site visit.

Prior to the site visit, documentation was provided including the center's mission and vision, and any center strategic plan documents separate from the over-arching NCEP strategic plan. In addition they were asked to provide an organization chart, list of present staff and visitors, a summary of the center's budget and sources of support including extramural support, a list of publications and/or reports covering the last two or three years, and material outlining recent highlights and accomplishments and collaborative work.

During the site visit, the panel received presentations from the center director Wayne Higgins, and the branch chiefs (Ed O'Lenic for the Operations Branch and Arun Kumar for the Development Branch). Additional presentations were provided on major center activities (Climate Test Bed, CFS Reanalysis and Reforecasts, Customers and Service, and the International Desk). The presentations augmented the written materials provided to the panel and allowed for questions and discussion with the panel. The director's presentation addressed broadly the center's mission and vision, its staffing and budget, accomplishments and activities since the last review, its products and services, any manpower issues and future plans, including concerns and/or opportunities. The branch presentations provided information on branch issues as they pertain to the areas of responsibilities for the branch, including workload and personnel issues, products, development and services, interactions within CPC, between NCEP centers, and outside of NCEP, and future challenges. The presentations on the major center activities – Climate Test Bed (CTB), CFS Reanalysis and Reforecasts (CFSRR), Customers and Service and the International Desk – provided information on the projects/activities with regard to the goals of the activities; whether they are being met with current effort; successes, weaknesses, plans and expectations; level of any interactions within CPC, between NCEP centers, and outside of NCEP, and future challenges. Prior to the site visit, the panel received recent reports from the CTB and CFSRR advisory panels. The panel also met separately with CPC leadership, managers and project leaders for further discussions as well as with CPC staff in small groups as indicated in the agenda. There was also a "walk-in" opportunity for any staff member to meet individually

with the panel. All of the above material, presentations and discussions form the basis for the findings and recommendations contained in this report.

2. CPC Overview

2.1 Mission and Vision

The Climate Prediction Center (CPC) was formed in 1979 and is NCEP's Climate Service Center, one of seven NCEP Service Centers across the country, helping the NCEP to achieve its mission. CPC is collocated with two other Service Centers (Hydrometeorological Prediction Center and Ocean Prediction Center), the Environmental Modeling Center and NCEP Central Operations at the NOAA Science Center in Camp Springs, Maryland.

CPC states that their mission is:

> *"We deliver climate prediction, monitoring, and assessment products for time scales from weeks to years to the Nation and the global community for the protection of life and property and the enhancement of the economy"*

and their vision is:

> *"To be the world's best and most trusted climate service center, using partnerships to develop cutting-edge climate products."*

As such it delivers climate outlook, monitoring and assessment products that span time scales from days 3-14 through monthly, seasonal and multi-seasonal, and it supports the NOAA goal of "Seamless Suite of Forecast Products" spanning climate and weather.

2.2 Organizational Structure

The CPC federal and support staff are distributed across two branches (Development Branch and Operations Branch) and the CPC Director's Office. Currently, there are 21 (25) federal employees in the Development (Operations) Branch and 4 federal employees in the CPC Director's Office for a total of 50 federal employees. Both the DB and OB are fully staffed at this time. There are currently 25 support contractors employed with Wyle Information Systems, McLean, VA. Most of the support staff works with Development Branch staff on operational and developmental projects that support the CPC mission and NCEP goals. Thus, overall, the CPC federal/support staff totals 75. CPC also hosts many short- and long-term visitors (15 during FY 2008) via several mechanisms, including the African Desk, bilateral exchanges with China, the National Research Council (NRC) and UCAR postdocs, and summer students from minority-serving institutions and NOAA sponsored programs (e.g. Student Career Experience Program (SCEP) and Student Temporary Employment Program (STEP)).

The CPC's base budget from NWS during FY 2008 was $6.2M. The labor (non-labor) portion of the CPC budget during FY 2008 was $5.7M ($0.5M). The labor budget is in support of salaries and benefits for the federal staff, while the non-labor budget is for supplies, travel, publication charges, desktop upgrades, etc. The CPC's reimbursable budget during FY2008 was $2.7M. Sources for CPC reimbursable (soft) funds include the NOAA/CPO, the NWS/International Affairs, the National Environmental Satellite, Data and Information Service (NESDIS), NASA and United States Agency for International Development (USAID). Reimbursable funding is obtained in response to proposals submitted in the competitive grants process.

To meet its mission and support the NOAA goal, CPC has been increasingly involved in a collaborative forecast process with the other NCEP Centers to ensure accuracy, consistency and quality of the product presentation and mix. Additionally, CPC collaborates with a number of NWS offices and outside groups. CPC has also been involved with other nations' weather and climate centers as well as academia in developing and assessing forecast products, as well as the private sector that use their climate prediction, monitoring, and assessment products. The CPC mission requires close coordination with three NCEP centers: HPC, EMC and NCO.

3. Developments Since Last Review

The panel asked for and the director reported on the response to the last CPC review, dated August 1998. Additionally, the panel asked that the center report on new developments since that review. The purpose of these requests was for the panel to hear, from the center's perspective, whether issues that arose during the last review have been addressed, and to hear about new developments, initiatives and responsibilities that have occurred since the last review.

The major issues and recommendations from that review included:

1. The support for the restructuring of CPC, with the concern that its increased focus on prediction could not be carried out with its (1998) resource constraints.
2. Concern regarding model development for use in prediction, with the recommendation that CPC develop a model development strategy that recognizes that the development will occur outside CPC, and that CPC needs to strengthen its working relationships with EMC and other modeling groups.
3. The need for continued diagnosis and assessment of operational products, including performance metrics.
4. The concerns regarding the number of ongoing projects and the optimal use of CPC resources, including the number of operational products, plans for data distribution and archiving, and data continuity.
5. The consensus that CPC provides a vital service to NOAA and NWS but that CPC has low priority within the NWS.

Areas where progress has been made on the earlier review recommendations include finalizing the restructuring of CPC by forming the Development and Operations branches and organizing Project Teams for major projects, developing internet services for delivering data products and

interacting with users, and developing products that relate to NOAA's 'climate services' initiatives like the ENSO Diagnostic Discussion, the Drought Monitor and the Drought Briefing telecons for the National Integrated Drought Information System (NIDIS), the NOAA Climate Portal, and new climate monitoring and product assessment tools. Other product developments by the OB since the last review include the U.S. Hazards Assessment, the 8-14-day Extended Range Outlooks, the Heat Index and Wind Chill Outlooks, the Hawaii Extended-Range Outlooks, and new protocols for preparing 1-month and 3-month outlooks. CPC has initiated telephone conference calls and webinars with their product users and collaborators. As indicated in our findings, these expanded activities are laudable yet pose challenges to CPC in managing these new activities without budget growth.

The panel was pleased that many concerns and recommendations from the 1998 review were addressed with improvements to center activities. Nonetheless, as will be discussed in Section 6, there were recommendations from the earlier review where progress has been slow – developing strategies for model development and improvements, improving product evaluation, perceptions within NCEP and NWS regarding seasonal climate modeling and forecast products, and providing the extensive suite of products and services with limited resources. Some of these issues are partially outside CPC's control and require NCEP Office of the Director (OD) leadership to help resolve. They are raised here to indicate that there are ongoing, organizational issues that remain to be resolved.

4. Summary of Stakeholder Survey

A stakeholder survey was developed by the panel and sent to approximately 370 people. The stakeholder list was the same for both CPC and HPC and included a broad cross-cut of groups that utilize CPC and HPC products. The survey list included the Directors of Regional Climate Centers (non-federal sites), Hydrologists in Charge or the Service Coordination Hydrologists at the NWS River Forecast Centers, the Meteorologists in Charge at the Weather Forecast Offices, and additional stakeholders from other Federal agencies, state climatologists, participants from a 2008 NOAA Climate Working Group Climate Services Workshop as well as seventy randomly-selected American Meteorological Society (AMS) Certified Consulting Meteorologists (CCM), people at RISA centers, both for-profit and non-profit non-governmental organizations (NGO), enterprises and educational institutions. A total of 84 individuals (23% of those surveyed) responded to the survey who identified themselves as federal employees (39%), private sector (14%), educators (11%), and media (9%), with smaller numbers of respondents in other categories.

Overall the respondents identified themselves as knowledgeable about climate and hydrometeorological information. The main results of the survey are as follows:

1. 80% of the respondents consider CPC products very appropriate and relevant to the missions of their organizations. Further, they had high praise for CPC personnel and their understanding of their organization's climate data needs.
2. Many products were cited as providing benefits to their organizations, with the following being most cited as being useful: the ENSO Diagnostics Discussion and ENSO outlooks,

the sub-seasonal outlooks (days 6-10, 8-14, and the Madden-Julian Oscillation (MJO)), the seasonal forecasts and drought outlooks including the US Drought Monitor. Over 75% felt that the products and services were of appropriate quality for their organizations' needs, and almost all respondents stated that there are no alternative sources for this information. Stakeholders are unclear regarding whether CPC was developing new products and retiring old products at an appropriate pace, with almost 60% responding "neutral" or "disagreed somewhat". Every respondent stated that all CPC products were obtained through the web, and over 85% that they were readily available in a timely manner, indicating the importance of continuing the development and support of web-services.

3. The survey revealed that CPC is not communicating effectively enough with its stakeholders. While over 70% of the respondents agreed "strongly" or "somewhat" that CPC effectively communicated its mission, only 30% felt that CPC has an effective mechanism for soliciting stakeholder inputs, responding to questions and problems (31%); soliciting suggestions for improving products and services (23%); or responding to such suggestions (16%). CPC communicates somewhat better, but not well, information about new products and services (53%) or those that are to be discontinued (40%).

The common themes across the survey responses are the recognition of the quality of CPC personnel; the recognition of the importance and quality of CPC's climate products; and a lack of effective communication with the stakeholder community, especially as it relates to soliciting their inputs and suggestions.

5. General Observations and Overarching Issues

Based upon the review of provided documents and discussion at the site visit, the review panel found three overarching issues that threaded throughout many of the discussions and interviews, and are cross-cutting to many sections in the report. Further, these issues tend to be larger than CPC, yet influence CPC's mission, strategic planning and performance. The issues are: (i) The role and importance of CPC within NCEP, NWS and the NOAA Climate Services initiative, including seasonal climate forecasting; (ii) The working relationships between CPC and EMC, and between CPC and NCO; and (iii) The advancement of seamless "weather-to-climate" forecast products through enhanced collaboration with HPC (and enhanced coordination with other laboratories and offices within NOAA, especially CPO) on week-2 forecast guidance and weeks 3-4 products. These three issues cut across NCEP's and CPC's strategic plan. The issues are broadly discussed below, with more specific findings and recommendations provided in section 6.

5.1 CPC's Role Within NCEP/NWS and in the NCS Initiative

The 1998 CPC review states "It is a consensus concern of the Panel that CPC and its components of Climate Studies and operational Products and Services are vital but appear to be a low priority

for the National Weather Service." The current UCAR review panel feels similarly, and such a low priority can adversely affect CPC's mission and the delivery of its products to stakeholders who rely on them. Some evidence of CPC's relatively low priority within NWS includes:

- Within NCEP, CPC seems to be under-resourced relative to its current mission, which results in an over-reliance on contractors for core activities and thus puts its mission at risk.
- A veil of uncertainty regarding CPC's role in the NCS initiative, bordering on marginalization, was apparent to the review panel, which negatively affects morale.
- The panel sees the NWS focusing mainly on weather time scales and emphasizing short-range prediction services as its premier core competency.
- CPC (in partnership with EMC) 'manages' the Climate Test Bed (CTB) but seems to have no real control over its funding, its R2O transitions, or prioritizing CFS model developments. The latter is reflected in CPC's limited access to models and computer resources for diagnostics and experimentation.
- CPC does not appear to have sufficient input in the strategic planning for a NMME seasonal forecasting system and little support within the NWS or OAR to resolve effectively those issues that adversely affects CPC's mission.
- The computer resources provided for advancing seasonal forecasting seem inadequate such that reanalysis and re-forecasting data sets needed by the stakeholder community for applications are currently inconsistent with the current version of CFS.

One possible reason why CPC is viewed as lower priority within NWS is the fact that NWS mission-critical operations are driven strongly by the clock on time scales of minutes to hours (i.e. watches and warnings to save lives and property), whereas the CPC product suite is aimed at longer timeframes and produced less frequently.

The panel is aware that EMC has been able to produce the current CFS reanalysis and has an ambitious hindcast plan for the new CFSRR. A long-term computing strategy is needed so the CTB has sufficient computing resources to do R2O and for CPC/EMC to compute new reforecasts to bring in new model developments. In addition, plans to provide the CFS and supporting datasets to the community (i.e. via the Model Test Facility) should be developed and implemented. The 4th NOAA CTB Science Advisory Board report highlights all these issues. From the perspective of this review, these overarching issues affect CPC's mission, its strategic planning, its science infusion process, and the development and delivery of products and services to the stakeholder community.

More broadly we have the nationwide, multi-agency debate associated with the planning for NCS. The discussion of NCS exhibits a tendency to focus on climate change at decadal to centennial time scales, and climate change adaptation decisions over decisions related to intraseasonal, seasonal and interannual (ISI) climate variability. The review panel is concerned about how this NCS thrust (or focus) affects the CPC mission programmatically and organizationally. NCEP and the NWS need to strongly articulate a seasonal climate forecast need to top NOAA management.

5.2 Collaborations and Relationships with other NCEP Centers

The apparent lack of balanced, mutually respectful and productive relationships with some centers within NCEP is impeding CPC from better executing its mission. Specifically, CPC requires cooperation with EMC in the further development of seasonal forecast models. CPC as the provider of the forecasts to stakeholders tends to be the recipient of criticism regarding the quality of the forecasts (as can be seen in some of the stakeholder survey comments), yet decisions regarding model enhancements and improvements are controlled by EMC. The establishment of the CTB to encourage CFS model improvements and improve seasonal forecasting skill, while producing a few successes, has failed to live up to expectations due to insufficient funding and a poor CTB administrative structure. The UCAR review committee was provided with the 4th NOAA CTB Science Advisory Board report, which indicated SAB frustration with the limited progress by the CTB activities. The SAB report raised significant concerns about the CTB, which include its management of R2O and operations-to-research (O2R) activities that influences the acceleration of CFS model developments, selecting projects for CTB activities, the development of a NMME system, improved forecast products, among others. The UCAR review panel concurs with these concerns. The review team recognizes that CTB requires an effective partnership among CPC, EMC, NCO and OAR (CPO). The lack of an effective partnership hampers the CTB, and by extension CPC's mission.

The CPC mission is also dependent on a productive relationship with NCO for transitioning to operations experimental systems for forecast products and services developed at CPC. An example of a mature experimental system that could be transitioned is the North American Regional Analysis (NARR). The CPC stakeholder survey revealed that 100% of the respondents receive their CPC products via the internet. The efficient development of advanced web-service delivery will require NCO participation under the current NCEP structure. The review team believes that CPC is being under-serviced by NCO relative to other centers and its mission needs, and that NCO needs to provide additional services to CPC commensurate to its mission needs. Currently the shortfall in NCO services requires CPC to carry out these services within their constrained budget. On the positive side, the panel observed a relatively effective partnership between CPC and HPC, although there were opportunities for developing stronger strategic alliances, particularly with regard to the development of a unified week-2 forecast guidance. This is discussed more below.

5.3 Improved Seamless Weather-to-Climate Forecast Products

This UCAR review panel reviewed both CPC and HPC. In reviewing the two centers, one issue to which NCEP Director Louis Uccellini requested that the review panel give attention was improved seamless *weather-to-climate* forecast products. CPC and HPC products and services currently overlap in the 1- to 2-week range. Week-2 prediction is a major challenge for techniques traditionally associated with deterministic weather prediction. Similarly, the probabilistic techniques traditionally employed by CPC can contribute to forecast skill at week 2. CPC's sub-seasonal outlooks (days 6-10 and 8-14) are some of its most popular products for its stakeholders, and HPC is planning enhanced week-2 forecast guidance. Instead of developing overlapping products that may be inconsistent, the review panel sees an opportunity for a joint

CPC-HPC research and development activity. This opportunity should be met by the formation of a joint team, reporting to both center Directors, with the goal of developing a 'unified' week-2 outlook and guidance product. Such a product raises issues connected to their Customers and Partners, Products and Services, People and Organizational Culture, and Science tying into other NCEP centers (EMC and NCO). Aspects of this issue are further discussed, with recommendations in section 6.3. Also related to seamless weather-to-climate are weeks 3-4 products that are important to CPC stakeholders. Having a week-2 and month-1 product leaves a gap that needs to be addressed, and has dimensions within CPC that are similar to the week-2 products.

The panel is supportive of NOAA's intent to address the decadal prediction problem within an NCS organization. CPC is well positioned to make important contributions, especially if the development includes a close partnership with GFDL modeling efforts. While the scientific basis for decadal predictability is yet to be determined, long-term variability and trends are already important components of CPC predictions, and there appears to be considerable demand for such products. Efforts to address the decadal prediction problem could also play an important role in bridging CPC's traditional focus on SI and potentially new services intended focus on multi-decadal to centennial climate trends.

6. Findings and Recommendations

In this section, a summary of the findings and recommendations of the review panel are provided. Most of the recommendations are related to each other and should not be evaluated in isolation, but rather considered collectively. These findings and recommendations are organized in the thematic areas of the NCEP Strategic Plan. This section is divided into seven sub-sections: Mission and Vision, Customers and Partners, Products and Services, Information Systems, Science and Technology, People and Organizational Culture, and Business Processes.

6.1 Mission and Vision

> CPC Mission: The Climate Prediction Center delivers climate prediction, monitoring, and assessment products for time scales from weeks to years to the Nation and the global community for the protection of life and property and the enhancement of the economy.
>
> CPC Vision: To be the world's best and most trusted climate service center, using partnerships to develop cutting edge climate products.

6.1.1 Findings

Finding MV1: The CPC continues to serve as a national and global asset for providing climate predictions, analyses and assessment products. CPC's products and services target time scales ranging from weeks to about one 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. The stakeholder survey (section 4) showed that they see CPC as an 'honest broker' of climate information. The CPC also maintains a world-class research and development program. The CPC has a successful track record in attracting extramural, competitive funding and its staff actively publishes in the peer-reviewed scientific literature. The vibrancy, commitment and talent of the staff are clearly evident and contribute to the productivity, value and relevance of CPC.

Finding MV2: The CPC has embraced strategic planning, and its implementation plan is consistent with the NCEP strategic plan. The shared strategic planning and vision is well- - communicated at all levels of CPC staff and provides a consistent framework for the Center personnel to conduct its Missionmission. The panel applauds CPC for its five-year strategic plan. While the CPC mission is well-articulated in its strategic plan, its current portfolio of products and the development of desired future products and services within its budget will be a challenge. This finding about resource constraints is similar to that found in the1998 review. As discussed in section 5.1, the panel found that CPC's mission is vital to athe NOAA Climate Services (NCS) initiative, but that CPC appears to have a low priority in mission planning and budgetary allocation, perhaps because the NWS is primarily focused on short-term weather over seasonal climate, and NCS planning appears to focus more heavily on decadal-to-centennial projections and climate change adaptation over than on seasonal climate prediction and seasonal decision decision-making needs. From these issues, the panel found within the center prevailing uncertainty about its future mission and activities.

Finding MV3: As discussed above in section 5.2, there is an apparent lack of balanced, mutually respectful and productive relationships with some other NCEP centers that is impeding CPC from better executing its mission, developing more skillful products and transitioning developed products into operations.

Finding MV4: Increasing stakeholder demand for current and new CPC products and services, including the development of new products for any NCS initiative, may impede CPC's mission. Further, CPC's belief that external stakeholders will convey the importance of CPC products to NCEP and NOAA management is misdirected given the stakeholder survey results showing confusion in how CPC establishes new products and retires old products (see section 4.) The panel found that CPC's expectation, that the external community will help establish a stronger role for CPC in the evolving NCS, may be overly optimistic. This finding is discussed further in subsequent sections.

Finding MV5. There is a need for seamless weather to climate forecast products during month 1 prediction. WMO, through the World Weather Research Program (WWRP) and WCRP activities, as well as all global operational weather centers are focusing on this need. This is reflected in responses to the panel's CPC stakeholder survey that identified the importance of CPC's sub-seasonal outlook (MJO, days 6-10 and 8-14), which are, arguably, medium range to extended range weather prediction. At this time scale, the products overlap with HPC's plans to enhance their week-2 forecast guidance. Additionally, there are stakeholder needs for weeks 3-4 seasonal predictions.

6.1.2 Recommendations

Recommendation MV1: The CPC must play a critical and essential role in any future NCS. Ongoing NCS planning must fully engage and involve CPC management, and ensure that CPC's mission objectives and expertise are represented, and that CPC stakeholders are served by future NCS activities.

Recommendation MV2: The CPC must be enabled to obtain the necessary support from other NCEP centers, particularly from EMC in seasonal forecast model improvement and creating an effective NMME system and from NCO for R2O transitions of forecast products and services. By "enable" the review team means having an effective mechanism whereby EMC and NCO are resourced to engage CPC needs beyond what exists currently.

Recommendation MV3: As part of CPC's strategic plan and to preserve its mission and vision related to being the "world's best and most trusted climate service center", CPC needs to evaluate products in terms of their use and value, including plans for retiring old products and transitioning (R2O) new and enhanced climate products and services. It is recommended that CPC not depend on stakeholders to establish such evaluations. The stakeholder survey results indicated confusion regarding product development, transitions, retirements and evaluations (see section 4).

Recommendation MV4: The CPC should modify its mission statement to reflect that it "delivers extended range weather and climate prediction, monitoring, and assessment products for time scales from week 2 to years", that they work with HPC to develop collaborative activities and products for week 2, and that they extend sub-seasonal forecast products to include week 3-4 products as part of a month-1 seamless "weather-to-climate" forecast suite.

6.2 Customers and Partners

6.2.1 Findings

Finding CP1: Customer service and partnership building are vital functions for CPC's mission and vision. The CPC received consistently positive ratings from stakeholders on customer service, staff accessibility, and product/service value (section 4). However, CPC must be positioned to strategically anticipate the current needs of its stakeholders, expand its customer base to non-traditional customers and fulfill their needs, while also adapting to emerging needs for both traditional and non-traditional customers. It is unclear what changes the NCS initiative, when implemented, will bring to CPC's customer base. The current CPC web redesign is a promising development that will enhance customer service with stakeholders.

Finding CP2: The CPC is effective at partnership building and outreach. The panel found numerous examples of CPC's proactive engagement in reaching out to and developing a broad stakeholder community that includes non-NCEP NWS partners, other NOAA partners and broader external communities though a variety of mechanisms that include climate focal points

in Weather Forecast Offices (WFOs) and the Climate Prediction Applications Science Workshop (CPASW). Additionally, CPC proactively reaches out to RISA centers and other organizations to understand how climate services can be more effectively delivered through partnerships, and to the external research community by hosting the annual Climate Diagnostics and Prediction Workshop (CDPW). Since the last review, CPC has utilized the internet as the mechanism for delivering its products, which has been fully embraced by its stakeholders. CPC management recognizes that improved web services (e.g. website redesign and advanced protocols) will enhance stakeholder access and the delivery of products and services

Finding CP3: The CPC relies heavily on satisfaction-based performance metrics. However, as repeatedly documented by projects funded by the NOAA CPO (e.g., RISA, Sectoral Applications Research Program (SARP), International Research Institute for Climate and Society (IRI)), National Research Council reports, and Climate Change Science Program products (e.g., SAP 5.2 and 5.3)), the development of climate information, products, and services is best served by deep understanding of how users operate within their specific decision-making context. Asking users what products they would like, or whether they are satisfied with a product, is insufficient. The panel also heard that CPC expects their external stakeholders to convey the importance of CPC products to NCEP and NOAA management, which the panel believes doesn't occur. The stakeholder survey results shows confusion in how CPC establishes new products and retires old products (see section 4.)

Finding CP4: As discussed in section 5, the CPC-HPC partnership is relatively healthy, but the panel noted deficiencies in CPC's relationship with EMC and NCO. Such deficiencies create a level of intra-NCEP tension and more importantly, limit the potential effectiveness and/or efficiency of the relevant Centers.

Finding CP5: The panel found that CPC is not developing partnerships within the private sector and other federal sectors in proportion to the growing private-sector demand for climate products and service. CPC needs to enhance its strategy to be more effective in engaging with the private sector and for developing such partnerships. The panel recognizes the complexity of the issue where CPC must develop products that are open to all, while the private sector takes CPC information and develops value-added, proprietary products. The CPC needs to work with the private sector to assess and prioritize areas where their products and services can facilitate the private sector in their activities. The panel recognizes that building and sustaining effective partnerships takes years and dedicated staff attention that would be challenging to meet under present CPC staffing levels and expertise, yet such partnerships will be critical as NOAA moves into an NCS era.

6.2.2 Recommendations

Recommendation CP1: The CPC must continue developing partnerships and fostering interaction with its stakeholders, including continued modernization of the delivery of its products through a content management system and web services (Web 2.0) automation. The

CPC must work with NCO to automate and shift CPC mature products to NCO, and to track products through version control software. As noted in section 4, CPC needs to improve its stakeholder communications with regard to changes to (or development of) products and services, especially as the NCS initiative evolves.

Recommendation CP2: The CPC should develop a multi-dimensional approach for assessing jointly their products and services as well as their partners' and stakeholders' climate information needs, and the value of the products to their stakeholders' decisions. Information needs may include (for example) information on product skill. As such, this recommendation must be considered together with recommendations under section 6.3 (Products and Services) on products and services evaluation.

Recommendation CP3: The relationships between CPC and EMC and CPC and NCO need to be improved. Management from all centers and the NCEP Office of the Director should clearly define roles, mission priorities, and intra-center roles and responsibilities. Further, such roles and responsibilities should be clearly articulated to all levels of staff.

Recommendation CP4: Both CPC and EMC would benefit by a true partnership for CFS development. The panel recommends activities such as CPC rotators in EMC and vice-versa.

Recommendation CP5: The CPC must develop a strategy and mechanisms to understand the emerging needs of the private sector. Further, CPC should seek opportunities to interact with private sector stakeholders via virtual mediums and face-to-face ventures. Given its limited resources, CPC should partner with other programs (e.g., NWS Climate Services Division, NOAA CPO) or member organizations (e.g., American Meteorological Society, American Association of State Climatologists) that interact with the private sector, with an emphasis on multidisciplinary partnerships that include social scientists and decision research specialists.

Recommendation CP6: The CPC needs to work more closely with the NWS Climate Services Division to enhance and expand outreach function and to understand potential new partners.

Recommendation CP7: The CPC needs to clarify and publicize both within CPC and to their stakeholders their policy on interactions with the private sector (e.g., who/when they can talk with the private sector). Given their limited resources, CPC needs to strategically prioritize interactions and to ensure that interactions with a necessarily limited number of partners will have system-wide benefits without favoring specific private sector end-users or intermediaries.

6.3 Products and Services

6.3.1 Findings

Finding PS1: Generating climate information products and delivering these products to their partners and stakeholders (i.e. CPC's service component) are the core activities of CPC and central to their mission. As discussed above and in section 5, CPC is dependent on other NCEP centers for vital components, and must address the needs of outside stakeholders, which they are

doing well (see section 4). As part of their overall strategy, CPC management has expressed interest in expanding CPC capabilities to better contribute to NOAA's efforts at developing a seamless prediction capability, and to better position CPC to contribute to the NOAA's emerging strategy for NCS.

Finding PS2: The CPC product suite has traditionally focused on time scales ranging from two weeks to interannual. The near-term plans include improving drought monitoring and prediction, a greater emphasis on intraseasonal variability with a focus on week's 3-4 and extreme events including seasonal hurricane outlooks, and increased emphasis on multi-model ensembles. The CPC has also expressed an interest in contributing to the emerging community effort to assess decadal predictability and prediction skill (Meehl et al., 2009; Bulletin of the American Meteorological Society). Nevertheless, CPC recognizes that the seasonal-to-interannual product suite (with a focus on ENSO) is one of their most popular products, and continued efforts must be made to improve those products.

Finding PS3: While ENSO is a critical component of CPC's product suite, model improvements that could lead to major advances in ENSO prediction capabilities currently are, to a large extent, outside of CPC's control.

Finding PS4: The CPC desires to contribute to efforts to assess decadal predictability and skill. While the scientific basis for decadal predictability is yet to be determined, long-term variability and trends are already an important component of CPC predictions, and there appears to be considerable demand for decadal prediction products. Efforts to address the decadal prediction problem could also play an important role in bridging CPC's traditional focus on seasonal to interannual time scales and the intended focus of NCS on climate change.

Finding PS5: The CPC's traditional focus on short-term climate (interannual and shorter time scales) doesn't fully address NCEP's strategic plan for seamless prediction out to decadal time scales. This also appears to be limiting CPC's ability to advance prediction skill at time scales that are impacted by decadal variability and climate change (e.g., impact of trends on seasonal forecasts, decadal variability in ENSO predictability, and decadal variability in hurricane activity). Given the current discussion that NOAA's climate service initiative will focus on such time scales, CPC needs to start developing a capability for products and services related to decadal predictions. The panel recognizes the challenges posed by developing such products and services, but feels that CPC is best positioned within NOAA to take the lead in these.

Finding PS6: The CPC and HPC products and services currently meet in the 1- to 2-week range. Week-2 prediction is a major challenge for techniques traditionally associated with deterministic weather prediction. Similarly, the probabilistic techniques traditionally employed by climate science contribute to forecast skill at week 2. Providing a consistent, unified week-2 product would be useful for both CPC and HPC stakeholders (as discussed in section 5.3). A joint HPC-CPC effort stands a far better chance to generate products and services of importance and relevance to a wide range of stakeholders in need of information at this range.

Finding PS7: There are other gaps in CPC's climate products that include week 3-4 forecast products, which would be useful to their stakeholders.

Finding PS8: The CPC faces dual challenges in providing a large and growing number of climate information products. While users are often best served by providing a great variety of products, including multiple formats of the same product as well as information products for new variables (e.g., winds), non-atmospheric variables (e.g., vegetation stress) and non-standard products (e.g., climate event attribution), the plethora of products creates a daunting challenge for both CPC and users. For CPC, the increasing number of products (currently on the order of 15,000 per year) challenges CPC's operational capacity to simply generate the products with current staffing levels. For users, the challenge is to identify the most appropriate products for their needs and to "connect the dots" across different types of products (e.g., historical climatologies, recent observations, forecasts).

Finding PS9: The CPC recognizes that climate information products require ancillary support, e.g., forecast discussions, descriptions of tools used in generating forecasts, and measures of forecast skill. However, ancillary support for users remains under-developed, especially in the areas of forecast evaluation in terms relevant to users, tutorials for interpretation, guidance in selecting products appropriate for different kinds of applications, and effectively connecting across products (e.g., use of consistent units between climatologies, observations, and forecasts).

Finding PS10: Users have multiple and diverse needs that are not optimally served by generic products. Rather, they need products that address the spatiotemporal coverage, lead times, and performance characteristics (e.g., forecast skill) of their specific decision processes, in forms compatible with their level of technical sophistication, and for the environmental variables used in their decision processes which are typically not those addressed in CPC products. However, CPC is sensitive to potential competition with the private sector and seems reluctant to embrace products that address unique needs of specific sectors.

Finding PS11: The CPC does not have sufficient internal expertise or staffing levels to identify, design, or implement the required decision-support capabilities to meet the widest spectrum of user and partner needs. Understanding those needs requires substantial time and skills in engagement, social science, decision making, and product design. Substantial progress in these areas has been made by external research groups and the private sector. Current CPC efforts are not sufficient for evaluating or incorporating that information into their services, but an approach that is more systematic and comprehensive would be.

6.3.2 Recommendations

Recommendation PS1: The CPC needs to be more actively engaged in both supporting and influencing the priorities of EMC's development of CFS (also see sections 5.2 and 6.5). This engagement includes efforts to enhance forecast capabilities for weeks 3-4 and weather extremes (including seasonal hurricane forecasts) where it appears that major improvements to the product suite are possible.

Recommendation PS2: The panel supports NOAA's goal of seamless predictions out to decadal time scales, and recommends that CPC should play a critical and essential role with a forecast product suite that includes decadal time scales, as the science supports it.

Recommendation PS3: The CPC should develop a strategic whitepaper on the needs, opportunities and challenges of CPC providing decadal climate projection products and services. CPC should involve GFDL as the primary decadal-scale climate modeling center, hydrologic expertise from the NWS Hydrologic Development Laboratory (HDL) and other NWS entities, stakeholder groups identified by the NWS Climate Service Division, RISA centers, and regional climate centers, among other interested parties.

Recommendation PS4: The development of improved forecast skill at week 2 should be a high priority for NCEP. Thus, CPC and HPC should create a week-2 development team (W2DT) to develop and evaluate a unified (CPC-HPC) forecast product. As recognized by co-sponsorship of the International THORPEX Program by the WMO and WCRP, W2DT should apply the methodologies and metrics of the extended range weather community together with sub-seasonal predictions of the short-range climate community.

Recommendation PS5: The CPC should establish the goal of providing a skillful week 3-4 forecast product to address the perceived gap at this lead-time range.

Recommendation PS6: The CPC needs to develop product generation and delivery capabilities that provide flexibility and choice to users, with a high level of ancillary support, and includes developing a multi-dimensional approach for assessing their products, measures of forecast skill, and services that consider stakeholders' and partners' needs (section 6.2). The CPC product capabilities should include providing multiple formats for the same products, providing capabilities for users to customize products to suit their specific requirements (e.g., spatial aggregation), facilitating initial selection of appropriate products and formats, transitioning users to more appropriate products, helping users relate different products to each other, evaluating forecast performance characteristics in terms meaningful to users, facilitating recurring access to updated customized products, and providing tutorials and examples of product interpretation and application in different contexts. The CPC needs to work with NCO, the NWS Climate Services Division and CPO-supported groups like RISA centers in developing a plan for such enhanced generation and delivery of their products.

Recommendation PS7: The CPC should develop a strategy for systematically engaging with the research and development community to comprehensively assess their product suite, identify options for improving CPC operational decision-support capabilities to meet user and partner needs, and prioritizing implementation of new products, tools, and processes. As part of this engagement, CPC needs to develop measures for assessing their products and services (e.g. forecast skill, economic and non-economic value in stakeholder decisions, and extent of use). The strategy should also address discontinuing some CPC products and transitioning users to new or more appropriate products, enhancing consistency (e.g., terminology, visualization) across internal and external products, and partnerships for sustainable distributed delivery of climate products as part of a research-to-CPC-operations transition or external delivery by others in the climate services enterprise.

6.4 Information Systems

6.4.1 Findings

Finding IS1: The CPC has made commendable improvements in their product delivery systems (e.g., XML, GIS and KML outputs), and that will likely continue with their website redesign. However, 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. The CPC does not have the internal capabilities to design or implement such systems without strong partnerships with NCO and the external community.

Finding IS2: The transition of research to operations for new products and tools is occurring, but at a scale and pace that is producing marginal improvements rather than the transformative improvements required by users and that is possible under current technological capacities. It was unclear to the panel the current activities in automating product generation or the potential to accelerate automation, as a strategy for improved transfer of products into operations. It was unclear to the panel the current status of the activities to automate product generation or of the potential to accelerate such automation, as automation is a potential strategy for improved transfer of products into operations. Products and tools are being developed by both the DB and OB, and it is unclear how they progress into operations (or alternatively, be are discontinued). External research groups have no guidance on what requirements must be met for new products or tools to be compatible with CPC operations (e.g., automation requirements) or information systems (e.g., coding standards, interoperability with operating systems or databases).

Finding IS3: The CPC Operations Branch is challenged in their ability to provide new products while continuing to support the present product mix. While additional automation of product generation will help, it is not sufficient to provide the increased staff effort needed to focus on entraining new products and tools.

Finding IS4: The NCEP hiring policies requires CPC to use operational forecasters and trained meteorologists as part-time software engineers to develop forecast and product information tools. This limits the CPC Operations Branch's abilities to utilize externally developed software tools and procedures. While CPC staff is dedicated and works to learn new technologies, this is an insufficient and inefficient substitute for software engineering expertise in designing, implementing, and transitioning software code and information systems.

Finding IS5: In the operational implementation of new products, CPC has been largely opportunistic and limited in scope, in part because they have been self-sufficient and under served by NCO as discussed earlier. Nonetheless, CPC needs to strengthen its strategy and coordination for prioritizing operational implementation of new products that effectively leverages prior investments in product and tool development in the OB, DB, CTB, other NOAA units, or external efforts (e.g., academia, other federal research units).

6.4.2 Recommendations

Recommendation IS1: The NCEP should establish policies, processes, and practices that will allow users to create customized interactions with CPC information systems, including dynamic process initiation, so that users can perform customized analysis and generate customized products on demand, user accounts and registration that allow maintenance of choices and portfolios across sessions, and implementation of new methods for providing information and engaging with users (e.g., podcasts, webinars).

Recommendation IS2: The NCEP should establish policies, processes, and practices that will foster interoperability among products and tools within CPC, 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. Engagement with the Earth Science Information Partners (ESIP) Federation, Earth Observing System Clearinghouse (ECHO), and similar groups is encouraged, with participation by CPC and NCO IT staff.

Recommendation IS3: The NCEP and CPC should establish policies, processes, and practices that more effectively leverage OB, DB and external partner capabilities in designing and implementing new products and decision-support tools. This includes policies and processes for prioritizing R2O transitions, assessing whether a transition is best accomplished through adoption of externally developed code or internal redesign and implementation, moving code to CPC and training staff on both system operations and code extensions, and for ensuring continued access of research groups to the operational code base which facilitates continued development of additional capabilities. The latter includes formal mechanisms for collaborative software development, including version control, task tracking, code reviews, and development of design documents. CPC should work with NCO in the implementation of this recommendation (see section 5.2).

Recommendation IS4: The NCEP should provide CPC with software engineering capabilities through changed policies that allow hiring outside the meteorologist classification or by assignment of NCEP NCO staff to CPC.

6.5 Science and Technology

6.5.1 Findings

Finding ST1: The principal science activities of CPC involve forecast tool development, climate monitoring and attribution, and model diagnostics and evaluation. The CPC scientists are very talented and committed people who are well versed with the current state of their science. Despite overall limited resources, CPC has in recent years had considerable success in attracting extramural, competitive funding, and CPC scientists have been active members of the research community as evidenced by the list of publications in peer-reviewed journals.

Finding ST2: The CPC has established itself as a leader in a number of science activities. In particular, the panel acknowledges CPC's important leadership role in climate monitoring and assessment (especially drought). The CPC, in collaboration with EMC, is also taking a leading role in the development of new high-resolution CFS-based seasonal hurricane forecast products. The panel also applauds CPC's pioneering role in the development and dissemination of reanalysis products for climate monitoring and analysis. CPC has a long history of proactively reaching out to the research community by hosting the annual CDPW.

Finding ST3: As part of their overall strategy, NCEP and CPO management have organized the CTB to accelerate CFS model improvements by infusing research results from the external community, to improve seasonal forecasting skill and for transitioning research to operations. The CPC has played an important leadership role in the CTB, and has been instrumental in some of its early successes, including the development of a consolidation tool that has helped considerably with seasonal prediction skill, and more recently performing hindcasts for the newly developed, high-resolution CFS-based seasonal hurricane outlooks, and in the development of a CTB seminar series. With the establishment of the CTB, CPC has played an increasingly important role in R2O activities. Nonetheless, as discussed in section 5.2, the CTB SAB has expressed concerns about the effectiveness of the CTB mission, which affects CPC science infusion activities, and particularly as it relates to the planning, development and evaluation of a NMME capability, which is further discussed below. The panel concurs with these concerns, particularly with the finding that CTB management and reporting isn't well structured to meet the development goals for CFS, which are important for CPC's strategic plans.

Finding ST4: The CTB faces a number of problems that threaten its viability, and limit the ability of CPC to influence science infusion and advance its product suite. Among these are a lack of transparency and coordination on CTB priorities, and funding levels that are insufficient to support a viable grants program, a grants program that is controlled by the CPO in OAR. The CTB has yet to develop a viable strategy for developing a NMME capability or for incorporating non-operational national models into a NMME system. While there have been improvements in the relationship and coordination between CPC and EMC (largely as a result of the CTB), CPC still does not seem to be a trusted partner in EMC's development efforts, and therefore has limited ability to influence CFS development priorities. This is a serious issue for CPC because the ability of CPC to provide improved climate predictions is strongly tied to advances in the CFS model (e.g., improvements in the simulation of the MJO, land-atmosphere interactions, and ENSO, among others). The panel is concerned that CPC currently has limited influence on the

development of CFS, and CTB lacks a strategy for developing a NMME capability that includes incorporating non-operational national models.

Finding ST5: The panel is supportive of CPC's nascent attribution activity, and believes that it can play an important role in both enhancing climate monitoring and diagnosing model forecast performance.

Finding ST6: The panel applauds the fact that CPC has played an important role in CFS Reanalysis and Reforecasting (CFSRR) monitoring and evaluation, and that it has taken on the challenge of doing the 1948-1978 period reanalysis. The latter could potentially allow extending reforecasts back to 1948; thus providing a longer baseline for calibrating CFS forecasts and allowing an assessment of decadal and longer time scale variability. While this appears to be an important opportunity for CPC to take on this challenge, and to contribute to the development of an ongoing reanalysis activity both at NOAA and at the national level, CPC does not yet appear to have a strategy in place for how that will be done.

Finding ST7: The ability of CPC to make substantial progress on climate reanalysis, particularly on how best to bridge reanalysis across uneven data, is limited by the lack of an extended period reanalysis strategic plan. The plan should accommodate system developments that account for the evolution of the observing systems used in reanalysis and of time varying model bias. Such developments could contribute to research in data assimilation occurring at EMC and the Earth Systems Research Laboratory (ESRL).

6.5.2 Recommendations

Recommendation ST1: NCEP and CPO should clarify the current structure of CTB to assure that it meets CPC's science infusion goals. Science priorities should include CFS model development and improvements, the development of a NMME capability, and climate forecast product development. The CTB needs to work more effectively with its Science Advisory Board (SAB) to achieve the CTB's envisioned goals when it was created. Additionally, the CTB should develop mechanisms for additional partnering with the external research communities and other research agencies (NSF, DOE, and NASA) that would bolster science infusion by leveraging resources.

Recommendation ST2: It is critical that the CTB receives sufficient funding for a viable grants program, that funding programs allow greater input by CPC and CTB in the competitive grants proposal review process, and that the funding programs do not constrain the scope of CTB activities.

Recommendation ST3: CPC should move forward with plans to establish a model test facility (as a combined CTB, NCEP and CPO effort) that gives the external research community (and CPC) access to the CFS with the aim of influencing and accelerating improvements to CFS.

Recommendation ST4: The CTB should develop a viable strategy for incorporating non-operational national models into an operational NMME framework. While this will require strong leadership from EMC, it should be done in partnership with CPC to ensure that the system

meets their needs, and it should leverage nationally-developed modeling resources such as the Earth System Modeling Framework (ESMF).

Recommendation ST5: Given CPC's critical dependence on CFS for many of its key products, and its unique role in CPC via EMC, it is to the benefit of both organizations that CPC play a more integral role in providing feedback to the development of CFS – this includes access to intermediate model versions and the computing resources necessary for assessing and diagnosing climate variability and predictability, and the capability to do sensitivity experiments that can provide feedback to EMC regarding model development priorities. For example, this could be done by an enhancement of CPC's attribution activity to include notable forecast successes and failures that can lead to improved understanding of model performance. This could be facilitated by having CPC rotators in EMC.

Recommendation ST6: The CTB efforts to develop new terms of reference for the CTB should be implemented quickly in order to provide greater coordination within CPC, and among CPC, EMC and NCO on R2O transition activities. This would create greater transparency and coordination in establishing CTB priorities.

Recommendation ST7: The CPC should develop a strategic plan for climate reanalysis and reforecasting that involves the CTB, other NCEP centers (esp. EMC), other NOAA groups (e.g. the National Climate Data Center (NCDC)), and coordinates with other reanalysis/reforecasting activities (e.g. at the Global Modeling and Assimilation Office (GMAO) and ESRL). Any plan needs to consider how timely reanalysis/reforecasting can be accomplished as CFS (and Global Forecast System (GFS)) model developments are implemented.

6.6 People and Organizational Culture

6.6.1 Findings

Finding POC1: The CPC has a talented and committed staff, well versed in the current state of the science. There is an extraordinary amount of activity and a passion for the mission of the Center. Under its current Director, CPC has gained an appreciation for the value of strategic planning, and has developed an implementation plan that is wholly consistent with the NCEP strategic plan. The staff understands CPC's importance to the mission of NCEP and appreciates the Center's effort to be fully responsive to it. CPC proactively reaches out to the RISA centers and other stakeholder organizations to understand how climate services can be more effectively delivered through partnerships.

Finding POC2: The development of new products and services occurs in both the DB and OB. The panel saw little evidence of coordination between the branches in the research and development activities, and there is the possibility of duplication and / or competition for research and development resources that weakens the overall enterprise. The panel also feels that the limited coordination and interaction between the branches is leading to less effective transitioning of R2O. A contributing factor may be CPC's organizational structure that relies heavily on contractors and "soft" money for the generation of its products and services. This reliance on contractors has ancillary effects that include pressure on CPC's mission and future

contributions to NCS, strategies for science infusion and the development of new products and services, and the need to find contractor support.

Finding POC3: For its current mission, CPC's access to models and computer resources is woefully insufficient. This situation impacts their ability for diagnostic experimentation, for example limiting the opportunity to consider a strategy for real-time reforecasts such as is being done at the European Center for Medium Range Weather Forecasts (ECMWF). This situation impacts their ability for diagnostics experimentation, to produce in a timely manner seasonal reforecasts that would consider a strategy for real-time reforecasts such as being done at the European Center for Medium Range Weather Forecasts (ECMWF). It is unclear to the panel the extent of the problem (inadequate computer resources) across NCEP, or how NCEP management priorities impact CPC's access to computer resources. Nonetheless, the panel raises this as a significant concern.

Finding POC4: The CTB, while organizationally part of the DB, does not have an integrated relationship with its parent branch and is relatively autonomous without clear lines of authority as discussed earlier in section 5.2 and 6.5. The CTB and the DB can and should function in a harmonious and mutual reinforcing manner, with well-defined roles, including complementary activities, undertaken by design. The current structure of the CTB hinders CPC in developing a unified organizational culture needed to meet its mission and strategic plan goals.

6.6.2 Recommendations

Recommendation POC1: CPC needs to clarify the relative roles of the DB and OB in the research and development of new products and services. Mechanisms must be developed to identify needed research, new products and determine what should be transitioned. These mechanisms must include approaches for creating opportunities for enhanced interactions between the DB and OB personnel.

Recommendation POC2: Mechanisms must be developed for reducing the reliance on contract personnel for product generation. One possible approach is by reducing the number of products (as called for in Recommendation PS7).

Recommendation POC3: CPC management needs to carefully assess issues that are, or potentially will, adversely affect meeting its mission and strategic goals, and work on resolving issues that are detrimental to CPC and enhance activities that strengthen its organizational culture and support its mission. Getting access to sufficient computer resources is a central issue, as is effectively managing staff across CPC branches and its product and service suites. This recommendation cuts across many elements of the review (e.g. mission goals, products and services, science and technology) and the underlying issues are inter-center, requiring CPC management to work with other NCEP centers and the OD in addressing them. Strengthening CPC's organizational culture is critical for CPC and NCEP so NCEP can contribute significantly to the NCS activity.

6.7 Business Processes

6.7.1 Findings

Finding BP1: Under its current Director, CPC has gained an appreciation for the value of strategic planning, and has developed an implementation plan that is wholly consistent with NCEP strategic plan. As a result, the staff members understand their roles, and CPC's importance to the mission of NCEP and appreciate the Center's effort to be fully responsive to it.

Finding BP2: Considerable effort seems to have been made since the last review to provide appropriate metrics of service in order to give CPC staff proper credit for service. This includes performance awards such as "Cash-in-Your-Account", "Special Act / Service Awards", NOAA Gold/Silver/Bronze Medals, and Isaac Cline Awards.

Finding BP3: As discussed earlier, there are several issues (many outside of CPC's control) that significantly impact CPC's ability to encourage innovation, efficiency and accountability. These include limitations on hiring professional software engineers to develop internet services; lack of input on CFS development decisions (EMC and CTB issues); issues related to carrying out reanalyses and reforecasts in a timely manner; transition of products and services to operations (an NCO issue); an apparent lack of clarity about to whom and when staff can talk to the private sector (a CPC service issue); insufficient coordination and communication between CPC's development and operations branches; NWS conference travel restrictions; and a fixed number of promotion slots and the average GS level – a retention and workforce skill issue).

6.7.2 Recommendations

Recommendation BP1: The CPC management needs to prioritize and work to resolve issues that affect CPC's innovation and efficiency, working with other center directors if the issues involve other NCEP centers. As an example, CPC management should further optimize the relationship between the DB and OB in order to promote efficiency and morale in both branches. Attention should be focused on ensuring that the DB solicits feedback from the OB on *post-mortem* forecast assessments, and on ensuring that the OB integrates products and tools from the DB as appropriate. Short-term exchanges of personnel or formalizing cross-branch partnerships (similar to RISA-CPC partnerships) are possible mechanisms to facilitate more effective relationships between the branches.

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 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 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 centers 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

CPC Review Panel Membership

Eric Wood (Chair)
Princeton University

Richard Carbone
National Center for Atmospheric Research

Holly Hartmann
University of Arizona

Gary Lackmann
North Carolina State University

Siegfried Schubert
NASA / Goddard Space Flight Center

Marshall Shepherd
University of Georgia

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 Droegemeier
University of Oklahoma

Genene Fisher
American Meteorological Society

Ronald McPherson
American Meteorological Society (Emeritus)

Leonard Pietrafesa
North Carolina State University

Eric Wood
Princeton University

Appendix C

Acronyms and Terms

AMS	American Meteorological Society
AWC	Aviation Weather Center
BAMS	Bulletin of the American Meteorological Society
BP	Business Practices
CCM	Certified Consulting Meteorologist
CDPW	Climate Diagnostics and Prediction Workshop
CFSRR	Climate Forecast System Reanalysis and Reforecasts
CP	Customers and Partners
CPASW	Climate Prediction Applications Science Workshop
CPC	Climate Prediction Center
CPO	Climate Program Office
CTB	Climate Test Bed
DB	Development Branch
DOE	Department of Energy
ECHO	Earth Observing System Clearinghouse
ECMWF	European Center for Medium Range Weather Forecasts
EMC	Environmental Modeling Center
ENSO	El Niño and the Southern Oscillation
ESIP	Earth Science Information Partners
ESMF	Earth System Modeling Framework
ESRL	Earth Systems Research Laboratory
FAA	Federal Aviation Administration
FTE	Full Time Equivalent
GFDL	Geophysical Fluid Dynamics Laboratory
GFS	Global Forecast System
GIS	Geographic Information Systems
GMAO	Global Modeling and Assimilation Office
GPS	Global Positioning System
HDL	Hydrologic Development Laboratory
HPC	Hydrometeorological Prediction Center
ICCP	Intergovernmental Panel on Climate Change
IRI	International Research Institute for Climate and Society
IS	Information Systems
IT	Information Technology
ISI	Intraseasonal, Seasonal and Interannual
KML	(formerly) Keyhole Markup Language
MJO	Madden-Julian Oscillation
MV	Mission and Vision
NARR	North American Regional Reanalysis
NASA	National Aeronautics and Space Administration
NCDC	National Climatic Data Center

NCEP	National Centers for Environmental Prediction
NCO	NCEP Central Operations
NCS	NOAA Climate Services
NESDIS	National Environmental Satellite, Data and Information Service
NextGen	Next Generation Air Transportation System
NGO	Non-Governmental Organization
NIDIS	National Integrated Drought Information System
NOAA	National Oceanic and Atmospheric Administration
NMME	National Multi-Model Ensemble
NRC	National Research Council
NSF	National Science Foundation
NWS	National Weather Service
O2R	Operations-to-Research
OAR	Office of Oceanic and Atmospheric Research
OB	Operations Branch
OD	Office of the Director
OHD	Office of Hydrologic Development
OPC	Ocean Prediction Center
POC	People and Organizational Culture
PS	Products and Services
R2O	Research-to-Operations
RISA	Regional Integrated Sciences and Assessments
SAB	Science Advisory Board
SARP	Sectoral Applications Research Program
SCEP	Student Career Experience Program
SPC	Storm Prediction Center
ST	Science and Technology
STEP	Student Temporary Employment Program
SWPC	Space Weather Prediction Center
THORPEX	The Observing System Research and Predictability Experiment
TPC	Tropical Prediction Center
UCAR	University Corporation for Atmospheric Research
USAID	United States Agency for International Development
W2DT	Week-2 Development Team
WCRP	World Climate Research Programme
WFO	Weather Forecast Office
WMO	World Meteorological Organization
WWRP	World Weather Research Programme
XML	Extensible Markup Language