2009 Community Review of the NCEP Ocean Prediction Center

Carried out by the University Corporation for Atmospheric Research

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Table of Contents

Executive Summary

The Ocean Prediction Center (OPC) strives to be the mariner's weather lifeline, providing marine forecasts, watches and warnings to a wide variety of customers and stakeholders with interests at sea. The OPC evolved from the Marine Prediction Group, prior to the creation of the National Centers for Environmental Prediction (NCEP) and was originally proposed to have been a joint venture with the National Ocean Service (NOS). One overarching recommendation of this review is that the National Weather Service (NWS) and NOS should reconsider the original proposal, converting OPC into Joint Center with an operations component and an applications component.

The OPC staff is enthusiastic and highly capable, effectively managing the highly demanding workload and making efforts to connect with the marine community. The OPC has addressed recommendations from the previous review within the constraint of available resources. In response to stakeholder demand, OPC must build upon its good morale and expand and enhance its product suite. However, the Review Panel has some concerns about whether OPC is at the forefront of ocean forecasting. To address this shortcoming, OPC should confidently engage partners to improve its research to operations (R2O), operations to research (O2R), and operations to applications (O2A) activities.

There is a need for the OPC to cover mandated US waters, in the provision of its products and services. Additionally, OPC must ensure that proper forecasts are prepared for all US coasts. At present, the OPC has insufficient staff to cover all coasts and suffers from the absence of a full-time Science and Operations Officer (SOO).

There is an expressed need and desire from OPC customers that OPC develop a robust "ecological" capability. The OPC should engage NOS, the National Marine Fisheries Service (NMFS), the National Environmental Satellite, Data and Information Service (NESDIS), and the National Oceanic and Atmospheric Administration (NOAA) Oceanic and Atmospheric Research (OAR) to provide an operational ecological forecasting and information and products dissemination capability.

Disciplinary diversity will greatly strengthen and undergird the ability of OPC to deliver the highest quality products and services. In order to meet emerging product and service demands, including ocean, coastal and probabilistic products, OPC should diversify its staff to include physical, ecological and chemical oceanographers, and statisticians.

Cross-training with the Tropical Analysis and Forecast Branch (TAFB) of the National Hurricane Center - Tropical Prediction Center (NHC-TPC) has been an excellent exercise for developing synergy between the two centers and enhancing support. The unified surface analysis has been a major advance. The Marine Zones of responsibility for OPC and NHC-TPC have been divided, with OPC holding rein north of 31°N and NHC-TPC in charge to the south of 31°N. OPC and NHC-TPC should revisit the 31^{o} latitude demarcation, support each other and take advantage each other's skills and expertise. For

example, OPC could extend its region of operations to 7^{o} N in the open Atlantic Ocean, and to 18.5° S in the eastern Pacific Ocean.

The OPC relies on the Meteorological Development Laboratory (MDL) and the Environmental Modeling Center (EMC) to meet its modeling needs. The OPC should clearly delineate its requirements and expectations to MDL and EMC, encourage interactions with the external model development community, seek state-of-the-science, physics-based models and consider ensemble forecasting capabilities.

The OPC does not have staff familiar with the implementation of data assimilation (DA) tools and methods, nor the co-joining of models. The OPC should work with EMC to develop a DA capability using modern methodologies and have in-house expertise to take advantage of emerging mathematical algorithms and NOAA observing assets.

Both remotely-sensed and in-situ data are valuable intrinsically as well as in improving numerical model output. The OPC requires the essential coastal and ocean network of observing networks on both sides of the air-water interface (like the National Data Buoy Center - NDBC - buoys) driving EMC's numerical model output and OPC data products and services.

The effort to transition to a digital forecast is applauded, and the interest and engagement in the Graphical Forecast Editor (GFE) and the Advanced Weather Interactive Processing System (AWIPS) II protocols is a good approach to building capability for the future.

One stop, easy access Internet delivery is the key to providing OPC stakeholders with the products and services that they expect and deserve. The OPC should explore the coordination of Center-specific needs in technical support and ensure access to a webmaster who understands and can address its needs.

The stakeholders have expectations that far exceed OPC's ability to deliver model output and easy to use products and services in a timely fashion, which leads to user frustration**.** The Director of OPC, along with the OPC administrative staff, the OPC SOO and the OPC branch chiefs should routinely poll and engage its stakeholder user community and address their needs and demands.

1. Introduction

1.1 Purpose: Context and Summary of Charge

The University Corporation for Atmospheric Research (UCAR) was requested in November 2008 by the National Centers for Environmental Prediction (NCEP) to facilitate a thorough and thoughtful community review of the nine centers that comprise NCEP, as well as the NCEP Office of the Director (OD). 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)
- National Hurricane Center - Tropical Prediction Center (NHC-TPC; Miami, FL)

This report summarizes the review of OPC and was conducted by the panel that also reviewed NHC-TPC. The last major review facilitated by UCAR was conducted in 1997, with a follow-up review held in 2001.

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

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

arisen that requires NCEP to operate at the highest possible level of scientific and technological excellence. Examples of challenges facing the Nation for which NCEP's products and services are essential include the following:

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

- The 2007 Intergovernmental Panel on Climate Change (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's) new Next Generation Air Transportation System (NextGen) will place increased demands on NCEP services.

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

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

In order to provide a review that could be most useful to NCEP, the community review was organized into five panels. 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. The full charge to the review panels is provided in Appendix A.

1.2 Procedure

The Review Panel, consisting of six members (see Appendix B) who were appointed by the President of UCAR, visited the OPC facilities in Camp Springs MD on 6-7 May 2009. To prepare for the visit, a set of questions was provided to center leadership. In return, a comprehensive binder of material was provided to the Review Panel. This included responses to the panel's questions, OPC overview documents, and information on customers, products, and services; transition of research to operations; performance measures; budgets; strategic plan; etc. A web-based survey also was distributed to a variety of stakeholders.

During the on-site visit, OPC Director Dr. Ming Ji presented center highlights, including successes and challenges. Other presentations were given by branch chiefs as well as cross-cutting teams. Considerable time was spent conducting interviews with branch staff and teams on topics including administration, information technology and facilities, community engagement, and science/research. Additionally, a closed lunch was held during the first day of the visit with contract employees, visiting researchers, civil servants and early career staff. The visit concluded with a briefing of initial findings and recommendations to OPC leadership and NCEP Director, Dr. Louis Uccellini.

2. Overview of the Ocean Prediction Center

2.1 Mission and Vision

The vision and mission of the OPC are:

> *Vision: "The OPC strives to be recognized as the mariner's weather lifeline and the center where NOAA's physical oceanographic observations, modeling research and operational services come together."*
>
> *Mission: "To deliver atmospheric and oceanographic warning, forecast, analysis and guidance products and services as part of the NOAA mission of protecting life and property and enhancing economic opportunity."*

The OPC quality controls global marine observations from ships, buoys, and automated marine observations for gross errors prior to being assimilated into computer model guidance. The OPC also provides forecast points in coordination with the NHC-TPC for tropical cyclones in the Atlantic Ocean east of 60°W and north of 20°N.

2.2 Brief History

The OPC, which evolved from the Marine Prediction Group and was established in 1995, was one of the original six service centers of NCEP. However, the basis for the OPC mission can be traced back to the sinking of the Titanic in April 1912. In response to that tragedy, an international commission was formed to determine requirements for safer ocean voyages. In 1914, the commission's work resulted in the Safety of Life at Sea Convention; the United States is one of the original signatories. The National Weather Service (NWS), through OPC, assumed the U.S. obligation to issue warnings and forecasts for portions of the North Atlantic and North Pacific Oceans.

The growth of the number of OPC customers and partners over the last few decades, and particularly the growing vulnerability of our burgeoning coastal populations, is evidence of the growing need for, use of and importance of ocean and coastal weather information and services. Ensuring the highest quality products in response to evolving customer needs requires OPC to maintain customer interactions, provide mechanisms to gather their requirements, and provide advice and education on the impacts of weather throughout the coastal zone. While OPC has reached out to numerous customers to gain an understanding of their impacts and requirements, the lack of a sufficient budget in recent years has led to gaps in the customer feedback and education process. To help bridge these gaps, OPC has tried to leverage the ocean and marine weather communities' capabilities and resources to meet customer requirements by developing and promoting partnerships.

2.3 Organizational Structure

The OPC is organized into the Ocean Applications and the Ocean Forecast Branches (OAB and OFB, respectively) with a total of 30 full time equivalents (FTEs). The OFB issues warnings and forecasts in print (bulletins) and graphical formats, on a 24x7 basis up to five days in advance. The OFB covers the North Atlantic Ocean from the west coast of Europe to the U.S. and Canadian east coast and the North Pacific Ocean from the U.S. and Canadian west coast to the east coast of Asia. The OFB weather forecasts and warnings for these areas primarily ensure the safety of ocean-crossing commercial ships and other vessels on the high seas. Imbedded in these high seas areas are smaller offshore zones off the Atlantic and Pacific coasts. These zones extend from near the coast seaward to just beyond the U.S. Exclusive Economic Zones, out to about 250 nautical miles.

The services provided by OPC ensure the safety of the extensive commercial and recreational fishing, boating, and shipping activities in these offshore waters. The OPC produces 136 operational products daily, counting experimental products such as storm surge model and ocean model graphics and digital data. The OPC also provides a limited number of products in other categories, including: text warning and forecast products; graphic forecast and analysis products via Radiofax; gridded products distributed via File

Transfer Protocol (FTP); on-demand weather support; graphic model guidance on the Worldwide Web (WWW); and digital model FTP output.

The OAB plays a critical role in transitioning scientific and technological advancements into enhanced OPC operations and services. One example is the adaptation of ocean surface vector wind observed from the QuikSCAT satellite in early 2000, after which OPC began to issue hurricane force (HF) wind warnings. In the 2006-2007 winter storm season, over 100 HF warnings were issued for North Pacific and North Atlantic oceans to warn ships of these most severe weather hazard conditions over major shipping routes. Preliminary results from a recent study estimates that in the absence of good information about extra-tropical ocean storms, the annual loss to container and dry bulk shipping would be more than $500 million. Operational marine warnings and forecasts reduce the above estimated annual loss by nearly one half.

The areal extent of OPC's region of coverage is the over marine areas of the Northern Hemisphere S of 67°N to 15°S (except the Indian Ocean). The guidance and forecasts are issued by OPC for time periods when useful skill exists out to 96 hours for seas and 120 hours for weather systems. The OPC application activities include conducting support of the civilian maritime community and other government agencies in support of safety of life at sea, such as the U.S. Coast Guard. The OPC product suite includes support for transoceanic, fishing, and recreational marine users, coastal communities, marine navigation, and other marine interests.

The OPC relies on or interacts closely with the CPC, the EMC, the HPC, the NHC-TPC and NCO. Within the context of the NCEP structure, OPC relies heavily and is critically dependent on the forecasts created and provided by the EMC and by the NWS Meteorological Development Laboratory (MDL).

3. Progress Since Previous Review

The OPC was last reviewed in 1999. Since that review, the recommendations from that review have been addressed and several improvements have been implemented, including a transition to digital forecasting, a number of new products and services, including components of the seamless suite of forecast products, several observing system advances, an improvement in performance (to over 99.7%) for over 40,000 charts, and on-demand support for the U.S. Navy and U.S. Coast Guard. Among the new products and services, the unified surface analysis, hurricane force warnings (mentioned above) and extra-tropical storm surge products are particularly noteworthy, although the addition of graphical depiction of superstructure icing on charts and several additions to the web page are important as well.

A "synergy team" was established between OPC and NHC-TPC that has accelerated progress and helped with efficiency and division of labor. The synergy team has been focused on streamlining and synchronization of text and graphical products. The

exchanges between OPC and NHC-TPC of forecasters enabled OPC to serve as a full backup forecast source for the NHC-TPC Tropical Analysis and Forecast Branch (TAFB) for the first time in 2008.

4. Summary of Stakeholder Survey

A stakeholder survey was developed by the panel and sent to several hundred individuals representing a broad spectrum of sectors and organizations that are known to utilize OPC products or that interact with OPC directly.

75 stakeholders accessed the survey, of whom 42 respondents (56%) completed the entire survey, while the other 33 (44%) answered questions related to their specific sector needs. Approximately half of the respondents (51%) were affiliated with federal government agencies, the vast majority of which were affiliated with the National Weather Service. Approximately 17% of the respondents were from academia, and 32% of the respondents identified themselves with non-governmental organizations or universities, specifically 17% from for-profit organizations, and 15% from non-for-profit organizations.

The common themes across the survey responses were that OPC forecasts are highly valued, because they support safe navigation and thus help to direct mariners away from hazardous conditions. In the words of respondents, OPC products are viewed as "remarkable" and the "best assortment of ocean products freely available to mariners". Respondents identified consistent analyses, wind and wave forecasts and point forecasts for ships as the most significant benefits of OPC products, although watches and warnings were viewed as less useful because they are sometimes issued too late or even after the fact.

The survey noted that OPC is slow to change, and needs to provide: more gridded or self-extracting electronic files; more ensemble-based, probabilistic, digital and automated products; ocean current information; a Gulf Stream location and currents chart; and more sophisticated tools that can support higher temporal and spatial resolution. Respondents find it difficult to navigate the entire suite of products and expressed desires for more outreach and more direct forecast support for marine vessels, particularly NOAA ships.

There was broad agreement that research outcomes, including those produced within the OPC as well those as brought in from external organizations and programs, are not translated into useful products and services in a sufficiently timely fashion, principally because of lack of resources. A summary of the statistics of the stakeholder survey may be found at http://www.vsp.ucar.edu/events/NCEP.

5. General Observations and Overarching Issues

The state of the science of environmental diagnostic and prognostic modeling has advanced significantly over the past decade and is expected to advance tremendously over the next decade. Complementary environmental observing systems, both remote and in-situ, are collecting and are expected to collect more data, more types of data, and overall better quality data, all of which, in principle, can be used to improve diagnostic and prognostic model output via data ingestion and data assimilation. Thus, OPC should become the direct beneficiaries of the improved numerical model output, including that driven by the assimilation of data, to improve and expand their product and service suite.

Modeling support for OPC products and services is provided largely by the EMC's Marine Modeling and Analysis Branch (MMAB). Also, the MDL provides the storm-surge model output used for coastal flooding guidance. While the flood and inundation models supported by the MDL and EMC are easy to use and forecasters have considerable experience with them, the models are two-dimensional or lacking a physical basis, or both, and are no longer considered state-of-the-science.

Environmental data is essential for OPC's existing suite and its future, planned products and services. Unfortunately, in-situ observations across and in the global ocean, the coastal oceans, estuaries, harbors and lower rivers are presently deemed inadequate to provide the essential, much less optimal, network of data necessary to serve OPC's needs. Further, the data assimilation systems used to update model projections of ocean and marine atmospheric variables are presently lacking. The issues of data coverage and data assimilation into models must be improved if OPC products and services are to realize sustained improvement.

The ocean prediction enterprise should have as a vision a state-of–the-science model in which the atmosphere, the global ocean, the coastal ocean, estuaries, and rivers and streams are fully coupled. Because modeling and observations are dependent on one another to maximize their joint forecast utility, coordinated programs of observations and models are required regionally and locally. In coastal ocean and estuary areas, as well as across the ocean, succinctly stated, there is insufficient data coverage to validate, let alone drive models. OPC produces forecasts of phenomena in these areas but lacks critical observations. Additionally, couplings to hydrologic systems, both atmospheric and land-based, are necessary both from monitoring and modeling perspectives. These are all feasible. The requirements to realize this vision are beyond OPC - this will require proactive development of partnerships among EMC, OPC, and the research community, as well as among the NWS, NOS, NESDIS, Department of Defense (DOD), specifically the Navy, and international partners. Investments in new observations, high-performance computing, data assimilation and model development will also be required.

The land-based atmospheric national observing network has recently been thoroughly evaluated with strong recommendations having been put forward in a National Research Council Report, the *Network of Networks* (NoN, 2008[1]). Unfortunately, the

[1] Committee on Developing Mesoscale Meteorological Observational Capabilities to Meet

adequacy of the observing network in the Nation's oceans, Great Lakes, Gulf of Mexico and coastal areas was not well covered in the report. These observing systems are key to establishing a better understanding of the thermodynamic processes which are involved in such processes as fueling the further intensification or spawning of gulf and mid-latitude cyclones, and in changing hurricane intensities as the vortices interact with their oceanic, western boundary and boundary currents and gulf heat and momentum sources and sinks.

There is a long-standing NOAA in-situ observing network consisting of the National Water Level Observation Network (NWLON), located primarily along the Nation's shorelines; the NWS/National Data Buoy Center (NDBC) meteorological buoys, located offshore; and the Coastal-Marine Automated Network (C-MAN) located near and along the coast. These collective systems measure coastal water level, coastal water surface temperatures and atmospheric winds at a few hundreds of locations nationwide including the Atlantic, Pacific and Gulf seaboards, Alaska, Hawaii and the Great Lakes, with very few other ocean, coastal and estuary state variable measurements, especially subsurface, collected in-situ. While the National Climate Data Center (NCDC) is presently evaluating its network, more and better parameters must be collected, particularly if the stated intention of OPC to conduct ecological forecasting is to be realized. Further, the existing in-situ coastal, Great Lakes and ocean coverage is not sufficiently dense and thus not adequate to the task of modern forecasting. This has been recognized for a decade and a half and has spawned the Global Ocean Observing System (GOOS) and Integrated Ocean Observing System (IOOS) initiatives; both funded by the US Congress, primarily as earmarks.

The OPC has an opportunity to capitalize on the fledgling GOOS and IOOS observing networks, thereby enhancing the existing marine buoy network. The OPC, working with EMC, must participate in the determination of optimal sitings of GOOS and IOOS elements. Taking advantage of GOOS and IOOS assets by influencing what is measured and where it is measured will lead to the improvement of OPC's products and services.

There was considerable discussion at the site review of OPC seeking new customers and partners. The US Navy has recognized this and, with NOAA and the National Aeronautics and Space Administration (NASA), is looking onto ways to engage the Air Force Weather Agency (AFWA), academia, and even industry to: (1) define what is needed in terms of connecting research and development to operational requirements; (2) express these requirements; and (3) find ways to engage, fund and leverage support. There is a national initiative to improve atmosphere and ocean forecasting. The OPC, and more broadly NCEP and NWS, needs to ensure participation and coordination with all parties.

Several of the findings and recommendations by the 2004 review of NCEP ocean

modeling[2], which was commissioned by NCEP via the NOAA Science Advisory Board (SAB) and provided to the OPC Review Panel, are still germane today. That report recommended that NCEP rapidly develop two-way, interactively coupled, state-of-the-science atmospheric, ocean, coastal ocean, and land-based models, driven by real-time data from smart buoys, and assimilated into the models. The objective is the immediate improvement of the quality and reliability of forecasts of atmospheric and oceanic and coastal weather events and their impacts on hydraulic systems and ecosystems, as air and water are interactively coupled in the real world, at commensurate space and time scales. The implications of that study, pertinent to this review are that OPC should: (1) push for the essential suite in-situ data in global and coastal ocean and in estuary areas, derived from smart buoys using modern technology; (2) work with EMC in the conduct of Observing System Experiments (OSE) and Observing System Simulation Experiments (OSSE) tests to guide improvements in NOAA's ocean and coastal observation networks, including atmospheric and ocean state variables; (3) work with EMC to insure that there are sufficient staff personnel trained in global ocean, coastal ocean, and estuary science; and (4) work with EMC and MDL to develop Model Output Statistics (MOS)-type products for the oceans.

6. Findings and Recommendations

Overall, the Review Panel found that the OPC is an effective center, with a well-balanced portfolio of operational forecasting, R2O transition and outreach to stakeholders and the public. The detailed findings and recommendations given below evaluate strengths and weaknesses of OPC and offer suggestions for improvement. The findings and recommendations are organized according to the themes used in the NCEP Strategic Plan (2009-2013), to facilitate implementation of the panel's recommendations.

6.1 Mission and Vision

The OPC mission is focused on ocean, marine and coastal processes, broadly defined. The OPC strives to be recognized as the mariner's weather lifeline and the center where NOAA's physical oceanographic observations, modeling research and operational services come together and to deliver atmospheric and oceanographic warning, forecast, analysis and guidance products and services as part of the NOAA mission of protecting life and property and enhancing economic opportunity.

Finding MV1: Despite many positive characteristics (staff morale and dedication, engagement with stakeholders, etc.), OPC cannot fully succeed in its mission and fulfill its vision, because of its reliance on EMC, which is not providing the highest quality products and services, and because it lacks some key staffing.

[2] Pietrafesa, L., D. Blaskovich, A. Blumberg, A. Busalacchi, J. McClean, C. Mooers, D. Rogers, R. Weisberg, 2004: **Review of National Centers for Environmental Prediction Ocean Modeling**. NOAA Science Advisory Board, 37 pages.

Recommendation MV1: The OPC should work with the NCEP Director, EMC and NCO to ensure that its present and future needs are met. This includes finding funding for the necessary expertise, computer power, and development; and guiding national science efforts to keep NOAA at the forefront, in cooperation with other operational agencies (DOD, etc.).

Finding MV2: There is an expressed need from OPC customers and a desire from OPC staff to develop a robust "ecological" prediction activity. The OPC is not presently engaged in ecological forecasting, although this should be a part of the OPC's vision for the future.

Recommendation MV2: The OPC should expand and develop an ecological forecasting activity that is in keeping with the expressed needs of its stakeholders, and in doing so should engage NOS, NMFS, and OAR and perhaps the Environmental Protection Administration (EPA) and the Department of Interior (DOI). NOS and NMFS should be major partners with the NWS in this undertaking.

6.2 Customers and Partners

The OPC interacts with a diverse group of customers and partners, ranging from its sister NCEP centers, to other parts of NOAA, other countries, other Federal entities (Federal Emergency Management Agency or FEMA, Navy, etc.), the media, commercial interests, and the general public. In general, OPC staff have engaged well with the stakeholder community. The findings and recommendations below are provided to foster additional collaborations.

Finding CP1: The OPC-TPC Synergy Team is a very effective initiative to enhance the coordination, streamlining, and synchronization of products and services.

Finding CP2: The unified surface analysis product is a great example of four groups working together to generate a seamless product.

Finding CP3. The OPC evolved from the Satellite Marine Section of the National Meteorological Center's Meteorological Operations Division, which preceded the creation of NCEP. OPC was to have been a joint venture with NOS. The Deputy was to have come from NOS along with 14 FTEs in a Techniques Development Branch, but it did not come to pass, because NOS withdrew.

Recommendation CP1: The NOS should be a major partner with the NWS in the OPC. The NWS and NOS should investigate creating a Joint Center that combines components of OPC and elements within NOS. The Joint Center effort could start with a synergistic entity such as an "experimental test bed".

Finding CP4: The OPC depends critically upon numerical guidance provided by the EMC. In many respects, this guidance is not state-of-the-science for the purposes of oceanic, marine and coastal weather, broadly defined, and environmental prediction.

Recommendation CP2: The OPC should work with EMC to develop a plan whereby state-of-the-science interactively coupled atmospheric-ocean-hydrologic models can be deployed for numerical model-based output products and services. OPC and EMC should include in the plan the possible use of multiple numerical models to produce ensemble forecasts. The OPC also should work with EMC to develop a robust data assimilation capability using modern methodologies.

Finding CP5: The OPC serves 45 coastal NWS Weather Forecast Offices (WFO). Many of those offices develop their own local coastal products. It is possible that some of these WFO products could represent a duplication of effort, may not be coordinated with OPC and may not be as advanced as OPC products; particularly those planned or undergoing development.

Recommendation CP3: The Director of NCEP should work with NWS to investigate WFO efforts that are presently being performed by OPC or are being advanced at OPC, and recommend realignment of these functions (with appropriate personnel and funding). Where there are large-scale or universal requirements that cover multiple WFO regions, the OPC should have the skills and capabilities to provide the necessary products to reduce duplication and provide the WFOs with the best information available.

Finding CP6: The broad mission of NOAA includes management of coastal marine resources**,** and there is an expressed need and desire from OPC customers that OPC develop a robust "ecological" capability. Ecological modeling has matured to where models can produce prognostic forecasts of biological-geological-chemical parameters in coastal and inland waters and the need for such forecasting is growing nationally.

Recommendation CP4: OPC should develop an operational ecological forecasting and information and products dissemination capability. In doing so OPC should engage and propose to partner with NOS, the National Marine Fisheries Service (NMFS), the National Environmental Satellite, Data and Information Service (NESDIS), and NOAA Oceanic and Atmospheric Research (OAR). The Environmental Protection Agency (EPA) and the Department of the Interior (DOI) also should be engaged in discussions and in the initiative, as appropriate.

6.3 Products and Services

The OPC produces 136 operational products daily, counting experimental products such as storm surge model and ocean model graphics and digital data. The OPC also provides a limited number of products in other categories, including: text warning and forecast products; graphic forecast and analysis products via Radiofax; gridded products

distributed via File Transfer Protocol (FTP); on-demand weather support; graphic model guidance on the Worldwide Web (WWW); and digital model FTP output.

Finding PS1: The OPC's products and services are valued by its customers.

Finding PS2: In the past, Marine Zones were arbitrarily divided up with OPC holding rein north of 31°N and NHC-TPC in charge to the south of 31°N.

Recommendation PS1: The OPC and NHC-TPC should revisit the 31^{o} latitude demarcation with an eye towards greater flexibility and efficiency in supporting each other and taking advantage of each other's particular skills and expertise. As an ancillary benefit, if OPC assumed some of the ocean forecasting responsibilities of NHC-TPC, their personnel would have more time to concentrate on hurricane forecasting

Finding PS3: There is a 58% to 42% East Coast to West Coast ratio in OPC products and services. This imbalance was attributed to the facts that (1) OPC is on the East Coast, and has more contact with east coast customers; and (2) OPC does not have a Warning Coordination Meteorologist (WCM) as an outreach person.

Finding PS4: The OPC is commended for meeting their Government Performance Results Act (GPRA) goals of wind speed, significant wave height and timeliness.

Recommendation PS2: The OPC should strive to ensure that products and services are of uniform quality in all of their areas of responsibility.

6.4 Information Systems

The OPC provides some gridded or self-extracting electronic files; some ensemble-based, probabilistic, digital and automated products; ocean current information; a Gulf Stream location and currents chart; and tools that support higher temporal and spatial resolution. There is an extensive suite of products to navigate. Research outcomes, including those produced within the OPC as well as those brought in from external organizations and programs are not sufficiently translated into useful products and services in a timely fashion, principally because of lack of resources.

Finding IS1: The OPC does not have a webmaster.

Recommendation IS1: The OPC should have a "go to" person, a focal point, for its web service needs.

Recommendation IS2: As web pages become OPC's main interface with their customer base, the web site should become more informative and complete, and should evolve continuously.

Finding IS2: The OPC relies upon NCO for Information Technology (IT) support, and in general the support is adequate. However, OPC does not have available an operational Graphical Forecast Editor (GFE), nor does it have a means for users to easily access subsets of OPC data sets. With the rapid advance in customer familiarity with Geographic Information System (GIS) interfaces (Google Ocean, etc.) the demands for innovative software support are increasing. In addition, they require support for some IT tools which are unique to OPC.

Recommendation IS3: The OPC needs a click-and-drag capability so users can grab what they need in reference to the data sets. The OPC should explore the coordination of Center-specific needs in technical support with NCO, especially in connection with the development of AWIPS II. NCO might consider devoting an appropriate percentage of support time specifically to OPC.

Recommendation IS4: The OPC should work with NCO to ensure automated tools, such as the GFE and capabilities in AWIPS II, are available and supported for OPC.

Finding IS3: The OPC forecast areas are quite large, and can result in a warning for an entire zone when only a small portion is expected to be affected. Changes to the zones will require greater automation and digital capabilities.

Finding IS4: The OPC is not included in the National Digital Forecast Database (NDFD) nor the plans for NDFD going forward, such as GIS, Google Earth and others.

Recommendation IS5: The OPC should be included in the NDFD.

Finding IS5: There are enormous forecast areas that must be covered during the transit of storms, such as a tropical cyclone or an extra-tropical cyclone. As a consequence, a tropical cyclone in one region may create unnecessary warnings at other regions, so perhaps the forecasted warning zones should be reduced in size. However this could involve more personnel time, and as such argues for greater automation and the use of the GFE.

Finding IS6: The forecasters at OPC perceive a lack of software support from NCO for the development of software that is specific to OPC.

Recommendation IS6: To reduce personnel time as regional storm forecasts become more sub-regionally focused, OPC should develop greater in-house automation capabilities and employ GFE technology.

Recommendations IS7: To better meet the needs of OPC's products and services delivery requirements, OPC and NCO should negotiate and reach an agreement that OPC's specific needs for software development will be met by NCO.

6.5. Science and Technology

Overall, the Review Panel found that the OPC is an effective center, with a modest portfolio of operational forecasting based on R2O transition and outreach to stakeholders and the public. There are, however, several science and technology issues affecting the future success of the center that should be addressed by OPC, working with the NCEP Office of the Director (OD) and its partners.

Finding ST1: The OPC does not have staff familiar with community advances in interactively coupled wave and ocean current modeling or with community advances in interactively coupled atmosphere-ocean-hydrology modeling or with the value of data assimilation for NOAA observing assets.

Recommendation ST1: The OPC should explore opportunities to participate in case studies and use in-house seminars on ocean science advances. The plan to develop a Techniques Development Branch, originally planned to come from NOS, should be revisited.

Recommendation ST2: Given the NCEP paradigm that all NCEP "modeling" is to be done within EMC, and that OPC is a "service center", EMC should collaborate with OPC and take advantage of OPC's expertise and experience in ocean observing platforms, observing systems, quality control, and the application of ocean data in EMC's Ocean Data Assimilation development effort.

Finding ST2: There is not a robust program for R2O and O2R transitions for OPC products and services.

Recommendation ST3: The OPC should engage other federal agencies, academia and the private sector to improve its R2O and O2R enterprise. Also, OPC should develop a robust interaction with its private sector partners.

Finding ST3: The OPC has not progressed very far in including uncertainty or probabilistic information in its products and services. The OPC does not presently make heavy utilization of NCEP ensemble forecast information.

Recommendation ST4: OPC should work with stakeholders to understand the type of uncertainty information that would be useful for their decision making. OPC could include this information in its product suite by taking advantage of the information content of NCEP's ensemble forecast system.

Recommendation ST5: The OPC should make greater use of NCEP's ensemble forecast information to produce probabilistic advisory information and products.

Finding ST4: OPC does not have a definition of its requirements for verification of its products.

Recommendation ST6: The OPC should define its validation and verification needs.

Finding ST5: OPC does not have a complete picture of what data sets it needs from other parts of NOAA to improve its present and future model output, either physical or ecological, and gridded products and services.

Recommendation ST7: The OPC should strive to have the essential (preferably optimal) observing network (Coastal and Ocean Network of Networks, CaO-NoN) driving its numerical model output and data products and services. The OPC, working with EMC, should lead an effort to evaluate the shortcomings in the NOAA Observing Network (NDBC, etc.) to advise the agency on where and what voids exist both in the atmosphere and the ocean, and in what order they should be addressed.

Finding ST6: The OPC's stakeholders have an expressed need for the highest quality of products and services, including numerical model output and uncertainty information for decision support. However, OPC does not produce its own numerical model output and relies on MDL and EMC to meet its stakeholder expectations. MDL still employs the Sea, Lake and Overland Surges from Hurricanes (SLOSH) model for coastal flooding and inundation guidance, and WWIII for shallow water wave forecasts. Neither of these models is considered to be state-of-the-science, and as they are either outdated or inadequate, and cannot produce the best model output guidance.

Recommendation ST8: The OPC should clearly delineate their requirements and expectations for the highest quality numerical model output from MDL and EMC, encourage interactions with the external model development community, and seek state-of-the-science physics-based models. The requirement for probabilistic information suggests that OPC should consider ensemble forecasting capabilities.

6.6. People and Organizational Culture

The OPC staff has high morale, and its members are highly dedicated. They have enthusiastically addressed recommendations from the previous review and have done extremely well, given available resources. The OPC must build upon its positive attitude and expand and enhance its product suite. However, the Review Panel has some concerns about whether OPC is at the forefront of ocean forecasting.

Finding POC1: The OPC staff is thoroughly professional, very dedicated to their mission, and exhibit very high morale.

Finding POC2: There are serious gaps in some skills of the staff as a whole. Every OPC FTE is a meteorologist, except for the Director, who is a Physical Scientist. There are no oceanographers, geophysical fluid dynamicists, or statisticians on the OPC staff. The Science and Operations Officer is also the Acting Chief of the Ocean Application Branch and there is no Warnings Coordination Officer. As in the overarching recommendation to NCEP as a whole, OPC should avail itself of social science expertise as well.

Finding POC3: While OPC staff members have an excellent grasp of the skills needed to do their job, they do not appear to be keeping current with evolving meteorological and oceanography developments. Basically, given workload requirements and responsibilities, there is a perceived lack of opportunity in continual learning, or professional development, on the part of OPC staff, including the Director. Limiting OPC's staff jobs to only generating products and services could lead to intellectual stagnation.
Recommendation POC1: OPC and NCEP leadership must work to correct these personnel deficiencies. The OPC should consider diversifying its staff to include physical, ecological and chemical oceanographers, and statisticians, either as contractors or as considerations for replacing staff members who retire. The OPC Deputy Director could perhaps come from NOS, and the SOO could then be a full-time NWS FTE. A position for a Warnings Coordination Officer should be the next highest priority for a Civil Service slot. The remaining gaps might be addressed through contractors or visiting scientists.

Recommendation POC2: The Director of OPC, an accomplished scientist in his own right, should take a leadership role and engage the OPC staff to draft an overall professional development and continual learning plan that is broad and generic. He should then meet with each staff member and establish individual development goals, including metrics and time lines. This will ensure that advanced learning and professional activities are valued and will increase the self image of the staff and the prestige of OPC.

Recommendation POC3: The SOO should ensure his people have the opportunity to keep learning. This may include arranging OPC (NCEP) seminars and ensuring they have time to take relevant college course (correspondence or in-class).

6.7. Businesses Processes

Overall, the OPC is operating effectively, and conducts its business in a manner that is well-suited to the suite of products and services and the stakeholder community, given the available resources. However, OPC is viewed by the Review Panel as being a work in progress with an enormous future given the burgeoning needs for ocean, marine and coastal information, products and services.

Finding BP1: The stakeholder survey indicates a widely diverse community of users of OPC products, services and forecasts. Moreover, the survey begs the questions: (1) Is OPC aware of all the communities they serve and do they ensure that its product are meeting their needs, as much as possible with available resources; and (2) Are there products that could be purged?

Finding BP2: This community has expectations for easy-to-use products and services that far exceed OPC's ability to deliver them, especially model output, in a timely fashion. This leads to user frustration.

Recommendation BP1: The Director of OPC, along with the OPC administrative staff, the OPC SOO and the OPC branch chiefs should routinely poll and engage its' stakeholder user community and address their needs and demands.

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 Center as well as NCEP as a whole, and will make recommendations for improvements.

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

Appendix B

OPC Review Panel Membership

Frank Bub
Naval Oceanographic Office

Kristen Corbosiero
University of California Los Angeles

Mary Erickson
NOAA National Ocean Service

Brock Long
Alabama Emergency Management Agency

Len Pietrafesa (Chair)
North Carolina State University

John Toohey-Morales
NBC-6 Miami

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, Panel Chair
American Meteorological Society

Ronald McPherson
American Meteorological Society (Emeritus)

Leonard Pietrafesa
North Carolina State University

Eric Wood
Princeton University

Appendix C

List of Acronyms & Terms

AFWA	Air Force Weather Agency
AWC	Aviation Weather Center
AWIPS	Advanced Weather Interactive Processing System
BP	Business Processes
CaO-NoN	Coastal and Ocean Network of Networks
C-MAN	Coastal-Marine Automated Network
CP	Customers and Partners
CPC	Climate Prediction Center
DA	Data Assimilation
DOD	Department Of Defense
DOI	Department of Interior
EMC	Environmental Modeling Center
EPA	Environmental Protection Administration
FAA	Federal Aviation Administration
FEMA	Federal Emergency Management Agency
FTE	Full Time Equivalent
FTP	File Transfer Protocol
GFE	Graphical Forecast Editor
GIS	Geographic Information System
GOOS	Global Ocean Observing Systems
GPRA	Government Performance Results Act
GPS	Global Positioning System
HF	Hurricane Force
HPC	Hydrometeorological Prediction Center
IOOS	Integrated Ocean Observing System
IPCC	Intergovernmental Panel on Climate Change
IS	Information Systems
IT	Information Technology
MDL	Meteorological Development Laboratory
MMAB	Marine Modeling and Analysis Branch
MOS	Model Output Statistics
MV	Mission and Vision
NASA	National Aeronautics and Space Administration
NCDC	National Climate Data Center
NCEP	National Centers for Environmental Prediction
NCO	NCEP Central Operations
NDBC	National Data Buoy Center
NDFD	National Digital Forecast Database
NESDIS	National Environmental and Data Information Service
NextGen	Next Generation Air Transportation System
NHC-TPC	National Hurricane Center – Tropical Prediction Center
NMFS	National Marine Fisheries Service

NOAA	National Oceanic and Atmospheric Administration
NOS	National Ocean Service
NWLON	National Water Level Observation Network
NWS	National Weather Service
OAB	Ocean Applications Branch
OAR	Oceanic and Atmospheric Research
OD	Office of the Director
OFB	Ocean Forecast Branch
OPC	Ocean Prediction Center
OSE	Observing System Experiment
OSSE	Observing System Simulation Experiment
O2A	Operations to Applications
O2R	Operations to Research
POC	People and Organizational Culture
PS	Products and Services
R2O	Research to Operations
SAB	Science Advisory Board
SLOSH	Sea, Lake and Overland Surges from Hurricanes
SOO	Science and Operations Officer
SPC	Storm Prediction Center
ST	Science and Technology
SWPC	Space Weather Prediction Center
TAFB	Tropical Analysis and Forecast Branch
TPC	Tropical Prediction Center
UCAR	University Corporation for Atmospheric Research
WCM	Warning Coordination Meteorologist
WFO	Weather Forecast Office
WWW	World Wide Web