Atlantic Oceanographic and Meteorological Laboratory
2008 Laboratory Research Review

Response and Implementation Plan

Submitted by Robert Atlas, Director, Atlantic Oceanographic and Meteorological Laboratory (AOML) with contributions from AOML division directors and research staff, April 2, 2009, with amendments included August 28, 2009 and January 11, 2010.

The following document addresses recommendations made by the research review panel, as well as additional comments highlighted in the reviewers' synthesis report by the office of Oceanic and Atmospheric Research (OAR) Headquarters. The latter were comments and recommendations that were not part of the reviewers' recommendations but that OAR felt were important to consider in AOML's response. Subsequent comments from OAR's Labs and Cooperative Institutes (LCI) office and Policy Planning and Evaluation (PPE) office have also been addressed. The responses are presented by research theme, the same format used in the Reviewer Response. This document also includes two appendices entitled "Filling Up the Gaps" and "AOML-GFDL Collaboration," referenced herein.

Hurricane (Tropical Cyclone Intensity Change, Tropical Cyclone Structure and Precipitation, Tropical Cyclone Tracks, and Tropical Cyclone Frequency and Intensity):

Recommendations:

1. **NOAA modeling centers must share model code in order to engage the research community in the development of better hurricane forecasts.**

   Since the review in the spring of 2008, the Atlantic Oceanographic and Meteorological Laboratory (AOML) has actively participated in a number of NOAA planning activities that have resulted in much closer cooperation between NOAA's Environmental Modeling Center (EMC) and the NOAA hurricane research community. These planning activities have resulted in AOML's Hurricane Research Division (HRD) and the Earth System Research Laboratory's (ESRL) Global Systems Division (GSD) having access to the operational model code. Under the umbrella of NOAA's Hurricane Forecast Improvement Project (HFIP, approved by NOAA management in June 2008), regional hurricane and global model improvements were made a high priority. In order to facilitate these developments, the operational model code (Hurricane Weather Research and Forecasting (HWRF) and Global Forecast System (GFS)) were ported to the Developmental Testbed Center (DTC) in Boulder, Colorado to make them part of the model repository for the general research community. HRD, working with DTC and EMC, has upgraded the HWRF atmospheric model to the latest Weather Research and Forecasting (WRF) model version (3.01) and has worked to improve the operational atmospheric model components. HFIP also held a workshop in April 2008 that organized a test of resolution impacts on the model forecasts. As part of tthis effort seven teams, including a NOAA research team using the upgraded

atmospheric version of HWRF, agreed to run their model configurations on 69 cases selected by NOAA's National Hurricane Center (NHC) at three horizontal resolutions (9-10 km, 3-5 km, and 1-2 km) and to evaluate them using the operational evaluation packages within one year. The test was to be evaluated by the DTC. As HFIP progressed, it received support under a Presidential Supplemental in the fall of 2008 that accelerated the HFIP effort by one year. Eleven teams were organized to create an implementation plan, milestones, and budgets. As part of this effort, two regional model developments were approved based on HWRF: the operational version coordinated and executed by EMC and an experimental research developed version, the Experimental Hurricane Weather Research Forecasting Model (HWRFX, the successor to the HRD and ESRL/GSD developed version), that would be available to the research community and supported through the repository at DTC. HFIP model development teams composed of NOAA research and operational staff laid out the first two years of HWRFX model development efforts that were of particular interest to the operational community, including the completion of the HFIP high-resolution test plan, addition of a third moving nest (developed at HRD), development of a code management system for research and operations, examination and evaluation of improved physics packages, and the establishment of a restart capability for HWRF to implement more experimental data assimilation approaches (e.g., Ensemble Kalman Filter (EnKF), Four Dimensional Variational Data Assimilation (4DVAR)). Much of the HWRFX development will be conducted at the new HFIP-funded hurricane research high-performance computing center.

As HWRF and HWRFX are advanced, the HFIP plan is to maintain and share all versions of the model code through the DTC central repository and to utilize DTC to provide documentation and training for the research community who wish to access the HWRF and HWRFX component software packages for the basic model and physics packages that DTC approves for addition to the repository. Currently, the final approved version of the HWRF code is being completed and documented for inclusion to the repository with support from HFIP (based on the operational version available in 2009 with an updated version of the Weather Research and Forecasting Non-hydrostatic Mesoscale Model (WRF-NMM) core to v3.1), and the first HWRF tutorial is scheduled for February 2010. As these HWRF components are finalized, the plan is to submit all additional components available through HWRFX (e.g., third moving nest, alternative physics packages) for approval, broadening the model components available for testing and evaluation by the research community.

2. AOML hurricane Observing System Simulation Experiments (OSSEs) initiative should be encouraged and it should be required that this plan be coordinated and synergized with the ongoing OSSE activities of the Joint Center for Satellite Data Assimilation (JCSDA).

(Associated comment highlighted by OAR Head Quarters from the reviewers' synthesis report)

We need to do a better job of setting requirements for the hurricane problem in particular, thereby avoiding problems like that dogging QuikSCAT. Hurricane OSSEs may help us see the benefits of an observing system before it is designed, built, and launched.

This is underway, and substantial progress has been made. Limited hurricane OSSEs are currently running at HRD, and plans for more detailed OSSEs are being prepared. For the more advanced OSSEs, an accurate model and data assimilation for the hurricane inner core are needed. This is part of the HFIP model development effort. As mentioned in the previous response, improved data assimilation and models are a major priority for the HFIP effort. A second high priority for HFIP was the development of a hurricane observing system analysis capability which is to be based on the improved models and data assimilation efforts. HFIP did not want to tie the forecast improvements to any one observing system approach; instead, the goal is to test the existing (dropsondes, Doppler radar, QuikSCAT, etc.) and new NOAA observing capabilities to determine how they improve the hurricane forecasts in particular (Geostationary Operational Environmental Satellite R-Series (GOES-R), Unmanned Aerial Systems (UAS), Extended Ocean Vector Wind Mission (XOVWM), etc.). HFIP is supporting the evaluation of a number of these systems using OSSE/OSE approaches starting in FY09. The AOML Director is currently coordinating our OSSE planning with the Joint Center for Satellite Data Assimilation (JCSDA) and external partners.* He also prepared a plan for an OSSE testbed for the U.S. Weather Research Program (USWRP) that was due by September 30, 2009. This was endorsed at the April 30, 2009 meeting of NOAA's USWRP Executive Committee.

* Partners include: ESRL, EMC, the National Environmental Satellite Data and information Service – Center for Satellite Applications Research (NESDIS-STAR), NASA (Goddard Space Flight Center (GSFC), Jet Propulsion Laboratory (JPL), Marshall Space Flight Center (MSFC), Langley), Simpson Weather Associates, Atmospheric Environmental Research, Rosenstiel School for Marine and Atmospheric Science (RSMAS), Florida State University (FSU), University of Central Florida (UCF), University of Utah, and Naval Research Laboratory (NRL). We are open to more partners, but these are the current partners to date.

3. **AOML needs to carefully consider where in the spectrum of hurricane research its mission should fall. A number of other institutions provide state-of-the art modeling expertise, but the historical strength of AOML hurricane research has been in observations, which it is uniquely qualified to provide.**

(Associated comment highlighted by OAR Head Quarters from the reviewers' synthesis report)

The observational leadership capability of HRD needs to be reinvigorated by hiring staff with observational skills and scientific capability and by redirecting the NOAA P3 aircraft back to the research role that they are intended to play. If AOML rebuilds HRD with too strong a priority on modeling and relegates observational work to secondary status there is a danger of killing the goose that laid the golden egg. Deemphasizing observations will reduce HRD's usefulness to the observational research community, particularly that part of the community outside of NOAA.

It is precisely HRD's leadership in observations of hurricanes that makes it imperative to have a modeling capability at HRD, especially at this critical juncture in time as the current research and operational models are starting to resolve and simulate features of the hurricane vortex. HRD scientists are ideally situated to take advantage of in-house modeling expertise

to advance research and operational model capabilities through the use of observations in model evaluation and improved initialization. HRD's observations and experiment design experience is critical to improving the representation of physical processes within the research and operational model systems, in particular those processes related to air-sea interaction, atmospheric and oceanic boundary layers, vortex evolution, and convective structure. The data sets collected by the NOAA P-3 hurricane hunter (WP-3D) and Gulfstream-IV (G-IV) aircraft in the storm core are also essential to improve the initial conditions for these model systems as we try to improve the analysis of the vortex structure. These data sets also improve our ability to sample the storm structure. HRD is continuing its leadership in pioneering new hurricane observing systems with Doppler Wind Lidar, a Hurricane Imaging Radiometer (HIRAD), and UAS. Having an in-house modeling and data assimilation capability affords a direct connection between the researchers who understand hurricanes through observations with those trying to simulate them. This capability was a mainstay of HRD and its predecessors (with scientists like Rosenthal, Ooyama, Jones, Lord, and Shapiro working closely with observationalists), which has been lost over the last 10-15 years through attrition.

Over the last two years, HRD has actively pursued modeling, data assimilation, and observational experience in a balanced manner. To date, HRD has hired Full Time Equivalent (FTE) employees to conduct hurricane model development (Gopalakrishnan), and we just filled two more positions, one to work on inner core data assimilation (Vukicevic) and one to assist with the analysis and use of the airborne Doppler radar (Reasor). We also hired two Cooperative Institute for Marine and Atmospheric Studies (CIMAS) model developers (Yeh and Zhang) and two CIMAS observationalists to oversee our dropsonde (Sellwood) and Stepped Frequency Microwave Radiometer (SFMR) (Klotz) observations. We also recently had four post docs, one modeler (Fierro, National Research Council (NRC)), one data assimilation specialist (Aksoy, CIMAS), and two working in hurricane boundary layer research (Zhang, NRC, and Lorsolo, CIMAS). Three of the four (Fierro, Aksoy, and Lorsolo) finished their post-docs in the last few months and two (Aksoy and Lorsolo) were retained as CIMAS assistant scientists.

In some ways, bringing modeling back into HRD at this critical juncture restores the balance in the capability for NOAA to tap the expertise in observing these storms. This approach fits the new HFIP paradigm perfectly (which focuses on improving the models, observing strategies, and products for the forecasters), providing a corps of talent that NOAA can capitalize upon to accelerate improvements in our hurricane forecasts. The HFIP approach recognizes that only through the combined expertise of all of NOAA’s hurricane research efforts in all three areas can we begin to accelerate improvement. HRD is the only place in NOAA where all these issues can be addressed in one place. HFIP has made a major commitment to address these issues and has provided the funding to support such an effort.

4. **OAR and AOML laboratory management should work with the Environmental Modeling Center (EMC) management to make it possible for the Hurricane Research Division (HRD) and EMC to share the model code on a continuing basis to accelerate the model development efforts.**

This is already happening very successfully through the DTC and HFIP teams. Initial discussions began between the Director of AOML and the Director of NOAA's National Centers for Environmental Prediction (NCEP) and have continued between the leadership of HRD and EMC. HFIP has unified all NOAA efforts in hurricane research and development around a single effort, and NOAA management has provided oversight (see prior response (1) for details).

5. HRD should be provided with additional flight hours annually solely for the purpose of carrying out focused research programs.

Through HFIP, NOAA has made a major commitment to provide the resources for flight hours and expendables for hurricane missions under the Intensity Forecast Experiment (IFEX) umbrella (e.g., 900 flight hours in FY09 for all hurricane flights, plus $1.5M for expendables - primarily dropsondes and Airborne Expendable Bathythermographs (AXBTs)). Through IFEX all of NOAA's requirements for missions into hurricane environments are met, and the resources are shared to insure that every mission provides the necessary data sets for NOAA's partners' needs, from a figure-4 pattern for the Doppler radar data for use by EMC and NHC, to repeated profiles in heavy rain and strong wind for NESDIS scatterometer work, to pre- and post-storm ocean surveys for EMC's ocean model initialization. Within this framework, there are substantial opportunities for research to implement short modules that can be executed between Doppler legs or during the NESDIS profiles. There are also enough flight hours for HRD to be aggressive in tasking the aircraft to look at weaker systems for genesis research and also near landfall when the operational interests are less. Beyond FY09, the HFIP plan calls for comparable commitments (on the order $1.5M-$2.0M) to augment the National Weather Service (NWS), NESDIS, and OAR resources needed to support IFEX.

6. HRD needs to continue to improve its publication record and recruit staff who will be intellectual leaders that contribute usefully to the literature on tropical cyclones.

The proliferation of significant HRD publications was described as diminished in the past two decades. The main reason given was attributed to HRD's resources being level for 20-25 years. According to the reviewer, this led to a loss of intellectual leadership in hurricane research and lower numbers and reduced impact of HRD's publications. We share the concern of the loss of some intellectual leadership at HRD in the past 10-15 years. It is true that some of this loss is attributable to the lack of budget increases over the last 25 years. However, in the last five years HRD has been very active in rebuilding its intellectual leadership in hurricane research through the addition of four young researchers who are demonstrating potential to grow into intellectual leaders in hurricane research. In the past year, we have also added three FTEs, four CIMAS scientists, plus two post-docs with great potential to grow into intellectual leaders. HRD has not seen such expansion since the influx of talent in the late 1970s. The impact of such growth is a strong upside for HRD, as there is clear evidence that over the last five years HRD's publication output has increased at a steady rate. HRD has produced roughly 15 papers per year. In the last three years, however, HRD has averaged 26 papers per year (a 75% increase). This includes a number of major papers in

the American Meteorological Society's (AMS) *Bulletin of the American Meteorological Society* (BAMS), *Monthly Weather Review* (MWR), and *Journal of the Atmospheric Sciences* (JAS).

It is important to note that HRD is part of a federal laboratory that has a core focus in one portion of the atmospheric and oceanic sciences. Our strength is the focused effort we can bring to bear on that single problem. We need a broad range of talents from data processing and analysis, data archival, and database management along with our research talent. Without the team members dedicated to managing our observational and model data sets, HRD would be unable to meet its obligations to NOAA and the general research community as stewards of NOAA's unique hurricane data sets. We would not term any of these team members as unproductive just because they do not publish on a regular basis. Most university departments could not afford to maintain such an effort and, in fact, HRD has many university partners who are able to write proposals and publish papers using our data sets thanks to the hard work of these individuals. HRD does have some researchers that are not publishing at a steady rate, and we are addressing this issue through a number of initiatives (e.g., building teams that work on papers, conducting regular monthly science meetings to discuss active research, requiring papers to be published on any conference presentation, restricting conference participation to those who publish, and redirecting staff who do not publish regularly to focus on providing vital data sets). Many of these team members are now responsible for major HRD data sets such as data from flight level, dropsondes, radar, SFMR, AXBTs, and H*Wind surface wind products and, therefore, provide significant value to HRD, NOAA, and the general research community.

7. HRD should rebuild its connection with the external community to carry out the aircraft experiments needed to advance hurricane knowledge.

HRD has a long, very successful track record of collaborating with the external community through its observing and research programs. Recent collaborations in the past ten years that come to mind include the National Aeronautics and Space Administration (NASA) Convection and Moisture Experiments (CAMEX-3 & 4), Tropical Cloud Systems Processes (TCSP), and NASA African Monsoon Multidisciplinary Analysis (NAMMA) field efforts, the National Science Foundation (NSF) Rainband Experiment (RAINEX) and upper ocean impacts field efforts, and the Office of Naval Research (ONR) Coupled Boundary Layer Air-Sea Transfer (CBLAST) effort. Because of this extensive field experience, HRD scientists are recognized internationally for their knowledge of tropical cyclones, as well as their expertise in technological areas such as airborne Doppler radar, dropsondes, cloud microphysics, and air-sea interaction, to name a few. These assets make HRD unique worldwide and provide NOAA a unique capability. HRD has close ties with a number of NASA (e.g., Braun, G. Heymsfield, Miller, Hristova), NRL (P. Black, Harasti, Hawkins), and the National Center for Atmospheric Research (NCAR) (e.g., A. Heymsfield, Lee, Bell) researchers working on hurricanes. We also collaborate very closely with a number of university Primary Investigators (PIs) in their research, e.g., Shay, Drennan, Majumdar, and Nolan (RSMAS); Barnes (University of Hawaii); Montgomery and Harr (Naval Post Graduate School (NPS)); F. Zhang, Evan, and Bosart (Pennsylvania State University (PSU)); Molinari (State University of New York, Albany (SUNYA)); Eastin and Etherton (University

of North Carolina (UNCC)); Zipser (University of Utah); Reasor (FSU); Emanuel (Massachusetts Institute of Technology (MIT)); Bluestein (University of Oklahoma (OU)); Houze (University of Washington (UW)); Wu (National Taiwan University (NTU)); Schroeder (Texas Tech University (TTU)); Masters (University of Florida (UF)); Willoughby (Florida International University (FIU)); and many others. HRD is known in the research community as the place to come for any hurricane observational data sets. We have expanded the number of these data sets that are available to the external research community, and we continue to improve our interactions with our data users, implementing a clear data policy available on our website that adheres to NOAA's data policy. We intend to keep pushing data availability to enable researchers to access near real-time data sets as part of the HFIP effort. HFIP also clearly recognizes that NOAA cannot make the improvements called for by ourselves, and we have begun to make funds available to the external community through vehicles such as the joint ONR-NOAA National Ocean Partnership Program (NOPP) effort for improving tropical cyclone research. HRD is also very active in the Office of the Federal Coordinator for Meteorology (OFCM) Working Group on Tropical Cyclone Research which is developing an implementation plan for all federally-funded hurricane research. These interactions demonstrate that a strong connection to the external community already exists. Nevertheless, we are actively expanding our collaborations through the HFIP and our visiting scientist program.

Within NOAA, HRD has collaborations with NHC (Franklin, Landsea), EMC (Talapragada, Kwan, Tuleya, Surgi, Zhang, Tolman), the Geophysical Fluid Dynamics Laboratory (GFDL) (Marchok, Bender), ESRL (Fairall, Bao), and the UAS office (Hood).

Oceans and Climate (Climate Observing Systems, Atlantic Circulation and Fluxes, Atlantic Meridonal Overturning Circulation, Western Hemisphere Warm Pool and CO_2):

Recommendations:

1. **AOML should facilitate and enable climate modelers to be more engaged with the scientists responsible for observations so that two-way feedback can be enhanced to ensure that modelers fully utilize observations to validate and improve their models and that field scientists are providing the optimal set of observations for the model efforts.**

   (Associated comments highlighted by OAR Head Quarters from the reviewers' synthesis report)

   AOML's Physical Oceanography Division (PhOD) should expand their involvement in validating models. This can be accomplished two ways: generate an in-house modeling capability, or increase collaboration with external modelers, either at NOAA labs (e.g., GFDL) or elsewhere (e.g., Los Alamos National Laboratory). The latter approach is favored. PhOD should move toward developing a large Ocean General Circulation Model (OGCM) or climate modeling capability.

   PhOD scientists are expanding their involvement in validating models. This is a significant effort currently underway. PhOD recently hired a senior modeler for OSSEs as a Federal employee and a junior modeler as a CIMAS contractor. AOML feels that in order to

successfully collaborate with external modelers the laboratory must first have an experienced modeler who conducts model studies in-house and can effectively collaborate with the broader modeling community. Our recent hires provide that crucial translations expertise.

PhOD made a proposal to GFDL for Collaborative Research on January 6, 2009 to improve climate/ocean models, predictions of climate variability for societal benefit, and our understanding of seasonal-to-multidecadal climate variability (*see appendix*). GFDL requested that the collaborative project commence after their laboratory review and the upcoming Fifth Intergovernmental Panel on Climate Change (IPCC 5). AOML will be providing data and analysis from relevant projects in the interim. AOML and GFDL scientists have also begun limited collaborations on climate issues, including recent joint publications and funding proposals. A new joint AOML/GFDL proposal will be submitted to NOAA's Climate Program Office (CPO) this year to improve characterization of variations in climate prediction models in the Atlantic. There is also a joint seminar series planned to enhance communication.

AOML is also submitting a proposal to NOAA/CPO entitled "Assessing the Sensitivity of Northward Heat Transport/Atlantic Meridional Overturning Circulation to Forcing in Existing Numerical Model Simulations" by S. Dong, M. Baringer, G. Goni, and G. Halliwell, in which it is proposed to investigate and assess differences in the Atlantic Meridional Overturning Circulation (MOC) index between observations and GFDL model output. The contact scientist at GFDL is Dr. Rong Zhange.

2. AOML should continue to emphasize strengths that have traditionally been in observational work but add complementary analysis and modeling efforts to better connect its work with the larger research community.

(Associated comment highlighted by OAR Head Quarters from the reviewers' synthesis report)

The perception of the present situation at AOML is that there are not sufficient funds made available by NOAA for the specific task of analyzing data, as opposed to collecting it. It is recommended that NOAA make more funds available specifically for data analysis.

AOML's efforts in maintaining its leadership in ocean observations for climate can be corroborated by its participation atthe recent OceanObs'09 international meeting. AOML scientists were lead authors of two white paper proposals and coauthors of 10 white papers. However, support to collect the observations has been kept at level funding, resulting in a net loss of about 10% per year due to inflation. The result is that fewer observations are collected and sustainability of the observing system components managed by AOML is becoming more difficult. Even more important is the lack of funding for analyzing these data. Drs. Gustavo Goni and Silvia Garzoli have submitted five alternative proposals to the Climate Observations and Monitoring Alternatives program to explore possibilities for increased funding in PhOD.

In order for modeling collaboration across NOAA to occur and for AOML observational expertise to be effectively used by NOAA modeling organizations, a limited number of modelers must exist at AOML. This will increase communication and collaboration.

Modelers at AOML research different aspects of modeling challenges than those addressed by modeling centers and other NOAA offices. These include:

- Observing system experiments (OSEs) which allow modelers to help identify how and where the ocean should be best sampled.
- Modelers working very closely with observational researchers to identify and study important climate processes.
- Observations and models constantly being compared since neither can completely and perfectly resolve all ocean processes.
- New models that will be researched and designed in direct relation to observational needs.
- Ocean modelers working with hurricane researchers to incorporate the HYCOM ocean model into the experimental HWRF model to improve characterization of ocean heat transfer.

Since the modeling effort was initiated at AOML, there has been an increase in the interaction with modeling centers and, in particular, GFDL. Projects initiated at AOML such as Observing System Simulation Experiments (OSSE) will continue increasing the interest of AOML PIs on modeling efforts and their interaction with GFDL scientists.

3. AOML should articulate in a new AOML strategic plan the scope of key projects, particularly related to long-term climate system observing including the most important cost-effective projects to the mission and the new emphasis on modeling to maximize future contributions of AOML to the ocean and climate community

(Associated commenst highlighted by OAR Head Quarters from the reviewers' synthesis report)

It is very important to articulate the rationale for the relevance, cost-effectiveness, etc., of PhOD's programs (and the other AOML division programs) to NOAA's mission goals be readily available to the public. (Following text recommending an AOML Strategic Plan be developed)

In order to maximize future contributions of AOML to the ocean and climate community, it would be helpful if the scope of key projects, particularly related to long-term climate system observing and the new emphasis on modeling, were articulated more specifically in a new AOML Strategic Plan.

Strategic Plans are essential for AOML's visibility and funding health. Especially, this would be the document where one would expect to see discussions of the rationale and linkage of AOML's specific programs to NOAA's Mission Goals.

The AOML Director, Deputy Director, and Science Division Directors held a retreat on April 15, 2009 to begin the process of creating a new AOML Strategic Plan. The plan will comprise a short summary document, as well as a longer version with more detail. It will articulate the rationale, scope, linkage to NOAA goals and the Five-Year Research Plan, and cost effectiveness of all of the major programs of each of the divisions and for the laboratory as a whole. This will include: development and maintenance of observing systems for

hurricanes, oceans, and climate; OSSEs; modeling and environmental assessments; oceanic microbiology related to human health; and process studies necessary for improving understanding and increasing predictive skill. The first draft of the new AOML strategic plan was completed October 1, 2009. The final version will likely be delayed so that the newly selected director of AOML's Ocean Chemistry Division (OCD) will be able to provide input. The pending announcement of the National Climate Service in NOAA may also require some updates to future planning. The target date for the final document is April 1, 2010.

4. **AOML should expand the visiting scientist program as a way to improve modeling activities at AOML. A good way to start would be to make sure all of the potentially important connections exist with the University of Miami's Rosenstiel School of Marine and Atmospheric Science (RSMAS) scientists across the street.**

   AOML and PhOD already conduct numerous joint activities with RSMAS, including running the Hybrid Coordinate Ocean Model (HYCOM) model, conducting Rapid Climate Change Meridional Overturning Circulation and Heat Flux Array (RAPID-MOCHA) experiments and analysis, sharing technicians, writing proposals, and publishing journal articles. Both AOML and RSMAS oceanographers receive announcements of each other's seminars and actively attend and participate in discussions. AOML also plans to adopt the Fellows program created at NOAA's National Severe Storms Laboratory (NSSL) and approved by OAR to provide a formal process for inviting distinguished faculty from RSMAS and other institutions to visit and interact with AOML on an annual basis to foster increased collaboration. The program will provide an opportunity for national and international scientists from academia, government, and private industry to partner with AOML scientists. Additionally, PhOD will start inviting modelers to visit the lab and work on manuscripts. A visit by Dr. Ricardo Matano of Oregon State University occurred in November 2009.

5. **AOML should begin planning for succession. A few senior level hires are needed to ensure that new division leaders are in place and overlap with present directors of the Ocean Chemistry and Physical Oceanography groups before they step down.**

   (Associated comment highlighted by OAR Head Quarters from the reviewers' synthesis report)

   A few senior level hires are needed to ensure that new division leaders are in place and overlap with present directors of the Ocean Chemistry and Physical Oceanography groups before they step down. A plan should be developed for retirement-eligible scientists to provide retirement incentives.

   A succession plan is in place at PhOD. Three scientists were promoted from band IV to band V in 2008. An announcement for band IV/V FTE positions was made last year. A new band IV scientist was hired. Other offers were issued but not accepted. The main problem is that salaries for AOML band V positions are considerably lower than those offered at universities at this level. We were not able to successfully hire anyone at the band V level. PhOD was successful in selecting an internal candidate, Dr. Gustavo Goni, to serve as the new division director as of May 12, 2009. OCD's Division Director departed in 2008 without the recruitment of a potential replacement. A recruitment action was initiated immediately, and AOML's Deputy Director, Judy Gray, assumed the duties of Acting OCD Director in

addition to her Deputy duties. The job announcement closed on March 13, 2009, and AOML selected Dr. Michelle Wood of the University of Oregon. Dr. Wood began at AOML on January 18, 2010. Within OCD, PIs have traditionally ensured that they have an heir apparent and continue to do so. This is true in the microbiology lab, the South Florida Program, and the Coral Reef Early Warning System – Integrated Coral Observing Network (CREWS/ICON) program where PIs are nearing retirement eligibility. This proactive planning will be considered in the future for other projects that currently have young PIs. We are also training an internal replacement for the OCD Deputy Director.

6. AOML leadership should consider partnering with operational NOAA elements and other agencies to evaluate impacts on ocean climate on natural resources, coastal communities, and other issues of relevance to people.

AOML agrees and will continue its efforts to work with other NOAA offices. Some examples of our collaborations include the following:

1) AOML's South Florida Program (SFP) and the developing South Florida Regional Observing System (SF-ROS) have been partnering with several operational NOAA elements (National Ocean Service (NOS)/ Florida Keys National Marine Sanctuary and National Marine Fisheries Service (NMFS) Southeast Fisheries Science Center (SEFSC)) and other agencies (United States Geological Survey (USGS), South Florida Water Management District (SFWMD)) since 1995. The goal of the evolving program is to observe, analyze, and understand the complex coastal and estuarine marine ecosystems of south Florida. Towards this end, we work with several universities (UM, FIU, and USF) to combine our oceanographic observations with meteorological observations, remote sensing products, and numerical model outputs. Part of the program aims to monitor and understand the changes to these ecosystems that are expected as a result of the massive Everglades restoration effort. The temporal and spatial scales involved include climate change issues such as sea level rise, global warming, ocean acidification, and hurricane severity and frequency. These issues are uniquely important to south Florida, which possesses the Everglades ecosystem, the largest (contiguous states) U.S. coral reef system, low coastal land elevations, economically significant tourism and fisheries industries, and a large and rapidly growing coastal population. AOML has also formed a partnership with the Florida Sea Grant program and has cost-shared a Sea Grant Outreach and Education Coordinator for the NOAA South Florida Program, hosted at AOML, since 2006.

2) AOML researchers have been partnering since 2002 with researchers from the NMFS/SEFSC. Collaborative research includes larval reef fish population distribution, abundance, and diversity with the physical connectivity of the coastal and offshore currents of south Florida, the Gulf of Mexico, the Mexican/Belizean Yucatan and, more recently, the northeastern Caribbean including the U.S. Virgin Islands and Puerto Rico. We collaborate with NOAA and non-NOAA entities to utilize remote sensing and numerical model products to aid in understanding the complex regional circulation of the Caribbean and Gulf of Mexico and its importance to the economically important coral reef ecosystems. The same climate change issues listed above for south Florida natural

resources, coastal communities, and other issues are also critically important to the coastal areas of the wider Caribbean/Gulf region and their diverse ecosystems. AOML and SEFSC have recently written a proposal to down scale a climate model to the Gulf of Mexico region and use this in collaboration with fisheries biologists to model climate impacts. Efforts like these will open doors to the future of true ecosystem modeling.

3) The coral work at AOML is integrated with coral activities from across NOAA, including NOS International Affairs, and the NESDIS Coral Watch Program. The CREWS data and alerts are broadcast worldwide, and researchers from other NOAA and national and international programs use or co-deploy instruments in conjunction with the CREWS/ICON stations.

4) With respect to climate impacts, the new Ocean Acidification (OA) aspect of the CO_2 program will be partnering with agencies concerned with impacts through an OA researcher who has been working with partners from NMFS/SEFSC and NOS' Center for Coastal Fisheries and Habitat Research, Center for Sponsored Coastal Ocean Research, and Office of National Marine Sanctuaries to develop a Southeast Atlantic and Gulf of Mexico Ocean Acidification Research Plan for NOAA.

7. The articulation and relevance of PhOD's programs to NOAA's mission should be made available to the public.

The relevance of each of AOML's research programs as they pertain to the NOAA mission will be articulated clearly in the new AOML strategic plan and will be made available to the public through our revised website. To date, the relevance of PhOD's programs to NOAA's mission has been made available to NOAA's Climate Office through their quarterly publication "Climate Goal Quarterly Newsletter." This newsletter is posted on the CPO website and is made available to the public. However, due to the availability of space, the newsletter does not always report all of our achievements. The new AOML website will help solve this problem by publishing all of our accomplishments and their relevance to the NOAA mission.

8. NOAA should allocate sufficient resources to analyzing data as opposed to simply collecting it.

AOML fully agrees with this suggestion and has submitted a total of five alternative proposals to support this deficiency. Please see the response to suggestion 2 above regarding modeling activities.

<u>Ecosystem (Florida Coastal Ecosystems, Corals):</u>

Recommendations:

1. Laboratory management should set some bounds on the degree to which specific applications are pursued versus research and development activities. It should be a high

priority of the Division to do a top-to-bottom review of its internal priorities and long-term focus consistent with NOAA's and AOML's priorities as identified in the strategic plans and research plans.

AOML and OCD agree. A top-to-bottom review of OCD will be the first assignment for the incoming OCD Director, to be accomplished within the first six months.

2. **The lab needs to carefully manage its ecosystem portfolio so as not to be subsumed by service functions to these other organizations, resulting in a predominant service portfolio.**

   OCD is carefully examining the activities being proposed with partners in Florida. OCD is committed to providing the scientific underpinning to describe the biogeochemical environment upon which the development of regulations or permits may be based. We recognize that this can be a delicate balance and with all new research we will continue to evaluate its relevance to the NOAA mission and its ability to advance the science. Peer-review publications will remain the hallmark of scientific productivity in the division.

3. **As staff retire, AOML should revisit the research portfolio rather than simply replace outgoing expertise one-for-one.**

   AOML agrees with this statement and performs regular reviews of the research portfolio and hires according to NOAA mission needs as articulated in the Strategic Plan and Five-Year Research Plan.

4. **AOML needs to assess whether the presence of reimbursable research activities are consistent with its long-term plans and priorities, especially if they require new hires to sustain in the future.**

   (Associated comment highlighted by OAR Head Quarters from the reviewers' synthesis report)

   The proportion of AOML's funding, especially in PhOD and OCD, has been drifting from base-generated to proposal-generated. Unless the in-house NOAA proposal success rate is very high, the reliance on proposal-driven funding is a dangerous trend toward an inefficient funding model. If the competition stiffens, and the funding success drops, productivity will decline.

   PhOD funds for the observing system are "quasi-base," that is to say, funds are renewed annually upon the submission of a report of the work completed. The erosion of available funds as a result of level funding in PhOD resulted (see item 2 above) in a reduction of the number of data collected. More important is the fact that NOAA does not allow inclusion of PI salaries in the proposals. While AOML as a lab complies with the reimbursable policy for FTE salaries, PhOD base funding does not cover 100% of PhOD FTE salaries. Proposals for the observing system partially solve this problem by including the salaries of engineers, technicians, and IT support. This allows us to compensate for the lack of scientists' salaries (note that the 10% loss in funding per year leads to an increase in AOML's contribution for FTE salaries, needed to fulfill the requirements). A serious problem occurs for scientists

conducting statistical, theoretical, or numerical models. Proposals for these activities do not cover any portion of their salaries nor allow for technicians' salaries as in proposals for the observing system. Modeling proposals do support Post Docs, but this is not a solution to the problem of funding NOAA scientists' salaries. NOAA scientists cannot obtain funds for salaries from NSF or NASA. Therefore, NOAA should make an effort to allow NOAA scientists whose salaries are not covered 100% by base funds to include salary costs in their proposals. This is particularly valid in light of the request from AOML to increase its model data validation and development program.

In OCD the percentage of funds from proposals versus base has not changed significantly in the last decade. Much of the proposal-based funds in OCD are now of a "sustained nature" (NOAA Climate Program Office Climate Observation Division (COD) and Coral Reef Conservation Program (CRCP)). OCD, too, is concerned with the inability to raise PI salaries for Federal PIs. Our CIMAS PIs are not similarly constrained. This inequity is not a good situation in the Division; however, we are fortunate to raise the CIMAS PI funds to offset the lack of funding for Federal PIs. OCD is funded by the "Oceans and Great Lakes" line item in the Federal budget. This line item has enjoyed one increase beyond Adjustments to Base (ATBs) in the last decade or two. That increase was for coral work that was in a separate line and was rolled-up into the AOML line. Besides this one increase, program changes have all been achieved through non-base funds. The level-funding of base means that the division cannot initiate a promising new direction until an existing PI and his or her program departs. The current profile of programs is complementary and interdependent and will, undoubtedly, inspire new directions for us to consider. ATBs are critical so that the division can recruit behind departing employees. We continue to pursue funding increases to the OCD base via the Federal budget process by active participation in the NOAA budget process but have been unsuccessful except for CREWS/ICON, which had support from a national initiative.

AOML plans to address this issue by raising the issue to LCI and OAR leadership for consideration by NOAA leadership. AOML will also develop a point paper for OAR leadership once the future of the National Climate Service is announced that will hopefully be elevated to the NOAA administration. These reimbursable activities should be funded from base funds from the new Climate Service. AOML will also continue to invite and host NOAA budget office staff to visit AOML for briefings on our science and issues that are of importance to the lab.

5. AOML and the NMFS facility should develop a strategic outlook and plan for cooperative ecosystem studies.

(Associated comment highlighted by OAR Head Quarters from the reviewers' synthesis report)

It would be in the best interest of both AOML and SEFSC to develop a strategic outlook and plan for cooperative ecosystem studies. The "One NOAA" concept should be pursued with increased vigor in the ecosystem realm among NOS, NMFS, and OAR in the southeast.

AOML enthusiastically agrees. The SEFSC and AOML Directors have begun monthly lunches, as have their Deputies (the IT staff continue to meet weekly with RSMAS as well).

There are several ideas on the table including cooperative model development using AOML for physical measurements that complement those of fisheries (expanding the work of Johns/AOML and Lamkin/SEFSC to other scientists and programs). There have also been discussions in regard to rejuvenating the marine mammals and acoustics program. Ocean acidification is a new AOML program that is already being researched jointly with SEFSC. AOML scientist Kelly Goodwin is currently located at the Southwest Fisheries Science Center (SWFSC) in La Jolla, California to increase NMFS/OAR interaction. During a June 2009 meeting to discuss possible collaborations between SEFSC and AOML, a jointly-funded NRC post-doc was discussed to facilitate more formal exchange.

6. **AOML needs to be a national and global leader in ocean acidification and geoengineering solutions to the CO_2 issues, taking advantage of its staff expertise and strategic relationships (e.g., among global, national, and the network of OAR researchers). Given its proximity to other line offices with complementary expertise (NOS, NMFS), such research should be conducted to evaluate not only ocean chemistry issues but ecological impacts as well.**

AOML recognizes the importance of multi-disciplinary studies on ocean acidification and has recently hired a well-established, mid-level scientist with expertise in this area. AOML is currently leading the Southeast Regional planning efforts on ocean acidification that encompasses the southeast coast (south of Virginia), Gulf of Mexico, and Caribbean. The possible impacts of ocean acidification have only recently been recognized. There are huge scientific misconceptions of the phenomena that can best be resolved by entraining young and mid-level scientists who have the time and energy to become leaders in this rapidly-evolving field. AOML has the senior personnel who are leaders in ocean carbon research and coral reef monitoring. They will provide the guidance to the personnel to become the leaders in NOAA's ocean acidification programs. Indeed, the scientists in question (Drs. Manzello and Gledhill) are already internationally recognized for their scientific contributions to OA research. AOML believes that this strategy of developing younger leaders in the field is a sound approach. Ocean acidification is a multi-faceted subtopic of the overarching goals of global carbon cycle research and coral reef health monitoring. Established leadership at AOML in these overarching goals should not be diverted; rather, we must entrain new leaders.

AOML has the only scientists in NOAA (Drs. Peng, Wanninkhof, and Zhang) who were involved in the original open ocean iron enrichment (cf. "ocean fertilization") studies and modeling. This work was either performed before the investigators joined NOAA or through funding from other federal agencies. Studies to date have shown that sequestration efficiency from deliberate iron additions is poor, and that quantification and verification of commercial sequestration endeavors would be costly (or perhaps even impossible). AOML scientists have been actively involved in the "scientific" debate within NOAA and development of a NOAA State of Science fact sheet on ocean fertilization and the position statement of the U.S. government on regulating ocean fertilization through appending the London Protocol on ocean dumping.

The NOAA Research Council has not yet approved a consensus document on iron fertilization, although AOML has provided input. At this point, AOML is not planning to become engaged in geoengineering solutions to the CO_2 issues due to the highly politicized nature of the topic and lack of engineering expertise necessary to fruitfully contribute.

Ship Support for Ocean Missions:

Recommendations:

1. **The research fleet of NOAA must be better maintained and regain reliability if AOML is going to be able to achieve its research mission. One reviewer thought this is the most important issue that emerged in the AOML review. If the lab is going to support an ocean observations program at the Atlantic basin to local scales, reliable access to ship time, either aboard NOAA ships with time allocated directly to AOML, allocated to its sister agencies (e.g., NOS, NMFS), charters aboard University-National Oceanographic Laboratory System (UNOLS) and other ships, or in conjunction with other entities (e.g., NSF) is critical.**

   Many, but not all, of the problems referred to by the reviewers relate to the use of the NOAA Ship RONALD H. BROWN. AOML is leading a team of representatives from OAR, the Climate Program Office, and the academic community who use the BROWN to work with NOAA's Office of Marine and Aviation Operations (OMAO) to find solutions to ongoing challenges with the management and operation of the vessel. In June 2009, a team meeting was held in Charleston, South Carolina to discuss progress to date and to continue searching for positive solutions to these challenges. The team is working closely with senior leaders from OMAO and will ultimately make formal recommendations to the director of OMAO for remedies. It is expected that the solutions developed for the BROWN will inform and aid operations on all OMAO vessels.

Other Recommendations:

1. **One of the best ways to improve the visibility of AOML is by improving its website. The Team strongly recommends that a professional web designer be brought in for this, and that this web designer does a considerable amount of beta testing with the external user community.**

   AOML has made tremendous progress in improving its visibility through increased publications, collaborations, and enhanced participation at national and international conferences, as well as on panels and committees. Nevertheless, we agree that improving our website is vital to our organization, and we are exploring different options to bring this about. This was discussed at our retreat on April 15, 2009 and again at a special web meeting on August 12, 2009. AOML is currently reviewing the options proposed to hire a dedicated web master with the programming skills necessary to both implement the new website we have already developed using content management software, as well as greatly improve the use of new technologies to communicate our research, data, and accomplishments to all of our

customers. We hope to hire a new webmaster once a decision on the local impacts of the Climate Service have been determined and have a new AOML website up and running within three months of the hire.

Additional Comments Highlighted by OAR Headquarters from the Reviewers' Synthesis Report)

- *OSSEs work best when the question being asked is focused on a characteristic of a specific phenomenon. For most oceanic/climate questions, such as how best to observe the AMOC (which no model known to me has accurately reproduced, either in magnitude or structure) or, even more broadly, how best to observe climate variability, the oceanic and climate models have much too little physical realism to trust their pronouncements of where and what to observe. Model validation should proceed before OSSEs.*

  This was a major topic of discussion at the Ocean OSSE Workshop that we held at AOML in April 2008. We agree that model validation should be performed, and AOML/PhOD has been leading this activity. However, we do not believe that meaningful OSSEs cannot be performed with the current state of ocean modeling. As the AOML Director explained at the workshop, OSSEs for the atmosphere were performed long before atmospheric models reached a satisfactory state. Those OSSEs contributed to advancing the models, observing system, and data assimilation in an iterative process. OSSEs for the ocean can contribute in a similar manner, as long as the limitations of each experiment are properly taken into account. AOML is continuing to expand its model validation activities and, at the same time, is developing OSSE systems for the ocean in collaboration with both internal and external partners.

  Please see the response to suggestion #2 under Hurricanes to reference model validation activities.

- *If there is insufficient science and technical support, the top-level researchers will be burdened with maintenance tasks that inhibit the accomplishment of knowledge producing research from the data. An important consequence of maintenance demands is that great care must be taken that with each new commitment, that is, each observing program initiated, a realistic assessment of technical personnel requirements for maintenance is made and funded.*

  AOML fully agrees. The Ocean Chemistry Division has implemented in its monthly PI meetings a budget presentation that is being negotiated with the PIs to show exactly where each project stands in terms of income-to-date, expected income, expenditures to date, expenditures planned, and needs to be met. The budget presentation is becoming a tool for both discussion and decision making. This new business model will be used to assist the new OCD Director in understanding the current state, future plans, and needs of this complex science division. The new OCD Director is responsible for assuring that new projects being proposed have available resources (money as well as people with the

correct skills) or a plan for assessing what is required and when programs or technology are deemed ready to be transferred to operations. An internal OCD review, to be conducted by the new Director, will also decide where needs are not being met.

- *There is a significant need for a seasoned, multidisciplinary researcher that comprehends the connections between the disciplines in the Ocean Chemistry Division and who can guide and shape ongoing priorities. It should be a high priority of the laboratory to replace the Ortner position with a similarly qualified individual with this capability.*

  The recruitment of the OCD Director is complete. AOML agreed that the optimal candidate would be an interdisciplinary researcher with a solid reputation and a deep understanding of the research conducted in this complex and diverse division. AOML has selected such a candidate in Dr. Michelle Wood from the University of Oregon.

- *The intensive work at the regional (South Florida) and local (water district) levels may drain focus from regional (Caribbean, South Atlantic, Gulf of Mexico), Atlantic basin, and international activities in keeping with NOAA's broader focus. In particular, it is evident that little of the Division and in fact the Laboratory's resources are devoted to the Gulf of Mexico issues, given the proximity to that sub-region and the focus for so many of NOAA's issues there.*

  AOML is no longer receiving support from NOAA's Integrated Ocean Observing System (IOOS), and this funding is required for increased regional observations. It also appears that ecosystems, like politics, are often viewed as local programs for primarily local funding. AOML is coordinating its research with those conducting research in the Gulf of Mexico. The Gulf has a rich research constituency. Historically, AOML has had large programs in the Gulf, e.g., the Nutrient Enhanced Coastal Ocean Productivity program (NECOP). When that program ended, efforts were focused on issues in the state of Florida that have far-reaching consequences, e.g., closing ocean outfalls by 2025. Several AOML PIs are involved with the Northern Gulf of Mexico Cooperative Institute and the Gulf of Mexico Alliance (GOMA). For example, PIs with AOML's microbiology lab are currently working on microbial source tracking and pathogen detection methodology in the Gulf, as well as participating on workshop committees to draft action items for GOMA. Two OCD PIs are working in Mobile Bay, Alabama in cooperation with the University of Southern Alabama. The microbiology lab is continuing its research on the long-term impacts of Hurricanes Katrina and Rita in regard to the local ecology and how the microbial landscape might be impacted in the Gulf. There are pending proposals for work in the Gulf of Mexico for the microbiology lab. There are also Gulf of Mexico proposals in development for ocean acidification research. OCD has a representative on NOAA's Gulf of Mexico Regional Team. Researchers with the CREWS/ICON program are working regionally throughout the Caribbean, as well as in the Pacific.

- *Very little and insignificant amount of work is being devoted to study the impact of satellite observations (in HRD), the assimilation of existing satellite measurements, or recommending new observation systems.*

  AOML and HRD do not have a long history of studying the impact of satellite observations, but this has been gradually changing over the last several years and will increase dramatically when their hurricane modeling and data assimilation capability reach maturity. At the present time, AOML and HRD in particular are interacting with several NASA science teams (Ocean Vector Winds, Altimetry Science and Precipitation, and Atmospheric Infrared Sounder (AIRS)) and are conducting satellite data impact studies for QuikSCAT, Advanced Scatterometer (ASCAT), HIRAD and NASA's Global Wind Observing System (GWOS). In addition, HRD participated in the OAR/NESDIS retreat which identified two research thrusts that are designed to improve the use of satellite observations for evaluating model simulations and forecasts, and to improve the use of satellite data in initializing these models through OSE/OSSE experiments. For more details, see the response to the OSSE/OSE strategy issue.

- *The HRD staff has participated in the development of all instruments on-board the NOAA aircraft and has played a strong role in the respective observation strategies. Some of these instruments are no longer state-of-the-art and there is no mechanism that appears to be in place to update the instrument suite.*

  HRD works with NOAA's Marine and Aviation Office (NMAO) on their roadmap planning. NOAA is actively updating the P-3 aircraft instrumentation, and HRD is participating in defining the requirements and providing evaluation for these observing system upgrades including the cloud microphysics system, ocean expendables, radar systems, dropsonde system, main data systems, turbulence sampling, and new remote sensors such as Imaging Wind and Rain Airborne Profiler (IWRAP), Wind Swath Radar Altimeter (WSRA), W-band radar, and a Doppler wind lidar. HRD is also providing a similar advisory role in the upgrades and instrumentation on the G-IV, as well as actively participating in the testing and evaluation of the SFMR and Doppler radar system.

- *Anecdotal evidence suggests the low salaries of the CIMAS science and technical support staff and the declining technical support within AOML. AOML's observation programs are too important to let falter for lack of technical support.*

  There is an annual effort to maintain equity between the UM and NOAA pay scales. Federal personnel benefit from an annual pay-for-performance increase (ZP average 1.86%) compounded by an annual cost-of-living/locality pay adjustment (recently over 3% per year). CIMAS personnel have averaged an annual pay increase of 3-3.5%, therefore lower than their Federal peers. However, CIMAS has several layers of potential promotion with a typical pay increase of 10%. Feds often have no promotions or, at most, two over their careers due to the low number of bands in the Commerce CAPSystem. This allows large jumps that, we hope, make up the difference in pay over time. CIMAS has other benefits that are not open to their Federal partners at AOML including tuition waivers for their children and other attractive university benefits.

Annually, AOML works with UM and CIMAS leadership to ensure that similar work is rewarded similarly. In addition, after years of requests, it appears that CIMAS will be allowed to offer parallel recognition awards for CIMAS employees who are partners on teams that win federal awards. If this succeeds, it will be a huge step forward. Our goal has been and will continue to be equity in pay for similar work.

Acronyms

4DVAR:	Four-Dimensional Variational Data Assimilation
AIRS:	Atmospheric InfraRed Sounder
AMOC:	Atlantic Meridional Overturning Circulation
AMS:	American Meteorological Society
AOML:	NOAA Atlantic Oceanographic and Meteorology Laboratory
ASCAT:	Advanced Scatterometer
ATB:	Adjustment to Base
AXBT:	Airborne Expendable Bathythermograph
BAMS:	Bulletin of the American Meteorological Society
CAMEX:	Convection and Moisture Experiments
CBLAST:	ONR Coupled Boundary Layer Air-Sea Transfer Experiment
CIMAS:	UM and NOAA Cooperative Institute for Marine and Atmospheric Studies
COD:	NOAA Climate Program Office Climate Observation Division
CPO:	NOAA Climate Program Office
CRCP:	Coral Reef Conservation Program
CREWS:	Coral Reef Early Warning System
DTC:	NOAA Developmental Testbed Center
EMC:	NWS Environmental Modeling Center
EnKF:	Ensemble Kalman Filter Data Assimilation
ESRL:	NOAA Earth System Research Laboratory
FIU:	Florida International University
FSU:	Florida State University
FTE:	Full Time Equivalent
FY:	Fiscal Year
GSFC:	NASA Goddard Space Flight Center
GFDL:	NOAA Geophysical Fluid Dynamics Laboratory
GFS:	Global Forecast System
G-IV:	Gulfstream-Four Aircraft
GOES-R:	Geostationary Operational Environmental Satellite-R Series
GOMA:	Gulf of Mexico Alliance
GSD:	ESRL Global Systems Division
GSFC:	NASA Goddard Space Flight Center
GWOS:	NASA Global Wind Observing System
HFIP:	Hurricane Forecast Improvement Project
HIRAD:	Hurricane Imaging Radiometer
HRD:	AOML Hurricane Research Division
HWRF:	Hurricane Weather Research and Forecasting Model
HWRFX:	Experimental Hurricane Weather Research and Forecasting Model
HYCOM:	Hybrid Coordinate Ocean Model
ICON:	Integrated Coral Observing Network
IFEX:	NOAA Intensity Forecast Experiment
IOOS:	NOAA Integrated Ocean Observing System
IPCC:	Intergovernmental Panel on Climate Change

IWRAP: Imaging Wind and Rain Airborne Profiler
JAS: AMS Journal of the Atmospheric Sciences
JCSDA: Joint Center for Satellite Data Assimilation
JPL: NASA Jet Propulsion Laboratory
LCI: NOAA Labs and Cooperative Institutes
MIT: Massachusetts Institute of Technology
MOC: Meridional Overturning Circulation
MOCHA: Meridional Overturning Circulation & Heat Flux Array
MSFC: NASA Marshall Space Flight Center
MWR: AMS Monthly Weather Review
NAMMA: NASA African Monsoon Multidisciplinary Analysis Experiment
NASA: National Aeronautics and Space Administration
NCAR: National Center for Atmospheric Research
NCEP: NOAA National Center for Environmental Prediction
NECOP: Nutrient Enhanced Coastal Ocean Productivity Program
NESDIS: NOAA National Environmental Satellite Data and Information Service
NHC: NWS National Hurricane Center
NMAO: NOAA Marine and Aviation Office
NMFS: NOAA National Marine Fisheries Service
MSFC: NASA Marshall Space Flight Center
NOAA: National Oceanic and Atmospheric Administration
NOPP: Naval Ocean Partnership Program
NOS: NOAA National Ocean Service
NPS: Naval Postgraduate School
NRC: National Research Council
NRL: Naval Research Laboratory
NSF: National Science Foundation
NSSL: National Sever Storms Laboratory
NTU: National Taiwan University
NWS: NOAA National Weather Service
OA: Ocean Acidification
OAR: NOAA Office of Oceanic and Atmospheric Research
OCD: AOML Ocean Chemistry Division
OFCM: NOAA Office of the Federal Coordinator for Meteorology
OGCM: Ocean General Circulation Model
OMAO: NOAA Office of Marine and Aviation Operations
ONR: Office of Naval Research
OSE: Observing System Experiment
OSSE: Observing System Sensitivity Experiment
OU: University of Oklahoma
PhOD: AOML Physical Oceanography Division
PI: Primary Investigator
PSU: Pennsylvania State University
QuikSCAT: NASA satellite scatterometer
RAINEX: NSF Rainband Experiment
RAPID: Rapid Climate Change

RSMAS: UM Rosenstiel School for Marine and Atmospheric Studies
SEFSC: NOAA Southeast Fisheries Science Center
SFMR: Stepped-Frequency Microwave Radiometer
SFWMD: South Florida Water Management District
SFP: AOML's South Florida Program
SF-ROS: South Florida Regional Observing System
STAR: NESDIS Center for Satellite Applications and Research
SUNYA: State University of New York at Albany
SWFSC: Southwest Fisheries Science Center
TCSP: NASA Tropical Cloud Systems and Processes Mission
TTU: Texas Tech University
UAS: Unmanned Aerial System
UCF: University of Central Florida
UF: University of Florida
UM: University of Miami
UNOLS: University-National Oceanographic Laboratory System
USF: University of South Florida
USGS: United States Geological Survey
USWRP: U.S. Weather Research Program
UW: University of Washington
WP-3D: NOAA P-3 aircraft
WRF: Weather Research and Forecasting Model
WSRA: Wide Swath Radar Altimeter
XOVWM: Extended Ocean Vector Wind Mission

Appendix A "Filling Up the Gaps"

Theme: Filling the gap between the NOAA Climate Observing System and modeling capabilities.

Contact: Silvia Garzoli

Program and Capability: Climate Goal
Annual Guidance Memorandum: Priority: "Globally integrated oceanic and atmospheric observations and data management."

Rationale
The world ocean, covering 70% of the surface of the earth, is the flywheel of the climate system. In order for NOAA to fulfill its climate mission, it is necessary to sustain a global ocean observing system that serves the needs of prediction and projections. While NOAA is committed to world leadership with its Climate Observing System and has an outstanding infrastructure for model development and forecasting, there is an artificial disconnect between these two activities that must be filled. A greater effort is needed to use the observations to evaluate the models and to use the models to design improvements to the observing system.

The Climate Observing System has been extremely successful in monitoring the state of the ocean, in particular at seasonal to inter-annual time scales. The multi-year phased implementation plan originally anticipated the completion of the system by 2010, but funding short-falls have now pushed the completion beyond 2014. The system is approaching 60% completion, and at this stage it is crucial to perform an evaluation of the current design, the observations collected, the data coverage, and the instrumentation used. The lack of funds and direction for the analysis and evaluation of the observations has made it difficult to determine if the initial design is adequate or if it could be improved.

Powerful model-based tools can be used to assess the design of the observing system to identify possible gaps or redundancies and to improve its implementation, namely Observing System Experiments (OSEs) and Observing System Simulation Experiments (OSSEs), which can be applied to high-resolution ocean forecasting, seasonal-to-interannual prediction, and climate analysis and reanalysis. However, in order to run such experiments, the data should be analyzed to identify the signals to be observed, and the observations should be used to validate the models under consideration for OSE or OSSE study.

To complete and sustain an observing system that will follow the requirements established may prove to be more difficult than deploying the parts of the initial system that are now in place. This request is based on the assumption that funds will be available to assure the sustainability of the observing system, as well as to fill identified gaps and to develop any new instrumentation that may be needed for climate observations.

It is proposed that the CPO start an initiative to fill the gaps between the observing system and modeling activities at NOAA. This new capability will have the main following activities:

1. Analyze and interpret the data collected to develop products that will lead to a better understanding of the state of the ocean and the implications of its variability for climate.
2. Perform model validation activities using available observations and determine what phenomena the different models resolve properly.
3. Analyze the data collected in concert with validated modeling results to optimize the observations.
4. Provide feedback to the modelers on potential deficiencies and solutions.
5. Based on the model validation activities establish what models can be used as nature runs to perform OSSEs and or OSEs experiments.
6. Perform model experiments to determine the optimal cost effective observing system.

Benefits and impacts

- The main impact of this additional activity will be to evaluate the accuracy of model outputs and to optimize the current observing system toward a cost effective sustainable coupled (models plus observations) system.
- The analysis of the data will produce results that would lead to better understanding of the climate signals to be observed.
- The model experiments will determine where those signals should be observed and will improve the attribution of the signals to physical processes.

In order to successfully achieve these objectives, a strong interaction between modelers (e.g., GFDL, NCEP) and observationalists (e.g., AOML, PMEL) is crucial.

Resources:

Basic funding profile.

	Y1 FY09	Y2 FY10	Y3 FY11	Y4 FY12	Y5 FY13
1-2 Analysis and interpretation	$1.2	$1.2	$1.2	$1.3	$1.3
3-4 Model data comparison/validation	$1.0	$1.0	$1.0		
5 OSE and OSSEs experiments		$1.2	$2.4	$2.4	$2.4
	$2.2	$3.2	$4.6	$3.7	$3.7
		Total			$17.4

Funds are requested to perform the activities listed under 1 through 6 above. Analysis of the data, generation of products, and identification of new signals should be a constant activity. A minimum of $1.2M-1.3M per year should be allocated to this activity. Simultaneously, model validation activities based on the data analysis should be started. It is estimated that an additional

$1M per year during the first three years should be required. This activity will lead to the determination of a nature model to be used to perform OSE and OSSEs activities. For this activity, $1.2M has been requested for Year 2 and $2.4M per year thereafter. Total FY9 to FY14 = $17.4 million, which represents only 11% of the 100% requirement to sustain the Observing System.

Appendix B "Collaborative Research between AOML and GFDL"

Collaborative Research between AOML and GFDL
January 6, 2009

Over the past several years, scientists with NOAA's Atlantic Oceanographic and Meteorological Laboratory (AOML) and Geophysical Fluid Dynamics Laboratory (GFDL) have convened several meetings to discuss mutual interests and potential cooperative projects. Specifically, the primary objective of these meetings has been to develop methodologies to improve forecast models on time-scales ranging from seasonal to multidecadal and the global observing systems needed to support these simulations. For example, the last meeting was directed at the creation of a national capability for conducting Observing System Simulation Experiments (OSSEs) and Observing System Experiments (OSEs) for the ocean, which requires addressing both modeling and observational issues. A previous meeting was directed at investigating predictability of Atlantic decadal variability combining observations and models.

Results from these meetings have provided the foundation for the next step in improving models and observing systems, i.e., developing specific joint AOML-GFDL activities. This document presents a strategic plan of climate/ocean modeling and related data analysis that leverage expertise and resources at AOML and GFDL. The overarching goal of the collaboration is to improve climate/ocean models, to improve predictions of climate variability for societal benefit, and to improve our understanding of seasonal-to-multidecadal climate variability. Success in meeting this overarching goal necessarily relies on substantive collaboration between scientists at both institutions. The vision is that this collaboration will go beyond merely sharing model and observational data sets, but will include coordinated numerical experimentation in which both institutions have a vested interest. To achieve this overarching goal, a science team which includes scientists from both institutions should form and work together in a coordinated manner.

Three main thrusts of collaboration are envisaged:

(1). Model-observation comparison and model improvement through the use of observations.
(2). Multi-model numerical hypothesis testing with CCSM3.5, CM2.1, HYCOM, and MOM.
(3). Ocean Observing System Simulation Experiments (OSSEs).

(1). Model-observation comparison and model improvement through use of observations

AOML is a major contributor to the Global Ocean Observing System (GOOS) including deployment capabilities, data collection, data quality control, and data analysis. In particular, AOML scientists have unique expertise in and access to the Atlantic Ocean observational data sets. GFDL is a developer of forecast climate coupled models (CM2.1) and of ocean models (MOM). The point of collaboration is to use observational data to evaluate and assess the models, to identify processes and/or parameterizations in the models that are responsible for generating model biases, and to provide feedback to GFDL's scientists for improving the models.

Despite the growing recognition of the importance of tropical Atlantic Ocean-atmosphere processes on climate variability, most state-of-the-art ocean-atmosphere coupled climate models cannot reproduce the annual cycle of tropical Atlantic sea surface temperatures (SSTs) or show the largest regions of cold SSTs and precipitation biases in the Atlantic warm pool region. Due

to these shortcomings in the climate models, we currently do not have the skill to simulate/predict tropical Atlantic climate variability. The exact cause of large tropical Atlantic errors is currently unknown. Therefore, our first task should be to identify the processes and/or parameterizations in the coupled models that are responsible for generating tropical Atlantic variability biases.

For collaboration on this topic, GFDL could provide AOML's scientists with model outputs and AOML could provide the observational data. Collaborative research could provide us with useful insights on the inherent model biases and give us guidelines for improving the models. AOML's scientists are interested in using model results and observations to identify model errors and to propose experiments that will ultimately identify methods for reducing these errors.

(2). Multi-model numerical hypothesis testing with CCSM3.5, CM2.1, HYCOM and MOM

The understanding and predictability study of climate and ocean variability require us to design and implement numerical experiments for testing some hypotheses developed from data analyses. Because of potential model dependence, the designed experiments should be performed with a multi-model approach. GFDL's scientists developed the coupled CM2.1 model and the MOM ocean model and have experience in designing and implementing numerical hypothesis testing experiments. AOML scientists are currently working with the CCSM3.5 coupled model and the HYCOM ocean model. This provides a good opportunity for AOML and GFDL scientists to collaborate.

The collaboration will be initiated with communications between scientists from AOML and GFDL, reaching a consensus on what climate/ocean phenomena should be focused on and how model experiments should be designed. A science team workshop could serve as a starting point. The potential focal points of collaboration may include climate variability and oceanic processes, as well as Atlantic hurricane activity. The coordinated diagnostic studies, analyses, and numerical experiments will be facilitated by establishing a visiting scientist exchange program between AOML and GFDL. That is, scientists from each institution could have a short visit to other institution for collaborative research.

(3). Ocean Observing System Simulation Experiments (OSSEs)

Ocean OSSEs consist of controlled, quantitative assessment of the value of a system of observations based on sophisticated numerical ocean models of governing dynamical, thermal, and other physical processes. The need for an ocean science community capability for performing ocean OSSEs/OSEs became apparent as a result of discussions from a workshop conducted at AOML in April 2008. OSSEs/OSEs can be in support of designing ocean observing systems, specifically with regard to quantifying and optimizing the existing and proposed ocean observing systems in the context of the Integrated Ocean Observed System (IOOS) and the GOOS. Thus, it is timely for AOML and GFDL scientists to collaborate on ocean OSSEs/OSEs.

The ocean models of HYCOM and MOM can be used to perform ocean OSSEs/OSEs. Prior to running OSSEs/OSEs experiments, the data should be analyzed to identify the signals to be observed, and observations should be used to validate the models under consideration for OSSEs/OSEs study. Based on the model validation, we can assess whether the models can be used as Nature Runs to perform OSSEs/OSEs experiments.