AOML Science Review
Synthesized Report AOML Science Review
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1. Oceans and Climate (Climate Observing Systems, Atlantic Circulation and Fluxes, Atlantic Meridonal Overturning Circulation, Western Hemisphere Warm Pool and CO_2

a. Quality

The quality of the AOML oceans and climate research is high. The number of publications and citation rates indicate that the ocean and climate program is productive, relevant, and a significant contributor to the field. The number of peer-reviewed articles shows an increasing trend during the last six years. AOML is particularly noted for its observational work that contributes to understanding the ocean and climate systems in important and complementary ways. These observations are critical for understanding climate variability and climate change, as well as understanding the potential impact of climate change on ecosystems.

There are several areas of research that connect the ocean and climate effort. One significant effort is on observing the oceanic transports of mass, heat, and carbon across latitude bands in the Atlantic Ocean. Recent AOML observations show that meridional heat fluxes vary temporally; this is important because most studies provide only a single number for these fluxes. Monitoring of currents through the Florida Straits provides another benchmark for understanding climate variability and climate change. AOML plays a major role in studying ocean carbon fluxes and in the Global Ocean Carbon program by helping to identify carbon sources and sinks in the ocean. The Argo float system is critical to oceanographers worldwide and to future collaborations among gloablly interconnected scientific research efforts. At the regional scale, work relating the Atlantic SST warm pool to hurricane activity raises important scientific and practical points, namely the relationship between ocean temperature change and hurricane activity.

One potential impact of climate change is on coral reefs, and AOML has been a leader in developing and deploying fluorometers to test the potential for long-term monitoring of coral stress. This work led to an AOML scientist being named researcher of the year last year. AOML plays a key role in helping NOAA address its ocean and climate missions and has forged significant collaborations with other national and international research groups, both inside and outside of NOAA, to carry out these large scale ocean and climate programs.

AOML is at the core of understanding climate variability and future climate change. There have been a number of group awards attesting to value of this work, including the 2002 NOAA Administrator's award which recognized AOML for its outstanding leadership in studying the oceanic carbon cycle and

its role in sequestering carbon dioxide as part of the Ocean Atmosphere Carbon Exchange Study; the NOAA/OAR 2002 Oustanding Scientific Paper Award on the increase in Atlantic hurricane activity; the 2003 NOPP Excellence in Partnering Award for AOML's role in the NOPP-funded Argo project; the 2004 NOAA Administrator's Award for pioneering the development of a system to deliver quality-controlled, global ocean data in real time to the international operational and research oceanographic communities; and the U.S. Dept. of Commerce Bronze and Gold medals in 2005 and 2007 for implementing an oceanographic and meteorological monitoring network in coral reef areas and for their long-term research, design, and support of an observing system for the Florida Current and the meridional overturning circulation. These group awards attest to the significance and quality of AOML scientists and programs and provide insight into the broad areas of AOML contributions in oceans and climate.

Ocean climate information has emerged as a principal concern of NOAA (e.g. its impending National Climate Service) and the country as a whole. AOML climate researchers have been at the forefront of collecting, processing and archiving climate-relevant information required to document climate impacts on oceans and vice-versa. In particular, research on AMOC is of primary importance in determining impacts of global warming on large scale circulation patterns. This collaboration has involved European researchers, other federal agencies and academics. Overall the program is innovative, (e.g., the use of abandoned undersea cables as circulation monitors) and has appropriately identified a lab priority in climate change research. The program published a commendable number of significant papers in the field

b. Relevance

One of the stated AOML research goals is to develop a sustained observing system to support NOAA mission requirements. AOML provides high quality atmospheric and oceanographic data that are very important to the ocean and climate community. These AOML contributions to national and international data bases and programs are critical in supporting our future ability to understand and predict climate change. They provide timely data to NCEP and NESDIS There are strong collaborative efforts between AOML researchers and other scientists both in national and international programs (e.g., CLIVAR, Argo drifter program, Ship of Opportunity Program, Ocean Carbon Program). AOML is involved in international quality-control activities to ensure accuracy, precision, inter-comparability, and accessibility of these global data sets.

AOML contributes to the NOAA climate mission by developing and providing observational benchmarks for various components of the meridional overturning circulation including, Florida Current transport, rings and eddies (Brazil and Agulhas Currents), and heat transports across latitude bands in the Atlantic Ocean.

The NOAA observational programs are important for climate modelers everywhere, both within NOAA and outside NOAA to provide baseline observational validation for models. This is an important group of customers, and their work ultimately will affect decision makers in government, private industry, the media, education communities, and the public. Determining the role of the ocean in long-term climate change is among the more pressing national and international issues of the day, and AOML is poised to make critical contributions. This is also an area where customers could be better engaged with AOML. Climate modelers should 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.

Outside of the ocean carbon research (reviewed in a companion section) overall the research is relevant at the large scale, but could be more tightly married to NOAA's broader mission fields. The climate issues will likely switch from overall phenomena (e.g., impacts of global warming on large scale processes) to impacts and adaptation programs. The 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. Very quickly the public will want to know how robust are sea level projections (e.g., for Florida), what the trend vs. variance will be, how the heat mediated expansion and land-ice melt will impact sea levels, and how ecological communities will mediate these processes. The laboratory is in a unique position to work nationally and regionally to help understand these dynamics, undertake adaptation modeling studies, and to help provide policy-relevant services and products. It is important to take advantage of the NOAA-wide strategic location of AOML with respect to NOS and NMFS as far as emerging climate-ecosystem issues.

I find the PhOD's activities to be highly relevant to NOAA's mission as articulated in *Research in NOAA: Toward Understanding and Predicting Earth's Environment - A Five-Year Plan: Fiscal Years 2008-2012* (hereafter referred to as the NOAA 5-Year Research Plan). Without going in to much detail, the PhOD is making essential contributions to NOAA's Climate Mission Goal through the acquisition of datasets that are being used to delineate and understand important climate variability, including programs to observe (i) upper ocean thermal variability (i.e., the volunteer observing ship XBT program, and the ARGO program), (ii) shallow and deep western boundary currents that are key elements of the meridional overturning circulation (i.e., the warm northward Florida Current transport at ~26^{o} N, the cold southward Deep Western Boundary Current transport at a similar latitude, and the warm northward North Brazil Current nearer the equator), (iii) global surface oceanic and meteorological conditions (currents, sea

surface temperature and salinity, air pressure, and winds) using over 1200 globally distributed surface drifters, (iv) circulation and water properties within Florida Bay with a variety of in situ sensors, and so on. The staff of the PhOD execute extensive quality control protocols on these data, provide these data to other NOAA agencies responsible for, among other things, weather and climate predictions, and make these data available to other Federal agencies, national and international academic researchers, and the public. This constitutes an enormous effort by all the PhOD staff, from principal investigators down through the ranks of the science and technical support staff. It is an effort for which there are no good metrics, so it is frequently downplayed in reviews such as this in favor of activities with more concrete metrics such as refereed publications.

PhOD researchers are not simply data collectors/disseminators. They have demonstrated a keen ability to employ the data they collect, as well as additional in situ and satellite datasets collected by others, to extract pertinent information for achieving NOAA's mission goals. As appropriate, they have teamed with other NOAA labs, as well as academics within and outside the U.S., in order to achieve their goals. The quality of the research is very high, equivalent to the performance of the upper third of physical oceanography/climate research units in the United States.

Perhaps most surprising to me, because I naively considered AOML's Oceans and Climate theme upon which the PhOD is focused to be a long-term research enterprise, was learning that PhOD researchers have already produced sophisticated products (in addition to quality-controlled data and data visualizations) that have directly improved weather and climate predictions. Examples include a number of climate indices and the Tropical Cyclone Heat Potential.

The climate system encompasses at least the Earth's entire environment that is accessible to man-made instruments. With only limited resources, the question naturally arises as to which parts of the climate system would it be most profitable to observe, assuming the ultimate goal is to understand the causes of climate variability at the Earth's surface.

While it became clear to me during the review that the data collection programs (partially enumerated above) undertaken by the PhOD are highly relevant to NOAA's Climate Mission Goal and are coordinated with NOAA's Climate Program Office and the U.S. Climate Change Science Program, the documentation is not readily available that explicitly describes why PhOD's particular programs are considered to be among the most important and/or the most cost-effective to the mission. I believe the articulation of these arguments needs to be much
more visible. This might naturally be part of an AOML Strategic Plan, which

I recommend be constructed.

The NOAA 5-Year Research Plan (op. cit.) and the documents "*NOAA Priorities for the 21st Century - NOAA's Strategic Plan - Updated for FY2006 - FY2011*", and "*Strategic Plan - NOAA Office of Oceanic and Atmospheric Research - FY2005 - FY2010*", provide excellent reviews of NOAA's broad mission goals and strategies, but they provide essentially no details about the individual programs undertaken by OAR's laboratories and cooperative institutes that are tasked to help achieve the mission goals. I think it's very important that the articulation of 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. With such an articulation in place, the job of external reviewers such as myself would become easier, but, more importantly, anyone (John Q. Public, reporter, curious academic, Congressional staffer) who wants to understand the role of AOML's divisions will be able to quickly grasp their value in general, and especially their value to NOAA mandates. **(HQ-1)**

As ocean and climate models have improved in resolution, speed and dynamical sophistication it has become almost expected that these models will not only provide insight into how the ocean and climate systems work, but also provide useful predictive capability. But the models still need a lot of improvement in order to accurately simulate ocean circulation, heat transports, air-sea fluxes and so forth.

Ocean observing systems now have two equally important and complementary roles: exploration, and model validation or constraint (e.g., assimilation). PhOD researchers have demonstrated the value of their observing systems for both these roles, but I believe they 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). I favor the latter approach. I don't believe that PhOD should move toward developing a large OGCM or climate modeling capability. **(HQ-2)** The resources required (personnel, funds, space) would likely mean a weakening of PhOD's observing programs. However, limited modeling capabilities (e.g., LES, ROM) could prove quite useful without draining substantial resources from PhOD's observational commitments; but, if these capabilities already exist at other NOAA labs it would be more cost-effective to collaborate with the existing modeling programs rather than develop new ones.

Another aspect of the question of whether to develop a modeling effort in PhOD is whether and how to use models to help design new observing efforts

or evaluate the utility of existing efforts. For instance, models have been used to run Observing System Simulation Experiments (OSSEs) that have been successful in improving designs of observing systems for large-scale weather prediction. OSSEs seem to work best when the question being asked is focused on a characteristic of a specific phenomenon, such as the track of a hurricane, and when the model of the phenomenon has a demonstrated high accuracy. Regarding the oceans, I could imagine that, for an existing ocean observing system such as the TAO mooring array in the Pacific Ocean, and given models which have demonstrated a reasonably good simulation accuracy of such phenomena as ENSO, it might be reasonable to run an OSSE to ask whether a particular component of the TAO has substantial value or not in yielding accurate ENSO predictions, and it might be reasonable to ask the OSSE to determine what other observations might help the predictions.

But 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 first. **(HQ-3)**

I can't help but believe that in the long run OSSEs must be employed to help optimize the utility of the limited resources available for observing the Earth's climate. This idea is enshrined in NOAA's 5-Year Research Plan (op. cit.). But I also can't help but believe that such a task will require major personnel, space and computer resources, at least as large as developing the climate models themselves, that are well beyond current AOML funding expectations. I believe a large OSSE effort will require new funding from NOAA. The best location (AOML, GFDL, ?) for such an effort should be carefully considered.

c. Performance

The AOML Director has laid out several objectives for the future. The goal is to continue to perform high value measurements of important ocean and climate processes, but with an increased emphasis on modeling as well as on an expanded visitor program to enhance collaborative work. One measure of performance and impact of AOML research is how well it is being transferred to other programs, including those within NOAA; there are 80 examples of such transfers in the past, present or future listed in Tab 12. 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. **(HQ-4)**

For the new AOML modeling effort, there should be some discussion of how much local model development is appropriate. The initial emphasis should be to use existing community models and collaborate with scientists at other modeling centers, both inside and outside NOAA. Dual benefits arise by increasing leveraging and enabling AOML to continue to focus on core strengths. The AOML objective of moving forward in developing OSSEs is somewhat controversial, but seems worthy of pursuing. One issue is whether existing models are good enough to do this. Although the answer today is probably no, it is nevertheless important to get the process started so that the pieces start to fall into place sooner rather than later. This is another area where strong collaboration with the external modeling community would benefit AOML, NOAA, and the larger research community. One important area of future research is to better understand how hurricane activity will change in the future. AOML is working with outside modeling groups on coupling different atmospheric and ocean models (e.g., POM and HYCOM) at several different fine resolutions to better understand hurricane frequency, intensity, and track. Although not yet well funded, this is a good example of how the observational and modeling communities can leverage their activities and their scientific productivity.

As one way to improve modeling activities at AOML, expanded visiting scientist programs should be encouraged. By rotating scientists from their home base to other labs, such as AOML, for a few weeks or up to a year, it would be much easier to initiate collaborative projects and provide expertise not already present in the lab. A good way to start would be to make sure all of the potentially important connections exist with RSMAS scientists across the street. Interactions with scientists there could be fostered by having more joint seminars or short-term exchange programs during which RSMAS scientists would spend most of their time in an office at AOML, or vice versa. The program could be expanded to bring in scientists from other NOAA, government, and academic research groups. It would also be productive to have programs for graduate students and, if possible, undergraduates to spend some time at AOML working with scientists there and then returning to their home institution to continue the collaborative work. A good example of how integrated collaborative efforts could be expanded between AOML and the adjacent NMFS was noted during the site visit and the call in from the ship Nancy Foster. This cruise in the Gulf of Mexico/Caribbean Sea was identifying physical pathways that could contribute to understanding how ecosystems and fisheries are connected.

It is somewhat difficult to evaluate whether the human resources are sufficient to meet current and future needs. The laboratory seems to be well organized and managed to support its research programs, however there is some anecdotal evidence that technical staff salaries, particularly at CIMAS, are not competitive with those outside and that strong technical staff are occasionally lost to the organization. To the extent this is true, there would be lost

productivity at several levels that is hard to measure. AOML does have some strong young scientists who provide a base for future work, however 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. **(HQ-5)**

Overall, AOML is performing its ocean and climate mission very well. It 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.

Overall performance to date is commendable, the laboratory directorate has many competing issues but climate impacts will be an emphasis area for NOAA in the next administration – without doubt

While it seems obvious, it has nevertheless surprised me over the years how many people don't realize that in order to understand climate variability you must have long time series of physical, chemical and biological variables in numerous locations. In the United States, NOAA is the only Federal agency with the will and the resources to uphold the commitment to sustain such observations (NSF's nascent foray into "observatory" science notwithstanding). To date, NOAA is doing an admirable job; this commitment must not falter. The observation programs maintained by AOML's divisions are very important (especially those within PhOD, with which I am most familiar). They should continue to be nurtured, while proposed modifications should be scrutinized very carefully, since continuity is one of the most important characteristics of a climate observing system in my opinion.

Sustaining an observing program is more expensive than establishing it. A critical aspect of sustaining observation programs is the manpower needed to maintain the data stream. 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. The apparent reduction of technical support noted in III.B.3 above, and the documented ~5% reduction of AOML's total staffing since 2000, are disturbing in this regard. 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. **(HQ-6)**

Having said this, it is important to add that the collection of data is only the beginning of the needed commitment. Quality control procedures must be applied to the data, metadata must be incorporated with the dataset, and the

data must be made available as soon as possible to all interested parties, within and outside of NOAA. And, most importantly, the data must be analyzed. There is little point in collecting the data if there isn't a plan and resources for analyzing it. My 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. I recommend that NOAA make more funds available specifically for data analysis. **(HQ-7)**

The quantity of PhOD's refereed publications is equivalent to many of the best physical oceanography/climate units in the U.S., which is all the more remarkable considering the considerable efforts required of the PhOD researchers to maintain their climate observing systems.

PhOD's instrument development is laudable and above expectations for a unit its size. I'm aware of seven instrument systems that have been completed or are in development since the last review: (i) an XBT autolauncher; (ii) a current measuring dropsonde; (iii) a shallow water surface drifter; (iv) a real-time data delivery system via "pods", for seafloor instruments; (v) the Looe Key real-time oceanographic spar buoy; (vi) the Conch Reef Oceanographic Station; and, (vii) the Moser Channel Station at Seven Mile Bridge in the Florida Keys.

The excellence and significance of PhOD oceans and climate activities has been recognized by the Dept. of Commerce via a number of internal awards, including for example the 2003 NOPP Excellence in Partnering Award for AOML's role in the NOPP-funded Argo project; the 2004 NOAA Administrator's Award for developing a system to deliver quality-controlled, global ocean data in real time to the international operational and research oceanographic communities; and, the Dept. of Commerce Bronze and Gold medals in 2005 and 2007 for implementing, respectively, an oceanographic and meteorological monitoring network in coral reef areas, and for long-term research, design, and support of an observing system for the Florida Current and the meridional overturning circulation.

PhOD staff are appropriately well connected with the national and international research communities through conference attendance, service on science planning committees, and collaborative research efforts such as (i) the collaboration with NSF- funded American researchers and U.K. researchers to monitor the meridional circulation and heat transport from the Americas to Africa along ~26^{o} N, (ii) the collaboration with French and Brazilian researchers to study air-sea interaction in the tropical Atlantic (PIRATA), etc.

PhOD researchers are constantly evaluating the quality of the data collected by their observing systems. Recently, they discovered systematic biases in

the temperatures acquired in the XBT volunteer observing ship program, and convened a workshop a week before this review's site visit to publicize and resolve the problem. The workshop was attended by national and international researchers.

"Is the proportion of proposal-generated funding relative to NOAA base funding appropriate?" To this question my answer is no. In the academic community, the reliance of support staff funding on external grants has pushed many researchers to spend too much of their time writing proposals as funding success has declined, leading to higher stress and lower productivity. The proportion of AOML's funding, especially in PhOD and OCD, has been drifting in this direction; that is, in PhOD, proposals generated 47% of total funding in FY01, but in FY08 the figure was 56%. In OCD the numbers are similar. 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. **(HQ-8)**

It is disturbing that base funding was essentially flat for all the divisions in the past 8 years (hence, it actually declined in terms of purchasing power), and that proposal-generated funds accounted for all the documented funding increases during that time for PhO and OC Divisions. HRD's total funding was essentially flat from 2000 through 2007.

2. Ecosystem (Florida Coastal Ecosystems, Corals)

a. Quality

Overall, the Ecosystems Research program at AOML is a diverse collection of projects, doing high quality research in a variety of fields, and contributing to NOAA's strategic goals as evidenced in its 5-year research plan. The median H' score for researchers identified in the Ecosystems domain is 8, which is on the low side due to a number of factors including the heavy responsibility for field observations, concentration on technological development, and staff turn over. That being said, the Ocean Carbon program is considered world-class and this is reflected in an H' score of its principal investigator of 32 – the highest in the laboratory. Because of the primary research focus of the laboratory, and the demand for its expertise as a service organization, Laboratory management should set some bounds on the degree to which specific applications are pursued vs. research and development activities.

b. Relevance

All of the ecosystem-related programs reviewed by the panel have specific relevance at the international, national, regional, or local levels. The lab's expertise is highly regarded and sought in all of these venues. The Ocean Carbon program's research is highly relevant to topical issues of carbon

storage and mitigation measures such as iron fertilization. The coral forecasting project provides basic research into the climate and other impacts on Caribbean coral reefs. Nutrient dynamics programs are a primary input to the South Florida restoration program, the regional ecosystem connections program supports NMFS work on stock dynamics and the microbiology program assists local water management agencies. Given all these competing demands 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.

c. Performance

Given the limited staff and the breath of activities pursued by the Chemistry Division, the fact that performance is as high as is evidenced is a tribute to the dedication and cooperation amongst the staff. A number of specific comments are relevant:

1. The loss of P. Ortner to the laboratory has resulted in a significant need for a seasoned, multidisciplinary researcher that comprehends the connections between the disciplines in the 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. Given the impending retirement (apparently) of the Acting Division Chief, it is a priority to hire and have in place a permanent Division chief hopefully with some significant time overlap. **(HQ-9)**

2. While it is commendable that the Division is able to cover a broad spectrum of activities at many differing scales, 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 priorities. While NOAA's broadly defined priorities in fact probably can justify each program and project pursued by the Division, it is the breadth of such projects that may be difficult to sustain given uncertain funding, personnel changes, and access to ship and other technological resources. As staff retire it is appropriate to revisit the research portfolio rather than simply replace outgoing expertise one-for-one. In particular 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. **(HQ-10)**

3. The lack of resources overall has resulted in reimbursable research to pay salaries and offset equipment needs. This has in fact guided research at the laboratory. While this has been an effective way to resolve long-standing funding issues, the laboratory 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. While the laboratory continues to have some joint projects with the NMFS facility across the parking lot, it would be in both organization's best interest to develop a strategic outlook and plan for cooperative ecosystem studies. Where AOML may have limited access to ship time and field activities, SEFSC has significant ship resources used to assist in its missions. Joint cruises research and proposals could be mutually beneficial, as they are between PMEL and AKFSC. While the models need not be identical, the strong synergy between Alaska programs is not as evident between AOML and SEFSC. Such relationships were stronger in the past. The "One NOAA" concept should be pursued with increased vigor in the ecosystem realm among NOS, NMFS and OAR in the southeast. **(HQ-11)**

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

a. Quality

In my opinion, the quality of HRD research is below academic standards. They are improving, but they have a long way to go because of a lot of dead wood. At one time (~15-20 years ago) HRD was the premier hurricane research institution in the world. However, the have lost all their great researchers (except for Marks). These were DeMaria, Willoughby, Shapiro, Ooyama, Jorgensen, Burpee, Landsea, and Peter Black. These eight were some of the best hurricane researchers of all time. Their average h-index is 16, ranging from 9 to 22. The average h-index of the top eight of the current staff is about 11.5. When these are normalized by years of service, the numbers look even worse. 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 HRD staff has very big shoes to fill. For the last 25 years, the HRD budget has been essentially flat. To keep up with inflation, it appears that FTEs were not replaced when they retired. While HRD has managed to keep a vigorous research program going, the net result was a total loss over the past 15-20 years of the model expertise (Ooyama, Jones, Rosenthal, Willoughby, Lord, DeMaria) and the ability to look analytically at the physical processes (Shapiro, Willoughby,DeMaria) responsible for hurricane track and intensity changes. Another way to look at it is to notice that this list of experts plus many of their prominent predecessors at HRD pioneered comprehensive hurricane research during the "golden years" in the 60s-80s and spread their expertise to many other sectors of our community. But there has not been a similar ability to "spread the seeds" from HRD for 10-20 years, and without restoring a similar capability at HRD, no other organization is able to take its place. Most of the improvements in recent years have been incremental in nature. We need some major breakthroughs. The proposed "OSSE" initiative

and some recent work on rapid intensification has the potential for providing the major advances that we seek.

The main point I was making is certainly an important one: HRD has been starved for resources for a long time. In many ways, it is remarkable that they have been able to bring in a few good people who are impressive young researchers. However, it will be a long time before the HRD is able to regain its former preeminence in hurricane theoretical and modeling research. The ongoing work suggests strong synergistic collaboration with national and international partners.

Highly accurate meteorological forecasts that can be used to ensure that credible hurricane warnings are issued in a timely manner are an essential factor in avoiding injury or loss of life and reducing property loss and economic disruption. The ongoing work at HRD focuses on R&D and the transition of research to operations to meet the current and future operational needs of the forecast and warning centers.

b. Relevance

Hurricane forecast improvement is a goal of high national priority. All of HRD's efforts contribute to this goal.

AOML's HRD continues to conduct scientific research into hurricanes and related tropical weather phenomena, using theoretical studies, computer models, and an annual field program employing NOAA hurricane research aircraft. This research has resulted in a deeper, scientific understanding and in numerous practical applications, which have improved forecasts. HRD employs meteorologists, computer scientists, and other professionals, who collaborate with other governmental and academic scientists worldwide in this on going effort to advance scientific knowledge of the hurricanes and increase public safety.

Because of their extensive field experience HRD scientists are recognized internationally for their knowledge about tropical cyclones, and also for their expertise in remote and in-situ sensing in and around hurricanes. This expertise has been acquired over many years 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 coordinates parts of its programs with other NOAA organizations, e.g. AOC, NESDIS, and the National Center for Environmental Prediction (NCEP), in particular the Environmental Modeling Center. It maintains active research programs with, and receives funding from other governmental agencies, in particular, the Department of the Navy's Office of Naval Research (ONR) and the National Aeronautics and Space Administration (NASA). In

program areas where it is beneficial to NOAA, HRD arranges cooperative programs with scientists at the National Center for Atmospheric Research, and at a number of universities.

A high priority HRD endeavor is the NOAA Intensity Forecast Experiment (IFEX), developed through a partnership of HRD, EMC, NCEP, and NESDIS. The goals of IFEX are the collection of data to directly aid the development and evaluation of the next generation operational tropical cyclone forecasting model system, the Hurricane Weather Research and Forecast model system (HWRF). The HWRF model development work at HRD, at the moment, does not appear to be well coordinated with the ongoing work at EMC. There is a great deal of discussion ongoing to optimize the model resolution, to study multi-scale interactions, to determine the best mix of model ensembles to bound the uncertainty in intensity forecasts and to study the optimal observing strategy for initializing the models. Very little and insignificant amount of work is being devoted to study the impact of satellite observations, the assimilation of existing satellite measurements or recommending new observation systems. **(HQ-12)**

The relationship between HRD's model development effort and that at EMC appears to be quite tenuous. This is probably a result of low resources at EMC, but also may be an attitude issue. It appears that EMC is afraid of competition and loss of control of model development. In this reviewers opinion this attitude has isolated them from the community they need to work with. NOAA's Hurricane Forecast Improvement Project (HFIP) may be an effort to get around this impediment. HFIP has proposed a new model development path using HRD as a means to work with the larger community in the hope that it would allow NOAA's model development to accelerate faster than through EMC alone. The main impediment is community access to the operational model code through DTC. EMC must follow through on sharing that code or the effort will need to start from another path further isolating EMC. This reviewer believes that EMC's strategy is paranoid and unproductive. They can only benefit from opening the code through the access of their code to a more diverse development pool of talent.

Each Atlantic and East Pacific hurricane season the HRD conducts a field program in which they collect data from the NOAA aircraft and process this data to support the National Weather Service operational needs. Most of the hours flown are devoted to operational needs and very little flight time is available for research. 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 appears to be in place to update the instrument suite. **(HQ-13)**

The HFIP plan also calls for an additional resource for research flight hours every 2-3 years to use in focused research programs such as have been put together in the past to focus on key research questions needing answers to improve the models. This reviewer very strongly supports the need for the continued funding of research flight hours above the needs for operations otherwise the type of research leading to new ideas about processes that drive changes in storms will be slow in coming.

The laboratory director plans to kick off a "hurricane" OSSE initiative. He is on of the best OSSE modelers in the world. This plan should be encouraged. However, it should be required that this plan be coordinated and synergized with the ongoing OSSE activities at the JCSDA. An Observing System Simulation Experiment, or OSSE, is a type of observing system experiment in which synthetic meteorological observations are used as a surrogate for real observations. The primary objective of an OSSE is to assess the potential impact on forecasting of assimilating observations from proposed/future satellite or aircraft based observing systems. In this way, the benefits of an observing system can be estimated before it is designed, built and launched into orbit. We need to do a better job of setting requirements for the hurricane problem in particular thereby avoiding problems like that dogging QuikSCAT. **(HQ-14)**

c. Performance

HRD is in transition. They have dropped off in quality and performance over the last decade and need to build back strength in BOTH observations and modeling. For the external community the observational capability of HRD is the most important. The external community can build and run models. However, few if any of the external community has the resources to independently obtain observations in hurricanes. No matter how important or valuable the modeling capability in HRD, HRD's greatest value to the overall (NOAA + external) community is its unique observational capability.

A decade ago HRD was the leader in hurricane airborne research observations. Because of weakened staff and pressure to focus on operationally related topics, they have lost much of this leadership capability through staff losses and through NOAA's redirection of the NOAA P3 aircraft to operational tasked flying. They have helped non-NOAA led programs, notably CBLAST, TCSP, and RAINEX to carry out programs that have utilized the NOAA P3 aircraft. However, by the time of RAINEX, the operational tasking had become a seriously hindering constraint on the research. As successful as these programs were they could have been more productive if they were free of the operational constraints. 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. HRD is one part of AOML that is highly visible to the community. Deemphasizing observations will reduce HRD's usefulness to the observational research community, particularly that part of the community outside of NOAA. **(HQ-15)**

In line with the previous paragraph, I would recommend that now that the SFMR is on the AF reconnaissance aircraft, that HRD rebuild its connection with the external community to carry out the aircraft experiments needed to advance hurricane knowledge. The SFMR on the P3s has caused those aircraft to be taken over for operational use rather than research. This is a misuse of the P3s—not what the taxpayers funded them for.

Although it is essential to rebuild HRD's observational strength, it is reasonable for HRD to also build up a modeling capability because the way that hurricane knowledge and forecasting capability is going to be advanced is by a combined use of models and observations. One to two decades ago HRD had a good modeling and theoretical capability. That capability was completely lost with the departure of key staff that was not replaced. Further hiring is needed, especially in data assimilation. A current weakness of the model development is the reluctance to interact with the RSMAS modeling group

The lack of interaction with RSMAS is hard to understand. Probably there is a history. RSMAS used to be weak, and HRD used to be strong. Now HRD is much weaker than it has been in the past and RSMAS has become a very strong group in tropical meteorology. RSMAS should be viewed as a resource and proactive steps should be taken by HRD to interact with them. This interaction should be directly done with RSMAS, not through CIMAS. The CIMAS interface obscures the communication. Programmatic discussions should be between Marks or Atlas and the RSMAS dean. Other interactions should be between HRD PIs (preferably Marks) and RSMAS professors. It is not healthy for HRD scientists to communicate directly with RSMAS students or postdocs without first discussing the interaction with the student or postdoc's RSMAS professor/mentor. Advising of students and postdocs can be sensitive and HRD staff should not be seen as interfering without advice and consent of the responsible faculty. A healthy relationship with RSMAS will help both HRD and RSMAS become stronger entities. A good role model is the NSSL/OU interaction in Norman. It might be useful to schedule regular joint RSMAS/HRD meetings to discuss the areas of common interest. Another idea would be a joint seminar series rather than separate seminars. At present, the HRD seminar notices are not always received at RSMAS. It would all work better if the seminar series was joint. **(HQ-16)**

An particular area of common interest to HRD and RSMAS is radar data assimilation. A joint working group of HRD and RSMAS on radar data

assimilation might be a useful activity. OSSEs of radar data assimilation in high-resolution models is an area that needs as much brainpower as possible and is a great need at both institutions.

d. Additional Comments Related to HRD

Dr. Atlas wants AOML's visibility in the community to be higher. I have three suggestions to improve AOML's visibility in the external community:

1. One of the best ways to improve the visibility of AOML is by improving its website. I strongly recommend that 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.
2. Another way to do raise the lab's visibility and overall usefulness to the community is by instituting (and funding) a strong visitor program in which the lab staff are encouraged to develop external collaborations. This will be a win-win proposition. It will empower the visitors to do more than they can do on their own, and it will broaden the publication and citation base of the AOML staff.
3. Restore HRD's pre-eminence as an observational science group. It is this capability that has drawn high-profile external collaborators into AOML/HRD. HRD is in danger of losing that pre-eminence and hence visibility in the larger community. While AOML may not be on the tips of the community's tongues, HRD has been, precisely because of its observational capability. AOML needs to be proactive in rebuilding HRD's observational strength, as I have noted elsewhere in this report, if its visibility is to be retained.
4. Irrespective of whether HFIP is implemented or not, the OAR and laboratory management should work with the EMC management to make it possible for HRD and EMC to share the model code on a continuing basis to accelerate the model development efforts.

4. Additional Comments

a. We received much input, from the division director level and from the PI level that the ship maintenance of the NOAA research fleet is woefully inadequate. Investigators are repeatedly experiencing disruptions to their research cruises because of inadequate maintenance of the ships. Of all the issues we heard about, this one is the most disturbing. The research fleet of NOAA must be better maintained and regain reliability if AOML is going to be able to achieve its research mission. I think this is the most important issue that emerged in the AOML review.

A major component of the AOML mission is to make observations of the atmosphere and ocean. To do this well, it is necessary to have research ships that are well maintained and operated. There is some evidence that the productivity during research cruises is below optimal because breakdowns

during scientific cruises lead to lost observations. NOAA should investigate whether there are significant issues related to poor ship maintenance, and if so, make the necessary corrections. There are also issues related to procedures for allocation of ship time and whether NOAA's Programming, Planning and Budgeting and Execution System (PPBES) has had a negative impact on ship-based field programs. There appears to have been some negative impact on the AOML mission that will continue in the future if not addressed.

A continuing theme heard among researchers, program leaders and technicians is the poor maintenance of NOAA ships supporting Ecosystem activities and the difficulty in obtaining sufficient fleet time to conduct relevant research. It was asserted that the material condition of the *Ron Brown* and other ships primarily used by the programs has contributed to loss of sea days, unreliable sailing dates, shortened cruises and unreliability of basic deck equipment used in conjunction with Lab-supplied equipment. 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 UNOLS and other ships, or in conjunction with other entities (e.g., NSF). Given the increasing operation and maintenance costs of the aging NOAA fleet, this will become an evermore pressing issue to be addressed at the NOAA management level.

b. The presentations on microbiological testing contained an error. It was stated that plate-based diagnosis is more accurate than the PCR analyzer. This is not true. The PCR analyzer's data based is determined from plate-based diagnosis. Clinical laboratory experts still consider the plate-based diagnosis as the "gold standard." What you gain from the PCR analyzer is speed (as was correctly noted) and that it becomes unnecessary to have staff skilled in the plate-based diagnosis.

c. Again, irrespective of HFIP, HRD should be provided with additional flight hours annually solely for the purpose of carrying out focused research programs.

d. NOAA rotating scientist programs should be encouraged and expanded to ensure better leveraging of scientific expertise found at OAR laboratories. This could be expanded to bring in scientists from other NOAA, government, and academic research groups.

The value of the datasets being collected by AOML, and the productivity of AOML researchers, will be strongly enhanced by increased interaction with scientists from other NOAA labs, other Federal labs, and from academia. Especially, the utility of AOML's datasets for model validation will be advanced most quickly if AOML researchers directly collaborate with

modelers, as opposed to simply making the data available and hoping that modelers will pick up on it. The need for establishing a Visiting Scientist Program cuts across all AOML divisions. The program should fund multiple-week visits by non-AOML scientists to work at AOML, as well as fund multiple-week visits by AOML scientists to work at other institutions. Insofar as such a program requires new funds for AOML, I would urge NOAA to provide those funds.

e. I believe it is important for AOML to increase its visibility to the public, the research community, Congress, OMB, etc. I have heard that NOAA has had an un-written policy of anonymity for its individual labs, that the successes of the labs should be blended into successes of NOAA as a whole. While I understand this teamwork concept, I think it should not prohibit the individual labs from becoming more visible to their communities. After all, it is public policy and the public welfare that ultimately motivate most of NOAA's activities. There is nothing wrong with the local communities becoming more aware of, and even more involved with, their local NOAA lab (if they have one). To be blunt, it can't be stopped. The internet has opened up the flow of information, and has engendered the expectation that public information must be readily available. How would it look if AOML had no web presence at all, but just delivered its data to other agencies for dissemination? I know how it would look, because there are still a number of NOAA entities that don't have their own web presence (or don't have a decent web presence). The impression is that these entities are backward and out of touch. As John Q. Public, I might then wonder why they're funded at all.

Taxpayer funded agencies, like AOML, whose missions are directly related to providing information for the public good should have a high visibility to the public. In 2008, this means having an outstanding web presence that provides data, useful products, educational material, mission statements, etc., all via a very user-friendly web site. AOML's current role as a collector and supplier of local and remote data and value added products ensures a growing group of users who will look for that data at AOML's web site. It is a public relations mistake to make it either difficult to navigate through the web site to the desired data, or to refer these users to other NOAA data servers.

This brings me to the problem. AOML's current web site is confusing and hard to navigate. For example, important physical oceanographic data is hidden under the link titled "GOOS Center", which link is never front and center but off to the side. I didn't even know that that's where I should look for the PO data until someone in PhOD told me. I strongly recommend that AOML's web page be redesigned immediately. The PMEL web site, although not ideal, is much better and could be used as a template. As a reviewer, I was impressed with PMEL's "Management Documents" link, under the "About Us" link, although like AOML they seem to have stopped producing

operating or strategic plans.

At a minimum, the upper pages of the AOML web site should be more graphical and list oriented, rather than textual (see the PMEL site). The upper levels should also be consistent (note the dissonance that one feels in switching from the PhOD, OCD and HRD pages on the AOML web site).

f.I think it's very important for AOML to have its own strategic plan, especially now that NOAA as a whole and OAR in particular have issued 5-year plans. To my knowledge, AOML has not issued a strategic plan since 2000.
Such plans are essential for AOML's visibility and funding health. Especially, this would be the document where I would expect to see discussions of the rationale and linkage of AOML's specific programs to NOAA's Mission Goals. **(HQ-17)**

Annual or biennial operations reports should also be generated and made available to the public via the AOML web site. I have heard that such reports are already being generated for internal NOAA use. Why not make them available on the web site?

g. The staff of PhOD is very high quality and is well distributed with respect to age (that is, with a good complement of younger researchers) so that the production of excellent research can be expected for the foreseeable future, unless the younger people are tempted to go elsewhere. A younger scientist at AOML actually has an advantage over his/her academic counterpart, because of the level of science and technical support available at AOML. Most academic institutions, for instance, do not provide any support personnel. Such people are almost always funded by external grants.

However, the academic environment currently has a distinct advantage in salary scales for senior researchers. The difference is at least 25% right now. If NOAA senior researcher pay scales are not increased, not only will it be nearly impossible to attract senior researchers to AOML (as needed, for instance, to lead the divisions when the current division heads step down), but the younger researchers will eventually be tempted to leave. This is obviously a problem that goes well beyond AOML's, or even NOAA's, capability to fix, but perhaps comments such as this from enough external reviewers will help to spur action at the appropriate governmental level.

Two other problems in this category that need attention are the low salaries of the CIMAS science and technical support staff, and the declining technical support within AOML (e.g., the dwindling number of electronics technicians). I only have anecdotal evidence of these problems, but I heard these themes enough times during the site visit to believe they are significant concerns.

Good science and technical support is hard to come by and should be well rewarded. The greatest regret I have in my career to date is that I let good support people slip through my fingers because I did not reward their services as well as I should have. AOML's observation programs are too important to let falter for lack of technical support. **(HQ-18)**

h. The Planning, Programming, Budgeting and Execution System (PPBES) while laudable in general has had a significant negative impact on the execution of timely research. Especially, the 18-month process puts AOML (and other NOAA) researchers at a decided disadvantage when trying to capitalize on the latest technological and research developments. Perhaps the system could be improved by allowing more authority at lower management levels.

i. In reading the NOAA 5-Year Research Plan (op. cit.) and the documents "*NOAA Priorities for the 21st Century - NOAA's Strategic Plan - Updated for FY2006 - FY2011*", and "*Strategic Plan - NOAA Office of Oceanic and Atmospheric Research - FY2005 - FY2010*", I was surprised by the lack of attribution of at least a few specific accomplishments of the NOAA labs. At least in OAR's Strategic Plan, the lab programs were given early (page 3) visibility rather than being relegated to an Appendix. It would have been a simple matter in the lengthy NOAA 5-Year Research Plan to acknowledge the labs that contribute significantly in each research area. I believe that providing such attribution will enhance morale within NOAA's labs, and engender a sense of ownership of NOAA with the public and with Congress. People like to be acknowledged for their efforts, and communities like to know that organizations within their borders are doing good work.

I believe future NOAA-wide and OAR strategic and operational plans should provide more specific attribution of the accomplishments and on-going contributions of the laboratories (and cooperative institutes) in pursuing and achieving NOAA's past and future research goals.