NOAA's Atlantic Oceanographic and Meteorological Laboratory
U.S. Department of Commerce

2019 AOML Laboratory Review Summary Report

November 19–21, 2019

Review Panel

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OVERVIEW

The on-site review was conducted over a three-day period, November 19–21, 2019 at the Atlantic Oceanographic and Meteorological Laboratory (AOML), Miami, Florida. Prior to the site review, the panel members were briefed on the review processes, and provided with instructions during two teleconferences with the Office of Oceanic and Atmospheric Research (OAR) staff. Review materials were posted on the AOML website ahead of the review.

The review process kicked-off on Monday, November 19th, 2019 with an informal breakfast at the Mayfair Hotel where OAR leadership briefed the panel on NOAA's Lab review process and their expectations for the present review. The review formally started at the AOML campus with presentations by Dr. Gary Matlock on NOAA's research program and charge to reviewers, followed by a remote presentation by Dr. Wayne Higgins who described OAR's Weather, Oceans, and Climate Portfolios. In the next couple of days, AOML leadership and scientists described the organization structure along with its goals, core competencies, research activities and science highlights in three major research areas:

- Hurricane Research and Modeling
- Physical Oceanography and its Impact on Weather and Climate
- Ocean Chemistry and Ecosystems

These 3 research areas closely map to AOML's main divisions:

- Hurricane Research Division (HRD)
- Physical Oceanography Division (PhOD)
- Ocean Chemistry and Ecosystems Division (OCED)

and the subsequent review will interchangeably refer to the research area or AOML division. In addition to the oral presentations the review also included a) walking tour of several lab facilities, b) telephone interview with stakeholders who had previously provided written statements, c) private meeting with early career scientists and staff, d) poster session in the lobby allowing contact with rank-and-file AOML scientists and staff, and e) a very informative simulation of a typical day during hurricane season, illustrating the scenario of map discussions, real time field observations, data assimilation and model runs. A presentation on the second day by AOML Associate Director, LCDR Andrew Colegrove, gave an overview of the current

physical infrastructure of AOML and the challenges faced with the aging facilities. The last day concluded with an opportunity for final questions and feedback between reviewers and AOML leadership, followed by a debrief by the Panel Review chair, Dr. Arlindo da Silva, of the key findings and recommendations. The review formally adjourned at 1 p.m. on November 21st.

The panel was extremely impressed with the breadth, depth and quality of science carried out by AOML in the last 5 years. The science output, measured by the number of refereed publications in high impact journals, is excellent. AOML scientists are leaders in their fields and are well respected nationally and internationally; they serve in multiple national and international committees/boards, and hold multiple chair/lead positions. Several prestigious awards have been received by AOML staff, including Department of Commerce Gold and Silver Medals. Especially notable is that AOML staff have been part of the last four AMS Banner Miller Awards (two as lead author). The research conducted by the three divisions is highly relevant and aligned with NOAA goals, although the panel is suggesting possible areas of expansion. Feedback from stakeholders were mostly positive, with recommendations for improvement appearing later in this report. Based on the review, it is clear that AOML plays a critical role in sustaining the global oceanographic climate data record, in addition to its role in real time hurricane-related measurements. In its totality, AOML contributions to hurricane science, model development, sustained observational platforms and assets are very impressive, with important innovations realized by all three divisions. Such activities are of the utmost importance for the nation and the science community in general, as evidenced below by the key findings for each AOML division. The outgoing AOML director, Dr. Robert Atlas, has demonstrated outstanding leadership in the past 5 years, achieving a good balance between delivering services to NOAA and the community, and the fundamental research that is needed to generate high quality products.

The summary evaluation for each AOML research area appears in Table 1. All three divisions scored high marks ("*Highest Performance"*) on the *Quality* element, further confirming the excellence of AOML's scientific output. Most of the panel recommendations are aimed at further improvements in the *Relevance* and *Performance* elements of the evaluation as defined in the Guidance to Reviewers.

Table 1. Summary evaluation per Research Area. Basic rating as defined by OAR.

Research Area	Rating	Reviewer 1	2	3	4	5	6	7
Hurricane Research and Modeling	Overall	●	◓	●	◓	●		
	Quality	●	◓	●	●	●		
	Relevance	●	●	●	◓	●		
	Performance	◓	◓	●	◓	◓		
Physical Oceanography and its Impact on Weather, Climate and Ecosystems	Overall	◓		●		●	●	
	Quality	●		●		●	●	
	Relevance	◓		●		◓	◓	
	Performance	◓		●		●	◓	
Ocean Chemistry and Ecosystems	Overall	◓		●		◓		◓
	Quality	●		●		●		●
	Relevance	◓		●		◓		◓
	Performance	◓		●		◓		○

● Highest Performance ◓ Exceeds Expectation ○ Satisfactory ◒ Needs Improvement

Overview of Key Findings and Recommendations

AOML-Wide

- The panel noticed the lack of a strong sense of an *AOML identity* and is recommending a strategic planning exercise for developing such an identity.
- While *ad-hoc* collaborations exist among the 3 divisions, the panel is recommending a more formal planning process for boosting collaboration and prioritizing science research.
- Given the flat budget and limited resources, the panel is recommending a process for clarifying who constitutes a stakeholder, and prioritizing their engagement.
- The panel found a sub-optimal utilization of satellite data at the lab, and is recommending the development of a remote sensing core competence at AOML.
- In order to maximize the utilization of human capital resources, the panel is recommending the creation of a lab-wide data assimilation group to serve as a resource to all 3 divisions.
- The panel is recommending that AOML takes concrete steps for the inventory and preservation of intellectual property.
- In order to address HPC and other IT challenges, the panel is recommending additional partnerships with computing centers within

universities, and the development of a strategic plan for cloud computing.

- The panel is recommending that AOML increases the geographic reach of its research to include other areas of the Atlantic.
- Many years of flat funding have limited certain elements of AOML research. The panel is recommending that AOML increase the percentage of its funding available for flexible purposes. The panel is also recommending that AOML engages OAR and similar NOAA Labs in a concerted effort to address the lack of dedicated funding for facility refurbishment.

Hurricane Research Division

- HRD has been the de-facto caretaker of research-quality tropical cyclone data for the nation. An increase in base funds for HRD is paramount for it to continue fulfilling its role.
- The panel is recommending a closer planning exercise with NHC, possibly in the form of annual workshops and the development of a joint strategic plan.
- HRD should continue developing its modeling and data assimilation activities, leveraging but not duplicating other NOAA modeling efforts. HRD OSSE work should focus on observations of relevance to tropical cyclone development and intensification, while de-emphasizing global measurements of no direct relevance.
- HRD scientific staff should be encouraged to participate in editorship of journals.

Physical Oceanography Division

- Continue the current activities in oceanographic data collection, and support NCEI with data archival and dissemination. The panel is recommending that AOML takes a leadership position in the emerging BGC Argo.
- The panel is recommending that PhOD expand its activities in satellite oceanography, as well as modeling and data assimilation, extending its modeling geographic domain.
- The panel is recommending that PhOD embarks on cross-cutting inundation research.
- The panel is recommending increased cooperation with regional and other entities.

Ocean Chemistry and Ecosystems Division

- Work at OCED seemed largely *ad-hoc* and disconnected. OCED could greatly benefit from a formal strategic planning exercise.
- The panel is recommending expansion of OCED research areas, including water quality research, additional social sciences work integrated with a lab-wide strategy, and more integration of the ecosystem assessment for fisheries.
- The panel noticed that OCED research is heavily proposal-funded, and has very little flexibility to respond to unanticipated events where OCED could significantly contribute scientifically. The panel recommends that OCED base funds be increased as to afford greater flexibility to respond to such needs.

In the remainder of this Report we further elaborate on these key findings and recommendations.

LABORATORY-WIDE KEY FINDINGS

Need for an Overall AOML Identity

The opening presentations left the panel with the impression that there is no strong sense of an overall unifying AOML identity. This was reinforced in the three divisions' vision/mission statements that were unique to, rather than unifying with, AOML's overarching vision/mission. Likewise, the panel's interaction with AOML staff conveyed that their primary affiliation was to their division, not to AOML as a whole.

Collaboration Across Divisions

From the presentations and material provided for the review, it appears that there is no overall AOML-wide science prioritization process. Instead, it appears that the science conducted by the lab is to a large extent independently defined by the three divisions. HRD appears to have a rather clear direction because it primarily serves a single customer, which co-establishes research priorities with HRD. OCED appears to be on the opposite end of the spectrum, with a more diverse research portfolio serving multiple parties, with no clear articulation of a common, unifying set of science priorities. While some examples were provided of inter-divisional collaboration, it was clear that cross-divisional collaboration is informal at best. It is possible, and perhaps even likely, that this approach to determining what science is initiated leads to sub-optimal allocation of

resources (both staff and funding) and may leave higher priority activities under-resourced.

Need for Prioritizing AOML Stakeholders

The diversity of research presented is broadly distributed across the basic-to-applied research continuum. Some AOML science appears to be primarily curiosity-driven, other research appears aimed at providing data to other non-AOML researchers, and still other research is much more directly applied with a specific, known, and closely-associated user/manager.

The definition of what constitutes stakeholders/end-users of AOML-produced information is highly variable across the Laboratory. Recognizing that resource limitations will not allow AOML to conduct research for all entities that may desire AOML to provide them with information, it becomes necessary to carefully and explicitly define the customers that AOML science will serve. This will aid in managing expectations of others about what AOML can and cannot deliver, and will partially establish boundaries for the type of research conducted. It appears that HRD has a single primary consumer: NWS. However, PhOD and OCED seem to serve information to a much broader set of consumers. While the logo of some of the consumer organizations appeared in some of the slides, the panel felt that many of the consumers remained unidentified during the review. During the review, there was much more information presented on *partners* in the research and much less on the *consumers/users* of the science produced by those partnerships.

Limited Geographic Scope of AOML Activities

Much of AOML's research is geographically split into 1) basin-wide research, 2) certain tropical/subtropical areas, Gulf of Mexico, and Caribbean research, and 3) everywhere else, including the Atlantic coast north of the northern extent of the Florida reef tract. From the material provided, there seems to be very little AOML research dedicated to areas north of the Florida reef tract, except for that which can be considered basin-wide in scale. While AOML is OAR's Atlantic Ocean research facility, it appears that there are vast areas of the Atlantic that are not being covered by the Laboratory. This observation is most strongly associated with OCED's portfolio and, to a somewhat lesser extent, PhOD's. Since the HRD's portfolio is basin-wide, this observation is not particularly germane to their current research portfolio.

Preservation of Intellectual Property

During lab tours the panel was introduced to a large number of new sensors or other technologies that have been developed by AOML staff. These include, but are not limited to, the Sub-Surface Autosampler, Opuhala Temperature Sensor, pCO2 sensor that *saved the company* to which it has been transitioned, bioerosion monitoring unit (BMU) from OCED, and the XBT sensors, launcher system, and data upload module shown in the engineering bay by PhOD. However, the panel could not find any information on patents or patent applications in the review materials. The panel believes that several of these innovations deserve an evaluation for potential patent applications. This could serve the dual purposes of protecting the government's intellectual property and recognizing the very significant innovation accomplishments of individual researchers and engineers at AOML.

Limitations of the Funding Structure

The AOML budget has been steadily declining and is sufficient to cover only fixed costs. The vast majority of AOML science is supported by OAR program funding, which is allocated on a short-term basis and cannot be encumbered by fixed costs (most particularly federal labor), and other federal funding sources that are similarly proposal-based. This means that much of AOML science is dedicated to the work that is funded by others, to produce deliverables that are core components of those funding agreements. Hence, AOML has very little flexibility to initiate research in novel areas or respond to unique opportunities to collect data/start new research efforts, unless external funding can be quickly identified.

Key Findings by Research Area

Hurricane Research and Modeling

Quality

During the past 5 years, HRD has made outstanding advancements in better understanding of the rapid intensification processes, and prediction of tropical cyclones (TC). Specifically, HRD scientists have:

- Developed comprehensive observing strategies, (aircraft and satellites) and analyses systems, as well as post-processed and archived historical datasets for TCs over the Atlantic Ocean.

- Through their partnerships, HRD staff are playing key roles in the testing and deployment of new and exciting observing technologies, most notably next-generation Doppler radars, unmanned aircraft systems, and infrared-enabled dropsondes. HRD has collaborated with PhOD scientists in deploying new prototypes of ocean observation platforms, *e.g.* gliders, that could lead to improved skills of TC forecasts.
- Developed unique atmospheric models (HWRF, HAFS), with multiple moveable high-resolution sub-domains following movement of TC; such a configuration provides better simulation of scale interactions among TC's, leading to better simulation, and potential increase in forecast skills of TCs. Contributions to operational modeling system, most notable being HWRF, is a research-to-operations highlight within AOML.
- Published influential papers in top journals in atmospheric and climate sciences.

The AOML/HRD staff are internationally recognized experts in tropical cyclones. They serve on national and international committees/boards, and hold multiple chair/lead positions. Several prestigious awards have been received by HRD staff. Especially notable is that HRD staff have been part of the last four AMS Banner Miller Awards (two as lead author). HRD staff have also been awarded a Department of Commerce Gold Medal (for development of HWRF) and Silver Medal (for collecting observations with unmanned aircraft in hurricanes).

Historically, HRD's primary strength has been in collection and analysis of hurricane observations, and this strength continues. HRD has maintained a strong partnership with NOAA's Aircraft Operations Center, highlighted by the annual Hurricane Field Project (HFP), which continues to be a great success that produces unique and valuable data in and around hurricanes. AOML/HRD should be commended for smoothly transitioning leadership and participation in the HFP to a younger and more-diverse generation of scientists.

In addition, HRD scientists have participated, and provided leadership in a large number of national and international TC field campaigns. Many of the aforementioned contributions by HRD represent unique, and critical work that can only be carried out at HRD, because of the right mix of scientists, observational systems, and facilities, and its geographic location that is under

the clear and present threat of more extreme TC's causing potentially devastating damage to the socio-economic well-being of Florida and the Gulf regions.

Relevance

HRD collaborates closely with operational partners within NOAA to improve forecasts of hurricane track and intensity: NOAA's National Hurricane Center, NOAA's Aircraft Operation Center, NESDIS/STAR, CPC, NOAA/NWS/EMC. Of the 20 research-to-operations projects listed in information to the review committee, 13 have Readiness Level of 8 or higher, which is clear proof that HRD's research benefits operational activities in NOAA. The feedback from stakeholders is generally positive, showing appreciation for collaboration, data and information sharing, with mutual benefits to HRD and their own organizations.

The observational data collected in partnership with AOC, including flight level data, radar and dropsonde observations, and numerical models, are highly valued by NOAA's and the broader research community alike.

HRD has been very proactive in emerging research areas and technology including machine learning, cloud computing, and coupled ocean-atmosphere data assimilation, as well as integrated social/behavioral/economic sciences. These areas are highly relevant to NOAA's strategic goals of R2O, utilizing cutting edge technology for science and application, with benefit to society.

Performance

Research leadership and planning

With 24 scientists (plus support staff), HRD is a relatively small organization compared to similar divisions at NCAR and NASA. Yet HRD has accomplished an international reputation as the premier center for hurricane research and predictions. This is a testimony to the leadership and strategic planning, and implementation of its operations.

Efficiency and effectiveness

There is no doubt that HRD management has high efficiency and effectiveness in its research focus, planning and execution. Under the current tight budget constraint, HRD is performing much better than expected. However, this situation is not sustainable, especially given the increasing demand to improve the prediction of extreme TCs in a changing climate. The current base budget for research has to be increased in

proportion to HRD work load and capacity to tackle emerging new challenges in research, technology, outreach, and R2O activities.

Transition of Research-to-Operations

While R2O is clearly an area of high relevance to NOAA/OAR, the panel found the description of the transition processes lacking in clarity, both at the NOAA and the AOML levels. In the review documents, only numbers of projects at different Readiness Level (RL) are provided, without explanation of what they mean, how they are determined, and how they compared to past standards, or compared with other NOAA organizations. One of HRD's biggest challenges is finding an appropriate balance between fundamental research and the short-term demands of research-to-operations (R2O) projects. The panel felt that the balance is leaning too much towards applied R2O already; for example, the Readiness Levels of projects within HRD are very heavily weighted towards RL7-9, with very few higher risk RL1-3 projects that could potentially have very high payoffs.

A consistent theme throughout the review is that HRD staff members feel *victims* of their own success. Expansion into every possible area of tropical cyclone research is unsustainable, especially considering the flat base funding. It is of some concern that more responsibilities are being placed on HRD from much higher levels (*e.g.*, UFS, EPIC, FACETS) without commensurate increase in financial support.

Physical Oceanography and its Impact on Weather and Climate

Quality

The Physical Oceanography Division (PhOD) is one of the most respected research groups in the country. The science conducted by the Physical Oceanography Division is excellent and it is recognized nationally and internationally. The Division has partnerships and collaborations at different levels, and generates scientific results for the scientific community at large. The research is timely and relevant to the Atlantic region that is the focus of AOML. They have developed innovative technology to fulfill the needs of their research objectives, though it has been conveyed by the staff that it is a challenge to find time to dedicate to innovation.

Central to the work at PhOD is the sustaining of long climate time series. These time series are of global importance, and they are expertly maintained by PhOD personnel. In some cases, it is fair to say that if PhOD were not doing this work, the time series would end. The presentation by Dr. Lumpkin

did an excellent job of summarizing PhOD's many contributions to the Global Ocean Observing System, abstracted in Table 2.

Table 2. PhOD role in oceanographic observing systems.

Observing system	PhOD role
Argo profiling floats	US data assembly center; contributes to Atlantic array
Global drifter program	Data assembly center; maintains global array;
Atlantic western boundary current moored arrays	Leads the North Atlantic time series (26.5°N); maintains the western half of the South Atlantic (34.5°S)
Florida current	Maintained since 1982
XBT network	Leads Atlantic component
PIRATA moored array	Leads annual cruise to service moorings

An initiative started during the last 5 years has been to use underwater gliders to provide upper ocean temperature and salinity data relevant to hurricanes. The goal is to put the gliders in regions historically transited by hurricanes, where the data might improve forecasts. The program has grown to the point that seven gliders were deployed during 3 months of the 2019 hurricane season. Continuing research has focused on the impact of these data on forecasts of intensity. In general, autonomous observations are a growth area for PhOD.

With the establishment of BGC Argo as an approved pilot project, it seems likely that the goal of 1000 BGC floats will be approached during the next 5 years. PhOD is well positioned to participate in this growing program. First, through the role as US Argo Data Assemble Center, PhOD personnel will be responsible for a substantial growth in the number of profiled variables from the current two (temperature and salinity) augmented by six more (dissolved oxygen, pH, chlorophyll fluorescence, optical backscatter, nitrate, and downwelling irradiance). Establishing climate quality data from BGC observations depends on careful quality control from AOML scientists. In general, BGC sensors are ready for deployment on a number of autonomous platforms, including the glider fleet operated in PhOD.

PhOD scientists are active in analyzing the data they collect to address important scientific problems. Presentations during the review included studies on meridional heat transport in the Atlantic, physical environments relevant to Gulf of Mexico fisheries, the effect of ocean observations on hurricane forecasts, climate modulation of extreme weather, and processes causing sea level changes on the US east coast. These studies have led to an impressive number of publications in the best oceanographic journals.

A major international event in ocean observing took place in September 2019. The OceanObs19 meeting was the third in the series, starting with the seminal 1999 meeting that was the origin of Argo. In the lead up to OceanObs19, the global community collaborated in the writing of over 100 white papers on aspects of ocean observing. PhOD scientists participated in 17 of these papers, in some cases as lead authors. The leadership of PhOD scientists at OceanObs was tangible, positioning AOML well for the next decade.

Relevance

The research conducted at PhOD is of broad scientific and societal relevance, and is highly relevant to NOAA's mission. The most important sustained contribution has been the long time series observations of ocean variables. These observations are essential for society to address climate issues. For example, PhOD efforts have been central to quantifying global ocean warming. The most important new effort, established during the past five years, are the glider observations of ocean properties under hurricane tracks. While work is ongoing to establish their value, the possibility is that these observations will help to make improvements in forecasts of hurricane intensity.

Despite the relevance of the work being performed, the panel felt that there is still room for enhancing the connection to society through closer partnership with other divisions within AOML. Specifically, the modeling efforts could be expanded to more directly address societal problems such as storm surges. Likewise, additional attention should be devoted to elaborating the transition plan for delivery of research products to customers/ stakeholders. This activity would require a better understanding of the benefits and suitability of applications to the end users.

Performance

PhOD has clear scientific objectives which it addresses through interconnected scientific research. PhOD has recently started to collaborate with HRD, and historically it has had tight links with OCED. The panel felt that the PhOD-OCED links could be improved by engaging in more effective joint modeling efforts.

Although the aging facility infrastructure is a limiting factor for some of the research performed at PhOD, the division leadership should be commended for securing resources to develop a state-of-the-art engineering lab to develop and maintain their comprehensive observational assets. On the other hand, the AOML building is past its projected lifetime. Some serious questions will have to be addressed concerning whether it would be better to invest in maintenance or to rebuild.

Ocean Chemistry and Ecosystems

Quality

Scientists in the OCED are recognized for excellence in their research, collaborations with partners, and national and international leadership positions. The research conducted has a strong focus on inorganic carbon in the ocean and its effects, as well as coral reef ecology and resilience. The *'Omics* field is emerging and the researchers in AOML are well positioned to be leaders in this area at a national and international level. OCED has a desire to expand their contribution and participation in the BGC Argo program, and they are well poised to do this, especially in collaboration with PhOD. In partnership with industry, NOAA and other laboratories, OCED has developed technologies to address sampling issues and reduce the cost of field work. However, the transition to operations remains a challenge (including technology and tools such as models to improve coral growth success).

The panel felt that OCED has not fully taken advantage of satellite remote sensing. Satellite data has a variety of applications that could benefit the Division, but there is a perceived lack of expertise in the division, and lack of time to utilize these resources due to other commitments.

Relevance

The research being conducted at OCED is extremely relevant to contemporary issues and is being conducted by top notch scientists.

Transition plans for delivery of research products to customers or operators need refinement. The Division has struggled to identify operational partners, and although there are potential customers and some users currently engaged, these remain limited. From the panel's interaction with stakeholders it was apparent that at a PI-to-PI level the interaction with OCED scientists have been positive, and stakeholders spoke very highly of the research and dedication of the AOML scientists. Public outreach is also conducted at the PI level, and the Division as a whole could benefit from help from communication and outreach professionals for a more concerted effort to promote the excellent work being conducted at OCED.

Partially because of OCED's heavy dependence on proposal funding, the research conducted at the division is very relevant. However, that does not indicate whether OCED is conducting the most relevant science. There are significant needs in multiple NOAA mission-aligned areas that could be met by capabilities at OCED, but many of those needs are not held by entities that provide federal funding to research organizations. As one example, OCED conducts very little research along the Atlantic coast north of Florida. The non-coral national marine sanctuaries in the Atlantic, many states' coastal management programs, and multiple topically-based programs could benefit from the expertise in OCED. There may be higher-priority science needs directly relevant to NOAA's mission areas that could be, but are not currently being met, by OCED mainly because of the funding profile of OCED science.

Performance

Research Leadership and Planning

It appears that most projects are effectively planned and implemented. There was discussion of the complexity and dedication necessary for out-year planning for major research cruises, project life-cycles, and resourcing requirements. That OCED is regularly publishing and obtaining repeated funding indicates that they are performing well in the administration of individual projects.

The Division could use more coherence in their research plans. It is unclear how OCED prioritize research activities, and how their research areas fit within the scientific objectives of AOML. In response to the past AOML evaluation, the Division did hire a new director. However, stakeholder engagement, which was also a recommendation from the last review, still

needs work. For example, the NW Fisheries were engaged as stakeholders, but not the SW Fisheries. The pool of stakeholders was very narrow, and many were not really users, but partners in research.

Lack of Funding Flexibility

Relative to AOML-wide fixed costs, it appears that the lab as a whole (and therefore OCED specifically) has relatively little flexibility to respond to unanticipated events unless there is additional external funding provided. This positioning means that the OCED research program is not performing as well as it could be if the budget structure were adjusted to provide greater flexibility.

Facilities and Infrastructure

There have been recent investments in infrastructure (e.g. for the 'Omics effort), which will help support the research; however, the aging facility presents challenges for all Divisions. AOML's physical infrastructure is no longer sufficient to support cutting-edge science and to attract a world-class scientific workforce. The dedicated lab space within AOML is under-sized for modern needs, the IT backbone is insufficient to support modern computing, and the current condition of the facility cannot be said to *exceed expectations*.

Efficiency and Effectiveness

OCED is relatively efficient in the administration of individual projects. However, the division (and likely AOML as a whole) is not managed to *optimize the planning…of research* (from the charge to reviewers). There was no discussion of an overall OCED planning process that spans their five main research themes.

Transition of Research to Applications

Transition of Research to Applications is another area deserving further attention by OCED leadership. While OCED has placed increased emphasis on research transitions since the 2014 Lab Review, many OCED major research themes pre-date the emphasis on transitions and some of the on-going research was not designed to be transitioned to a receiving organization. The panel felt that there is no clear plan for transitioning research to applications, though it is a recognized issue by the Division.

SUMMARY OF RECOMMENDATIONS

AOML-wide Recommendations

For AOML, the balance of basic research and R2O applications, budget constraint, talent retention/recruitment, high performance computing, and aging facilities remain major challenges. These are the same issues raised during the 2014 Lab Review. Not much has changed since then.

AOML-1 Recommendations for an AOML Strategic Plan

Moving forward, the panel recommends the development of a 5-year strategic plan by the AOML leadership, with inputs from rank-and-file, to prioritize research directions, and tackle the challenges from a Lab-wide perspective. We recommend that AOML develop a formal science prioritization process that holistically examines its entire research portfolio. Ideally, this prioritization process would include components that

a) Set the medium-term (2-7 years) direction for the entire lab, which would facilitate decisions on staffing and identification of multi-year, project-based funding that can be pursued by staff and

b) Allow for near-term (0-2 years) allocation of flexible resources to ensure that high priority emerging research needs can be addressed in a timely manner.

To enhance cross-division collaboration and definition of a unifying AOML identity, the 5-year plan should include, as a top priority, the formation of a Laboratory level task force to identify cross-division collaborative projects, set priorities for science goals, deliverables, with designated budget, and annual progress report, aimed at growing, and maturing these projects along R2O pathways. In a participatory process that includes heavy staff involvement, this task force should establish the core, unique, and defining attributes of AOML (not the individual divisions) and arrive at a clearly-defined AOML-wide statement of identity. From this commonly-held identity can then come clarity on the science direction of the organization. Some questions for consideration include:

a) What fraction of AOML science should be on the basic vs. applied side of the basic-to-applied science continuum?

b) How much should be anticipatory research versus science responding to specific users that work with AOML to co-produce the science?

c) Much of AOML science appears to be science to serve other scientists' needs. How much of the lab's science should be data provision for other scientists and how much should be more tightly associated with management/user requirements?

As part of the science prioritization process, the panel recommends that AOML considers extending the geographic breadth of its science, with a particular emphasis on reviewing past and planned future investment in research targeted along the U.S. Atlantic coastline north of the Florida reef tract. There are likely a large number of unmet needs for scientific information that AOML capabilities could address, and those needs are held by NOAA-associated entities (National Marine Sanctuaries, National Estuarine Research Reserves, state coastal zone management programs, etc.) In addition, there could be ancillary benefits to AOML by conducting research in additional states' waters.

As part of this strategic planning process, the panel recommends that AOML explicitly defines a core group of customers for which it will produce science. Such an articulation need not be strictly exclusionary, but should prioritize those that will have greater AOML resources dedicated to and those that are secondary. Some questions for consideration include:

a) Who has standing to have AOML conduct research for them?
b) Who are your primary consumers of science and do they know they have a greater priority than secondary and tertiary consumers?
c) How are their needs factored into the research that is conducted by AOML (links to Recommendation 1 on the development of a formal science prioritization process for all of AOML)?
d) How will this customer identification and declaration process lead to management actions such as influencing staff skills sought in recruitments, equipment procurement, and data dissemination/tool development paradigms?

AOML-2 Development of Remote Sensing Expertise

There is a need to have a remote sensing hire (physical and/or biological remote sensing oceanographer) to help PhOD and OCED incorporating satellite data into current and future research. More integration of satellite data into the AOML research was recommended in the previous lab review

(2014), and the panel felt that there is still room for improvement in this area. The panel recommends a significant expansion of satellite remote sensing data and resident expertise in support of emerging biological and ecological NOAA drivers.

AOML-3 Development of Lab-wide Data Assimilation

For maximum impact and cost effectiveness, AOML should concentrate its effort on the development of a lab-wide integrated modeling and data-assimilation system, incorporating various existing observational platforms and models in meteorological, oceanographic and biogeochemistry, retaining its focus on tropical cyclones and the Atlantic, Florida and Gulf regions. A new hire with solid scientific software development skills is recommended, who will help formulate such a plan and organize/focus existing expertise at AOML.

Given the multiple emerging modeling and data assimilation technologies at NOAA (UFS, JEDI, NUOPC, to name a few) it is critical that AOML develop its own modeling and data assimilation strategic plan (see above), fully aligned to NOAA's and integrated across its three divisions. For effectively setting requirements, and to provide early feedback on the adequacy of these systems, AOML must have a "*seat at the table*" at NOAA-wide developments such as UFS and JEDI, providing the "Atlantic" and "tropical cyclone" perspective that the Lab has to offer.

AOML-4 Addressing Computing Needs

Greater access to high-performance computing is needed to advance AOML's numerical modeling efforts. In addition to pursuing larger allocations on NOAA and other federal supercomputers, AOML should consider stronger partnerships with universities having local computing systems, a device that could help provide opportunities for foreign nationals that are having difficulty gaining access to federal computing systems.

Likewise, AOML should develop its own strategic plan for cloud computing. In particular, AOML should explore the feasibility of using a commercial cloud service such as Amazon Web Services (AWS) to ingest, archive, process, distribute, and manage its data portfolio.

AOML-5 Exploring Coastal Focused Research

Explore/pursue more coastal-focused research, including regional/nearshore dynamics (*e.g.,* coupling across the land-sea interface); sub-mesoscale/ small-scale processes and phenomena (run-off plumes, fate and transport of

pollutants and pathogens, eddies/fronts and larval recruitment etc.), more end-to-end coastal water integration (hurricanes, storm surge, inundation, water quality), and the potential for a WCOFS (NOAA's West Coast Ocean Forecasting System) type analog for the Gulf of Mexico and likewise off the East Coast; all with robust physical, biogeochemical (BGC), and ecosystem linkages between PhOD and OCED, as well as HRD and WPC for the water activities. (NB: would be clear and distinct separation from GFDL efforts with this particular focus)

AOML-6 Striving for Funding Flexibility

A flat base fund for many years has clearly limited certain components of AOML research that are in tandem with emerging new science and technologies. Additional funds are needed to upgrade the aging infra-structure, and sustain the growth of AOML.

The panel felt that there is significant risk to AOML given its current funding profile, specifically: 1) the relatively high proportion of total funding that is from project-level, proposal-based sources and 2) the very high proportion of AOML's base budget this is consumed by fixed costs. While these challenges are largely the result of OAR budget allocation process, the panel recommends that AOML work to increase the percentage of its total funding available for flexible purposes, which will enable it to take advantage of ephemeral data collection opportunities or unexpected high-priority short-turnaround (<1 year) research requests.

Similar to several other NOAA organizations, AOML does not have a dedicated source of recurring funding for facility refurbishment. Outside of supplemental appropriations, most recently linked to damage caused by particular hurricanes, more funding for necessary facility maintenance must come from the same limited base funding that is mostly consumed by fixed costs. The panel recommends that AOML engage OAR headquarters and other NOAA entities with similar laboratories in a concert process to address the lack of dedicated, routine funding for facility refurbishment.

AOML-7 Inventory of Intellectual Property and Training

The panel recommends that AOML have a thorough, one-time, in-person meeting with staff from NOAA's Technology Partnerships Office (TPO) to obtain advice on which recent innovations should be more fully evaluated for potential patent applications. Furthermore, AOML could benefit from specific training by TPO staff on intellectual property, the challenges of the

blended workforce (federal and grantee-based at CIMAS), and patents. We recommend this training be given periodically, perhaps every three years.

Hurricane Research Division Recommendations

HRD-1 Oceanographic Data Collection, Archival and Dissemination

Since its inception, HRD has been the *de facto* care-taker for research-quality TC observations for the nation. As the observing systems become increasingly complex, the resource requirements (manpower and facility) have grown significantly. This has put a severe constraint on the budget of HRD, with no new resource to deal with increasing demands from new emerging areas of science and technology. A case in point is the insufficient number of dropsondes that have been made available to the Hurricane Field Program for research purposes. Some research modules have been planned for nearly 10 years, but haven't been executed due to lack of dropsondes. A significant increase in base funds for HRD is paramount in order to continue the data collection and improvement, and conduct high-quality research.

HRD-2 Modeling and Data Assimilation

HRD should continue development and improvement of the movable multi-domain models (HWRF and its evolution within NOAA's modeling suite) for TC simulations and prediction, to include coupled ocean-atmosphere models and data assimilation systems for TCs, in coordination of NOAA/NWS/EMC.

HRD should focus on maturing its data assimilation and OSE/OSSE capabilities for more efficiently and effectively impact R2O deliverables for NOAA operations and product suites. However, HRD should focus its OSE/OSSSE efforts on observing systems of more direct relevance to tropical cyclones; parallel efforts, although of relevance to global operational systems, as well as science investigations which do not align well with AOML priorities, should be discouraged.

Explore use of synthetic aperture radar (SAR) data for better understanding, monitoring and forecasting of hurricanes, e.g., high-resolution winds, hurricane high morphology, etc.

HRD-3 Interaction with Stakeholders

From our interaction with stakeholders it became apparent that two-way interactions seem to be somewhat lacking in some cases. It will be very helpful to implement a more formal process (with regularity) by which HRD provides a summary of its recent work, and implications for stakeholders,

gathers feedback and then uses it to revise/update the HRD R2O plans. More specifically, new approaches to enhance collaboration between HRD and NHC should be pursued. Perhaps an annual workshop between HRD and NHC could be considered, in which recent results are presented, and plans for further work are discussed. Another possibility is a *jointly developed Strategic Plan* to more closely align HRD research with NHC's needs.

HRD-4 Participation in Journal Editorship

Scientific staff should be encouraged to participate more in editorship of journals. AOML's contributions to AMS editorial boards, in particular, seems low compared to other OAR labs (*e.g.*, NSSL, ESRL).

Physical Oceanography Division Recommendations

PhOD-1 Tropical Cyclone Data Collection, Archival and Dissemination

It is important to sustain current sea-going operations (e.g. gliders) so that the data streams are utilized in prediction models and by the scientific community at large. In particular, strengthen PhOD and NWS/EMC collaboration to establish an observing system of autonomous vehicles (gliders) for hurricane forecasts. AOML leadership should ensure there are adequate resources in place for this activity.

There is no question that BGC is a growth area in the very near future. AOML is perfectly positioned to be a leader in BGC observations and data management. One of the looming challenges is to organize NOAA's response to the sort of data BGC sensors produce. A related problem involves the quality control of literally thousands of new sensors. AOML should be a leader of NOAA's effort in these areas.

Continue in house support of the Data Assembly Center activities, such as US Argo, drifters, XBTs as these require active scientific oversight. In this case, as noted above, a moderate assurance operational model would suffice instead of the conventional NOAA operational model/approach for NRT data (*e.g.*, NDBC buoys).

PhOD-2 Modeling and Data Assimilation

Expand satellite oceanography and modeling/data assimilation efforts. In particular, AOML is establishing itself as the leader in ocean observations below hurricanes. We recommend effort and investments in research to quantify forecast improvements directly caused by ocean observations. This

research may have a wide ranging impact, as the value of regional ocean observations to weather forecasts is a hot topic.

The panel also supports the expansion of PhOD's modeling domain, in particular beyond the GoMex domain. Research in storm surge modeling is desired, in particular expanding partnership within AOML (HRD/OCED) and outside AOML

The panel strongly recommends strategic investments and new federal hire(s) in these areas.

PhOD-3 Cross-cutting Inundation Research

Coastal inundation is caused by processes with a wide range of time scales. AOML is a leader in the study of some of these processes, including notably hurricanes and climate. AOML should consider investment in cross-cutting inundation research. Such research is especially relevant considering the possible effects of inundation on Florida.

PhOD-4 Cooperation with Regional and Other Entities

AOML is doing a wide range of research relevant to southeast US. As research is brought closer to the coast, a number of stakeholders are involved including IOOS, and state and local agencies. Considering AOML's leadership in the research, there should be a concurrent effort to lead regionally. For example, this would make AOML work on hurricanes and coral reefs even more prominent in regional settings.

The CoastWatch/OceanWatch (CW/OW) Nodes at AOML are extremely productive and valuable, and particularly important for their transitions from research to users, applications and services. As such consider how to further leverage and expand upon these highly successful enterprise activities.

Continue support of technological capabilities required to perform increased interdisciplinary work, in cooperation with other NOAA line offices , *e.g.* coastal activities.

Ocean Chemistry and Ecosystems Division Recommendations

OCED-1 Need for a Strategic Plan

Work within OCED seemed largely disconnected and *at hoc*, responding to funding opportunities. The Division is encouraged to elaborate a more

cohesive plan that clearly delineates OCED's scientific priorities. Such a divisional strategic plan would help OCED respond to the most relevant funding opportunities and bring cohesion to the several research activities in the division.

OCED-2 Expansion of Research Areas

Water quality research should be considered.

Incorporating social sciences for the future is a desired facet of the research; there is a natural connection between ecosystems, disturbances (e.g. Hurricanes) and humans living in the region. Those connections and relevant research should be explored. The Division has social sciences work, but as the Lab as a whole develops their social science integration strategy, this will enable each Division to carry out these activities in a more cohesive and stronger fashion. This will also provide new opportunities for funding.

More integration of the ecosystem assessment to fisheries is desired.

OCED-3 Collaboration with Other Divisions and Stakeholder Engagement

While there is some collaboration with other AOML divisions (e.g. hurricane impacts on coral reefs), the panel felt that there is still room for tighter collaboration between OCED and the other divisions. In particular, the panel recommends increased collaborations with PhOD on coastal research activities as well as better link and coordination of the Omics work with the broader AOML physical/biogeochemical ocean activities.

Stakeholder engagement is another area that deserves attention. While it is recognized that the existing PI-to-PI engagement is positive, a more comprehensive engagement at the division level is necessary for the long term sustainability of these relationships.

OCED-4 Funding Structure

The proportion of base to external funding is not appropriate. The base allocation should be increased, in both absolute dollars and as a fraction of OCED's overall budget. This will enable greater flexibility to respond to unexpected events and hiring more federal staff to provide greater federal employee depth across the five major research themes (and provide for succession planning-in-place by having federal "bench strength").

List of Acronyms

AOC	Aircraft Operations Center
AOML	Atlantic Oceanographic and Meteorological Laboratory
AWS	Amazon Web Services
BGC	Biogeochemical
BMU	Bioerosion Monitoring Unit
CIMAS	Cooperative Institute for Marine and Atmospheric Studies
CW	Coast Watch
DAC	Data Assembly Center
EMC	Environmental Modeling Center
JEDI	Joint Effort for Data Assimilation Integration
HAFS	Hurricane Analysis and Forecast System
HFP	Hurricane Field Program
HRD	Hurricane Research Division
HWRF	Hurricane Weather Research and Forecast model
NDBC	National Data Buoy Center
NHC	National Hurricane Center
NRT	Near real time
NUOPC	The National Unified Operational Prediction Capability
NWS	National weather service
OAR	Oceanic and Atmospheric Research
OCED	Ocean Chemistry and Ecosystems Division
OSSE	Observing System Simulation Experiment
OW	Ocean Watch
PhOD	Physical Oceanography Division
PIRATA	Prediction and Research Moored Array in the Tropical Atlantic
R2O	Research to operations
RL	Readiness level
SAR	Synthetic Aperture Radar
TC	Tropical cyclone
TPO	Technology Partnership Office
UFS	Unified Forecasting System
XBT	Expendable Bathythermograph
WCOFS	West Coast Ocean Forecasting System