

# **Atlantic Oceanographic and Meteorological Laboratory**

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## *Mission Statement and Vision:*

The Atlantic Oceanographic and Meteorological Laboratory (AOML) conducts basic and applied research related to oceans and climate, coastal ecosystems, and tropical meteorology. The laboratory seeks to understand the physical, chemical, and biological characteristics and processes of the ocean and the atmosphere, both separately and as a coupled system. The principal focus of these investigations is to provide knowledge that will ultimately lead to improved prediction and forecasting of high-impact weather events, including hurricanes, better use and management of marine resources, better understanding of the factors controlling climate and affecting environmental quality, and improved ocean and weather services for the nation.

## *Core Competencies:*

- ✓ Developing innovative scientific and technical approaches that leverage AOML's unique observational expertise to evaluate model and forecast fidelity across and in collaboration with atmospheric, oceanic and chemical disciplines
- ✓ Developing, implementing and evaluating in situ hurricane observation techniques using hurricane hunter aircraft, including airborne instrumentation development and application
- ✓ Designing and implementing highly accurate and reliable "reference" ocean observing systems to monitor global ocean phenomena, which are often used to evaluate and/or calibrate other observing system
- ✓ Monitoring and describing the ocean's role in our global carbon cycle, including how ocean physics and chemistry affect the uptake and release of carbon between the ocean and atmosphere. This includes understanding ocean acidification and its likely threat to ocean ecosystems
- ✓ Evaluate chemical and physical changes at coral reef sites to understand how coral reef ecosystems are changing, how they are likely to respond to emerging threats such as ocean acidification, and forecast their future conditions
- ✓ Application of 'omics data and techniques to inform fisheries, coral reef, and coastal ecosystem management
- ✓ Develop innovative technical approaches to the design and application of physical, chemical, and biological oceanographic technology and systems
- ✓ Conducting Global and regional Observing System Simulation Experiments and Observing System Experiments for the atmosphere and oceans
- ✓ Developing next-generation models for hurricane forecasting using data assimilation techniques to incorporate observations

## *Statute Authority and Charge Under NOAA's Strategic Plan:*

AOML research is mandated by 28 federal statutory authorities (listed below), including recent legislative and executive mandates include:

- The Weather Research and Forecasting Innovation Act of 2017. In particular, "to develop improved understanding of and forecast capabilities for atmospheric events and their impacts", with particular emphasis on improving rapid intensification and tracks of hurricanes, undertaking Observing System Simulation Experiments to 'evaluate observing systems, data, and information needed to meet' requirements.
- National Climate Program Act of 1978, 15 U.S.C. § 2901-2908, at 2904(d) (4), et seq.: Requires that one program element will be the provision of "useful and readily available information on a continuing basis." It authorizes global data collection, monitoring, and analysis activities to provide reliable, useful and readily available information on a continuing basis.
- The Coral Reef Conservation Act of 2000 – This Act is the primary driver for the CRCP activities by directing NOAA to develop and implement a national strategy and program for coral reef conservation and management that includes coastal uses and management.

In addition AOML research specifically targets the following NOAA Goals:

- Weather and Water –
  - Increase lead-time and accuracy for weather and water warnings and forecasts
  - Increase development, application, and transition of advanced science and technology to operations and services
  - Reduce uncertainty associated with weather and water forecasts and assessments
  - Enhance environmental literacy and improve understanding, value, and use of weather and water information and services
- Ecosystems –
  - Provide tools, technologies, and information services that are effectively used by NOAA partners and stakeholders to improve ecosystem based management
  - Advance understanding and characterization of coastal, marine, and Great Lakes ecosystem health and associated socioeconomic benefits, and develop forecasting capabilities to meet management needs
- Climate –
  - Describe and understand the state of the climate system through integrated observations, monitoring, and data management

- Understand and predict climate variability and change from weeks to decades to a century
- Improve the ability of society to plan for and respond to climate variability and change

#### *Science Themes and Research Areas:*

- Hurricanes
  - Improve the basic physical understanding and prediction of tropical cyclone track, intensity, and structure change and their impacts (rainfall, storm surge, flooding, damaging waves and winds) by using observations and numerical models.
  - Evaluate how new and existing observations improve hurricane forecasting by conducting Observing System Experiments (OSEs) and Observing System Simulation Experiments (OSSEs).
  - Advance hurricane forecasting by creating next generation numerical models, improved use of observations and advancing data assimilation techniques in forecast models.
- Ocean Chemistry and Ecosystems
  - Characterize, understand and predict the impact of remote and local forcing pressures, including climate change, ocean acidification, and land-based sources of pollution, and their synergistic interactions, on coastal and coral reef ecosystems of south Florida, the Gulf of Mexico and the Caribbean Sea.
  - Integrate data, models, and information to develop reliable ecological assessments and forecasts, and incorporate these into resource management decision support.
  - Quantify the role of the oceans in sequestering carbon dioxide using buoys, research ships and vessels of opportunity, and the role of coastal oceans in the global carbon cycle and the impacts of ocean acidification on marine resources.
- Physical Oceanography and its Impact on Weather, Climate and Ecosystems
  - Observe variations in the ocean circulation and property transport from fine-scale mixing to long-term climate change and improve our understanding of the physical processes and mechanisms that control these variations.
  - Characterize, understand and predict the influence of the ocean on regional and global climate, severe weather, and fisheries to improve forecasts and resource management.
  - Evaluate how new and existing observations improve fundamental understanding of ocean circulation to improve ocean modeling by conducting Observing System Experiments (OSEs) and Observing System Simulation Experiments (OSSEs).

#### *Products and Results:*

AOML produces a wide range of products that are used in NOAA operations and by external groups. These products include quantitative evaluations of new and existing observing systems; advancements in current hurricane forecasts and the next generation of weather forecasting; quality assured data sets from flying into hurricanes, field experiments sea using ships and autonomous instrument data collection such as drifters, buoys and unmanned systems; assessments of the state of the ocean physical and chemical properties; new instrumentation; peer-reviewed scientific findings; specialized forecasts; observing system requirements, recommendations, and protocols; and associated training and outreach materials. Notable examples include:

- Developed and continuously improve the Hurricane Weather Research Forecast Model in partnership with the National Weather Service to develop more accurate, timely, and effective warnings and forecasts of high impact weather events that endanger life and property
- Deliver to Congress and stakeholders quantitative assessments of the impact of new and existing observing systems as required by the Weather Research and Forecasting Innovation Act
- Coordinate and conduct yearly Intensity Forecast Experiment in partnership with National Weather Service, National Environmental Satellite Data and Information Service, and Office of Marine and Aviation Operations, to collect high quality observations in support of operations and the Hurricane Forecast Improvement Project to improve hurricane track and intensity forecasts, particularly instances of rapid intensity change
- Developed an ocean acidification product suite to visualize and monitor ocean acidification in the Caribbean Sea and Gulf of Mexico
- Designed, deploy and maintain the Global Ocean Observing System which provides highly accurate and reliable observations for evaluating U.S. climate variability and change
- Provide significant contribution to national and international assessments of climate which inform critical environmental management decisions
- Developed and published a Gulf of Mexico Ecosystem Status Report and Web-based indicators to inform managers of ecosystem health and productivity, related to sustainability, restoration, and the blue economy

- Developed a method to estimate air-sea CO<sub>2</sub> fluxes on seasonal time scales using ship of opportunity and satellite remote sensing data to provide estimates of the amount of carbon transferred across the ocean/atmospheric boundary.
- Applied observations from Autonomous Vehicles to improve understanding and forecasts for hurricane and ocean environments
- Developed molecular analysis of coastal pathogens including source tracking for use by managers addressing human health in the coastal environment
- Developed ecological forecasting and monitoring for Marine Protected Area managers and researchers to understand and predict coral reef ecosystem response to climate change, such as coral bleaching, ocean acidification, harmful algal blooms, ocean current shifts, spawning, migration, and other marine phenomena

#### *Customers:*

AOML key customers include NOAA's National Weather Service, National Center for Environmental Protection, Environmental Modeling Center, and National Hurricane Center; NOAA Fisheries, Southeast Fisheries Science Center, Southwest Fisheries Science Center, Pacific Islands Fisheries Science Center; National Ocean Service, Center for Operational Ocean Products and Services, Florida Keys National Marine Sanctuary, Flower Garden Banks National Marine Sanctuary; NOAA's National Environmental Satellite Data and Information Service, U.S. Army Corps of Engineers, National Park Service, Bureau of Ocean Energy and Management, Florida Fish and Wildlife, The Nature Conservancy, FI Sea Grant, emergency managers, city planners, policy makers, industry, and universities.

#### *Future Expectations:*

AOML expects to continue advancements in the areas identified above and to direct greater attention toward the following:

- Under the NOAA Quantitative Observing System Assessment Program, AOML will conduct Observing System Simulation Experiments to design and optimize the global ocean observing system
- Continue to develop quantitative assessments to evaluate data assimilation techniques for the next-generation Hurricane Analysis and Forecast System focusing on improving the use of reconnaissance aircraft data
- Enhanced 'omics measurements, ocean acidification chemistry, and ocean optics observations will be added to the existing observational and research programs in the Gulf of Mexico, Florida Keys, Puerto Rico, and the U.S. Virgin Islands
- Development of predictive capabilities of the ocean's influence on extreme weather, such as tornadoes and heat waves, and as fisheries stock assessments.

#### Charge Under Statutory Authority (full list):

1. Weather Research and Forecasting Innovation Act of 2017, Public Law 115–25: —The Assistant Administrator for the Office of Oceanic and Atmospheric Research shall conduct a program to develop improved understanding of and forecast capabilities for atmospheric events and their impacts, placing priority on developing more accurate, timely, and effective warnings and forecasts of high impact weather events that endanger life and property. Sec. 107 (2) : OAR shall undertake Observing System Simulation Experiments to quantitatively assess the relative value and benefits of observing capabilities and systems, and (c) (1) Shall conduct OSSEs prior to the acquisition of major Government-owned or Government-leased operational observing systems, including polar-orbiting and geostationary satellite systems, with a lifecycle cost of more than \$500,000,000; or (2) new commercially provided data with a lifecycle cost of more than \$500,000,000.
2. National Weather Service Organic Act of 1890 (as amended), 15 U.S.C. § 313 et seq.: Ensures there are atmospheric, oceanic, and terrestrial measurements suitable for establishing and recording U.S. climate conditions.
3. National Climate Program Act of 1978, 15 U.S.C. § 2901-2908, at 2904(d) (4), et seq.: Requires that one program element will be the provision of "useful and readily available information on a continuing basis." It authorizes global data collection, monitoring, and analysis activities to provide reliable, useful and readily available information on a continuing basis. In addition, the act authorizes measures for increasing international cooperation in climate research, monitoring, analysis, and data dissemination.
4. Coastal Zone Management Act (CZMA) of 1972 (as amended 1990), 16 U.S.C. § 1450 et seq.: Requires understanding and predicting long-term climate change, which may have large impacts in the coastal zone such as global warming and associated sea level rise.
5. Global Change Research Act of 1990, 15 U.S.C. § 2921 et seq.: This act provides for the development and coordination of a comprehensive and integrated United States research program which will assist the Nation and the world to understand, assess, predict, and respond to human-induced and natural processes of global change. Ensures the establishment of global measurements and worldwide observations, and requires an early and continuing

commitment to the establishment and maintenance of worldwide observations and related data and information systems.

6. Clean Air Act 1990, 42 U.S.C. § 7401 et seq.: Amendment to the Clean Air Act mandates that “the Administrators of the National Aeronautics and Space Administration and the National Oceanic and Atmospheric Administration shall monitor, and not less often than every 3 years following November 15, 1990, submit a report to Congress on the current average tropospheric concentration of chlorine and bromine and on the level of stratospheric ozone depletion.”
7. Global Climate Protection Act of 1990, 7 U.S.C. § 6701 et seq.: Requires research in climate change needed to protect the environment.
8. Oceans Act of 2000, Pub. Law No. 106-256: Led to the Congressionally-mandated report of the U.S. Commission on Ocean Policy and the Executive response, the U. S. Ocean Action Plan of 2005: Requires federal agencies to participate in building a Global Earth Observation Network that includes integrated oceans observations. The U.S. is implementing this through the Integrated Ocean Observation System (IOOS), the Integrated Earth Observation System (IEOS), and participation in GEOSS.
9. Consolidated Appropriations Act of 2005, Pub. Law No. 108-447: “Establish[es] a Federal research program that examines ocean resources and their applications to human health.” The Act aims to “...ensure that any integrated ocean and Coastal observing system provides information necessary to monitor, predict and reduce marine public health problems including: (A) baseline observations of physical ocean properties to monitor climate variation; (B) measurement of oceanic and atmospheric variables to improve prediction of severe weather events; ...”
10. Integrated Coastal and Ocean Observation System Act of 2009, Pub. Law No. 111-11 (as passed in the Omnibus Public Land Management Act of 2009): Establishes NOAA as the lead Federal agency for the implementation of a national integrated system of ocean, coastal, and Great Lakes observing systems “to support...weather, climate and marine forecasting...improve the Nation’s capability to measure, track, explain, and predict events related directly and indirectly to weather and climate change, natural climate variability, and interactions between the oceanic and atmospheric environments, including the Great Lakes; and authorize activities to promote basic and applied research to develop, test and deploy innovations and improvements in coastal and ocean observation technologies, modeling systems, and other scientific and technological capabilities to improve our conceptual understanding of weather and climate, ocean-atmosphere dynamics, [and] global climate change.”
11. Federal Ocean Acidification Research and Monitoring Act of 2009, Pub. Law No. 111-11 (as passed in the Omnibus Public Land Management Act of 2009): Establishes an ocean acidification program within NOAA to conduct research, monitor ocean chemistry and biological impacts of ocean acidification, and coordinate with appropriate international ocean science bodies.
12. Secure Water Act of 2009, Pub. Law No. 111-11 (as passed in the Omnibus Public Land Management Act of 2009): NOAA shall provide the Secretary of the Interior with “access to the best available scientific information with respect to presently observed and projected future impacts of global climate change on water resources.”
13. Ocean and Coastal Mapping Integration Act, Pub. Law No. 111-11 (as passed in the Omnibus Public Land Management Act of 2009): Requires NOAA to: (1) “establish a program to develop a coordinated and comprehensive Federal ocean and coastal mapping plan for the Great Lakes and coastal state waters, the territorial sea, the exclusive economic zone, and the continental shelf of the United Seas...to facilitate, to the extent practicable, the collection of real-time tide data,” and (2) “advance the use of remote sensing technologies for ... ocean observations.”
14. Omnibus Public Land Management Act of 2009: NOAA and DOI are directed to establish and lead an inter-agency panel to review current scientific understanding of climate change on the quantity and quality of U.S. water resources and develop strategies to improve observational capabilities, expand data acquisition, increase the reliability and accuracy of modeling and prediction systems to benefit water managers, and increase the understanding of the impacts of climate change on aquatic ecosystems. NOAA will establish an ocean acidification program and in collaboration with NSF and NASA will develop and coordinate an interagency plan that will assess impacts from ocean acidification. NOAA is authorized to perform research on marine ecosystem adaptation to ocean acidification, including coordinated interdisciplinary and international research, long-term monitoring, and research to develop adaptation strategies for marine ecosystems.
15. Federal Water Pollution Control Act (Clean Water Act), 33 U.S.C. § 1251 et seq. - The principle statute governing water quality with the goal is to restore and maintain the chemical, physical, and biological integrity of the Nation’s waters. The CWA regulates both the direct and indirect discharge of pollutants into the Nation’s waters and prohibits the discharge into navigable waters of any pollutant by any person from a point source unless it is in compliance with a National Pollution Discharge Elimination System (NPDES) permit.

16. National Response Framework, Department of Homeland Security (March 22, 2008), <http://www.dhs.gov/xlibrary/assets/NRPbaseplan.pdf> - Uses the foundation provided by the Homeland Security Act, HSPD-5 and the Stafford Act to provide an all hazard approach to incident management. It tasks the Department of Commerce and NOAA with acquiring and disseminating weather data, forecasts, and emergency information.
17. The U.S. Ocean Action Plan, December 17, 2004, calls for a national monitoring network to observe, analyze, and forecast natural and human-induced changes that affect watershed, estuarine, and coastal ecosystems.
18. U.S. Weather Research Program (USWRP) Authorization Act: The U.S. Weather Research Program (USWRP) is mandated to accelerate forecast improvements of high impact weather and facilitate full use of advanced weather information.
19. U.S.C. § 883d, Improvement of methods, instruments, and equipments; investigations and research. To improve the efficiency of the National Ocean Survey and to increase engineering and scientific knowledge, the Secretary of Commerce is authorized to conduct developmental work for the improvement of surveying and cartographic methods, instruments, and equipments; and to conduct investigations and research in geophysical sciences (including geodesy, oceanography, seismology, and geomagnetism).
20. 33 U.S.C. § 883(d), Improvement of methods, instruments, and equipments; investigations and research: To improve the efficiency of the National Ocean Survey and to increase engineering and scientific knowledge, the Secretary of Commerce is authorized to conduct developmental work for the improvement of surveying and cartographic methods, instruments, and equipments; and to conduct investigations and research in geophysical sciences (including geodesy, oceanography, seismology, and geomagnetism).
21. The Coral Reef Conservation Act of 2000 – This Act is the primary driver for the CRCP activities by directing NOAA to develop and implement a national strategy and program for coral reef conservation and management that includes coastal uses and management; water and air quality; mapping and information management; research, monitoring, and assessment; international and regional issues; outreach and education; local strategies developed by the States and Federal agencies, including regional fishery management councils; and conservation, including how the use of marine protected areas to serve as replenishment zones will be developed consistent with local practices and traditions
22. Coastal Zone Management Act – Provides direction for NOAA and the CRCP to work with state/territory and local entities to collaboratively develop coral reef management actions.
23. National Marine Sanctuary Act - mandates that NOAA shall support, promote, and coordinate scientific research on, and long-term monitoring of, the resources of marine sanctuaries, and evaluate the implementation of each sanctuary's management plan and goals. It also mandates NOAA to "prevent or eliminate damage to the environment and biosphere and stimulate the health and welfare of man."
24. Harmful Algal Bloom and Hypoxia Research Control Act: NOAA shall develop research plans and assessments and examine alternatives to reduce, mitigate, and control hypoxia and HABs in coastal waters including the Great Lakes.
25. National Sea Grant College Program Act (as amended by the Reauthorization Act of 2008): The Act directs the Secretary of Commerce to "...provide support for . . . national strategic investments in fields relating to ocean, coastal, and Great Lakes resources..."
26. Oceans and Human Health Act - the Secretary of Commerce established an Oceans and Human Health Initiative to coordinate and implement research and activities of NOAA related to the role of the oceans in human health.
27. America Competes Act [P.L. 110-69] Title IV of this Act directs NOAA to coordinate with NSF and NASA to establish a coordinated program of ocean, coastal, Great Lakes, and atmospheric research and development (in collaboration with academic institutions and other nongovernmental entities) that focuses on the development of advanced technologies and analytical methods that will promote United States leadership in ocean and atmospheric science and competitiveness.
28. Magnuson Stevens Fishery Conservation and Management Reauthorization Act (1976, 1996, 2006): Provides for research to support fishery conservation and management, including but not limited to, biological research concerning the abundance and life history parameters of stocks of fish, the interdependence of fisheries or stocks of fish, the identification of essential fish habitat, the impact of pollution on fish populations, the impact of wetland and estuarine degradation, and other factors affecting the abundance and availability of fish.
29. National Coastal Monitoring Act (Title V of the Marine Protection, Research, and Sanctuaries Act: Requires the Administrator of the Environmental Protection Agency and the NOAA Under Secretary, in conjunction with other Federal, state and local authorities, jointly to develop and implement a program for the long-term collection, assimilation, and analysis of scientific data designed to measure the environmental quality of the nation's coastal ecosystems.