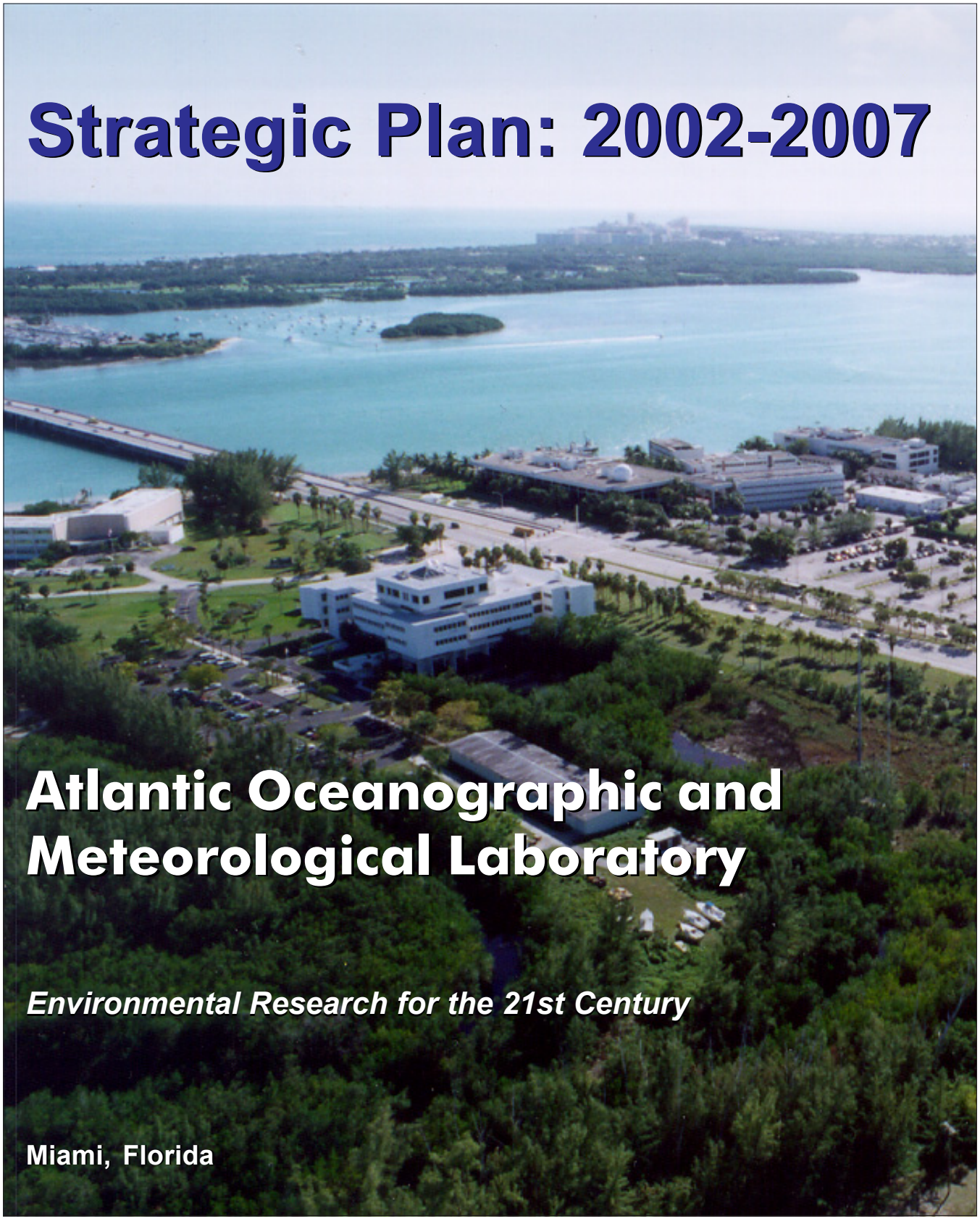
United States Department of Commerce
National Oceanic and Atmospheric Administration

Strategic Plan: 2002-2007

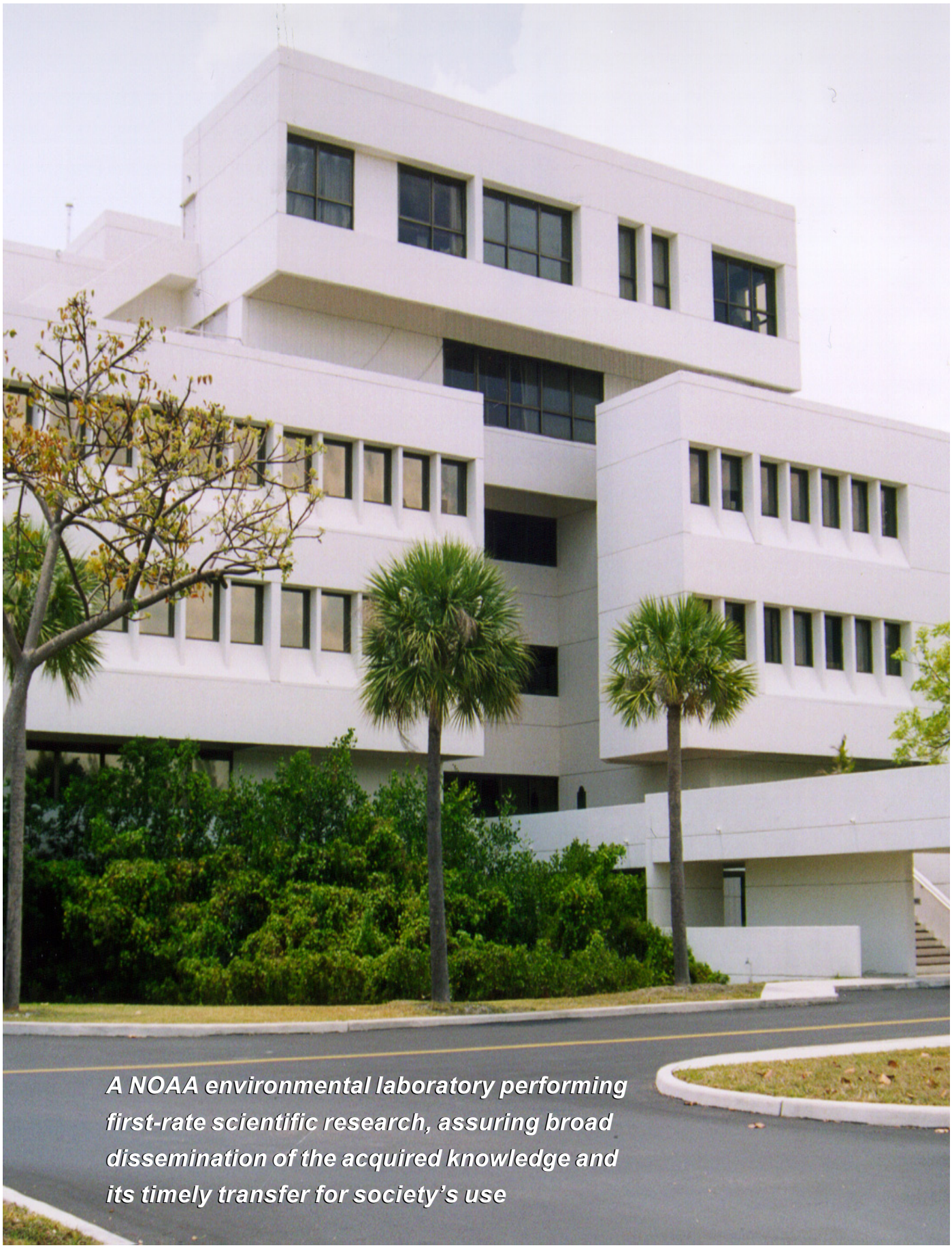


Atlantic Oceanographic and Meteorological Laboratory

Environmental Research for the 21st Century

Miami, Florida

Cover photograph: *Aerial view of the Virginia Key science community. On the left is the National Marine Fisheries Service/Southeast Fisheries Science Center, in the center is the Atlantic Oceanographic and Meteorological Laboratory, and to the right is the University of Miami's Rosenstiel School of Marine and Atmospheric Science/Cooperative Institute for Marine and Atmospheric Studies.*



A NOAA environmental laboratory performing first-rate scientific research, assuring broad dissemination of the acquired knowledge and its timely transfer for society's use

A Message from the Director

Research conducted by the Atlantic Oceanographic and Meteorological Laboratory (AOML) embraces three major scientific themes: oceans and climate, coastal and regional environments, and hurricanes and tropical meteorology. The Laboratory's research is recognized as first rate and significant for the evolution of these theme areas on both national and international scales. The close proximity of scientists with expertise in these three theme areas is an advantage for the Laboratory that naturally leads to interdisciplinary research with rewarding outcomes. One example is the analysis of the relationship between ocean surface temperature variability and frequency and intensity of hurricanes over many decades; other examples include the relationship between physical properties in the ocean with carbon fluxes and coastal chemistry and biology. The specific research areas addressed by AOML are the consequences of a three-decade evolution that began with the establishment of AOML between 1967 and 1973.

AOML's research benefits greatly from partnership with the University of Miami's Rosenstiel School of Marine and Atmospheric Science, the Cooperative Institute for Marine and Atmospheric Studies, and NOAA's Southeast Fisheries Science Center, all of which are in close proximity to AOML on Virginia Key. The Laboratory also has a wide net of collaborators in several of the other NOAA research laboratories and with numerous universities and other federal, state, and local agencies.

AOML has a distinguished history of research in ocean circulation and its importance for climatic variability, especially in terms of mass and heat flux between ocean basins. The choke points in the Atlantic Ocean and the Intra Americas Sea (Caribbean and Gulf of Mexico) have been studied over a long period of time, leading to discoveries of cold water pulses from the Labrador Sea and mechanisms for variations in the heat and mass transfer northward across the equator. The role of the oceans in carbon dioxide exchange with the atmosphere, as well as that of other

greenhouse gases, has been studied with new techniques that allow elucidation of the processes involved. AOML houses NOAA's Global Ocean Observing System (GOOS) Center, ensuring several measuring programs, data quality, archiving, and dissemination.

AOML has assumed leadership roles in the scientific planning, monitoring, and analysis of the Everglades restoration, particularly its effects on Florida Bay. New directions for studies of the coastal ocean and living marine resources include using acoustics for studying whales, their movements, numbers, mating calls, and their response to human-induced noise in the ocean. Coral reef monitoring and research has been a growing emphasis due to the precarious condition of many local reefs.

AOML's hurricane research is unique in the world in that it employs aircraft to obtain data inside the storms. Scientists regularly penetrate hurricanes for direct observations by flight-level instruments, dropsondes, radar, and other remote sensing devices. They work hand-in-hand with the National Hurricane Center in selecting research topics and converting their discoveries to practical forecast improvements.

The future provides tremendous challenges for a governmental laboratory to meet the accelerating demands for new knowledge and instant information as increasingly complex science questions are asked. Our charge is to protect the population, particularly our home area of south Florida, from the vagaries of severe weather, climate effects, and ecological deterioration. These concerns are all becoming more urgent as the population moves to coastal areas and increases in number. Nurturing the relationship of the Laboratory to our constituency, NOAA service line offices (National Weather Service, National Marine Fisheries Service, National Ocean Service, and National Environmental Satellite, Data and Information Service) and other agencies, as well as the general population, is a significant part of our work. This document is our roadmap for change and development of the science, human resources, infrastructure, and outreach activities of the Atlantic Oceanographic and Meteorological Laboratory focused on the coming five-year period. We meet these challenges with enthusiasm and confidence.

Kristina B. Katsaros
December 2001

Vision Statement and Mission

Vision

We envision an Atlantic Oceanographic and Meteorological Laboratory (AOML) whose research provides the backbone of information required to improve ocean and weather services for the nation through improved prediction of severe tropical storms, better utilization and management of marine resources, and better understanding of the factors affecting both climate and environmental quality.

Mission

AOML conducts basic and applied research that seeks to understand the physical, chemical, and biological characteristics and processes of the ocean and atmosphere, both separately and as a coupled system. The Laboratory's research themes (ocean and climate, coastal and regional environments, and hurricanes and tropical meteorology) employ a cross-disciplinary approach, conducted through collaborative interactions with national and international research and environmental forecasting institutions. The work also provides reliable information based on oceanic and atmospheric measurements and analysis. Stewardship of those measurements, including custodianship of major data sets, development and deployment of new sampling methods, new analysis tools, and carrying out long-term consistent environmental measuring programs, are part and parcel of the mission, particularly for research focused on the Atlantic Ocean, Caribbean Sea, Gulf of Mexico, and Florida coastal areas.

NOAA's two WP-3D Orion reconnaissance aircraft.

AOML strives to mesh its research goals and activities with those of NOAA as a whole and the Office of Oceanic and Atmospheric Research. We conduct research to support the following strategic goals (2002) of NOAA:

- Advance short-term warning and forecast services
- Predict and assess decadal to centennial change
- Implement seasonal to interannual climate forecasts
- Sustain healthy coasts
- Recover protected species
- Build sustainable fisheries

Our aim is to protect human life and natural resources by providing improved knowledge of forecasting weather, climate (seasonal to decadal scales), and ecological conditions as a basis for informed decision making by local managers and regional and national political entities. This strategic plan establishes the foundation for AOML's leadership in providing this unbiased expertise. It forms the basis for our research agenda and is intended as a guide for our partners, colleagues, and our constituency as we work together to face the scientific, societal, and environmental challenges of the 21st century.

NOAA research vessel Ronald H. Brown.

The Laboratory's vision involves several goals listed below for each of the three science themes, worklife (including human resources and infrastructure improvement), and outreach.

Oceans and Climate

- Determine the role of the Atlantic Ocean in the "multidecadal mode," low frequency climate fluctuations
- Improve estimates of the exchange of heat and fresh water between the south and north Atlantic Oceans
- Quantify the role of the oceans in modulating climate through study of the global balance of CO_2 and other radiatively important gases
- Study tropical Atlantic Ocean variability and its influence on climate and weather of the surrounding continents
- Understand the circulation pathways in the tropical Atlantic Ocean and their effect on climate
- Understand variability of the tropical Western Hemisphere warm pool
- Develop sustained ocean observing systems for understanding and predicting climate change

Coastal and Regional Environments

- Improve understanding of the impact of the Comprehensive Everglades Restoration Plan and other restoration actions upon the south Florida coastal marine ecosystem including Florida Bay and the Florida Keys National Marine Sanctuary
- Predict the effects on coral reef ecosystems of global climate change and local anthropogenic stresses
- Develop the next generation of sensors and integrated environmental monitoring systems required to monitor ecological and chemical processes in the coastal marine ecosystem
- Improve understanding of marine mammal distribution, abundance and migration patterns, and possible deleterious interactions with human activities or man-made marine structures
- Evaluate quantitatively the coastal air-sea flux of carbon dioxide
- Determine if Langmuir cells and larger scale mesoscale features regulate the distribution of harmful algal blooms
- Determine the degree to which the coastal ecosystems of the Intra-Americas Sea are interconnected and affected by remote oceanographic and meteorological forcing
- Determine the degree to which the south Florida coastal ecosystem is affected by the landfall of hurricanes and tropical storms

Hurricanes and Tropical Meteorology

- Improve understanding of hurricane intensity change by employing several promising avenues
- Improve measurement and analysis of surface winds in tropical cyclones
- Establish climatology of hurricane intensity and occurrence
- Improve prediction of hurricane tracks
- Improve quantitative precipitation estimates for tropical systems

Worklife

- Capitalize on our diverse workforce
- Strengthen the presence of AOML's Office of Equal Employment Opportunity (EEO) within AOML, in the south Florida Federal community, and at the OAR and NOAA levels
- Work with our Virginia Key community towards a fully integrated campus
- Improve the health and functionality of our facility
- Sustain state-of-the-art computing resources

Outreach

- Project to the public a sense of a vital enterprise whose scientific accomplishments are important and relevant to society's needs.
- Reach out to under-represented groups in science
- Improve our Internet world-wide web presence to better serve colleagues and the general public

The *actions* required to fulfill these goals form the body of this strategic plan

Oceans and Climate

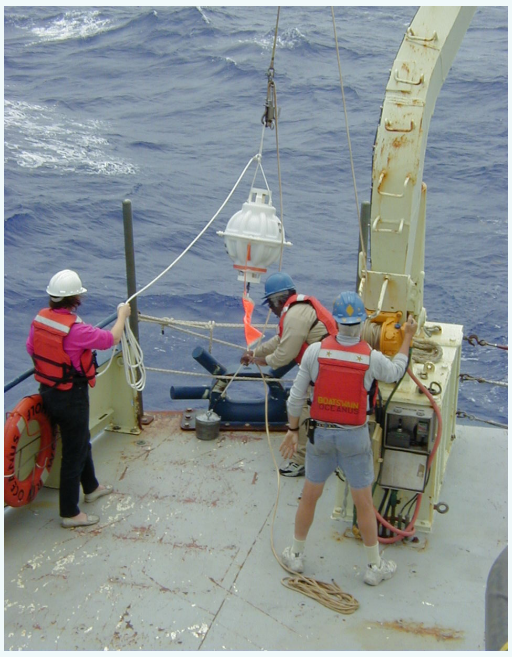
Background:

Deployment of a drifting buoy.

AOML is conducting climate studies with global scope to better understand the global setting for regional signals, and how the regional signals contribute to global phenomena. Multi-institutional efforts include studies of the El Niño-Southern Oscillation (ENSO) and the North Atlantic Oscillation (NAO), research on the global ocean carbon cycle, atmospheric chemistry, and western boundary currents including the Gulf Stream, Deep Western Boundary Current, North Brazil Current, tropical Atlantic circulation, and Caribbean oceanography. Techniques vary from shipboard-conducted process studies, models, long-term continuous time series, and satellite-derived products. In addition, AOML is the home of the NOAA Global Ocean Observing System (GOOS) Center, as part of the new paradigm for operational oceanography which places operational activities within research laboratories.

Challenges:

One of the major challenges that we impose upon ourselves is the search for new indices that will allow us to predict and forecast long-term climate changes. By collecting long-term, excellent-quality observations in the ocean and the atmosphere, we will be able to confirm or modify the results derived from model predictions. We have a unique opportunity in the study of the Atlantic. The Atlantic Ocean is responsible for over half of the heat transported by the global ocean due to the Meridional Overturning Circulation (MOC) and thus plays a major role in the global circulation and heat transport budget. Another challenge is collecting oceanic and atmospheric data and distributing these data in real time. A fast response of quality-controlled data is crucial to the improvement of forecasts. We intend to improve the existing technology, the data acquisition systems, and the distribution of data.



Launch of an inverted echo sounder.

Priorities:

Our main priority is to collect high-quality observations for climate studies. The effort should be divided into research and operations. Operations should be guided by scientific needs (*e.g.,* we need sea surface temperatures to run the forecast models; therefore, we deploy drifters and collect other shipboard observations). Research programs that we plan for the near future are given in what follows.

Oceans and Climate

Research Goals and Actions for 2002-2007:

Preparing a float for deployment.

Goal:
Determine the role of the Atlantic Ocean in the "multidecadal mode," low frequency climate fluctuations

Actions:

- Improve understanding of large scale interactions between the ocean and atmosphere (so-called teleconnections) logged in space and time
- Determine regional impacts of changes in precipitation/drought patterns; hurricane genesis, intensification, and landfall; and atmospheric circulation (*e.g.,* storm tracks)
- Provide oceanic data for continued improvements in predictions of the atmosphere-ocean coupled system

Goal:
Improve estimates of the exchange of heat and fresh water between the south and north Atlantic Oceans

Actions:

- Define a network of observations to assess heat transport and variability across key regions (*e.g.,* the subtropical Atlantic Ocean)
- Determine circulation features and variability associated with these transports (*e.g.,* the role of Brazil Current rings versus interior oceanic pathways)
- Continue high resolution expendable bathythermograph (XBT) networks to determine heat transport and circulation

Launch of a conductivity-temperature-depth (CTD) sounder.

Goal:
Quantify the role of the oceans in modulating climate through study of the global balance of CO_2 and other radiatively important gases

Actions:

- Develop technology for automated CO_2 measurements from ships
- Establish baseline estimates of anthropogenic carbon storage in the oceans and assess change through continued monitoring efforts
- Collect observations of important gases in key choke points (*e.g.,* the Deep Western Boundary Current and the Gulf Stream)
- Improve understanding of air-sea exchanges, ventilation, and mixed layer dynamics including nutrient cycling

Oceans and Climate

Goal:

Study tropical Atlantic Ocean variability and its influence on climate and weather of the surrounding continents

Actions:

- Improve our understanding of the Atlantic Ocean El Niño and the tropical Atlantic Ocean meridional gradient mode
- Understand the relationship between the Intra-Americas Sea and the tropical Atlantic Ocean
- Define dominant pathways into and out of the Caribbean basin (*e.g.,* through the Windward Island Passages)

Goal:

Understand the circulation pathways in the tropical Atlantic Ocean and their effect on climate

Actions:

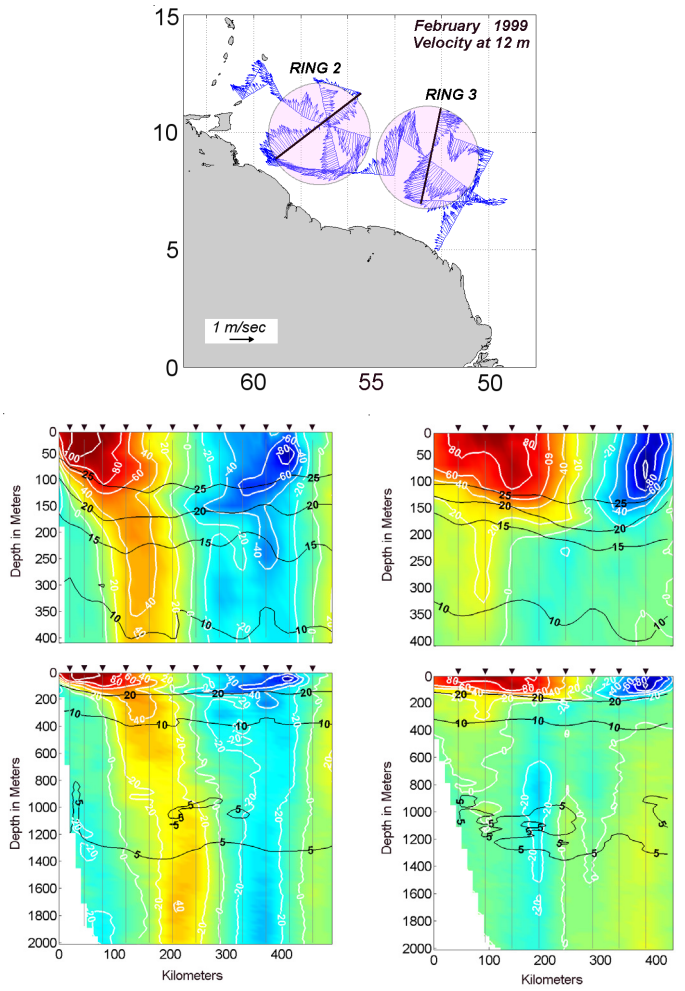
- Measure the role of subtropical cells and the Brazil Current in ventilation of the equator
- Determine dominant pathways of the meridional overturning circulation return flow and associated heat transport across the equator
- Improve uses of altimetry to monitor mesoscale oceanic features
- Continue profiling float and drifter deployments to determine circulation pathways

Goal:

Understand variability of the tropical Western Hemisphere warm pool (WHWP)

Actions:

- Investigate the seasonal cycle of the WHWP
- Study variability of the WHWP on interannual and longer time scales
- Improve our understanding of the relationships of the WHWP with eastern North Pacific and Atlantic hurricane activities and rainfall, from northern South America to the southern tier of the United States



First observations of the surface (top) and vertical (bottom left and right) velocity structure of two North Brazil Current rings.

Oceans and Climate

Goal:

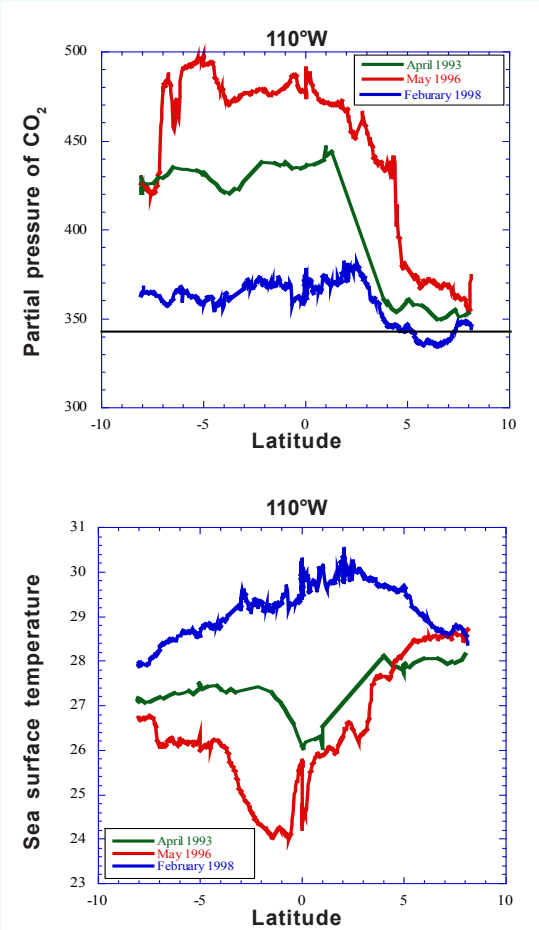
Develop sustained ocean observing systems for understanding and predicting climate change

Actions:

- Provide the scientific background for designing observing systems
- Monitor the meridional overturning circulation at selected locations (*e.g.,* the Straits of Florida)
- Provide data for large-scale ocean state estimation using ARGOS profiling subsurface floats, surface drifters, expendable temperature profilers, *etc.*

Anticipated Impacts:

AOML will have improved significantly the understanding of the role of the global ocean in decadal and larger time scales of climate variability–in particular, the role of the Atlantic overturning circulation–and we will join other institutions in pioneering the extension of climate research to regional applications such as agricultural and water resources. AOML and cooperating institutions will have completed the first cruises of the global repeat hydrography survey and obtained the first decadal scale estimates of carbon sequestration in the South Atlantic and North Atlantic Oceans. AOML will lead the Atlantic alliance of surface pCO_2 measurers and will have established a comprehensive observing plan to determine basinwide air-sea CO_2 fluxes on seasonal time scales. We will also be at the center of a new frontier in oceanography, one in which ocean variability is sampled in real time and analyzed and predicted operationally much the way the atmosphere is today.



The equatorial Pacific is the largest and most variable oceanic source of CO_2. NOAA investigators have monitored the trends of surface water CO_2 levels over the past decade and have determined a strong correlation with the El Niño cycle. As the figure shows, during El Niños (such as 1998) the amount of CO_2 emitted from the equatorial Pacific decreases dramatically. The opposite occurs during La Niñas such as 1996 when the amount of CO_2 released increases dramatically compared to normal years such as 1993. The trends of surface water CO_2 are opposite those of sea surface temperature.

Beyond 2007:

As our understanding of climate processes and their indices, precursors, and impacts improve, as real-time *in-situ* and satellite measurements become *de rigueur*, and as we learn how to simulate and predict global ocean variability with our academic partners, we will be moving into exciting new areas of climate research and society-driven applications. The future research will likely still target the Atlantic overturning circulation and its role in climate variability, but will now move towards ways to predict its regime shifts. We will complete the global survey of anthropogenic CO_2 content in the ocean for the first decade of the 21st century, producing an operational product of seasonal air-sea CO_2 flux maps on global scales.

Coastal and Regional Environments

Background:

South Florida mangrove.

Coastal and regional environmental problems have been a focus of AOML activities for more than two decades. Prior major interdisciplinary, multi-institutional efforts have included the Nutrient Enhanced Coastal Ocean Productivity (NECOP) program, study of the New York Bight, and a series of fisheries oceanography-related studies (Fisheries Oceanography Cooperative Investigations, South Atlantic Bight Recruitment Experiment, and Southeast Florida and Caribbean Recruitment). At present, our interdisciplinary field efforts include physical, biological, and chemical studies supporting the South Florida Ecosystem Restoration (SFER) effort and the underlying health of this ecosystem to the regional Intra-Americas Sea program and the status and health of coral reef ecosystems worldwide. We have also begun a new cooperative effort with the National Marine Fisheries Service/ Southeast Fisheries Science Center in marine mammal acoustic studies and a collaborative ship-of-opportunity coastal observations effort with the University of Miami's Rosenstiel School of Marine and Atmospheric Science, Royal Caribbean Cruise Lines, and the National Science Foundation. At the same time, we are seeking to develop the next generation of instrumentation and data assimilation tools necessary to provide the nowcast and forecast products required by the coastal ocean resource management community.

Challenges:

AOML's role in coastal and regional environmental research will expand in the coming years, both in regard to basic research and integrated operational monitoring/modeling. There is no question that the problems coastal managers and planners face require information on processes at both shorter time and space scales than previously studied, but over longer periods than previously available. In our view, progress requires time series Eulerian data sets best and most cost effectively obtained from fixed platforms, moorings, or buoys nested within remotely-sensed wider fields. Ship-based process studies have a role but will, in the future, no longer be exploratory in nature. Much greater use will be made of ships-of-opportunity and unmanned platforms. Recent advances have been made and will continue to be made both in regard to *in-situ* sensor technology and in adapting and integrating commercially-available sensors into instrument packages tailored to our questions of interest. Real-time data assimilation and creative analysis are now possible and will become practical due to advances in both computer hardware and software. All of these information sources will have to be integrated into end-to-end information systems to deliver the products relevant to our future.

Scuba diver explores coral reef environment.

Coastal and Regional Environments

Priorities:

Florida Bay, looking east from Route 1, south of Key Largo.

In coastal and regional research, AOML's efforts should be approximately equally divided between basic research, applied research, and quasi-operational programs. We are seeking to reach a programmatic balance. In regard to quasi-operational activities, we see our role as inherently transitional. We believe this transition period is critical and requires commitment for periods considerably longer than traditionally allotted to research projects. Our goal is to provide the intellectual and physical tools necessary for the NOAA line organizations with operational missions to accomplish their mandated objectives. We are intimately connected with our user community through a built-in feedback loop that we must make every effort to strengthen. AOML has substantially invested in measurement, analysis of measurement, and long-term environmental monitoring. These efforts must continue to receive much of our time and attention. In addition, as a government laboratory with a core of base funding, some part of our efforts must be directed towards high risk/high return applied research, *e.g.,* the prototype development of measurement platforms to be deployed in remote regions worldwide, coupled with decision support systems that may lead to better understanding of factors critical to harmful algal blooms. Last, we must continue to take advantage of a unique aspect of AOML. We are a meteorological laboratory as well as an oceanographic laboratory. We intend to more diligently and creatively capitalize upon and exploit the unique possibilities open to us due to this inherent interdisciplinary character. Within this context, the following research topics are projected to be the foci of our efforts in the coming years.

Research Goals and Actions for 2002-2007:

Goal:

Improve understanding of the impact of the Comprehensive Everglades Restoration Plan and other restoration actions upon the south Florida coastal marine ecosystem including Florida Bay and the Florida Keys National Marine Sanctuary (FKNMS)

Actions:

- Provide the physical, water quality, and biological data required to verify models and analyze alternative water management and restoration scenarios
- Define the degree to which restoration actions threaten the FKNMS and its living marine resources
- Fully implement a real time interdisciplinary regional monitoring network utilizing state-of-the-art data assimilation, computational, and information dissemination methodologies

Deployment of shallow-water drifters into Florida Bay.

Coastal and Regional Environments

Goal:

Predict the effects on coral reef ecosystems of global climate change and local anthropogenic stresses

The Salt River Bay CREWS station in St. Croix gathers atmospheric and oceanic data that assists researchers in monitoring coral reef environments.

Actions:

- Incorporate additional biological and chemical parameters into the Coral Reef Early Warning System (CREWS) neural-net based analysis and automated information dissemination system
- Determine the relationships between reef calcification, photosynthesis, and environmental stress by enhancing CREWS sites with continuous pCO_2 sensors
- Utilize advanced acoustic and optical methods to define the interdependence of coral reef and planktonic tropical marine ecosystems

Goal:

Develop the next generation of sensors and integrated environmental monitoring systems required to monitor ecological and chemical processes in the coastal marine ecosystem

Actions:

- Develop remote sensor systems based upon molecular quantification of planktonic organisms and microbial contaminant abundance
- Extend the concentration range over which we can measure atmospheric ammonia in the marine boundary layer and develop an *in-situ* dissolved ammonia sensor sufficient to assess air-sea fluxes in coastal environments
- Distribute near-real-time value-added integrated analysis products based upon coastal ocean measurements to coastal managers, emergency service managers, and environmental regulators
- Adapt present and next generation sensors to a range of platforms, *e.g.*, research ships, moorings, towers, airplanes, ships-of-opportunity, and/or automated underwater vehicles

Electronic engineers Nelson Melo and David Bitterman display shallow-water drifter designed at AOML.

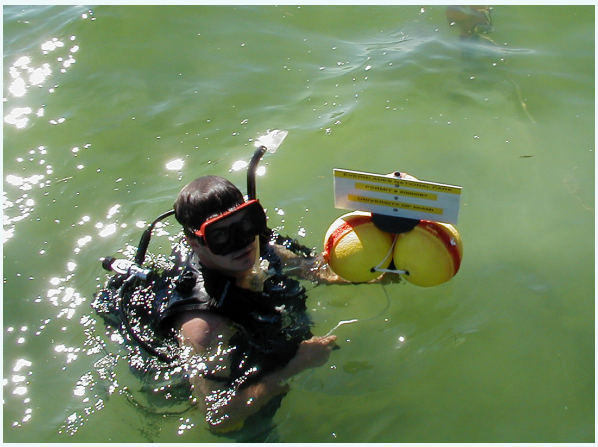
Coastal and Regional Environments

Goal:

Improve understanding of marine mammal distribution, abundance and migration patterns, and possible deleterious interactions with human activities or man-made marine structures

Actions:

- Design, develop, and construct passive acoustic sensor arrays to monitor sperm whale abundance and possibly vertical distribution in the northern Gulf of Mexico
- Conduct passive acoustic surveys of baleen whale distribution throughout the Caribbean
- Implement a data processing center to process National Marine Fisheries Service/Southeast Fisheries Science Center marine mammal data utilizing AOML's parallel processing computation system



Retrieval of a float from Florida Bay.

Goal:

Evaluate quantitatively the coastal air-sea flux of carbon dioxide

Action:

- Conduct collaborative shipboard process studies using dual deliberate inert gas tracers to estimate gas transfer rates and the effect of coastal wave environments and surfactant properties

Goal:

Determine if Langmuir cells and larger scale mesoscale features regulate the distribution of harmful algal blooms

Actions:

- Conduct collaborative interdisciplinary process studies in water parcels tagged with deliberate inert gas tracers
- Document algal bloom dynamics using molecular-based, species-specific sensors

The R/V Virginia Key is used for research in the south Florida area.

Coastal and Regional Environments

Goal:

Determine the degree to which the coastal ecosystems of the Intra-Americas Sea are interconnected and affected by remote oceanographic and meteorological forcing

Actions:

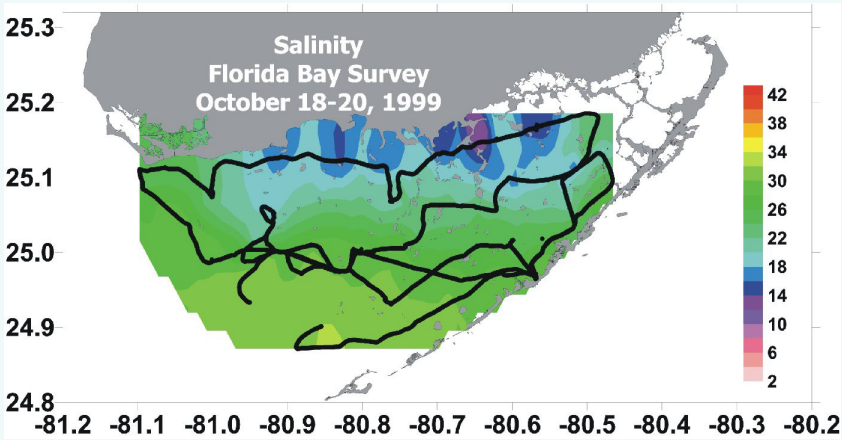
- Conduct interdisciplinary studies of the impact of Brazil Current eddies upon coastal ecosystems in the lower Caribbean basin
- Document the inherent variability of the Gulf Stream using ship-of-opportunity and remote sensing data

Goal:

Determine the degree to which the south Florida coastal ecosystem is affected by the landfall of hurricanes and tropical storms

Action:

- Conduct biological and chemical studies of the coastal ecosystem before and after tropical storm landfall in conjunction with appropriately scaled wind field, tidal surge, and wave height studies



Depending upon their exact path, intensity, and size, tropical storms and hurricanes may substantially affect the distributions of salinity and other ecologically significant water properties in Florida Bay. A shipboard survey of Florida Bay in the wake of Hurricane Irene (1999) indicated not only considerable discharge into the Bay through channels in the Buttonwood Embankment well to the west of the typical center of discharge but also a consequent, if comparatively shortlived, phytoplankton bloom.

Anticipated Impacts:

This research will lead to more informed management of coastal marine resources and better prediction of the consequences of continuing coastal development and global climate change. It will permit rational, science-based decisions regarding NOAA coastal stewardship obligations and interagency ecosystem and habitat restoration efforts. The information generated is essential if we are to mitigate or avoid unintended deleterious effects upon coastal environments.

Beyond 2007:

As our measurement and analytical capacities improve, our research is expected to contribute to progressively more quantitative predictions of environmental change and to truly adaptive management of coastal resources. Moreover, with continued evolution in computing resources and data assimilation strategies, we will be providing progressively more real-time information to our user community. Rather than real-time raw data, or even quality-controlled data, this information will consist of value-added products tailored to the information needs of our user community.

Hurricanes and Tropical Meteorology

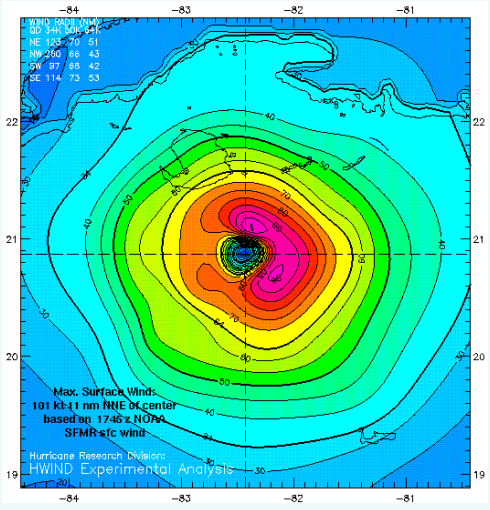
Background:

Inside the eyewall of Hurricane Floyd (September 1999). Wingtip of the NOAA WP-3D reconnaissance aircraft appears in the upper left corner.

Over the last 20 years, hurricane research at AOML has focused on improved scientific understanding of hurricanes and of tropical meteorology generally, with the ultimate objective of better forecasts on all spatial and temporal scales. Specific scientific goals for AOML's hurricane research derive from the U.S. Weather Research Program's (USWRP) Hurricanes at Landfall (HaL) focus (Marks and Shay, 1998, *Bull. Amer. Met. Soc.*). They reflect a broad consensus across the USWRP consortium composed of forecasters and researchers in academia and government. Within the USWRP framework, the first dedication is to cutting-edge science at the frontier of hurricane research, with an overwhelming bias for science that will improve forecasts and reduce human and economic losses. AOML's Hurricane Research Division (HRD) scientists lead airborne field observing campaigns, facilitate instrument and model development, provide the theoretical framework for understanding hurricane dynamics, and collaborate widely with scientists from universities and other government laboratories.

Challenges:

Studies of historical hurricanes show that cyclones in Simpson-Saffir categories 3 and 4 account for 80% of the economic losses. Most hurricanes that reach category 3 and all hurricanes that reach category 4 do so through rapid deepening. Thus, rapid deepening is important both because it is difficult to forecast and because it causes the most destructive hurricanes. A testable hypothesis is: Are the necessary and sufficient conditions for rapid deepening category 2 or greater initial intensity, an ocean that stays warmer than some threshold (~28°C), and low shear of the environmental wind; or are these conditions only necessary? If the latter, what else is essential?



Surface wind analysis plot for Hurricane Michelle (November 4, 2001). Wind analyses are used for determining the intensity and radial extent of the maximum sustained winds in tropical systems.

AOML must continue to strive for more and better observations of surface winds for assimilation into its analysis scheme, H*WIND. Analysis of surface winds is a key complement to a predictive capability because it enables rational hurricane-resistant design. HRD scientists are currently collaborating with National Weather Service (NWS) forecasters through the new Joint Hurricane Testbed (JHT) to make H*WIND fully operational.

Currently, the way to improve track forecasts is through improved specification of the flow around the storm. This strategy typically reduces forecast errors by 1-2% annually. In 15 to 20 years, the improvement will asymptote with <100 km error at 24 hours. Then, propagation due to the storm's internal dynamics will become the focus. Even before forecasts reach the deterministic limit, ensemble-

Hurricanes and Tropical Meteorology

based probabilistic techniques will predominate. Track forecasting is an important and scientifically elegant topic to which AOML would like to commit more resources.

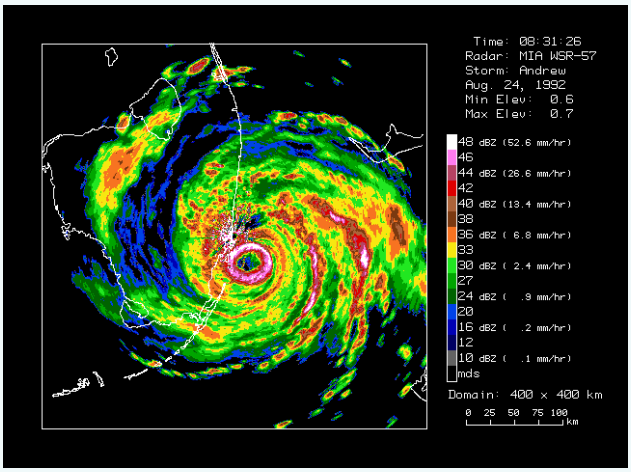
A shift of emphasis from hurricane winds to quantitative rainfall forecasting was envisioned in the USWRP long-term planning. This investigation leverages AOML's expertise in cloud microphysics and radar with NASA's capabilities in remote sensing through NASA's recurring Convection and Moisture Experiment (CAMEX) field campaigns. It entails both basic science and technique development. The hurricane is an ideal laboratory for study of precipitation processes because of the strong kinematic control by the stable, long lasting vortex. A key first step, supported under JHT, is development of a climatology and persistence forecast model (R-CLIPER) for hurricane rainfall, based upon remotely-sensed data. As studies of intensity change and surface winds mature, resources will be shifted to rainfall.

An airborne expendable bathythermograph (AXBT) is launched from one of NOAA's WP-3D reconnaissance aircraft.

During the 1970s, 1980s, and early 1990s, these storms were relatively rare. The 1990s saw a return to the higher levels of activity that characterized the middle of the 20th century. This shift appears to be largely independent of global warming. It is instead a manifestation of the Atlantic Multidecadal Oscillation, a 70-year cycle in the Atlantic thermohaline circulation. Increasingly detailed and reliable predictions of these cycles will prove vital as tropical cyclones pose a dramatically increased threat to the Caribbean islands and east coast of North America during the first two or three decades of the 21st century.

Priorities:

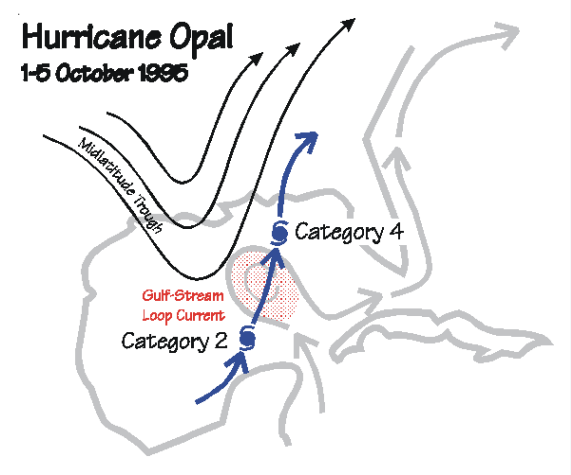
The Hurricane Research Division's most important scientific goal is advancement of physical understanding of hurricane intensity change and implementation of increasingly skillful intensity forecasts. A particular target of this work is rapid intensification, the phenomenon that will unquestionably cause the next hurricane catastrophe. An equally important technology transfer effort is analysis of hurricane surface winds. This work is essential to support forecasting, emergency management, design of survivable structures, wise land use, and insurance regulation. The effort to improve track forecasts through synoptic surveillance and targeted observations continues, but with somewhat fewer resources than in the past. Quantitative estimation and prediction of tropical cyclone rainfall is becoming an increasingly vital part of AOML's program because drowning in fresh water inland is a significant cause of hurricane-related mortality.



Radar image of Hurricane Andrew (August 1992) approaching landfall in south Florida.

Hurricanes and Tropical Meteorology

AOML commits a modest, but sustained, effort to sophisticated understanding of the climatology of hurricane occurrence. This research is the key to preparing the human and natural environments for the rare, but extreme, events that dominate hurricane impacts.



Hurricane Opal's northward careen across the Gulf of Mexico, schematically showing the storm's rapid intensification as a result of its interaction with a "digging" mid-latitude trough and its passage over a deep pool of warm water in an eddy spun off from the Gulf Stream.

Research Goals and Actions for 2002-2007:

Goal:
Improve understanding of hurricane intensity change by employing several promising avenues

Actions:

- Provide measurements and analysis to elucidate two-way coupled sea-air interaction in hurricanes
- Provide analysis of the roles of shear and trough interaction
- Use chemical tracers to understand tropical cyclone dynamics and thermodynamics
- Test statistical prediction of rapid intensification onset (**JHT**, indicates work being transitioned to operations under the Joint Hurricane Testbed)

Goal:
Improve measurement and analysis of surface winds in tropical cyclones

Actions:

- Analyze dropsonde and remotely-sensed observations of boundary layer winds
- Perform analysis of winds during catastrophic landfalls
- Implement operational objective surface wind analysis (**JHT**)

NOAA's Gulfstream-IV SP jet is a state-of-the-art high altitude research platform. It was acquired in 1996 to improve NOAA's tropical cyclone forecast capability. Dropsondes are deployed from high altitudes over large areas of open sea, where few observations are available.

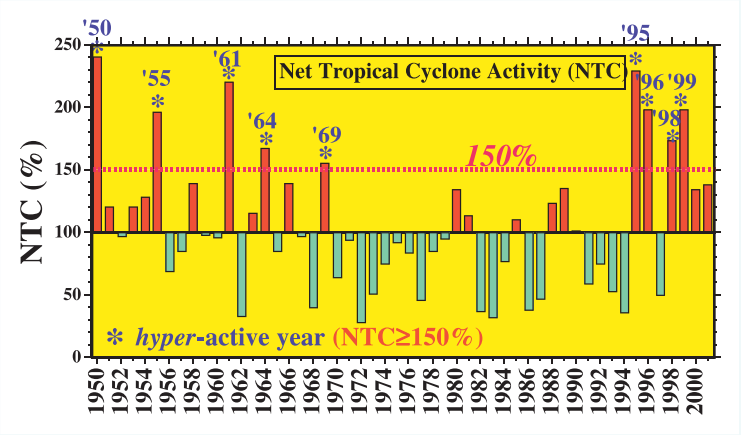
Hurricanes and Tropical Meteorology

Goal:

Establish climatology of hurricane intensity and occurrence

Actions:

- Analyze decade-to-decade fluctuations in hurricane occurrence
- Analyze economic and human impacts of hurricane landfall to establish the vulnerability of society to these events
- Utilize the climatology to improve prediction of the seasonal activity six months in advance



Net tropical cyclone activity is a measurement of overall activity that includes the number, strength, and duration of storms. Atlantic basin tropical cyclone activity has increased dramatically since 1995.

Goal:

Improve prediction of hurricane tracks

Actions:

- Continue optimal targeted aircraft observations to establish better methods of decision making (**JHT**)
- Conduct ensemble forecasting and determine/develop better methods (**JHT**)

Goal:

Improve quantitative precipitation estimates for tropical systems

Actions:

- Use airborne and spaceborne remote observations of precipitation to establish predictive relationships
- Perform observational studies of precipitation processes
- Derive the climatological storm-relative distribution of hurricane rainfall (**JHT**)

Anticipated Impacts:

This research will reduce expense and disruption due to warning of areas that do not actually experience the hurricane. It will also mitigate property damage to some extent and reduce the probability of catastrophic loss of life. Finally, it will support rational design of the built and social environments to make them resilient against the hurricane threat.

Beyond 2007:

As understanding and forecasts of intensity change improve, the research emphasis will shift more strongly to quantitative precipitation forecasting. When the improvement in track forecasts due to more accurate specification of the steering current begins to reach a deterministic limit, the effect of storm propagation will need reexamination. At about the same time, ensemble-based, probabilistic forecasts will yield further improvement in all aspects of the forecast problem.

Human Resources

Background:

Aerial view of the marine science community on Virginia Key in Miami, Florida.

AOML comprises a Federal workforce of 98 and a non-Federal contingent of 52, including 38 employees of the Cooperative Institute of Marine and Atmospheric Studies (CIMAS) of the University of Miami's Rosenstiel School of Marine and Atmospheric Science (RSMAS), 11 contractors, two National Research Council postdoctoral researchers, and one employee of the Florida International University. AOML is an integral part of a unique community of research and educational institutions on Virginia Key in Miami, Florida. Approximately $70M per year invested in marine science and education among the University of Miami'sRosenstiel School of Marine and AtmosphericScience, NOAA's Southeast Fisheries Science Center, the Miami Seaquarium, the Maritime and Science Technology (MAST) High School, and AOML.

Challenges:

A big challenge to scientific institutions is limited workforce diversity due to the lack of diversity in graduates with advanced degrees in marine and atmospheric sciences. AOML is fortunate that employees are drawn from the diverse population of south Florida, as well as employees and visitors from across the United States and from other countries. AOML is committed to respecting and celebrating the strengths of its diverse workforce. We are similarly committed to supporting the goals of Equal Employment Opportunity (EEO). We strive to provide a warm and enriching work environment.

Priorities:

People are AOML's most valuable asset. The ratio of Federal-to-non-Federal workers is anticipated to remain approximately constant. AOML encourages all employees to develop career plans (short- and long-term) to ensure their careers are progressing along a desired path. AOML will continue to reach out to groups who are under-represented in ocean and weather sciences, both in our hiring actions and in encouraging local students to choose careers in ocean and weather-related mathematics, science, engineering, and technology. The AOML Office of EEO will assist in resolution of informal

Scientist Rik Wanninkhof receives an award from AOML Director Kristina Katsaros.

Human Resources

complaints of discrimination; plan, develop, monitor, and evaluate AOML affirmative employment plans, collect and report quarterly employee activities and recruitment relevant to EEO; participate in activities that support the OAR EEO Manager, the NOAA Office of Civil Rights, and the NOAA EEO Council; and coordinate and encourage employee attendance at workshops and other training opportunities relevant to EEO. AOML is committed to encouraging all employees to integrate EEO and diversity principles into their daily worklife interactions. As telework concepts are embraced by the Department of Commerce and NOAA, these flexible working arrangements should enhance AOML's ability to attract and retain a high-quality workforce.

Meteorologist Howard Friedman displays certificate of recognition celebrating 40 years of federal employment.

Goals and Actions for 2002-2007:

Goal:
Capitalize on our diverse workforce

Actions:

- Ensure that promotions, selections, and all personnel actions are awarded based solely upon technical merit and ability
- Adjust work schedules to accommodate cultural and religious traditions
- Aggressively advertise hiring actions locally and to under-represented groups
- Partner and make presentations in local schools to encourage students to choose relevant curricula for their education
- Implement telework and other technologies that support a flexible and creative workplace

Staff members of the Atlantic Oceanographic and Meteorological Laboratory.

Human Resources

Goal:

Strengthen the presence of the AOML Office of Equal Employment Opportunity (EEO) within AOML, in the south Florida Federal community, and at the OAR and NOAA levels

Actions:

- AOML's Office of EEO will routinely coordinate speakers and training sessions to inform employees of policies and rights under EEO and recommend alternatives to formal proceedings such as Alternative Dispute Resolution
- Organize the AOML Office of EEO to more closely reflect the needs and abilities of the AOML workforce
- Coordinate AOML's efforts related to EEO, diversity, and educational outreach
- Establish closer program ties with the EEO and Diversity Councils of the South Florida Federal Executive Board
- Engage in EEO-diversity education and adopt a school or two

Anticipated Impacts:

AOML will enjoy a workforce representing the broad diversity of the south Florida region and will provide a setting in which individuals grow and develop as professionals and are encouraged to actively pursue their career goals. By combining efforts regarding diversity, educational outreach, and EEO, AOML will have better informed employees about opportunities in the Federal service, and the breadth and scope of ethnicities, personalities, and abilities that comprise the Federal workforce.

Beyond FY2007:

AOML will continue activities that: (1) encourage individual career development; (2) seek to create a more diverse workforce; (3) strengthen adherence to applicable EEO principles and policies; and (4) provide opportunities for employees and management to resolve issues informally. We will continue to strive for a completely integrated, harmonious, and happy work force.

Facilities

Background:

The award-winning facility of AOML was opened in 1973. The building has remained essentially as it was designed with the addition of a warehouse and fundamental changes in laboratory and computing/communications capabilities. It provides a comfortable and inspiring environment for creative work. However, over the past 30 years many once state-of-the-art laboratories have become obsolete and air conditioning and other systems have aged.

Eastern view of the AOML facility.

Challenges:

Both the integration of activities among the many institutions on Virginia Key and the challenges of working in a 30-year old building will be addressed over the next several years as AOML, the Southeast Fisheries Science Center, and RSMAS design and build a revitalized joint campus. The continuing challenge of remaining state-of-the-art in terms of laboratory and computing capabilities will also be addressed in this campus revitalization.

Being located on an island in an area prone to severe weather presents challenges for continuity and recovery of operations during and after events such as severe thunderstorms and, especially, hurricanes. AOML has developed an approach that minimizes disruption of work, including orderly shut-down and start-up procedures, off-site mirror servers, and an information phone line maintained by Bell South to ensure communication among affected employees. These procedures need augmentation and expansion.

Priorities

View of the AOML facility from Rickenbacker Causeway.

By working with the University of Miami and Southeast Fisheries Science Center on a campus revitalization, AOML's unique architecture will be preserved and enhanced while critical maintenance and enhancements will be addressed. Our priority projects include improving our aging air conditioning system, which is used 365 days per year, redistributing electricity to accommodate the needs of laboratories and distributed computer systems, repairing leaks in our roofs and windows, and gaining access to air conditioned warehouse space. Physical security of the laboratory and its grounds will be enhanced in the campus revitalization project. AOML fully supports the principles stated in the Scientific Computing Section of the NOAA Research Information Technology Architecture and the overarching NOAA Information Technology Architecture. We plan to consolidate servers, increase our network bandwidth to 10 Gbps over the next five years, and to mirror all of our critical Internet world-wide web, ftp, data, and financial servers at remote locations. We will continue to exploit multi-processor clusters for mid-range computer modeling and are committed to providing user-friendly access to our data stores. Computer security remains a high priority as we become increasingly dependent on electronic media.

Facilities

Goal:

Work with our Virginia Key community towards a fully integrated campus

The mangrove that occupies the northern portion of the AOML facility is home to many native species of birds and reptiles.

Actions:

- Work with Rosenstiel School architects and NOAA facilities staff to develop a campus design
- Develop and market attractive funding scenarios
- Incorporate state-of-the-art laboratory and computing capabilities into new buildings

Goal:

Improve the health and functionality of our facility

Actions:

- Pursue an energy conservation project with Florida Power and Light to replace the air conditioning system through an energy savings payback arrangement
- Work closely with the Capital Improvement Plan process to solicit funds for building repairs
- Implement the latest security measures
- Mirror all critical Internet world-wide web, ftp, data, and financial servers at remote locations
- Make transfer of our extensive data stores more transparent and consistently available

Goal:

Sustain state-of-the-art computing resources

Actions:

- Employ multi-processor clusters for mid-range computer modeling
- Increase network bandwidth to 10 Gbps

Anticipated Impacts:

AOML will have an effective 21st century science research facility with the latest technology in laboratory space and equipment, computing, and information technology services. This will immensely facilitate the important work of AOML's scientists and technical support and administrative staff.

Beyond 2007:

The AOML facility will continually evolve as warranted by developments in science, technology, and communications. It is likely that the upgrade and campus development will be continuing beyond 2002 to the period 2007. Our dream is to add a teaching/training and meeting facility on the new science campus of Virginia Key.

Background:

AOML is part of an international community of research laboratories, educators, environmental decision makers, weather and climate forecasters, Congressional policy setters, and an international public, all of whom benefit from our research. An essential element of AOML's mission is communicating with these diverse communities via the media, sharing data and research results, and publication in professional and popular journals.

Scientists discuss research results during AOML's Quadrennial Review.

Challenges:

Over the last decade, the need to translate complex scientific results into easily understood language has increased due to an increasing pressure on the Federal budget and a general hunger by the public to be better informed. In particular, with the migration of our population to coastal areas, there is an increasing need to understand their vulnerability to changes in weather, climate, and ocean conditions.

Priorities:

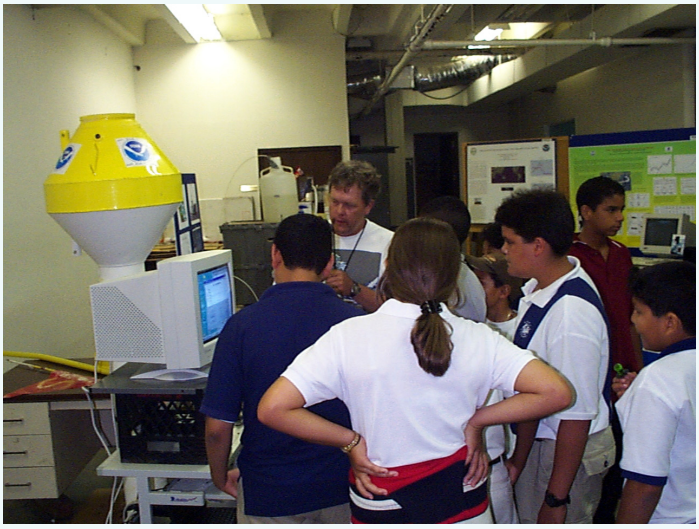
AOML will continue to employ an expert in scientific communications to ensure a clear and professional message. Our outreach coordinator provides the communities with whom we interact with a single point of contact for outreach activities.

Goal:

Project to the public a sense of a vital enterprise whose scientific accomplishments are important and relevant to society's needs

Actions:

- Maintain contact and briefings with local Congressional representatives
- Distribute press releases for each major journal article or field program endeavor
- Create full color brochures and pamphlets for current research projects



Middle-school students learn about the instruments AOML scientists use to gather atmospheric data.

Goal:

Reach out to under-represented groups in science

Actions:

- Partner with and make presentations in local schools to encourage students to choose educational curricula relevant to marine and atmospheric sciences
- Encourage employees of all races and gender to participate in outreach and educational activities
- Encourage employees to work with student interns, allowing hands-on experience with researchers

Students learn about hurricane research during an open house hosted by AOML.

Goal:

Improve our Internet world-wide web presence to better serve colleagues and the general public

Actions:

- Assess the utility and accessibility of AOML web pages and make adjustments based on input from external users
- Develop web pages aimed at middle school students and the general public for each of the research themes, describing research in basic terms with graphics

Anticipated Impacts:

The primary result of AOML's emphasis on outreach will be improved partnerships with our scientific collaborators, OAR, Congressional policy setters, and the public.

Beyond 2007:

AOML will continue activities to: improve communications between AOML and their fellow scientists, Congress, educators, and the public; ensure ready access to AOML data and information; and, by participation in science and career fairs and other educational outreach, encourage students to make NOAA the employer of choice.

Children participate in a science project during Bring Your Children to Work Day.

Key to the success of NOAA is a long-term commitment to its research and the many talented and dedicated people who work daily to solve mysteries of our earth's systems. NOAA Research partnerships with academia, with other federal institutions, and with the private sector are also critical components in an overall strategy to provide our nation's leaders with the knowledge they need to make informed decisions. We have a dual responsibility to address urgent current issues through the creative transfer of new concepts to practical use, and to explore the facets and trends of our environment that will influence our future. Through a renewed commitment to research, our human talent, and strengthened relationships with our partners, NOAA Research will continue to provide the nation with the scientific information it requires to thrive in a changing world.

(source: NOAA Research Strategic Plan, 2000)

Department of Commerce
National Oceanic and Atmospheric Administration
Office of Oceanic and Atmospheric Research

Atlantic Oceanographic and Meteorological Laboratory
4301 Rickenbacker Causeway
Miami, FL 33149-1026 USA

Telephone: (305) 361-4300
Fax: (305) 361-4449

http://www.aoml.noaa.gov