Cooperative Institute of Marine
and Atmospheric Studies

CIMAS

Fifth Year Annual Report
NOAA Cooperative Agreement NA17RJ1226

2005 – 2006

Joseph M. Prospero, Director
David Die, Acting Associate Director

University of Miami
Rosenstiel School of Marine and Atmospheric Science

http://cimas.rsmas.miami.edu

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ROSENSTIEL SCHOOL OF MARINE AND ATMOSPHERIC SCIENCE

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EXECUTIVE SUMMARY

Above, a view of Virginia Key looking toward the northwest, showing the Rosenstiel School, foreground, the NOAA Atlantic Oceanographic and Meteorological Laboratory, center, and the Southeast Fisheries Science Center of the National Marine Fisheries Service (right center, above the causeway). Virginia Key is about 3 miles east of downtown Miami, Florida.

The Cooperative Institute of Marine and Atmospheric Studies (CIMAS) is a research institute at the University of Miami in the Rosenstiel School of Marine and Atmospheric Science (RSMAS), CIMAS is jointly sponsored by the University and the National Oceanic and Atmospheric Administration (NOAA). CIMAS works closely with two local NOAA laboratories: the Atlantic Oceanographic and Meteorological Laboratory (AOML) and the Southeast Fisheries Science Center (SEFSC). CIMAS carries out research under six Themes:

Theme 1: Climate Variability
Theme 2: Fisheries Dynamics
Theme 3: Regional Coastal Ecosystem Processes
Theme 4: Human Interactions with the Environment
Theme 5: Air-Sea Interactions and Exchanges
Theme 6: Integrated Ocean Observations

All research carried out in CIMAS is closely linked to the NOAA Strategic Goals.

Total funding from NOAA sources in FY 5 of the Cooperative Agreement was $7.0M, a decrease of $1.3M from FY 4 but essentially identical to FY 3. Nonetheless, FY 5 was substantially above the average for the first two years of the Agreement ($5.8M) and a little above the average for the five year period as a whole ($6.8M). Task 2, which supports CIMAS employees who work closely with AOML and SEFSC, has experienced strong growth over the Agreement, doubling from YR 1 to YR 4. In YR 5, Task 2 has stabilized at $2.5M, essentially the same as FY 4.

Research funding (Task 3 and Task 4) in FY 5 was $3.4M, down from $3.8M in FY4 but substantially above the average for the first two years of the program, $2.5M. Over half the research funds are expended under Theme 1: Climate Variability. Theme 1 activity reflects in part an increased effort on hurricane research. There is also substantially more research in the areas of climate, weather, and hurricane research. We also continue to see steady growth in fisheries-related research. The second most active area of research is under Theme 3: Regional Coastal Ecosystem Processes, reflecting activities in the large effort associated with the South-Florida Everglades Restoration. A close third is research under Theme 2: Fisheries Dynamics, some aspects of which are closely linked to Theme 3.

During FY 5 a total of 108 persons were involved with CIMAS activities in various capacities. Of these, 96 were associated with local NOAA laboratories, 54 with AOML and 42 with SEFSC; of these 96 personnel, 83 receive over 50% of their support from NOAA funding sources. The CIMAS Research Associate/ Scientist work force is highly diverse. Females make up 39% of the employee pool. Foreign-born individuals comprise 43%; of these Hispanics make up 25% of the ranks; Asian and Pacific Islander, 12%.

The research program in CIMAS continues to yield many exciting results. Here we highlight some of our achievements. These are selected to be representative of the wide range of activities carried out in CIMAS. A more detailed description of these results can be found in the body of the Report under the Themes.

Research Highlights

- We carried out the first direct measurements of air-sea fluxes under hurricane conditions during the CBLAST campaign. These data will contribute to developing better forecasts of hurricane intensity.

- In cooperation with the Tropical Prediction Center and the Central Pacific Hurricane Center, we developed an oceanic climatology of ocean heat content (OHC) and provided daily OHC estimates for the Eastern Pacific Ocean for use in SHIPS hurricane intensity forecasts.

- An unprecedented number of flights were made into major hurricanes in 2005. We participated in the first flights made with Stepped Frequency Microwave Radiometers (SFMR) mounted on both WP-3D aircraft. We have devised a new microwave emissivity/wind speed model function which will lead to better air/sea exchange parameterizations and to improved hurricane intensity forecasts.

- The Hurricane Loss Project Model, developed jointly with AOML/HRD, provides estimates of future losses that can be used by insurance companies to determine windstorm policy rates and also to make immediate estimates of losses from hurricane events as was done for Katrina, Wilma, and Charley.

- With AOML/HRD and using the GIV, we began a study of the impact of the Saharan Air Layer (SAL) on the development of tropical cyclones and hurricanes. Earlier work suggests that strong SAL events tend to suppress hurricane development.

- In an intensive ship, aircraft and satellite study of the climatically-important cloud regime over the South Pacific Ocean, we made observations that provide a base line for evaluating cloud and boundary layer models, a critical component of climate models.

- Using a coordinated set of 21st century climate scenarios, we made a study of coupled ocean-atmosphere models. We find that water vapor provides the largest positive feedback in all models and that the strength of this feedback is consistent with that expected from climate-change-driven increases in water vapor.

- In an assessment of the variability in the tropical radiation budget, we obtained good agreement between satellite-observed changes of shortwave radiation and model-simulated radiances. This agreement supports the use of models to calculate decadal variations in spectral radiances, an essential component in climate models.

- Contrary to the general belief that an adaptive observing strategy over the North Pacific will to lead to improved forecasts of high-impact weather for North America, our research shows that rapidly growing errors in operational forecast models may negate any positive influence on forecasts.

- As a part of the CO_2 synthesis group, we are involved in the creation of a globally integrated ocean CO_2 database that yields a much better picture of the role of the ocean in the global carbon cycle. These data show that inorganic carbon has increased at a rate consistent with the anticipated impact of the anthropogenic carbon source changes and the associated climate change.

- For the first time, a comprehensive, regional model of circulation and transport dynamics has been developed for the vast area that encompasses the Straits of Florida and the southwest Florida shelf. The SoFLA-HYCOM model nests a high-resolution version of HYCOM within a larger-scale HYCOM model so that regional-scale transports can be linked to small-scale coastal and bay circulations.

- Contrary to expectations, a study of the distribution and condition of coral communities on patch reef habitats does not show any substantial impact from the outflow of lower-quality water from Florida Bay and Biscayne Bay and from land-based sources of pollution in the Florida Keys.

- The development of hypersalinity in Florida Bay was found to be caused by the combination of reduced fresh water inputs during the dry season combined with weak basin water renewal rates. Hypersalinity could be greatly reduced by relatively modest diversions of fresh water to Whipray basin during dry seasons.

- A study of persistent organic pollutants (POPs) in the skin of bottlenose dolphins (*Tursiops truncatus*) in Biscayne Bay shows a very large gradient with the highest concentrations found in dolphins living in the northern Biscayne Bay where human impacts are greatest.

- Using hydro-acoustic technology, we have carried out an assessment of grouper-snapper spawning aggregations on the Puerto Rico and US Virgin Island shelves. This work will enable better management actions (i.e. the establishment of temporal or spatial marine protected areas) and facilitate sustainable fisheries.

- Feeding-hook tests show that the incidental capture and mortality of sea turtles, an endangered species, by pelagic longline fishing gear can be greatly reduced by making relatively simple changes in hook bait practices and in hook design.

- Long-term monitoring of the Deep Western Boundary Current and the Florida Current show that there has been little change over the past 20 years. This suggests that there has been no appreciable slowdown of the circulation.

- The South-East Climate Consortium has developed methodologies to identify ENSO-related climate variability patterns in temperature and precipitation and to use these to quantifiably predict agricultural impacts and to make forest-fire forecasts in the Southeast US.

- Many field programs in South Florida were adversely impacted by the intense hurricane activity in 2005 which resulted in the damage or complete destruction of much monitoring equipment. On the other hand, the equipment that did survive provides a unique picture of the impact of hurricanes on the ecosystem.

CIMAS MISSION AND ORGANIZATION

CIMAS, the University, and NOAA

The Cooperative Institute of Marine and Atmospheric Studies (CIMAS) is a research institute at the University of Miami in the Rosenstiel School of Marine and Atmospheric Science (RSMAS). CIMAS is sponsored jointly by the University of Miami and the National Oceanic and Atmospheric Administration (NOAA) through NOAA's Office of Oceanic and Atmospheric Research (OAR), a line office in NOAA also known as "NOAA Research". CIMAS was established in 1977 through a Memorandum of Understanding between NOAA and the University of Miami. It is one of thirteen such Cooperative Institutes nationwide.

The CIMAS Vision

- *To become a center of excellence in Earth Systems Science and the human interactions with the Earth System;*
- *To serve as a means of using this knowledge to improve and protect our environment and to use it more effectively and benevolently;*
- *To convey this knowledge to the public through education and outreach.*

The CIMAS Mission

- *To conduct research in the terrestrial, ocean, and atmospheric environment within the general context of NOAA's mission;*
- *To focus on the physical, chemical, and biological interactions between and among these environments;*
- *To understand the role of humans in affecting these environments and the impact of the changes in the environment on humans;*
- *To facilitate and participate-in education programs that are grounded in advanced Earth System Science.*

How CIMAS Carries Out Its Mission

CIMAS serves as a mechanism to promote synergisms between University scientists and those in NOAA. Most of our research is related to programs in OAR and in the National Marine Fisheries Service (NMFS). Most activities in CIMAS are associated with research programs at the local NOAA Atlantic Oceanographic and Meteorological Laboratory (AOML) and the Southeast Fisheries Science Center (SEFSC) both of which are located on Virginia Key in close proximity to the CIMAS/RSMAS campus.

CIMAS addresses issues of national interest within the context of NOAA's missions of environmental prediction and stewardship. CIMAS accomplishes this:

- *By fostering joint projects between University of Miami scientists and those employed at the NOAA laboratories;*
- *By providing a mechanism for engaging undergraduate students, graduate students and post-doctoral fellows in the research at these laboratories;*
- *By arranging for short-term visiting specialists to enhance the general effort in relevant research areas through short term consultations and seminars or by arranging for their involvement in ongoing projects for longer time periods;*
- *By providing training for personnel in various areas of research in marine and atmospheric science.*

CIMAS enhances NOAA-University cooperation and thus promotes both the quality and attractiveness of the local NOAA laboratories as a scientific working environment. It also serves to increase the breadth of University activities in research areas that are complementary to NOAA's mission.

The Link between CIMAS Research and NOAA Goals

CIMAS research and its scientific objectives are guided by the general objectives of NOAA's *Strategic Plan for FY 2005-2010*. NOAA identifies four mission goals:

1. *Protect, restore and manage the use of coastal and ocean resources through ecosystem-based management.*
2. *Understand climate variability and change to enhance society's ability to plan and respond.*
3. *Serve society's needs for weather and water information.*
4. Support the Nation's commerce with information for safe, efficient, and environmentally sound transportation.

NOAA's Mission Goals are consistent with the broader mission of CIMAS in the Earth System Sciences. Each research project in CIMAS is associated with a specific NOAA mission goal.

The Administration and Governance of CIMAS

The organization of CIMAS is designed to reflect the joint interests of the University and NOAA in carrying out the CIMAS Mission. In accordance with the MOU, the Director of CIMAS must be a faculty member of the University. Many aspects of the governance of CIMAS are dealt with in consultation with the CIMAS Fellows who act much like a Board of Directors. Fellows are scientists of established national or international standing who hold regular teaching or research faculty appointments in the University or who are staff members of NOAA. The Fellows play an important role by providing guidance to the Director of CIMAS in matters regarding the promulgation of research programs. One of the Fellows' most important tasks is to work on the development of CIMAS activities that benefit both University and NOAA research objectives.

CIMAS activities fall into four Task categories. The administrative functions of CIMAS are carried out under Task I with funding provided by both the University and NOAA. Most research activities are carried out under Task II wherein CIMAS provides highly specialized research scientists who work on research projects carried out in NOAA's Miami laboratories. The expertise of these CIMAS employees complements that present in NOAA and the University. CIMAS employees provide support that is essential to the success of specific activities or projects under the collaborative research themes of the Institute.

Research programs in CIMAS are carried out under Task III and Task IV. These provide funds to University faculty and scientists to support research on CIMAS themes. Support for specific projects under these tasks is based on proposals submitted to specific NOAA units or to programs in response to a general announcement of opportunity. Task 3 encompasses activities of CIMAS scientists that are carried out in cooperation with NOAA laboratories in Miami and elsewhere. Under Task 4 are projects that support or complement the NOAA mission but which are not directly linked to activities in NOAA laboratories

PERSONNEL

Distribution of Personnel

CIMAS personnel participate in a wide range of NOAA-related activities. During FY 2005-2006 a total of 106 persons were involved with CIMAS in various capacities. Of these, 83 received over 50% of their support from NOAA sources. Table 1 shows the distribution of personnel by category and by their association with the local NOAA laboratories. Of the 106 who received NOAA support, 54 are associated with AOML and 42 with SEFSC.

Table 1: CIMAS Personnel 2005 – 2006
Personnel

Category	Number	BS	MS	PhD
Research Associate/Scientist	43	18	18	7
Visiting Scientist	7			5
Postdoctoral Fellow	6			6
Research Support Staff	22	8	3	3
Administrative	5			2
Total (> 50% NOAA support	83	26	21	23
Undergraduates Students	12			
Graduate Students	11	4	7	
Part Time (L<50% NOAA Support	2			
Location of Lab	54-AOML 42-SEFSC			
Obtained NOAA employment within the last year	1			

Research Associates/Scientists are those employees under Task 2 who work closely with the local NOAA laboratories. There has been a steady growth in Task 2 personnel in the middle and late 1990s. During the first three years of the current Cooperative Agreement Task 2 personnel levels had remained relatively steady – about 34. In FY 4 the number increased sharply to 44. In FY 5, the total is essentially the same, 43.

CIMAS Research Associates/Scientists are hired into a well-delineated series of categories that allow for professional advancement in the research ranks. There is a sequence of five positions targeted for advanced technical or scientific staff who are required for the support of research activities at the University. Advanced education, continuing professional achievement, and/or increased experience are the basis for advancement to a higher-level position. The progression order is: Research Associate, Senior Research Associate, Assistant Scientist, Associate Scientist, and Scientist. The "Scientist" ranks (Assistant Scientist, Associate Scientist, Scientist) are structured to parallel those of the research faculty at the University (i.e., Assistant Research Professor, Associate Research Professor, Research Professor).

There are a total of 6 Postdoctoral Fellows. Postdocs have become an important part of the CIMAS employee pool during the current Cooperative Agreement with numbers usually in the range of 7 to 9.

Research Support Staff are temporary employees, hired for the duration of specific projects. These include persons from a variety of backgrounds including local high schools as a part of outreach programs.

It should be noted that although CIMAS has the status of a division in the School it has no faculty. School faculty participate in CIMAS activities in many ways, but they hold their primary appointment in one of the School academic divisions. These faculty are not counted in the listing of persons associated with CIMAS except for those who serve as Fellows. Similarly, graduate students who work on CIMAS programs have their primary affiliation with an academic division which has the ultimate responsibility for overseeing the students' academic performance and the granting of degrees.

CIMAS Fellows

Many faculty participate in CIMAS as Fellows who play a role in the governance of the Institute. At present there are 21 CIMAS Fellows. In addition to the regular members of the Fellows, there are three *ex officio* members, the Dean of RSMAS (O. Brown) and the directors of the two local NOAA laboratories (P. Ortner, AOML; N. Thompson, SEFSC). A list of the CIMAS Fellows membership is shown in the *Fellows* section of this report along with their affiliation. At present 13 Fellows are from RSMAS and 8 from the local NOAA laboratories.

CIMAS Staff

CIMAS staff consists of the Director, Dr. Joseph M. Prospero, and the Associate Director, Dr. Claes Rooth, and three administrative personnel. Both Prospero and Rooth hold their primary appointments in School academic divisions. Dr. Rooth retired from the School at the end of the academic year, thus completing almost 30 years as a member of CIMAS. He was one of the original founding members of CIMAS in 1977. Taking the position of Associate Director is Dr. David Die a member of the Division of Marine Biology and Fisheries. Dr. Die has worked with CIMAS for many years and serves as a Fellow. He is also the Director of the Cooperative Unit for Fisheries Education and Research (CUFER) a unit with CIMAS that is closely associated with NMFS research activities.

Transition to Federal Positions

During the past year one CIMAS employee assumed position as a Federal Employee in the local NOAA laboratories. Since the start of the current Cooperative Agreement a total of eight have assume Federal positions in the local laboratories.

Demographics of CIMAS Employees

The employees in the Research Associate and Research Scientist ranks have a rather diverse demographic profile. The population is 39% female. Foreign-born individuals make up 43% of the personnel; of these Hispanics make up 25% of the ranks; Asian and Pacific Islander, 12%. Only 1 African-American has been recruited, despite our efforts to expand this demographic. The population of CIMAS is relatively young with an average age of 36. The largest age group are in their 30s, with a total of 22.

CIMAS FUNDING

General Funding Trends

In FY 5, funds from all NOAA sources totaled $7,018,367. A summary of CIMAS funding under the four Tasks in FY 5 is shown in Table 1 along with funding under the first four years of the Cooperative Agreement. The history of Total NOAA funding is shown graphically in Figure1. Total funding in FY 5 ($7,018K) was somewhat below FY 4 ($8,346K), and almost identical to FY 3. Nonetheless, the total for FY 5 was considerably above the average for the first two years of the CA ($5,750K) and a little above the average for the five year period as a whole ($6,790K).

Table 1: CIMAS Funding from NOAA Sources Under the Cooperative Agreement

	Task I	Task II	Task III	Task IV	Total
Year 1	1,620	1,434	2,604	320	5,978
Year 2	1,381	2,059	1,444	625	5,509
Year 3	700	2,435	3,548	413	7,096
Year 4	1,847	2,701	2,853	945	8,346
Year 5	1,133	2,527	2,683	675	7,018

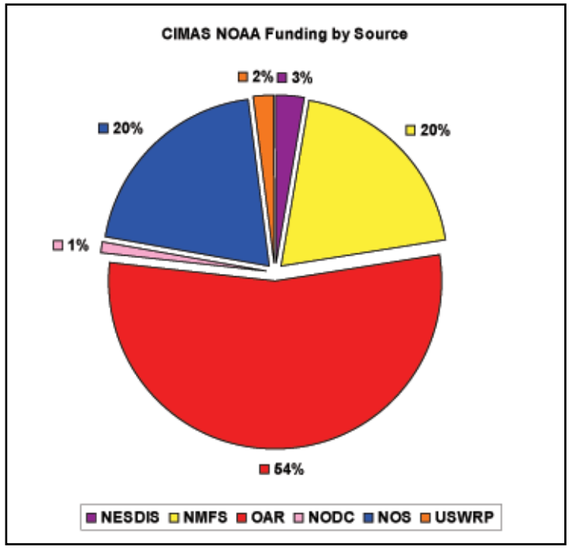


Figure 1: CIMAS funding from NOAA sources

The sources of funding are shown in Figure 2. OAR is clearly the dominant source, providing 54% of the total funds; NMFS was second at 20%. Of the total OAR funding, 43% comes from the Office of Climate Programs.

Over the course of the Cooperative Agreement, on average about 90% of CIMAS funds has come from four NOAA sources: OAR, NMFS, NESDIS, NOS. Figure 3 shows the trends in funding from these major sources. In the graph, OAR funding is divided in two parts: funding from OGP/CPO, the competitive grants program in OAR, and funding from all other OAR sources. The OGP/CPO funding history shows no overall trend: the funding level in Year 5, $1644K, is close to the five year mean, $1,516K. In contrast OAR-Other shows a large change. Funding

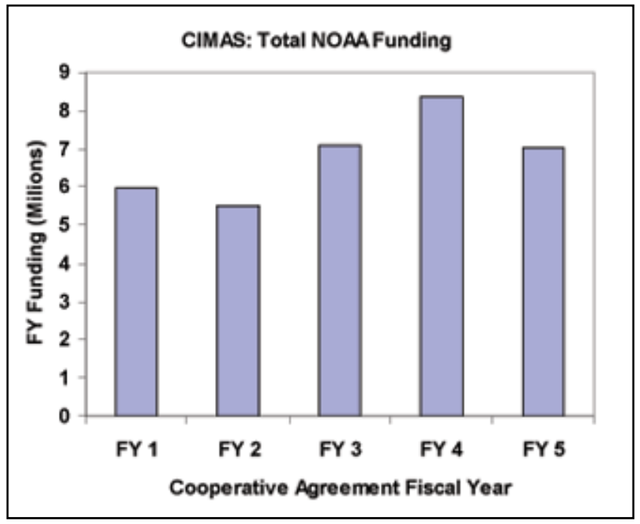


Figure 2: Funding by NOAA Line Office Source

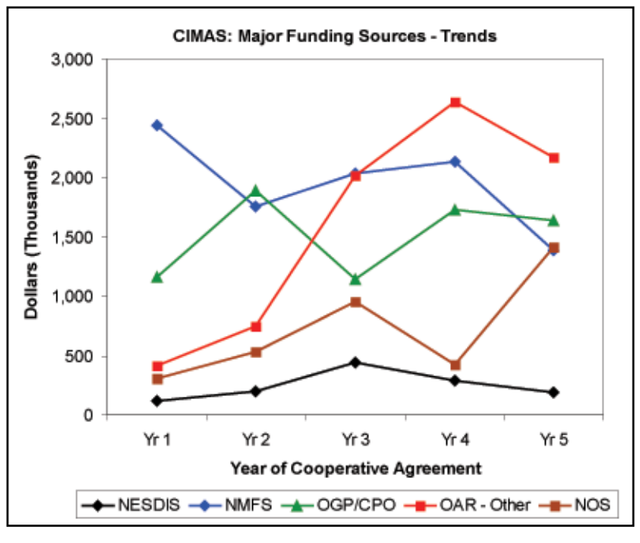


Figure 3: Trends in funding from the major NOAA sources under the current Cooperative Agreement

started at low levels, increased sharply in Yr 3, reached a maximum in Yr 4, and declined somewhat in Yr 5. The average for the past three years, $2274K, is four times larger than the average of the first two years, $579K. This strong growth is due to increased research funding form OAR sources other than OGP/CPO and to the strong growth in funding of research employees in CIMAS, see Task 2 below.

Funding Trends by Task

CIMAS activities are administratively grouped under four distinct Tasks that are related to different aspects of the CIMAS mission.

- **Task 1** provides the administrative structure for the Institute and includes support for limited-term postdoctoral research associates, graduate students and limited-term collaborating research scientists from outside Miami. The University contributes to the administrative support of CIMAS in its role as a Division in the School. Task 1 also provides travel expenses and honoraria for short-term visits by scientists. CIMAS has an active Visiting Scientist program.
- **Task 2** provides support for highly specialized research scientists who are employed by CIMAS to complement existing expertise at NOAA and the University in the collaborative research themes of the Institute.
- **Task 3** and **Task 4** encompass the directed research programs of CIMAS. These provide support for research in CIMAS themes by University faculty, scientists and students. Task 3 encompasses activities of CIMAS scientists that are carried out in cooperation with the personnel at the local NOAA laboratories in Miami. Under Task 4 are projects that support or complement activities at NOAA laboratories other than those located in Miami. The indirect cost rates for these two tasks differs in recognition to the direct funding support that CIMAS receives under Task 1 from the local NOAA laboratories.

The history of Task 1 funding under the Cooperative Agreement is presented in Figure 4. Year 5 shows

a sharp decrease over Year 4 which was high because of a large number of postdoctoral fellows who were employed under Task 1. Postdoctoral fellows are now being employed under Task 2. Nonetheless Year 5 is roughly comparable to the mean for the five years of the Cooperative Agreement, $1,335K.

The School contributes to the funding of administration costs under Task 1. In Year 5, the contribution was $0.204M, 18% of the total Task 1 activities.

The distribution of NOAA Task 1 funding is shown in Figure 5. The total Task 1 budget, $1.134M, does not reflect the $0.204M contribution from the UM to Task 1 which is used primarily to support the salaries of staff. The largest expenditure, 30%, is Temporary Staff, persons hired on a temporary basis to support research. "Other" (26%) includes: travel associated with Task 1 scientists, students, visitors; also new-hire expenses, consulting agreements, and supplies.

The history of funding for the Research Associate/Scientist program (Task 2) is shown in Figure 6. There was strong and steady growth in Task 2 over the first four years of the Agreement, a reflection of the growth of research personnel in CIMAS. This growth now appears to have leveled off, stabilizing since FY3 at an annual rate of $2.5M.

The history of NOAA-supported research funding (Task 3 and Task 4 combined) is shown in Figure 7. Research funding in Year 5 is somewhat lower than the previous two years although still substantially higher that in the first two years of the Cooperative Agreement.

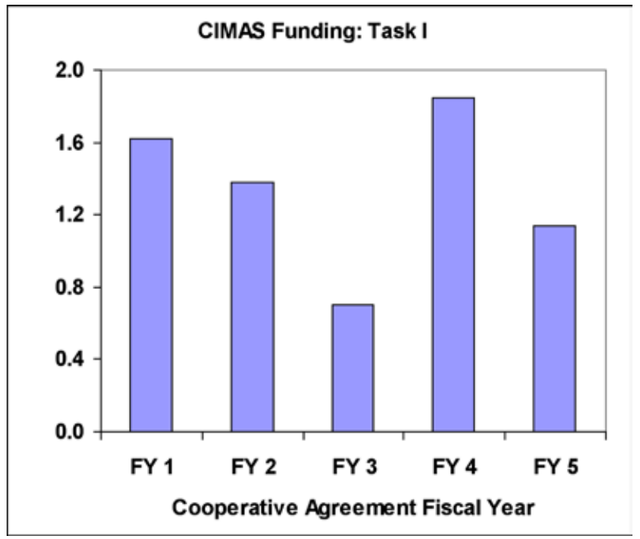


Figure 4: History of Task 1 Funding

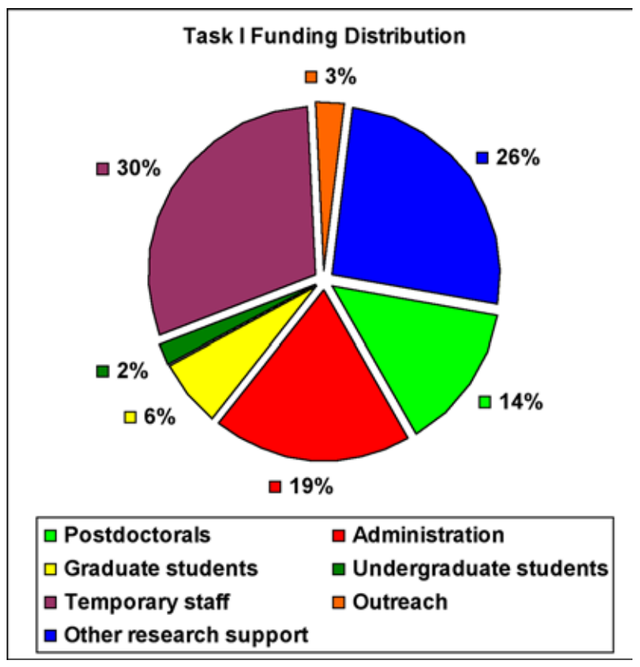


Figure 5: Distribution of Task 1 Funding

Funding By Theme

Figure 8 shows the percentage of Task 3 and Task 4 funding that is expended in the CIMAS Themes. Over half of CIMAS research funds are expended under Theme 1: Climate Variability. Second is Theme 3: Regional Coastal Ecosystem Processes, reflecting activities in the large effort associated with the South-Florida Everglades Restoration. Theme 2: Fisheries Dynamics, is a close third.

The distribution of research funding by Theme as shown in Figure 8 is based on the scientists' own assessments of the major focus of their research. Some research could reasonably be assigned to more that one Theme, e.g., much research under Theme 1: Climate Variability also could be assigned to Theme 5: Air-Sea Interactions and Exchanges. Indeed, many scientists reported more than one Theme for their research. The allocation used here based on their assessment of the Theme of primary relevance.

Note that this figure only shows the distribution of funding under Theme 3 and Theme 4; it does not show the funding that supports Task 2 personnel, many of whom carry out research in the local NOAA laboratories in programs that fall under the CIMAS Themes.

In this report we have detailed research expenditures made through CIMAS. We emphasize once again that there are a substantial number of research programs carried out by RSMAS faculty that are complimentary to the NOAA-supported CIMAS-linked programs but supported by other agencies. The grants obtained by these faculty are credited to the academic division in which they reside. Consequently there is considerable leveraging of NOAA funds across the campus which does not show up in the present accounting.

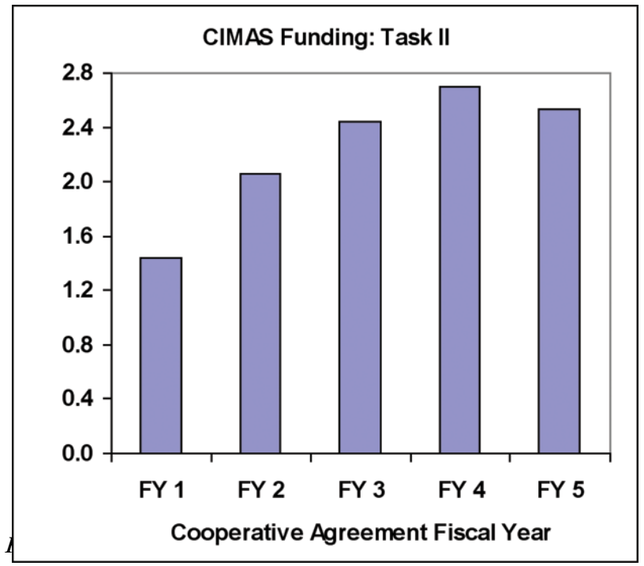


Figure 6: History of Task 2 Funding

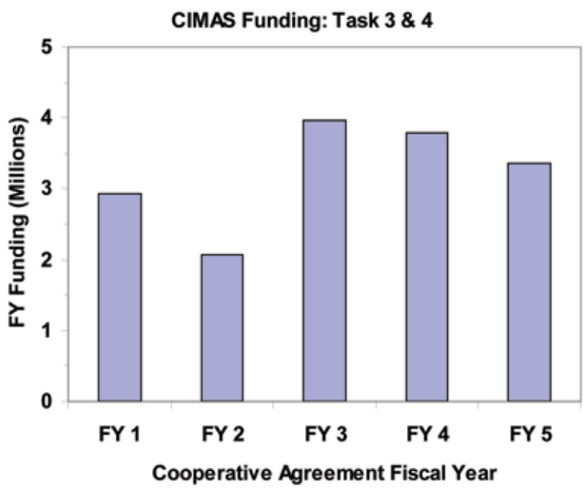


Figure 7: History of Task 3 & 4 Funding

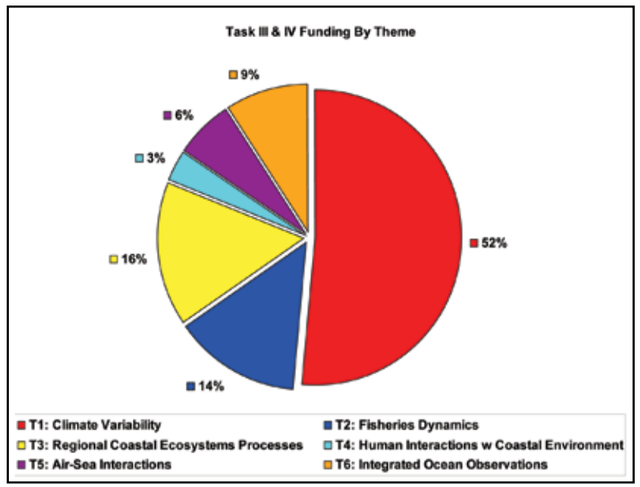


Figure 8: Percentage of Task 3 and Task 4 (Research) funding in the CIMAS Themes

RESEARCH THEMES OVERVIEW

Organization of CIMAS Themes

Scientific activities in CIMAS are organized under broad Research Themes. The selection of Theme topics is guided by the major environmental issues that confront our Nation today. The Themes and their scientific objectives complement those in NOAA's Strategic Plan. Specific goals are set in the context of the research activities and expertise resident in the University and the local Miami laboratories of NOAA. Under the current Cooperative Agreement, scientific activities in CIMAS are carried out under six themes.

Theme 1: Climate Variability
Theme 2: Fisheries Dynamics
Theme 3: Regional Coastal Ecosystem Processes
Theme 4: Human Interactions with the Environment
Theme 5: Air-Sea Interactions and Exchanges
Theme 6: Integrated Ocean Observations

Theme 1: Climate Variability

- ***Investigate the dynamics of the ocean and the atmosphere and the ways in which they interact on interannual and longer-scales and they link to climate variations.***

The major challenges in climate research are to accurately characterize climate variability on time scales ranging from weeks to centuries, to detect trends in climate, and to identify the factors causing those changes, especially those deriving from human activities. Theme 1 research focuses on climate variations that occur on an interannual-to-longer time-scale. The objective is to understand the dynamics of oceanic and atmospheric processes that affect climate variations. The ultimate goal is to increase our capability to predict climate through the use of models.

The CIMAS program includes: process-oriented field programs involving ships, aircraft, and satellite systems; to climate-oriented long-term observations of oceanic transport processes; the systematic analysis of environmental data sets; modeling of weather and climate. These efforts contribute to the development of climate-prediction capabilities and to the assessment of climate change.

RSMAS pursues a vigorous program in atmospheric and ocean chemistry as related to climate processes and their variability. Research is underway with on the role of chemistry in radiative energy transfer processes by direct effects as well as by indirect aerosol effects that involve the modification of oceanic cloudiness. Recently RSMAS has expanded its research capability in tropical meteorology with a strong focus on tropical cyclones and hurricanes.

Because climate and climate variability are fundamentally global-scale phenomena, CIMAS research activities often involve strong interactions with the national and international research communities. To this end, CIMAS plays a role in fostering international cooperation. The major focus is with individuals and institutions in Latin America in the area of tropical air-sea interaction and in Europe with regard to research into the climatic role of the subtropical and tropical Atlantic circulation.

Theme 1 activities contribute to NOAA Mission Goal 2: Understand climate variability and change to enhance society's ability to plan and respond.

Research in this theme is consistent with three NOAA Mission Strategies:

- ***Monitor and observe the land, sea, atmosphere, and space and create a data collection network to track Earth's changing systems.***

- *Understand and describe how natural systems work together through investigation and interpretation of information.*
- *Assess and predict the changes of natural systems, and provide information about the future.*

Theme 2: Fisheries Dynamics

- ***Enhance our understanding of fisheries and ecosystem dynamics so as to improve the management of fisheries and marine protected species.***

Many ocean fisheries are undergoing rapid change, some due to natural variability and others due to human activities – over-fishing, the destruction and polluting of coastal habitats, climate changes resulting from greenhouse gases. While these issues are complex, in many cases it is clear that heavy fishing pressures, both recreational and commercial, are a major factor. The main objectives of Theme 2 are to enhance our understanding of fisheries dynamics so as to foster better fisheries management, and to provide educational opportunities in this area of research.

CIMAS has a long history of research that focuses on applications of prediction models to specific fisheries. Recently emphasis has shifted to the development and use of risk assessment methods that take into account the role of uncertainty in our understanding of ecosystem and fishery dynamics and the impact of uncertainty in the management process.

The current emphasis on rational management of fishery resources is coincident with an increasing demand for these resources, often in the face of declining fish catches. Emphasis is also placed on proper management of marine protected species. Analysis has shown that there are fundamental constraints on our knowledge of fisheries systems in the context of marine ecosystems. In particular, theoretical models are mostly based on hypothesized relationships among the various components of marine ecosystems, including exploitation by humans. Most models are still in the development stage and they have limited ability as forecasting tools.

Many activities related to this theme are carried out in a sub-unit in CIMAS, the Cooperative Unit for Fisheries Education and Research (CUFER). CUFER was established in 1992 in response to a need for the development of methods for improved quantitative assessment of fish populations and as a source of advice for resource sustainability. CUFER offers the opportunity to work on research issues with long-time horizons, an advantage afforded by academic research. An important ancillary component of CUFER is to develop the human resources and expertise needed for the future research and management of Florida and Caribbean fishery resources. However, the results from this program are also broadly applicable to tropical and subtropical fisheries all over the world.

Another fisheries-related unit housed in CIMAS is the Center for Independent Experts (CIE) established in 1998. The primary function of CIE is to organize and facilitate independent peer reviews of stock assessments carried out by the National Marine Fisheries Service (NMFS). Under this program, CIE arranges for the solicitation and selection of qualified scientists who carry out reviews of ongoing and completed assessments and who serve as independent experts on advisory panels and working groups.

Theme 2 activities contribute to NOAA Mission Goal 1: Protect, restore and manage the use of coastal and ocean resources through ecosystem-based management.

Research in this theme is consistent with three Mission Strategies as related to fisheries research:

- ***Monitor and observe the land, sea, atmosphere, and space and create a data collection network to track Earth's changing systems.***
- ***Understand and describe how natural systems work together through investigation and interpretation of information.***
- ***Assess and predict the changes of natural systems, and provide information about the future.***
- ***Manage coastal and ocean resources to optimize benefits to the environment, the economy, and public safety.***

Theme 3: Regional Coastal Ecosystem Processes

- ***Carry out research on the ecological health of coastal ocean ecosystems in the Southeast U.S so as to lead to better management strategies.***

South Florida is beset with a broad range of environmental problems that are the result of many decades of intense development in this fragile subtropical environment, unique in the continental United States. Because of the unique character of the region and the widely-diverse and closely-linked terrestrial and aquatic ecosystems, new strategies are required to address these issues. To this end Theme 3 focuses on the development of a scientific framework that links the multitude of special problems and scientific studies across the region.

A major part of the research in Theme 3 is carried out in the context of the South Florida Ecosystem Restoration initiative, a program that seeks to reverse the damage caused by the rapid growth in this region. Legislation passed by Congress several years ago has already allocated over ten billion dollars for this effort which will take place over several decades. CIMAS and NOAA's Miami laboratories are playing a central role in this program. Research activities under Theme 3 include:

- ***Observations and analyses of atmospheric and ocean chemical and physical variability and their impact upon the health of the regional coastal ocean.***
- ***Observations and modeling to elucidate how indigenous biological populations and communities respond to the unique physical and chemical environment of South Florida.***
- ***Special integrated studies of critically-stressed or keystone components of the South Florida coastal ecosystem.***
- ***Development of theories and methodologies necessary to understand the biological, ecological and oceanic variables controlling and regulating South Florida coastal fisheries populations, their food sources and their habitat.***

The activities under Theme 3 bring together local management expertise and experience so as to provide analytical tools - models and techniques - for making timely and informed assessments of the combined effects of natural processes and restoration-related actions upon the regional coastal ecosystem. Such tools are essential for the informed management of regional coastal ecosystem resources.

Theme 3 activities contribute to NOAA Mission Goal 1: Protect, restore and manage the use of coastal and ocean resources through ecosystem-based management. They also contribute to Mission Goal 3: Serve society's needs for ... water information.

Research in this theme is consistent with Mission Strategies dealing with coastal ocean processes and their impact on fisheries and other aspects of the coastal environment.

- ***Monitor and observe the land, sea, atmosphere, and space and create a data collection network to track Earth's changing systems.***
- ***Understand and describe how natural systems work together through investigation and interpretation of information.***
- ***Assess and predict the changes of natural systems, and provide information about the future.***
- ***Manage coastal and ocean resources to optimize benefits to the environment, the economy, and public safety.***
- ***Study how humans interact with the environment so as to lead to better policy making.***

Theme 4: Human Interactions with the Environment

- ***Study how humans interact with the environment so as to lead to better policy making.***

Theme 4 highlights the role of human systems in environmental decision making. Studies of these human interactions range from assessing societal risks from natural hazards to considering how population growth and land use changes may affect the health of ecosystems. Humans shape natural systems and are shaped by them. Examples are climate change, the utilization of marine resources, and the urbanization of coastal regions. The inter-dependence of humans and ecosystems makes human interactions a topic of interest to

environmental managers as well as to stakeholders and the scientific community.

Researchers use ***integrated assessments*** to study and resolve the complex dynamics of overlapping human and natural systems. This approach goes beyond synthesizing and advancing what is known about a problem - it also ensures that the results are relevant to society. It is the interplay of natural and human systems that creates problems for resource managers and opportunities for stakeholders.

There are three distinct foci in Theme 4:

- ***Human dimensions of climate change and variability*** - to improve our understanding of how social and economic systems are currently influenced by climatic fluctuations, and how human behavior can be affected by using our gained knowledge about variability in the climate system, for example, by using El Niño forecasts in agriculture.
- ***Sustainable use of the world's fisheries*** - to quantify the impact of human exploitation of fisheries and marine ecosystems so that these can be better managed.
- ***Urbanization of the Coastal Zone*** - to assess coastal zone impacts and to identify the dominant ecological risks including habitat alteration, hydrological alteration, and the over-exploitation of natural resources. Half the nation's population lives on coastal lands which comprise only 17% of the total land area. This research leads to the development of new analytical tools with which to identify problems, to characterize sources of environmental degradation, and to monitor progress towards restoration.

Theme 4 activities contribute to NOAA Mission Goal 1: Protect, restore and manage the use of coastal and ocean resources through ecosystem-based management. Also, Mission Goal 2: Understand climate variability and change to enhance society's ability to plan and respond.

Research in this theme is consistent with all five Mission Strategies as related to the human dimensions of environmental change:

- ***Monitor and observe the land, sea, atmosphere, and space and create a data collection network to track Earth's changing systems.***
- ***Understand and describe how natural systems work together through investigation*** **and** ***interpretation of information.***
- ***Assess and predict the changes of natural systems, and provide information about the future.***
- ***Engage, advise, and inform individuals, partners, communities, and industries to facilitate information flow, assure coordination and cooperation, and provide assistance in the use, evaluation, and application of information.***
- ***Manage coastal and ocean resources to optimize benefits to the environment, the economy, and public safety.***

Theme 5: Air-Sea Interactions and Exchanges

- ***Understand the energy exchanges and interactions between the atmosphere and the oceans and the consequent effects on atmospheric and ocean mixing and circulation.***

The oceans are an important source of the energy that drives large-scale atmospheric circulations; conversely, the wind systems drive oceanic mixing and circulation. The interplay between the ocean and the atmosphere can result in large variations in global weather patterns as demonstrated by the impact of el Niño events. These interactions involve a wide range of properties such as air and sea-surface temperatures, humidity, wind speed, rainfall, salinity, mixed-layer depth, and heat content. Moreover the oceanic biogeochemical cycles can play a role in climate forcing: e.g., CO_2, halocarbons, aerosols. Air-sea exchange processes control the amount of these materials transported to the atmosphere and thus the degree to which these species can affect radiative processes and climate.

In CIMAS research on air-sea interactions focuses on processes in the atmosphere and the surface waters of the ocean including the oceanic mixed layer; this interaction is critically important in driving hurricane intensity changes. Our research also extends into maritime cloud climatology and to maritime weather system prediction including tropical cyclones and hurricanes. An equally important area of research focuses on the exchange and interaction between the atmospheric environment of the coastal urban complex

and the coastal marine atmosphere; the deposition of pollutants to coastal waters are known to have a substantial impact on coastal ecosystems. The ultimate objective of these various programs is to develop and test physical-chemical models of the atmosphere and ocean and the processes that couple them.

RSMAS has developed a strong program in air-sea interaction studies. University scientists work closely with AOML in research on *in situ* exchange processes and in the development of new instrumentation. Remote sensing techniques are playing an increasing role in studies of the marine boundary layer and the upper ocean including the interface.

Theme 5 activities contribute to NOAA Mission Goal 2: Understand climate variability and change to enhance society's ability to plan and respond.
Research in this theme is consistent with two Mission Strategies:

- ***Monitor and observe the land, sea, atmosphere, and space and create a data collection network to track Earth's changing systems.***
- ***Assess and predict the changes of natural systems, and provide information about the future.***

Theme 6: Integrated Ocean Observations

- ***Study the integration of modeling and physical measurements in the ocean and the atmosphere so as to achieve optimal designs of observing systems.***

The development of integrated observing systems such as the Integrated Ocean Observing System (IOOS) requires the interplay of numerical models and observing system networks so as to accurately and efficiently estimate the optimal fields of essential oceanic variables. Another objective is to develop the criteria for the acquisition of oceanic data needed to determine and document the role of the ocean in climate change and to monitor these changes.

Observational evidence indicates that the coupled air-sea system is undergoing dramatic changes - for example, increasing surface temperatures and the melting of the Arctic and Greenland ice caps. These changes will have a great impact on transport and mixing in the Atlantic. CIMAS investigators have a long history of tracking Atlantic thermohaline circulation, a major factor in climate variability over longer periods. We currently lack a good understanding of the time and space-scales of the factors that control Atlantic basin-scale and coastal ocean circulation. This requires continued observations in the Atlantic open ocean and coastal ocean and atmosphere coupled with numerical modeling.

The optimal observing system must accomplish several objectives. It must efficiently characterize climate variability and change in the presence of geophysical noise; it must provide a product that can support marine emergency and ecosystem-based management with physical transport estimates; and it must provide initialization, validation, and verification data for climate and ocean circulation forecast models. The design of ocean observing systems depends on the scale of the domain which ranges from global to regional to coastal, the processes of interest, and the application of the data that is to be obtained. The current direction of design studies is to carry out Observing System Simulation Experiments - OSSEs which can yield the optimal mix of *in situ* (Eulerian and Lagrangian) sensors, satellites, and other remote sensing observations. CIMAS and RSMAS scientists are currently involved in the development of OSSEs in conjunction with scientists in AOML.

Theme 6 activities contribute to NOAA Mission Goal 2: Understand climate variability and change to enhance society's ability to plan and respond. Also, Mission Goal 4: Support the Nation's commerce with information for safe, efficient, and environmentally sound transportation.
Research in this theme is consistent with three Mission Strategies:

- ***Monitor and observe the land, sea, atmosphere, and space and create a data collection network to track Earth's changing systems.***
- ***Understand and describe how natural systems work together through investigation and interpretation of information.***
- ***Assess and predict the changes of natural systems, and provide information about the future.***

RESEARCH REPORTS
THEME 1: CLIMATE VARIABILITY

Studies of Emissions, Transport, and Transformations of Reactive Organic Trace Gases During ITCT Missions

E. Atlas, X. Zhu and R. Lueb (UM/RSMAS)

Long Term Research Objectives and Strategy to Achieve Them:
Objectives: To understand the relationships between emissions of organic gases, their transport, and their atmospheric transformation to aerosols and oxidants that impact human health and climate.
***Strategy*:** To conduct coordinated ground-based and airborne measurements and modeling studies near and downwind of major regional urban emissions.

CIMAS Research Themes:
***Theme 1*:** Climate Variability (*Primary*)
***Theme 4*:** Human Interactions with the Environment (*Secondary*)

Link to NOAA Strategic Goals:
***Goal 2*:** Understand Climate Variability and Change to Enhance Society's Ability to Plan and Respond

NOAA Funding Unit: CGCP

NOAA Technical Contact: Kea Duckenfield

Research Summary:
The NOAA NEAQS-ITCT2004 study combined airborne measurements, ground and ship based studies and computer models to examine the impact of natural and anthropogenic activities on air quality and climate. The major scientific questions of the study included five themes:

- **Emissions verification** - How well do current inventories represent actual emissions for: cities, point sources, ships, and vegetation?
- **Transport and mixing** - What are the relative amounts of pollution imported to New England and exported from the continental boundary layer to the marine boundary layer and the free troposphere?
- **Chemical transformation** - How do gaseous and aerosol emissions evolve chemically and physically as they are transported away from the source regions to the remote atmosphere?

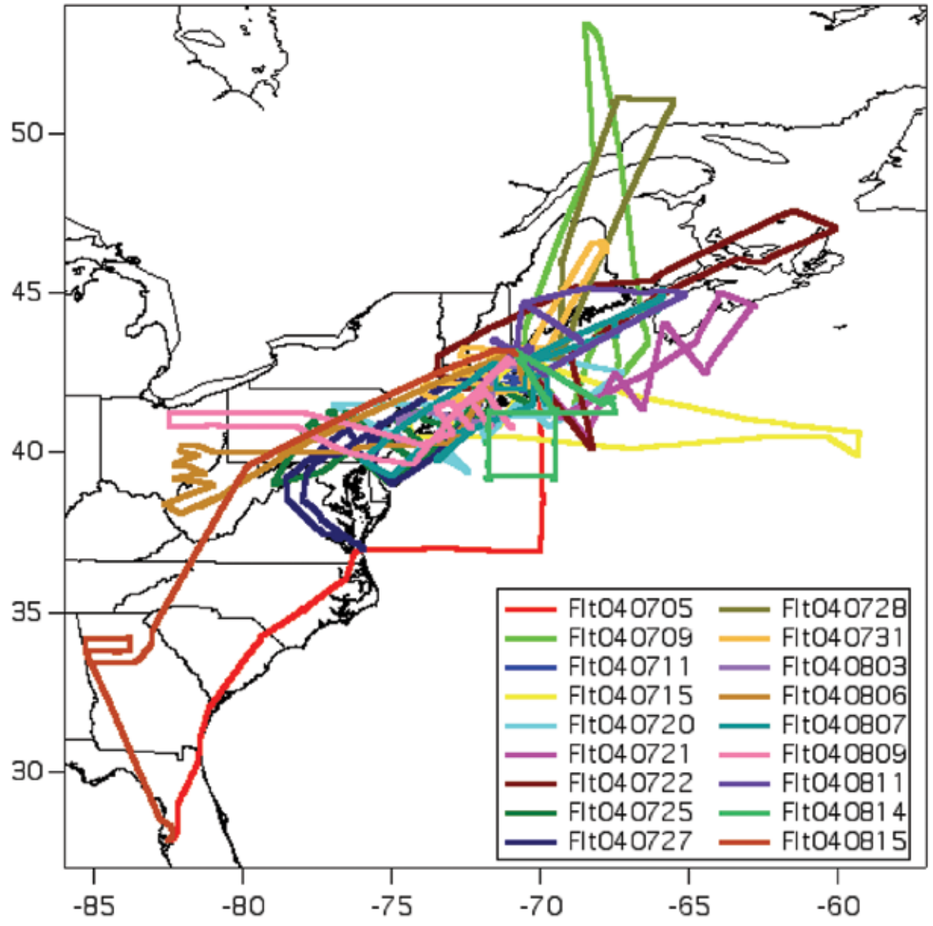


Figure 1: Flight tracks of the NOAA WP3-B aircraft during the NEAQS-ITCT 2004 mission.

- **Aerosol properties and radiative effects** - What are the chemical, physical, and optical properties of the regional aerosol and how do these properties affect regional haze and aerosol direct and indirect radiative forcing of climate?
- **Forecast** models - What is the current skill of air quality forecast models on local, regional and global scales and what improvements can be made to enhance the accuracy and extend the periods of these forecasts?

The main focus of our research was to measure a wide variety of atmospheric trace gases from the NOAA P-3B aircraft to help answer the questions above. The gases measured are volatile organic compounds (VOC) that include both primary emissions and secondary photochemical products. The gases measured provide a characteristic fingerprint of different source emissions that impact the chemical composition of airmasses in and downwind of the NE United States. These emission sources include anthropogenic activity (e.g. mobile emissions, industrial emissions, power generation, shipping), biomass burning, natural forest emissions, and emissions from the coastal ocean surface waters.

The flights of the P-3 aircraft (Figure 1) covered much of the NE US, including upwind areas of the Ohio valley and areas downwind of the major urban plumes of the NE (Boston/New York/Philadelphia/ Washington). The flights were conducted to investigate chemical processes that occur in the nighttime atmosphere as well as during normal daytime photochemical processing. A number of different investigations of the large data set are currently in progress.

One example of the use of VOC measurements to diagnose source contributions to the chemistry of the NE US region is related to quantifying biomass versus anthropogenic emissions. A major perturbations to the atmospheric chemical composition and aerosol properties over the NE US and southern Canada during the summer of 2004 was from Alaskan forest fires. VOC measurements from the P3-B (including both PTR-MS and canister VOC measurements) were used to examine the relative contributions of anthropogenic vs biomass burning emissions on the levels of carbon monoxide in the region. Using chloroform as a marker of urban sources, and acetonitrile as a marker of biomass burning emission, Warnecke et al. (2005) found that, on average biomass burning from boreal fires in Alaska elevated CO levels about 25% over background conditions (nominally 75 ppbv). Anthropogenic emissions, as expected, were found to add another 75% (on average) to the background CO concentration in the atmosphere over the NE US. (Figure 2). This contribution is less than predicted by computer models that utilize currently available emission estimates for CO in the NE US.

Research Performance Measure:
The research goals for this project were met successfully.

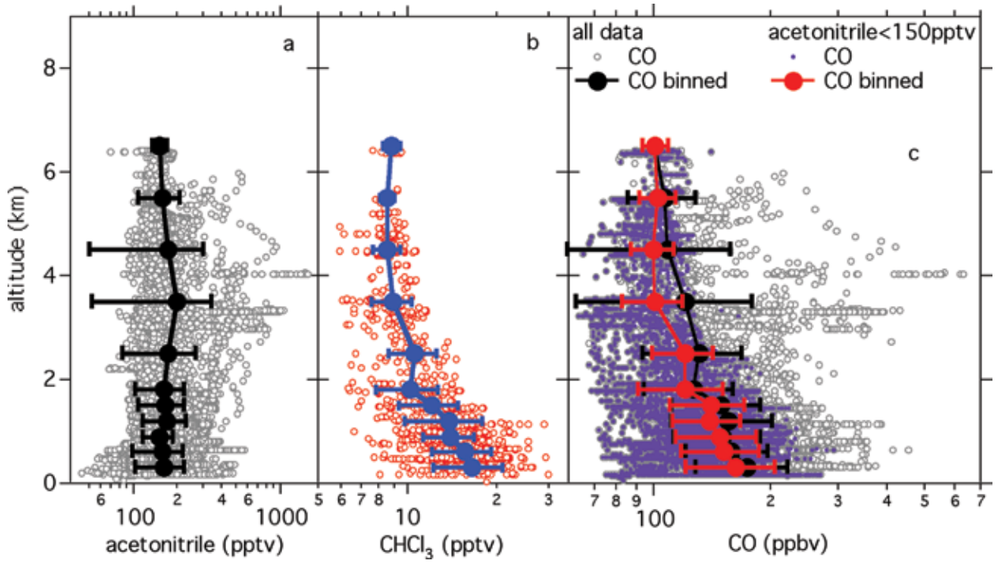


Figure 2: Vertical profiles of acetonitrile (a biomass burning marker), chloroform (an urban tracer), and carbon monoxide based on measurements from the P3-B aircraft. Filled circles are averages in each altitude bin, and error bars are the standard deviation. CO from urban sources is represented by the red trace. (from Warnecke, 2006).

Integrated Access to Pacific Regional Data Assimilation

E. Chassignet and A. Srinivasan (UM/RSMAS)

Long Term Research Objectives and Strategy to Achieve Them:
***Objectives*:** To develop a data and information web site with a regional focus on the Hawaiian Islands and American Flag Territories.
***Strategy*:** To use of the HYCOM consortium's data service and the PMEL Live Access Server as the data/ information source

CIMAS Research Themes:
***Theme 1*:** Climate Variability (*Primary*)
***Theme 6*:** Integrated Ocean Observations (*Secondary*)

Link to NOAA Strategic Goals:

***Goal 2*:** Understand Climate Variability and Change to Enhance Society's Ability to Plan and Respond (*Primary*)

***Goal 3*:** Serve Society's Needs for Weather and Water Information (*Secondary*)

NOAA Funding Unit: OAR/AOML

NOAA Technical Contact: Carlisle Thacker

Research Summary:
The overall aim of this project was to develop a data and information web site with a regional focus on the Hawaiian Islands and American Flag Territories. The web site provides integrated access to state-of-the-art data assimilation model outputs and related observations in support of both decision makers and researchers. The HYCOM Consortium participates in this effort as a data provider. The Hybrid Coordinate Ocean Model (HYCOM) consortium's data service (*http://hycom.rsmas.miami.edu/dataserver*) provides easy and fast access to near real-time HYCOM-based 1/12° ocean prediction system outputs through the Internet. The system typically makes available nowcast and forecasts within a day after the outputs become available. The data can be accessed using tools such as the Open Project for Network Data Access Protocol clients (OPeNDAP,*http://www.OPeNDAP.org*), the Live Access Server (LAS, *http://ferret.noaa.gov/Ferret/ LAS/*) and FTP. This system has been synergistically linked with the PRIDE Live Access Server (PRIDE-LAS) setup by the PMEL/TMAP group. Model outputs from HYCOM configured for the Pacific Basin at 1/12 degree resolution is now available from the PRIDE-LAS server can be accessed at http://apdrc.soest. hawaii.edu/PRIDE/ pride_projects.html (see Figure 1).

The PRIDE-LAS presents a uniform user interface for the comparison of HYCOM model-generated forecasts and for obtaining estimates of current ocean state against observations. HYCOM data can be visualized as maps, vertical sections, profiles, and time series. Data subsets may be viewed as tables of values or downloaded in various formats. Further, data may be averaged over regions in lat/long/depth/time and compared as overlays and anomaly plots. For scientists who wish to pursue further analysis with desktop tools such as Matlab or Ferret, the PRIDE-LAS provides HYCOM specific command scripts that ensure a seamless link from the PRIDE-LAS web browser environment to the desktop tool.

Access to HYCOM data is provided by an OPeNDAP aggregation server that has been setup at RSMAS, Univ of Miami. At this time, the data management and distribution is managed by Ashwanth Srinivasan who is responsible for obtaining the Ocean Prediction System Outputs from the Naval Research Laboratory at Stennis Space Center Mississippi, interpolating the data to standard depth levels, and converting the data from the native model format to the standard NetCDF format before making it available to the public. The PRIDE-LAS currently serves a HYCOM Pacific hindcast run for the year 2003. This run was configured as a place-holder pending the availability of the operational, real-time HYCOM output

for the region. Programs have already been developed for addressing the challenges of real-time updates to the data. Output form the near real-time system will consist of forecasts, nowcasts and hindcasts. The individual forecast, nowcast, and hindcast files will be aggregated logically into forecast, nowcast, and hindcast timeseries for each variable and will be presented as a single comprehensive dataset. This will enable easy access to the HYCOM data for PRIDE purposes. Scripts/Programs have been developed to automate this process end to end.

Further, HYCOM modeling consortium is actively collaborating with the PMEL/TMAP group, developers of LAS technology to provide nesting and downscaling services. The addition of these services to PRIDE-LAS will make it a useful tool for researchers for linking global/basin scale models to Pacific Island regional (including bio-geochemical) models.

Research Performance Measure:
All major objectives have been met and completion is pending the availability of the operational, real-time HYCOM output for the region.

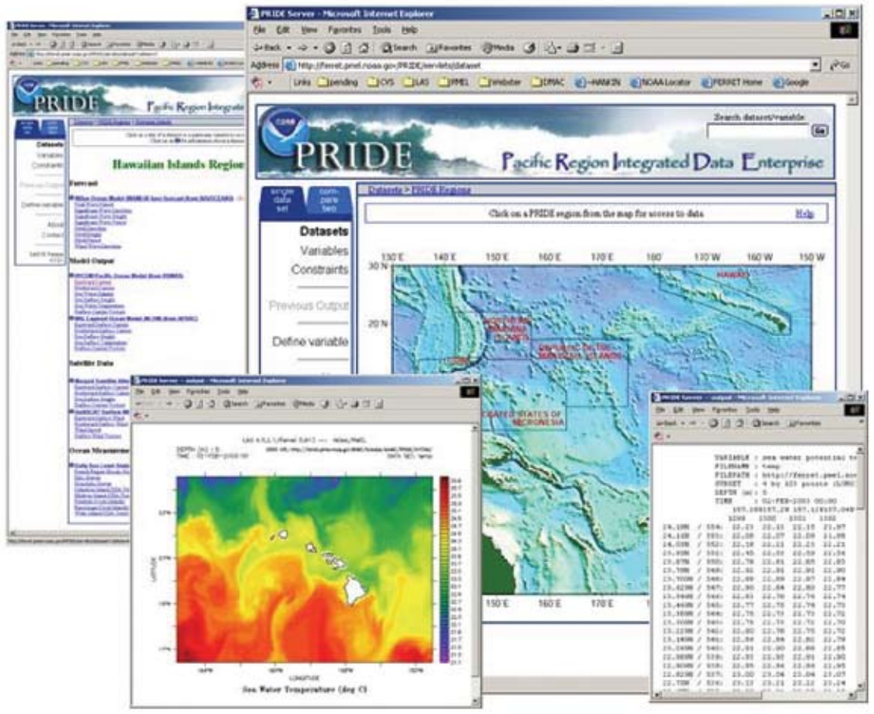


Figure 1: The PRIDE-LAS Server web interface

Investigating the Impact of the Saharan Air Layer on Tropical Cyclone Intensity Change

J. Dunion and J. Prospero (UM/RSMAS); S. Aberson, W. Barry, M. Black, N. Dorst, S. Feuer, J. Kaplan, P. Leighton, F. Marks, M. Powell and R. Rogers (NOAA/HRD); J. Hawkins (NRL/Monterey); C. Velden (UW/CIMSS)

Long Term Research Objectives and Strategy to Achieve Them:
Objectives: To understand how the Saharan Air Layer (SAL) affects Atlantic tropical cyclone (TC) intensity change in the North Atlantic Ocean and Caribbean; to investigate how the SAL affects the moisture climatology in the tropics.

Strategy: To develop satellite products for monitoring the SAL; to use NOAA's G-IV high altitude jet to investigate SAL/TC interactions.

CIMAS Research Theme:
Theme 1: Climate Variability

Link to NOAA Strategic Goals:

Goal 2: Understand climate variability and change to enhance society's ability to plan and respond (*Primary*)

Goal 3: Serve Society's Needs for weather and water Information (*Secondary*)

NOAA Funding Unit: OAR/AOML

NOAA Technical Contact: Mark Powell

Research Summary:
The SAL is a commonly-observed feature over the Tropical Atlantic during the summer and early Fall. The SAL is a deep, well-mixed, dry adiabatic layer that forms over North Africa. As this air mass emerges from the northwest African coast, it is undercut by the cool, moist marine layer to form a sharp inversion at the base; the top of the SAL is typically at about 5km altitude where it is capped by a second inversion.. The SAL is often associated with a mid-level easterly jet and it contains very dry air and high concentrations of African mineral dust. Our research over the past several years has shown that when the SAL engulfs tropical waves and TCs, it suppresses their development. The SAL's influence on tropical cyclones may be an important factor in the difficulty of forecasting TCs in the Atlantic. Also the effects of the SAL may also explain, in part, why there is relatively less TC activity in the Atlantic compared to the Pacific. Our research focuses on the possible mechanisms that could lead to this suppression. These could include the injection of dry air into the TC, the suppression of convection by the strong temperature inversion, and the presence of a mid-level easterly jet which brings strong vertical wind shear into the system. As a part of this effort several new satellite products were developed for tracking the SAL and its interactions with TCs. These products are now available in real-time at the University of Wisconsin-Madison/CIMSS tropical cyclone web site: http://cimss.ssec.wisc.edu/tropic/real-time/wavetrak/sal.html

Dunion has also led a field program (Saharan Air Layer Experiment - SALEX) to investigate the impact of the SAL on TCs and the possible mechanisms for this impact. See the SALEX web site: http://www.aoml.noaa.gov/hrd/project2005/sal.html. There were four SALEX missions using NOAA's G-IV high altitude jet during the 2005 Atlantic hurricane season. These flights included two missions in August that studied Tropical Storm Irene and the SAL, followed by two SAL missions in late September into an African easterly wave and pre-Tropical Depression 19. The objective of the 2005 flights and those planned for 2006 SALEX are: a) to sample the high gradient regions of moisture along the SAL's boundaries, b) to study the SAL's mid-level easterly jet along its southern periphery, c) to characterize intrusions of low humidity SAL air into the TC circulation and to observe how the SAL's vertical structure and moisture content change as the

SAL advects closer to the TC inner core. We also continue to assess the impact of the humidity data (which are not currently assimilated into the GFS) as part of an ongoing NOAA/Joint Hurricane Testbed project. An example of a G-IV SALEX flight track that was flown from Barbados to investigate the interaction of Tropical Storm Irene and the SAL is shown in Fig. 1 and a photo of vast amounts of Saharan dust suspended in the SAL on 27 September 2005 is shown in Fig. 2.

Research Performance Measure:
The program is on schedule as planned.

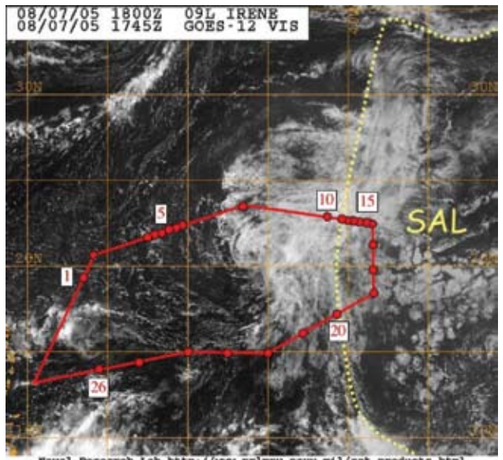


Figure 1: G-IV flight track for SALEX mission 050807n flown from Barbados on 07 August 2005. The flight track (red line) and GPS dropwindsonde drop points (red circles) were designed to sample the interaction between Tropical Storm Irene and the SAL. The dashed yellow line indicates the leading edge of the SAL.

Figure 2: Photo taken from the NOAA G-IV jet from ~45,000 ft. The photo was taken at ~1820 UTC at ~14°N 35°W during SALEX mission 050927n on 27 September 2005. Saharan dust can be seen as a milky white haze in the photo and is well below the flight level. Note also the suppressed convection.

Western Boundary Current Time Series project

R. Garcia, C. Fonseca, G. Rawson, P. DiNezio, N. Melo,
A. Stefanick, L. Gramer and G. Berberian (UM/CIMAS);
M. Baringer, C. Meinen, S. Garzoli and E. Johns (NOAA/AOML)

Long Term Research Objectives and Strategy to Achieve Them:
Objectives: To monitor the meridional overturning circulation through sustained time-series observations of the western boundary currents at 27°N.
Strategy: To use a wide range of observations - satellite, hydrographic, moored instruments and submarine-cable measurements - to study the Florida Current, Deep Western Boundary Current and Antilles Current systems.

CIMAS Research Themes:
Theme 1: Climate Variability (P*rimary*)
Theme 6: Integrated Ocean Observations (*Secondary*)

Link to NOAA Strategic Goals:

Goal 2: Understand Climate Variability and Change to Enhance Society's Ability to Plan and Respond

NOAA Funding Unit: OAR/AOML

NOAA Technical Contact: Christopher Meinen

Research Summary:
Variations in the transport of the Meridional Overturning Cell (MOC) in the Atlantic Ocean have been shown in numerical climate models to have significant impacts on the climate at both the international and local levels. Near 27°N in the Atlantic the southward deep flow of the MOC is contained primarily within the Deep Western Boundary Current east of Abaco Island in the Bahamas, although some fraction is also thought to transit near the Mid-Atlantic Ridge. The warm upper-limb of the MOC is principally carried by the Florida Current between the eastern Florida coast and the Bahamas, although the Antilles Current east of the Bahamas also carries some of the warm northward flow. Long-term observations of the Florida Current, Antilles Current and Deep Western Boundary Current are required in order to quantify the natural time scales of variability for these currents.

This project maintains NOAA's well-established and climatically-significant Florida Current volume transport time series. Over 24 years of daily mean voltage-derived transports have been obtained for the Florida Current using out-of-use and in-use telephone cables spanning the Straits of Florida. The cable voltages are converted to physically meaningful volume transport estimates (i.e. intensity of the flow) using electromagnetic induction theory and data from calibration sections.

This project also maintains repeated hydrographic sampling east of Abaco Island that has established a high-temporal-resolution record of water mass properties in the Deep Western Boundary Current near 27°N. Events such as the intense convection period in the Labrador Sea and the renewal of classical Labrador Sea Water in the 1980s are clearly reflected in the cooling and freshening of the Deep Western Boundary Current waters off Abaco, and the arrival of a strong pulse of Labrador Sea Water approximately 10 years later.

During the past year, the monitoring and data distribution systems for the Florida Current cable program have continued to see improvement, providing Florida Current transports in near real time via the web page www.aoml.noaa.gov/floridacurrent/. We recently collaborated with other researchers to produce a comparison between the transport fluctuations observed by the Florida Current cable system and those observed in a global ocean model run by at the Naval Research Laboratory, and a publication detailing the results was featured in EOS (Mooers et al., 2005). Cable voltages were also calibrated to obtain

heat transport time series of the Florida Current. Furthermore we completed two hydrographic cruises to monitor water mass changes along 26.5ºN east of Abaco Island in the Bahamas during the past year on the NOAA *R/V Ronald H. Brown*. The latter cruise involved recovering and redeploying an array of international moorings that is monitoring the net flow across 27ºN in the basin interior, the Meridional Overturning Circulation Heat-flux Array, as well as downloading data from three NOAA funded moorings via acoustic telemetry and recovering and redeploying two NOAA funded moorings. Calibration cruises for cable transport and water mass changes within the Florida Current were conducted on the University of Miami's *R/V Walton Smith* (5 cruises) and small sport fishing boats charter from Sailfish Marina in West Palm Beach (8 cruises).

Research Performance Measure:
All research goals were met during this year.

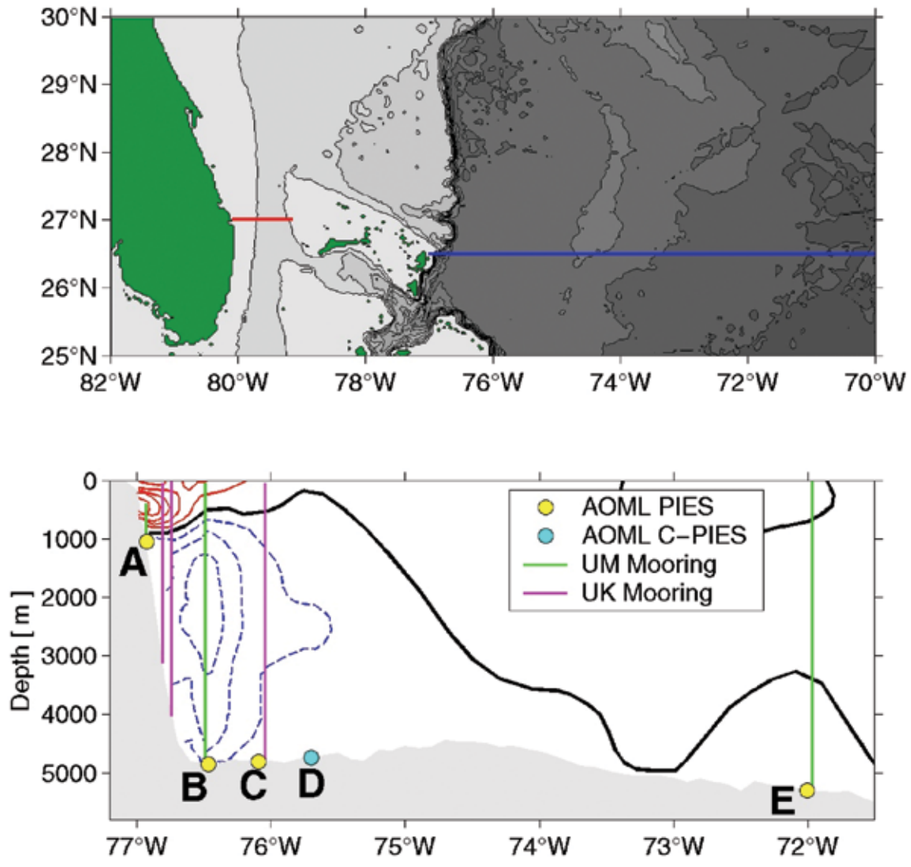


Figure 1: Upper panel – Location of the NOAA Florida Current cable (red line) and the section along which the IESs are deployed and where annual NOAA hydrographic cruises are completed (blue line). Lower panel – Locations of the NOAA IESs across the continental shelf and slope. Also shown are the locations of the tall MOCHA-RAPID moorings. Contours are an average of Pegasus and LADCP data obtained in the late 1980s and early 1990s; contour interval is 5 cm s^{-1}, with blue contours indicating southward flow and red contours indicating northward flow; black indicates zero flow.

Data assimilation with a HYbrid Coordinate Ocean Model (HYCOM)

H. Kang (UM/CIMAS); W. Thacker (NOAA/AOML)

Long Term Research Objectives and Strategy to Achieve Them:
Objectives: To improve simulations of HYbrid Coordinate Ocean Model (HYCOM) by assimilating in-situ and satellite observations such as altimetry, multi-channel sea surface temperature (MCSST), and profile data from ARGO floats.
Strategy: To implement the NRL Coupled Ocean Data Assimilation (NCODA) System which uses a multi-variate optimal interpolation (MVOI) to assimilate in-situ and satellite observations.

CIMAS Research Theme:
Theme 1: Climate Variability

Link to NOAA Strategic Goals:
Goal 2: Understand Climate Variability and Change to Enhance Society's Ability to Plan and Respond

NOAA Funding Unit: OAR/AOML

NOAA Technical Contact: Christopher Meinen

Research Summary:
The HYCOM model is widely used in ocean-climate modeling. We wish to use the HYCOM model products to feed into the NRL Coupled Ocean Data Assimilation (NCODA) System. Because the NCODA analysis has been done on pressure coordinates, it is necessary to first build an interface to communicate with the model's hybrid vertical coordinate which varies both spatially and temporally to be density-like within the thermocline and below it, pressure-like in the mixed layer, and depth-proportional in shallow water.

Previous attempts to build an interface by interpolating between z-levels and hybrid vertical layers led us to conclude that NCODA analysis should be done in HYCOM's native coordinated because repeated interpolation between z-levels and hybrid layers caused the vertical diffusion, enough to rapidly weaken the stratification. Therefore our strategy has been changed from interpolation between two vertical coordinate to modifying the NCODA codes to work directly with HYCOM's layers.

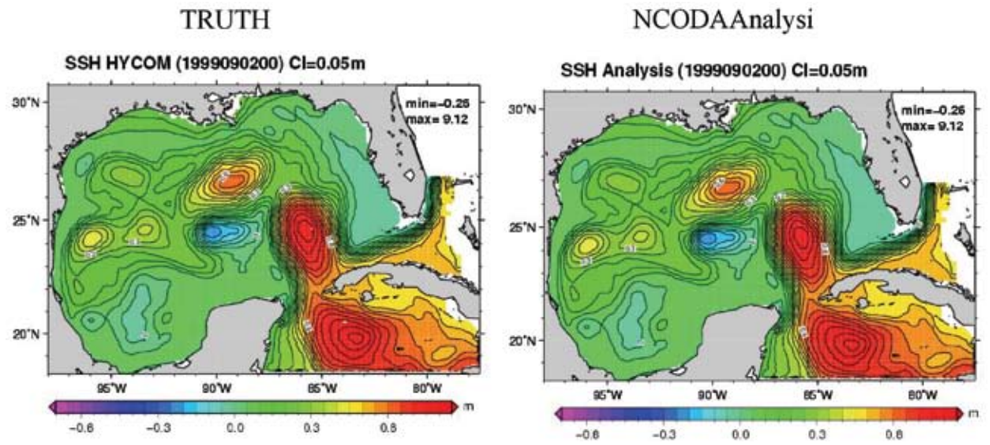


Figure 1: Pseudo Sea Surface Height (SSH) assimilation with the twin experiment on September 2, 1999. True SSH from HYCOM is shown on the left while NCODA SSH analysis is on the right.

After spending some time learning NCODA codes, as the first step an identical twin experiment has been designed and prepared. The idea is to treat the model data (SSH, SST, and profiles) as observations to make sure that NCODA can handle layered data. Since observations and forecast data (background) are identical, we expect to see zero increment from the NCODA analysis. In Figure 1, we show on the left Sea Surface Height on 2 September 1999 from HYCOM and on the right from NCODA. As can be seen in the two figures, they look identical. Its assimilation errors are close to zero. The assimilation errors of pseudo MCSST and pseudo profile data (temperature and salinity) are of the same order as with SSH. In Figure 2, we show the verification of assimilated data in the twin experiment. From the results of the twin experiment, it is very clear that NCODA can now handle layered profile data.

The next step will be working on velocity fields. We are going to introduce the HYCOM method to NCODA to correct velocity fields. After making sure that NCODA is working properly with HYCOM, real observations will be applied.

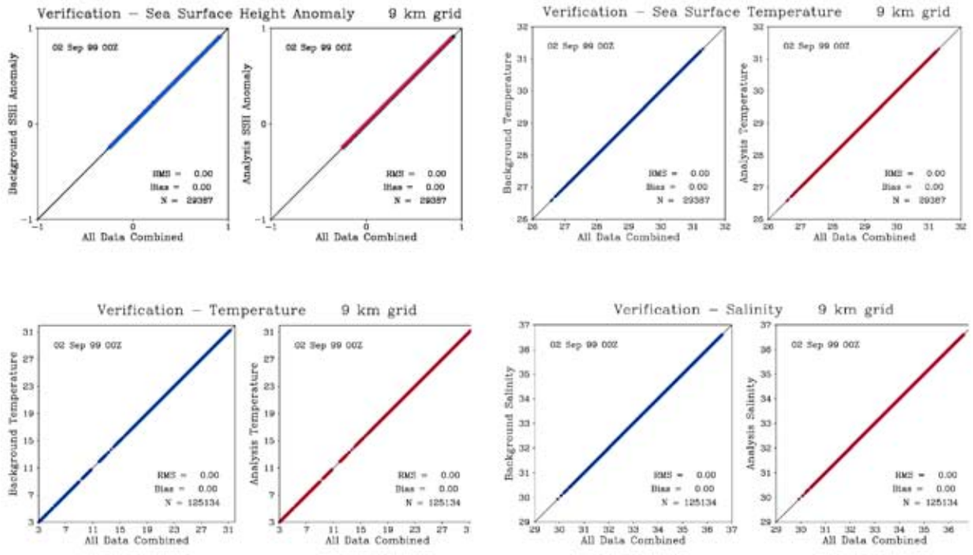


Figure 2: Verification of assimilated data with the twin experiment; SSH, SST, and Temperature & Salinity from profiles on 2 September 1999.

Research Performance Measure:
All objectives are being met.

Climate Impacts of the Western Hemisphere Warm Pool on the Americas

S.-K. Lee (UM/CIMAS); C. Wang, and D. Enfield (NOAA/AOML)

Long Term Research Objectives and Strategy to Achieve Them:
Objectives: To understand the impact of the Western Hemisphere warm pool on the climate (rainfall and hurricanes) of the Americas.
Strategy: To use both data and a model (NCAR Community Atmospheric Model: CAM3) to eludicate relationships.

CIMAS Research Themes:
Theme 1: Climate Variability (*Primary*)
Theme 5: Air-Sea Interactions and Exchanges (*Secondary*)

Link to NOAA Strategic Goals:
Goal 2: Understand Climate Variability and Change to Enhance Society's Ability to Plan and Respond

NOAA Funding Unit: OAR/AOML

NOAA Technical Contact: Chunzai Wang

Research Summary:
The North Atlantic subtropical high (NASH), being the strongest during the summer, determines the strength of the tropical easterly trade winds at its southern flank. The easterly trade winds carry moisture

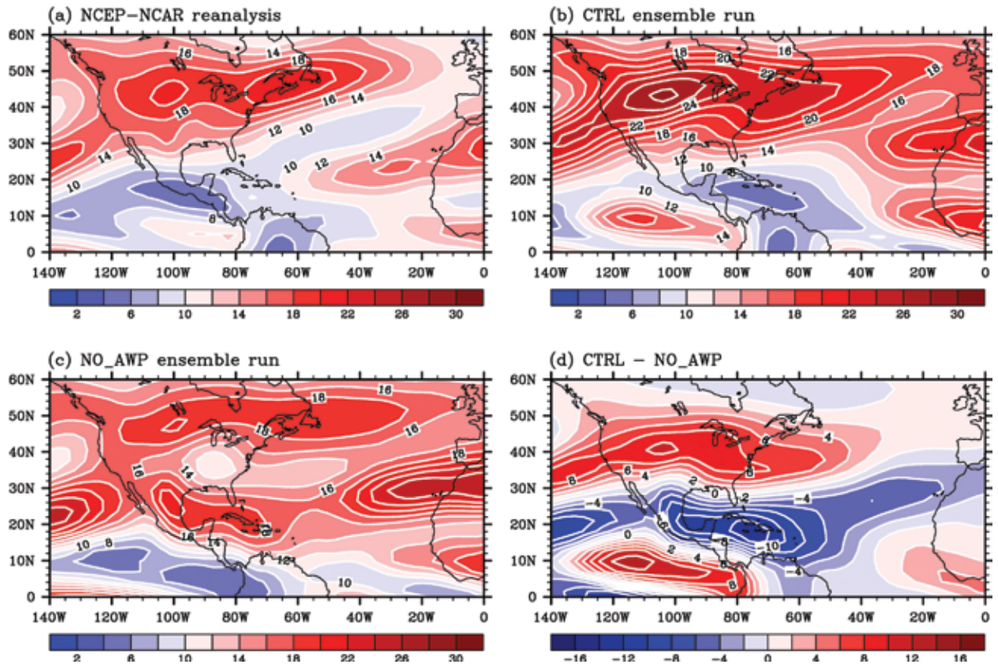


Figure 1: The tropospheric vertical wind shear (m s^{-1}) during August-September-October (ASO): (a) from the NCEP-NCAR reanalysis, (b) from the CTRL ensemble run, (c) from the NO_AWP ensemble run, and (d) the difference between the CTRL and NO_AWP runs.

from the tropical North Atlantic into the Caribbean Sea where the flow intensifies forming the Caribbean low-level jet (CLLJ). The CLLJ then splits into two branches: one turning northward and connecting with the Great Plains low-level jet (GPLLJ), and the other continuing westward across Central America into the eastern North Pacific. This study finds that the easterly CLLJ is maximized in the summer and winter, whereas it is minimized in the fall and spring. The semi-annual feature of the CLLJ results from the westward extensions and eastward retreats of the NASH that creates the semi-annual variation of sea level pressure in the Caribbean region.

The Atlantic warm pool (AWP) is comprised of a large area of warm water in the Gulf of Mexico, the Caribbean Sea, and the western tropical North Atlantic. The NCAR community atmospheric model (CAM3) and observational data are used to investigate the impact of the AWP on the summer climate of the Western Hemisphere. We performed two groups of the model ensemble runs with and without the AWP and compared the outcomes. The results show that the AWP's effect is to weaken the summertime NASH, especially at its southwestern edge. The AWP also strengthens the summertime continental low over the North American monsoon region. In response to these pressure changes, the CLLJ's strength is weakened, while its semi-annual feature remains unchanged. The weakening of the CLLJ decreases the westward moisture transport from the AWP and thus suppresses rainfall in the eastern North Pacific. The AWP's impact on the GPLLJ is to strengthen (weaken) its northward moisture transport for summer (fall) rainfall over the central United States. Finally, the AWP largely reduces the tropospheric vertical wind shear in the main development region that favors hurricane formation and development during August-October.

Research Performance Measure:
We accomplished our main objective: to investigate the impact of the AWP on the summer climate of the Western Hemisphere using the NCAR community atmospheric model and observational data.

Effort Response, Harvest, the Economy, and Climate in the Gulf of Mexico Recreational Fishery

D. Letson, (UM/RSMAS); D.W. Carter (NOAA/SEFSC)

Long Term Research Objectives and Strategy to Achieve Them:
Objective: To predict the effect of climate, economic, and regulatory changes on the value of recreational fishing in the Gulf of Mexico.
Strategy: To develop and estimate models that can be used to forecast recreational fishing effort and the value per unit effort or species.

CIMAS Research Themes:
Theme 1: Climate Variability
Theme 2: Fisheries Dynamics
Theme 4: Human-Environmental Interactions

Link to NOAA Strategic Goals:
Goal 2: Understand Climate Variability and Change to Enhance Society's Ability to Plan and Respond

NOAA Funding Unit: NMFS/SEFSC

NOAA Technical Contact: David Carter

Research summary:
In previous research we found that El Niño-Southern Oscillation (ENSO) events affect trip demand and, subsequently, red snapper landings in the Gulf of Mexico head boat fishery. (A head boat is a vessel that charges a fee per passenger "head" for recreational fishing trips.) Climate studies indicate that ENSO events will strengthen or become more frequent as a result of climate changes. This suggests that climate change could have an impact on head boat activity and the outcome of fishery regulations in the future.

To examine this assertion, we use the head boat forecasting model developed in 2004-05. The model has been improved so that red snapper biomass can factor in landings changes and changes in effort can be influenced by income and energy prices. This model is used to simulate the changes in head boat trip demand and red snapper landings expected from potential ENSO frequency and strength shifts. Specifically, we assume the frequency of both the El Niño and La Niña phases would increase, while the Neutral phase frequency would be reduced, and that stronger events such as 1982 and 1997 would become more likely. We construct a Markov chain of ENSO years consistent with these assumptions and use it to simulate changes in the fishery. The ENSO scenarios are simulated with and without red snapper bag and size limit changes to evaluate the sensitivity of policy outcomes to climate change.

The simulation results suggest that climate change leading to either strength or frequency ENSO shifts could increase the demand for trips and red snapper landings in the Gulf of Mexico head boat fishery. However, these effects do not vary significantly under different policy regimes. Therefore, while individual ENSO events can influence the effectiveness of recreational fishery policy changes in the short term, gradual climate change is not likely to be a key influence on the outcome of long run management strategies in this fishery.

The results of this study are consistent with current NOAA emphasis on rational management of fisheries and the increasing demand for these resources, often in the face of declining fish catches. The results will help provide a scientific basis to environmental decision-making about the coastal environment and human systems.

Research Performance Measures:
The goals in the development of models and forecast information systems have been met on schedule.

Understanding and Improving the Ensemble Transform Kalman Filter Targeting Strategy

S.J. Majumdar (UM/RSMAS); S.D. Aberson (NOAA/AOML);
C.H. Bishop (NRL, Monterey)

Long Term Research Objectives and Strategy to Achieve Them:
Objectives: To assess whether upstream observations are useful for 3-7 day forecasts and whether their effects can be predicted in advance on a daily basis.
Strategy: To test in various flow regimes whether the Ensemble Transform Kalman Filter (ETKF) can predict the reduction in forecast error variance due to upstream observations.

CIMAS Research Theme:
Theme 1: Climate Variability

Link to NOAA Strategic Goals:
Goal 3: Serve Society's Needs for Weather and Water Information

NOAA Funding Unit: USWRP

NOAA Technical Contact: John Gaynor

Research Summary:
A core objective of NOAA is to improve 3-7 day forecasts of precipitation over North America. One method of making such improvements is by augmenting the present routine observational network with extra upstream observations. The primary goal of this NOAA/CIMAS/THORPEX research is to evaluate and further develop the Ensemble Transform Kalman Filter (ETKF) adaptive observing strategy, which is presently used in operational NWS Winter Storm Reconnaissance (WSR) to improve 1-3 day forecasts.

In order to assess the performance of the ETKF, the influence of observations on numerical forecasts is first being analyzed via 'data denial' experiments, in which selected observational data are withheld from the data assimilation. Approximately 60 datasets from the 2005 and 2006 WSR program have been produced using the data denial software at NCEP. Some surprising, and perhaps unfortunate, results were found. The downstream influence of observations on forecasts was often found to be contaminated by rapid local growth of initially tiny errors around the globe.

The ability of the ETKF to predict signal variance of 3-7 day forecasts is being evaluated. At the NOAA THORPEX PI workshop in January 2006, it was suggested by several colleagues that a NCEP ensemble alone is inadequate for such a study, and considerable effort has been spent incorporating the ECMWF ensemble into the ETKF. Now that the ECMWF ensemble is ready for use, the evaluation is ongoing. Kathryn Sellwood, the M. S. student funded on this grant, is performing the evaluations which she aims to complete by the end of Fall 2006. A preliminary result is shown in Fig. 1. Various indices describing the flow regime (blocking index, North Atlantic Oscillation etc) have been studied in order to categorize the ~60 cases under investigation.

Research Performance Measure:
The work in Year 2 has largely gone to plan, although there have been numerous problems in logging into the computers at EMC and bugs in the software. .

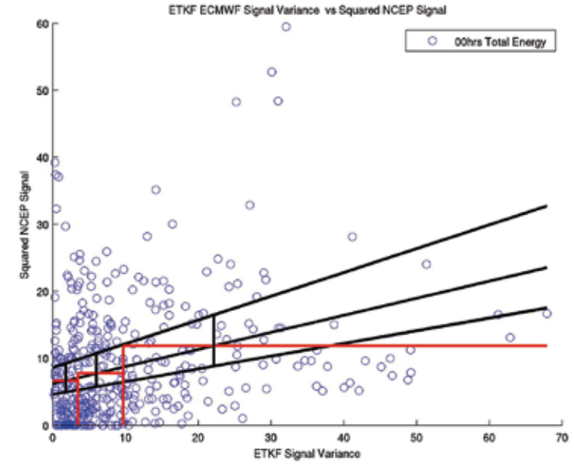


Figure 1: Scatter plot, showing a monotonic increasing relationship between the "signal variance" predicted by the ETKF and the variance of NCEP signal realizations.

Improving the MJO Simulation of the NCEP GFS Model

B. Mapes (UM/CIMAS); J. Lin (CIRES)

Long Term Research Objectives and Strategy to Achieve Them:
Objectives: To improve the MJO Simulation of the NCEP GFS Model.
Strategy: To adjust cumulus parameterization so as to increase its sensitivity to moisture.

CIMAS Research Theme:
Theme 1: Climate Variability

Link to NOAA Strategic Goals:

Goal 2: Understand Climate Variability and Change to Enhance Society's Ability to Plan and Respond;

NOAA Funding Unit: COP

NOAA Technical Contact: Ken Mooney

Research Summary:
We are obtaining the NCEP Global Forecast System (GFS) model code in order to experiment with its cumulus parameterization scheme. We intend to increase the entrainment rate, which will make the scheme more sensitive to humidity, while at the same time adjusting other aspects in order to offset the undesirable side effects of entrainment.

Research Performance Measure:
The program is proceeding according to schedule. The measure of MJO fidelity will follow Lin *et al*. 2006, which intercompared many models and found clear and similar shortcomings in many global models.

CO_2/CLIVAR Repeat Hydrography Program CO_2 Synthesis Science Team

F.J. Millero (UM/RSMAS); R. Wanninkhkof and T.-H. Peng (NOAA/AOML);
R. Feely and C.L. Sabine (NOAA/PMEL); R. Key (Princeton);
A. Dickson (Scripps/San Diego); A. Kozyr (CDIAC)

Long Term Research Objectives and Strategy to Achieve Them:

Objectives: To synthesize a globally consistent data set (e.g., corrected for recognized analytical errors and systematic biases) and combined with similar data sets from our international partners.

Strategy: To create a CO_2 Synthesis Science Team with PIs and investigators who have expertise in data synthesis; to gather data sets from national and international sources for sytnthesis into the integrated data set.

CIMAS Research Theme:
Theme 1: Climate Variability

Link to NOAA Strategic Goals:
Goal 2: Understand Climate Variability and Change to Enhance Society's Ability to Plan and Respond (*Primary*)

Goal 3: Serve Society's Needs for Weather and Water Information (*Secondary*)

NOAA Funding Unit: OAR/AOML

NOAA Technical Contact: Rik Wanninkhof

Research Summary:
During the 1990s ocean sampling expeditions were carried out as part of the World Ocean Circulation Experiment (WOCE), the Joint Global Ocean Flux Study (JGOFS) and the Ocean Atmosphere Carbon Exchange Study (OACES). Most of the cruises included various inorganic carbon species among the suite of routinely measured parameters. Both during and after the field work, a group of U.S. scientists collaborated to synthesize the data into easily usable and readily available products. This collaboration is known as the Global Ocean Data Analysis Project (GLODAP).

Both measured results and calculated quantities were merged into common format data sets, segregated by ocean. The carbon data were subjected to rigorous secondary quality control procedures, beyond those typically performed on individual cruise data, to eliminate systematic biases in the basin-scale compilations. For comparison purposes, each ocean data set included results from a small number of high quality historical cruises. The calibrated 1990s data were used to estimate anthropogenic CO_2, potential alkalinity, CFC watermass ages, CFC partial pressure, bomb-produced radiocarbon and natural radiocarbon. The calibrated-merged data were used to produce objectively gridded global property maps designed to match existing climatologies for temperature, salinity, oxygen and nutrients. Both the data sets and the gridded products are available from the Carbon Dioxide Information Analysis Center (CDIAC).

The synthesis was carried out for each ocean basin progressing from the Indian to Pacific and ending with the Atlantic. The entire synthesis required about five years. During that period new methods were developed and old ones modified. At the same time, the data set itself changed and expanded. Many of the GLODAP results are already published. Important details of the data assembly, calibration, calculations, and mapping are described in a recent data report.

Research Performance Measure:
The integration program is proceeding according to schedule.

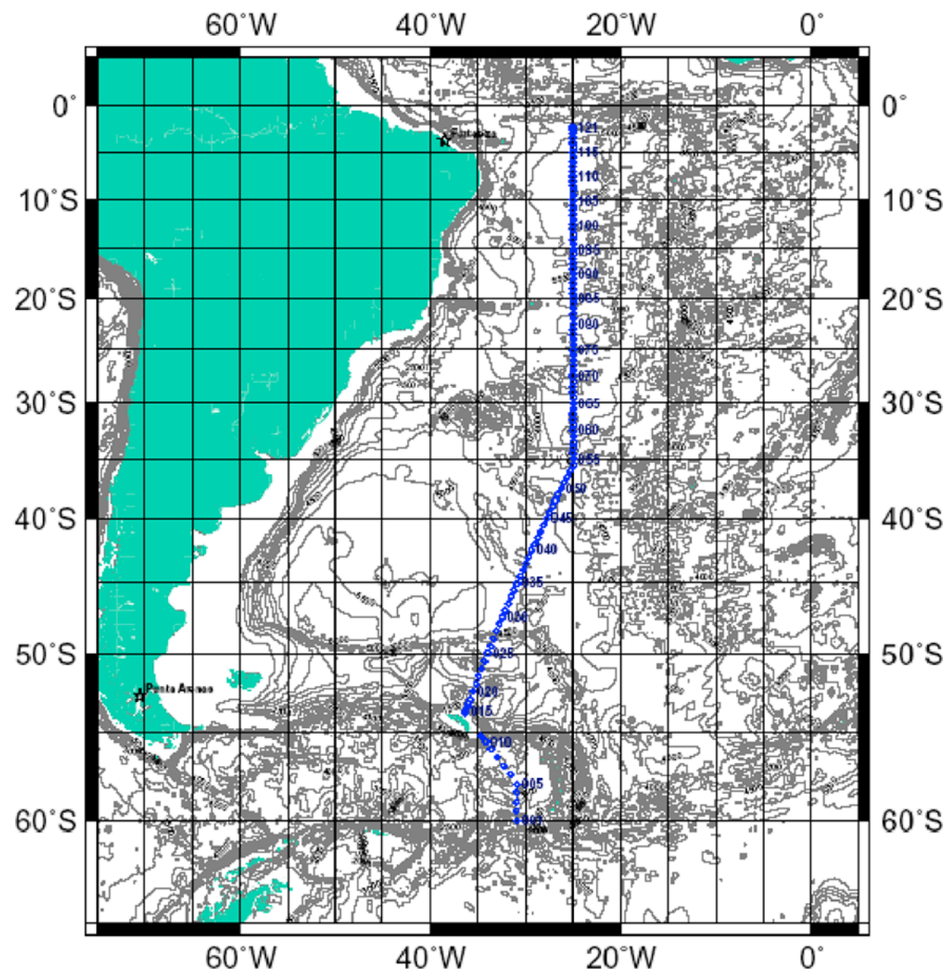


Figure 1: Cruise track of the R/V Brown from Punta Arenas, Chile to Fortaleza, Brazil. Millero's group measured pH and total alkalinity (TA) as part of the CLIVAR/CO2 Repeat Hydrography Program. A16S cruise track (11 January-24 February 2005)

Studies of Climate Feedbacks and Sensitivity Using GFDL Models

B.J. Soden (UM/RSMAS); I.M. Held (NOAA/GFDL)

Long Term Research Objectives and Strategy to Achieve Them:
Objectives: To provide a quantitative assessment of the strengths of climate feedbacks in current coupled ocean-atmosphere climate models.
Strategy: To use the results from the Intergovernmental Panel on Climate Change (IPCC) 4th Assessment model archive to compute climate feedback parameters from radiative adjoint calculations.

CIMAS Research Theme:
Theme 1: Climate Variability

Link to NOAA Strategic Goals:

Goal 2: Understand Climate Variability and Change to Enhance Society's Ability to Plan and Respond

NOAA Funding Unit: OAR

NOAA Technical Contact: Steve Mayle

Research Summary:
Climate models exhibit a large range of sensitivities in response to increased greenhouse gases due to differences in feedback processes which amplify or damp the initial radiative perturbation. Analyzing these feedbacks is therefore of central importance to our understanding of climate sensitivity, yet there are complexities in these analyses that result in confusion when intercomparing models and when trying to quantify feedbacks from observations. With respect to water vapor feedback, most of these complexities arise from the correlations between water vapor, temperature, and clouds, and the desire to distinguish between water vapor and cloud feedbacks. Previous studies have focused on this issue and clarified the important distinction between "cloud feedback" and the change in "cloud forcing". An additional source of confusion is the recognized need to compute the net radiative fluxes at the tropopause in such analyses to avoid complexities arising from stratospheric adjustment, the resulting dependence of these calculations on one's definition of the tropopause, and the extent to which one can avoid this issue by simply looking at top of atmosphere (TOA) fluxes when analyzing GCMs.

In this work, we attempt to clarify several misconceptions regarding the underlying physical processes which determine its strength and vertical distribution, compare model simulations of water vapor feedback from the latest versions of the GFDL, NCAR and BMRC GCMs, and assess the strength of water vapor feedback in the published literature.

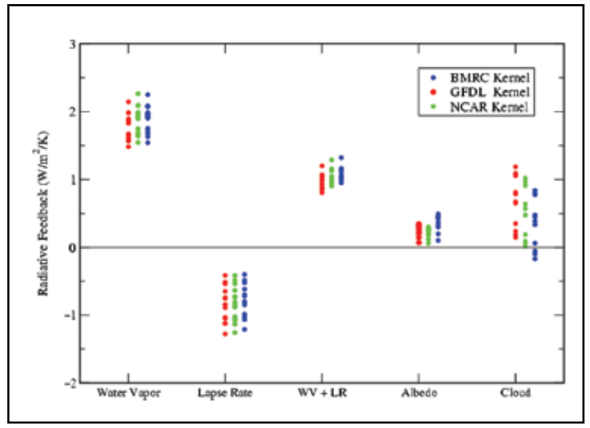


Figure 1: Climate feedbacks for 14 different coupled ocean-atmosphere models plotted computed using 3 different model kernels.

Research Performance Measure:
All objectives were attained on schedule.

A Radiance-Based Analysis of Satellite and Radiosonde Records to Document Long-Term Water Vapor Changes

B.J. Soden (UM/RSMAS); V. Ramaswamy (NOAA/GFDL)

Long Term Research Objectives and Strategy to Achieve Them:
Objectives: To assess the decadal scale variability of upper tropospheric water vapor.
Strategy: To compare satellite observations with radiosonde measurements, reanalyses, and climate model simulations to evaluate the presence of radiative signatures of upper tropospheric water vapor trends.

CIMAS Research Theme:
Theme 1: Climate Variability

Link to NOAA Strategic Goals:
Goal 2: Understand Climate Variability and Change to Enhance Society's Ability to Plan and Respond

NOAA Funding Unit: COP

NOAA Technical Contact: James Todd

Research Summary:
The primary goal of this project is to perform a radiance-based analysis of satellite observations and climate model simulations to quantitatively assess their long-term changes. After documenting increases in upper tropospheric water vapor, our research subsequently focused on lower stratospheric cooling trends. The global lower stratosphere, the region of the atmosphere from ~12-22 km above the surface, has cooled substantially over the past two decades, with the difference in temperature between 2000 and 1980 ascribed to well-mixed greenhouse gas increases and ozone depletion. Observations indicate that the decrease in temperature is step-like rather than a steady decline. While the overall trend in the observed temperature has been modeled previously, the step-like evolution of the global temperature anomaly and the pattern of cooling has not been explained in terms of specific physical causes, whether this be external forcing and/or internal variability of the climate system. Thus, the roles of various agents in the unusual cooling of the lower stratosphere during the 1980s and 1990s have yet to be addressed, along with potential implications for the future. Here, we employed a coupled atmosphere-ocean model to demonstrate that the complex space-time pattern of the lower stratospheric temperature is a consequence of the combined temporal changes in natural and anthropogenic forcings.

Research Performance Measure:
The research program is on schedule.

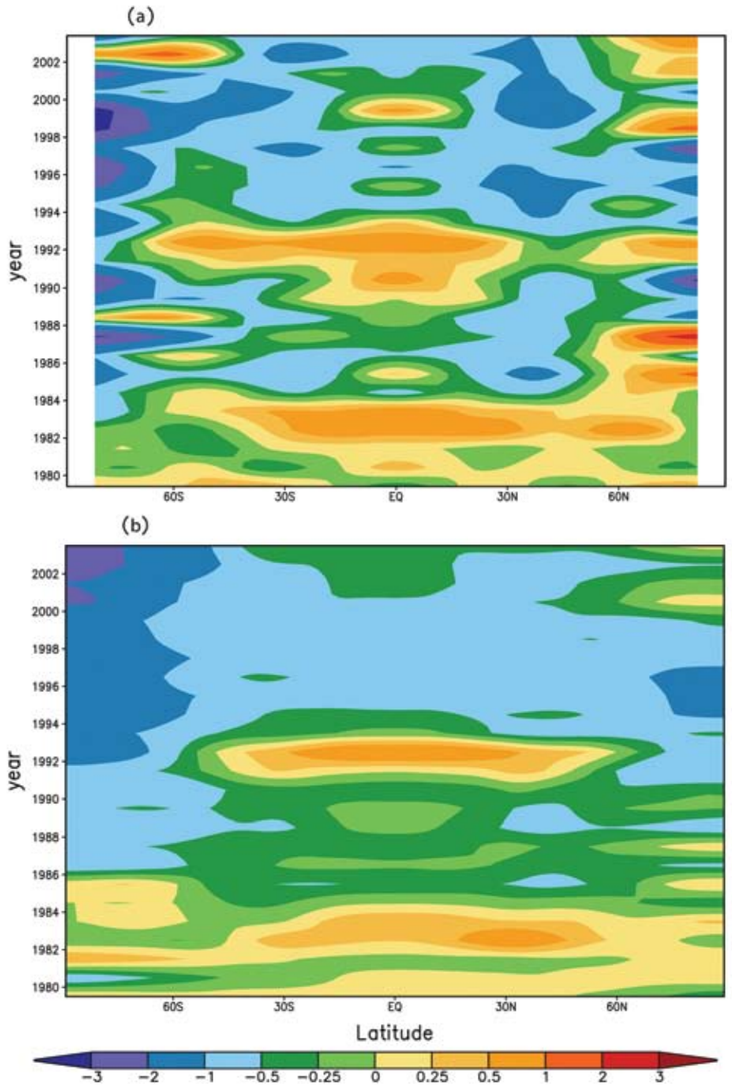


Figure 1: A plot of the zonally-and-annually-averaged temporal evolution of lower stratospheric temperature†anomalies (**relative to 1979-1981 average**) **from MSU satellite observations.**

Assessment of Decadal Variability in the Tropical Radiation Budget

B.J. Soden (UM/RSMAS); D. Jackson (CIRES/U. Colorado)

Long Term Research Objectives and Strategy to Achieve Them:
Objectives: To assess the decadal scale variability of the tropical radiation budget.
Strategy: To compare satellite observations with empirical analyses and climate model simulations to evaluate the veracity and cause of decadal variations in the net radiation at the top-of-the-atmosphere.

CIMAS Research Theme:
Theme 1: Climate Variability

Link to NOAA Strategic Goals:

Goal 2: Understand Climate Variability and Change to Enhance Society's Ability to Plan and Respond

NOAA Funding Unit: COP

NOAA Technical Contact: James Todd

Research Summary:
In this work, we quantified the effects of intercalibration problems and diurnal sampling biases for the HIRS radiances and developed a method for correcting these problems which ultimately yielded data sets suitable for studying decadal variability. Twenty-eight years of HIRS radiance satellite data (1978-2005) were reprocessed to create a set of monthly mean grid data that categorizes the observations by local observing time through averaging ascending and descending orbits separately.

Figure 1 (next page) shows the ascending, descending and ascending-descending for the HIRS all-sky observations for the 11.1 micron channel. The diurnal sampling bias due to orbital drift in HIRS radiance is clearly evident in time series of the ascending and descending averages. The ascending anomalies show the greatest diurnal drift from the afternoon (2 PM) NOAA polar-orbiting satellites. As the local crossing time of the afternoon satellites drifts toward evening, the surface sensing channels respond by progressively cooling. The bias is less evident for the ascending (8 PM) or descending (8 AM) morning satellites observations since the satellite drift was much smaller for these satellites. Descending afternoon orbits (2 AM) show little diurnal drift since most the drift occurs at night where there is little change in diurnal temperatures.

Corresponding HIRS simulated radiance data from the GFDL climate model were constructed using HIRS satellite sampling so to determine if the model accurately represents the diurnal sampling bias and to correct the HIRS observations from the observed diurnal sampling bias using this model. A three-parameter exponential function was determined to provide the best fit to model and remove the diurnal bias. Diurnal bias mostly affects the ascending orbit observations of the afternoon (2 PM) satellites. Lower tropospheric temperature and water vapor channels contained the largest bias and biases over land were more than twice as large as those over the ocean. Figure 1 (next page) shows the drift-corrected versions for the HIRS 11.1 micron channel separately for each satellite prior to intercalibration.

Research Performance Measure:
The research program is proceeding on schedule.

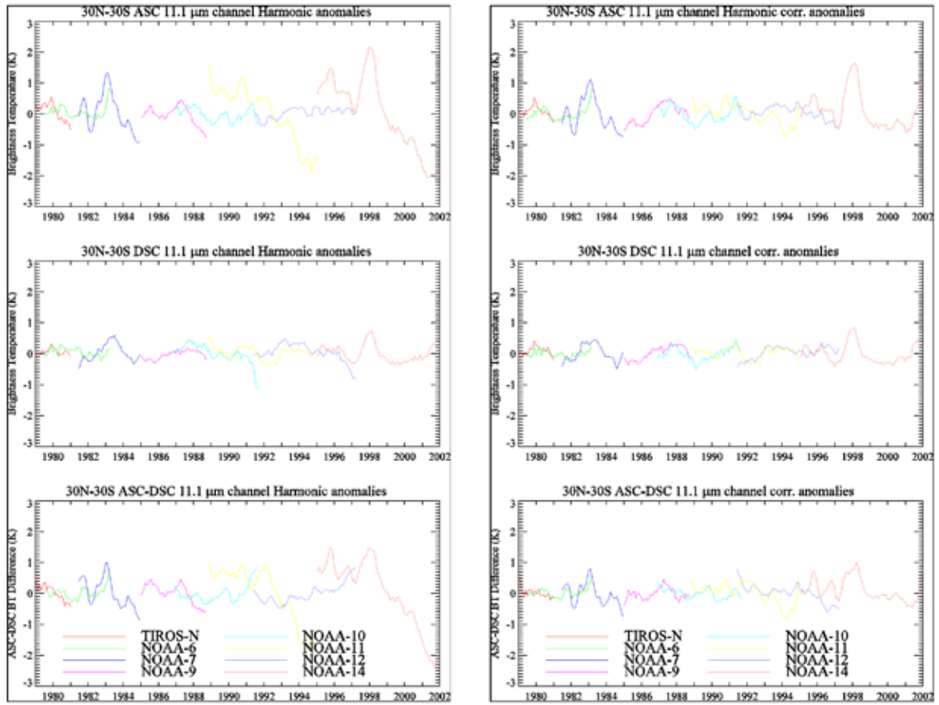


Figure 1: Time series of HIRS ascending (top), descending (middle), and ascending-descending (bottom) observations. **Right** The HIRS anomalies after correcting for diurnal sampling bias arising from orbital drift in the equatorial crossing time.

Improving the Prediction of Tropical Cyclone Intensity and Rainfall by Evaluating and Comparing Microphysics Fields Measured from High-Resolution Numerical Models and Airborne and Space-Borne Platforms

K. Valde and P. Willis (UM/CIMAS); S. Chen (UM/RSMAS);
R. Rogers, F. Marks, M. Black and R. Black (NOAA/AOML);
A. Heymsfield (NCAR); G. Heymsfield (NASA/GSFC)

Long Term Research Objectives and Strategy to Achieve Them:

Objectives: To improve the understanding and prediction of tropical cyclone intensity change and rainfall by evaluating and improving the representation of microphysical fields in tropical cyclone model simulations at all stages of their lifecycle.

Strategy: To evaluate and compare the microphysical fields from both high-resolution MM5 model simulations and in situ and remotely-sensed data collected by the NOAA-WP-3D's and NASA ER-2 aircraft, as well as data from the TRMM Precipitation radar and Microwave imager.

CIMAS Research Theme:

T***heme 1***: Climate Variability (*Primary*)
Theme 5: Air-sea interactions and exchanges (*Secondary*)

Link to NOAA Strategic Goals:

Goal 3: Serve Society's Needs for Weather and Water Information

NOAA Funding Unit: OAR/AOML

NOAA Technical Contact: Michael Black

Research Summary:

A major source of energy that fuels a tropical cyclone is latent heat which is a product of the microphysical processes occurring within a storm. It is hypothesized that knowing the amount and distribution of latent heat released within a system will help improve tropical cyclone intensity and rainfall forecasting. However, the processes that determine the magnitude and distribution of latent heat can differ throughout the lifecycle of systems and can span a large range of spatial and temporal scales, making it difficult to correctly represent them in forecast models. Through evaluating the microphysical fields of a tropical cyclone (e.g. vertical velocity, hydrometeor mixing ratio, radar reflectivity), we are attempting to answer the following questions:

1) How do the microphysics fields differ within an incipient tropical cyclone compare to a mature storm and how do they play a role in the development of and evolution of convective and stratiform regions in the incipient storm?
2) Does the stratiform region have any importance in the possible development of an incipient tropical cyclone?

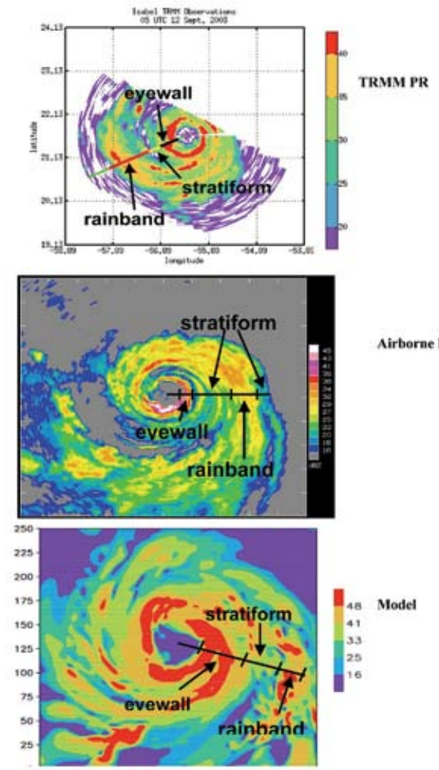


Figure 1: Reflectivity plan-view showing example of sorting scheme for reach data platform.

3) How well do model simulations represent the microphysical differences between incipient and mature tropical cyclones? How could they be improved?

To answer these questions, we are comparing the statistics of the distributions and concentrations of tropical cyclone microphysics fields from airborne (Doppler radar) and space-borne (TRMM satellite) observations and from a high-resolution numerical model (MM5). These comparisons will advance our understanding of the microphysical processes within tropical cyclones, and reveal any model biases in tropical cyclone microphysics fields. These studies will ultimately help in the improvement of intensity and rainfall predictions.

We have developed an algorithm for partitioning a mature tropical cyclone into three different regions: eyewall, rainband, and stratiform based on reflectivity (Fig. 1). With this algorithm we stratified reflectivity (TRMM PR, model, Doppler) and vertical velocity (model, Doppler) and compared the distribution difference between the three platforms by Contour Frequency by Altitude Diagrams (CFADs) (Fig. 2). The comparisons showed the model had a broader reflectivity distribution and higher reflectivity maximum and a narrower vertical motion distribution and lower vertical motion maximum compared to the TRMM PR and airborne Doppler radar data. Recently, we have updated our algorithm by partitioning the tropical system into convective and stratiform to be applied to both incipient and mature systems. We currently have the sorting algorithm for the model data and are still working on the sorting algorithm for the TRMM PR and TMI data.

During the Tropical Cloud System and Processes (TCSP) field program, conducted in July 2005, we successfully sampled data from different systems at different stages of their lifecycle. The systems flown were as follows: Hurricane Dennis, from tropical storm to landfall; a tropical cluster in the East Pacific, which may have developed into Tropical Storm Eugene; and Tropical Storm Gert, prior to being declared a tropical depression until a tropical storm. With the observations from Hurricane Dennis, we began to compare the microphysics fields and storm structure at different stages of its lifecycle with a model simulation. A statistical comparison of the distributions of the model-derived reflectivity and vertical motion by CFADs from two different stages of Hurricane Dennis lifecycle has begun but for now only includes the beginning stages.

Research Performance Measure:
Objectives are being met on schedule.

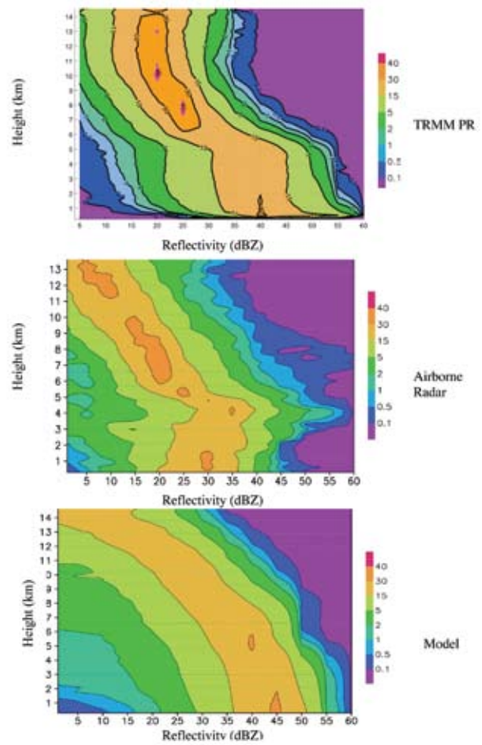


Figure 2: Contour Frequency By Altitude Diagrams (CFADs) of eyewall reflectivity of TRMM PR, Airborne Radar, and Model.

Shallow Meridional Circulation and Saharan Heat Low: Their Roles in the Tropical Atlantic Variability

C. Zhang (UM/RSMAS)

Long Term Research Objectives and Strategy to Achieve Them:
***Objectives*:** To understand the seasonal cycle over West Africa, especially the West African monoon.
***Strategy*:** To diagnose *in situ* sounding observations from West Africa and compare them with global reanalyses; to diagnose climate model simulations.

CIMAS Research Theme:
***Theme 1*:** Climate Variability

Link to NOAA Strategic Goals:
***Goal 2*:** Understand Climate Variability and Change to Enhance Society's Ability to Plan and Respond

NOAA Funding Unit: COP

NOAA Technical Contact: Michael Black

Research Summary:
The recent research by the PI has revealed a new feature in the large-scale circulation pattern over the tropical eastern Pacific Ocean, namely, a shallow meridional circulation. This current study explores the extent to which similar circulation patterns might also exist over the tropical Atlantic Ocean and West Africa and, if they do exist, the role of such shallow circulation in West African monsoon.

An analysis of atmospheric sounding data from West Africa shows that the shallow circulation does indeed exist in the region, but it has a quite different structure from that over the eastern Pacific Ocean. A comparison of three global reanalysis products indicates that in the entire tropics, the shallow meridional circulation is the strongest over the tropical Atlantic Ocean and West Africa. A hypothesis is proposed to distinguish shallow meridional circulations associated with the marine ITCZ and the monsoon (see figure).

Research Performance Measure:
The research has made progress as planned during its first year.

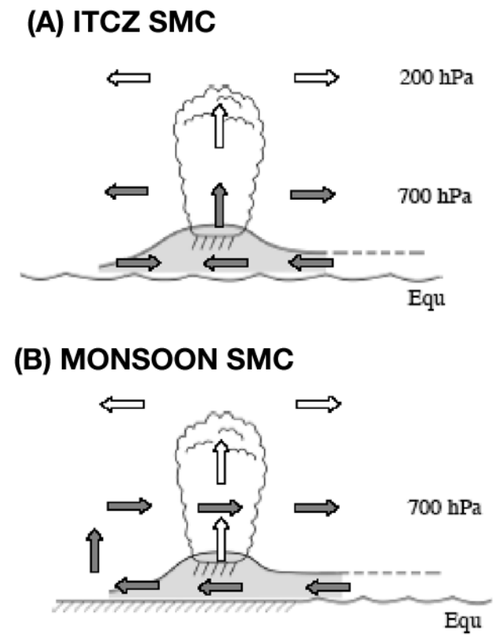


Figure 1: Schematic diagrams of the vertical-meridional circulations (solid arrows) associated with (a) the ITCZ and (b) monsoon rainbands (represented by cloud symbols) The approximate location of the equator is marked. The boundary layer is shaded. The deep meridional circulations are indicated by open arrows. SMC stands for shallow meridional circulation.

A Study of the MJO-ENSO Problem

C. Zhang (UM/RSMAS)

Long Term Research Objectives and Strategy to Achieve Them:
Objectives: To improve ENSO prediction by quantifying the contribution to ENSO from the MJO as a source of stochastic forcing and understanding the mechanism for the MJO-ENSO relationship.
Strategy: To carry out a series modeling exercises using a hierarchy of coupled models with different complexity forced by stochastic forcing derived from observations.

CIMAS Research Theme:
Theme 1: Climate Variability

Link to NOAA Strategic Goals:
Goal 2: Understand Climate Variability and Change to Enhance Society's Ability to Plan and Respond

NOAA Funding Unit: COP

NOAA Technical Contact: James Todd

Research Summary:
ENSO prediction remains an unmet challenge. Prediction of major warming events is always too late, too slow, and too weak in comparison to observations. It has been suggested that atmospheric variability unresolved by the current dynamic and statistical ENSO prediction models acts as stochastic forcing which can be essential to ENSO evolution. The Madden-Julian Oscillaiton (MJO) is an important component of stochastic forcing of ENSO. This study focuses on effects of the MJO as a source of stochastic forcing on ENSO.

A series modeling experiments using atmosphere-ocean coupled models has shown that the MJO dominates the total stochastic forcing of ENSO (70%). The main mechanisms for the MJO to affect ENSO are its low-frequency variability, oceanic Kelvin waves, and air-sea coupling. These results point to a possibility that including known MJO statistics (e.g., its seasonal cycle) in models as external stochastic forcing may help improve ENSO predictions.

Research Performance Measure:
All major objectives have been met.

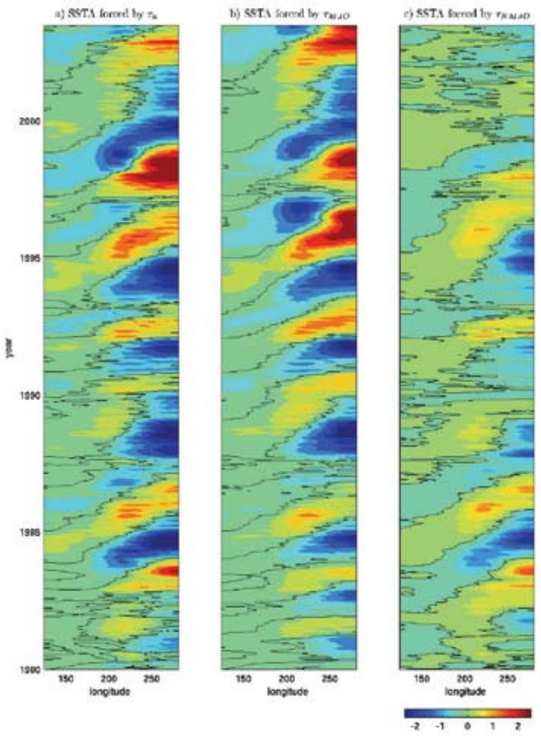


Figure 1: Sea surface temperature anomalies associated to ENSO induced by stochastic forcing of (a) total, (b) its MJO component, and (c) its non-MJO component as simulated by a coupled model.

A Study of African Dust and Dry-Air Outbreaks and Their Effects on the Atlantic Marine ITCZ

C. Zhang (UM/RSMAS), J. Prospero (UM/CIMAS)

Long Term Research Objectives and Strategy to Achieve Them:
Objectives: To explore possible effects of African aerosol and dry air on the large-scale variability of precipitation in the Atlantic ITCZ.
Strategy: To diagnose satellite observations of aerosol/dust, water vapor, precipitation with meteorological data from global re-analyses.

CIMAS Research Theme:
Theme 1: Climate Variability

Link to NOAA Strategic Goals:
Goal 2: Understand Climate Variability and Change to Enhance Society's Ability to Plan and Respond

NOAA Funding Unit: COP

NOAA Technical Contact: James Todd

Research Summary:
Both African aerosol and precipitation in the Atlantic ITCZ undergo substantial seasonal and interannual variability. Their possible connection, however, has never been studied before. Exploring such a connection helps us to understand how climate variability over the tropical Atlantic Ocean and West Africa interact with each other.

Preliminary results from this study show that spatial distributions of precipitation over the tropical Atlantic Ocean are quite different between years of extreme large and small concentration of African aerosol in the region. There are considerable seasonal variations in such differences.

Research Performance Measure:
Progress is slower than planned because the postdoctoral research associate joined the research team only recently (August 2006). We expect to be back on schedule within the next few months.

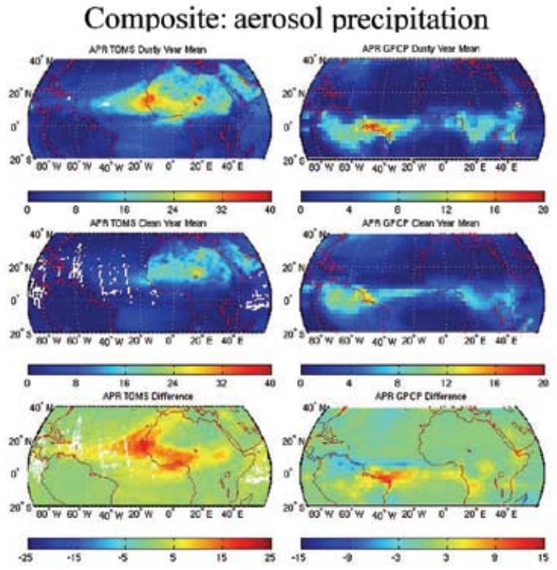


Figure 1: Composite of aerosol (TOMS) and precipitation (GPCP) in April for years of extreme high (upper row) and low (middle) aerosol concentration over the tropical Atlantic Ocean, and their differences (bottom). Unit for precipitation is mm/day.

Coral Reef Assessment, Mapping and Monitoring Efforts in Florida, US Caribbean and Pacific Islands

J.S. Ault, S.G. Smith and J. Luo (UM/RSMAS); M. Monaco (NOAA/NOS)

Long Term Research Objectives and Strategy to Achieve Them:

***Objective*:** To quantify changes in reef fish communities and benthic habitats on a spatially explicit basis so as to assess future impacts of the natural and anthropogenic changes; to provide a scientific basis for management strategies to build sustainable reef fish populations, coral reef habitats, and the reef fish community in Florida, US Caribbean and Pacific Island coral reef ecosystems.

Strategy: To develop a cooperative field and analytical program between the NOAA Biogeography Program and the University of Miami RSMAS to support coral reef assessments, mapping and resource monitoring efforts by NOAA.

CIMAS Research Themes:

Theme 2: Fisheries Dynamics (*Primary*)
***Theme 3*:** Regional Coastal Ecosystem Processes (*Secondary*)

Link to NOAA Strategic Goals:

Goal 1: Protect, Restore, and Manage the Use of Coastal and Ocean Resources Through Ecosystem-based Management

NOAA Funding Unit: NOS

NOAA Technical Contact: Mark Monaco

Research Summary:

For the past decade out research groups have been conducting large-scale synoptic assessments of coral reef fisheries and benthic habitats to explore and characterize these unique marine environments and to support management decision making. The University of Miami RSMAS has been an integral partner with NCCOS in implementing coral reef mapping and monitoring in Florida and the US Caribbean. This agreement provides for the implementation, assessment, inventory, and monitoring of U.S. coral reef ecosystems in Florida and the US Caribbean, as endorsed by the U.S. Coral Reef Task Force that was established on June 11, 1998, through Executive Order 13089 for "Coral Reef Protection."

Specifically, this collaborative research program is designed to achieve the following goals: (1) to assist in development of benthic habitat schemes; (2) to assist in determining the accuracy of benthic habitat map products; (3) to provide analytical support and develop new database products in support of coral reef fish assessment and monitoring protocols; (4) to conduct quantitative analyses of the long-term Caribbean and NOAA Biogeography Division's US Virgin Islands visual census databases; (5) to conduct analyses on the biogeography of reef fishes throughout Florida and the US Caribbean; and, (6) to coordinate the Florida scientific community in development of integrated coral reef ecosystem mapping and monitoring studies in support of NOAA's National Monitoring Program.

Research Performance Measure:

The objectives of this program are being met by the extensive monitoring, mapping and assessment program that is currently underway.

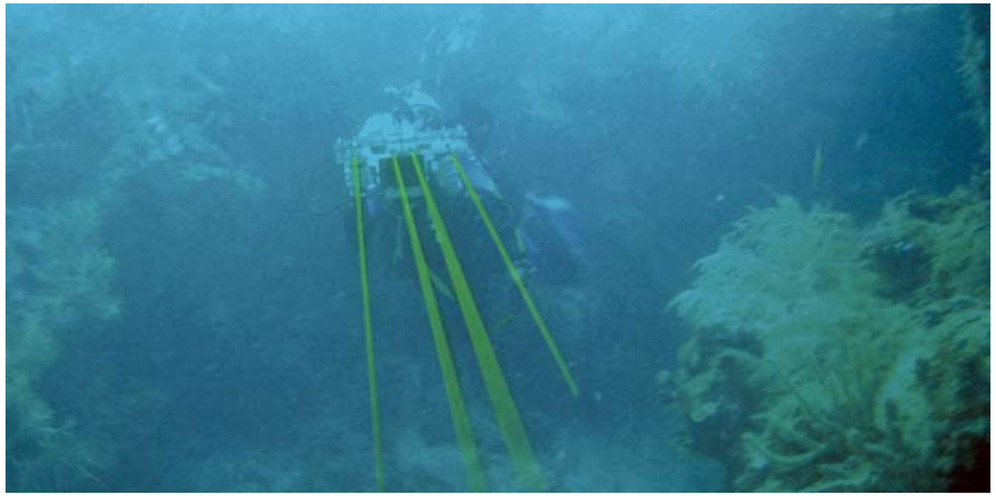


Figure 1: A laser sizing and ranging camera system developed for the reef fish visual census is employed in the Florida Keys.

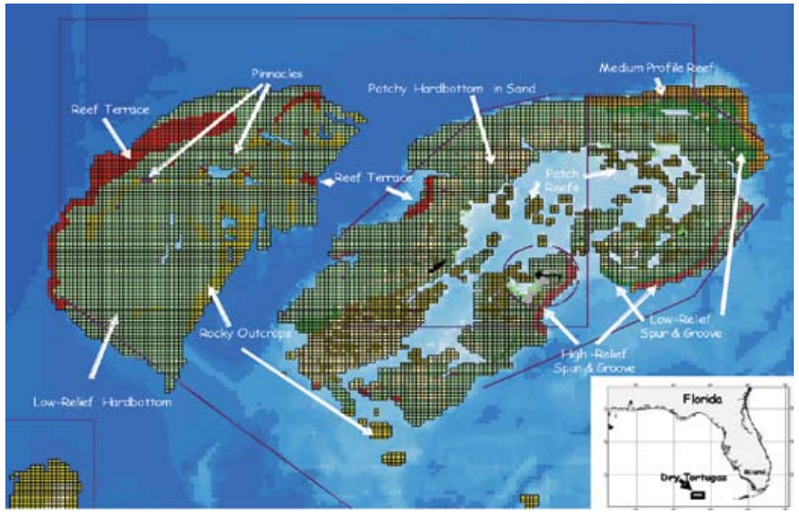


Figure 2a: Spatial distribution of the eight classified coral-reef habitats in the Dry Tortugas region overlain by the 200 × 200-m primary unit sampling grid used in RVC monitoring surveys.

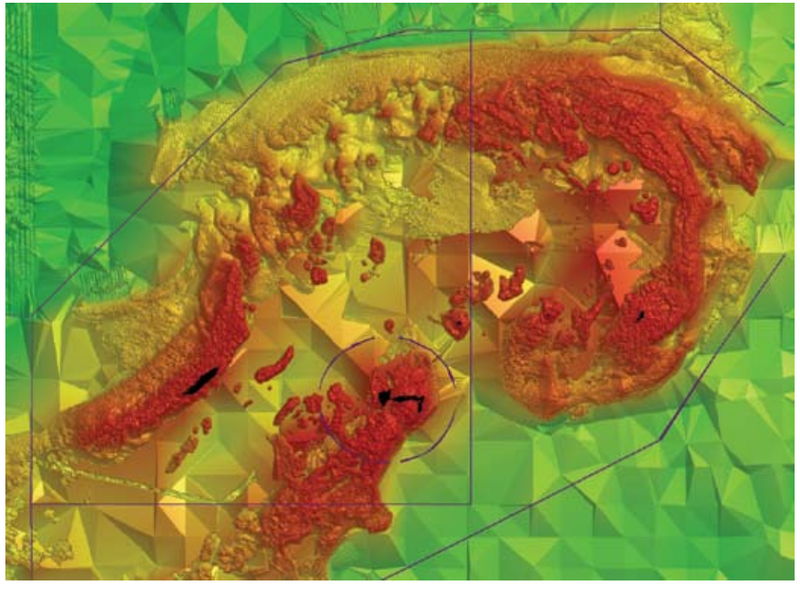


Figure 2b: Integrated bathymetric map of Dry Tortugas National Park using multibeam hydroacoustic and 15 cm footprint green laser topographic data from USGS-NPS-NASA EAARL Lidar. Black are islands, red is shallow and green is relatively deep (>35 m)

Monitoring Coral Reef Fish Populations in the Florida Keys

J.S. Ault and S.G. Smith (UM/RSMAS); J.A. Bohnsack (NOAA/NMFS)

Long Term Research Objectives and Strategy to Achieve Them:

Objectives: To augment the South Florida Ecosystem Restoration Program research by providing a comprehensive quantitative evaluation of trends in the Florida Keys National Marine Sanctuary (FKNMS) and Dry Tortugas National Park (DTNP) 'no-take' zones, Sanctuary Preservation Areas (SPAS), Ecological Reserves (ERs), and Research Natural Area (RNA).

Strategy: To carryout state-of-the-art multispecies assessments in the region, mapping coral reef habitats, and spatially-based monitoring of coral reef fish composition, occurrence, abundance, and size structure in the Florida reef tract to assess population changes, ontogenetic habitat associations, and ecosystem responses to fishing, recreational use, pollution, MPA zoning, and Everglades restoration.

CIMAS Research Themes:

Theme 2: Fisheries Dynamics (*Primary*)
Theme 3: Regional Coastal Ecosystem Processes (*Secondary*)

NOAA Funding Unit: NOS/SEFSC

NOAA Technical Contact: James Bohnsack

Link to NOAA Strategic Goals:

Goal 1: Protect, Restore, and Manage the Use of Coastal and Ocean Resources Through Ecosystem-based Management

Research Summary:

No-take marine reserves (NTMRs) in the National Marine Sanctuary (FKNMS) and Dry Tortugas National Park of the Florida Keys are a joint fishery and ecosystem management effort between the NOAA National Marine Sanctuary Program, National Park Service (NPS), and the State of Florida. The FKNMS has implemented three types of no-take areas: (1) 16 small Sanctuary Preservation Areas (SPAs) totaling approximately 46 km^2 that protect the high-relief coral reef; (2) one large (30 km^2) ecological reserve (ER) that includes several different habitats; and, (3) 4 special-use SPAs designed for research purposes. Two large Ecological Reserves, 206 and 312 km^2, are were added in 2001 west of the Tortugas, Florida. The NPS Service has scheduled a 100 km^2 Research Natural Area (RNA) for implementation in the western half of Dry Tortugas National Park in late 2006.

The main objective was to design and conduct comprehensive surveys of coral reefs and reef fish stocks along the Florida coral reef tract. Simultaneous assessment surveys were conducted of fishes, corals, conch, spiny lobster, other reef species and coral reef habitats using newly developed state-of-the-art sampling strategies. Results have been used to define current baseline conditions and to monitor future changes that result from management actions in Biscayne National Park, the Florida Keys National Marine Sanctuary, and Dry Tortugas National Park. Regionally-synoptic monitoring and assessment expeditions, led by Drs. Ault (Univ. of Miami) and Bohnsack (NOAA NMFS/SEFSC), have included participation by scientists from many state

Figure 1: A large black grouper (bottom) shares a colorful cave with a large cubera snapper in the Florida Keys.

and federal agencies, several universities, and a volunteer non-profit organization. Although still early in the recovery process, our results are encouraging. They suggest that NTMRs, in conjunction with traditional management, can potentially help build sustainable fisheries while protecting the Florida Keys coral reef ecosystem. This is a win-win scenario - good for the fish, the ecosystem, fishermen, and the Florida's economy!

The NOAA/NMFS Southeast Fisheries Science Center Coral Reef Initiative is supporting University of Miami RSMAS scientists in implementing interdisciplinary research on multispecies fisheries dynamics in the Florida Keys and wider Caribbean coral reef ecosystems. Quantitative baseline assessments were conducted on data collected from Biscayne National Park and Dry Tortugas National Park for design and analysis of their coral reef monitoring plans.

Research Performance Measure:
The objectives of this program are being met by the extensive monitoring program that is currently underway.

Figure 2: A rare marbled grouper is seen by RVC divers in the Dry Tortugas in 2006.

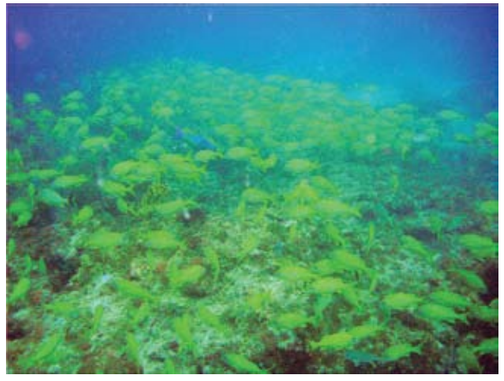


Figure 3: A large school of French grunt move in diametric opposition to a Creole wrasse in waters of the Florida Keys.

Statistical Analysis of Existing Data towards the Application of Ecosystem-based Management in the Northwest Hawaiian Islands

J.S. Ault and S.G. Smith (UM/RSMAS); M. Chow (NOAA/NOS)

Long Term Research Objectives and Strategy to Achieve Them:
Objective: To develop a cooperative program that is focused on strategic support for the Northwest Hawaiian Island Monument and the Pacific Island Fishery Science Center for coral reef fish stock assessment and resource monitoring efforts; to provide critical analyses for coral reef resource data inventory, assimilation and mapping, and development of statistical sampling designs for monitoring, ultimately supporting stock assessment efforts by NOAA in the US Pacific Islands.
Strategy: To work cooperatively with NOAA Fisheries Pacific Islands Fishery Science (PIFSC) Center in the development of the program.

CIMAS Research Themes:
Theme 2: Fisheries Dynamics (*Primary*)
Theme 3: Regional Coastal Ecosystem Processes (*Secondary*)

Link to NOAA Strategic Goals:
Goal 1: Protect, Restore, and Manage the Use of Coastal and Ocean Resources Through Ecosystem-based Management

NOAA Funding Unit: NMFS/SEFSC

NOAA Technical Contact: James Bohnsack

Research Summary:
The NOAA Northwestern Hawaiian Islands Coral Reef Ecosystem Reserve has recently undergone a process to designate the Northwestern Hawaiian Islands (NWHI) as a National Marine Monument (hereafter referred to as NWHI Monument). This new designation, combined with NOAA's goal to manage the use of coastal and ocean resources through ecosystem approaches to management, requires advancements to existing observing systems and analytical approach methodologies. To achieve this goal, the NWHI Monument is collaborating with NOAA Fisheries Pacific Islands Fishery Science Center (PIFSC) to undertake investigations that promote the application of ecosystem approaches to fisheries management (EAF) in the NWHI.

The PIFSC is responsible for assessing the status of deepwater snapper (hereafter referred to as bottomfish), crustacean, coastal pelagics, coral reef fish, and precious coral populations using the application of EAF in the NWHI. The fisheries management plans (FMP) for these resources require that annual stock assessments be openly conducted and published. However, no assessments have been done for any species listed in the Western Pacific Regional Fishery Management Council's Coral Reef Ecosystem FMP. Those stock assessments that have been conducted rely heavily on biased fishery-dependent data sets that lack information on important segments of the populations; this leads to uncertainty in stock assessments.

A recent surge in research activity in the NWHI has resulted in the collection of fishery-independent data to improve stock assessments. However, the quality of these data is unknown as most of the data sets have not been analyzed or subjected to formal quantitative evaluation for consistency, completeness, accuracy, precision, etc. The Fisheries Ecosystem Modeling and Assessment Research (FEMAR) group at the University of Miami, RSMAS, has developed an unprecedented capability by using a systems-science approach that stresses an applied scientific research strategy to support policy made by federal, state, and local agencies. For the past decade, FEMAR, in collaboration with state and federal partners, has been conducting large-scale synoptic assessments of coral reef fisheries and benthic habitats in the Florida coral reef ecosystem to explore and characterize these unique marine environments and to support management decision making. In this relatively new program, the NWHI Monument, working jointly with PIFSC, is working with to FEMAR to conduct the following three tasks: 1. Data Inventory, 2. Data Assimilation

and Mapping, and 3. Statistical Sampling Design. The NOAA/PIFSC is supporting University of Miami RSMAS scientists in implementing interdisciplinary research on multispecies fisheries dynamics in the Hawaiian Archipelago.

Research Performance Measure:
The objectives of this program are being met in activities that are currently underway.

Shallow-Water Grouper Distribution, Habitat Characteristics and Spawning Behavior

D.J. Die and V. Koch (UM/RSMAS); T. Kellison (NOAA/SEFSC)

Long Term Research Objectives & Strategy to Achieve Them:
***Objectives*:** To quantify habitat preferences for black groupers.
***Strategy*:** To tag fish and to use self-contained receivers in an array so that we can triangulate the position of a tagged fish and track it for months without the need for constant monitoring.

CIMAS Research Theme:
***Theme 2*:** Fisheries Dynamics

Link to NOAA Strategic Goals:
***Goal 1*:** Protect, Restore, and Manage the Use of Coastal and Ocean Resources Through Ecosystem-based Management

NOAA Funding Unit: NOS

NOAA Technical Contact: Todd Kellison

Research Summary:
In October, 2005, we placed an array of 25 omni-directional, single-channel acoustic receivers (VR2s) on Conch Reef (Key Largo); additional receivers were placed on Pickles and Little Conch Reef to act as "gates" to allow fish to be detected on their way in and out of the study area. The range of these receivers is approximately 300m in radius, encompassing an area of ½ km^2 (varying with bathymetry and water conditions). The receivers sample data from acoustically tagged fish at a near-continuous rate (sampling at a rate of once every 3 minutes for the duration of a deployment). The array was set up so that many of the ranges are overlapping. We surgically implanted acoustic tags in 17 Black (*Mycteroperca* bonaci) and 1 red grouper (*Epinephelus morio*).

In March, 2006, we conducted our first download of the receivers. Preliminary analysis from the first download shows a high success rate from the receivers. All but one of the receivers had detections, and only one black grouper was never detected. The most detections received by a single receiver was 272,711, at which point the receiver's memory was 88% full.

In addition to the acoustic telemetry study, we have also begun the development of interview process intended for commercial fishers. This process includes the development of draft interview format and content and the identification of commercial fishers to be interviewed.

Research Performance Measure:
We successfully deployed the acoustic array in our sample site as planned and we have obtained data as planned.

Figure 1: Surgical introduction of an acoustic tag in a live black grouper.

Studies on Billfish Spawning and Movement

R.K. Cowen, P. Rice, D. Richardson and J. Luo (UM/RSMAS);
E.D. Prince, J.E. Serafy, D. Snodgrass, E. Orbesen and D. Kerstetter (NOAA/SEFSC);
D. Shultz (UM Medical School); C.P. Goodyear (Goodyear Consulting);

Long Term Research Objectives and Strategy to Achieve Them:
Objective: To collect and analyze empirical data on the movement behavior of live billfish during the peak of their spawning seasons, as well as on the movement of longline fishing gear in the water column; to quantify degree of overlap between target species, bycatch species, and fishing gear and to explore strategies that minimize impacts on billfish when and where they are spawning.
Strategy: To use popup satellite archival tags (PSATs) on mature billfish; the latter involves the deployment temperature-depth recorders and hook-timers on longline gear during experimental research cruises.

CIMAS Research Theme:
Theme 2: Fisheries Dynamics

Link to NOAA Strategic Goals:
Goal 1: Protect, Restore, and Manage the Use of Coastal and Ocean Resources Through Ecosystem-based Management

NOAA Funding Unit: NMFS/SEFSC

NOAA Technical Contact: Eric Prince

Research Summary:
We used a combination of recreational and commercial fishing vessels to catch adult billfish, attach popup satellite tags to them, and release them back into pelagic waters to record their (horizontal and vertical) movements for periods up to 120 days. We have deployed a total of over 150 billfish were popup tagged in both the Atlantic and the Pacific Oceans since 2000: 58 blue marlin, 78 sailfish, 10 white marlin, and 6 swordfish. About 80% of the data collected by these tags was successfully transmitted back to us via the Argos satellite system and is currently undergoing data quality control and analysis. During May 2005, a pelagic longline research cruise was conducted in the Northern Gulf of Mexico. Two short pelagic longline sets per day, over a two week period, were deployed with a wide range of gear configurations from a NOAA research vessel to assess gear behavior under various oceanographic conditions and also to compare several experimental fishing techniques on catch rate. Time depth recorders were put on

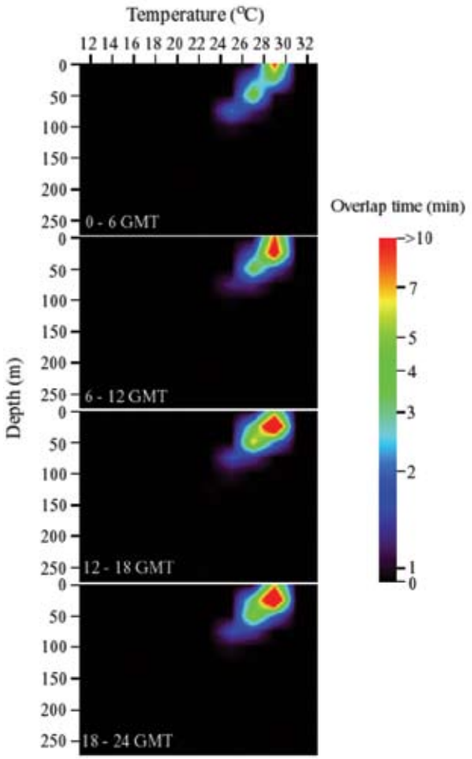


Figure 1: Depiction of the potential overlap between fishing gear and blue marlin for each time 6-hr time window. Color scale indicates time ranging from 0 to 10 minutes.

every hook gangion (i.e. in this saturation experiment) so that the depth that each hook fished could be accurately assessed. This aspect of the cruise distinguished it from previous research and offered a novel opportunity to investigate the effect of gear configuration on pelagic longline hook depth. In addition, several experimental fishing treatments were employed to assess impacts on catch composition, catch rates and/or fish condition. Longline cruise data are being analyzed to characterize gear movement and hook distribution in the water column. Ultimately we want to determine the degree of overlap with pelagic animal habitat (see Figure 1). Preliminary results indicate that longline gear behavior is complex and dynamic. Further studies of this type are required. In addition during this period we finalized research efforts that focused on the movement of Atlantic white marlin from a possible spawning area (Punta Cana, Dominican Republic), the development of analytical tools to assess vertical habitat use using PSAT data, and on an analysis of vertical habitat use (using PSAT tags) of marlin and sailfish in the eastern Pacific and western North Atlantic, as well as the association of these results with oceanographic features.

Research Performance Measure:
Research is proceeding as planned.

Modeling Connections Between Life Stages and Habitats Of Pink Shrimp in South Florida

M.M. Criales and H. Cardenas (UM/RSMAS); J.A. Browder and T.L. Jackson (NOAA/SESFC); M.B. Robblee (USGS/CWRS)

Long Term Research Objectives and Strategy to Achieve Them:

Objectives: To develop a pink shrimp simulation model and performance measures to evaluate the impact on Florida Bay of upstream water management changes resulting from efforts to restore the Greater Everglades ecosystem.

Strategy: To monitor different life history stages of pink shrimp; to model the population changes in the context of water quality measures for a better understanding of the ecology of this important fishery species in relation to the processes influencing transport, settlement, survival, and recruitment.

CIMAS Research Theme:

Theme 2: Fisheries Dynamics

Link to NOAA Strategic Goals:

Goal 1: Protect, Restore, and Manage the Use of Coastal and Ocean Resources Through Ecosystem-based Management

NOAA Funding Unit: NMFS/SEFSC

NOAA Technical Contact: Joan Browder

Research Summary:

The pink shrimp (*Farfantepenaeus duorarum*) is an important species in south Florida that supports a multi-million-dollar fishery in the vicinity of Dry Tortugas and Key West, and serves as an important prey species in Florida Bay. The pink shrimp spawn offshore near the Dry Tortugas and larvae migrate into the nursery grounds of Florida Bay where they settle for several months before entering the adult population (Fig. 1). Population dynamics are strongly influenced by biological and physical processes that affect the different life history stages. Without an understanding of these processes it would not be possible to fully identify the controls of the variability of population abundance, thus hampering attempts at effective management of the ecosystem and the fishery.

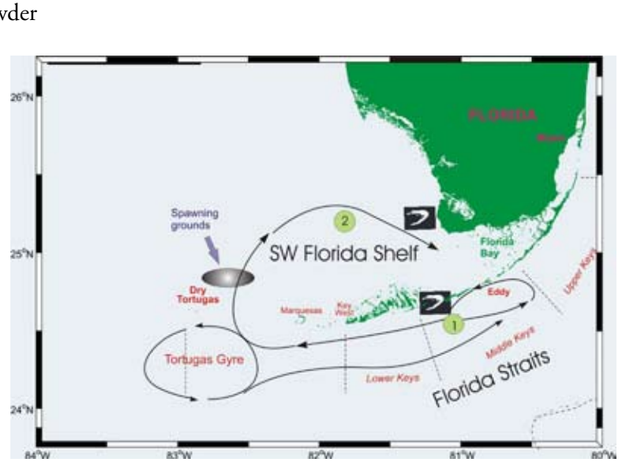


Figure 1: Map of the study area indicating the two main hypothesized recruitment pathways (1 and 2) for pink shrimp larvae, the spawning grounds near Dry Tortugas and nursery grounds in Florida Bay.

During the first phase of this research we test hypotheses of larval transport routes from spawning to nursery grounds: 1. via Florida Straits-Florida Keys, 2. via the southwestern Florida (SWF) shelf-western Florida Bay. Results of four years of monthly sampling on the influx of postlarvae at tidal channels demonstrated that the vast majority of postlarvae enter Florida Bay throughout its NW border. This suggests a feasible

transport mechanism across the SWF shelf (Fig. 2). Simulations of transport from a Lagrangian (horizontal) model indicated that larvae with a tidally-related behavior could consistently travel between 100 and 200 km in 30 days (5 km d^{-1}) across the wide, tidally-dominated SWF shelf. However, this behavior has been identified only in pink shrimp postlarvae entering nursery grounds but not in earlier stages during their onshore migration.

As a joint effort of several institutions in Miami (NOAA/SEFSC, NOAA/AOML, USGS, the CIMAS/UM) and in Pascagoula (NOAA/SEFSC) we conducted an oceanographic cruise to investigate cross-shelf transport mechanisms on the SWF shelf and larval behavior of pink shrimp larvae. At the Marquesas station (20 m depth), midway between Dry Tortugas and Florida Bay, internal tides were recognized by anomalously cool water, a shallow thermocline with strong density gradients, and current reversal and intensification at the pycnocline depth (8-12 m). We found high concentrations of larvae at the thermocline at Marquesas, where larval concentrations were seven times higher than at the Dry Tortugas (Fig. 3). We also found evidence of ontogenetic differences in larval behavior potentially affecting cross-shelf transport. The youngest larvae (protozoeae) performed a daily vertical migration; in contrast, advanced larvae (myses and postlarvae) occurred at the surface layer in two large peaks, day and night, with a semidiurnal periodicity in phase with the flood tides. Our time series of larval flux and water velocity at the Marquesas site indicated that larvae with a semidiurnal periodicity and a shallow distribution experienced considerable onshore transport. This constitutes the first tidal transport mechanism reported for decapod larvae migrating in continental shelf waters far away from the coastal nursery grounds.

Research Performance Measure:

We have met our objective: to develop a pink shrimp simulation model and performance measure to evaluate the impact of upstream water management changes on Florida Bay.

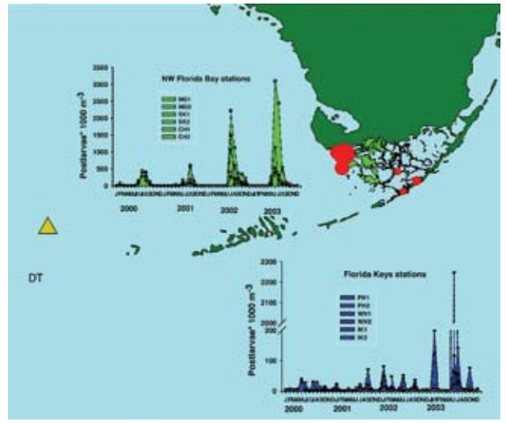


Figure 2: Map of the study area showing the monthly concentrations of pink shrimp postlarvae over 4 years of sampling at stations in the northwestern border of Florida Bay and stations in the Middle Florida Keys region. The red circles represent mean concentrations at each station, and circle sizes are proportional to the concentrations.

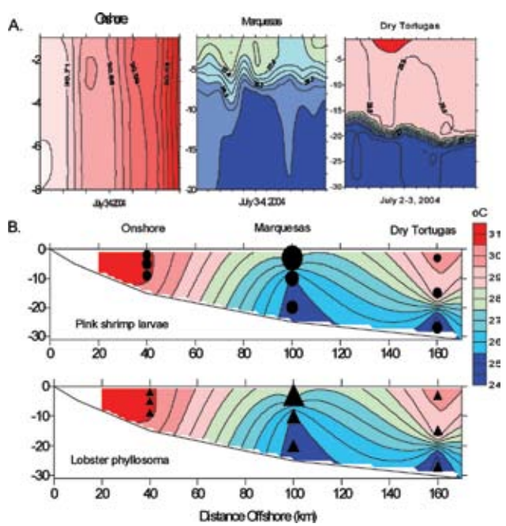


Figure 3: A. Time-depth plots of temperature recorded at three stations (Dry Tortugas, Marquesas, Onshore) located in a cross-shelf transect on the SW Florida Shelf. B. Temperature contours across the transect with the concentration of pink shrimp larvae and lobster (*Scyllarides* sp.) phyllosoma superimposed on temperature contours and symbol sizes proportional to concentrations.

Hydroacoustic Biomass Assessment of Reef Fish Spawning Aggregations

S. Frias-Torres (UM/CIMAS); Todd Kellison (NOAA/SEFSC); Jose Rivera (NOAA)

Long Term Research Objectives and Strategy to Achieve Them:
Objectives: To locate and quantify grouper-snapper spawning aggregations in Puerto Rico and USVI.
Strategy: To use state-of-the-art hydroacoustic echo integration technology, towable underwater video systems, and SCUBA for systematic surveys of Puerto Rico and USVI.

CIMAS Research Theme:
Theme 2: Fisheries Dynamics

Link to NOAA Strategic Goals:
Goal 1: Protect, Restore, and Manage the Use of Coastal and Ocean Resources Through Ecosystem-based Management

NOAA Funding Unit: NMFS/SEFSC

NOAA Technical Contact: Todd Kellison

Research Summary:
Many commercial fishery stocks on the submarine shelf of Puerto Rico are depleted or are near depletion in spite of federal and state management regulations. The precise location of many spawning aggregations targeted by fishers remains unknown to scientists. This ongoing projet provides an estimate of fish biomass, abundance and size of fish spawning aggregations on the submarine shelf of Puerto Rico and the US Virgin Islands. In our study we perform biomass stock assessment surveys using state-of-the-art hydroacoustic echo integration technology, towable underwater video systems, and SCUBA. These methods enable us to identify habitats and depths preferred by grouper and snapper spawning aggregations. This information can be incorporated in the planning of future policies for sustainable fisheries management.

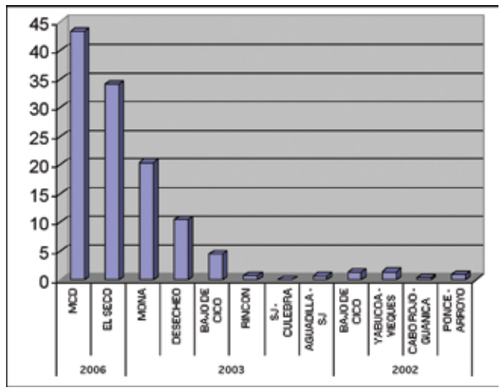


Figure 1: Comparison of fish abundance in Puerto Rico and the U. S. Virgin Islands as determined by hydroacoustic biomass survey (MCD = Marine Conservation District in St. Thomas).

We have completed all surveys as planned and our results are being used in setting management objectives. The Puerto Rico Department of Natural Resources recently published regulations prohibiting all fishing of red hind (*Epinephelus guttatus*) during their spawning season (December 1st to February 28th) around the entire shelf in Puerto Rico jurisdictional waters. This management action, intended to reduce overfishing, was the direct result of hydroacoustic research which showed that fish spawning aggregations were widespread around the shelf. Closures apply to commercial and recreational fishing under Puerto Rico Fishing Regulations (Feb 10, 2004, No 6768), Article 8 –General Fishing Limits. All fishers and vendors must dispose of fish captured in jurisdictional waters before the start of the closed season. Importers of this species must demonstrate compliance by means of purchase receipts.

Research Performance Measure:
All program milestones are being met.

Epibenthic Fauna Adjacent to the South Biscayne Bay Shoreline in Relation to Seagrass, Shoreline Fishes, and Salinity

D. Hazra, D. Johnson, J. Tomoleoni, H. Cardenas, and R. Esteve (UM/CIMAS); J.A. Browder, J. Serafy and C. McCain (NOAA/SEFSC); M.B. Robblee (USGS/CWRS)

Long Term Research Objectives And Strategy To Achieve Them:
Objectives: To develop information on interrelationships as a foundation for detecting early ecological changes brought about by changes in hydrology as part of the Comprehensive Everglades Restoration Project and its Biscayne Bay Coastal Wetlands component.

Strategy: To carry out baseline characterizations of the epifauna of the very shallow open-water area immediately adjacent to the South Biscayne Bay shoreline.

CIMAS Research Theme:
Theme 2: Fisheries Dynamics

Link to NOAA Strategic Plan:
Goal 1: Protect, Restore, and Manage the Use of Coastal and Ocean Resources Through Ecosystem-based Management

NOAA Funding Unit: NMFS/SEFSC

NOAA Technical Contact: Joan Browder

Research Summary:
The ecosystems in the shallow water regions of Biscayne Bay are sensitive to a number of environmental variables, especially the fresh-water flow into the region. To better understand the response of this area to seasonal changes in flows, we carried out an extensive series of surveys. Epibenthic fish and macroinvertebrates were sampled with a 1-m^2 throw-trap in shallow-water nearshore seagrass habitat in proximity to fish visual survey sites in mangrove shoreline habitat. Collections were made in the dry seasons (winter) and wet seasons (summer) of 2005 and 2006. A summary and analysis of the 2005 data has been completed. Significant cross species correlations were noted both within and between habitats. Statistical models were developed to further explore relationships of species to each other and to physical and habitat variables. The dry season and wet season data were analyzed separately, and 15 significant dry season models and 14 significant wet season models were obtained, each with significant explaining variables. Salinity was the most frequently included single explaining variable, found in 10 of the 15 dry season models and seven of the 14 wet season models. One or more of the four habitat variables (*Halodule* BB, *Thalassia* BB, canopy height, or mixed algae BB) was included as a significant variable in most models. One or more faunal variables was included in nine of the dry season models and seven of the wet season models. While some may reflect prey-predator relationships, others may suggest competition for food-resources or habitat, a more complex relationship of some type, or a common affinity for physical conditions and habitat. It is significant that some relationships suggested by our models—especially the density related effect of code gobies on clown gobies—are supported by reported results of other investigators.

The interrelationships suggested by the models are shown in Figures 1 (dry season) and 2 (wet season). Gulf toadfish was the major predator and second most abundant fish in the seagrass habitat. Our models indicated possible predator-prey relationships of toadfish with rainwater killifish, clown gobies, and carideans. The relationship with carideans could be due to direct predation of juvenile toadfish on carideans or, alternatively, to predation by toadfish on small fish that feed on carideans. Gray snapper was the most abundant predator in the mangrove habitat. Both toadfish and gray snapper were related to portunus crab in the wet season, possibly indicating some competition for food resources. Information in the literature indicates that gray snapper and toadfish are connected by a predator-prey relationship, with larger gray snapper eating toadfish.

Research Performance Measure:
All program objectives are being met.

Figure 1: Dry season environmental and trophic relationships as suggested by statistical models.

Figure 2: Wet season environmental and trophic relationships as suggested by statistical models.

Monitoring Coral Reef Fish Utilization of MPAs and Recruitment Connectivity between the Florida Keys and Meso-American Reefs

M.R. Lara and D.L. Jones (UM/CIMAS); J.T. Lamkin (NOAA/SEFSC)

Long Term Research Objectives and Strategy to Achieve Them:
Objectives: To investigate aspects of reproduction and transport of fish larvae in the context of physical oceanographic parameters in order to better understand the variables involved in the transport of these organisms to the coral reef ecosystem.
Strategy: To carry out shore-based sampling of plankton and concurrent measurements of physical oceanographic variables at points along the Yucatan coast and on extended research cruises so as to gather plankton and physical data along the entire Yucatan coast; to use newly developed methodologies for otolith microchemistry to answer questions about larval transport.

CIMAS Research Theme:
Theme 2: Fisheries Dynamics

Link to NOAA Strategic Goals:
Goal 1: Protect, Restore, and Manage the Use of Coastal and Ocean Resources through Ecosystem-based Management

NOAA Funding Unit: NMFS/SEFSC

NOAA Technical Contact: John Lamkin

Research Summary:
The aim of the study is to investigate aspects of reproduction and transport of larvae of fish inhabiting coral reef and tropical seagrasses and to measure physical oceanographic phenomena that may be involved in this transport. We are interested in the connectivity among different regions as sources and sinks of fish larvae and the large and small scale oceanographic processes that may be acting to determine the scale of this connectivity. Specifically we attempt to address the questions: 1. What physical oceanographic mechanisms are important in the transport of fish larvae and at what scale do these mechanisms come into play? 2. What patterns of larval fish distribution do they produce? 3. Can newly developed methods of otolith trace element analysis be applied to elucidate patterns of transport? 4. Can spawning aggregations known to occur off the Yucatan coast contribute as upstream sources of reef fishes to the Florida Keys and Dry Tortugas?

The long term goal of this research is to establish the existence and degree of connectivity among sources and sinks of reef fish metapopulations. This is a necessary step for the proper management of fish stocks, the design and maintenance of Marine Protected Areas, and the establishment of essential fish habitats. We have begun the collection of fish larvae which will extend over several years at various sites in Yucatan, Mexico. This region was chosen as a possible upstream source of larvae to Florida. We are in the process of conducting a series of research cruises to collect oceanographic data and samples of fish larvae off the Yucatan coast. In conjunction with this large scale characterization of larvae and physical-oceanographic studies, we are conducting smaller scale experiments nearshore to characterize local recruitment and small scale physical mechanisms of transport.

We have thus far completed five trips to the Yucatan. The first was to establish collaboration with researchers at the Mexican university El Colegio de la Frontera Sur (ECOSUR). The second trip was in 2004 to bring equipment and provide training in the field of the sampling techniques to be employed. Sampling was subsequently conducted on a monthly schedule. This work resulted in an extensive collection of fish larvae from a number of locations in the Yucatan. In March 2005 we conducted the first extended sampling and monitoring study that involved the capture of fish larvae and simultaneous measurement and documentation of physical oceanographic phenomena. We obtained over 100 plankton samples using 3 different types of collecting gear. In March 2006 we collected coastal oceanographic data and plankton

during cruises aboard the NOAA ship GORDON GUTNER. These studies found very high abundances of larvae.

Light trap studies were carried out off Banco Chinchorro (an atoll and biosphere reserve in the Mexican Caribbean) during Feb - Mar 2006. Here too we collected an astounding diversity of fishes over three days of sampling. Lagrangian drifter data show a current reversal that was associated with a marked peak in larval supply. Several economically important species were collected, notably three species of groupers, and several other species were identified that had not previously recorded for the area.

Research Performance Measure:
The program is on schedule.

Monitoring Coral Reef Fish Utilization of MPA's and Inshore Habitats in Florida Bay

M.R. Lara and D.L. Jones (UM/CIMAS); J.T. Lamkin (NOAA/SEFSC)

Long Term Research Objectives and Strategy to Achieve Them:
Objectives: To monitor coral reef fish recruitment processes in the Florida Keys reef system and adjacent juvenile habitat.
Strategy: To use trace element analysis of the otoliths (ear bones) of fishes as a basis of estimating the contribution of various nursery habitats as sources of recruits.

CIMAS Research Theme:
Theme 2: Fisheries Dynamics

Link to NOAA Strategic Goals:
Goal 1: Protect, Restore, and Manage the Use of Coastal and Ocean Resources through Ecosystem based Management

NOAA Funding Unit: NMFS/SEFSC

NOAA Technical Contact: Isabel Holder

Research Summary:
Commercially important snapper species are believed to migrate to reefs from juvenile nursery areas such as sea grass and mangrove habitats in Florida Bay and the lower Florida Keys. Little is known about the nature of these nursery areas (physical characteristics, seasonality, quality, persistence), the migration corridors that exist between nursery and reef, and the timing of these migrations. Our research has focused on developing techniques that could be used to identify the principal nursery areas of the commercially, recreationally, and ecologically important reef fish species in South Florida and to subsequently identify the nursery areas used by adults collected on the reef tract.

We have been able to identify nursery areas based on the concentrations of trace elements, including rare earths, in the otoliths (ear bones) of fishes. Our program is the first to study the of use rare earth elements as a tracer in otoliths. Seventeen of the 32 elements examined contributed substantially to the spatial resolution of nursery regions. Cross validation indicated that 80% of all fish were correctly classified to region of origin. When fish were classified as either originating from Florida Bay or not, 13 elements contributed substantially to population separation. In this case, cross validation indicated that 86% of all fish were correctly identified. We have improved our cross validation success by analyzing isotopes from otoliths and with these two data sets combined we approach 100% correct classification. We are now studying the use of the same chemical signatures in adults captured on the reefs of South Florida. In this way, we will better understand the contribution of each of these regions as nursery habitats for the adult population of Florida's reefs. The long-term

monitoring and effective management of these areas requires research on the links between habitats and particularly their function as sources and destinations of recruits. This is of particular importance given the recent efforts to restore Florida Bay and the establishment of Marine Protected Areas (MPAs) and the Tortugas Ecological Reserve. The South Florida Coral reef initiative calls for the establishment of no-take reserves within these MPAs and we believe that only with effective identification and protection of sources of recruits can we ensure the effective function of MPAs as reef fish sanctuaries. Information on key nursery areas can help guide decisions such as where to establish no-take and other protected areas.
We have recently compared the otolith elemental signatures among three species of snappers (gray, schoolmaster, and yellowtail) and found highly significant differences between pairs of species that co-occur. These results confirm our suspicion that one species cannot be used as a proxy for another in studies examining spatial variation of microchemical signatures. While the basis for these taxon-specific microchemical signatures may well have a physiological basis, we cannot presently rule out the existence of a behaviorally mediated environmental mechanism (e.g., species-specific diel migrations across microhabitats resulting in prolonged exposure to different water masses).

Research Performance Measure:
We have attained our first major objective, the successful matching of fishes to their nursery regions in South Florida based on the microchemical signatures in their otoliths.

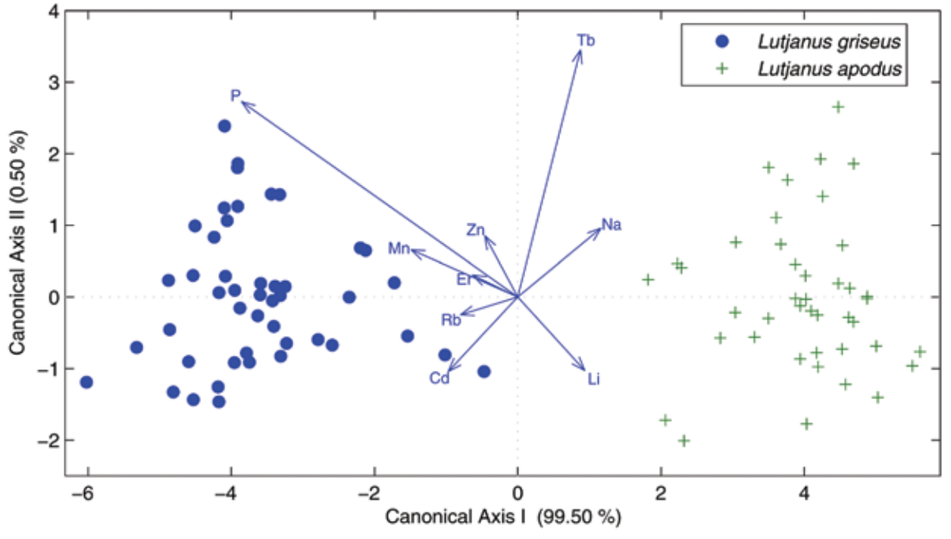


Figure 1: Canonical discriminant analysis (CDA) plot depicting 9 of the 29 otolith trace elements examined that contributed substantially to the separation of species (i.e., Lutjanus griseus vs. L. apodus, n = 88) from 5 collection sites in Florida Bay. Length of correlation vectors indicates the relative contribution each element made in separating species; the gradient of elemental concentration is indicated by the vector heading.

Settlement, Growth, and Migration of Snappers in Florida Bay and Adjacent Marine Ecosystems

M. Lara and D. Jones (UM/CIMAS); T.L. Gerard (NOAA/SEFSC)

Long Term Research Objectives and Strategy to Achieve Them:

Objectives: To investigate and monitor the movement, migration and growth of juvenile stages of gray snapper in Florida Bay and adjacent marine ecosystems through the use of stable isotope analysis of their otoliths (ear bones).

Strategy: To use stable isotope analysis of carbon and oxygen and otolith ageing to enhance our understanding the size-age structure of juveniles in the Bay, their growth rates and migration patterns, and how these relate to habitat characteristics and environmental variables such as salinity and temperature and ontogenetic shifts in habitat use.

CIMAS Research Theme:

Theme 2: Fisheries Dynamics

Link to NOAA Strategic Goals:

Goal 1: Protect, Restore, and Manage the Use of Coastal and Ocean Resources Through Ecosystem-based Management

NOAA Funding Unit: MNFS/SEFSC

NOAA Technical Contact: Trika Gerard

Research Summary:

Stable isotopic ratios of carbon and oxygen, obtained from the otoliths (ear bones) of fish, have been well documented as useful tools for providing a wealth of information on environmental variations and stock structure of fish throughout their life history. Some of the valuable data include information about habitat temperature and salinity, migratory patterns and habitat use, diet and metabolic rates, and determination of the degree of stock mixing. In this study, we investigate the size-age structure of gray snapper (*Lutjanus griseus)* juveniles in Florida Bay, examine their migration patterns, and explore how these relate to habitat characteristics and environmental variables such as salinity, temperature, and ontogenetic shifts in habitat. Our results are interpreted in terms of natural variability in population parameters such as recruitment and growth and how these parameters are influenced by natural environmental variability. Ultimately, we expect to provide fisheries managers with information on possible impacts of ecosystem change on gray snapper populations as a result of the implementation of the Comprehensive Everglades Restoration Plan.

Phase one of this study has been completed. Measurements were made of $^{18}O/^{16}O$ and $^{13}C/^{12}C$ ratios in the otolith carbonate obtained from juvenile gray snapper collected in 2001-2004 from various locations within Florida Bay and surrounding marine ecosystems. Results established that stable isotopes of carbon and oxygen enable us to make a conclusive identification of fish from five regions in South Florida and from specific sites within those regions.

Phase two includes using a high-resolution Micromill drill to obtain samples along a transect of individual otoliths thereby providing data from different periods over the life cycle of the fish. The record provided by the otolith enables us to examine transitions in habitats and migrations between them. Phase three involves determining the age of our juvenile samples by adding the daily calcium carbonate rings present on the otolith. Ultimately, we will establish a size-age growth curve to determine the age at which habitat transitions and migrations occur as well as provide baseline age to size data for general fisheries research and management purposes.

Research Performance Measure:

We have attained our first objective: to examine fish from different regions to look for differences in isotope ratios in their otoliths, and our second objective, to produce a length-age curve for juvenile gray snappers from Florida.

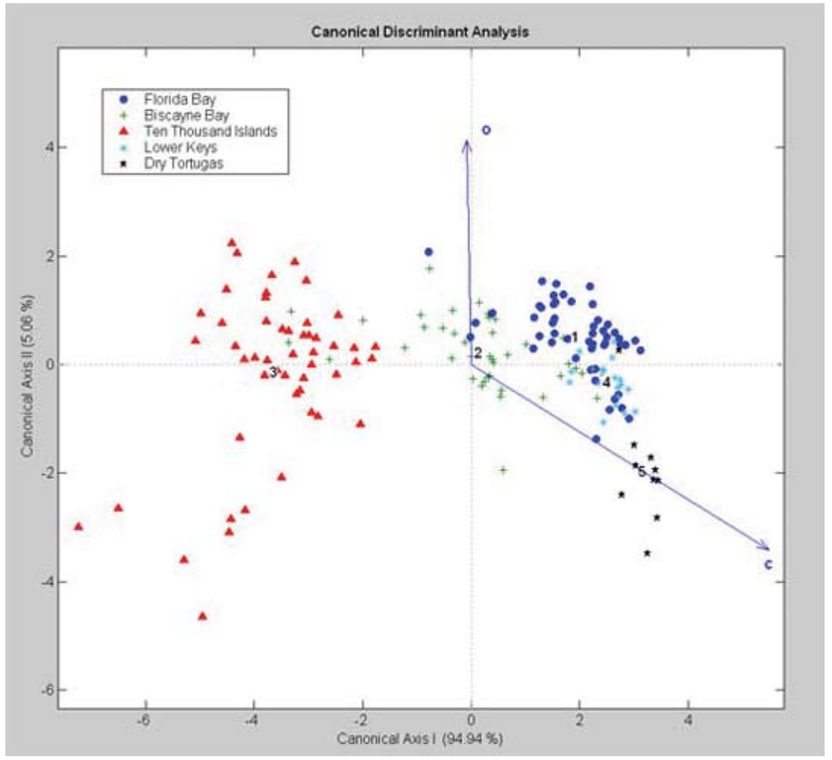


Figure 1: Canonical Discriminant Analysis for ^{13}C and ^{18}O determining differences in otoliths from five regions in South Florida.

Monitoring Shoreline Fish Assemblages of Biscayne and Florida Bays

J. Luo, J.E. Serafy, M. Valle, C. Faunce, B. Teare,
E. D'Alessandro, and C. Peyer (UM/RSMAS)

Long Term Research Objectives and Strategy to Achieve them:

Objectives: To characterize the "baseline conditions" and variability in fish communities in Biscayne Bay so as to be able to quantify any changes that might occur in response to variations in fresh water flow (and salinity) especially after the regional water flow is changed as part of the Everglades Restoration.

Strategy: To continue the seasonally-resolved fish monitoring effort in southern Biscayne Bay; to expand this effort to sites in northern Biscayne Bay, Card Sound, Barnes Sound and northeastern Florida Bay; to correlate changes in salinity with changes freshwater flow and in shoreline ichthyofauna.

CIMAS Research Themes:

Theme 2: Fisheries Dynamics (*Primary*)
Theme 3: Regional Coastal Ecosystem Processes (*Secondary*)

Link to NOAA Strategic Goals:

Goal 1: Protect, Restore, and Manage the Use of Coastal and Ocean Resources Through Ecosystem-based Management (*Primary*)
Goal 2: Understand Climate Variability and Change to Enhance Society's Ability to plan and Respond (*Secondary*)

NOAA Funding Unit: NMFS/SEFSC

NOAA Technical Contact: Joe Serafy

Research Summary:

The program Shoreline Fish Community Visual Assessment (SFCVA) is a monitoring component of the REstoration, COordination and VERification (RECOVER) program of the Comprehensive Everglades Restoration Plan (CERP). SFCVA began in 1998 and the sampling effort has continued to grow throughout the monitoring domain. In the current year we completed over 200 visual fish transects during the wet and dry seasons. However, poor visibility, especially due to recent hurricane activity, had an impact on sampling distribution and intensity in northeastern Florida Bay. In the baseline condition analyses, we took a generalized linear mixed model (GLMM) approach, to construct time series of nominal and standardized indices for taxonomic richness, taxonomic dominance, and the abundances of four fish taxa: gray snapper (*Lutjanus griseus*), great barracuda (*Sphyraena barracuda* and two mojarras (*Geres cinereus* and *Eucinostomus* spp.). Mean seasonal levels, with 95% confidence intervals, of each fish metric have been generated from 1998 through 2004 and these have been plotted for the

Figure 1: Sun beam penetrating through mangrove canopies and prop roots, highlighting mangrove snappers in hiding.

mainland shoreline and its component segments, as well as for shorelines on the leeward side of Sands and Elliot Keys. New shoreline fish data (i.e., that for 2005 and beyond) continue to be collected and will be incorporated into our database, ultimately to serve to gauge future impacts of CERP-related modifications to freshwater flow. Finally, in this study we focus on the properties and patterns of six potential performance measures, a small fraction of the total number of potential shoreline fish community metrics in our dataset that could have utility. Evaluation of additional fish community variables is underway. Thus the current suite of fish metrics is expected to grow and become increasingly important as CERP-related modifications to freshwater flow proceed.

Research Performance Measure:

The program is on schedule. However, poor visibility, especially due to recent hurricane activity, had an impact on sampling distribution and intensity in northeastern Florida Bay.

Figure 2: Mangrove shoreline is an essential habitat for many fish species.

Figure 3: Up and down view of mangrove habitat.

Design and Development of the Caribbean-wide Reef Fish Visual Census Universal Database

M.-L. Shyu (UM/ENG); J.S. Ault (UM/RSMAS); J.A. Bohnsack (NOAA/SEFSC)

Long Term Research Objectives and Strategy to Achieve Them:

Objective: To develop a standardized, state-of-the-art web-based data entry, error checking validation, storage, and report generating system for centralizing Reeffish Visual Census (RVC) monitoring data collected with the stationary diver method in the Florida Keys and the U.S. Caribbean.

Strategy: To use state-of-the-art technologies including Oracle Database 10g Enterprise edition, Oracle's JDeveloper 10g, HTML, Apache, JSP (Java Server Pages), JDBC (Java Database Connectivity) API, JavaScript, Microsoft Visual Studio environment, and Visual C++ to facilitate design and wide-ranging use and applicability of the web-based RVC system.

CIMAS Research Themes:

Theme 2: Fisheries Dynamics
Theme 3: Regional Coastal Ecosystem Processes

Link to NOAA Strategic Goals:

Goal 1: Protect, Restore, and Manage the Use of Coastal and Ocean Resources Through Ecosystem-based Management

NOAA Funding Unit: NOS/SEFSC

NOAA Technical Contact: Jim Bohnsack

Research Summary:

The RVC database provides a highly integrative and essential part this project. The improved Oracle database schema now considers the identified requirements and realizes this goal through improved design. The stream-lined data entry program and schema consumes very low computer processing power and memory capacity. The system provides an attractive user interface to the divers and it automatically validates the data when the divers enter the critical resource monitoring data that they have recently collected in field samples. The RVC Web-based interface provides an efficient and convenient way to centralize the data and to distribute the software needed to efficiently access the RVC data entry program. This interface is designed to accommodate different users with varying levels of database privileges and access, thereby providing great management and processing power to this project.

Research Performance Measure:

The objectives of this project for this project period were met.

Figure 1: Initial screen of the data entry program used by reef fish visual census (RVC) divers to enter sample data.

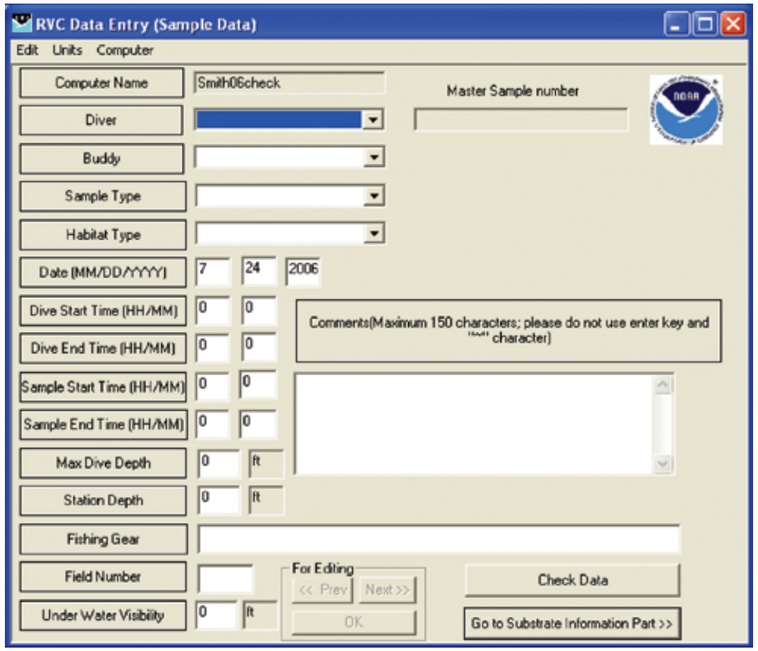
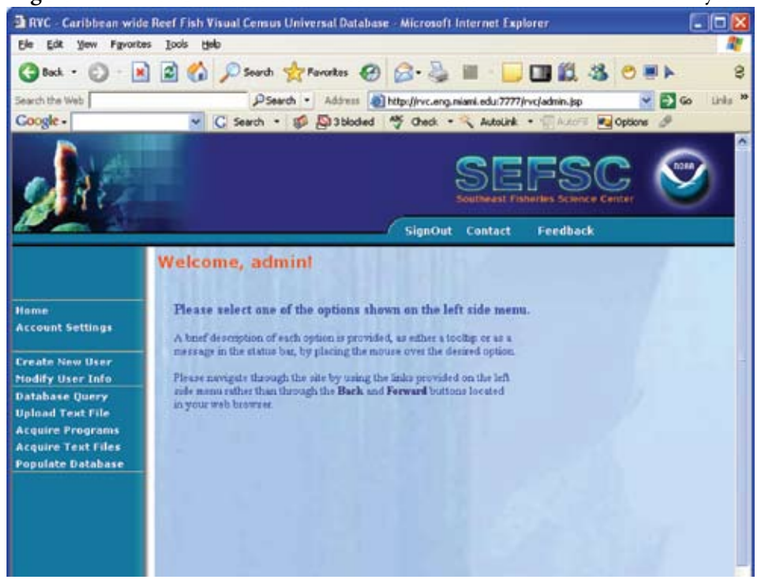


Figure 2: RVC web-based interface welcome screen for the system administrator



Pelagic Longline Sea Turtle Mitigation Research: Hook and Bait Feeding Trials

L. Stokes (UM/RSMAS); S. Epperly, J. Watson, D. Hataway, C. Bergmann, L. Belskis, B. Higgins, D. Foster, J. Gearhart and L. Saxon (NOAA/SEFSC)

Long Term Research Objectives and Strategy to Achieve Them:
Objectives: To reduce the incidental capture and mortality of sea turtles in pelagic longline fishing gear.
Strategy: To develop an empirical understanding of the interaction between loggerhead sea turtles and baited hooks.

CIMAS Research Theme:
Theme 2: Fisheries Dynamics

Link to NOAA Strategic Goals:
Goal 1: Protect, Restore, and Manage the Use of Coastal and Ocean Resources Through Ecosystem-based Management

NOAA Funding Unit: NMFS/SEFSC

NOAA Technical Contact: Sheryan Epperly

Research Summary:
We conducted laboratory feeding trials to further investigate methods to reduce incidental capture and post-hooking mortality of sea turtles in pelagic longline fisheries. We investigated the effects of hook size, animal size, bait type and baiting technique as they relate to loggerhead sea turtles' ability to swallow a baited hook. To this end, we modified 14/0, 16/0, 18/0 or 20/0 circle hooks by removing the barb and wrapping the end to prevent injury to the turtle and baited (either "single hooked" or "threaded") the hooks with whole squid or sardines. We offered the baited hooks to captive-reared loggerheads (Fig. 1) in three size classes (45, 55, and 65 cm straight carapace length). A recorder coded the turtle's reaction based on its response: "did not take hook into mouth," "hook partially in mouth," "hook fully in mouth," or "attempted to swallow." A videographer taped the interactions to further elucidate behavioral details of the interaction.

As expected, the potential for full ingestion decreased as hook size increased, thus reducing the likelihood of a serious injury. As the turtles increased in size, though, so did their ability to swallow the larger hooks. Turtles were less likely to fully or partially ingest hooks baited with sardines than those baited with squid. They were also less likely to fully or partially ingest "single hooked" bait than "threaded" bait, as single hooked bait was more likely to tear away. These results are likely due to the differences in bait texture, potential shielding effects of the bait, and behavioral differences in how turtles feed on different bait types.

Although these results are highly relevant to several fisheries, there are other fisheries (e.g., mahi-mahi and tuna) where large hooks would decrease catch. These would benefit from the ability to use smaller hook sizes to maximize their target catch. Therefore, we are expanding this research to test an innovative technology - wire appendage hooks (Fig. 2) which would allow the use of smaller hooks. These are circle hooks that are modified with a wire appendage attached perpendicular to the eye; this, in effect, increases the overall hook diameter. These hooks have been shown to reduce gut hooking and undersized catch in commercial snapper fisheries, and have shown promise in reducing incidental sea turtle capture in pilot field tests on commercial vessels targeting mahi-mahi in Ecuador and Peru.

Research Performance Measure:
The program is progressing according to plan.

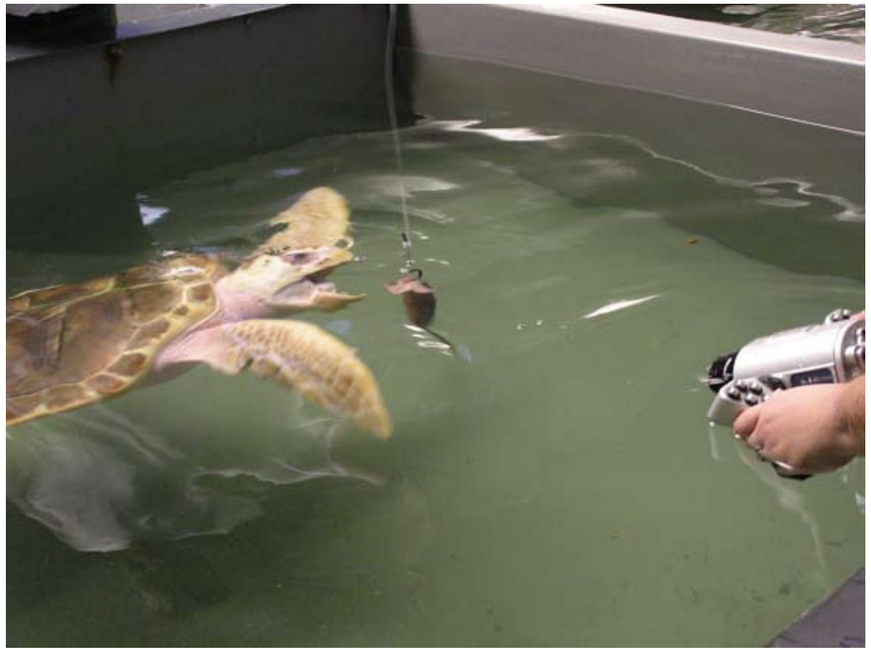


Figure 1: Feeding trial. Photo by L. Belskis, NOAA Fisheries

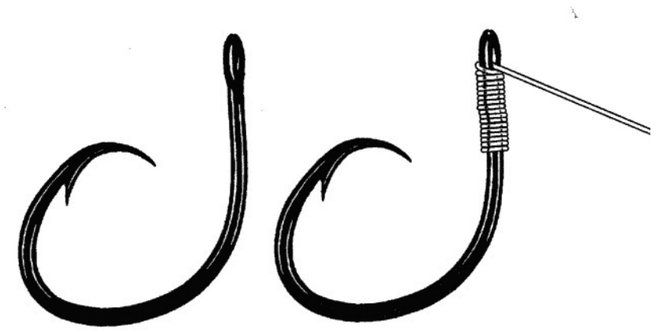


Figure 2: Unmodified circle hook (left) and circle hooks with wire appendage (right). Diagram by J. Javech, NOAA Fisheries

Pelagic Longline Sea Turtle Mitigation Research: Oral Cavity Morphometrics

L. Stokes, M. Burgos (UM/RSMAS); S. Epperly, L. Belskis,
D. Hataway and B. Higgins (NOAA/SEFSC)

Long Term Research Objectives and Strategy to Achieve Them:
Objectives: To reduce the incidental capture and mortality of sea turtles in pelagic longline fishing gear.
Strategy: To investigate the morphometric parameters and ontogeny of the oral cavity in loggerhead sea turtles.

CIMAS Research Theme:
Theme 2: Fisheries Dynamics

Link to NOAA Strategic Goals:
Goal 1: Protect, Restore, and Manage the Use of Coastal and Ocean Resources Through Ecosystem-based Management

NOAA Funding Unit: NMFS/SEFSC

NOAA Technical Contact: Sheryan Epperly

Research Summary:
In order to further understand the interaction between sea turtles and hooks on pelagic longline fishing gear, we investigated the morphometric parameters of the oral cavity in loggerheads. Of particular interest is how these measures relate to the size parameters of hooks currently fished in the pelagic longline fisheries. We performed a series of measures, both standard and specific to the oral cavity, on 210 loggerheads ranging in size from 35 cm to 80 cm straight carapace length. This range spans the turtle size classes most often incidentally captured. These measures included: mass, straight carapace length (SCL) notch-to-notch (minimum) and notch-to-tip (maximum), straight carapace width (SCW), head length (HL), head width (HW), gape height, internal gape width, esophagus width, upper jaw length and lower jaw length. We used both captive-reared and wild-caught turtles in this study. Using a standard canine mouth gag to hold open the animal's jaws, we took oral cavity measures with inside spring calipers and/or dial calipers.

We have finished collecting for this study and are currently working to analyze the data and create a predictive model for future data. These measures will be analyzed to develop an understanding of how the oral cavity changes as turtles grow. We are currently examining hooks commonly used in pelagic longline fisheries to compare how the anatomical characters of the oral cavity relate to hook diameter. Fisheries observers often take the standard external measures when they encounter an incidentally captured turtle onboard a fishing vessel, but the oral cavity measures are likely too difficult for them to obtain under these field conditions. We are developing mathematical relationships between the standard measures easily collected and these oral cavity measures. Using these relationships, we may predict the ability of a turtle of a given size to ingest hooks, and the associated injury risk. With this knowledge, we hope to prevent future incidental capture and mortality through mitigation measures.

Research Performance Measure:
The program is on schedule.

Figure 1: Oral cavity of a loggerhead sea turtle restrained with canine mouth gag. NOAA Fisheries/SEFSC photo

Figure 2: Taking jaw length measurements using dial calipers. NOAA Fisheries/SEFSC photo

Photo-Identification of Bottlenose Dolphins in Biscayne Bay, Florida

J.A. Wicker (UM/CIMAS); L. Garrison and J.P. Contillo (NOAA/SEFSC)

Long Term Research Objectives and Strategy to Achieve Them:

Objectives: To conduct research to understand and describe the parameters of bottlenose dolphin populations in Biscayne Bay; to monitor and observe their role in the South Florida ecosystem and the impacts of human activities on them.

Strategy: To develop and maintain a long-term database on bottlenose dolphin population parameters using photographic identification techniques which can be used to monitor the overall health of the Biscayne Bay ecosystem.

CIMAS Research Themes:

Theme 2: Fisheries Dynamics (*Primary*)
Theme 3: Regional Coastal Ecosystem Processes (*Secondary*)

Link to NOAA Strategic Goals:

Goal 1: Protect, Restore, and Manage the Use of Coastal and Ocean Resources Through Ecosystem-based Management

NOAA Funding Unit: NMFS/SEFSC

NOAA Technical Contact: Lance Garrison

Research Summary:

The National Marine Fisheries Service (NMFS) is responsible for monitoring the populations of bottlenose dolphins (*Tursiops truncatus*) in southeastern United States waters. The main goals of this monitoring are: 1) the detection of large-scale changes in bottlenose dolphin abundance, and 2) the establishment of archival databases for long-term trend detection. Biscayne Bay has been greatly impacted by development of the Miami area in the past 80 years. Information from 15 years of photo-ID surveys have confirmed the presence of a relatively large, long-term resident, core population of bottlenose dolphins in the Bay. Their role as apex predators characterizes these animals as excellent indicators of the overall health of Biscayne Bay.

Aside from 20 aerial surveys (40 survey hours), conducted by Odell in the mid-1970's, very little formal research had been conducted on the abundance and distribution of bottlenose dolphins in Biscayne Bay prior to 1990. From 1990-2004, a total of 322 photo-ID surveys comprising 1606 hours of sampling effort were conducted in Biscayne Bay. Sampling has continued uninterrupted into 2005. These surveys have defined the basic parameters of the Biscayne Bay bottlenose dolphin population, including abundance, distribution, natality and mortality. To improve data management of photo-ID information in the SEFSC, and to facilitate efficient data sharing among other photo-ID research groups in south Florida, an Oracle database application was developed. This database enables "Internet web-based" online data entry, update, categorization, search, and download capabilities. The data resident on the system include scanned digital and digital photos, associated collection information and meta-data, and allows viewing and sharing of this information between researchers and the general public via web browsers.

Continuation of the established photo-ID sampling regimen will provide the framework for defining biologically based management units and, ultimately, understanding the consequences of anthropogenic influences on the bottlenose dolphin population in Biscayne Bay.

Research Performance Measure:

The program is meeting its goals as planned.

Bottlenose Dolphin

Development, Maintenance, and Migration of the Pathfinder Sea Surface Temperature Algorithm and Associated Data Systems

R. Evans, K. Kilpatrick, V. Halliwell and S. Walsh (UM/RSMAS);
K. Casey (NOAA/NODC)

Long Term Research Objectives and Strategy to Achieve Them:

Objectives: To support the infrastructure and research needed to continue the production of the global V5 Pathfinder SST fields.

Strategy: To continue the production of the global Pathfinder SST fields including: (1) derivation of the time-dependent Pathfinder algorithm coefficients, (2) data screening improvements that will reduce the remaining errors in the SST estimates, and (3) begin to develop a strategy for the migration of Pathfinder SST technology from the University of Miami to NOAA/NODC.

CIMAS Research Theme:

Theme 3: Regional Coastal Ecosystem Processes (*Primary*)
Theme 1: Climate variability (*Secondary*)

Link to NOAA Strategic Goals:

Goal 1: Protect, Restore, and Manage the Use of Coastal and Ocean Resources Through Ecosystem-based Management (*Primary*)
Goal 2: Understand Climate Variability and Change to Enhance Society's Ability to Plan and Respond (*Secondary*)

NOAA Funding Unit: NODC

NOAA Technical Contact: Ken Casey

Research Summary:

Sea surface temperature (SST) estimates are derived from a variety of satellite sensors, but none have continuously acquired global observations for as long as the Advanced Very High Resolution Radiometer (AVHRR). RSMAS continues to be responsible for production of the SST fields, generation of algorithm retrieval coefficients, and providing the basis for SST calibration, validation and sensor characterization *via* generation and analysis of a collocated satellite *in situ* matchup database. The products are then transferred to NOAA-NODC and JPL PO.DAAC for public distribution.

The Pathfinder sea surface temperatures (SST) algorithm has proven to be a superior tool for the production of accurate and temporally consistent SSTs for the global ocean. The detection and quantification of variations in SSTs in the coastal zone is vital to understanding the stresses faced by coral reefs and their related ecosystems. Many designated communities including climate-change scientists, weather and hurricane research, ecosystem managers, and shipping and maritime interests currently use the PFSST data set. These users are located at US and international academic institutions as well as a wide range of US federal, international, operational, and commercial agencies.

User statistics collected by NODC and the PO.DDAC illustrate that the Pathfinder SST CDR is an active data set accessed by a large number of users. The following two figures document the combined total users and volumes per month accessed through the two data centers over the time span from January 2004 to June of 2006. These figures indicate that since 2004 roughly 25,000 users have accessed more than 19 Terabytes (TB) of Pathfinder data. To put those accesses in perspective, the total distribution of the CLASS web site was reported in an October 2005 presentation at 44 TB during the previous 12 months, or 3.63 TB per month. On average about 0.64 TB/month of Pathfinder SST data were served, or roughly 1/6th of the volume distributed by CLASS with all of its datasets.

Research Performance Measure:
The original Year 1 milestones were met as scheduled.

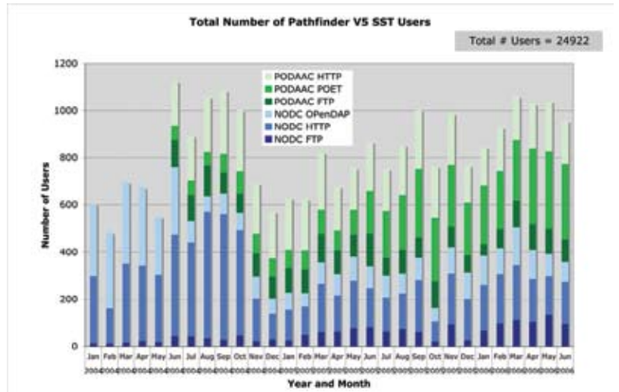


Figure 1: Number of users of the Pathfinder SST data set per month, January 2004 - June 2006

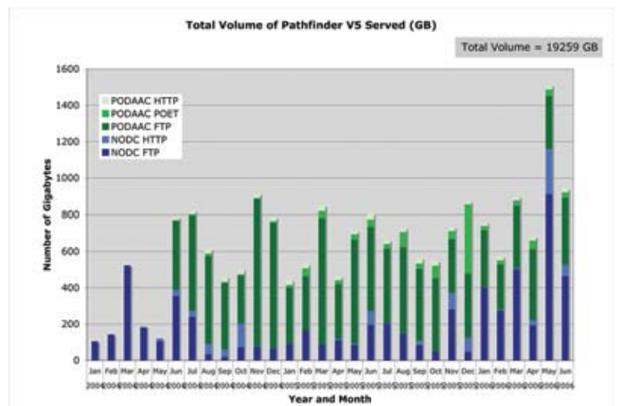


Figure 2: Volume of Pathfinder SST data set distributed per month, January 2004 – June 2006

Ecological Restoration in the Florida Keys National Marine Sanctuary

P. Glynn (UM/RSMAS); L. Kramer (UM/CIMAS); L. Johnston (NOAA/AOML); M. Miller (NOAA/SEFSC); A. Szmant (UNCW)

Long Term Research Objectives and Strategy to Achieve Them:
Objectives: To develop methods for restoring reef-building coral populations *via* larval recruits.
Strategy: To collect, culture, and settle gametes/larvae of broadcast spawning coral species to replace in-field populations and conduct experiments on factors to enhance survivorship; to determine natural levels of settlement of the keystone grazer, *Diadema antillarum*, to serve as the basis of a possible strategy of active *Diadema* restoration.

CIMAS Research Theme:
Theme 3: Regional Coastal Ecosystem Processes

Link to NOAA Strategic Goals:
Goal 1: Protect, Restore, and Manage the Use of Coastal and Ocean Resources Through Ecosystem-based Management

NOAA Funding Unit: NOS/SEFSC

NOAA Technical Contact: Margaret Miller

Research Summary:
Given the paucity of coral resources available for coral reef restoration in the Florida Keys, there is a need to develop tools to enhance coral abundance, especially of broadcast-spawning, hermatypic species, for application in reef restoration endeavors. NOAA has an interest and, in some cases, a legal mandate to undertake habitat restoration to enhance fisheries and repair natural resource damage (e.g., in National Marine Sanctuaries). We are refining methods for larval seeding of hermatypic corals and documenting settlement patterns of important reef grazers to enhance NOAA's strategies and capacity for coral reef restoration.

Specifically, we collect, culture, and seed elkhorn coral (*Acropora palmata*) larvae to in situ reef and/or restoration structure substrates as well as onto manipulable pieces of reef rubble that can be used to experimentally evaluate different factors' influence on early survivorship of coral recruits. Secondly, there is a growing recognition that substrate quality is crucial for successful recruitment to reef substrates and that grazing by the urchin *Diadema antillarum* may be crucial to enhancing substrate quality. In a second component of this project we are quantifying seasonal and spatial patterns of natural settlement of *Diadema antillarum*, at two sites in the Florida Keys and, for comparison two sites in Puerto Rico. The resulting information documents the natural supply of *Diadema* recruitment in the upper Florida Keys and can guide future ecological restoration plans.

CoPI Szmant and her group were able to collect spawn and raise larvae of *Montastraea faveolata* in Puerto Rico. With permission from FKNMS managers ~ 70,000 Puerto Rican larvae were deployed in different types of settlement enclosures at the Wellwood restoration site, Molasses Reef, from 30 Aug – 1 Sept. Microscopic examination of small rubble pieces that we retrieved from within the settlement enclosures showed that at least some of these field-enclosed larvae did settle successfully in the field. An additional 60000 *M faveolata* larvae and 1000 *Acropora palmata* larvae were settled in the laboratory onto freshly collected reef rubble. We estimate that ca. 20 *M faveolata* and ca. 30 *A palmata* juveniles survived Hurricane Rita and reached 6 weeks of age.

We have been monitoring *Diadema* settlement at monthly intervals in the Florida Keys throughout 2006 and monitoring was begun in Puerto Rico in June 2006. Low levels of settlement have been observed to both sites (one with and one without adult *Diadema* present) in the Florida Keys.

Research Performance Measure:
Substantial progress has been made in this program despite the problems presented by three separate hurricanes (Dennis in July, Katrina in Aug, and Rita in Sept). We expect to meet our projected schedule.

Figure 1: A 1.5 yr old cultured larval recruit of threatened elhorn coral, *Acropora palmata*, residing on a reef restoration structure at Molasses Reef, Florida Keys National Marine Sanctuary.

Effect of Salinity and Temperature on the Sediment/Water Exchange of Phosphorous: Predicting Response of Phosphorous Cycling to Increasing Freshwater Flow into Florida Bay

X. Huang (UM/CIMASRSMAS); J.-Z. Zhang (NOAA/AOML)

Long Term Research Objectives and Strategy to Achieve Them:

Objectives: To quantify the effect of salinity and temperature on sediment/water partitioning of phosphorus in Florida Bay.

Strategy: To carry out systematic experiments to quantify sediment characteristics for P exchange, such as the zero equilibrium phosphate concentration, the distribution coefficient, and P buffering capacity of sediment; to investigate these properties over a range of water salinities at different ambient temperatures.

CIMAS Research Theme:

Theme 3: Regional Coastal Ecosystem Processes

Link to NOAA Strategic Goals:

Goal 1: Protect, Restore, and Manage the Use of Coastal and Ocean Resources Through Ecosystem-based Management

NOAA Funding Unit: OAR/AOML

NOAA Technical Contact: Jia-Zhong Zhang

Research Summary:

Phosphorous is an important nutrient in aquatic ecosystems. The zero equilibrium phosphate concentration, the distribution coefficient, and P buffering capacity of sediment are essential in water quality models for predicting the effect of increasing freshwater input, as proposed by the Comprehensive Everglades Restoration Plan, on the P cycle in Florida Bay.

We quantified the effects of salinity and temperature on sediment/water partitioning of phosphorus by using a systematic approach. For a given station location, we studied individual sediment characteristics for P exchange, such as the zero equilibrium phosphate concentration (ZEC), the distribution coefficient, and P buffering capacity of sediment.

We found exchangeable phosphate content in the sediment governs the overall sediment sorption behaviors. In contrast the amorphous iron oxides content in the sediments

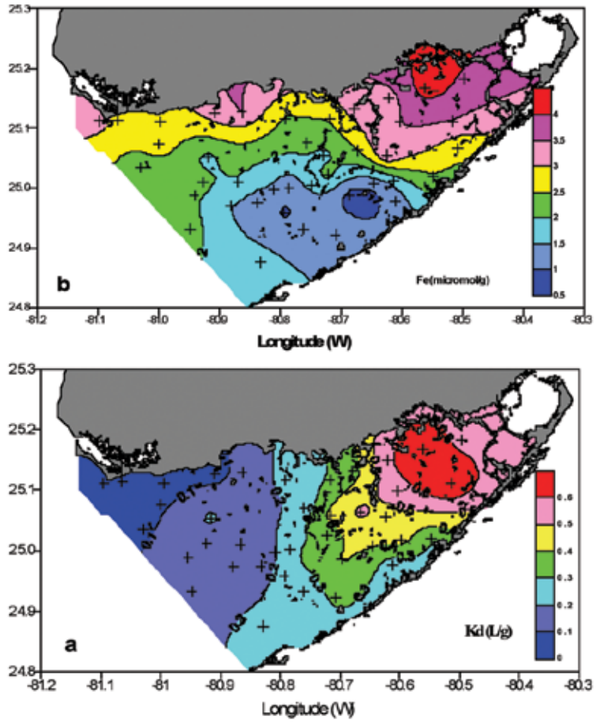


Figure.1: Spatial distribution of EPC_0 (a) in comparison to that of sediment exchangeable phosphate (b) in Florida Bay.

plays a secondary role, becoming important only in sediments that are poor in phosphorus. The spatial distributions of the sediment zero equilibrium phosphate concentration and distribution coefficient are consistent with that of sediment's exchangeable phosphate. Quantitative relationships between sediment sorption characteristics and sediment exchangeable phosphate content are derived for the first time from this study.

Most of the work on the phosphorus sorption of sediments was focused on the inorganic phosphorus. However, dissolved organic phosphorus is an important component in seawater, especially in coastal waters. We made some preliminary studies on the sorption of different organic phosphorus compounds on sediments from selected stations in Florida Bay and found that the sorption behavior of organic phosphorus is quite different from inorganic phosphorus. This study will be continued, focusing on different types of organic phosphorus and sediments from different areas of Florida Bay.

Research Performance Measure:

The research program is on schedule and all performance objectives are being met.

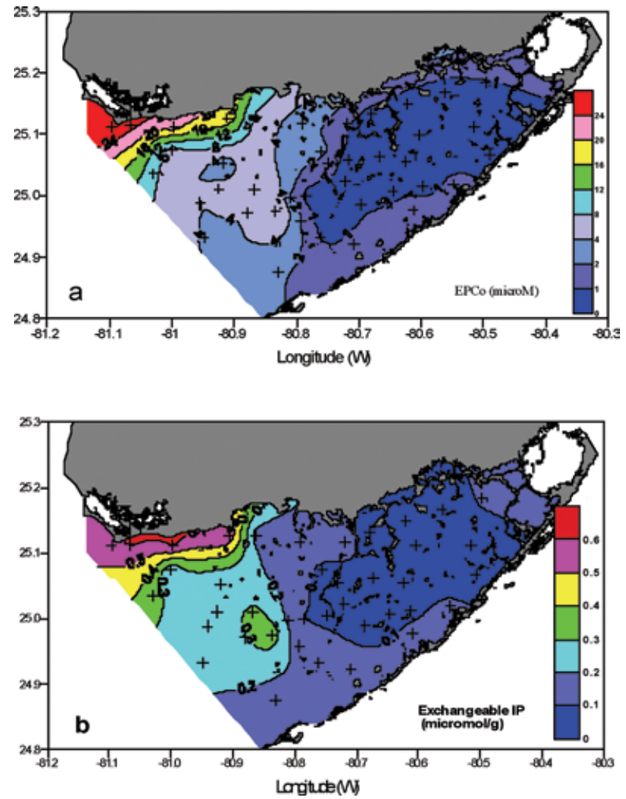


Figure 2: Spatial distribution of Kd (a) in comparison to that of surface reactive iron oxides contents (b) and sediment exchangeable phosphate (Fig. 1 b) in Florida Bay.

Regional Model for South Florida Coastal Seas

V. Kourafalou (UM/RSMAS); G. Goni (NOAA/AOML)

Long Term Research Objectives and Strategy to Achieve Them:

Objectives: To develop a regional circulation model around South Florida that encompasses the Florida Straits and the southeastern Gulf of Mexico, including environmentally sensitive areas as the Dry Tortugas, the Florida Keys, and Florida Bay.

Strategy: To use the regional model, which has high resolution and detailed bathymetry to resolve the shallow areas; to embed this model within a larger scale model, which has coarser resolution and bathymetry, to ensure the proper linkage between coastal and oceanic flows and between the South Florida ecosystems and remote, upstream sources of nutrient-rich waters.

CIMAS Research Theme:

Theme 3: Regional Coastal Ecosystem Processes (*Primary*)
Theme 6: Integrated Ocean Observations (*Secondary*)

Link to NOAA Strategic Goals:

Goal 1: Protect, Restore, and Manage the Use of Coastal and Ocean Resources Through Ecosystem-based Management;

NOAA Funding Unit: NOS/AOML

NOAA Technical Contact: Peter Ortner

Research Summary:

A comprehensive, high resolution, numerical model of circulation and transport dynamics has been developed for the seas around South Florida. The regional South Florida model includes ecologically sensitive shallow areas (Florida Bay, the Dry Tortugas Ecological Reserve and the Florida Keys Marine Sanctuary), shelf areas (the relatively broad southwest Florida shelf and the narrow shelf along the Atlantic side of the Florida Keys) and deep areas (Straits of Florida). The motivation for the development of the regional model is based on results from long term observational monitoring around South Florida. These studies show that the area's distinct marine environments are strongly inter-connected by circulation and biochemical exchange processes on a regional scale, while oceanic boundary currents connect them to remote ecosystems of the Gulf of Mexico and the Caribbean. The Regional model addresses these connections by nesting a high resolution model within a larger scale model of the North Atlantic and Gulf of Mexico. Thus, the South Florida coastal areas receive the proper connections with the oceanic flows that surround them.

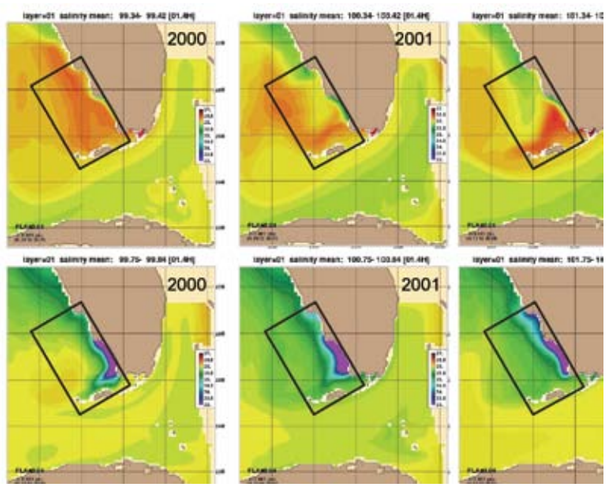


Figure 1: Inter-annual variability for the monthly averaged surface salinity fields in May (dry season, upper panels) and October (wet season, lower panels); the box covers the R/V Walton Smith bi-monthly monitoring surveys area.

The Regional model has been named SoFLA-HYCOM (for South Florida HYCOM), as it is an adaptation of the state-of-the-art Hybrid Coordinate Ocean Model (HYCOM). The SoFLA-HYCOM model has two particular features that allow realistic numerical simulations for the coastal seas surrounding South Florida: (a) it receives information from a larger scale model, so it "knows" about fundamental South Florida processes such as the variability of the Loop Current/Florida Current (LC/FC) system, the eddies that travel along the LC/FC front, the inflow of low salinity (and nutrient-rich) waters of remote river origin (west Florida shelf rivers and the Mississippi River); (b) it employs detailed shallow shelf bathymetry, derived from a digital terrain data set with 2ft resolution (NAVO-NRL DBDB2 data set) and further refined in the shallow coastal areas. Two types of simulations with the SoFLA-HYCOM have been completed: with long-term (climatological) atmospheric forcing and with realistic forcing for the period September 1999 to December 2002. Processes that are known from observations have been reproduced in the numerical simulations, such as the propagation of eddies along the FC front, as well as the formation of wind-driven southwestward flow along the Atlantic Keys shelf, which agrees well with drifter trajectories and wind-driven events recorded in moored current meters.

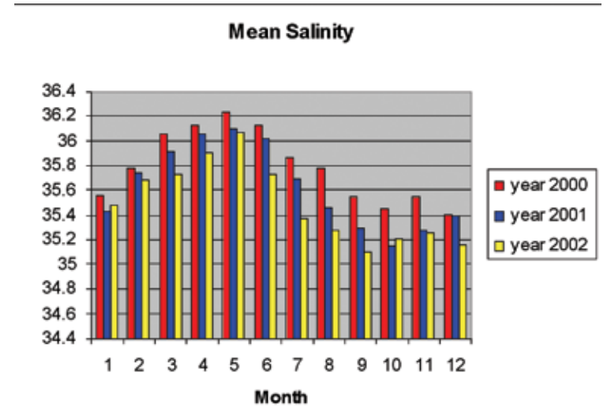


Figure 2: Model computed monthly mean salinity over the average area sampled by the R/V Walton Smith (marked as a box in Fig. 1) showing a pattern of wet (summer) and dry (winter) seasons over three years (2000 to 2002).

The analysis of model results has focused on circulation and salinity patterns on the SW Florida shelf and along the Florida Keys, i.e. areas that have a direct influence on circulation and water characteristics in Florida Bay. It was found that salinity patterns are dominated by the changes in river inputs and precipitation patterns. An example of seasonal and inter-annual variability in surface salinity patterns is shown in Figures 1 and 2. In general, low precipitation conditions occur in the winter to spring months ("dry season", typically from December to May) and high precipitation dominates in the summer to fall months ("wet season", typically from June to November). Monthly averaged fields are presented in Figure 1 for May (dry period) and October (wet period). The rivers have close to negligible discharge in the dry season and high salinities are evident in and around Florida Bay. The opposite occurs in the wet season, when the overall salinity fields attain lower values, with substantial freshening of coastal waters along the river area. The model results show how low salinity waters from regional rivers on the SW Florida shelf can alleviate hyper-salinity conditions in Florida Bay, typical of the summer season, through intrusions in the western basin; potential effects from remote rivers, such as the Mississippi, are also evident. The driest conditions occurred in May 2000 and particularly wet conditions occurred in October 2002. Figure 2 depicts the monthly mean salinity over a subset of the model area (marked on Figure 1). The results from three years are employed (2000-2002) and a distinction between "wet" and "dry" seasons is apparent: salinities are generally highest in April-May and lowest in September-October. Furthermore, it is obvious from Figure 2 that the overall salinity was highest in 2000 and lowest in 2002, in agreement with observed precipitation patterns. Detailed comparison between model derived parameters and observations at buoy locations and ship surveys have validated model results.

Research Performance Measure:

The model SoFLA-HYCOM development and implementation is moving forward on schedule.

SFP 2004: Transport and Exchange of Florida Bay Interior Waters

T.N. Lee (UM/RSMAS); N. Melo (UM/CIMAS);
E. Johns and R. Smith (NOAA/AOML); N. Smith (HBOI)

Long Term Research Objectives and Strategy to Achieve Them:

Objectives: To understand the circulation and exchange processes that regulate the residence times and flushing rates within interior basins of Florida Bay; to improve prediction of the effects of modifying fresh water supply to the Everglades as part of Everglades restoration plans.

Strategy: To analyze, describe, and understand the results of observations of salinity variability and water exchange recently made within the major sub-regions of Florida Bay during wet and dry seasons.

CIMAS Research Theme:

Theme 3: Regional Coastal Ecosystem Processes

Link to NOAA Strategic Goals:

Goal 1: Protect, Restore, and Manage the Use of Coastal and Ocean Resources Through Ecosystem-based Management (*Primary*)

Goal 3: Serve Society's Needs for Weather and Water Information (*Secondary*)

NOAA Funding Unit: NOS/AOML

NOAA Technical Contact: Peter Ortner

Research Summary:

The objectives of this project are to identify the primary physical processes controlling water renewal and salinity variability within the inner basins of Florida Bay and their interactions with connecting regions of the southwest Florida shelf and Florida Keys. This information is needed to aid the calibration and verification of hydrodynamic models for prediction of the impact of future changes in water deliveries to the Everglades and Florida Bay as part of Everglades restoration projects.

During the previous year we participated in a concentrated approach that combined the observational resources of HBOI, AOML and RSMAS to focus on the western basins of Florida Bay (Figure 1). By combining resources we were able to directly measure the volume and salt transports through all the major channels to Twin Key and Rabbit Key western basins while making detailed surveys of changes in salinity patterns over the 2004 dry season and 2005 wet season. Circulation within the basins was measured with shallow water drifters that transmit GPS positions *via* satellite. The Rabbit Key and Twin Key basins are a pair of shallow water bodies adjacent to the western boundary of Florida Bay; these are enclosed by expansive mud banks that can be partially exposed at times of low water (Figure. 1). The basins are

Figure 1: Location of Rabbit Key and Twin Key basins within the western sub-region of Florida Bay. Current salinity time series were made during wet season (Jun to Nov 2004) and dry season (Dec 2004 to Jun 2005) in channels connecting the basins to surrounding regions. Mooring locations are shown with solid triangles and squares. Shown with solid line is the vessel track of bi-weekly salinity surveys.

separated from the southwest Florida shelf waters by 9-Mile Bank to the west and from the southeast sub-region of Florida Bay by Twin Key Bank. To the north lies a broad bank region separating the basins from the north-central region of the bay where hypersalinity is commonly observed during dry seasons. These western basins serve as a transition zone for water exchange between the southwest shelf and more restricted, poorly flushed inner basins of Florida Bay. Exchange of western basin waters takes place through a series of flow channels through the shallow banks, as well as directly over the banks when water levels are sufficiently deep.

Initial results show a vigorous exchange between the western basins and the surrounding regions driven by tide and wind forced transports. The exchange of Rabbit Key basin waters with the southwest shelf caused considerable freshening of the western basins with Rabbit Key basin waters consistently fresher than waters of Twin Key basin (Figure. 2). Twin Key basin had significant exchange with Rabbit Key basin to the west and the southeast sub-region of Florida Bay to the east. Interestingly, all channels display significant mean outflows in both basins. To account for these outflows, we believe that there may have been mean inflows over the banks prior to our measurements. In Rabbit Key basin the interior circulations were a mixed response to tide and wind forcing, but in Twin Key basin they were primarily wind driven. This indicates strong frictional dampening of the semi-diurnal and diurnal tidal wave by the shallow Twin Key Bank separating the two basins as the water moved into the basins from the Gulf. These results clearly show that shelf and oceanic transport of Shark River discharge and riverine inputs from the west Florida coast southward to the western Florida Bay region can have a considerable effect in moderating the development of hypersalinity in Florida Bay. These observations provide a comprehensive data set for use in the calibration and validation of the Florida Bay hydrodynamic model.

Research Performance Measure:

All operational and scientific project objectives are being met on schedule.

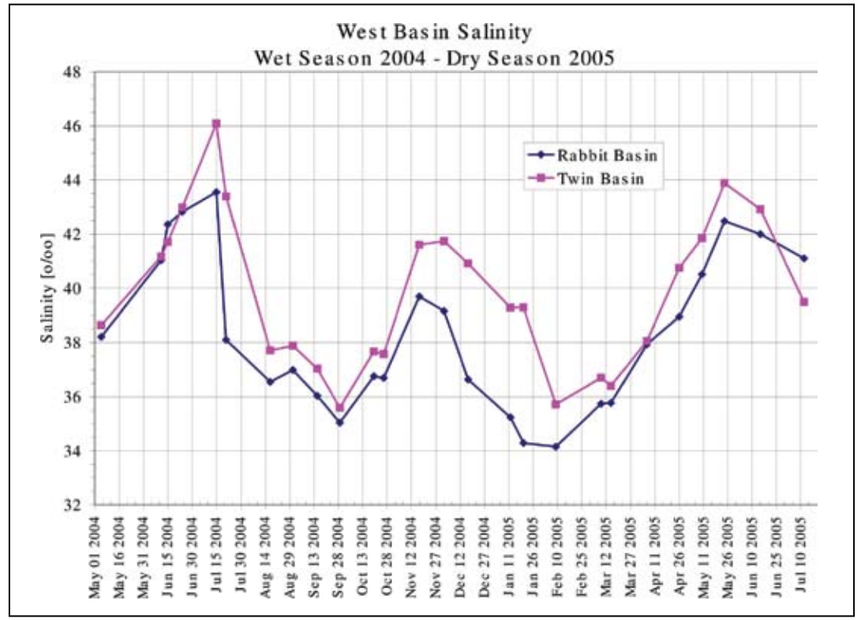


Figure 2: Time series of basin average salinity from bi-weekly shipboard surveys of Rabbit and Twin Key basins.

Long-Term Measurement of Physical, Chemical, and Biological Water Column Properties in the South Florida Coastal Ecosystem

T.N. Lee (UM/RSMAS), C. Kelble, G. Rawson, N. Melo and A. Stefanick(UM/CIMAS); P. Ortner, L. Johns, R. Smith and J.-Z. Zhang (NOAA/AOML)

Long Term Research Objectives and Strategy to Achieve Them:
Objectives: To determine the circulation and water property patterns within Florida Bay and surrounding coastal waters on "event" to inter-annual time scales; to quantify the effect of singular climactic events, such as tropical cyclones and *El Ninõ*, on the water column properties in Florida Bay.
Strategy: To carry out regular and supplemental event-focused monitoring cruises in conjunction with a moored instrument array and targeted drifter releases.

CIMAS Research Theme:
Theme 3: Regional Coastal Ecosystem Processes

Link to NOAA Strategic Goals:
Goal 1: Protect, Restore, and Manage the Use of Coastal and Ocean Resources Through Ecosystem-based Management

NOAA Funding Unit: NOS/AOML

NOAA Technical Contact: Libby Johns

Research Summary:
Water properties in Florida Bay and Biscayne Bay can change dramatically depending on a wide range of factors including weather (e.g., storms), runoff from land, and variations in currents in adjacent coastal waters. To better understand the factors affecting these changes we make high resolution surveys of Florida Bay and Biscayne Bay on a bimonthly basis. These are supplemented by special surveys following "events" such as hurricanes. On these surveys, we continuously measure salinity, temperature, chlorophyll, percent light transmittance, and chromophoric dissolved organic matter (CDOM) using a flow-through water system. Periodically, we stop at discrete sampling stations for more extensive measurements of water column properties including light attenuation, chlorophyll *a*, total suspended solids (TSS), dissolved inorganic nutrients, zooplankton, and we take a profile of temperature and salinity throughout the depth of the water column. Contour maps are produced from the cruise data and posted in near realtime at www.aoml.noaa.gov/sfp/ thereby permitting timely access to our results by the South Florida Ecosystem Restoration (SFER) scientific and management communities. Figure 1 depicts the two salinity extremes observed in Florida Bay with the top panel showing an estuarine bay after the passing of hurricane Irene and the bottom panel showing Florida Bay at its most hypersaline during our study period.

In addition, we conduct quarterly, large-vessel surveys on which we measure similar parameters in the near-shore waters of South Florida from Ft. Myers to the Dry Tortugas and along the Florida Keys National Marine Sanctuary (FKNMS) reef tract northward to Miami. Acoustic doppler current profiler (ADCP) surveys are made during the large-vessel cruises in an effort to document eddy development and the interaction between the Gulf Stream and FKNMS coastal waters. We also make quarterly releases of surface drifters in the Dry Tortugas, just offshore of Charlotte Harbor, and at the mouth of the Shark River to document current trajectories in these areas. These data are also made available on the project website in near real-time. Furthermore, a moored instrument array is maintained to continuously measure temperature, salinity, current trajectories along the southern SW Florida shelf and along the perimeter of Florida Bay. All project data can be accessed at www.aoml.noaa.gov/sfp/.

Research Performance Measure:
All objectives are being attained on schedule

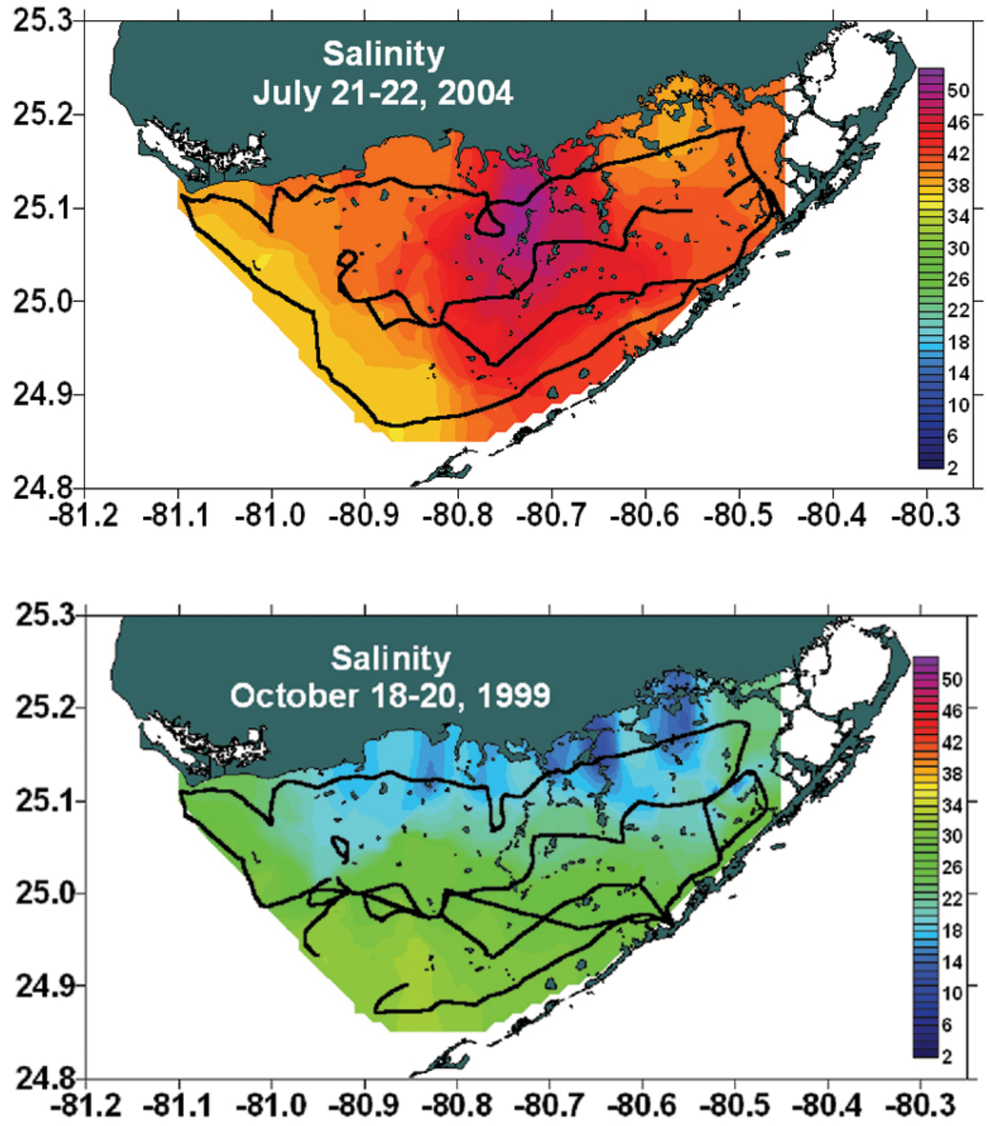


Figure 1: Contour maps of the salinity extremes of Florida Bay depicting the bay at its freshest just after the passing of hurricane Irene on October 15, 1999 and at its saltiest in July of 2004 after a period of anomalously low rainfall over South Florida.

Real-time Currents and Water Quality Monitoring in the Florida Keys National Marine Sanctuary (FKNMS)

T.N. Lee (UM/RSMAS); N. Melo, C. Kelble, G. Rawson, A. Stefanick and B. Kates (UM/CIMAS); E. Johns, P.B. Ortner, J.C. Hendee, R. Smith, S. Cummings, D. Bitterman and U. Rivero (NOAA/AOML)

Long Term Research Objectives & Strategy to Achieve Them:

Objectives: To monitor and understand the coastal circulation in and around the FKNMS on tidal to interannual time scales, with primary emphasis on the "event" time scale.

Strategy: To maintain, upgrade and expand the existing network of real- time oceanographic observations in the FKNMS and adjacent coastal waters, and to use the resulting real-time data in conjunction with other available oceanographic data to achieve the stated research objectives.

CIMAS Research Theme:

Theme 3: Regional Coastal Ecosystem Processes

Link to NOAA Strategic Goals:

Goal 1: Protect, Restore, and Manage the Use of Coastal and Ocean Resources Through Ecosystem-based Management (*Primary)*

Goal 3: Serve Society's Needs for Weather and Water Information (*Secondary*)

NOAA Funding Unit: NOS/AOML

NOAA Technical Contact: Libby Johns

Research Summary:

The operational part of this project focuses on the construction, deployment, and testing of the instrumentation needed for real-time data collection. Stations in the network that are currently operating in real-time are located at Looe Key, the 7-Mile Bridge at Moser Channel, and at Conch Reef offshore of Key Largo. Station web pages can be accessed *via* the project's web site www.aoml.noaa.gov/sfp. The Looe Key Oceanographic Buoy is a rigid spar located offshore of Looe Key. The buoy has been transmitting temperature, salinity, and ocean current velocity nearly continuously in real-time *via* MSAT since early 2004. The Moser Channel real-time station records temperature, salinity, relative chlorophyll, and light transmittance. These data are transmitted back to AOML *via* cellular phone. This station has been operational since early 2005. The Conch Reef station at "Aquarius", NOAA's undersea research habitat, is operated in collaboration with NOAA's National Undersea Research Center (NURC) and the University of North Carolina at Wilmington (UNCW). This real-time station has been incorporated into the undersea habitat's Life Support Buoy (LSB). Data are transmitted back to shore through the existing LSB wireless broadband radio link. This station is instrumented with temperature, salinity, relative chlorophyll, light transmittance, dissolved oxygen, ocean current, and directional wave sensors. Efforts during this report period have been directed at improving the existing mooring and array designs, and experimenting with cheaper, faster, and more reliable ways of telemetering data back to AOML.

The scientific part of this project focuses on collecting and quality controlling the real-time data, incorporating additional non-real-time data from other projects into the analysis, and providing web-based presentations of the results. These additional data include shipboard observations, data from other moored real-time and non-real-time moorings around the region, real-time trajectories of satellite-tracked surface drifters, and satellite remote sensing.

Research Performance Measure:

Most of the operational project objectives as listed in the NOAA South Florida Program (SFP 2004) proposal have been met, with two exceptions. The planned upgrade to the CMAN/Seakeys station located in the Dry Tortugas was not made because this station was destroyed by a hurricane in 2004 and has not

yet been redeployed by the NOAA's National Data Buoy Center (NDBC). The station planned for Long Key Channel was also not deployed, due to the destruction of the dock that was to have been its location. Despite these setbacks, the scientific objectives are being met, and our understanding of how to monitor the highly variable marine environment of the FKNMS continues to develop.

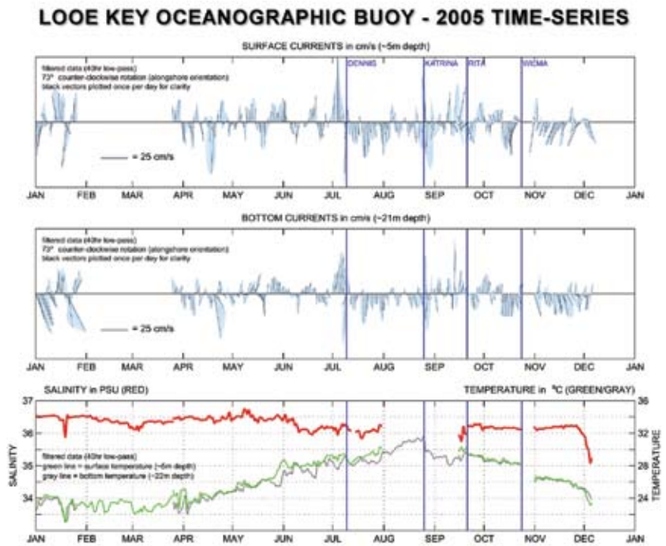


Figure 1: The 2005 time series from the Looe Key station, highlighting the types of oceanographic and meteorological events which affect the Looe Key site. The temperature and salinity data (lower panel) show the expected annual cycle of summer wet season and winter dry season, and the surface and bottom currents show how the Looe Key site is dominated by alternating interaction with Florida Current (eastward) and countercurrent (westward) flows. Both the temperature/ salinity and the current records demonstrate the dominating effect throughout the water column of the passage of tropical cyclones.

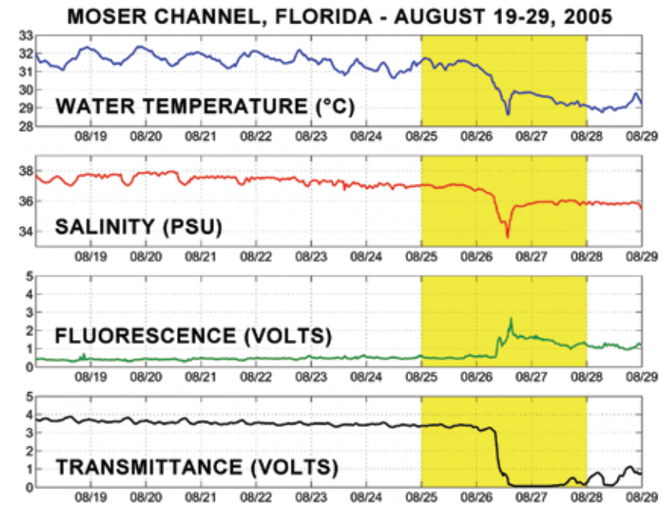


Figure 2: A portion of the 2005 Moser Channel temperature, salinity, fluorometer, and transmissometer data time series, documenting the passage of Hurricane Katrina. The record shows a marked decrease in salinity due to direct precipitation associated with the passage of the storm. An increase in chlorophyll concentration and water turbidity (decreased transmittance) was also recorded, likely due to the re-suspension of sediments caused by wind-driven mixing.

SFP 2004: Monitoring and Modeling Approaches to Assess the Condition of Coral Communities within Patch Reef Habitats of the Florida Reef Tract

D. Lirman (UM/RSMAS)

Long Term Research Objectives and Strategy to Achieve Them:

Objectives: To document the demographic parameters required to develop and parameterize coral population models that can be used to test hypotheses about the potential effects of different stressors, including impacts from human populations, on the long-term survivorship of these important resources.

Strategy: To carry out repeated sampling of permanently marked coral colonies and recruitment plots in order to document colony-based parameters such as growth, partial, and total coral mortality in relation to environmental gradients influenced by distance to shore and the urban centers of the Florida Keys.

CIMAS Research Theme:

Theme 3: Regional Coastal Ecosystem Processes

Link to NOAA Strategic Goals:

Goal 1: Protect, Restore, and Manage the Use of Coastal and Ocean Resources Through Ecosystem-based Management

NOAA Funding Unit: NOS

NOAA Technical Contact: Larry Pugh

Research Summary:

Over the past four years, we have documented the demography of coral populations within patch-reef habitats that, due to their proximity to shore, were hypothesized to be negatively influenced by urban sources of pollution and the outflow of lower-quality water from coastal bays. This research, based on the repeated sampling of > 4,000 colonies of *Montastraea faveolata*, *M. cavernosa*, *Porites astreoides*, *Siderastrea siderea*, and *S. radians*, has shown that, contrary to expectations, the condition of nearshore patch reef communities was healthier than that of offshore reef communities in the region. In fact, compared to offshore habitats, inshore patch reefs showed greater coral cover and colony growth; moreover partial and total mortality were lower.

This information, obtained during a period without significant sources of acute stress, provides a crucial baseline against which we will be able to measure the eventual impacts of the proposed Everglades Restoration Plan. In the summer of 2005, the passage of four major storms (Dennis, Katrina, Rita, Wilma) and the onset of a severe coral bleaching event have also provided an opportunity to directly evaluate the impacts of these disturbances. These data, collected under background and disturbed conditions, provide the basis for the continued development of coral population models that will be used to forecast damage and recovery patterns of reef communities under different levels of stress.

Research Performance Measure:

Our research has proceeded on track and we are meeting all of the proposed targets and milestones.

Figure 1: Photographs of coral colonies showing signs of bleaching. Photographs were taken at an inshore patch reef in Biscayne National Park (depth=3 meters) in September 2005 at the peak of the bleaching event.

Burdens of Resident Bottlenose Dolphin (Tursiops truncatus) within Biscayne Bay, Florida

J. Litz, J. Wicker (UM/CIMAS); L. Fieber and P. Walsh (UM/RSMAS); L. Garrison, J. Kucklick, P. Rosel, A. Martinez and J. Contillo (NOAA/SEFSC); M. Gaines (UM); C. Hughes (FAU)

Long Term Research Objectives and Strategy to Achieve Them:

Objectives: To define the genetic structure of resident bottlenose dolphins within Biscayne Bay using molecular genetic techniques; to evaluate the current profiles of persistent organic pollutants in a model organism, the bottlenose dolphin, in Biscayne Bay.

Strategy: To use mitochondrial DNA haplotypes and genotypes from 14 microsatellite loci to examine genetic structure within Biscayne Bay; to analyze blubber samples from Biscayne Bay dolphins for persistent organic pollutants using gas chromatography/mass spectrometry.

CIMAS Research Theme:

Theme 3: Regional Coastal Ecosystem Processes

Link to NOAA Strategic Goals:

Goal 1: Protect, Restore, and Manage the Use of Coastal and Ocean Resources Through Ecosystem-based Management

NOAA Funding Unit: NMFS/SEFSC

NOAA Technical Contact: Joseph Contillo

Research Summary:

Bottlenose dolphins are year-round residents in Biscayne Bay, Florida. This project is using genetic techniques to determine if the resident bottlenose dolphin population within Biscayne Bay consists of one breeding stock of dolphins or of several distinct breeding stocks. By integrating these genetic data with photo-identification data from NOAA SEFSC, we obtain a clearer picture of the overall social and stock structure of this dolphin community. In addition, dolphins have previously been shown to bioaccumulate persistent organic pollutants (POPs) such as PCB's, and DDT's in their blubber layer. Because of these characteristics, bottlenose dolphins can be used as biological indicators of the health of their habitat and can be used to compare contaminant levels from different geographical areas. This project is collecting baseline data on the types of compounds stored in the blubber of resident dolphins and comparing the results to those found in dolphins in other areas of Florida. The POP levels found are being compared among dolphins from Biscayne Bay to determine if animals are limiting their feeding activities to different areas of the bay.

Following approved animal techniques and with the appropriate permits, we used a remote biopsy sampling procedure to obtain skin and blubber samples. This procedure consists of firing specially designed darts with biopsy sampling heads from a modified rifle. The samples obtained generally consist of a layer of skin and core of blubber that are roughly 1 cm in diameter and weigh between 0.5 and 1 gram. Photographs were taken of the dorsal fin of each animal sampled to match to the NOAA Fisheries photo-identification catalogue. This allows sighting histories of individuals to be linked with the tissue samples. The dolphins' reactions to biopsy sampling were carefully observed and recorded as required by the Marine Mammal Protection Act. Although we do not expect any long-term effects on the animals caused by the sampling, observations of the biopsy wound and behavior are recorded when previously sampled animals are sighted in subsequent surveys.

Research Performance Measure:

The program is currently underway and all objectives are being met on schedule.

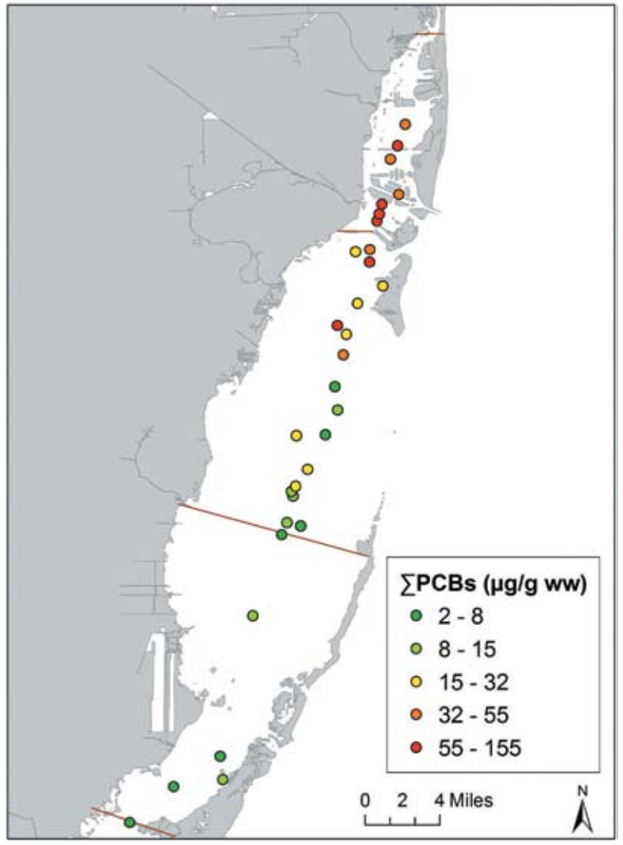


Figure 1: Sum of 73 PCB Congenes (ug/g net weight) for 45 dolphin

Developing Site Fidelity and Essential Habitat Assessment Tools for Juvenile Snappers in Florida Bay (Juvenile Snapper Micro-Acoustic Tagging Project – JSMAT)

S. Whitcraft (UM/CIMAS); B. Richards and J. Lamkin (NOAA/SEFSC);
N. Davis (NOAA Corps/SEFSC)

Long Term Research Objectives and Strategy to Achieve Them:
Objectives: To understand the early life-history habitat-protection requirements for recreationally and commercially important reef-associated snapper species in South Florida.
Strategy: To conduct a pilot study implementing micro-acoustic tags and receiving arrays to track the smallest-possible juvenile snappers in shallow-water habitat patches around Cotton Key, Florida Bay.

CIMAS Research Theme:
Theme 3: Regional Coastal Ecosystem Processes

Link to NOAA Strategic Plan Goals:
Goal 1: Protect, Restore, and Manage the Use of Coastal and Ocean Resources Through Ecosystem-based Management

NOAA Funding Unit: NMFS/SEFSC

NOAA Technical Contact: John Lamkin

Research Summary:
Snappers are one of the most heavily fished species in South Florida waters. In order to effectively manage this important commercial and recreational fishery, we need a better understanding of the movements of juvenile snapper within and between habitat types. Therefore, we address the research question: What are the juvenile habitat protection requirements for reef-associated snapper species such as gray snapper, *Lutjanus griseus*?

Figure 1: Newly caught juvenile snapper is measured before micro-tagging surgery

With funding from the NOAA Coral Reef Conservation Program, the JSMAT project is collaborating with HTI Inc. to apply their micro-acoustic tracking tools to our pilot study objectives. The long-term goal is to apply acoustic arrays and surgically implanted micro-acoustic tags (originally developed to track migration and survival of salmon smolts in the Pacific Northwest) to focus on tracking small (95 to 125 mm) juvenile snapper movements and home-ranges within and between distinct habitat-types. Research is centered on habitat areas in Florida Bay such as mangrove prop-roots and seagrass beds. We are focusing on Cotton Key because our past studies have identified this area as a known nursery and juvenile snapper habitat along with adjacent sea-grass beds/hard-bottom and mangrove shoreline in distinct, quantifiable patches. This configuration allows us to investigate the effectiveness of the arrays in shallow waters. Understanding site fidelity, home-ranges, and habitat-use patterns of these juvenile fishes both within and between fully protected areas and in non-protected areas is essential to aid in understanding the dynamics and effectiveness of current and future MPAs in South Florida.

This completes the second year of the JSMAT pilot project. We focused on capture methods (Figure 1), micro-surgery methodology, and survival of juvenile gray snappers at the State of Florida's Institute of Oceanography – Keys Marine Laboratory, Long Key (Figure 2). Our results are promising in that our survivorship study found greater than 95% survivorship of juvenile snappers that were surgically implanted with the micro-acoustic tags and no significant difference in behavior or survivorship between surgery fish and control fish i.e. those that were not operated on or those that were sutured but not implanted with a micro-tag.

Figure 2: Greater than 95% survivorship of juvenile snappers after acoustic micro-tagging surgery

Research Performance Measures:
All major objectives are being met on schedule.

Assessment of Candidate Corals

D.E. Williams and L. Kramer (UM/CIMAS); M.W. Miller (NOAA/SEFSC)

Long Term Research Objectives and Strategy to Achieve Them:

Objectives: To document the present distribution of elkhorn and staghorn coral (*Acropora* spp.) in the Florida Keys; to document the 'threats' impacting the remaining *A. palmata* populations in the upper Florida Keys and to determine the relative importance of each 'threat'.

Strategy: To survey shallow reef areas and map *Acropora* spp. presence and absence using GPS; to assess on a quarterly basis the status of individually-tagged colonies of coral at several sites in the upper Florida Keys.

CIMAS Research Theme:

Theme 2: Fisheries Dynamics (*Secondary*)
Theme 3: Regional Coastal Ecosystem Processes (*Primary*)

Link to NOAA Strategic Goals:

Goal 1: Protect, Restore, and Manage the Use of Coastal and Ocean Resources Through Ecosystem-based Management

NOAA Funding Unit: NMFS/SEFSC

NOAA Technical Contact: Margaret Miller

Research Summary:

Since the 1980s, elkhorn and staghorn corals (*Acropora* spp.*)* have declined by more than 90% on reefs throughout the Caribbean. Because of its fast growth rates and structural complexity, it is ecologically irreplaceable on Caribbean reefs. In May 2006, NOAA Fisheries (NMFS) listed acroporid corals as 'threatened species' under the U.S. Endangered Species Act. NMFS is in the process of designating critical habitat and will develop a recovery plan based on the current status and threats to these corals in U.S. waters. The results of this project have directly supported several phases of the listing process.

The overall objectives of this project are to document the status and distribution of the remaining Elkhorn populations in the upper Florida Keys and to determine the relative importance of the various 'threats' (disease, predation, etc.) present in those populations. This project consists of two complementary components: demographic monitoring and regional-scale mapping. The mapping component of this project aims to survey shallow reef areas offshore from Key Largo and mark the location of *Acropora* spp. colonies using GPS. These points along with surveyed tracks are entered into a GIS database, providing current data on both presence and absence for all surveyed areas. These data are being directly used for the designation of critical habitat as part of the ESA listing process. The resulting map (Fig. 1) will also provide a valuable tool for monitoring long-term changes in the status of this threatened species.

For the monitoring component of this project, we survey individually tagged *Acropora palmata* colonies quarterly to document their condition. Based on these observations, we can estimate basic population parameters including recruitment, growth and mortality, along with the causes of mortality and the source of the recruitment (asexual or sexual). These data will provide an estimate of population trajectory for *Acropora palmata*, as well as provide guidance for reducing the manageable threats to population recovery. The 2005 hurricane season provided a rare opportunity to document the effect of sequential storms on *Acropora palmata*. Our quarterly survey interval was augmented to include surveys following three of the four storms. Prior to the summer of 2005, disease (of unknown etiology) was a dominant threat to colony survival. However after July 2005, physical damage and colony fragmentation due to storm events was substantial component of live tissue loss. Asexual recruitment (attachment) of the loose colony fragments was estimated to be very low (<5%). The poor survival and retention of the fragments has

prompted an ancillary project investigating the feasibility of using storm-generated colony fragments for reef restoration.

Research Performance Measure:

All major objectives of this project are ongoing and progress is approximately on schedule. Progress on the mapping component was delayed due to the very active 2005 hurricane season; however, a positive outcome is that we carried out additional monitoring surveys that will enable us to document specific storm impacts.

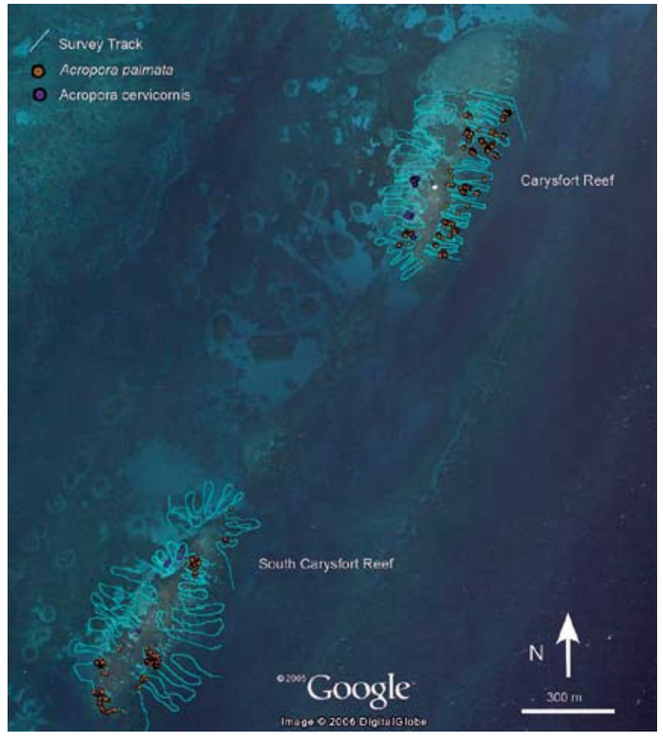


Figure 1: Aerial map showing the results of our mapping effort for the Carysfort and South Carysfort Reefs. The survey tracks records areas having no *Acropora* spp. corals and the points mark the locations of individual colonies. To date, 3km^2 of reef area has been surveyed and the data are stored in a GIS database.

Impacts of Water Resources Management Choices in Ceara, Brazil: Roles of Stream Forecasts, Rainfall, and Participatory Decision-making

K. Broad (UM/RSMAS); A. Pfaff (Earth Institute, Columbia University); U. Lall (Earth and Environmental Engineering and the International Research Institute for Climate and Society, Columbia University)

Long Term Research Objectives and Strategy to Achieve Them:

Objective: To develop a decision support system for the Jaguaribe Valley in Ceara, Brazil, that will increase the profitability and decrease economic risks by improving the management of water resources and understanding the extent that local farmers are able to cope with water variability in a region lacking insurance and risk-mitigating institutions.

Strategy: To conduct household economic surveys and use state-of-the art climate-based streamflow forecasts to develop an optimal water management regime, considering each household's ability to adapt to water variability.

CIMAS Research Themes:

Theme 4: Human Interactions with the Environment (*Primary*)
Theme 1: Climate Variability (*Secondary*)

Link to NOAA Strategic Plan Goals:

Goal 2: Understand Climate Variability and Change to Enhance Society's Ability to Plan and Respond (*Primary*)
Goal 3: Serve Society's Needs for Weather and Water Information (*Secondary*)

NOAA Funding Unit: COP

NOAA Technical Contact: Ken Mooney

Integrated Research Summary:

The overall objective of this program is to understand how farmers might adjust their water-use strategies in response to climate forecasts. We collect extensive information regarding households' behavior in the Jaguaribe Valley given various water availability scenarios. The data from these surveys are being used to parameterize a farm household decision model, which allows for the measurement of the impact of increasing water availability (using climate-based streamflow forecasts) on farmers' welfare. Additional

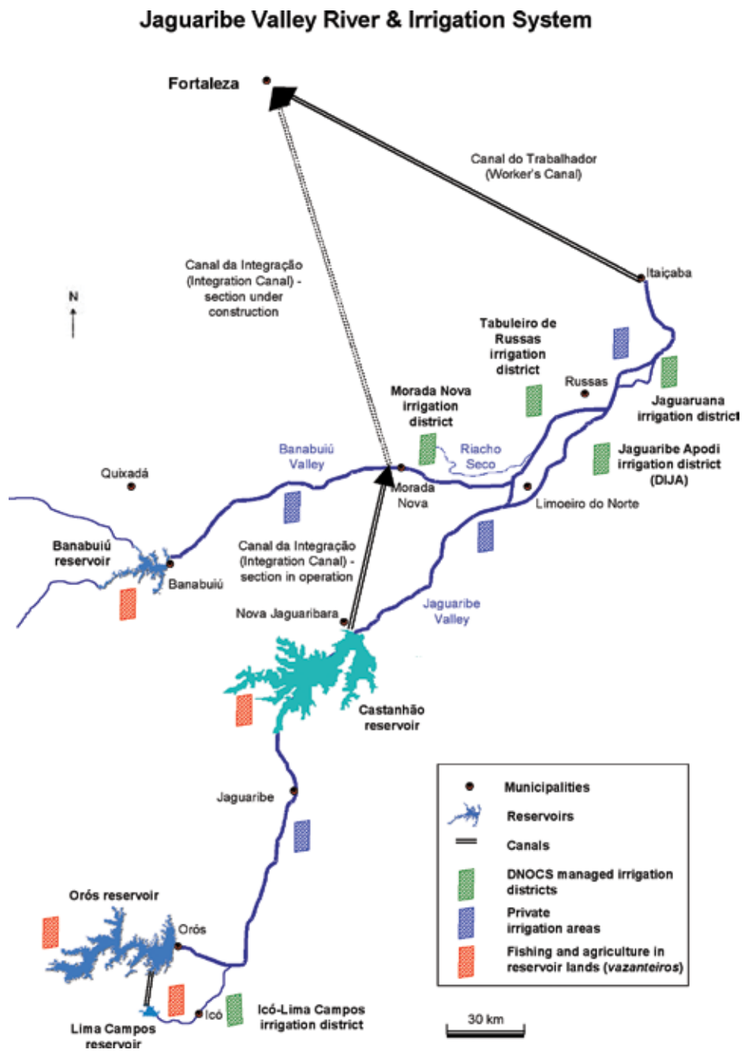


Figure 1: Map of the geographic area of interest. The figure shows the three reservoirs that we are focusing on in integrating streamflow forecast information in the water management scheme: the Oros, Banabuiu, and Castanhao. The figure also presents the geographical distribution of the water user groups in the area, which demonstrates why introducing streamflow forecasts into the existing water management scheme may benefit the groups differently. For example, the *vazanteiros* or floodplain farmers live adjacent to the reservoirs and cannot produce when the reservoirs are full or overflowing.

research involves observing the ability of households to cope (or smooth consumption) given water variability. Our survey asks farmers to report their consumption, saving, borrowing, asset, on-farm and off-farm income, remittance, and migration behavior given changes in water availability. The welfare impact of improving the infrastructure of water allocation may be greatly reduced given households' innate abilities to adapt to water variability. Household coping behavior may also shed light on the need for institutional development in the area of risk-mitigation, through the creation of micro-credit institutions or insurance mechanisms, for example. This is a cooperative program that involved groups at Columbia University and University of Miami. In the sections that follow, we summarize the activities of these groups.

Columbia University

Climate-induced water loss is of great concern for future agricultural water use. We are investigating ways of assisting individuals dependent on the local reservoirs by developing a reservoir-release regime to balance water releases over time. The regime is based on reservoir stream flow forecasts, which are estimated using sea-surface-temperature indices used to predict the El-Niño Southern Oscillation (ENSO). We have designed several versions of the household survey used to assess the welfare impacts of mitigating income risk from water variability. Due to the hypothetical nature of the survey, several iterations of the survey were piloted to ensure that the survey was appropriately characterizing water variability and communicating the idea effectively. Pilot tests were conducted starting October 2004 and ending May 2006 intermittently.

There were additional issues with designing the sampling scheme in the area. Due to the lack of external data sets providing a census of the region or sources of basic descriptors of the distribution of water users and farmer types in the region, quite a bit of resources were designated to getting a sense of these factors through numerous discussions with agricultural extension workers and brute force, i.e. sending our interviewers in the community and getting maps and facts through correspondences with the locals of each community. The final survey was administered in June 2006. The survey forms will be digitalized in the city of Fortaleza. A local research assistant will develop the data entry template. He will oversee a team of four typists hired to type in all of the material.

University of Miami

Research has initially focused on the economic and statistical methodology used to measure the welfare impact of increasing water availability through the use of climate-based forecast information. The results from our empirical model show which inputs are complementary with water, the supply response of crops given changes in water availability, and how the marginal contribution of labor to the production of outputs changes with water availability. The impact of increasing water availability on welfare is explicitly measured by calculating the change in profit for non-marginal changes in water. Using this model, we run several simulations to measure the welfare impact given different levels of prices and water.

Our second research pursuit involves observing the ability for households to cope or smoothing consumption when facing water availability shocks. A large effort has been dedicated to determining how farmers cope with crop loss and weather shocks in the absence of insurance mechanisms and other institutions. Several papers suggest that farmers cope with these shocks by using savings, borrowing, risk sharing, adjusting their labor supply, and liquidating their assets. There is anecdotal evidence that farmers in Ceara migrate to urban areas or work on neighboring farmers during times of limited water availability. We will use our survey to observe to what extent farmers are able to self-insure themselves against water variability. This adaptation behavior will first and foremost impact our measure of welfare from improving water availability. Additionally, the results will provide insight as to what mechanisms (other than climate-based forecasts) are best-suited in assisting households to cope with adverse water shocks.

Workshop: Conservation and Sustainable Use of Coral Reefs and Associated Habitats in the Mayan Riviera, Mexico

S. Frias-Torres and H. Cardenas (UM/CIMAS);
R. Araujo and M. Shivlani (UM/RSMAS); M. Bello (NOAA/SEFSC)

Long Term Research Objectives and Strategy to Achieve Them:
Objectives: To improve the level of Education and Outreach of decision-makers on Coral Conservation issues in the Mexican Caribbean
Strategy: To conduct a workshop in Spanish for local scientists, managers, government officials and tourism developers in Cancun, Mexico

CIMAS Research Theme:
Theme 4: Human Interactions with the Environment

Link to NOAA Strategic Goals:
Goal 1: Protect, Restore, and Manage the Use of Coastal and Ocean Resources Through Ecosystem-based Management

NOAA Funding Unit: NMFS/SEFSC

NOAA Technical Contact: Jim Bohnsack

Research Summary:
The Mayan Riviera (Mexican Caribbean) has one of the fastest tourism growth rates in the world. It contains part of the Meso-American Barrier Reef. Uncontrolled tourism development threatens its coral reefs and associated habitats (mangroves and seagrass). The decision-making process in this region lacks a crucial tool: The ecological and legal basis to ensure the conservation and sustainable use of coastal ecosystems while promoting tourism. Local communities do not have access to essential information because most of the relevant research is published in English in specialized journals. This workshop focused on capacity building for decision-makers (local scientists, managers, government officials and tourism developers) to ensure the conservation and sustainable use of mangroves, seagrass and coral reefs within an integrated coastal zone management plan. The workshop successfully initiated the process of establishing mechanisms for the transfer of scientific and management knowledge to Mexican decision makers.

Research Performance Measure:
The workshop was completed as planned. Written positive feedback was obtained from workshop attendees.

Figure 1: A group of Mexican workshop attendees with assistant scientist S. Frias-Torres (yellow hat) after completion of fieldwork in Puerto Morelos, June 2006.

Electrochemical Biosensors to Monitor Coastal Waters for Biological Threats to Human Health

M.J. LaGier (UM/CIMAS); K. Goodwin (NOAA/AOML)

Long Term Research Objectives and Strategy to Achieve Them:
Objectives: To increase the social and economic value of marine resources by improving the monitoring capabilities for harmful microorganisms in coastal waters.
Strategy: To develop portable and remote electrochemical biosensors that can rapidly detect microbial fecal indicators, harmful algae, microbial pathogens and source tracking markers in coastal waters.

CIMAS Research Theme:
Theme 4: Human Interactions with the Environment (*Primary*)
Theme 6: Integrated Ocean Observations (*Secondary*)

Link to NOAA Strategic Goals:
Goal 1: Protect, Restore, and Manage the Use of Coastal and Ocean Resources Through Ecosystem-based Management (*Primary*)

Goal 3: Serve Society's Needs for Weather and Water Information (*Secondary*)

NOAA Funding Unit: OAR/AOML

NOAA Technical Contact: Kelly Goodwin

Research Summary:
We are developing electrochemical biosensors to monitor microbial contaminants in coastal systems. Standard methods to identify microbial contaminants in the environment are slow, laborious, and can require specialized expertise. Electrochemical assays were developed for a red-tide dinoflagellate (*Karenia brevis*), fecal-indicating bacteria (*Enterococcus* spp.), markers indicative of human sources of fecal pollution (human cluster *Bacteroides* and the *esp* gene of *Enterococcus faecium*), bacterial pathogens (*Escherichia coli* 0157:H7, *Salmonella* spp., *Campylobacter jejuni*, *Staphylococcus aureus*), and a viral pathogen (adenovirus). For *K. brevis*, two assay formats (Rapid PCR-Detect and Hybrid PCR-Detect) were tested and both provided detection limits of 10 genome equivalents for DNA isolated from *K. brevis* culture and amplified by PCR. Sensitivity with coastal water samples was sufficient to detect *K. brevis* that was "present" (≤ 1000 cells/L) without yielding false positive results and the electrochemical signal was significantly different than for samples containing cells at "medium" concentrations (100,000 to $<10^6$ cells/L). Detection of *K. brevis* RNA was also shown. Multi-target capability was demonstrated with an 8-plex assay for bacterial and viral targets using isolated DNA, natural beach water spiked with human feces, and water and sediments collected from New Orleans, Louisiana following Hurricane Katrina. Furthermore, direct detection of dinoflagellate and bacterial DNA was achieved using lysed cells rather than extracted nucleic acids, allowing streamlining of the process. The methods can be used to rapidly (3-5 hours) screen environmental water samples for the presence of microbial contaminants and have the potential to be integrated into semi-automated detection platforms.

Research Performance Measure:
The program is on schedule. Electrochemical assays for a variety of targets have been designed and tested. In collaboration with an engineering team, work is on pace to convert these methods to a more automated system.

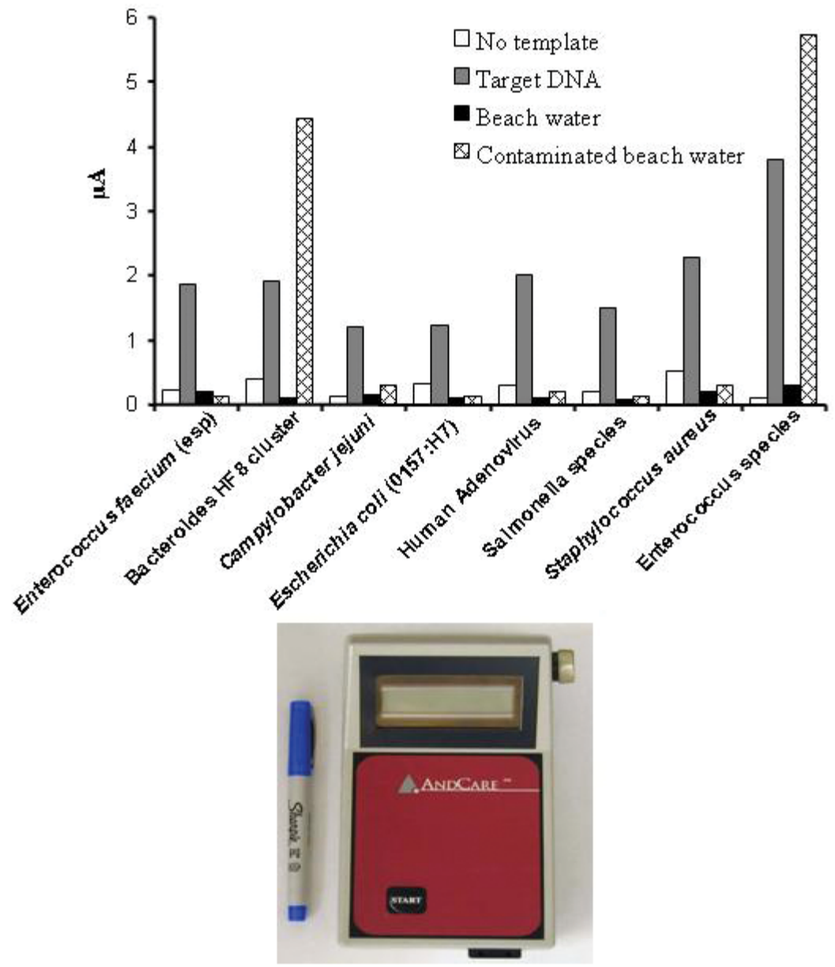


Figure 1: Detection of fecal indicator bacteria, fecal source tracking markers, and human pathogens by a handheld, electrochemical biosensor. "No template" = all PCR reagents except target DNA; "Target DNA" = PCR reactions with 1 ng target DNA; "Beach water" = PCR reactions with 5 µl of DNA extracted from 100 mls of natural beach water; "Contaminated beach water" = PCR reactions with 5 µl of DNA extracted from 100 mls of natural beach water spiked with 0.001% (w/v) human feces.

Assay and Sensor Development to Identify, Detect, and Quantify Microbial Contaminants

D. Wanless (UM/CIMAS); J.W. Fell (UM/RSMAS); K. Goodwin (NOAA/AOML)

Long Term Research Objectives and Strategy to Achieve Them:
Objectives: To increase the social and economic value of marine resources by improving coastal water quality monitoring.
Strategy: To develop a rapid hybridization technique that utilizes DNA probes capable of simultaneously detecting several fecal indicators.

CIMAS Research Theme:
Theme 4: Human Interactions with the Environment

Link to NOAA Strategic Goals:
Goal 1: Protect, Restore, and Manage the Use of Coastal and Ocean Resources Through Ecosystem-based Management

NOAA Funding Unit: OAR/AOML

NOAA Technical Contact: Kelly Goodwin

Research Summary:
The Luminex xMAP™ system is well suited to rapidly detect a variety of bacterial species that indicate contaminated water because it provides high throughput, multi-target detection. We have been designing assays to detect fecal-indicating bacteria in coastal waters and beach sand, and have recently expanded the assay to include source tracking markers. We have improved the sensitivity of the Enterococcus assay, overcome challenges with multiplex PCR, and have made strides to improve upstream concentration and extraction procedures. The detection targets now available include the following fecal-indicating bacteria: Enterococcus, E. *coli*/*Shigella*, the *Bacteroides fragilis* group, *Bacteroides distasonis*, and these markers of human fecal pollution: human- specific Bacteroides (HF8 marker) and human-specific Enterococcus (esp marker).

Research Performance Measure:
We are on schedule with this program.

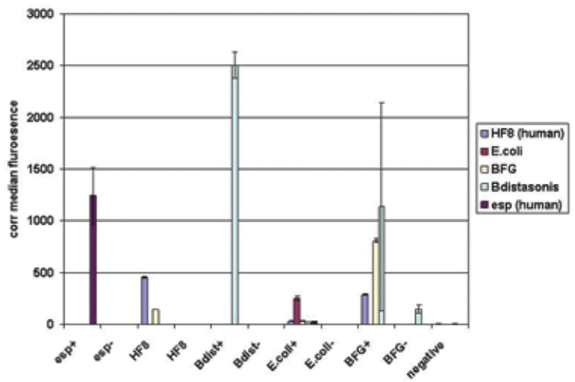


Figure 1: Luminex assay showing multiplex detection of the fecal indicating bacteria E. coli, the *Bacteroides fragilis* group (BFG), and *Bacteroides distasonis* (Bdist) and the human source-tracking markers esp and HF8.

Climate Information System for Agriculture and Water Resources Management in Southeastern USA: The Southeastern Climate Consortium (SECC)

G.P. Podestá, D. Letson and K. Broad (UM/RSMAS); S. Ahmad and R. Garcia (UM/Eng.); J.W. Jones, C.W. Fraise, S. Jagtap, C. Porter and K.T. Ingram (U. Fla., Agricultural and Biological Engineering); P.E. Hildebrand (U. Fla, School of Natural Resources and the Environment); J.J. O'Brien and D. Zierden (FSU); G. Hoogenboom, D. Stooksbury, L. Guerra, J. Paz, C. Ronconi and A. Garcia y Garcia (U. Georgia)

Long Term Research Objectives and Strategy to Achieve Them:
Objective: To use advances in climate sciences, including improved capabilities to forecast seasonal climate; to provide scientifically sound information and decision support tools for agriculture, forestry, and water resources management in the Southeastern USA.
Strategy: To develop generic tools for the production and dissemination of relevant climate information (diagnostic and forecasts); to strengthen decision making in agriculture.

CIMAS Research Themes:
Theme 4: Human Interactions with the Environment (*Primary*)
Theme 1: Climate Variability (*Secondary*)

Link to NOAA Strategic Goals:

Goal 2: Understand Climate Variability and Change to Enhance Society's Ability to Plan and Respond (*Primary*)

Goal 3: Serve Society's Needs for Weather and Water Information (*Secondary*)

NOAA Funding Unit: COP

NOAA Technical Contact: Caitlin Simpson

Integrated Research Summary:
The SECC is a multi-disciplinary, multi-institutional team that conducts research and outreach to a broad community of potential users and forms partnerships with extension and education organizations to ensure that SECC products are relevant and reliable. The goal of the SECC is to develop a climate information and decision support system for the Southeastern USA that will contribute to an improved quality of life, increased profitability, decreased economic risks, and more ecologically sustainable management of agriculture, forestry, and water resources. Toward this goal we have established the following objectives:

1. To develop an improved understanding of seasonal climate variability and climate predictability at local to regional scales across the Southeastern USA.

2. To characterize the contributions of climate variability to risks in management of agricultural, forestry, and water resources.

3. To develop information and decision aids based on the use of seasonal climate forecasts, historical climate data, and other climate analyses that help decision-makers identify management options to reduce risk and increase profits while sustaining the ecosystems of the Southeast USA.

4. To design and implement appropriate vehicles for disseminating climate and decision support information, including an Internet-based learning and decision support system.

5. To develop partnerships needed to build socially equitable extension and outreach programs for farmers, forest managers, water resource managers, homeowners, and policy makers to enhance

users' familiarity with these new seasonal climate forecasts and decision aids and to provide mechanisms for users to give feedback to researchers.

We use nested, coupled, regional climate models to explore the process of using an ENSO forecast system to provide tailored output for various socioeconomic sectors in small regions, primarily the Southeast United States and Southeast South America. However, these models only have skill in predictions of seasonal climate anomalies; further work is needed to resolve the complete spectrum of anomalous climatic behavior required for agricultural and climate study purposes. Thus, additional methods of "downscaling" the model results are utilized to produce worthwhile results.

Additional research at the SECC includes the integration of weather generators with climate models; the assessment of agricultural impact through the analysis of historical crop yields and simulated yield potentials; understanding forestry risk and its minimization; water quality assessment and policy analysis; and the development of crop management optimization toolkits and programs to explore optimal management options under different ENSO conditions and optimization criteria.

Component Programs

The SECC is comprised of groups at the University of Miami (UM), the University of Florida (UF), the Florida State University (FSU), and the University of Georgia (UG). The UF, FSU, and UG groups operate under subcontracts to the UM. In the following sections we present the research summaries of each of the four universities.

University of Miami

We have developed and adopted some common methodologies in our approach to identify climate variability patterns in temperature and precipitation associated with ENSO events and the assessment of related agricultural and water resource impacts. We use nested, coupled, regional climate models to explore the process of using an ENSO forecast system to provide tailored output for various socioeconomic sectors in small regions, primarily the Southeastern US and Southeastern South America. However, these models only have skill in predictions of seasonal climate anomalies. We are working with our collaborators to resolve the complete spectrum of anomalous climatic behavior required for agricultural and climate study purposes including the development of "downscaling" of model results to more useful region sizes.

We have introduced an economic modeling framework to study the value of the climate information under federal farm programs in the SE USA in collaboration with SECC members at all locations. This is an integration of climate, biophysical, socioeconomic, and policy components in a comprehensive optimization and simulation model to study the impacts of government intervention in the use of ENSO-based climate forecast. This research is intended to influence users' decisions and government policy making in order to improve socioeconomic well being and to reduce risk. A pilot study has been started in Northwest Florida that includes selected farm programs. This framework is in process of being replicated in Alabama and it is also expected to be introduced in Georgia. Using this framework to study the value of the climate information, a new framework to strategize crop insurance options has also been developed and is in the process of improvement.

Additional research includes: the integration of weather generators with climate models; the assessment of agricultural impact through the analysis of historical crop yields and simulated yield potentials; understanding forestry risk and its minimization; water quality assessment and policy analysis; and the development of crop management optimization toolkits and programs to explore optimal management options under different ENSO conditions and optimization criteria.

UM also leads an assessment effort that seeks to understand potential adoption and applications by end users of seasonal climate forecasts in Georgia, Alabama and Florida. We elicit regular feedback from end users to guide our research and development activities.

University of Florida

The UF focus is on improving downscaled climate forecasts. Climate forecasts may be downscaled for a

region by using nested models within the cells of a global circulation model (GCM). These downscaled results, however, have relatively poor skill at a 20 km by 20 km grid size. A statistical method based on nearest-neighbor analogue technique was developed to downscale global climate model outputs given by the coupled Atmospheric-Oceanic General Circulation Model (developed by FSU/COAPS) to local surface temperature, solar radiation, and rainfall in Southeastern US. One objective is to understand how crops respond to climate variability under different phases of the El Niño Southern Oscillation (ENSO) phenomenon. To this end we are using crop simulation models for tomato, peanut, and potato in combination with historic weather data and daily data generated through resampling. We obtain a series of probability distribution functions to show crop response. Simulations were run under a range of crop establishment dates, fertilizer application rates, and irrigation regimes.

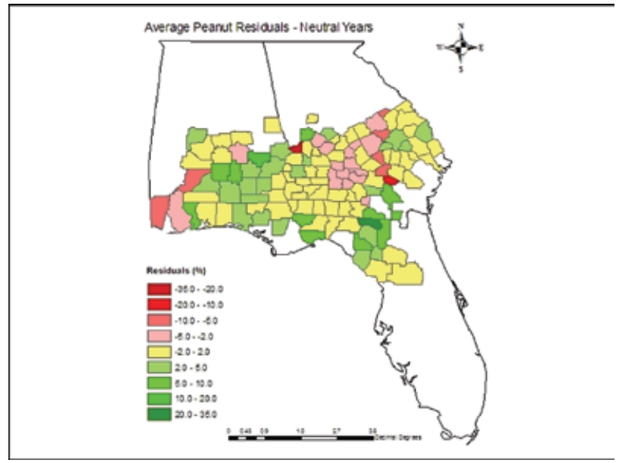


Figure 1: Map of average yield residuals calculated for Peanuts during the Neutral ENSO phase. Positive values (green colored counties) indicate that yields were expected to be good during this ENSO phase when rainfall is generally good. Peanut production risks associated with seasonal climate are greatest during dry phases when yields are generally low.

In order to increase access of decision makers to the decision support tools developed by the SECC, UF has led the development of a web site that will eventually be open to the general public. Personnel from UM, FSU and UGA have also made important contributions to this web site. A beta-test version of the web site may be viewed at: http://www.agclimate.org/

The AgClimate system has been further tested and improved during FY2006. An important development has been the addition of periodical releases of climate and commodity seasonal outlooks. Climate outlooks are provided on a quarterly basis focusing on the expected climate patterns for the next three months and topics of interest to producers. The fall outlook, released in September, focus primarily on the forecast of the upcoming ENSO phase and on climate conditions of interest for the development of winter crops, such as temperature and rainfall, as

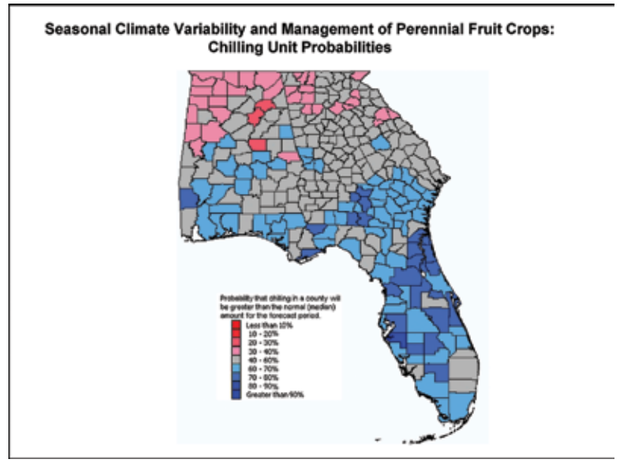


Figure 2: Map of seasonal climate variability impacts on Peach production sensitive to the amount of chilling during dormancy. In the Southeast, El Niño years tend to have more chilling and more rain during the dormant season than normal, while La Niña years have less chilling and may require additional irrigation during fruit growth and maturation. With dry conditions and low humidity, La Niña years may also impact pest and disease incidence. During Neutral years damaging freezes are more common.

well as the likelihood of severe freezes during the winter. The winter climate outlook, released in January, focus on the forecast of climate conditions during the planting season of summer crops that takes place mainly during the months of April and May. Spring and summer outlooks focus primarily on climate conditions related to the development and yield potential of the summer crops. The summer outlook also focuses on the expected level of activity of the upcoming hurricane season. Climate outlooks are released on AgClimate and at the same time announced to State Cooperative Extension Services through mail lists. Press releases are also forwarded to traditional agricultural publications in the Southeast US, such as the Southeast Ag Network.

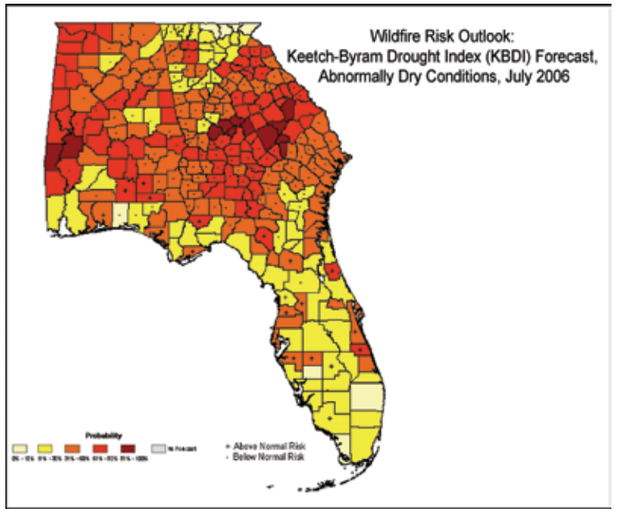


Figure 3: Wildfire activity potential forecast, based on the Keetch-Byram Drought Index (KBDI). The maps show the probability of exceeding the threat level at least 7 days during the month. The forecast is based on both initial conditions (current KBDI values) and expected climate patterns associated with ocean temperatures in the tropical Pacific, updated monthly. No forecasts are given for North Alabama and North Georgia due to a lack of skill (no discernable climate signal) in these regions.

Florida State University

FSU has developed a dynamically downscaled regional forecasts for agriculture in the southeastern US. Our approach is to improve downscaled climate forecasts by using nested models within the cells of a global circulation model (GCM) using the University of Florida statistical method described above. The goal of this work is to demonstrate that forecasts from dynamical downscaling have higher prediction skill than those based on ENSO phase alone when applied to biophysical models. Previous agricultural applications of climate forecasts have generally used statistical analysis of historical climate and ENSO phase to arrive at climate scenarios for adaptive management which reduces risk. The downscaling procedure uses the global climate outputs from the FSU/COAPS coupled Atmospheric-Oceanic General Circulation Model to generate local surface temperature, solar radiation, and rainfall in Southeastern US. Downscaled outputs significantly improved the skill of raw GCM forecasts of temperature, radiation, and precipitation. Crop yields forecast using downscaled climate data as inputs to crop simulation models have higher skill (~0.60 or better) than traditional GCM forecast climate data.

Second, FSU has also developed a Wildfire Risk Forecast System. This wildfire threat potential is based upon the Keetch-Byram Drought Index (KBDI). The KBDI is well-suited as a seasonal forecast medium for two reasons: 1) It is based on daily temperature and rainfall measurements and responds to changing climate and weather conditions on time scales of days to months, and 2) It has been widely used in forestry in the Southeast U.S. since its development in the 1970s, with foresters and firefighters have a good level of familiarity with the index and its applications. Weather data that drives the forecast is taken from hundreds of NWS cooperative observer sites in Florida, Georgia, and Alabama. The large number of weather stations makes it possible to provide the forecast at a county level.

Because the KBDI is driven by daily weather and because it can change drastically based on one or more rainfall events, the maps show the probability of exceeding the threat level at least 7 days during the month rather than for the month as a whole. Counties are given a plus sign to indicate a greater than normal threat for that month, and given a minus sign to indicate a risk level lower than climatology. The forecast is

based on both initial conditions (current KBDI values) and expected climate patterns associated with ocean temperatures in the tropical Pacific. For this reason, the forecast is updated monthly throughout the season as conditions change in the field. The initial forecast is made in January for the months of January through July, and then updated monthly as the season progresses. The wildfire threat forecast is available through AgClimate. The KBDI forecast format was developed through many discussions with fire weather experts at the Florida Division of Forestry, the Georgia Forestry Commission, USDA Forest Service, and with extension forestry specialists. The forecast is used by State forestry officials in their allocation of equipment and manpower and in decisions regarding the requests for additional resources.

University of Georgia

The calibration and evaluation of crop models requires good data for crop growth and development, yield and yield components, and management practices. However, the dynamics of the agricultural technology, such as new varieties that are released, is not matched with the frequency by which field experiments can be carried out to obtain the required data set for calibrating crop models. As a result, there is a lack of cultivar coefficients describing new and recently released varieties. Further, crop models should be evaluated with field data for a wide range of environmental conditions and management practices to provide credibility prior to applications for decision making.

An accurate simulation of irrigation water use is needed to help improve yield predictions and contribute to the resolution of the tri-state (Alabama, Florida and Georgia) water dispute. We used an optimization procedure to estimate the cultivar coefficients for widely-grown peanut varieties in southeastern USA as well as for new and recently released varieties. At the same time, we evaluated the performance of the DSSAT Cropping System Model in simulating irrigation applications and its impact on yield in farmers' fields in southwest Georgia. Crop growth and development variables and farmers' management practices such as irrigation applications were collected during the 2003 and 2004 growing seasons.

Long-term daily weather data are required for many applications of decision support systems in agricultural and natural resource management. The availability of daily solar radiation has been limited until recent years, restricting the application of crop and natural resource management models when long-term solar radiation data are required. We used a computer program, WGENR, to generate daily solar radiation data for selected counties in Alabama, Florida and Georgia using locally observed maximum and minimum temperature and precipitation data as input.

Research Performance Measure:

The goals in the development of models and forecast-information systems are being met on schedule.

Public Hurricane Loss Projection Model

B. Annane (UM/CIMAS); M. Powell (NOAA/AOML)

Long Term Research Objectives and Strategy to Achieve Them:
Objectives: To make probabilistic assessments of risk to insured residential property associated with wind damage from hurricanes
Strategy: To develop a wind field model that will provide wind risk information to engineering and actuarial components

CIMAS Research Theme:
Theme 5: Air-Sea Interactions and Exchanges

Link to NOAA Strategic Goals:
Goal 3: Serve Society's Needs for Weather and Water Information

NOAA Funding Unit: OAR/AOML

NOAA Technical Contact: Mark Powell

Research Summary:
The Public Hurricane Loss Projection Model incorporates atmospheric science, engineering, and financial/actuarial components. The atmospheric component includes modeling the track and intensity life cycle of each simulated hurricane within the Florida threat area. When a model storm approaches within a damage threshold distance of a Florida zip code location, the wind field is computed by a slab model of the hurricane boundary layer coupled with a surface layer model based on the results of recent GPS sonde research. A time series of open terrain surface winds is then computed for each zip code in the threatened area. Depending on wind direction, an effective roughness length is assigned to each zip code based on the upstream fetch roughness as determined from remotely sensed land cover/land use products. Based on historical hurricane statistics, thousands of storms are simulated allowing determination of the wind risk for all residential zip code locations in Florida. The wind risk information is then provided to the engineering and loss models to assess damage and average annual loss, respectively.

The activities of the past year have focused on evaluating the model and updating it to make use of the latest climatic data. The model updates have thus far been focused on meeting the standards of the 2005 Report of Activities of the Commission on Hurricane Loss Projection Methodology. We conducted validations

in a manner never attempted by the commercial proprietary models. We compare the cumulative effect of a series of modeled and observed wind fields by comparing the peak winds observed at a particular zip code during the entire storm lifecycle. We also compare our modeled wind fields to those that have been constructed from all available observations, and which are freely available on the NOAA AOML-HRD web site. In order to run the Loss Model in "scenario" mode for doing validation studies, we had to construct detailed storm track histories for recent storms affecting Florida using the HURDAT, Rmax and Holland Beta databases. The validation suite included the following 2004 and 2005 storms: Charley, Frances, Jeanne, Ivan, Dennis, Katrina, Rita, and Wilma. The validations make use of the Hurricane Research Division's Surface Wind Analysis System (H*Wind).

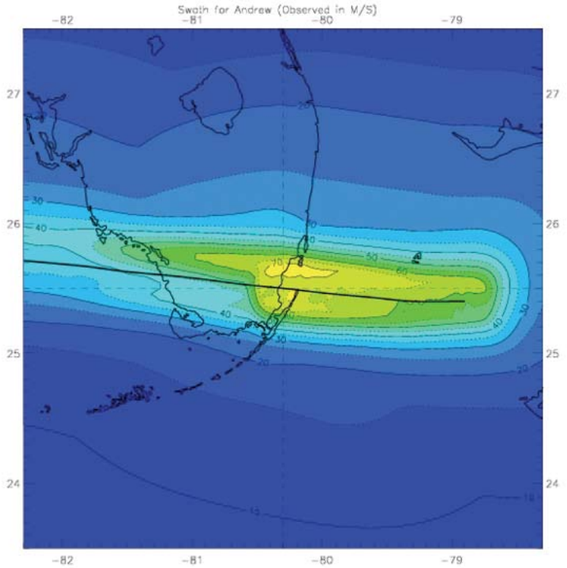


Figure 1: Swath of Hurricane Andrew 1992

After obtaining a detailed wind swath (e.g. Fig. 1) comparisons from hurricane Andrew and eight storms from the 2004 and 2005 seasons were conducted in parts of the storm where the public model indicates winds were capable of producing damage (winds > 38 mph over open ocean). Proprietary models are not evaluated on the basis of wind swath comparisons but are usually tuned to provide time series comparisons at a few individual locations.

Research Performance Measure:
All objectives are being met on schedule.

Process Studies of Marine Boundary Layer Clouds and Structures Over the Eastern Pacific

B. Albrecht (UM/RSMAS)

Long Term Research Objectives and Strategy to Achieve Them:

Objectives: To determine how cloud and boundary layer structures vary over the southwestern Pacific stratocumulus regime and elucidate the processes responsible for this variability; to explain the occurrence and the temporal variability of drizzle from shallow stratocumulus clouds over this region.

Strategy: To use observations from instrumented research vessels in collaboration with NOAA ESRL scientists to study cloud and boundary layer properties and processes that affect and maintain these structures.

CIMAS Research Theme:

Theme 5: Air-Sea Interactions and Exchanges (*Primary*)
Theme 1: Climate Variability (*Secondary*)

Link to NOAA Strategic Goals:

Goal 2: Understand Climate Variability and Change to Enhance Society's Ability to Plan and Respond

NOAA Funding Unit: COP

NOAA Technical Contact: Jin Huang

Research Summary:

We have worked on the analysis of extensive data sets collected on three research cruises that included extensive instrumentation deployed by NOAA ETL of ESRL in the area of interest. The cloud and boundary layer analyses use observations made during the EPIC 2001 and the Stratus 2003 and Stratus 2004 cruises. During the 2004 cruise we deployed a state-of-the-art FMCW Doppler radar that was used with the ETL instrumentation to provide high temporal and spatial representations of the drizzle observed in the marine stratocumulus decks. This radar operated continuously for about 44 days of cruise time. For all three cruises our analysis focuses on cruise legs that extend across the southeast Pacific stratocumulus decks and 4-5 day periods in the vicinity of the WHOI buoy located at 20°S, 85°W.

The data analyses performed under this grant focus on establishing the factors that control the type and the amount of boundary layer clouds and explaining differences in the cloud and boundary processes operating during these three different observing periods. A summary of the analyses made for the three cruises is shown in Figure 1. Here the time-height sections of water vapor obtained from radiosondes are shown with the cloud top height from radar observations, cloud base from ceilometer observations, and LCLs calculated from *in situ* temperature and moisture measurements. Although results from the 2001 and 2003 cruises have been published previously, this study provides an opportunity to compare and contrast cloud and boundary layer features. Distinct variations in the mean boundary layer structure were observed during the three cruises. These cloud and boundary layer observations are being combined with the surface flux measurements obtained from the NOAA ETL flux tower and large-scale temperature, moisture, and wind fields from the NCEP reanalysis to examine the processes that are responsible for the observed variability in cloud and boundary layer structure. The FMCW radar on the 2004 cruise provides a detailed description of drizzle observed during this cruise. A comparison of the radar returns from the FMCW radar with the NOAA ETL MMCR (35 GHz radar) illustrates the high resolution of the FMCW measurements; furthermore the absence of a dead zone near the surface allows for estimates of the evaporation of drizzle at these levels.

Research Performance Measure:

The program is on schedule. The results to date represent a major portion of the proposed work on describing the structure of the marine stratocumulus clouds.

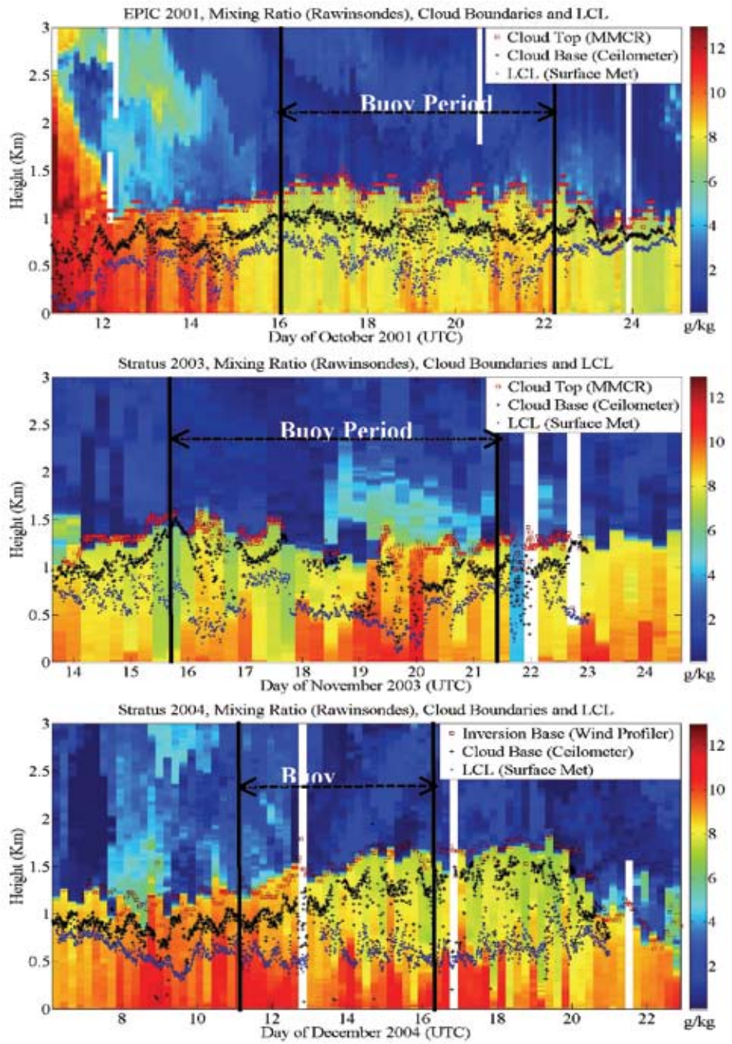


Figure 1: Boundary layer and cloud structures over southeast Pacific from three research cruises. Time-height of mixing ratio r (g kg-1) during EPIC 2001 (upper panel), Stratus 2003 (middle panel) and Stratus 2004 (lower panel). The cloud boundaries and the LCL are also displayed. Periods when the vessels were stationed at the WHOI buoy (20°S, 85°W) are bounded by black vertical lines, while white segments indicate missing values.

Air-sea Fluxes in High Winds – Analysis of the CBLAST Data

W. Drennan and J. Zhang (UM/RSMAS);
P. Black (NOAA/AOML); J. French (U. Wyoming)

Long Term Research Objectives and Strategy to Achieve Them:
***Objectives*:** To improve forecast accuracy for hurricanes and tropical systems.
***Strategy*:** To provide direct measurements of the air-sea fluxes of momentum, heat, and moisture in hurricane conditions for use as vital input parameters to coupled hurricane models

CIMAS Research Theme:
***Theme 5*:** Air-Sea Interactions and Exchanges

Link to NOAA Strategic Goals:
***Goal 3*:** Serve Society's Needs for Weather and Water Information

NOAA Funding Unit: OAR/AOML

NOAA Technical Contact: Peter Black

Research Summary:
As part of the CBLAST ("Coupled Boundary Layer Air-Sea Transfer") experiment, we carried out turbulence and supporting measurements from P3 aircraft during hurricanes Fabian and Isabel. We have calculated the air-sea fluxes of humidity, heat and momentum, along with their bulk transfer coefficients. These are the first data for winds speeds above 20m/s.

The bulk humidity transfer coefficient or Dalton number is found to be consistent with the earlier COARE-3 relation and HEXOS dataset, with no wind speed dependence for winds up to 30m/s. This implies that any significant effect of sea spray on the humidity flux would be limited to even higher wind speeds. Likewise, the bulk sensible heat flux coefficient was found to be constant with wind speed. The bulk momentum flux or drag coefficient was found to be consistent with earlier parameterizations (i.e. to increase with wind speed) up to 22m/s, and then to become constant for higher winds. The ratio of enthalpy to drag coefficients was found to be close to the Emanuel (1995) threshold for tropical cyclone development (Fig. 1).

Research Performance Measure:
The goals of the project were largely achieved and progress continues.

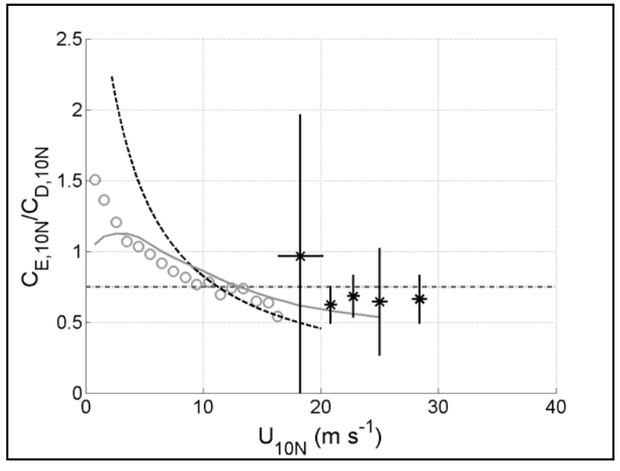


Figure 1: Ratio of bulk humidity to drag coefficients derived from CBLAST measurements. The asterisks represent average values in 2.5 ms^{-1} bins, and the bars show 95% confidence limits. The black dashed curve is the mean ratio from HEXOS. The solid green line is the ratio values from COARE 3.0. The grey circles are from CBLAST-Lo . The dash-dot horizontal magenta line is the 0.75 threshold for tropical cyclone development proposed by Emanuel (1995)

Drag Coefficient Distribution and Wind Speed Dependence in Tropical Cyclones

N. Morisseau-Leroy and R. St. Fleur (UM/CIMAS); M. Powell (NOAA/AOML)

Long Term Research Objectives and Strategy to Achieve Them:
***Objective*:** To improve the understanding of tropical cyclones through advances in computing technology
***Strategy*:** To used advanced computing techniques to integrate tropical storm data in near real-time and to make the data available in a flexible format.

CIMAS Research Theme:
***Theme 5*:** Air-Sea Interactions and Exchanges

Link to NOAA Strategic Goals:
***Goal 3*:** Serve Society's Needs for Weather and Water Information

NOAA Funding Unit: OAR/AOML

NOAA Technical Contact: Mark Powell

Research Summary:
The HRD GPS Dropwindsonde Management Tool (GDDMT) is a robust software tool that allows scientists to manage GPS sonde profiles collected in hurricanes from 1997-2004. These GPS profiles are processed, quality controlled, and organized by mean boundary layer wind speed, storm relative location, and water depth and, then, stored in a modern object-relational database. GDDMT will allow the scientists to ingest GPS profiles into a database, quality control, analyze, update, and query the GPS dropwindsonde data. The tool consists of three sub-components: data collection, the database, and the client interface. Data ingestion and queries are done via Oracle PL/SQL packages that reside in the database and SQLJ components that reside in the application server.

We continue to develop user and programmer use cases, Oracle PL/SQL packages, SQLJ components, decoders and parsers in order to ingest GPS profiles in the database, and a data management tool (see Figure 1). We are also developing the GPS Dropwindsonde Management Tool (GDDMT), for viewing and interacting with raw and processed GPS dropwindsonde data. At present the database spans 1997 – 2005 and contains over 2000 GPS profiles and 556 storm tracks. The project has been expanded to include flight-level measurements taken from aircraft that launch the GPS dropwindsondes and, in addition, the flight leg data recorded aboard the aircraft.

Research Performance Measure:
The research program is developing according to schedule.

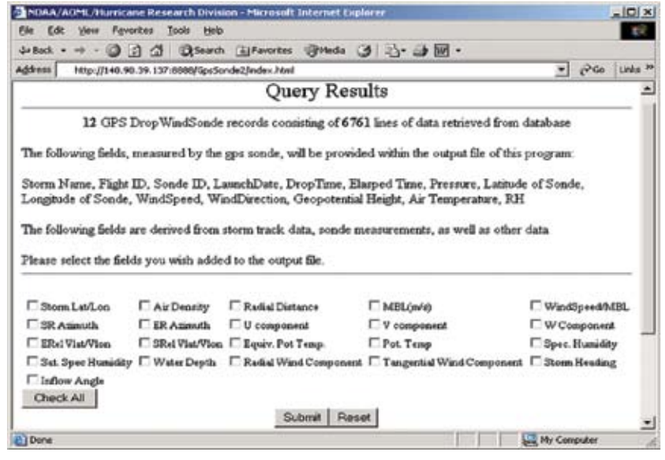


Figure 1: View of Processed GPS DropWindSonde Data

Real-Time Hurricane Wind Analysis

N. Carrasco, B. Annane, S. Otero, R. St. Fleur and
N. Morisseau-Leroy (UM/CIMAS); M. Powell (NOAA/AOML)

Long Term Research Objectives and Strategy to Achieve Them:
Objectives: To improve our understanding of the wind systems in tropical cyclones
S*trategy*: To apply advanced computing methodologies to integrate cyclone data and to make the data more readily available to scientists in real-time

CIMAS Research Theme:
Theme 5: Air-Sea Interactions and Exchanges

Link to NOAA Strategic Goals:
Goal 3: Serve Society's Needs for Weather and Water Information

NOAA Funding Unit: OAR/AOML

NOAA Technical Contact: Mark Powell

Research Summary:
The HRD Real-time Hurricane Wind Analysis System (H*Wind) is a distributed system that ingests real-time global tropical cyclone observations measured by land-, sea-, space-, and air-borne platforms and subsequently adjusts them to a common framework, 10m marine exposure. These observations are stored in a relational database, and then graphically displayed via an interactive Java application where scientists can quality-control, objectively analyze, and visualize the information. The H*Wind system consists of five sub-components: data collection, database, quality control interface, analysis package, and product generation package.

Data collection is accomplished through a suite of Unix scripts and C programs. Current platforms being ingested include Air Force and NOAA reconnaissance, Dropwindsondes, GOES, SSM/I, TM/I, QSCAT satellites, METAR, C_MAN, Buoys, Ships, mobile Towers, MESONET data from FSL MADIS Group. This year, starting with Hurricane Katrina's wind re-analysis project funded by the U.S. Army Corps of Engineers, a new standardization method was used to adjust winds to a common framework. It was developed based on findings published in a Powell et al. 2003 Nature paper "Reduced drag coefficient for high wind speeds in tropical cyclones", using roughness tables and other known facts about the various observing platforms.

The H*Wind Quality Control (QC) Client is the focal point of the H*Wind system. The QC Client allows scientist to interact with the data stored in the database. QC graphically displays the data and allows close inspection, editing or removal of data from the analysis, and customization of analysis parameters. The analysis algorithm consists of a process of estimating the continuous spatial field of a physical variable from a set of discrete observational data. For our purposes, the physical variables of concern are wind, pressure, temperature and relative humidity. The product of this analysis is a colored and annotated wind contour plot, as seen in Figure 1.

During the past year, we embarked on a migration towards an open-source software solution for the database and analysis package of H*Wind. We are motivated by the cost savings, by the increased reliability offered in this competitive industry, and by the possibility of bundling the whole software infrastructure for a more predictable and inexpensive transition to operations. The acquisition of a Linux server realized the establishment of an open-source database with geo-spatial features (PostgreSQL) and the recompilation of the analysis code to this new operating system. With this new composition of H*Wind subsystems, new methods for adjustment, integrating airborne radar with surface data, gridding at a 1-km resolution, we accomplished the most comprehensive set of wind analyses ever conducted for a landfalling tropical cyclone for Hurricane Katrina.

Research Performance Measure:
All objectives are being met on schedule.

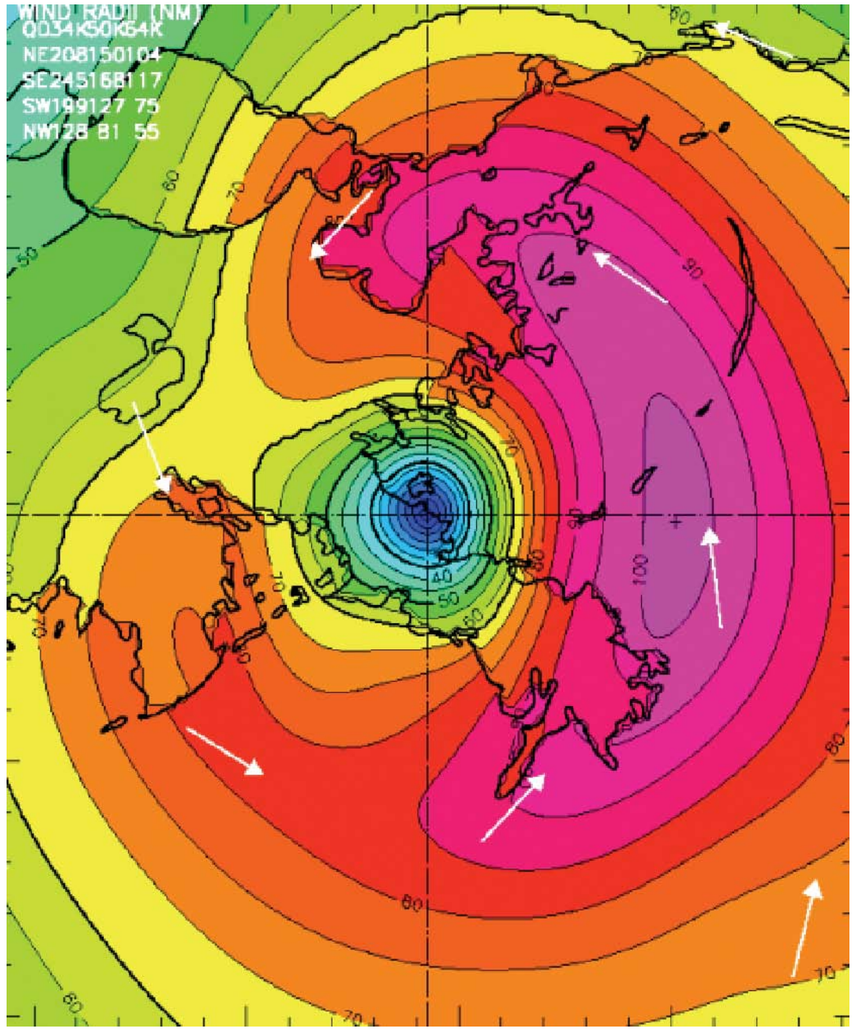


Figure 1: Hurricane Katrina on August 29, 2005, 1200 UTC.

Eastern Pacific Ocean Heat Content Estimates For SHIPS Forecasts

L.K. Shay and J. Brewster (UM/RSMAS);
M. Mainelli (NOAA/TPC); M. DeMaria (CIRA)

Long Term Research Objectives and Strategy to Achieve Them:
***Objective*:** To improve hurricane intensity forecasting using oceanic heat content (OHC) estimates in the Eastern Pacific Ocean (EPAC) at NOAA's Tropical Prediction Center (TPC) and the Central Pacific Hurricane Center (CPHC)
***Strategy*:** To estimate and evaluate satellite-derived OHC variations using in situ data in the EPAC and assess its relationship to hurricane intensity structure and change

CIMAS Research Theme:
***Theme 5*:** Air-Sea Interactions and Exchanges

Link to NOAA Strategic Goals:
***Goal 3*:** Serve Society's Needs for Weather and Water Information

NOAA Funding Unit: USWRP

NOAA Technical Contact: Chris Landsea

Research Summary:
The Eastern Pacific Ocean (EPAC) is a region of significant oceanic variability because of the effects of the warm pool and the equatorial cold tongue. In this regime, surface winds can force warm eddies along the coast that move westward and impact tropical cyclone (TC) intensity change. Given the TC activity over this region (May through October) and large sea surface temperature (SST) gradients, ocean heat content (OHC) estimates are needed for use in the Statistical Hurricane Intensity Prediction Scheme (SHIPS) to improve forecasts of hurricane intensity. In the EPAC, the seasonal thermocline at the base of the ocean mixed layer (OML) is sharp with large gradients starting at about 40 m beneath the surface. As shown in Figure 1, it is a prime region for rapid intensification as observed during hurricane Juliette in 2001. The research approach involves developing an oceanic climatology and modifying SHIPS with daily OHC estimates from altimeter measurements and SSTs; these are supplied to TPC and CPHC for their hurricane intensity forecasts.

We use ocean structure data sets from Volunteer Observing System ship transects, NOAA Tropical Atmosphere Ocean buoys, and field measurements acquired during the NOAA/NSF Eastern Pacific Investigation of Climate (EPIC) program to evaluate satellite-derived OHC and isotherm depths. These measurements are crucial to establish an accurate seasonal OHC climatology using the U.S. Navy's Generalized Digital Environmental Model data base in conjunction with radar altimeter measurements of the surface height anomaly (SHA) and SST fields from multiple platforms.

Research Performance Measure:
The research program is progressing according to plan.

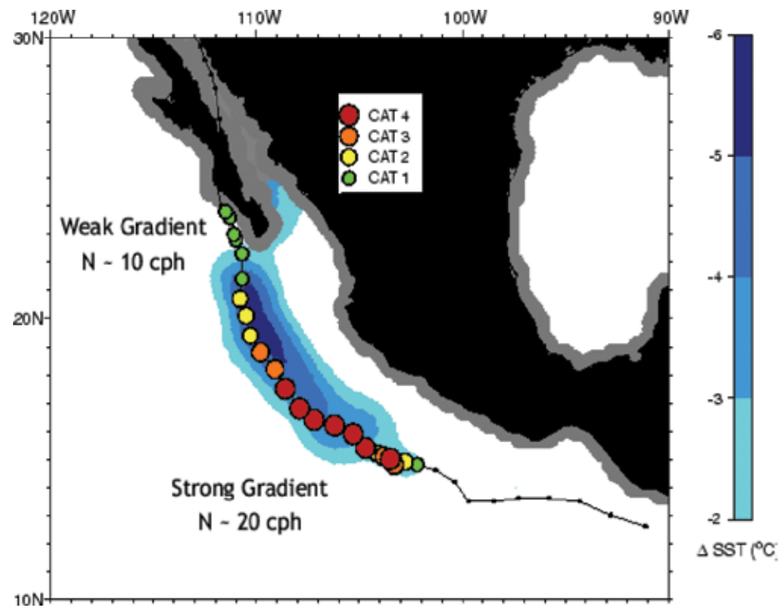


Figure 1: TRMM Microwave Imager-derived SST cooling response (°C) relative to hurricane Juliette's intensity (see legend) and track (20 to 25 Sept 2001). The strong vertical density gradient (buoyancy frequency: N) region in the upper ocean lies between 10 to 15°N where N is ~20 cycles per hour (cph) compared to 10 cph between 16 to 20°N (As N decreases from south to north, SST cooling increases).

Initial Steps Towards a Global Surface Water pCO_2 Observing System

F.J. Millero (UM/RSMAS); R.Wanninkhof and S. Cook (NOAA/AOML); R. Feely (NOAA/PMEL); N. Bates (BBSR, Bermuda); T. Takahashi (LDEO/Columbia Univ.)

Long Term Research Objectives and Strategy to Achieve Them:
***Objectives*: To** determine the changes in the pCO_2 in the Atlantic and Pacific Ocean waters in order to examine the uptake of fossil fuel CO_2 by the oceans over time.
***Strategy*:** To use Volunteer Observing Ships (VOS) in the Atlantic and Pacific oceans.

CIMAS Research Theme:
***Theme 5*:** Air-Sea Interactions and Exchanges

Link to NOAA Strategic Goals:
***Goal 2*:** Understand Climate Variability and Change to Enhance Society's Ability to Plan and Respond (*Primary*)
***Goal 3*:** Serve Society's Needs for Weather and Water Information (*Secondary*)

NOAA Funding Unit: OAR

NOAA Technical Contact: Joel Levy

Research Summary:
It is critically important to understand the global carbon cycle and to determine the regional sources and sinks of carbon so that international policy decisions are soundly based. These data are also critical for forecasting long term climate trends. Projections of long-term global climate change are closely linked to assumptions about feedback effects between the atmosphere, the land, and the ocean. To understand how carbon is cycled through the global climate system, ocean measurements are of utmost importance. In this effort NOAA is outfitting research and commercial vessels with automated carbon dioxide sampling equipment to analyze the seasonal variability in carbon exchange between the ocean and atmosphere. The documenting of carbon sources and sinks relies critically on other efforts undertaken by the Climate Observations and Services Program (COSP) including the implementation of the ship lines, and moored and drifting arrays. The surface water pCO_2 programs support climate services by providing knowledge and quantification of climate forcing of the radiatively important gas, carbon dioxide. The near-term focus is on completion of the Northern Hemisphere ocean carbon observing system to assist in determining carbon dioxide sources and sinks over the coterminous United States in partnership with the atmospheric CO_2 observing system.

The pCO_2 observing program on volunteer observing ships (VOS) and research ships involves a partnership of AOML, AOML/GOOS, PMEL, LDEO of Columbia University, RSMAS, and the Bermuda Biological Station for Research (BBSR). A major component of the VOS pCO_2 work revolved around designing, building and testing the second generation of underway pCO_2 systems for ships of opportunity. A contractor at the University of Bergen built twelve systems with extensive input from the NOAA/COSP sponsored partners. Four of the systems are being purchased by the participants of this project. The others are going to groups throughout the world. The first generation systems that we currently have installed on VOS will be retrofitted to be fully compatible with the new systems. Data from the project is being served from three websites that are linked and accessible from each.
1. http://www.aoml.noaa.gov/ocd/gcc
2. http://www.pmel.noaa.gov/co2/uwpco2/
3. http://www.ldeo.columbia.edu/res/pi/CO2/

Research Performance Measure:
This program is on schedule.

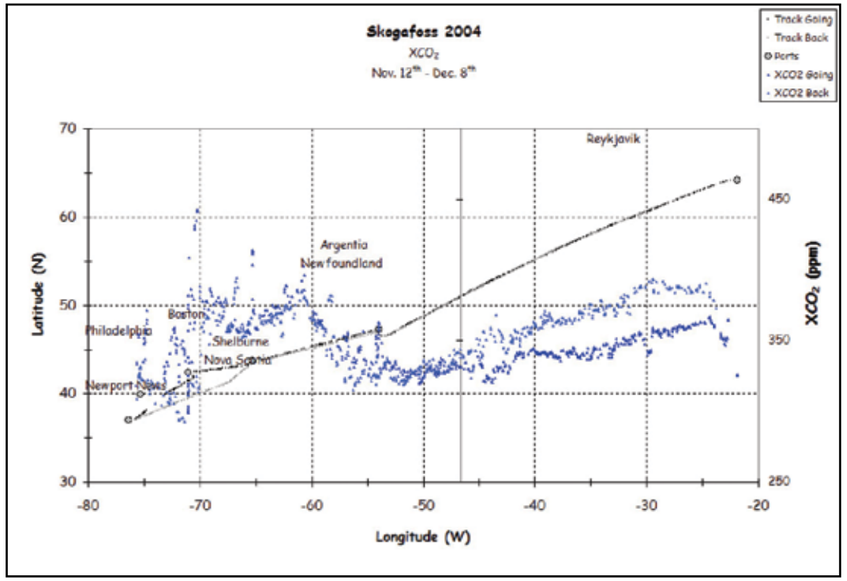


Figure 1: The concentration of CO_2 in seawater measured on the ship Skogafoss as part of the VOS program.

Evaluation of NOAA's Operational Stepped Frequency Microwave Radiometer

E.W. Uhlhorn (UM/CIMAS); P.G. Black (NOAA/AOML/HRD);
A.S. Goldstein (NOAA/OMAO/AOC)

Long Term Research Objectives and Strategy to Achieve Them:
Objectives: To evaluate the performance of the NOAA Stepped Frequency Microwave Radiometer (SFMR) and its ability to accurately measure surface wind speeds in hurricanes; to prepare to transition the SFMR to operations aboard Air Force Reserve Command WC-130J hurricane reconnaissance aircraft.
Strategy: To finalize instrument calibration procedures; to test surface wind retrievals against in situ measurements under a broad range of wind speeds in the hurricane environment.

CIMAS Research Theme:
Theme 5: Air-Sea Interactions and Exchanges

Link to NOAA's Strategic Goals:
Goal 3: Serve Society's Needs for Weather and Water Information

NOAA Funding Unit: OAR/AOML

NOAA Technical Contact: Peter Black

Research Summary:
For the first time, the NOAA/Aircraft Operations Center (AOC) flew Stepped Frequency Microwave Radiometers (SFMR) on both WP-3D research aircraft for operational surface wind speed measurement in hurricanes in 2005. An unprecedented number of major hurricanes provided ample data to evaluate both instrument performance and surface windspeed retrieval quality up to 70 m s^{-1} (Saffir-Simpson category 5). With this data we have devised a new microwave emissivity/wind speed model function based on estimates of near-surface winds in hurricanes by GPS dropwindsondes. This new function removes a previously-documented high bias in moderate SFMR-measured wind speeds and it corrects a systematic underestimate at extremely high wind speeds.

The model function behaves differently both below and above the hurricane wind speed threshold (32 m s^{-1}). This may have implications for air-sea momentum and kinetic energy exchange. The change in behavior is at least qualitatively consistent with recent laboratory and field results

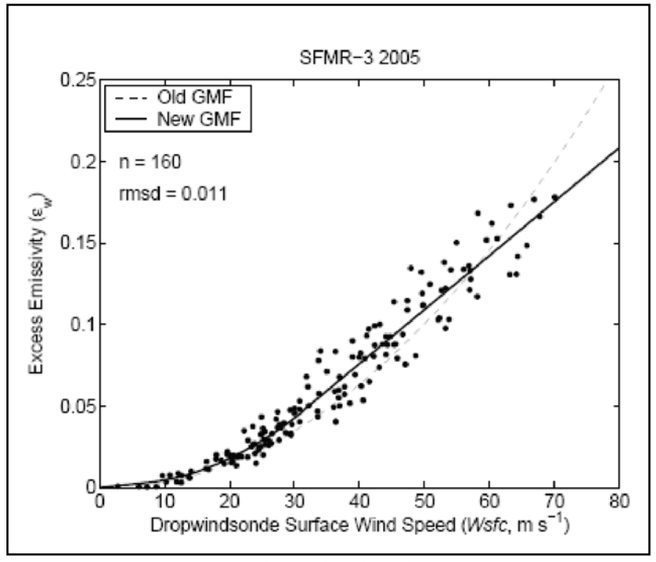
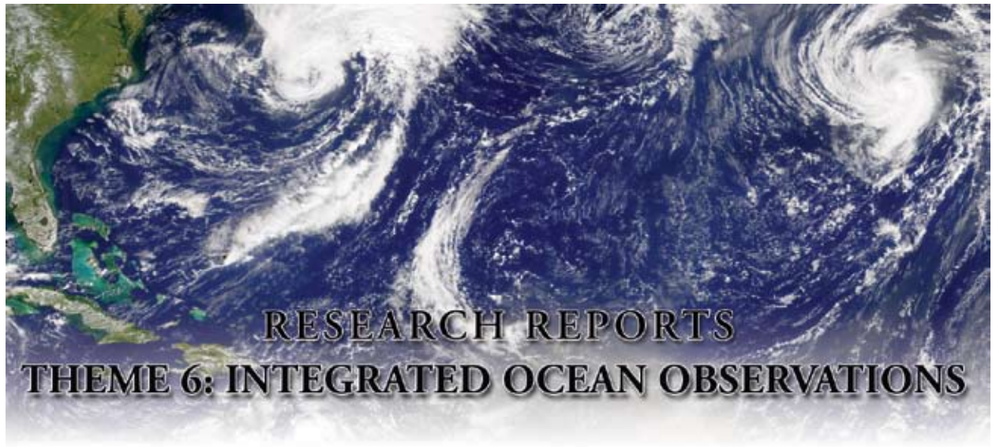


Figure 1: SFMR-measured wind-induced (excess) emissivity as a function of GPS dropwindsonde surface wind speed for data obtained in 2005. Results indicate a distinct change in sea surface radiometric properties as winds exceed the hurricane threshold.

concerning the drag coefficient (C_d) in high wind speed conditions which show a fairly clear ``leveling-off" of C_d with increased wind speed above ~30 m s^{-1}. This gain in understanding will lead to improvements in air/sea exchange parameterizations, ultimately resulting in superior hurricane intensity forecasts.

The NOAA SFMR and the updated model function are now in operation during the 2006 season. With the recent spate of North Atlantic major hurricanes and the expected continuation of increased activity, accurate intensity diagnosis is crucial for improved coastal watches/warnings and more efficient evacuations. The future installation of SFMRs aboard Air Force Reserve Command (AFRC) hurricane reconnaissance aircraft will greatly increase the frequency at which storms are observed by SFMR, and additional algorithm improvements utilizing concomitant precipitation data from advanced airborne radars are expected to further improve SFMR hurricane wind speed measurements.

Research Performance Measure:
The research program is progressing according to schedule.



Integrated Coral Observing Network (ICON) Project

J. Absten, L. Florit, L. Gramer, M. Jankulak and D. Manzello (UM/CIMAS);
C. Langdon (UM/RSMAS); J. Hendee, M. Shoemaker and
J. Craynock (NOAA/AOML); E. Stabenau (NOAA/NRC, currently NPS)

Long Term Research Objectives and Strategy to Achieve Them:

Objectives: To facilitate in-situ observations at coral reef areas; to integrate *in-situ*, remote-sensing, and other data so as to better understand the physical processes that affect the health and life cycles of organisms in the reef system; to compile ecological forecasts for coral reef ecosystems to help to understand them, and to aid in decision support for Marine Protected Area management.

Strategy: To construct meteorological and oceanographic monitoring platforms near coral reef areas; to provide data archiving and artificial intelligence tools that can facilitate the acquisition and integration of high-quality data from these and other sources and enable rapid assessment of the physical environment at these areas.

CIMAS Research Themes:

Theme 6: Integrated Ocean Observations (*Primary*)
Theme 3: Regional Coastal Ecosystem Processes (*Secondary*)

Link to NOAA Strategic Goals:

Goal 1: Protect, Restore, and Manage the Use of Coastal and Ocean Resources Through Ecosystem-based Management (*Primary*)
Goal 3: Serve Society's Needs for Weather and Water Information (*Secondary*)

NOAA Funding Unit: OAR/AOML

NOAA Technical Contact: James Hendee

Research Summary:
ICON (formerly known by the acronym CREWS) provides scientists and managers with data critical to understanding the complex physical, chemical, and biological processes influencing coral reef ecosystems through continuous data collection and real-time monitoring,. ICON stations are currently installed at North Norman's Reef near the Island of Exuma, Bahamas; at Salt River, St. Croix in the U.S. Virgin Islands; and at La Parguera, Puerto Rico. There are plans for additional stations in the Caribbean, Pacific and Indo-Pacific regions. For the 2005-2006 year, the project has centered its efforts around two primary areas: (1) integration of data and the ability to draw automated, real-time inferences about ecological and physical events on the basis of that data; and (2) continued deployment of new stations and maintenance of existing stations and in-situ sensors based on an updated structural hardware design that offers improved stability and reliability of the instrumentation at the study sites. The ICON expert system combines station observations from instruments such as pCO_2 sensors, multi-spectral light instruments, temperature loggers, meteorological instruments to predict conditions conducive to coral bleaching events as well as reproductive activities of corals and other reef organisms. These ecological forecasts can then be distributed via email to researchers and via the Coral Health and Monitoring Program website at http://www.coral.noaa.gov. Continuous baseline data collection, combined with real-time monitoring tools, enable scientists, modelers, and managers to understand the processes that drive coral reef ecosystems and provide the necessary information to properly manage and protect these unique and valuable natural resources.

Figure. 1: January 2006 installation of the new ICON monitoring station "LPPR1", near La Parguera, Puerto Rico.

The utility of the ICON stations was demonstrated in the summer 2005 when the PAM sensor at the North Norman's Reef station in Lee Stocking Island, Exuma, Bahamas provided a convincing early warning of coral bleaching conditions that was later confirmed by divers. The PAM sensor measures the fluorescence of the zooxanthellae that live in the host coral and provide most of its photosynthetic energy. A parameter known as the photosynthetic yield can be estimated from the PAM measurements of variable

Figure 2: PAM fluorometer monitoring the health of zooxanthellae in the hard coral *Agaricia sp*. This picture was taken after the colony became heavily bleached. North Norman's Reef, Lee Stocking Island,

and maximal fluorescence. When zooxanthellae become thermally stressed the yield drops significantly and, consequently, there is a decrease in the production of organic matter needed to fuel the metabolism of the coral host. If this condition persists the coral host will digest or expel the zooxanthellae and come "bleached." Fig. 2 shows the experimental set up at the Lee Stocking Island ICON station consisting of a colony of Agaricia sp. growing at a depth of 7 m and a Glademan PAM Fluorometer. Fig. 3 shows the time course of seawater temperature and photosynthetic yield. Yield dropped sharply on July 20, 2005. A series of photographs of the *Agaricia* colony taken by divers is permitting us to get a better understanding of when corals first become physiologically stressed and when they first start exhibiting physical signs of bleaching.

Research Performance Measure:
All objectives were reached.

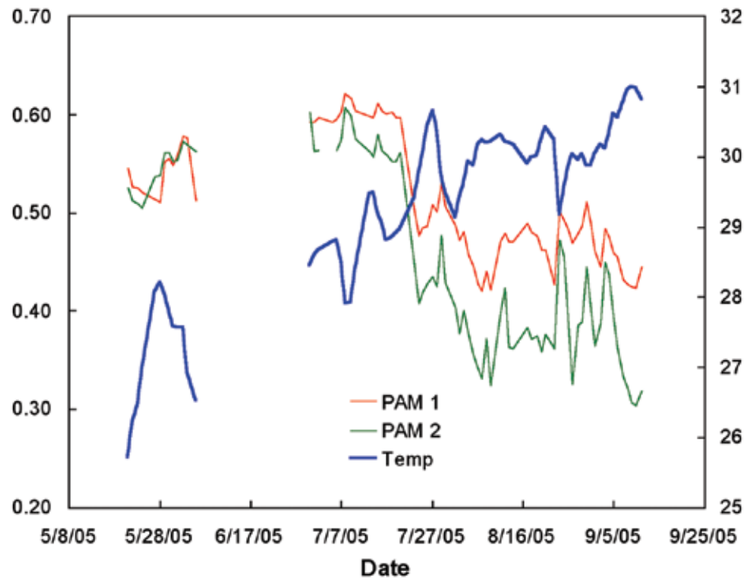


Figure 3: Time course of seawater temperature and photosynthetic yield of the zooxanthellae living in the *Agaricia sp*. colony pictured in Fig. 2. Note the sharp decline in yield on July 20, 2005 associated with temperature exceeding 29.0-29.5 C.

Upgrade and Development of SADCP/LADCP Operations and Processing for NOAA/AOML

L. Beal (UM/RSMAS)

Long Term Research Objectives and Strategy to Achieve Them:
Objectives: To bring NOAA/AOML Shipboard Acoustic Doppler Current Profiler (SADCP) and Lowered Acoustic Doppler Current Profiler (LADCP) operations and processing protocols into line with contemporary practices in order to improve the quality of both the raw measurements and the resulting data sets.
Strategy: To provide command files, software, documentation, and training in order to achieve the objectives.

CIMAS Research Theme:
Theme 6: Integrated Ocean Observations (*Primary*)
Theme 1: Climate Variability (*Secondary*)

Link to NOAA Strategic Goals:
Goal 3: Serve Society's Needs for Weather and Water Information (*Primary*)
Goal 2: Understand Climate Variability and Change to Enhance Society's Ability to Plan and Respond (*Secondary*)

NOAA Funding Unit: OAR/AOML

NOAA Technical Contact: Molly Baringer

Research Summary:
SADCP: Following the installation of a new OS75 ADCP aboard the NOAA Ship *Ronald Brown* tests were carried out on the instrument set-up in terms of optimal configurations, calibration, heading correction, and GPS position data. Completion of SADCP processing for Abaco, Florida Straits, and Subtropical Cells cruises was contingent on the provision of the appropriate raw data by the relevant PIs. Four of seven Abaco SADCP data sets have been final processed thus far.

LADCP: Documentation and training has been provided for configuration, logging, deployment, recovery, and first and second-pass processing of LADCP data. Use of a hybrid system has been recommended - that is, a down-looking 150 kHz instrument paired with an up-looking 300 kHz instrument - to maximize measurement range in the low-scatter waters of the subtropical Atlantic. Training of technicians and scientists for set-up, deployment, recovery, and first and second-pass processing has been provided. Training of two technicians for final-pass processing, as well as SADCP processing, is planned for August or September 2006.

Once again, completion of processing for the three sets of cruises was contingent on the provision of raw data by the appropriate PI's. Four of seven Abaco cruises have been final processed, with a fifth awaiting some more careful consideration owing to unexpectedly high error estimates.

Research Performance Measure:
The program is on track except that there has been some delay in training AOML technicians to carry out SADCP/LADCP operations owing to scheduling difficulties and trying to pinpoint the ideal technicians for the training.

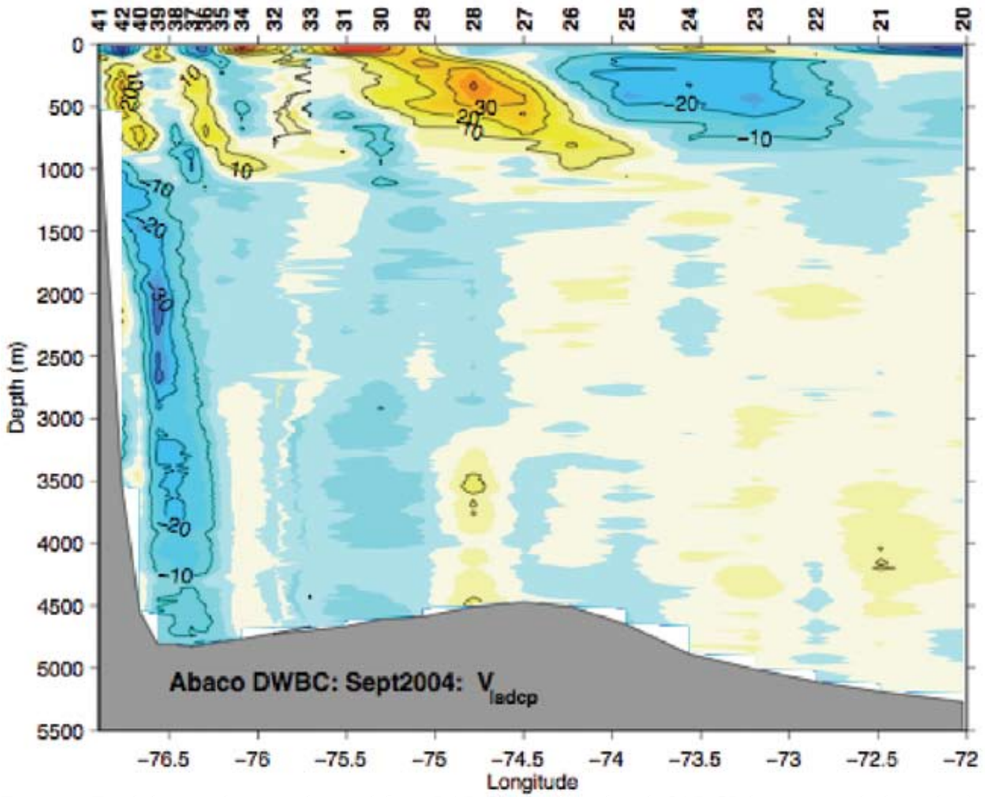


Figure 1: Final direct velocities obtained from LADCP combined with SADCP, bottom track data, ship's position data, and CTD data. Section shows the Deep Western Boundary Current off Abaco Island, Bahamas (to left of section).

The Ship Based Surface pCO_2 Program

K. Sullivan and H. Lueger (UM/CIMAS); R. Wanninkhof (NOAA/AOML)

Long Term Research Objectives and Strategy to Achieve Them:
Objectives: To constrain regional ocean CO_2 fluxes to 0.2 Pg C/yr
Strategy: To carry out sustained observations using automated pCO_2 systems on volunteer observing ships

CIMAS Research Theme:
Theme 6: Integrated Ocean Observations (*Primary*)
Theme 5: Air-Sea Interactions and Exchanges (*Secondary*)

Link to NOAA Strategic Goals:
Goal 2: Understand Climate Variability and Change to Enhance Society's Ability to Plan and Respond

NOAA Funding Unit: OAR/AOML

NOAA Technical Contact: Rik Wanninkhof

Research Summary:
The ship-based surface pCO_2 program is designed to document regional oceanic carbon sources and sinks on seasonal timescale by measuring surface water and atmospheric marine boundary pCO_2 on Volunteer Observer Ships (VOS). The program contributes to the goal of creating regional flux maps on seasonal timescales to quantify uptake of anthropogenic CO_2 in the ocean and short-term changes thereof (Fig 1). The near-term focus is on development of the Northern Hemisphere ocean carbon observing system This effort is closely linked to an assessment of the carbon dioxide sources and sinks over the coterminous United States through the North American Carbon Program (NACP). In FY-05 the NOAA funded participants maintained instrumentation and reduced data from seven ships and posted the data. Flux maps, based on extrapolation routines using remotely sensed wind and sea surface temperature (SST) have been created for the Equatorial Pacific, and Caribbean.

The major effort in the North Atlantic has been to outfit more VOS with automated sensors to measure the partial pressure of CO_2 in surface water (pCO_{2sw}). This effort has yielded a large database of surface ocean carbon data. CIMAS-postdoc Heike Lueger used this dataset to create pCO_{2sw} algorithms for three biogeochemical provinces. Different mechanisms affect the carbon cycle in the Atlantic north of 30°N. The pCO_{2sw} is changed by thermodynamics, biology, mixing, and air-sea gas exchange. The importance of the different mechanisms that control surface pCO_{2sw} varies among the three provinces. A parameter of fundamental importance for changes in the upper water column is the mixed layer depth (MLD). The MLD is a promising tool for the prediction of surface pCO_{2sw}, especially when combined with SST. MLD climatologies are available but they do not reflect the interannual changes. As an alternative, mixed-layer depth data on a regional scale can be obtained from profiling float temperature data such as those provided by the ARGO project. More than 2400 floats have been deployed to date in the global oceans, 1250 of which are currently active. These profilers automatically record temperature and salinity on 10-day intervals between the surface ocean and a depth of 2000 m. The root mean square difference between the algorithms and pCO_{2sw} data were 9-10 atm with a precision determined from independent data of 9-11 atm. This precision is close to that necessary to constrain the sea-air flux in the mid-latitude North Atlantic Ocean to 0.1 Pg C yr^{-1}. The algorithms were applied on high-resolution SST and MLD data to yield pCO_{2sw} proxy data for the entire region. The proxy data served to produce seasonal CO_2 flux maps. In 2002 the mid-latitude North Atlantic was a year-round sink which took up 5 mol m^{-2} yr^{-1}. Satellite chlorophyll was unsuccessful as a predictive parameter.

Research Performance Measure:
All objectives are being met on schedule.

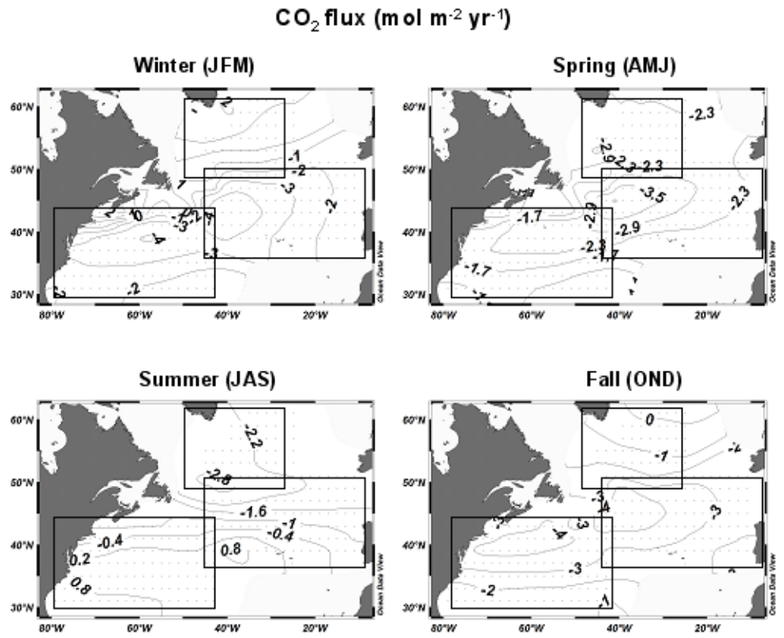


Figure 1: Seasonal flux maps for the North Atlantic for 2002 based on observations of several volunteer observing ships using remotely sensed SST and ARGO MLD.

Global Drifter Center Data Assembly Center (DAC)

J. Redman (UM/CIMAS); R. Lumpkin and M. Pazos (NOAA/AOML)

Long Term Research Objectives and Strategy to Achieve Them:

Objectives: To collect and validate data from the Global Telecommunications System (GTS) and provide for its dissemination; to provide uniform quality-controlled data from the historical data sets of sea surface temperature (SST) and surface velocity.

Strategy: To monitor on a daily basis GTS sensor failure and removes these sensors from the GTS; to places newly deployed drifters onto the GTS; to create global population maps showing drogued and undrogued drifters; to make DAC data promptly available on the web.

CIMAS Research Theme:

Theme 6: Integrated Ocean Observations

Link to NOAA Strategic Goals:

Goal 2: Understand Climate Variability and Change to Enhance Society's Ability to Plan and Respond

NOAA Funding Unit: OAR/AOML

NOAA Technical Contact: Mayra Pazos

Research Summary:

The AOML DAC is responsible for processing data from the profiling float program and the global surface drifter project. This specific program focuses on the maintenance and support of a population of 1250 active drifters (see Fig. 1). The DAC works closely with researchers to provide high-quality drifter data in a rapid and accessible manner. The DAC drifter program has four primary objectives: GTS distribution, quality control, web access, and performance evaluation. The DAC inserts and deletes drifters onto the GTS. The accuracy of data is monitored and drifters are removed once sensors fail. The DAC also notifies Argos of drifters that have lost their drogue so that this information can be noted in the GTS message.

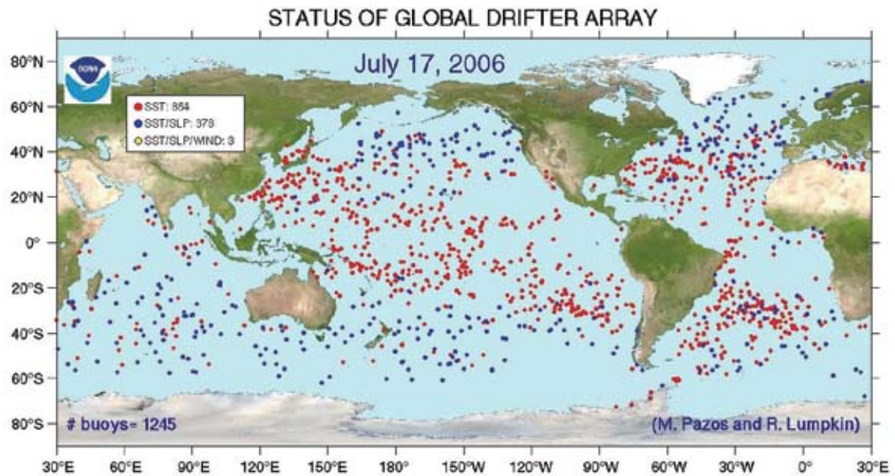


Figure 1: Status of Global Drifter Array (updated weekly).

The DAC decodes raw data that is received from Argos and applies calibrations. New drifters are identified and deployment times and positions determined. Drifters that have stopped transmitting are identified and the last good time and position is determined. Drogue-off day is also determined. The DAC than compares the drifter's SST with Reynold's climatology to determine the last good day for the SST sensor. Bad SST's and positions are removed and data is interpolated to six-hour intervals using Kriging method. The DAC inserts this interpolated data in the NOAA/AOML database for web access. Database updates are periodically sent to MEDS for archiving and distribution.

Various web products are also updated weekly. Examples include Global Distribution Maps that include drogue status and 90-day forecasts, which aid in the study of mixed layer currents. This last year, the DAC completed a major review of drogue loss dates of drifters over the past six years. We have corrected any errors, created a log of all changes, and made the correct dates and changes available to the scientific community.

Research Performance Measure:
All goals were met during this year.

US Argo Project: Global Ocean Observations for Understanding and Predicting Climate Variability

X. Xia, E. Forteza and H. Yang (UM/CIMAS);
C. Schmid, R.L. Molinari, R. Sabina and Y.-H. Chong Daneshzadeh (NOAA/AOML)

Long Term Research Objectives and Strategy to Achieve Them:
Objectives: To improve our understanding of interannual-to-multidecadal ocean variability and its role in climate.
Strategy: To monitor ocean parameters over large areas of the ocean through the deployment of 1500 profiling floats as a part of a global array of 3000 floats.

CIMAS Research Theme:
Theme 6: Integrated Ocean Observations

Link to NOAA Strategic Plan Goal:
Goal 2: Understand Climate Variability and Change to Enhance Society's Ability to Plan and Respond

NOAA Funding Unit: OAR/AOML

NOAA Technical Contact: Reyna Sabina

Research Summary:
The Argo array is part of the Global Climate Observing System/Global Ocean Observing System (GCOS/GOOS). Argo profilers provide measurements of temperature and salinity to depths of 1000-2000 meters, and currents at the drift depth of the floats. Researchers in many scientific disciplines - meteorology, climatology and oceanography - use data collected from the floats. The Argo array will eventually consist of a total of 3000 profilers.

The US Argo Data Assembly Center (US DAC) at AOML is responsible for deploying floats, and for acquiring and processing the data. The US DAC has developed and maintained an automatic system for decoding, quality control, and distribution of data obtained from the US Argo floats in real-time. The system runs in a 24/7 mode. The data are open to the public, and are used by scientists working on climate models and oceanographic data analysis. Some of the accomplishments in this year are:

- 444 floats were deployed by the USA
- 157 of these floats were deployed by AOML
- 1251 US floats are actively reporting

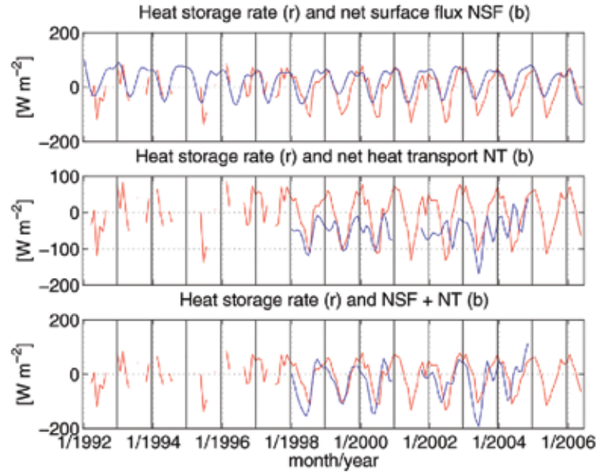


Figure. 1: Preliminary estimates of the heat budget in the Tropical South Atlantic (10˚-3˚S, 0˚-15˚W). Top panel: heat storage rate from hydrographic observations and net surface heat flux (NSF) from NCEP reanalysis 1. Middle: heat storage rate and net heat transport (NT) from a combination of drifter and satellite observations. Bottom: heat storage rate and net surface flux plus net heat transport.

- 40510 profiles sent to GTS by the US DAC
- US DAC is processing 91 Argo-equivalent floats (i.e. not funded by Argo) from different institutions and organizations (Florida State University, NAVOCEANO, University of Hawaii and National Buoy Data Center)

The US DAC is maintaining a website (http://www.aoml.noaa.gov/phod/ARGO//HomePage/ home.html) that provides documentation and information about the operations at the US Argo DAC. As part of the South Atlantic Regional Argo Data Assembly Center the final quality control steps are being developed. They involve comparing Argo profiles after scientific quality control by float providers with each other and with other independently obtained profiles (for example those collected during research cruises) to determine if additional corrections are needed. A web page has been developed that is accessible through the home page of the US Argo DAC (link given above). Quality controlled Argo profiling data are also used to calibrate thermosalinograph (TSG) data. Float data have to be measured within one week and 200km distance from the TSG measurement for this purpose.

Research Performance Measure:
This program has attained all objectives and has met all time schedules. It continues to operate as planned.

Thermosalinograph Data Quality Control System

H. Yang (UM/CIMAS); G. Goni (NOAA/AOML)

Long Term Research Objectives and Strategy to Achieve Them:
Objectives: To quality-control the thermosalinograph (TSG) observational data and study the seasonal and interannual variations so as to understand the influence of the oceans on global climate.
Strategy: To develop an automatic system to quality-control the TSG data; to provide good-quality data for scientists to use in research programs.

CIMAS Research Theme:
Theme 6: Integrated Ocean Observations (*Primary*)
Theme 1: Climate Variability (*Secondary*)

Link to NOAA Strategic Plan Goals:
Goal 2: Understand Climate Variability and Change to Enhance Society's Ability to Plan and Respond

NOAA Funding Unit: OAR/AOML

NOAA Technical Contact: Claudia Schmid

Research Summary:
Thermosalinograph (TSG) instruments are deployed on voluntary observing ships (VOS). High frequency sampling (every 10 seconds) and recording of the median values for every 5 minutes results in the precise monitoring of the sea surface temperature (SST) and sea surface salinity (SSS). At present, there are 3 VOS ships (*Skogafoss*, *Oleander* and *Cap Victor*) operated by AOML that use TSG to measure the SST and SSS. AOML has developed a quality-control system for TSG data that validates 10 parameters. SST/SSS data are archived with quality control flags for each data point along the ship track which is determined by GPS.
In addition, we compared the TSG data with several oceanographic datasets including the global Argo data from the AOML Argo Data Assembly Center (DAC), the world ocean dataset 2001 from the National Ocean Data Center, and XBT data. Each TSG data point is compared with the neighboring data points from the above-mentioned databases using data obtained within 5 days of the TSG data and within a distance of 100 km. Comparisons of the temperature and salinity data from the TSG with data from the other systems reveals that the TSG temperature was greater than the Argo and XBT temperatures. However the measured TSG salinity agreed with the float and CTD salinity. We are looking into reasons that might explain the temperature differences.

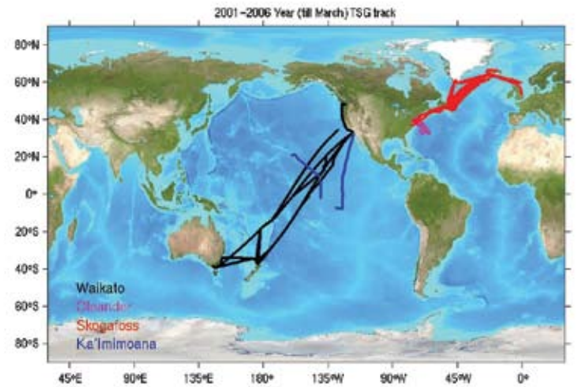


Figure 1: 2001-2006 TSG ship tracks

Research Performance Measure:
This program has attained all objectives and has met all time schedules.

Atlantic High Density XBT Lines

Q. Yao, P. DiNezio, L. Gramer, A. Stefanick, G. Rawson, N. Melo, R. Garcia,
C. Fonseca and G. Berberian (UM/CIMAS); M. Baringer, G. Goni,
S. Garzoli, C. Thacker and C. Lumpkin (NOAA/AOML)

Long Term Research Objectives and Strategy to Achieve Them:
Objectives: To study the upper ocean thermal structure and associated ocean dynamics; to estimate the poleward temperature transport in the Atlantic Ocean.
Strategy: To measure the upper ocean thermal structure in the center of the subtropical gyre in the North Atlantic and South Atlantic Ocean using high-density XBT lines; to combine these observations with those from other platforms, such as satellites, floats, drifters and moorings, to enhance the global ocean observing system.

CIMAS Research Theme:
Theme 6: Integrated Ocean Observations (*Primary*)
Theme 1: Climate Variability (*Secondary)*

Link to NOAA Strategic Goals:
Goal 2: Understand Climate Variability and Change to Enhance Society's Ability to Plan and Respond

NOAA Funding Unit: OAR/AOML

NOAA Technical Contact: Silvia Garzoli

Research Summary:
This program is designed to measure the upper ocean thermal structure in key regions of the Atlantic Ocean (Figure 1). The seasonal-to-interannual variability in upper ocean heat content and transport is monitored to understand how the ocean responds to changes in atmospheric and oceanic conditions and how the ocean response may feedback to the important climate fluctuations such as the NAO. This increased understanding is crucial to improving climate prediction models. Within this context, five XBT lines have been chosen to monitor properties in the upper layers of the Atlantic Ocean. The global atmospheric and oceanic data from volunteer observing ship (VOS) have been the foundation for understanding long-term changes in marine climate. This program is a component of the NOAA's Program Plan for building a sustained Ocean Observing System for Climate.

High-density XBT lines provide real time high resolution temperature profiles spaced approximately 30-50 km apart along five important lines in the Atlantic Ocean. These XBT transects are critical to investigate the upper ocean circulation since they offer the only means to measure subsurface temperature fields in spatial and temporal scales designed to map the mean and fluctuating components of the ocean thermal structure. Data obtained from these lines - called AX25, AX18, AX08, AX10 and AX07 - are used to investigate the inter-basin mass exchange between the Indian and Atlantic Ocean (AX25), the meridional heat transport at 30°S (AX18) and 30°N (AX07), the variability of the Gulf Stream (AX10) and the zonal current system in the tropical Atlantic (AX08). Moreover, in the South Atlantic, line AX18 provides information on major boundary currents, such as the Brazil, Malvinas, Benguela and Agulhas, and their associated eddies. These are all important components of the Meridional Overturning Circulation in the Atlantic Ocean, which is driven by temperature, salinity and wind variations.

This project includes extensive operations that collect the data: up to eighteen cruises are conducted each year, including in excess of 225 days at sea and more than 2500 XBTs deployed. Data obtained from these transects are provided to the scientific community to investigate the thermal structure of the subtropical gyres, the equatorial system and the Antarctic Circumpolar Current - also to study and understand the role that the ocean plays in climate fluctuations, and to improve the ability to predict important climatic signals such as the North Atlantic Oscillation (see http://www.aoml.noaa.gov/phod/hdenxbt/ for additional

details). Additionally, satellite altimetry data are being used to complement the observations provided by the XBT transects.

Research Performance Measure:
All research goals were met during this year.

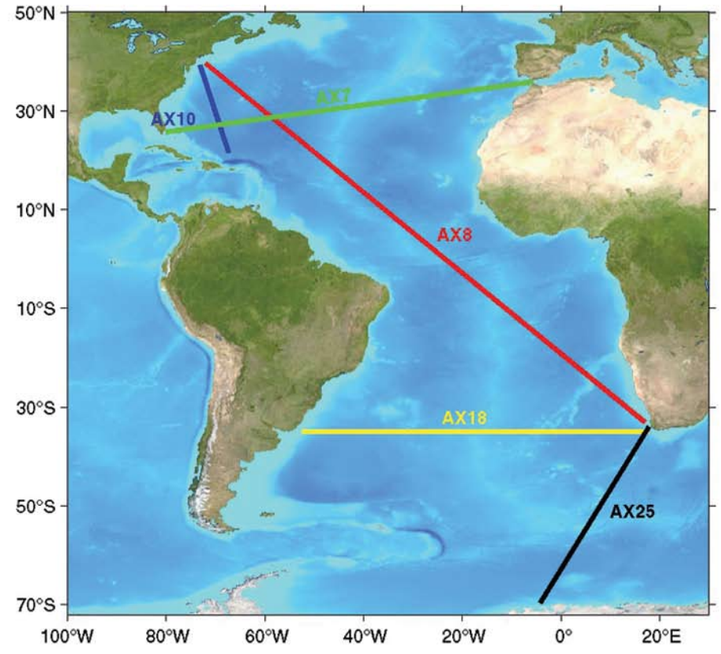


Figure 1: Map of station locations for the five high density lines maintained by OAA/AOML.

OUTREACH

The Rosenstiel School and CIMAS are active in education and outreach at the undergraduate and high school level. We are also involved with outreach to the general public. Many of these activities take place in cooperation with the local NOAA laboratories. Here we present a brief overview of outreach activities at the School in which CIMAS in involved. We only list those activities that describe on-going activities that follow a specific theme. There are many other outreach activities that are one-time events such as presenting talks to students, to groups of special-interest adults (e.g., fisherman), conducting tours, preparing articles for various media, etc. We do not list those here. Also many CIMAS personnel are active in setting up and maintaining web sites at AOML and SEFSC that perform an outreach function. We do not list these here.

Explorer of the Seas Programs

The Rosenstiel School and Royal Caribbean Cruise Lines (RCCL) with support from NOAA and NSF, and with the close cooperation of NOAA and CIMAS scientists are engaged in a unique collaboration to study the ocean and atmosphere during routine cruises of the RCCL ship Explorer of the Seas. http://www.rsmas.miami.edu/rccl/. Explorer is a new state-of-the-art cruise ship (142,000 tons, 1020 feet LOA, 157.5 ft beam; 3114 passengers; cruising speed, 23.7 kts) which started operations out of Miami in October 2000. Each week the Explorer cruises across the Gulf Stream to ports in the Caribbean and the Bahamas. RCCL provides free-of-charge two science laboratories (installed at RCCL's expense) to RSMAS and AOML, an atmospheric sciences laboratory and an oceanographic laboratory. Laboratory instrumentation was obtained with funds provided by RCCL, NOAA, and NSF. RCCL also provides at no charge two passenger cabins for RSMAS, AOML and visiting scientists and technicians. All data are made available to the general scientific community and to the public.

CIMAS and NOAA Research on the Explorer

The ship carries a wide range of instrumentation that allows continuous unattended measurements of a wide range of ocean and atmospheric properties. Data is returned via various communication links to data centers at RSMAS, National Weather Service, NOAA's National Data Buoy Center at Stennis Space Center, and the GLOBE (Global Learning and Observations to Benefit the Environment) program. A number of research programs supported through CIMAS make use of the Explorer as described in this annual report. The program is designed to facilitate the participation of scientists outside the UM and NOAA communities as described on the Explorer web site.
http://www.rsmas.miami.edu/rccl/participate.html

Outreach Aboard the Explorer

The research facilities were designed to facilitate observation and educational activities by the vacationing passengers. The passengers can observe data being collected in real time. Also all scientists who participate on the one-week cruises must provide one or more lectures to the passengers. Educational materials are provided to passengers as well. Scientists from the local NOAA laboratories and from RSMAS-CIMAS routinely participate on these cruises and lead the outreach activities.

Miami-Dade County Scientist-Teacher Mentor Program.

During the past year, RSMAS initiated a new program in conjunction with the Miami-Dade Public School System and Royal Caribbean.: The Scientist-Teacher Mentor Program.
http://www.rsmas.miami.edu/rccl/miamidade_teacher.html. Teachers apply for 6 annual spots in the program by writing a proposal that describes research that they would like to perform on the Explorer. The program consists of familiarization workshops onboard the Explorer of the Seas and at RSMAS. Teachers then participate in a seven day cruise on the Explorer during which they perform the research activities outlined in their proposal. Teachers must submit a post-cruise summary of their activities in the program, a curriculum module with separate classroom lessons developed from your research onboard. Ongoing

real-time data can be provided for use in the classrooms year-round. In addition, teachers are expected to present their experiences and resulting lessons at a local, regional or national educator conference or meeting within 12 months after their cruise.

The MAST Academy and High School Student Outreach

Starting in 1984 the Rosenstiel School and CIMAS have participated in a high school apprenticeship program made possible through NOAA funding. Students participate in summer internships at AOML and SEFSC. This activity is carried out through a Miami-Dade County "magnet" school, the MAST Academy (Maritime and Science Technology High School) which is located on Virginia Key, only a few hundred meters from CIMAS and the NOAA laboratories. http://mast.dade.k12.fl.us/

The MAST Academy curriculum is organized around a marine theme. The school has been recognized by the U. S. Department of Education with a Blue Ribbon School of Excellence and by Business Week magazine as one of seven most innovative schools of choice in the nation. The total enrollment is 550 in grades 9-12. The school has a broad cultural-ethnic mix of students: 36% Caucasian; 32% African American; 29% Hispanic; 3% Asian. Approximately 94% of the students eventually enroll in college. MAST students excel according to traditional measures of student performance, exceeding national averages on the PSAT, SAT, and ACT. For the past three years, the school has received an "A" rating from the Florida Department of Education.

RSMAS participates in education-related activities at MAST by providing faculty and graduate students, including CIMAS-linked personnel, to deliver lectures and to teach courses. Every summer, 12-18 students are selected to participate in summer research programs supported through CIMAS. The students assist in programs at AOML and SEFSC as well as at RSMAS. In addition to the summer program, CIMAS hires MAST students during the course of the year. As a result of these activities MAST students have co-authored papers with RSMAS and NOAA scientists; students have attended national conferences and presented the findings of their research. They have participated in field programs, for example in a comprehensive study of Biscayne Bay. In this way, we have developed a solid working and teaching relationship with the MAST Academy

In addition to MAST students, we have students from other high schools participating in CIMAS - NOAA activities. Here we cite a few examples:

- Assisted in SEFSC fish tagging program. Prepared tagging kits for distribution to fishery constituents, coding incoming tagging data, data entry of both tag release and tag recapture, and interacting with constituents about tag requests and tag recovery reports.
- Assisted in sorting and identifying postlarval pink shrimp from the Florida Bay program and working with bird by-catch data.
- Assisted in downloading sea-surface temperature (SST) data from the NOAA Coast Watch web site and using it in analyses of fisheries and environmental data.
- Assisted in a study modeling connections between life stages and habitats of pink shrimp in South Florida.
- Assisted in using bioinformatics software in a study to identify, detect, and quantify microbial contaminants in coastal waters. A second student worked on the development of a microbial contaminant database using FileMaker Pro Software.

Undergraduate Student Education

CIMAS hires undergraduate students from the University of Miami and other local universities who work part time on projects at AOML and SEFSC. This program has been effective in exposing bright students to the scientific working environment. Some of these students have subsequently gone on to graduate school at RSMAS and other institutions and some have been eventually hired as full time employees. Some examples:

- During the past year, students actively participated in the SEFSC-CIMAS program: Monitoring Coral Reef Fish Utilization of MPAs and Recruitment Connectivity between the Florida Keys

and Meso-American Reefs. The program drew students from UM, from Florida International University (FIU) and from Miami-Dade College. Students have used this work for there senior these research topic. Past students have gone on to graduate school in the sciences.

- Several UM undergraduate students participate in the bi-monthly cruises that take place as a part of the program: Long-Term Measurement of Physical, Chemical, and Biological Water Column Properties in the South Florida Coastal Ecosystem.

Global Ocean Surface Current Web Outreach

CIMAS provides partial support for a web site that presents information of ocean surface currents. The site, still under development, is designed to provide students with general information about oceanography but with a specific focus on ocean currents. The current information is derived from a data-assimilative hybrid isopycnal-sigma-pressure (generalized) coordinate ocean model (called HYbrid Coordinate Ocean Model or HYCOM). HYCOM is a multi-institutional effort funded by the National Ocean Partnership Program (NOPP), as part of the U. S. Global Ocean Data Assimilation Experiment (GODAE). A web-based reference site on ocean currents intended for students is accessible at http://oceancurrents.rsmas.miami.edu). The site contains introductory material for the non-specialist, a glossary, descriptions of named currents, etc.

A critical problem in ocean modeling and data assimilation is making both the observational data and model output available to (a) the members of our consortium for HYCOM and data assimilation code development, (b) the wider oceanographic and scientific communities, including climate and ocean ecosystem researchers; and (c) the general public. We are making a special effort to create modules that appeal to students in elementary and high school. The real-time global and basin model outputs are being made available to the community at large within 24 hours via the U.S GODAE and Miami Live Access Servers (LAS). The web activity is under the direction of Dr. Arthur Mariano (RSMAS, Div. Meteorology and Physical Oceanography).

University of Miami, a Minority Serving Institution

The National Oceanic and Atmospheric Administration (NOAA) has established research and education centers to advance the community of under-represented minority scientists in the US and, especially, in the NOAA workforce. The UM participates in this program carried out under the lead of Florida A & M University (FAMU) through the Environmental Cooperative Science Center (ECSC). The Center is funded through a cooperative agreement between NOAA and FAMU. Other partners are Morgan State University, Delaware State University, South Carolina State University and Jackson State University. Located on the campus of FAMU, the science center was established to study and address ecological and coastal management issues. So far, the science center has supported more than 130 students in the environmental and marine sciences.

The goals of the science center are to increase the number of underrepresented minority scientists in NOAA-related sciences, develop ways to monitor coastal ecosystems and assess impacts of human and natural actions, improve the scientific knowledge base used in coastal resource management, and facilitate community education and outreach relating to coastal ecosystems. The Center was started in 1995 and was recently renewed with NOAA in late 2004.

The central research themes of ECSC focus on the human environment interactions involving the coastal environment and the development of conceptual models of those interactions.

- to develop the next generation of MS and PhD-level scientists in the environmental sciences from under-represented minorities, especially African-Americans, Hispanic-Americans, and American Indians;
- to develop research activities on coastal environmental issues, focused on a set of NOAA National Estuarine Research Reserve (NERR) sites, plus the Florida Keys National Marine Sanctuary (FKNMS); and
- to conduct institutional capacity-building in partnership with Historically Black Colleges and University (HBCU) institutions (e.g., graduate degree programs).

The Rosenstiel School's roles are:

- to provide fellowships for minority students for MS and PhD studies at RSMAS in environmental science and policy fields;
- to provide ship and other field experiences for undergraduate students;
- to assist in developing distance-learning classes in environmental sciences;
- to assist in the capacity building at partner institutions; and,
- to serve as the linkage to Florida Keys Sanctuary.

Many of the RSMAS activities associated with this program are carried in the context of CIMAS-related programs.

Monitoring Coral Reef Fish Populations in the Florida Keys:

Reef fish populations are monitored as a part of this CIMAS program, led by J. Ault, a RSMAS faculty member. The research carried out in this program is an excellent example of coordination, cooperation, and participation by different government agencies, universities, and private organizations to achieve a common goal. The research was documented in a number of media pieces including National Geographic, Los Angeles Times, BBC (British Broadcasting Company), NBC, Discovery Channel, Animal Planet, Chicago Tribune, Miami Herald, Associated Press, Christian Science Monitor, etc. In addition, Ault provided expert testimony before the Florida Governor and Cabinet at the Capital Building in Tallahassee, Florida, on approval of the Dry Tortugas National Park Research Natural Area.

CIMAS FELLOWS

The Fellows provide guidance to the Director on matters concerning the ongoing activities and future direction of CIMAS. There are currently 21 Fellows, 13 from RSMAS and 8 from the local NOAA laboratories. Normally membership is approximately balanced between RSMAS and NOAA. Because of several personnel changes during the past year, NOAA is currently underrepresented. In addition to the regular members, The Dean of RSMAS and the Directors of the NOAA laboratories are invited to attend on an *ex officio* basis.

The Fellows are typically scheduled to meet on a nominal quarterly basis although scheduling is usually difficult because of the extensive travel schedules. During Year 5 there were three formal meetings: 13 July 2005, 18 October 2005, 16 March 2006. In addition there are frequent meetings of focus groups. Also many matters are implemented by means of email exchanges. Finally, because of the close proximity of the three Institutions and the frequent social activities, there are many ad hoc meetings and discussions.

FELLOWS	AFFILIATION
Dr. Bruce Albrecht	UM/RSMAS Meteorology and Physical Oceanography
Dr. James Bohnsack	NOAA/Southeast Fisheries Science Center
Dr. David J. Die	UM/RSMAS Marine Biology and Fisheries
Dr. Mark Donelan	UM/RSMAS Applied Marine Physics
Dr. Nelson Ehrhardt	UM/RSMAS Marine Biology and Fisheries
Dr. David Enfield	NOAA/AOML/Physical Oceanography
Dr. Rana A. Fine	UM/RSMAS Marine and Atmospheric Chemistry
Dr. Silvia Garzoli	NOAA/AOML/ Physical Oceanography
Dr. Kevin D. Leaman	UM/RSMAS Meteorology and Physical Oceanography
Dr. David Letson	UM/RSMAS Marine Affairs
Dr. Frank Marks	NOAA/AOML/Hurricane Research Division
Dr. Christopher N.K. Mooers	UM/RSMAS Applied Marine Physics
Dr. Donald B. Olson	UM/RSMAS Meteorology and Physical Oceanography
Dr. Peter B. Ortner	NOAA/AOML
Dr. Joseph E. Powers	NOAA/Southeast Fisheries Science Center
Dr. William J. Richards	NOAA/Southeast Fisheries Science Center
Dr. Claes G.H. Rooth	UM/RSMAS Meteorology and Physical Oceanography
Dr. Nick Shay	UM/RSMAS Meteorology and Physical Oceanography
Dr. Sharon S. Smith	UM/RSMAS Marine Biology and Fisheries
Dr. Rik Wanninkhof	NOAA/AOML/Ocean Chemistry Division
Dr. Rod Zika	UM/RSMAS Marine and Atmospheric Chemistry
Ex Officio	
Dr. Robert M. Atlas	NOAA/AOML
Dr. Otis B. Brown	UM/RSMAS Dean
Dr. Nancy Thompson	NOAA/Southeast Fisheries Science Center

CIMAS AWARDS AND HONORS

Ault, J.S. (UM/RSMAS)
- Certificate of Recognition, for valuable contributions as Technical Review Committee Member to development of South Dade Watershed Plan, by Mayor Carlos Alvarez, February 2006.

Ault, J.S., S.G. Smith, and J. Luo (UM/RSMAS)
- Winner, National Planning Award. Category: '*Outstanding Collaborative Planning Project or Program: Tortugas National Park General Management Plan*'. Federal Planning Division. American Planning Association. University of Illinois at Chicago. Recipients: National Park Service, Southeast Region; National Park Service, Denver Service Center; Dry Tortugas National Park; University of Miami, Rosenstiel School of Marine and Atmospheric Science; Florida Keys National Marine Sanctuary.

Ault, J.S., and S.G. Smith (UM/RSMAS)
- Winner, National Planning Award. Category: '*Outstanding Collaborative Planning Project or Program: Tortugas National Park General Management Plan*'. Federal Planning Division. American Planning Association. University of Illinois at Chicago. Recipients: National Park Service, Southeast Region; National Park Service, Denver Service Center; Dry Tortugas National Park; University of Miami, Rosenstiel School of Marine and Atmospheric Science; Florida Keys National Marine Sanctuary.

Carrasco, N., B. Annane, R. St. Fleur, S. Otero, and M. Powell (UM//CIMAS)
- Letter of appreciation from the US Army Corps of Engineers Waterways Experiment Station in Vicksburg, MS, for the post-Katrina wind reanalysis effort producing 1-km resolution wind fields.

Lee, T.N. (UM/RSMAS)
- Appointed to serve on The Florida Oceans and Coastal Resources Council which was created by the 2005 Florida Legislature through House Bill 1855 for the purpose of developing priorities for ocean and coastal research and establishing a statewide ocean research plan.

Millero, F.J. (UM/RSMAS)
- Sigma Xi, President-Elect, 2004-2006

Prospero, J.M. (UM/CIMAS)
- Ursinus College, Distinguished Alumni Award (2006), For Exemplary Service in the Field of National and International Atmospheric Sciences.
- Chair of the NOAA Cooperative Institute Executive Committee.

POSTDOCTORAL FELLOWS AND GRADUATE STUDENTS

A total of 6 Postdoctoral Fellows and 11 Graduate Students were supported with NOAA funds through CIMAS in Year 5 of the Cooperative Agreement. These are listed below as "CIMAS Supported".

In addition, there are many Postdocs and Graduate Students associated with CIMAS program who are not supported through CIMAS. Many are Research Associates/Scientists who are pursuing graduate work at the University of Miami under the tuition-remission benefit or who are attending other local universities while carrying out their normal employment duties. Many of these are using research carried out in their work as a part of their thesis or dissertation. In addition, there are Postdocs and Graduate Students who are supported on funds from other sources but who are involved with CIMAS-related programs. The Postdocs and Graduate Students in this second category are listed below.

In total, there are 43 Graduate Students and 12 Postdocs working on CIMAS related programs.

CIMAS-Supported Postdoctoral Fellows and Graduate Students

CIMAS Postdoctoral Fellows

Apostalaki, Panagiota
Kang, HeeSook
Kerstetter, David
Lueger, Heike
Valle-Equivel, Monica
Walter, John

CIMAS Graduate Students

Chormaski, Scott
Freibaum, Joy
Gleason, Art
Grace, Cynthia
Kempenski, Sherri
Kofron, David
Lopez, Cassandra
McClendon, Kristin
McMillan, Mary
Mounding, Alison
Saul, Eugene

Other Postdoctoral Fellows and Graduate Students Associated with CIMAS Programs

Other Postdoctoral Fellows

Balotro, Rolando
Bellows, John
Breuer, Norman

Cabrera, Victor
Hodyss, Daniel
Hoolihan, John
Huang, Jingfeng
Mueller, Valerie
Pierrot, Denis
Shoosmith, Deborah
Taddei, Renzo
Zavala-Garay, Javier

Other Graduate Students

Bolson, Jessica
Carrasco, Nichols
Cazarez, Dalia
Chanson, Mareva
Cohou Colli, Jose Angel
Cooper, Wade
Davis, Natasha
Farmer, Nick
Feeley, Mike
Forsee, William
Gerard, Trika
Ghate, Virendra
Gintert, Brooke
Hiscock, William
Johnson, Lyza
Kelble, Christopher
Koch, Veronique
Larkin, Mike
Litz, Jenny
Llopiz, Joel
Mason, Benjamin
McCrea, Ashley
Molina, Helena
Morisseau-Leroy, Nirva
Ortt, Derek
Quintal Lizama, Carolina
Ranasingha, Maththondage Chamara
Ravitz, Guy
Rice, Patrick
Richardson, David
Schiller, Rafael
Smith, Ryan
Swanson, Dione
Sellwood, Kathryn
Serpetzoglou, Efthimios
Trapp, J. Michael
Uhlhorn, Eric
Vasquez-Yeomans, Lourdes
Wanless, David
Whitcraft, Samantha
Yniguez, Aletta
Zhang, Jun
Zheng, Shirley

CIMAS RESEARCH STAFF

Absten, Michael	Research Associate II
Annane, Bachir	Senior Research Associate III
Carrasco, Hector N.	Research Associate II
DiNezio, Pedro	Research Associate I
Dunion, Jason	Senior Research Associate III
Florit, Louis	Senior Research Associate I
Fonseca, Carlos	Research Associate II
Forteza, Elizabeth	Research Associate II
Frias-Torres, Sarah	Assistant Scientist
Garcia, Claudia	Research Associate I
Garcia, Rigoberto	Research Associate II
Gramer, Lewis	Research Associate I
Hall, Jeremy	Research Associate I
Hazra-Smith, Destiny	Research Associate II
Huang, Xialoan	Senior Research Associate II
Jankulak, Michael	Research Associate II
Kates, Benjamin	Research Associate Ii
Kelble, Christopher	Senior Research Associate I
Kramer, Katherine	Research Associate II
La Gier, Michael	Assistant Scientist
Lara, Monica	Associate Scientist
Lee, Sang-Ki	Assistant Scientist
Litz, Jenny	Research Associate III
Mason, Benjamin	Research Associate I
Melo, Nelson	Research Associate III
Mestas-Nunez, Alberto	Associate Scientist
Morisseau-Leroy, Nirva	Assistant Scientist
Otero, Sonia	Research Associate III
Rawson, Grant	Research Associate III
Redman, Jessica	Research Associate II
Andrew Stefanick	Research Associate I
Stokes, Lesley	Senior Research Associate I
Sullivan, Kevin	Senior Research Associate II
Uhlhorn, Eric	Senior Research Associate III
Valde, Krystal	Research Associate I
Whitcraft, Samantha	Research Associate II
Wicker, Jesse	Research Associate II
Williams, Dana	Assistant Scientist
Xia, Xiangdong	Research Associate III
Yang, Huiqin	Research Associate II
Yao, Qi	Research Associate III

VISITING SCIENTISTS

Dr. Ron Miller
NASA, Goddard Institute for Space Studies
Department of Physics
Columbia University
New York, NY
7 December, 2005
"How Much Dust is in the Wind and How Does it Affect Climate?"

Prof. Stanley D. Gedzelman
Department of Earth and Atmospheric Sciences
The City College of New York
138th Street & Convent Avenue
New York, NY 10031
26 January, 2006
"The Sky in Art"

Prof. Yuli D. Chashechkin
Laboratory of Fluid Mechanics
Institute for Problems in Mechanics
Russian Academy of Sciences
101/1 Prospect Vernadskogo, Moscow 117526
28 February - 14 March, 2006
"About Resolvability of Governing Equations: Generation of 2D and 3D Periodic Internal Waves (Linear and Slightly Non-Linear Theory and Lab Experiments)

"2D Wave and Vortex Wakes Past Uniformly Moving Plates and Cylinders: Formation of Streaky Structures, Soaring Interfaces with Vortex Pairs and Vortex Systems"

"3D Diffusion Induced Boundary Currents; Double Diffusive Convection"

"On the Problem of Measurements of Oceanic Parameters and Optimization of Measurement Protocol"

Dr. Fritz Schott
IfM-GEOMAR
Leibniz-Institut für Meereswissenschaften
Kiel, Germany
28 March - 13 April, 2006
"Tropical Atlantic Variability: Observations vs. Models and Assimilations"

Dr. William K.M. Lau
Laboratory for Atmospheres
NASA, Goddard Space Flight Center
Greenbelt, MD
14 - 18 June, 2006
"Aerosol-Water Cycle Interaction: A New Challenge for Monsoon Climate Research"

PUBLICATIONS

We list all publications for the years 2005-2006, presented in categories. The category "Conference Proceedings" lists only publications that derive from presentations at meetings, it does not include oral presentations.

In Table 1 we summarize the record of publications over the period 2001 – 2006, listed as "peer reviewed" and "non-peer reviewed". The table also shows the distribution of lead author affiliation (CIMAS, NOAA scientist, or other institutions).

Table 1: Publication Record 2001-2006

	Institute Lead Author				NOAA Lead Author				Other Lead Author			
	2001-02	2002-03	2003-04	2004-05	2001-02	2002-03	2003-04	2004-05	2001-02	2002-03	2003-04	2004-05
Peer Reviewed	54	60	36	33	0	7	14	14	--	--	30	28
Non Peer Reviewed	7	8	34	10	0	3	17	11	--	--	28	6

	Institute Lead Author				NOAA Lead Author				Other Lead Author			
	2005-06	2006-07	2007-08	2008-09	2005-06	2006-07	2007-08	2008-09	2005-06	2006-07	2007-048	2008-09
Peer Reviewed	37				17				37			
Non Peer Reviewed	9				7				15			

Refereed Journal Articles

Ault, J.S., S.G. Smith and J.A. Bohnsack (2005), Evaluation of average length as an estimator of exploitation status for the Florida coral reef fish community, *ICES J. Mar. Sci.* 62, 417-423.

Ault, J.S., J.A. Bohnsack, S.G. Smith, and J. Luo (2005), Towards sustainable multispecies fisheries in the Florida USA coral reef ecosystem, *Bull. Mar. Sci., 76*(2), 595-622.

Ault, J.S., S.G. Smith, J.A. Bohnsack, J. Luo, D.E. Harper, and D.B. McClellan (2006), Building sustainable fisheries in Florida's coral reef ecosystem: positive signs in the Dry Tortugas, *Bull. Mar. Sci., 78*(3), 633-654.

Bandstra, L., B. Hales, and T. Takahashi (2006), High-frequency measurements of total CO_2: Method development and first oceanographic observations, *Mar. Chem,. 100* (1-2), 24-38.

Bartholomew, A., J.A. Bohnsack, S.G. Smith, J.S. Ault, D.E. Harper, and D.B. McClellan. (2006), Influence of marine reserve size and boundary length on the initial response of exploited reef fishes in

the Florida Keys National Marine Sanctuary, USA, *Landscape Ecology*, in press.

Black, P.G., E. D'Asaro, W.M. Drennan et al. (2006), Air-sea exchange in hurricane winds: Synthesis of observations from the Coupled Boundary Layer Air-Sea Transfer Experiment, *Bull. Am. Meteorol. Soc.*, in press.

Brix, H., N. Gruber, D.M. Karl, and N.R. Bates (2006), On the relationships between primary, net community, and export production in subtropical gyres, *Deep Sea Res. Part II, 53* (5-7), 698-717.

Brooks, N, I. Chiapello, S. Di Lernia, N. Drake, M. Legrand, C. Moulin and J. Prospero (2005), The ClimateEnvironmentSociety Nexus in the Sahara from Prehistoric Times to the Present Day, *J. North African Studies, 10* (3-4), 253-292, doi:10.1080=136293 8050033668.

Brown, S.S., J. A. Neuman, T. B. Ryerson, M. Trainer, W. P. Dubé, J. S. Holloway, C. Warneke, J. A. de Gouw, S. G. Donnelly, E. Atlas, B. Matthew, A. M. Middlebrook, R. Peltier, R. J. Weber, A. Stohl, J. F. Meagher, F. C. Fehsenfeld and A. R. Ravishankara (2006), Nocturnal odd-oxygen budget and its implications for ozone loss in the lower troposphere, *Geophys. Res. Lett., 33*, L08801, doi:10.1029/2006GL025900.

Cabrera, V.E., P.E. Hildebrand, J.W. Jones, D. Letson, and A. de Vries, (2006), An integrated simulation model to reduce environmental impacts under seasonal variability, *Agriculture, Ecosystems, and Environment, 113*, 82-97.

Cabrera, V.E., C. Fraisse, D. Letson, G. Podesta, and J. Novak (2006), Impact of climate information in reducing farm risk by selecting crop insurance programs, *Trans. Am. Soc. Agricul. Biologi Eng.*, *49* (4), 1-11.

Cabrera, V.E., N.E. Breuer, P.E. Hildebrand, and D. Letson (2005), The dynamic North Florida dairy farm model: a user friendly computerized tool for increasing profits while minimizing environmental impacts under varying climatic conditions, *Com. Electron. Agri., 49*, 286-308.

Cabrera, V.E., P.E. Hildebrand, and J.W. Jones (2005), Modelling the effect of household composition on the welfare of limited-resource farmers in Coastal Cañete, Peru, *Agri. Sys., 86*, 207-222.

Chanson, M. and F. J. Millero (2006), The solubility of boric acid in electrolyte solutions, *J. Sol. Chem., 35*(5), doi:10.1007/s10953-006-9021.5.

Chen, G., L.G. Huey, M. Trainer, D. Nicks, J. Corbett, T. Ryerson, D. Parrish, J.A. Neuman, J. Nowak, D. Tanner, J. Holloway, C. Brock, J. Crawford, J.R. Olson, A. Sullivan, R. Weber, S. Schauffler, S. Donnelly, E. Atlas, J. Roberts, F. Flocke, G. Hübler and F. Fehsenfeld (2005), An Investigation of the Chemistry of Ship Emission Plumes during ITCT 2002, *J. Geophys. Res., 110*, D10S90, doi:10.1029/2004 JD005236, 2005.

Chiapello, I., C. Moulin, and J.M. Prospero, (2005), Understanding the long-term variability of African dust transport across the Atlantic as recorded in both Barbados surface concentrations and largescale Total Ozone Mapping Spectrometer (TOMS) optical thickness, *J. Geophys. Res., 110*, D18S10, doi:10.1029/2004JD005132.

Criales, M.M., J. Wang, J.A. Browder, M. Robblee, T. Jackson, and C. Hittle (2006), Variability in supply

and cross-shelf transport of pink shrimp (*Farfantepenaeus duorarum*) postlarvae into western Florida Bay, *Fish. Bull., 104*, 60-74.

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