Cooperative Institute for Marine and Atmospheric Studies

Ninth Year Annual Report

NOAA Cooperative Agreement NA17RJ1226
Continuation Award NA08OAR4320892
Shadow Award NA08OAR4320889

2009 – 2010

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ROSENSTIEL SCHOOL OF MARINE AND ATMOSPHERIC SCIENCE

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I. EXECUTIVE SUMMARY

The Cooperative Institute for 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). Reflecting the diversity of research conducted at these laboratories, CIMAS carries out research under six inter-related Themes all of which are linked to NOAA's Strategic Goals.:

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

CIMAS activities during Fiscal Year 2009 - 2010, Year 9 under the Cooperative Agreement (CA), continued at a high level. Total expenditures in Year 9 were $13.60M, considerably higher than the previous year, $10.49M. The average expenditure of the past two years (Years 8 and 9) is more than double that of the first two years (Years 1 and 2). Task II, which supports CIMAS employees whose primary work site is off campus (typically at either AOML or SEFSC), continues at the high levels of recent years; Task II expenditures in Year 9 totaled ca. $6.4M, almost quadruple that in Year 1.

Additional research funding (Tasks III and IV) in Year 9 totaled ca. $6.1M. This is an increase in funding from Year 8 of ca. 50%. In contrast to Task II funding, this funding has exhibited no long term systematic trend over the past five years of the CA but was low in Year 8 and high in Year 9. Nonetheless the total has remained substantially greater than that in the first two years which averaged only $2.5M. The largest portion of research in Tasks III and IV are Themes 4 – Human Interactions, 2- Fisheries Dynamics and 1- Climate Variability, which together account 67% of the total. The smallest portion (only slightly) was in Theme 3, Regional Coastal Ecosystem Processes, 10%. These percentages are deceptive in that there is some ambiguity because the assignments reflect only the “primary” not secondary “theme” designations and in some cases which is primary is not entirely clear.

During Year 9 a total of 125 persons were associated with CIMAS in various capacities. Of these, 95 received over 50% of their support from NOAA through CIMAS. Of the 95 research employees who received over 50% NOAA support, 66 worked with AOML and 29 with SEFSC.

The employees in the Research Associate and Research Scientist ranks have a diverse demographic profile. The population is 38% female. Foreign-born individuals make up 52% of the personnel. Of these, Hispanics make up 23% of the ranks; Asian and Pacific Islander, 16%. The population of CIMAS is relatively young with an average age of 39.

The research program in CIMAS continues to be productive. In 2009-2010 CIMAS employees were lead authors or co-authors on 106 peer-reviewed publications and lead authors or co-authors on another 31 non-peer reviewed technical reports and other publications. The results from some of the individual projects are highlighted in below. They were selected from each of the themes to be representative of the wide diversity of activities carried out within CIMAS. A more detailed

description of these results can be found in the body of the Report under the more complete individual project summaries within each of the six Themes.

SOME RESEARCH HIGHLIGHTS

Climate

Assessing the Sensitivity of Northward Heat Transport/Atlantic Meridional Overturning Circulation to Forcing in Existing Numerical Model Simulations. Analyses suggest that while northward heat transport is significantly correlated with the strength of the AOMC both geostrophic and Ekman transports are important in explaining the AMOC variability. Since they are out of phase this results in weak seasonal variability of the AMOC.

Simulation Experiments for the Pacific Upwelling and Mixing Physics (PUMP) Study. Both Simulation experiments and observations confirm a significant influence of tropical instability waves on mean meridional and vertical currents in the central equatorial Pacific Ocean. This implies that to resolve the essential circulation features an observing system must sample at 0.5 degrees or less separation.

Re-Writing the Climatology of the Tropical North Atlantic and Caribbean Sea Atmosphere. New atmospheric sounding information presented in this study represents a new standard for the tropical North Atlantic and Caribbean Sea region and has important implications with respect to tropical cyclone forecasting and modeling.

Fisheries Dynamics

Development of Biological and Physical Indices for Stock Evaluation in the Dry Tortugas Pink Shrimp Fishery: FATE Project. A coupled biophysical Individual-Based Model (IBM) has been developed to simulate the life history and migratory movements of pink shrimp (*Farfantepenaeus duorarum*) in south Florida. The model will help determine the main environmental factors that affect their journey and successful recruitment into Florida Bay.

Variations in Carbon and Oxygen Stable Isotopes Snapper (Lutjanidae) in Florida Bay and Florida Keys. Preliminary data analysis shows an overlap in isotope measurements for the juvenile portion of adult otoliths to isotope values for the Florida Bay region, thereby suggesting a migratory connection. Results were presented at the International Otolith Symposium.

Simulation of Management Strategies. The accuracy of our estimates of abundance of marine fish is contingent on our ability to understand their spatial correlation structure. Biases in relative abundance indices caused by ignoring spatial correlation can lead to inaccurate evaluations of stock status and thus more uncertain advice on the appropriateness of fishery management measures.

Regional Coastal Ecosystems

Characterization of Ocean Acidification in Coral Reef Waters. Results from the first years observations reveal $pCO_{2,sw}$ values values well in excess of 450 µatm throughout the summer with rapid declines in January, 2010. These values are at least 50 µatm higher than that expected in the offshore Caribbean waters based on the OAPS v0.4.

Documenting Everglades Restoration Impacts on Biscayne Bay's Shallowest Benthic Habitats Photographically based remote sensing studies reveal for the first time how local salinity patterns can influence the landscape structure of seagrass patches

Coral Ecological Restoration in the Florida Keys National Marine Sanctuary. Observations reveal marked asynchrony (distinct genets spawning on different nights, precluding effective fertilization and larval production), implying significantly greater reproductive impairment of threatened coral populations than their abundance and clonal structure would suggest.

Photo-Identification of Bottlenose Dolphins in Biscayne Bay, Florida. Bottlenose dolphins in Biscayne Bay have been identified as a separate stock from neighboring populations and can now be used as an indicator species with respect to Biscayne Bay ecosystem health and water quality.

Human Interactions

Marine and Estuarine Goal Setting for South Florida (*MARES).* The development and subsequent utilization of science-based ecosystem goals that incorporate both the human- and natural-systems represents significant progress towards enacting Ecosystem Based Management in south Florida. The MARES process is being emulated in other regions for NOAA's Integrated Ecosystem Assessment and Marine Spatial Planning purposes.

EPA/FIU Molecular Microbial Source Tracking for the Florida Keys Little Venice Service Area. Results to date suggest that implemented infrastructure improvements in the Little Venice area are having a positive impact on reducing human-source microbial fecal indicator levels and presumably upon human fecal contamination in the canal and nearshore coastal waters.

Air-Sea Interactions and Exchanges

Ensemble-Based High-Resolution, Vortex-Scale Data Assimilation for Hurricane Model Initialization. An ensemble Kalman filter was developed to assimilate high-resolution, vortex-scale observations collected by NOAA/AOML's Hurricane Research Division. The more realistic representation of the initial hurricane vortex thus obtained will contribute to the overall NOAA effort to improve hurricane intensity forecasts.

In Support of NOAA's Operational Oceanic Heat Content Analysis at NESDIS. A new OHC product was developed and carefully evaluated. It is expected that using this new product will significantly reduce uncertainties for both SHIPS and dynamical intensity guidance.

Advanced Modeling and Prediction of Tropical Cyclones. An experimental Hurricane Weather Research and Forecast (HWRFx) system) was developed and used to perform real-time forecasts at 9/3 km resolution during the 2009 hurricane season. Results indicate that the performance of the HWRFx is at least comparable to those of the NOAA operational models. A new nesting algorithm and moving algorithm was then implemented in HWRFx3.0 version and the code for both transferred to EMC for testing in an operational environment.

Studies of Cloud, Drizzle, Turbulence, and Boundary Layer Variability over the Eastern Pacific in Support of the VOCALS Regional Experiment. Observations from this study have been instrumental in documenting surface flux and cloud variability in the marine stratocumulus regimes over the southeast Pacific. Accurate simulation of these atmospheric features is critical for understanding of climate variability and the role of air-sea interaction in this variability.

Integrated Ocean Observations

Synoptic Estimates of Sea Surface Ocean Acidification. Improvements made in using SEAWIFS and MODIS ocean color products can now be readily adopted by the OAPS model to enhance NOAA's capacity to monitoring regional changes in sea surface ocean chemistry in response to ocean acidification. The approach developed will allow for better constraint of the carbonic acid system allowing NOAA to map the distribution and variability of carbonate mineral saturation state.

Western Boundary Time Series Project. The high percentage of variance in sub-annual periods conclusively establishes the necessity of of continuous time-series observations in order to extract and study annual and interannual variations in Florida Current transport.

Observing System Simulation Experiments for the Atlantic Meridional Overturning Circulation. The eventual goal is to design and execute viable OSSEs to evaluate and recommend AMOC monitoring strategies, Work to date has emphasized the development of the required software toolboxes. A "demonstration" OSSE was set up using a sub-optimal low-resolution ocean model that enables efficient testing of the software. The demonstration OSSE effort employed the "fraternal twin" approach, which uses one model type (HYCOM) as both the nature run and operational ocean models.

II. 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) and managed by NOAA's Office of Oceanic and Atmospheric Research (OAR) through the NOAA Cooperative Institute Program Office. CIMAS was established in 1977 through a Memorandum of Understanding between NOAA and the University of Miami. It is one of eighteen Cooperative Institutes.

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 has served as a mechanism to promote synergisms between University scientists and those in NOAA. Most of our research is related to Oceanic and Atmospheric Research (OAR) or National Marine Fisheries Service (NMFS) programs and associated with research activity at the adjacent OAR/Atlantic Oceanographic and Meteorological Laboratory (AOML) and the NMFS/Southeast Fisheries Science Center (SEFSC) 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 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 have been 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.*

These 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 is 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 (and in one case at Florida International 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 fostering the development of new CIMAS research activities that benefit both NOAA and the University.

CIMAS activities fall into four Task categories. The administrative and most of the educational functions of CIMAS are carried out under Task I with funding provided by both the University and NOAA. About half of all CIMAS research is carried out under Task II wherein CIMAS provides highly specialized research scientists who work on research projects primarily carried out at NOAA's Miami facilities. The expertise of these CIMAS employees complements that already present within 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.

The remaining research in CIMAS is carried out under Tasks III and Task IV. These Tasks provide funding to University faculty and scientists to conduct research on CIMAS themes. Support for specific projects under these tasks is based on proposals submitted to specific NOAA units or funding programs often but not necessarily in response to a general Announcement of Opportunity or Request for Proposals. Task 3 encompasses collaborations with NOAA scientists and NOAA projects (typically but not necessarily with the Miami laboratories) while Task 4 encompasses projects that support or complement the NOAA mission but are funded by another federal, state or private funding source.

III. PERSONNEL

Distribution of Personnel

CIMAS personnel participate in a wide range of NOAA-related activities. During Year 9 a total of 125 persons were associated with CIMAS in various capacities. Of these, 95 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 95 who received over 50% NOAA support, 66 are associated with AOML and 29 with SEFSC.

Table 1: CIMAS Personnel 2009 – 2010

Personnel				
Category	**Number**	**BS**	**MS**	**Ph.D**
Research Associate/Scientist	60	22	20	17
Part Time Research Associate/Scientist	7	2	2	3
Postdoctoral Fellow	11			11
Research Support Temporary Staff	31			
Total (> 50% NOAA support)	95	24	22	31
Full Time Administrative Staff	5			
Task I Undergraduates Students	7			
Task I Graduate Students	9			
Visiting Scientist	9			
Location of Lab	66-AOML 29-SEFSC			
Obtained NOAA employment within the last year	2			

Research Associates, Research Scientists and Postdoctoral Associate are those employees under Task 2 who work closely with the local NOAA laboratories. A total of 71 persons in these categories were employed under Task 2 in Year 9. This represents a substantial increase. There had been a steady growth in such personnel in the middle and late 1990s. During the first three years of the current Cooperative Agreement, personnel levels for these positions had remained relatively steady – about 34. In FY 4 the number increased sharply to 44 and remained at that level for the next two years, 43 in FY 5 and 45 in FY 6.

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 essential to support of research activities at the University. Advancement is not automatic with time in grade. Additional education, continuing professional

achievement, and/or increased responsibility are the basis for advancement to higher-level positions. The progression order is: Research Associate, Senior Research Associate, Assistant Scientist, Associate Scientist, and Scientist. The "Scientist" ranks (Assistant Scientist, Associate Scientist and Scientist) are designed to parallel those of the research faculty at the University (i.e., Assistant Research Professor, Associate Research Professor and Research Professor). In Year 9 there were a total of eleven Postdoctoral Fellows. Postdoctoral Fellows have become an increasingly important part of the CIMAS employee pool during the current Cooperative Agreement.

Research Support Staff are temporary employees, hired for the duration of specific projects. These include persons from a variety of backgrounds including both retired PhDs and local high school students often as a part of CIMAS associated K-12 outreach programs.

It should be noted that although CIMAS has the status of a Division within the Rosenstiel 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. Such faculty are not counted in the listing of the 125, not even those who serve as CIMAS Fellows. The graduate students who work on CIMAS programs and are listed above all have their primary affiliation with an Academic Division which has the ultimate responsibility for overseeing the students' academic performance and the granting of degrees.

Over this last year, CIMAS has made an renewed effort to improve the working environment of its off-campus employees. Specific efforts include:

1. Initiating an Awards Policy modeled upon the awards available to NOAA employees (http://cimas.rsmas.miami.edu/pdfs/CIMAS_Award_Program_Policy.pdf);
2. Expanding the breadth and increasing the upper limit of the Pay Bands applicable to CIMAS employees (http://cimas.rsmas.miami.edu/pdfs/pay-bands.pdf);
3. Assisting personnel with respect to the increasing difficulty of negotiating the escalating requirements of the Department of Homeland Security (many CIMAS Task II employees are not U.S. citizens); and,
4. Preparing and providing briefing documents and workshops for relevant NOAA personnel regarding UM Human Resources policies, practices and regulations.

CIMAS Fellows

CIMAS Fellows play a critical role in the governance of the Institute. At present there are 17 CIMAS Fellows. In addition to the regular members of the Fellows, there are three *ex officio* members, the Dean of RSMAS (R. Avissar) and the directors of the two adjacent NOAA laboratories (R. Atlas, OAR/AOML; B. Ponwith, NMFS/SEFSC). A list of the present CIMAS Fellows is given in the *Fellows* section of this report along with their affiliation. At present 11 CIMAS Fellows are from RSMAS, 5 from the adjacent NOAA laboratories, 1 from the National Hurricane Center and 1 from Florida International University. The Council of Fellows will be completely reconstituted after October 1 with the Evolutionary Reinvention of CIMAS resulting from the recompetition process (see section below).

CIMAS Staff

CIMAS staff consists of a Director: Dr. Peter B. Ortner, an Associate Director: Dr. David Die, and three full-time administrative personnel. Dr. David Die also serves as the Director of the Cooperative Unit for Fisheries Education and Research (CUFER) and administers the NMFS Center

for Independent Experts (CIE). While both are housed within CIMAS they are independent. Nonetheless they provide additional important linkages between UM/RSMAS and NMFS/SEFSC. A new MOU will be developed for the reinvented CIMAS and when that MOU goes into effect CUFER will no longer be independent of CIMAS.

Transition to Federal Positions

More than thirtyfive former RSMAS undergraduate/graduate students and/or CIMAS employees hold Federal positions in the local NOAA laboratories: AOML, NHC and the SEFSC. During the past year, two more CIMAS employees joined their predecessors in this regard. This total represents only a small fraction of the number contributed to the national NOAA workforce.

Demographics of CIMAS Employees

The CIMAS population is 38% female. Foreign-born individuals make up 52% of the personnel; of these Hispanics make up 23% of the ranks; Asian and Pacific Islanders, 16%. Only one African-American has been recruited, despite our efforts to expand this group's participation. The population of CIMAS is relatively young with an average age in the mid-30's. The largest age decade is that between 30 and 40, for a total of 32. Comparison with local laboratory populations and NOAA workforce analyses, this is a much younger and more diverse group than the overall federal NOAA population.

CIMAS Student Employees

There are currently 9 graduate students supported through CIMAS Task I. In addition 7 undergraduates are currently supported. A number of high school students are also being employed as temporary hires (in the category Research Support Staff). Most of these are enrolled in the Miami-Dade MAST Academy, a magnet school in the county (see Outreach) which is co-located on the Virginia Key Marine Campus.

IV. FUNDING

General Funding Trends

Total funding during Fiscal Year 2009 – 2010, Year 9 of the Cooperative Agreement (CA), was much higher (by $3.1M) than in the preceding year. In Year 9, funding from all sources totaled ca. $13.6M compared to ca. 10.4M in Year 8. A summary of CIMAS funding under the four Tasks in Year 9 is shown in Table 1 along with funding under the prior seven years of the CA.

Table 1: CIMAS Funding from All Sources (Thousands of Dollars)

	Task I	Task II	Task III	Task IV	Total
Year 1	1,620	1,434	2,604	320	5,979
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	8,345
Year 5	1,133	2,527	2,683	675	7,018
Year 6	2,343	4,301	3,360	580	10,584
Year 7	1,043	4,148	4,011	709	9,911
Year 8	1,917	4,715	2,949	908	10,489
Year 9	1,142	6,370	4,934	1,156	13,602

The history of funding through CIMAS is shown graphically in Figure 1. Total funding in Years 8 and Year 9 was about equal to that of the first four years of the CA. The average of the last two years of the CA is more than double that of the first two years.

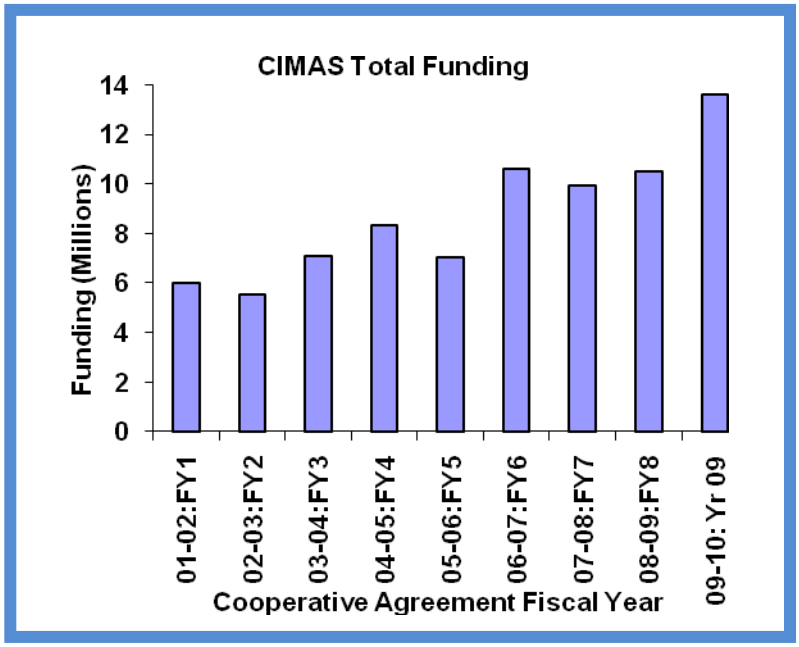


Figure 1: CIMAS funding

The sources of funding in CIMAS are shown in Table 2. The major source of funding continues to be OAR which provided 60% of the total. NMFS and NESDIS are second at 13% and 7% respectively. Over the course of the CA most CIMAS funds have come from two NOAA sources: OAR and NMFS although the relative proportions have changed in different years. Of the total OAR funding most originates within the Climate Program Office (CPO). The funding from CPO increased sharply in FY 6 more than doubling that received in prior years. The other major source of OAR funding is associated with the implementation of the NOAA Hurricane Forecast Improvement Program (HFIP) program. The "Other" sources of funding include DoD (the USACE in support of the South Florida Restoration program) and smaller awards from NSF, EPA, NASA and private industry.

Table of Funding by Source - Year 9

1July 2009 – 30 June 2010		
Line Office	**Funding $M**	**% Total**
OAR	8.14	60%
NMFS	1.74	13%
NESDIS	0.91	7%
OMAO	0.75	5%
NOS	0.66	5%
OTHER	0.90	6%
NWS	0.25	2%
USWRP	0.23	2%
GRAND TOTAL	13.60	100%

The trends in the principal NOAA sources of CIMAS funding over the lifetime of the current CA are shown in Figure 2. Funding through OAR has grown considerably over the past seven years. The other major sources of funding, NMFS and NOS, are relatively small compared to OAR. NMFS funding suggests a slight downward trend whereas NOS funding had been growing, the sum of the two holding relatively constant over the CA. Of the various OAR sources, funding through the Climate Program Office (CPO) - previously the Office of Global Programs (OGP), has been increasing sharply over the past few years reflecting the increase in overall climate funding.

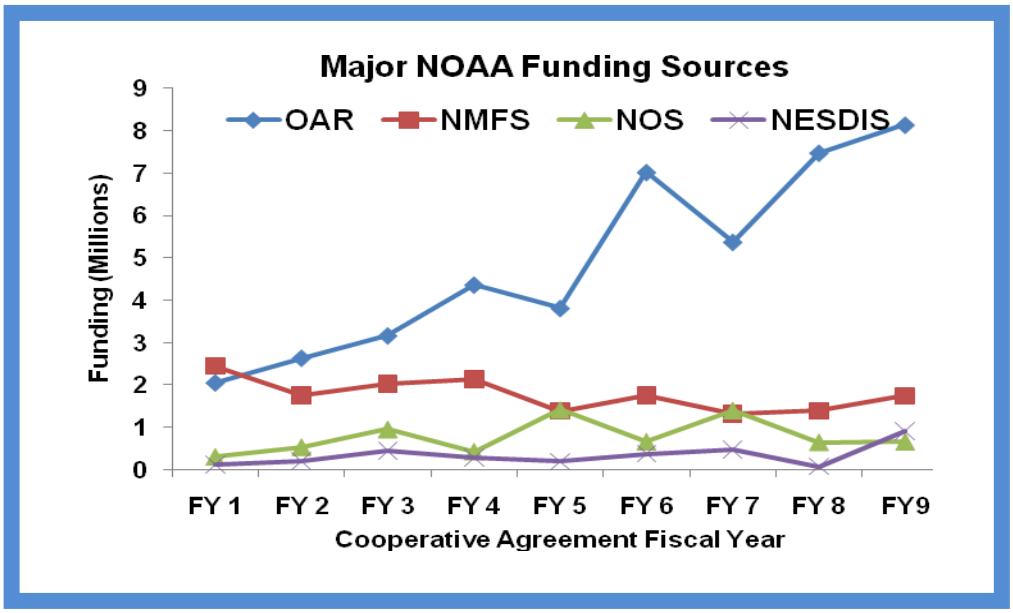


Figure 2: Trends in funding from the major sources under the current Cooperative Agreement

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, some research infrastructure as well as support for graduate students and for limited-term visiting research scientists. The University contributes to the administrative support of CIMAS in its role as a Division within the School.
- **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. Support for limited-term postdoctoral research associates is also included in this Task.
- **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 funded by NOAA and very often carried out in cooperation with NOAA personnel in the local NOAA laboratories and elsewhere in the United States. In Task 4 are those projects that are relevant to NOAA and CIMAS missions but fall outside the scope of Tasks 1, 2 and 3. With the exception of one five year legacy project these are in all cases funded by other sources than NOAA. The indirect cost rate for Task 3 is 40% and Task 4 is either the federally negotiated UM rate (currently 53%) or a rate specified in the relevant RFP. The different rates for the two tasks are in recognition of the substantially funding support that CIMAS receives from the local NOAA laboratories under Task 1 for the administrative support toward which that IDC would have contributed.

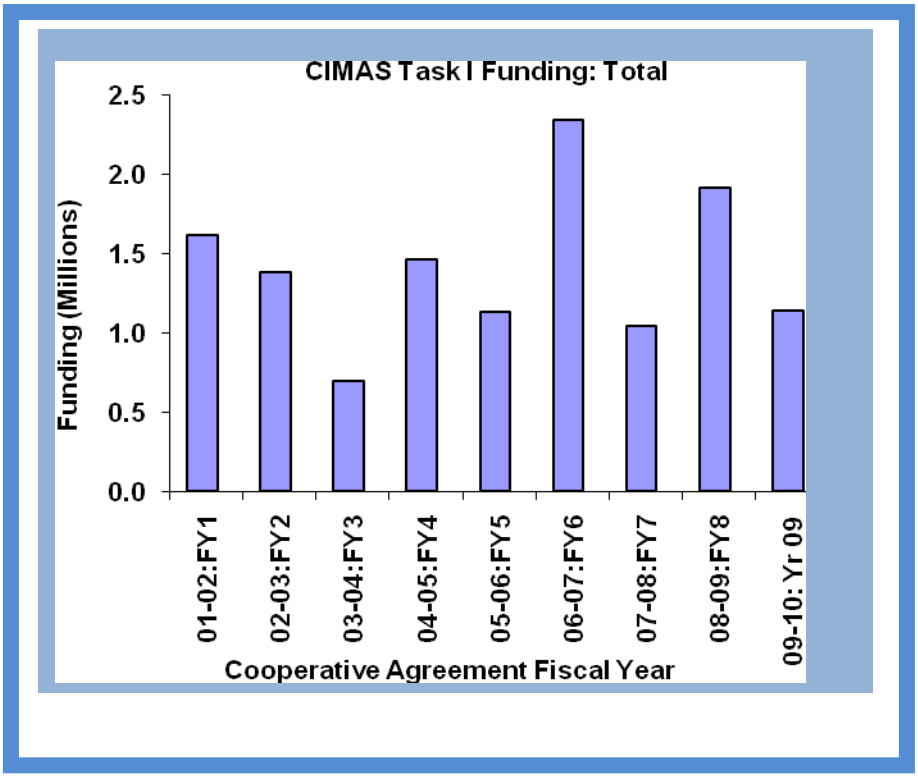


Figure 3: History of Task 1 Funding

The history of Task 1 funding under the CA is presented in Figure 3. Funding in FY 7 was down sharply from FY 6. In FY08 it grew substantially. The relatively low value in FY 7 was due to a number of factors including a policy change initiated late in FY 5 with regard to Postdoctoral Fellows. The growth over this next year reflected an increase in other aspects of Task I since there continues to be no Postdoctoral Fellows in Task 1. The considerably lower value this year is in part a reflection of the Transition Process addressed in a subsequent section.

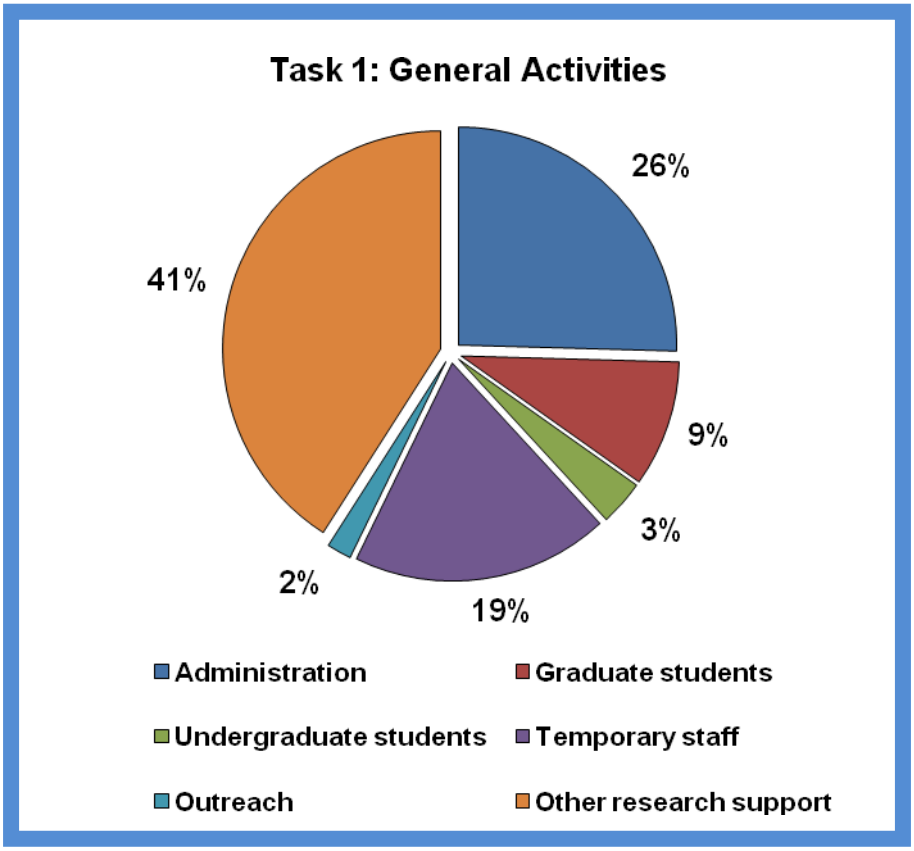


Figure 4: Distribution of Task 1Funding

The distribution of NOAA Task 1 expenditures is shown in Figure 4. The total NOAA-supported Task 1 budget was $1.2M. The category “Administration” (26%) covers only a portion of the salary of CIMAS staff including its Director and Associate Director. In addition, in FY09 the University of Miami provide a direct contribution to Task I of $.286M.

The category "Other" (41%) includes: travel for students, visiting scientists and temporary staff in support of research activities; relocation expenses for new hires including research personnel on Task II; new hire expenses (drug tests, background searches); advertisements for new positions; visa costs; consulting agreements, other supplies (computer equipment, peripherals, etc.). Temporary Staff (19%) covers persons hired on a temporary basis to support research.

The history of funding under Task 2, which supports CIMAS employees who work closely with NOAA scientists (i.e., the Research Associate, Research Scientist and Postdoctoral Associate

programs) is shown in Figure 5. In FY 9, Task 2 totaled $6.0M, much higher than FY8. There has been strong and steady growth in funding for Task 2 over the CA, essentially quadrupling from FY 1 to FY 8. In contrast, as we show below, the other research budgets (Tasks 3 and 4) have been relatively stable. The growth in Task 2 accounts for much of the sharp growth in the overall budget of CIMAS. Part of the increase in FY09 reflects pre-funding of summer salaries for CIMAS employees as part of the transition process.

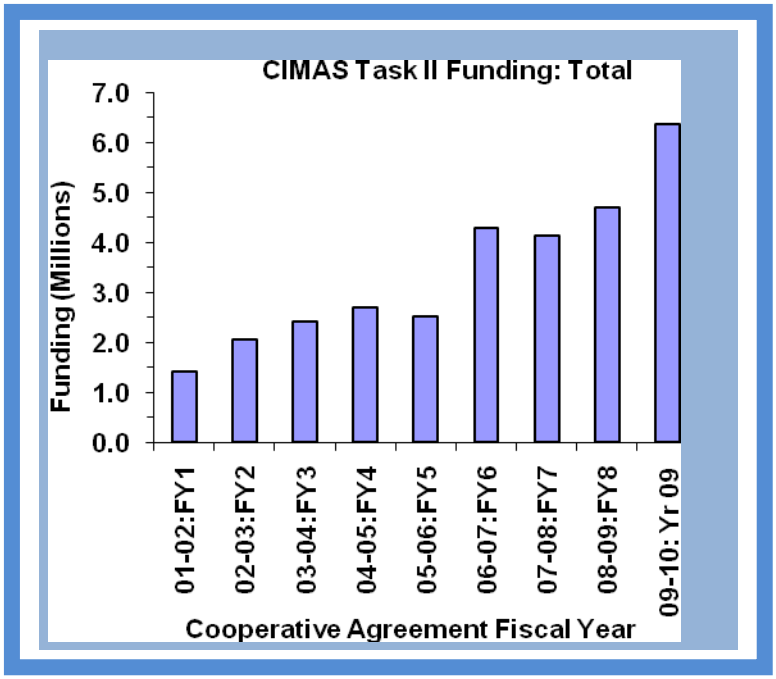


Figure 5: History of Task 2 Funding over the Cooperative Agreement

The history of other research funding (Task 3 and Task 4 combined) is shown in Figure 6. In Year 9 this totaled ca. $6.1M which is an increase in funding from Year 8 of ca. 50%. There is really no long term systematic trend but recent years have been well above the level of the first two years. Included in this total under Task 3 are the competitive program awards funded through the "shadow award" process terminated this past winter. Although this process is no longer available, the projects funded through that process (See Appendix A) will continue to be so funded until they terminate. All but three of the projects in Appendix A are now in their final year of funding. The NOAA Research Council has recently stated a commitment to finding a more convenient and administratively simpler process to fund competitive program awards to Cooperative Institutes.

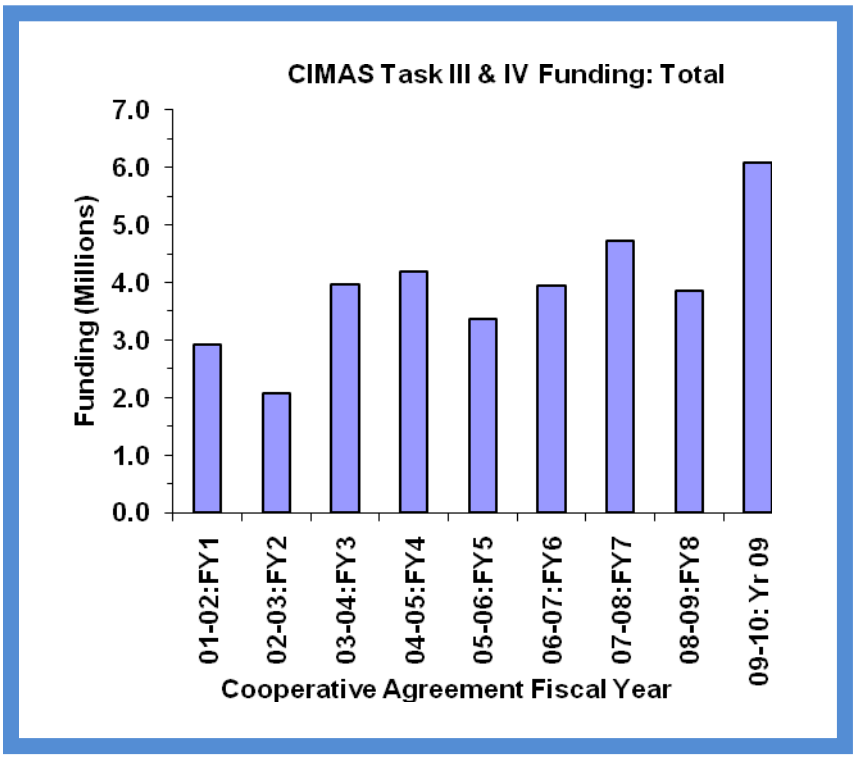


Figure 6: CIMAS Research Funding (Task 3 and Task 4)

Funding By Theme

Figure 7 shows the percentage of Task 3 and Task 4 funding that is expended in the CIMAS Themes. Of total CIMAS research funds, Theme 4, Human Interactions with the Coastal Environment., accounts for the largest portion of the funding - 29%. The smallest portion of funding was in Theme 3, Regional Coastal Ecosystem Processes – 11%

The distribution of research funding by Theme as shown in Figure 7 is based upon somewhat arbitrary assessments of the major focus of specific projects. In truth nearly all CIMAS projects are highly interdisciplinary and could reasonably be assigned to more than one Theme. For example, some projects categorized as Theme 1: Climate Variability could with equal plausibility have been assigned to Theme 5: Air-Sea Interactions and Exchanges. On the other hand, the large proposal accounting for most of the funding in the Human Interactions theme could have been classified as Climate (and had been so classified in prior years). Because the primary focus of that effort at RSMAS is Human Dimensions Science rather than Physical Science it was assigned for the first time to Theme 4.

To reflect this complexity projects were given not only primary but also secondary (and sometimes tertiary) theme assignments.

Note that this figure only shows the distribution of funding under Tasks 3 and 4; it does not show the funding that supports Task 2 personnel working on projects that fall within these same Themes.

While the salary of these personnel is funded through CIMAS all the other costs for those research projects are budgeted directly within NOAA and no specific project proposal was submitted through CIMAS for that funding.

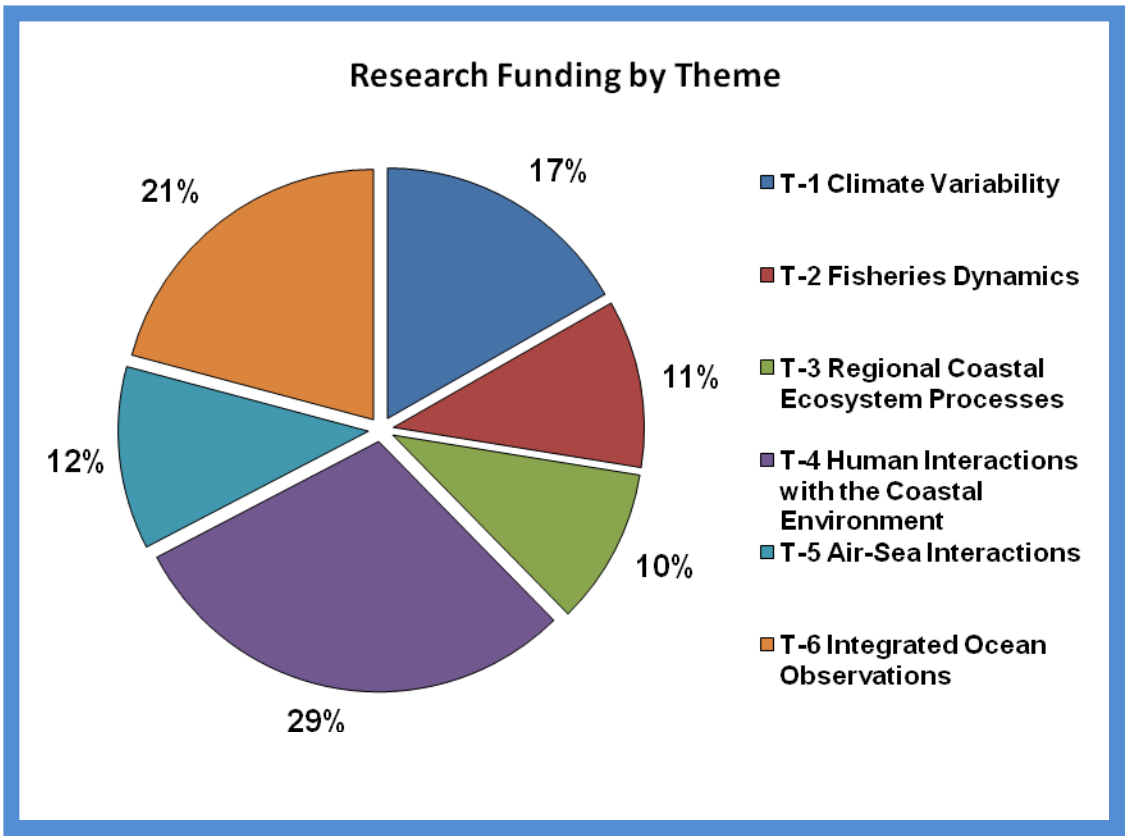


Figure 7: Percentage of Task 3 and Task 4 (Research) funding in the CIMAS Themes

Conclusion

In our funding summary we report only expenditures made through CIMAS. We emphasize once again that there are a substantial number of research programs carried out by RSMAS faculty that are complementary to the NOAA-supported CIMAS-linked programs but supported directly by other agencies. The grants obtained by those faculty members are credited not to CIMAS but to the Academic Division in which they reside. Consequently there is considerable leveraging of NOAA funds across the campus which does not appear in the present accounting. One example of such an activity 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. The concept of the CIE was developed in CIMAS and it was initially funded through the CIMAS CA. For legal reasons the CIE was removed from the CA and since 2002 it has been funded by a separate contract with NOAA. Since 2002, the CIE has received nearly $3.4M in funding from NMFS but this funding is not reported herein.

V. RECOMPETITION AND TRANSITION

Although CIMAS served its purpose well for more than three decades, it needed to substantially change in order to keep pace with changes in scientific and societal priorities as well as changes in both NOAA and the regional university landscape. The re-competition process provided an opportunity to establish a renewed institution that will take full advantage of the scientific and educational capabilities of the academic community within our region, better connect NOAA with the needs of its stakeholders and enable NOAA to better address the enormous challenges of the twenty first century.

Vision:

- *To serve as a center of excellence in Earth System, Ecosystem and Human Dimensions Science and improve information about and understanding of the changes transforming our environment and society;*
- *To disseminate this information and the understanding resulting from it through targeted education and outreach activities; and,*
- *To facilitate the process of applying our scientific knowledge to effectively sustaining, protecting and restoring our natural environment as well as the economy and human society that ultimately depend upon it.*

Mission:

- *To conduct research in the terrestrial, ocean, and atmospheric environments consistent with the priorities expressed in NOAA's present and future Goals and Mission.*
- *To characterize physical, chemical and biological interactions and processes within, between, and amongst these environments;,*
- *To better understand the role of humans in affecting these environments and the impacts of change in these environments upon human societies and economies, and,*
- *To create and implement formal education and training programs creating the intellectual capital required by the present and future NOAA*

To achieve this Vision and carry out this ambitious mission, CIMAS proposed to re-invent and restructure itself:

- **By enhancing interconnections with the regional NOAA community beyond Virginia Key;**
- **By broadening the participation of the regional academic community by incorporating; complementary capabilities from other Florida and U.S. Caribbean universities;**
- **By offering NOAA access to state-of-the-art research infrastructure both at UM and its partner universities;**
- **By developing new graduate and undergraduate educational programs to train the NOAA workforce of the future.**
- **By establishing collaborative relationships with other regional CI's;**

- **By specifically addressing NOAA priorities most relevant to our thematic focus including the Future NOAA Workforce, the NOAA Hurricane Forecasting Improvement Program, Community Resilience to Extreme Weather Events, Climate Services, Ecosystem Approaches to Management and Marine Spatial Planning as reflected in NOAA's Annual Guidance Memorandum, Research Plan and Next Generation Strategic Plan.**

In June 2010, the NOAA announced its selection of the University of Miami (UM) to continue to lead its partnership with the Cooperative Institute for Marine and Atmospheric Studies (CIMAS). See http://www.rsmas.miami.edu/pressreleases/20100601-cimas.html. New university partners in CIMAS include: Florida Atlantic University, Florida International University, Florida State University, Nova Southeastern University, University of Puerto Rico, University of Florida, University of South Florida and University of the Virgin Islands. The National Hurricane Center will join AOML and NMFS/SEFSC on the Executive Advisory Board and seven new themes will replace the six present themes. The "evolutionary reinvention" of CIMAS will take effect on October 1, 2010.

The renewed partnership with NOAA will allow investigators not only from UM but also the Partner Institutions to receive directed NOAA support for research and will facilitate collaboration with NOAA scientists nationwide but especially at NOAA's Atlantic Oceanographic and Meteorological Laboratory, National Hurricane Center and Southeast Fisheries Science Center.

Since this announcement CIMAS Administration has worked closely with the NOAA CI Office and the local NOAA Sponsors to assure a seamless transition with no interruption in service. We will continue the present agreement under a no cost extension through next year and have been able to prefund much of the initial phase of the new Cooperative Agreement with FY09 resources. The process has been complicated since we were only selected so late in the fiscal year. Moreover, bringing the larger regional institution into being will be administratively challenging given its diversity and geographic scope, The first meeting of the new Executive Advisory Board including both its enhanced NOAA membership and all eight participating Universities has already been held and shortly after October 1 we will have a new CIMAS website and appropriate informational materials. Shortly after the first meeting of our new and much enlarged Council of Fellows in the Fall of 2010 we hope to host a "roll-out" to inform NOAA personnel of the new capabilities available to it through CIMAS. Funds have been allocated for this purpose in recognition of the importance of face-to-face interaction between our new Partners and NOAA. We have not been entirely occupied with administrative and financial issues and during this summer's transition phase, CIMAS research personnel have been actively assisting NOAA with respect to the Deepwater Horizon spill (see http://www.rsmas.miami.edu/pressreleases/20100612-noaa.html) as well an unusually active hurricane season (see http://www.rsmas.miami.edu/pressreleases/20100907-cimas.html).

VI. 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 ranges includes: involvement in process-oriented field programs involving ships, aircraft, and satellite systems; making 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 regards to the role of chemistry in radiative energy transfer processes by direct effects as well as 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 the 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 fishery 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 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 in the past decade 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 the 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

Intra-Americas Studies of Climate Processes (IASCLIP)

D.B. Enfield (RSMAS/CIMAS); C. Wang (NOAA/AOML)

Long Term Research Objectives and Strategy to Achieve Theme:

***Objectives*:** To improve our understanding of and ability to predict the summer climate in the Intra-Americas Sea and surrounding land regions.

***Strategy*:** Improve in-situ monitoring and model predictions within the IAS region and facilitate climate forecast outreach for climate applications in the IAS region.

CIMAS Research Theme:

***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:** Gustavo Goñi

Research Summary:

Based on recent research indicating that the Western Hemisphere warm pool (WHWP) provides the climate memory in the IAS region, developing in the spring and influencing the atmosphere in the summer, an international research program has been developed to achieve the above objectives, as part of the International CLIVAR program on American monsoons (VAMOS). The Intra-American Studies of Climate Processes (IASCLIP) began in 2009 and continues through 2014. At the 11th Annual VAMOS Panel Meeting in May 2008, David Enfield was named as chair of the IASCLIP Science Steering Committee.

The potential impact of IASCLIP is illustrated by the attached figures. Figure 1 shows the large difference in warm pool size between the five largest and five smallest warm pools since 1950,

approximately a factor of three. Research indicates a strong relationship between warm pool size and extreme climate events, in particular, Atlantic hurricane activity, and the influence on floods, droughts and tornados east of the Rocky Mountains, controlled by the flow of moisture into the United States across the gulf coast. Figure 2 shows the climate scenario in the Western Hemisphere tropics during spring 2010, illustrating the development of a very large WHWP (warm tropical North Atlantic) in response to a prolonged El Niño in the Pacific and a persistent (six months) negative North Atlantic Oscillation (NAO). The Hovmuller of SSTA illustrates how the tropical Atlantic has gone from being somewhat cool in 2009 to being extremely warm in 2010, each in response to distinct atmospheric forcings in the winter-spring season. The mantra of IASCLIP is that by emulating this and other warm pool development mechanisms (e.g., ENSO), improved numerical models can produce useful summer climate forecasts.

Orchestrating the launch of IASCLIP. This has involved (1) working with other IASCLIP scientists to organize the efforts of several working groups; (2) participating in trips to several Caribbean countries to organize collaborative activities, and now, (3) preparing to address the VAMOS Panel meeting (July 2010) regarding the progress and future plans for IASCLIP.

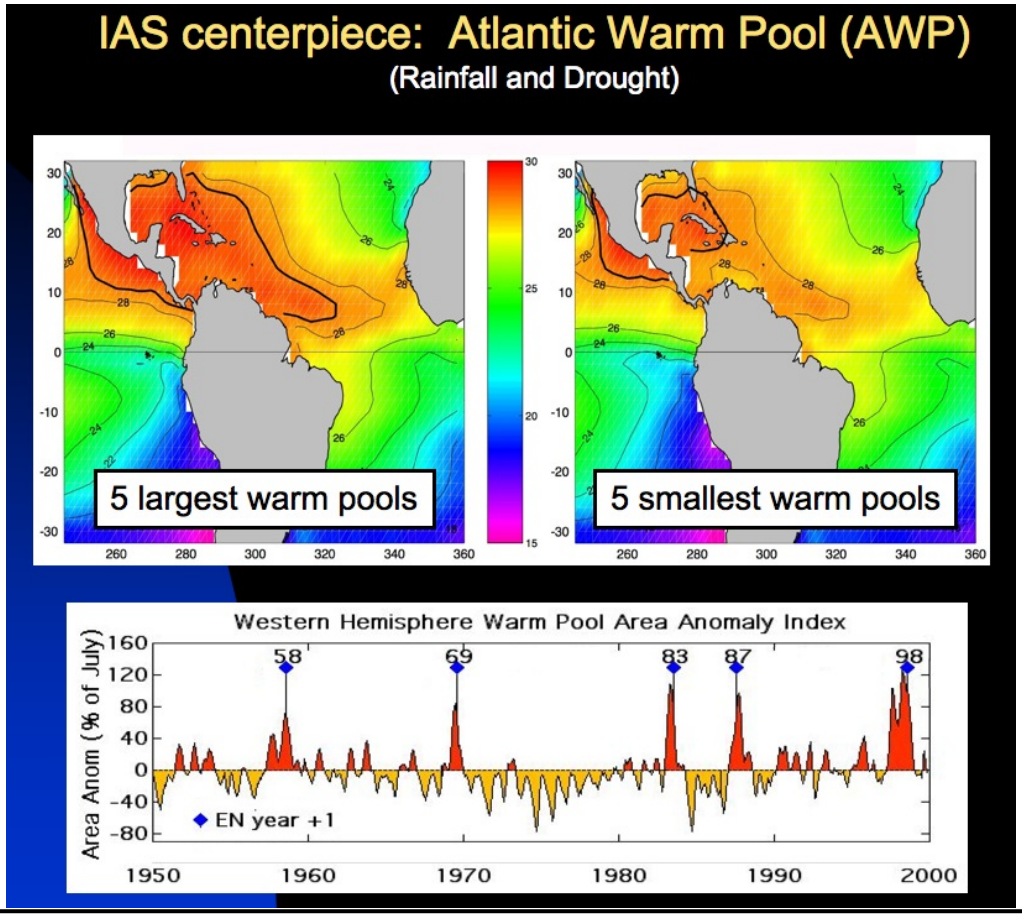


Figure 1: (a) Difference between the largest and smallest wrm pools since 1950 (heavy contour = 28.5°C). (b) Time series index of WHWP size (% of climatological July value).

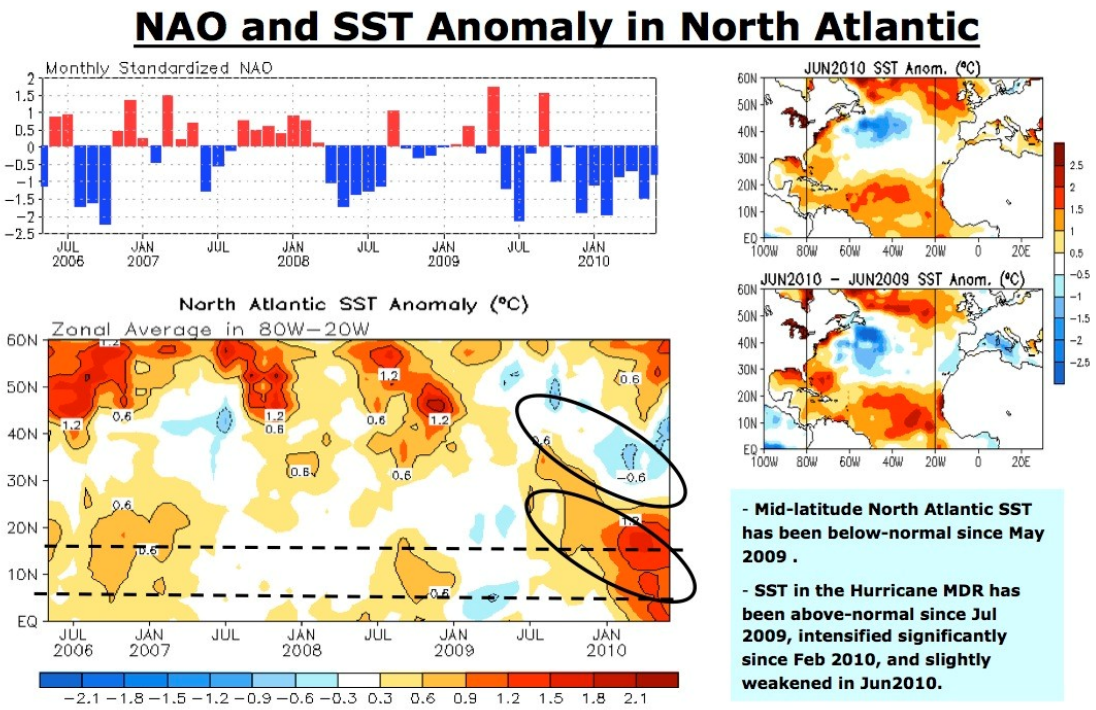


Figure 2: The evolution of the Atlantic warm pool (AWP) in spring 2010 is an excellent illustration of the importance of winter-spring climate patterns to AWP growth. There is a warming in the tropical North Atlantic in response to a prolonged El Niño in the Pacific and a persistent (six months) negative North Atlantic Oscillation (NAO). These are associated with a weaker-than-normal NASH and easterly low-level winds over the TNA (lower left), allowing the tropical North Atlantic to warm faster than normal.

Research Performance Measure: The immediate objectives of launching IASCLIP and presenting it to the parent science panels in VAMOS and CLIVAR, have been achieved. We will continue to implement working group activities over the next year and host IASCLIP sessions at major conferences in 2010.

Assessing the Sensitivity of Northward Heat Transport/Atlantic Meridional Overturning Circulation to Forcing in Existing Numerical Model Simulations

S. Dong (UM/CIMAS); M. Baringer, G. Goni and G. Halliwell (NOAA/AOML)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** To investigate the mechanisms underlying the observed differences in the role of Ekman and geostrophic transports in the Atlantic Meridional Overturning Circulation (AMOC) and the net northward heat transport in both the North and South Atlantic on seasonal to longer time scales, and to diagnose the causes for the inconsistency between their observed variability and that demonstrated in the numerical model simulations.

***Strategy*:** Combine data analyses and numerical model outputs.

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:** Molly Baringer

Research Summary:

The Atlantic Meridional Overturning Circulation (AMOC) is characterized by a northward flow of warm water in the upper layers from the tropics and the South Atlantic into the North Atlantic, and a southward return flow of cold water at depth. This large-scale ocean circulation is the main route for the global ocean heat conveyor belt circulation in the Atlantic, and it is an important benchmark for Earth's climate. The AMOC carries 25% of the total global ocean-atmosphere northward heat flux. The majority of this heat is lost to the atmosphere in the mid-latitudes where warm water meets cold,

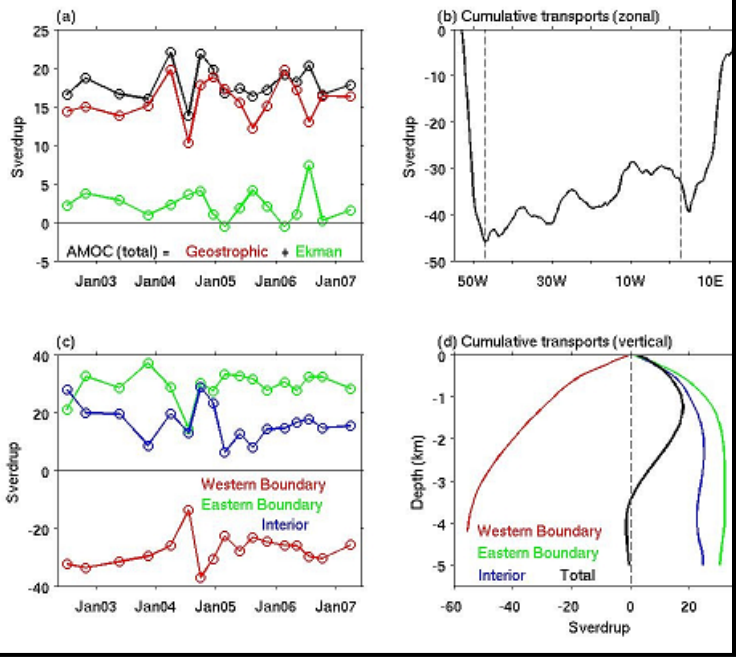


Figure 1: (a) Time series of the AMOC (black) and contributions from the geostrophic (red) and Ekman (green) components. (b) West-to-East cumulative transports (in Sv) averaged over the 17 AX18 transects. The dashed lines indicate the separation points for the boundary currents and interior. (c) Contributions of the western (red) and eastern (green) boundaries and interior (blue) to the AMOC. (d) The total cumulative volume transport (black) from the surface to ocean bottom, and those in the western (red) and eastern (green) boundaries and interior (blue) for the December 2004 transect.

dry continental air masses. The AMOC regulates and maintains the meridional temperature distribution in the Atlantic. Variations in the AMOC and its associated ocean heat transport are coupled to atmospheric heat transport variations through the mechanism of Bjerknes compensation. As a result, changes in the AMOC can have a direct and pronounced impact on variety of climate phenomena, such as African and Indian monsoon rainfall, hurricane activity, climate over the North America and Western Europe. Thus, understanding and monitoring AMOC variability are crucial for improving our knowledge of the mechanisms of climate system and for assessing future climate change.

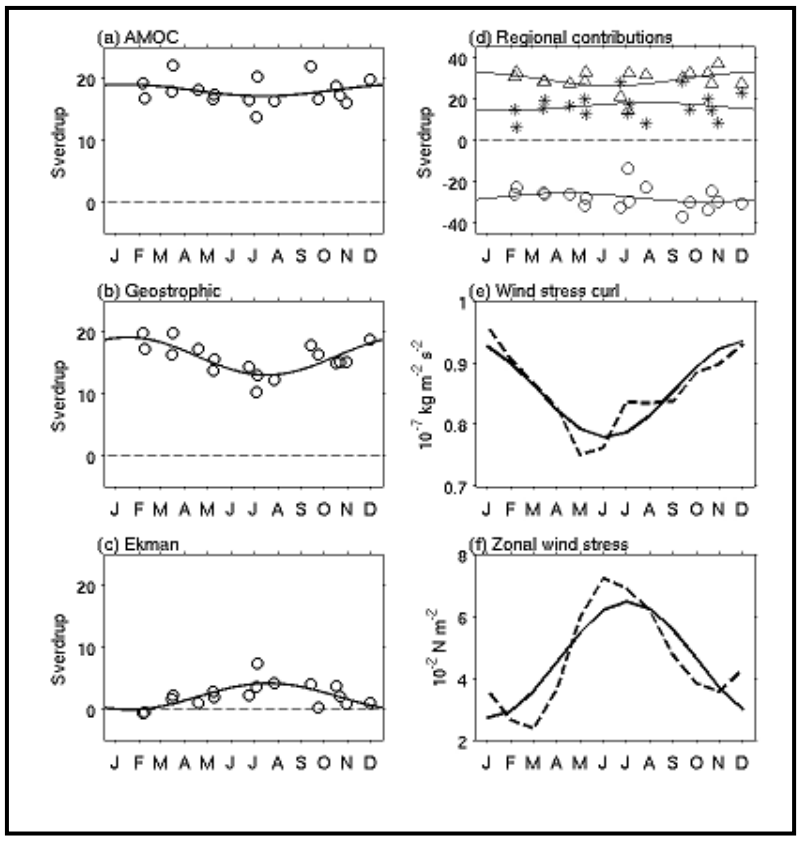


Figure 2: Scatter plots of the (a) AMOC, and its (b) geostrophic and (c) Ekman contributions versus month. (d) Contributions of the western (circles) and eastern (triangles) boundaries and the interior (stars) to the AMOC. The black lines show the annual cycle. Monthly climatological (dashed) wind stress curl (e) and zonal wind stress (f) averaged in the subtropical south Atlantic (box indicated in (d)). Solid lines in (e) and (f) are the corresponding annual harmonic.

Variability of the AMOC and its effect on the net northward heat transport in the South Atlantic were investigated using a trans-basin expendable bathythermograph (XBT) high-density line at 35°S (AX18). The mean time-mean AMOC was 17.9±2.2 Sv during 2002-2007. Although geostrophic transport dominates the time-mean AMOC, both geostrophic and Ekman transports are important in explaining the AMOC variability. The contributions of geostrophic and Ekman transports to the AMOC both show annual cycles, but they are out of phase, resulting in weak seasonal variability of the AMOC. Northward heat transport variability is significantly correlated with the AMOC, in that a 1Sv increase in the AMOC would yield a 0.05±0.01 PW increase in the northward heat transport. Partitioning transport at the western and eastern boundaries suggests that, to quantify changes in the AMOC and total northward heat transport, it is essential to monitor all three regions.

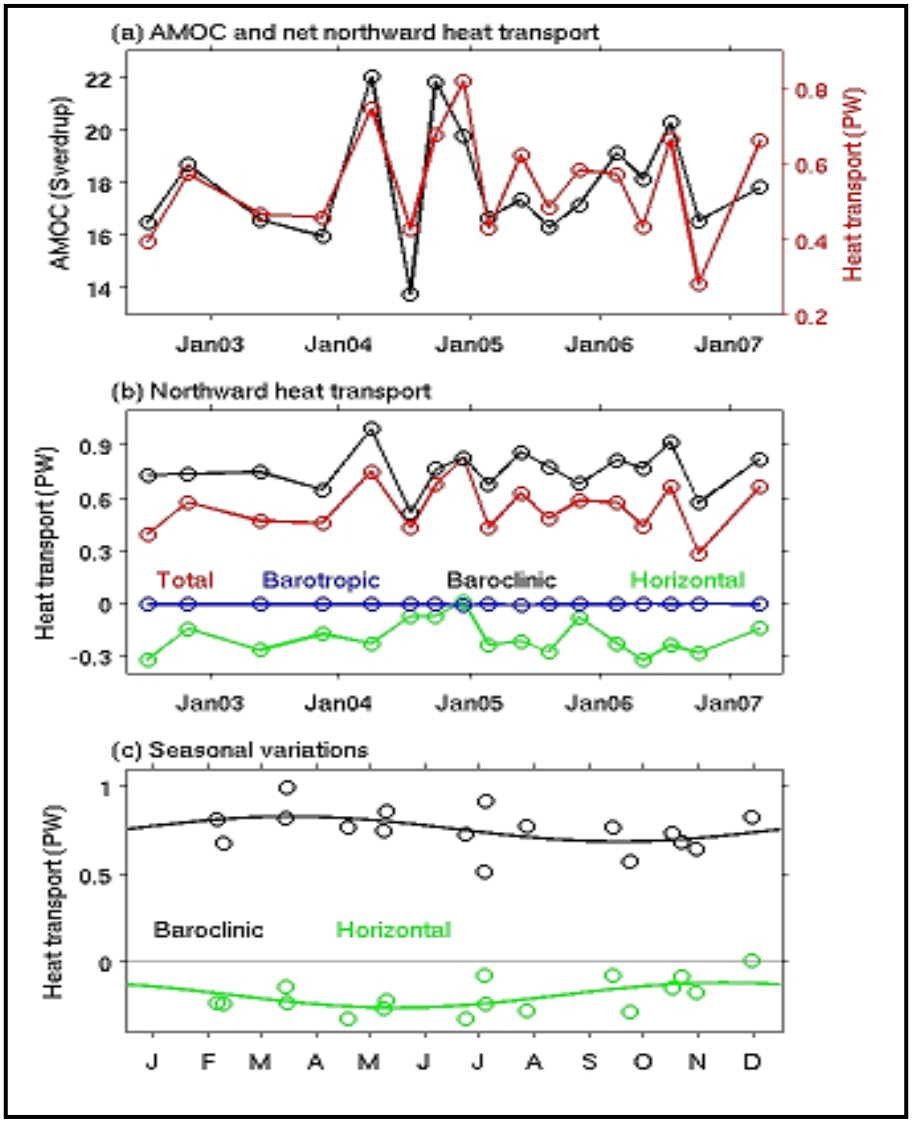


Figure 3: Time series of (a) the NHT (red, right axis) and the AMOC (black, left axis), and (b) the NHT (red) and contributions from the barotropic (blue), overturning (black), and horizontal (green) components. (c) Scatter plots of the overturning (black) and horizontal (green) heat fluxes versus month. Units are PW for heat transports and Sv for volume transports.

Research Performance Measure: The main object is to investigate the contributions of various processes to the AMOC variability.

Re-Writing the Climatology of the Tropical North Atlantic and Caribbean Sea Atmosphere

J.P. Dunion (UM/CIMAS)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** To revise the Jordan (1958) mean tropical atmospheric sounding by developing new updated soundings for the tropical North Atlantic and Caribbean Sea region.

***Strategy*:** To utilize new infrared GOES satellite imagery, microwave derived satellite imagery, model analyses of aerosol optical depth and model back trajectories to identify the various air masses that impact the tropical North Atlantic and Caribbean Sea atmosphere during the hurricane season and to incorporate these findings into the development of new mean atmospheric soundings for this region of the world.

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:** Frank Marks

Research Summary

The Jordan mean tropical sounding has provided a benchmark reference for representing the climatology of the tropical North Atlantic and Caribbean Sea atmosphere for over 50 years. In fact, it is still routinely used as a reference for tropical soundings during the North Atlantic hurricane season and as an initial background state in model simulations. However, recent observations and studies have suggested that during the months of the North Atlantic hurricane season, this region of the world is affected by multiple air masses with very distinct moisture and wind characteristics. These environments include moist tropical, dry Saharan Air Layer [(SAL); i.e. Saharan dust storms, Figure 1] and dry air originating form the mid-latitudes. This CIMAS project poses the following hypotheses:

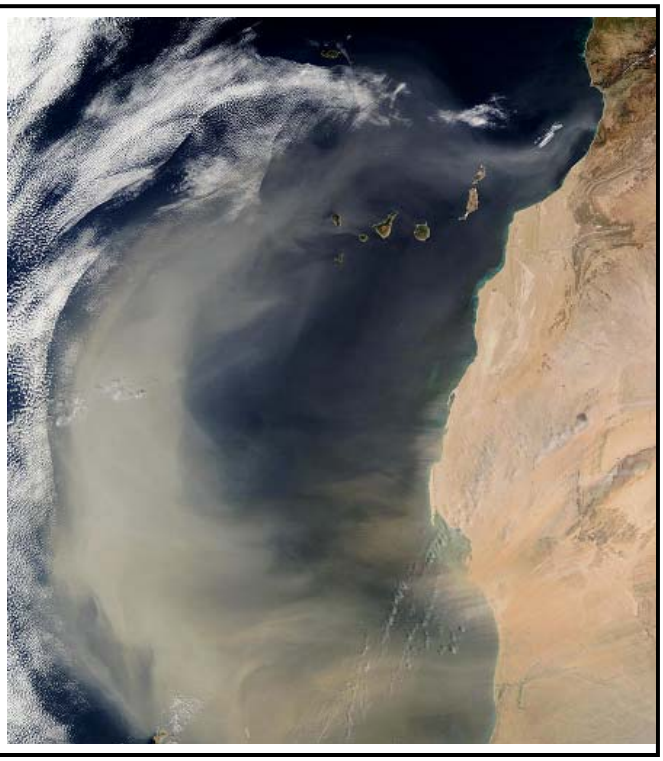


Figure 1: True color satellite image of a Saharan Air Layer Outbreak moving off the North African Coast on 02 March 2003. The image shows the vast amount of suspended mineral dust associated with this outbreak and was captured by MODIS aboard NASA's Terra satellite.

1. Jordan's work may need to be revisited based on recent advances in our understanding of the SAL.
2. Since the SAL can cover and area the size of the continental U.S. and can reach as far west as the western Caribbean Sea, Central America and the Gulf of Mexico, it is hypothesized that his 10-yr climatology may have contained a mixture of moist tropical, dry Saharan and dry mid-latitude-originating atmospheric soundings. This suggests that the North Atlantic contains a tri-modal distribution of soundings and that a single mean sounding (i.e. Jordan's) may not effectively represent the atmospheric conditions that occur in this basin during the hurricane season.
3. It is hypothesize that new GOES SAL tracking satellite imagery developed by the PI can be used to identify dry, dusty SAL and dry mid-latitude vs moist tropical atmospheric soundings. It is desirable that these three types of distinct soundings be partitioned to create a new set of mean "hurricane season" atmospheric soundings (moist tropical, SAL and mid-latitude dry air intrusion) for the tropical North Atlantic and Caribbean Sea region.

This study examined ~6,000 rawinsonde (balloon sounding) observations from the Caribbean Sea region taken during the core months (July-October) of the 1995-2002 hurricane seasons. It was found that single mean soundings created from this new dataset were very similar to Jordan's 1958 sounding work. However, recently developed multi-spectral satellite imagery [Figure 2] that can

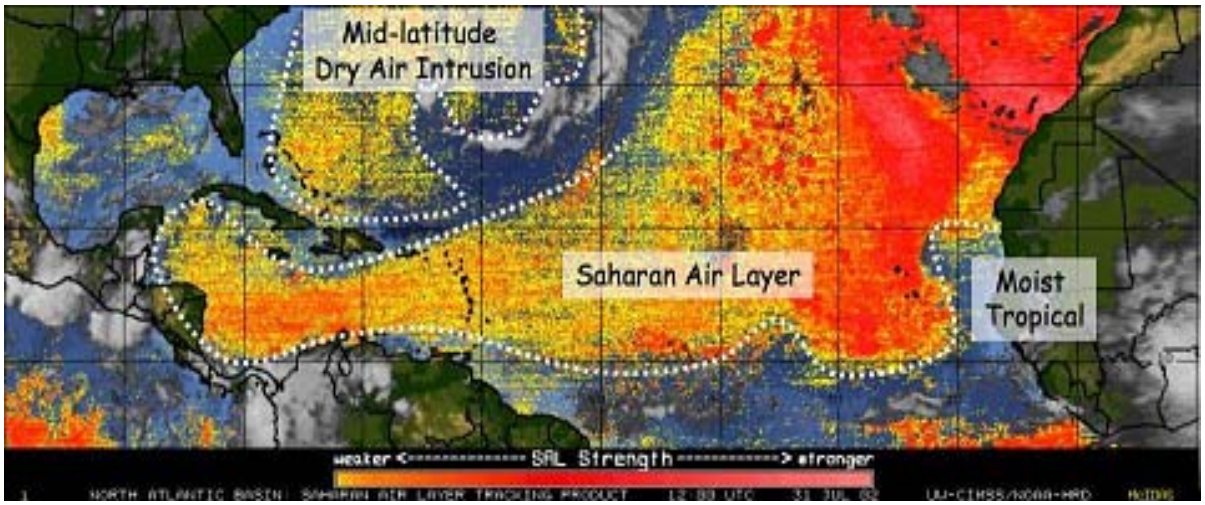
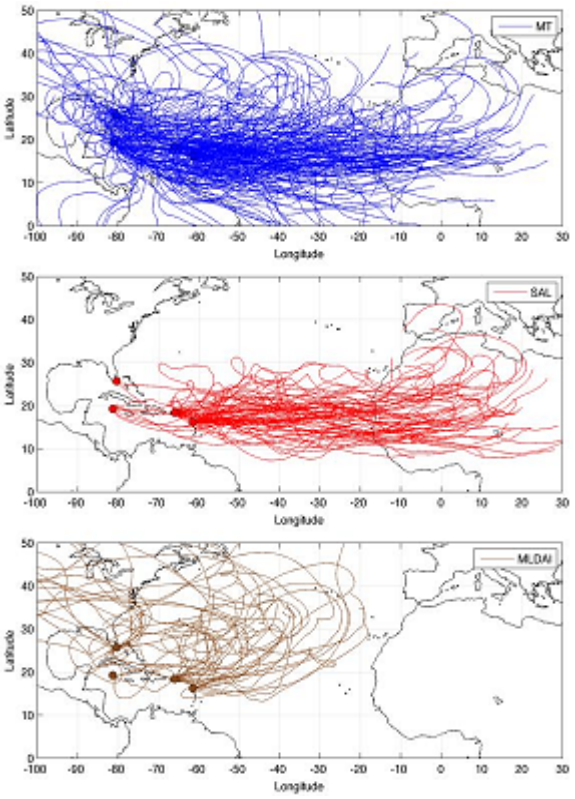


Figure 2: GOES SAL-tracking imagery for 1200 UTC 31 July 2002 indicating a large SAL outbreak spanning from the western Caribbean Sea to the eastern North Atlantic a moist tropical environment off the west coast of Africa (associated with a tropical wave) and a mid-latitude dry air intrusion off the southeast coast of the U.S. The yellow-red shading depicts increasing amounts of dust content and dry lower-tropospheric air, as detected by the GOES imagery.

track low to mid-level dry air masses indicated that the 1995-2002 hurricane season dataset (and likely Jordan's dataset as well) was dominated by three distinct air masses: moist tropical (MT), Saharan Air Layer (SAL) and mid-latitude dry air intrusions (MLDAIs). Findings suggest that each sounding is associated with unique temperature, moisture, wind, stability and mean sea level pressure characteristics and that none of these soundings is particularly well-represented by a single mean sounding like Jordan's. It was also found that the SAL and mid-latitude dry air intrusion air masses have unique and trackable origins in the North Atlantic basin [Figure 3] This work presents three new mean tropical soundings (MT, SAL, and MLDAI) for the tropical North Atlantic Ocean and



Caribbean Sea region and includes information on their temporal variability [Figure 4], temperature, moisture, winds, wind shear, stability, total precipitable water and mean sea level pressure attributes. The new atmospheric sounding information presented in this study represents a new standard for the tropical North Atlantic and Caribbean Sea region and could have important implications related to our understanding of the climatology for this region of the globe. Additionally, this work could help enhance our understanding of intra- and inter-annual climate variability in the region and has relevancy to tropical cyclone forecasting and modeling.

Figure 3: Plots of NOAA HYSPLIT Model 12-day back trajectories (3,000 m) originating from the four rawinsonde (balloon sounding) stations used in this study (Grand Cayman; Miami, FL; San Juan, PR; and La Raizet, Guadeloupe). Trajectories are shown for (top) MT, (middle) SAL, and (bottom) MLDAI air masses that were identified at 1200 UTC 01/10/20/30 July-October 1995-2002.

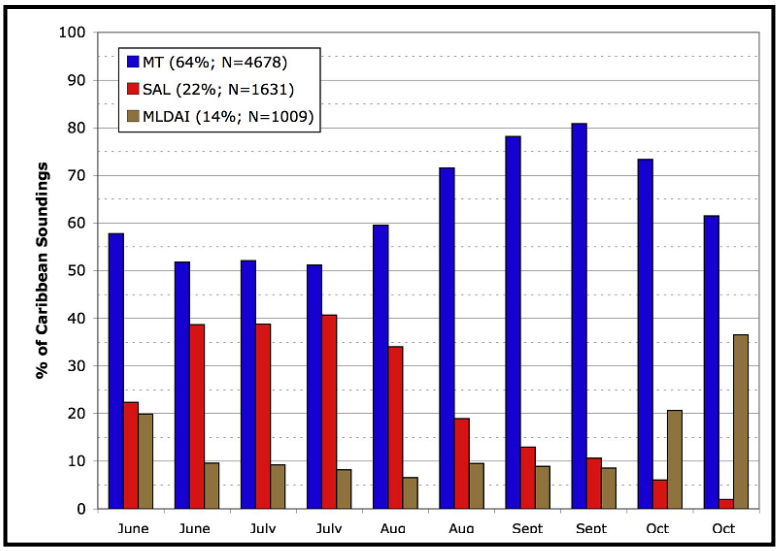


Figure 4: Bi-weekly occurrences of moist tropical, SAL and mid-latitude dry air intrusion atmospheric soundings from June-October (1995-2002) at the Grand Cayman, Miami, San Juan, and Guadeloupe rawinsonde (balloon sounding) stations. For the core months of the hurricane season (July-October) the occurrence of each sounding type (66% moist tropical, N=3927); 20% SAL, N=1212); and 14% mid-latitude dry air intrusion, N=807) was similar to the June-October period (see legend).

Research Performance Measure: Preliminary results of this work based on 1-year of Caribbean balloon soundings was recently published in the Journal of Climate, [Dunion, J.P., and C.S. Marron (2008), A Reexamination of the Jordan mean tropical sounding based on awareness of the Saharan Air Layer: Results from 2002. *J. Climate*. 21(20), 5242-5253]. More recently, portions of the results from this project were presented at the AMS Tropical Conference in Tucson, AZ (April 2010). Additionally, a manuscript describing the results of this work has been accepted for publication in the Journal of Climate.

Design and Testing of a Monitoring Array of the MOC in the South Atlantic

R.C. Perez (UM/CIMAS); S.L. Garzoli and C.S. Meinen (NOAA/AOML);
R.P. Matano (OSU/COAS)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** To determine the optimal location and minimum requirements for a monitoring system designed to measure components of the Meridional Overturning Circulation (MOC) in the South Atlantic Ocean.

***Strategy*:** To conduct observing system experiments within high-resolution ocean general circulation models to design an optimal array.

CIMAS Research Theme:

***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

NOAA Funding Unit: NOAA/AOML **NOAA Technical Contact:** Silvia Garzoli

Research Summary:

A multi-model analysis has been conducted to determine the optimal location requirements for a monitoring system designed to measure components of the MOC in the South Atlantic Ocean. This study evaluated the MOC as reproduced in two high-resolution (eddy permitting to eddy resolving) ocean general circulation models chosen for their skill at simulating boundary currents in the South Atlantic: Parallel Ocean Circulation Model (POCM) and the Ocean general circulation model For the Earth Simulator (OFES). The ability to reconstruct the MOC signal from an array of density profiles (either from direct T, S measurements or estimated from inverted echo sounders), bottom current measurements, and Ekman transports was evaluated at five latitudes, 15S, 20S, 25S, 30S, and 35S. Preliminary analyses were presented at the SAMOC3

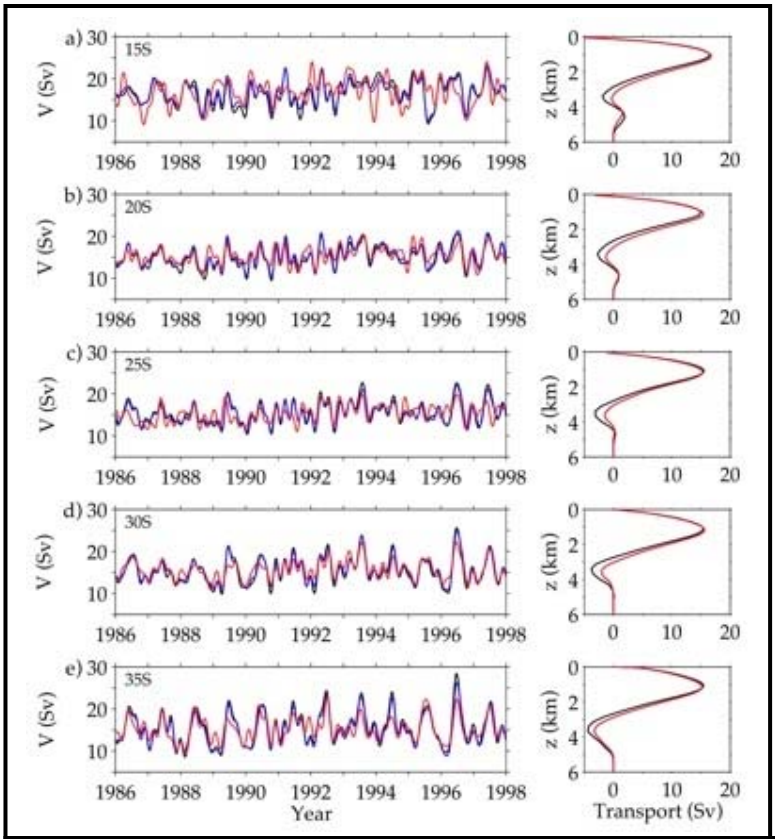


Figure 1: Reconstruction of the OFES MOC signal (black) with a perfect array of direct T,S measurements (blue) vs. a perfect array of CPIES (red) at 15S, 20S, 25S, 30S, 35S.

workshop in Niteroi, Rio de Janeiro, Brazil on May 11-13, 2010. Based on our findings and findings from modeling groups in UK/Southampton and KNMI, a nominal latitude of 35S was selected for the main *in situ* array. This modeling work will continue and contribute to a SAMOC Implementation Plan. Specifically, sampling experiments will be conducted to determine the minimum requirements (e.g., type of measurement, resolution) for the monitoring system.

Research Performance Measure: Based on our findings and findings from modeling groups in UK/Southampton and KNMI, a nominal latitude of 35S was selected for the main *in situ* array. One paper is in preparation for submission to the Journal of Physical Oceanography.

Simulation Experiments for the Pacific Upwelling and Mixing Physics (PUMP) Study

R.C. Perez (UM/CIMAS); W.S. Kessler and M.F. Cronin (NOAA/PMEL)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** To investigate the influence of tropical instability waves on the mean meridional and vertical currents in the central equatorial Pacific Ocean.

***Strategy*:** Conduct simulation experiments to determine the temporal and spatial variability of meridional and vertical currents in the central equatorial Pacific Ocean.

CIMAS Research Theme:

***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/CPO **NOAA Technical Contact:** James Todd

Research Summary:

Shallow tropical cells (TCs) in the central equatorial Pacific Ocean are characterized by strong equatorial upwelling, near-surface wind-driven pole-ward flow, down-welling near the cold tongue boundaries, and equator-ward flow below the surface mixed layer. This qualitative picture is derived primarily from models, which are poorly constrained by observations due to the aliasing of nonlinear tropical instability waves (TIWs), and little is known about the intra-seasonal to inter-annual variability of the TCs. A better understanding of these currents is needed to accurately model and predict the coupled climate system. In anticipation of a mooring array designed to resolve the meridional and vertical structure of the TCs along 140W (see Pacific Upwelling and Mixing Physics scientific implementation plan, http://faculty.washington.edu/kessler/clivar/pump.html), we conducted a suite of simulation experiments using the Modular Ocean Model (MOM4) to determine the mean structure and temporal variability of the TCs. A subsequent analysis of Tropical Atmosphere Ocean (TAO) shipboard Acoustic Doppler Current Profiler (ADCP) measurements grew from the need for model-data validation.

In the simulation experiments, we studied the spinup of the TCs along 140W in response to perturbed trade winds during various phases of the annual cycle. We found that weakening of the trade winds in any season rapidly weakened the TCs, decreased the zonal current shear, and reduced the amplitude and propagation speed of the TIWs. In boreal fall and winter, when the background TCs and TIWs were seasonally strong, the ocean response was equatorially asymmetric and the mean circulation was altered by the nonlinear TIWs (stronger modification of the flow north of the equator, and a reduction of the meridional length scales in the northern TC).

ADCP measurements and output from a MOM4 simulation with inter-annual wind forcing were used to describe the mean structure of the TCs in the central equatorial Pacific (Figure 1 shows model means). When averaged in geographic coordinates, the observed and model TCs were equatorially asymmetric with surface pole-ward flow and subsurface equator-ward flow increasing across the northern front of the equatorial Pacific cold tongue (Figure 1a). When averaged in coordinates aligned with the center of the meandering northern cold tongue front, both observations and model provide evidence of a mean secondary circulation at the front. This secondary circulation enhanced the equatorial asymmetry of the TCs with converging flow and down-welling south of the front (1 in Figure 1b) and diverging flow and upwelling north of the front (2 in Figure 1b). The model is used to demonstrate that this mean quasi-adiabatic secondary circulation is not a frozen field that migrates with the front, but is instead highly dependent on the phase of the TIWs: southward-upwelling flow on the warm side of the front tends to occur when the front is displaced southward, while northward-downwelling flow on the cold side of the front occurs when the front is displaced northward. Consequently, when averaged in geographic coordinates, the observed and simulated TCs show little trace of a secondary circulation near the mean front.

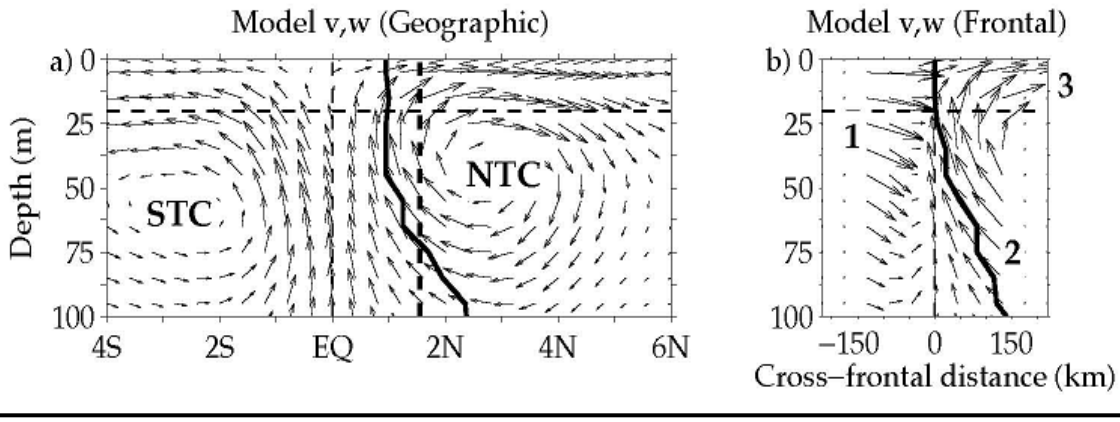


Figure 1: Model mean meridional and vertical velocity structure. Panels compare zonally and temporally-averaged velocity vectors in a) geographic and b) frontal coordinates at the central meridians. Frontal means are plotted relative to the mean position of front (thick dashed line). Thick solid line corresponds to maximum mean temperature gradient. Labels STC and NTC identify southern and northern TCs, respectively. Labels 1, 2, 3 identify components of the secondary circulation associated with the front.

Research Performance Measure: We achieved our main objective: to investigate the influence of tropical instability waves on the mean meridional and vertical currents in the central equatorial Pacific Ocean. One paper has been published in *J. Phys. Oceanogr.*, and another is in press in *J. Phys. Oceanogr.*

Global and Atlantic Ocean HYCOM Simulations in Support of Atlantic Meridional Overturning Circulation Observing System Design

Z.D. Garraffo (UM/RSMAS)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** To contribute to ocean Observing System Simulation Experiments (OSSE) by producing the necessary base ocean global simulation with emphasis on the global Meridional Overturning Circulation (MOC) and its Atlantic component (AMOC).

***Strategy*:** To use HYCOM in several configurations as a basis for OSSE.

CIMAS Research Theme:

***Theme 1*:** Climate Variability.

***Theme 6*:** Integrated Ocean Observations

NOAA Strategic Goals:

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

NOAA funding unit: AOML **NOAA technical contact:** George R. Halliwell

Research Summary:

The Atlantic Meridional Overturning Circulation (AMOC) is one limb of the global overturning circulation and plays an important role in climate variability due to the associated large northward heat flux in the Atlantic basin and its impact on SST. This flow is difficult to monitor because it has complicated three-dimensional flow pathways and the northward upper ocean limb must transit through wind-driven gyres that have large annual cycles at low latitudes. A potential approach to designing new observing strategies is to utilize Observing System Simulation Experiments (OSSEs) for evaluating the impact of new observing systems and Observing System Experiments (OSEs) for evaluating the impact of existing observing systems.

The first steps in an OSSE procedure are:

- Using a state-of-the-art OGCM (the "nature run" model), generate a long non-assimilative ocean simulation that realistically represents phenomena of interest. Assume that this model output represents the "true" ocean.
- Using a second OGCM (the "operational" model), perform a non-assimilative ocean simulation spanning the same time interval as the nature run. Statistically analyze the differences between this run and the nature run. These differences represent the "errors" in the operational model with respect to the nature run. Ideally the magnitude of these errors should be the same as the expected errors in state-of-the-art OGCMs with respect to the real ocean.

Our initial OSSE approach consisted of using the same model code base ("fraternal twin" approach), specifically the HYbrid Coordinate Ocean Model (HYCOM). This code is highly flexible in terms of choosing the vertical coordinate discretization, and also offers multiple choices of numerical algorithms and subgrid-scale parameterizations.

Two simulations were produced, in a global 1/3 degree grid. The first realization consisted of the standard hybrid configuration of HYCOM that maximizes the use of isopycnic coordinates in the ocean interior while transitioning to fixed pressure coordinates near the surface and to fixed pressure

or sigma coordinates over shallow water regions. The second realization mimics the hybrid sigma-z version of a z-level model, by using fixed sigma-pressure vertical coordinates. These two configurations were spun up for at least 15 years (20 years for the 1st simulation) using climatological ECMWF ERA40 forcing including 6-hourly wind anomalies. The simulations are ready to be forced with inter-annual NCEP forcing during the last 60 years.

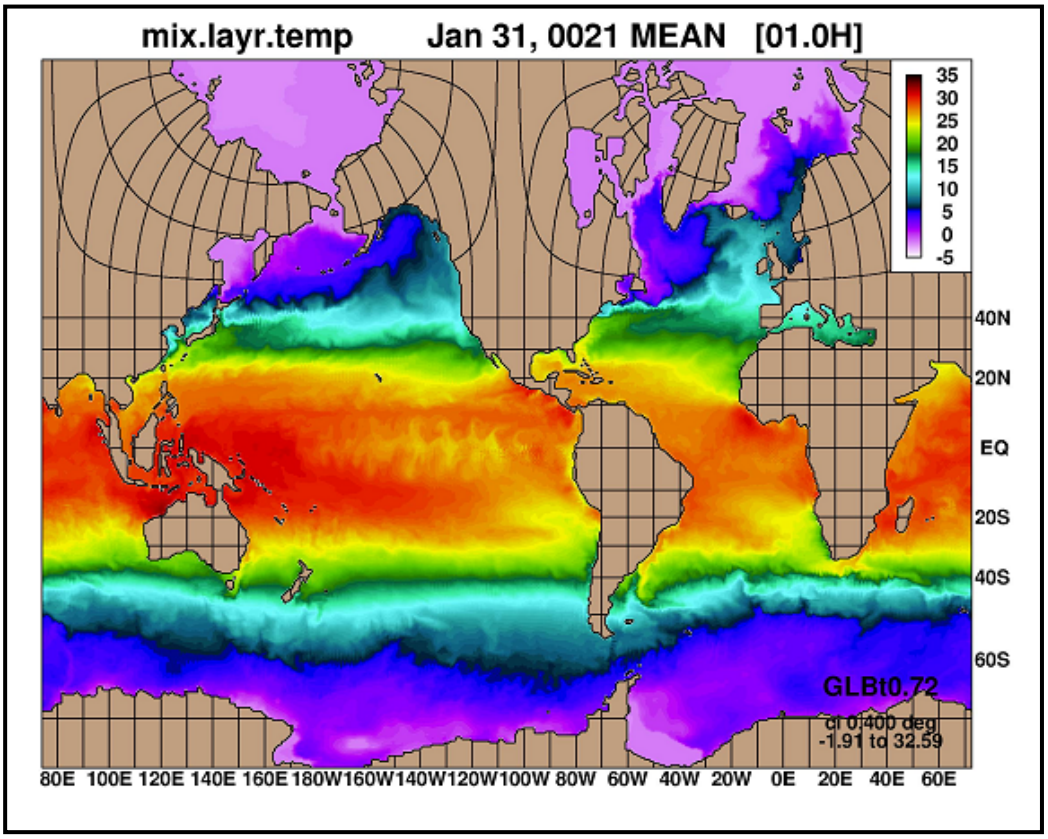


Figure 1: Sea Surface Temperature for one day at the end of 20 years of spin-up, for the Global 1/3 degree HYCOM simulation in the standard HYCOM configuration.

Research Performance Measure: The projected objectives for the period were accomplished. Two successful simulations were produced (three simulations were tested).

Diagnostic and Modeling Studies on Impacts, Mechanisms and Predictability of the Atlantic Warm Pool

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

Long Term Research Objectives and Strategy to Achieve Theme:

***Objectives*:** To understand and improve coupled model simulation of AWP variability and its influence on climate and extreme weather events.

***Strategy*:** To diagnose the IPCC-AR4 simulations for the 20th century and perform coupled model experiments using the NCAR Community Climate System Model (CCSM3).

CIMAS Research Theme:

***Theme 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: NOAA/AOML **NOAA Technical Contact:** Chunzai Wang

Research Summary:

The performance of IPCC-AR4 models in simulating Atlantic warm pool (AWP)-related atmosphere-ocean processes is evaluated in the light of previous observational and diagnostic modeling studies. Among twenty-two IPCC models, only three models reproduce warm pool behavior comparable to observations. It is shown that almost all IPCC models have limited abilityto simulate AWP variability even though models such as NCAR CCSM3 and GFDL CM2 can capture the major characters of AWP variability to some extent. The analyses are important because they will provide a basis for improving our CCSM3 simulations and predictions by providing a backdrop of common pathologies found in global coupled models. The role of regional SST warming variations in the drying of Meso-America in future climate projections is also studied.

By analyzing observational data and performing modeling runs, we show that the AWP has remote and inter-hemispheric influences on the southeastern tropical Pacific where the VOCALS program is focused. The AWP alternates seasonally with the Amazon basin in South America as the seasonal heating source for circulation of the Hadley-type in the Western Hemisphere. Both observations and AGCM models demonstrate that an anomalously large (small) AWP during the boreal summer/fall results in a strengthening (weakening) of the Hadley-type circulation with enhanced descent (ascent) over the southeastern tropical Pacific. It is further demonstrated – by using a simple two-level model linearized about a specified background mean state – that the inter-hemispheric connection between the AWP and the southeastern tropical Pacific depends on the configuration of the background mean zonal winds in the Southern Hemisphere. This research indicates that the model bias in the AWP can influence model bias in the southeastern Pacific where almost of all state-of-the-art coupled models exhibit serious errors in the form of a severe warm bias in simulated SSTs. Thus, the correctly simulating AWP and fixing model bias in the AWP region are important.

The springtime AWP is also explored in additional to the summer/fall hurricane season. The springtime SST anomalies in the AWP region, moisture transport to U.S. and the associated extreme events are examined. During the spring, the AWP SST anomalies feature a dipole SST anomaly pattern, i.e., an opposite SST anomaly pattern between the Gulf of Mexico and the Caribbean Sea.

We found that the dipole forms mostly in response to changes in the air-sea heat fluxes. In the AWP region, the atmosphere manifests the low-level jets. These low-level jets serve to carry moisture from the AWP to the central U.S., which is related to the extreme events such as tornado activity and flood/drought in the central United States.

The Western Hemisphere warm pool includes the regions of the eastern North Pacific warm pool and the Atlantic warm pool (AWP), both places where hurricanes can form and develop. We show that hurricane activity in the Atlantic varies out-of-phase with that in the eastern North Pacific on seasonal, interannual, and multidecadal timescales. That is, when hurricane activity in the Atlantic increases (decreases), hurricane activity in the eastern North Pacific decreases (increases). Both atmospheric vertical wind shear and convective instability contribute to the out-of-phase relationship, whereas relative humidity and vorticity variations at the lower troposphere do not seem to cause the relationship. Our AGCM modeling experiments show that AWP variability can produce the out-of-phase relationship. This research result was highlighted by many media including USA TODAY on March 15, 2010.

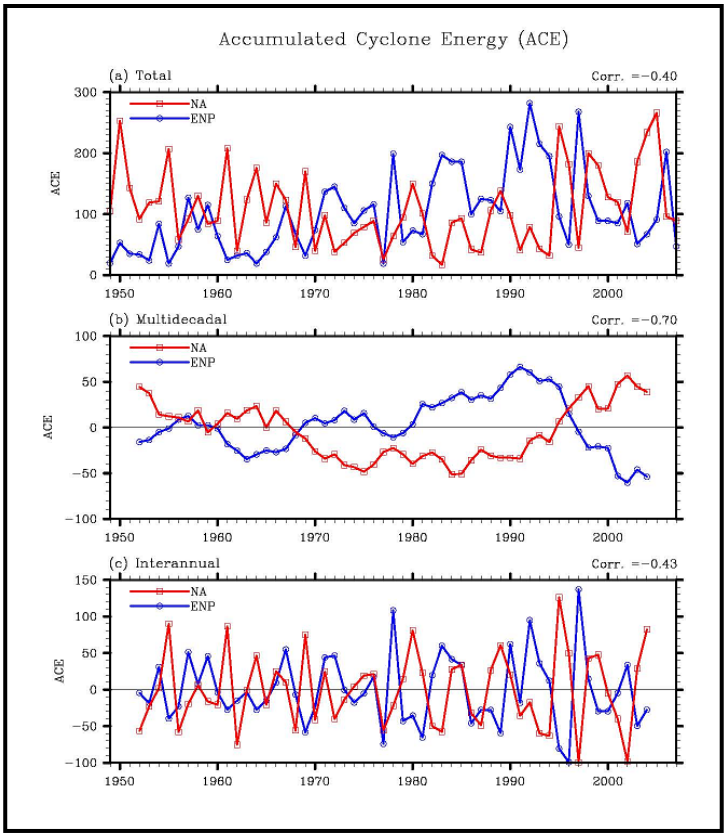


Figure 1: Time series of accumulated cyclone energy (ACE; depicted on the y-axis in units of 10^4 square knots) in the North Atlantic (NA) and eastern North Pacific (ENP) from 1949 to 2007. Shown are the (a) total, (b) multidecadal, and (c) interannual variations. The multidecadal variability is obtained by performing a 7-year running mean after the linear trend is removed from the ACE indices. The interannual variability is calculated by subtracting the multidecadal variability from the detrended ACE indices.

Observations show that AWP multidecadal variability coincides with the signal of the Atlantic Multidecadal Oscillation (AMO); that is, the warm (cool) phases of the AMO are characterized by repeated large (small) AWPs. Since climate models consistently show that warm (cool) AMO phases occur in concert with increases (decreases) in the Atlantic Meridional Overturning Circulation (AMOC), understanding the multidecadal oscillation mechanism of the AMOC is a key to acquiring decadal prediction skill of the AWP and AWP-related climate variability in the 21st century. Previous studies have shown that when the AMO is in its positive (negative) phase, SSTs in the tropical North Atlantic and the AWP also become warmer (cooler). However, our analyses show that the upper ocean averaged over depths of 0-700 m in the AWP and western tropical North Atlantic is cool (warm) when the AMO is in its positive (negative) phase. The subsurface temperature cooling in the tropical region associated with the AMO may result from the AMOC-induced variation through basin-scale thermocline adjustment by coastal/equatorial Kelvin and Rossby wave propagations. We also proposed a simple dynamic model to illustrate the mechanisms that control and affect the natural and forced AMOC variability. The proposed

oscillation relies on alternating actions of positive and negative feedbacks, which operate by a slow adjustment of the baroclinic ocean circulation and the associated delayed advection in response to a meridional density gradient. The proposed delayed advective oscillation model will contribute to the fundamental issue of decadal predictability of the AWP.

Given the relationship between the AWP and AMO, we performed some studies of the North Atlantic Oscillation (NAO) related to the AMO, AWP and the cold/snowy 2009/10 winter. The 2009/10 winter is an unusual winter because it is extremely cold in many places and is the snowiest on record for many cities, e.g., about 72 inches of snow has fallen in Washington D.C. this winter up to 10 February 2010. We show that the record-breaking cold temperatures from North America to Europe and Asia during the period of 28 December 2009 to 13 January 2010 are associated with extremely negative values of the NAO index, which produce northerly surface wind anomalies and cause the southward advection of the cold Arctic air. Corresponded to longer-term variations of Pacific and Atlantic SSTs, the downward trend of the NAO has occurred since the early 1990s. It is speculated that if the downward trend of the NAO continues, more frequent cold outbreaks and heavy snow are likely in the coming years.

Research Performance Measure: We achieved 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. We also investigated other climate related links.

Atmosphere-Ocean Interactions and Summer Rainfall Variability and Predictability in the Intra-American Region?

B. Kirtman (UM/RSMAS)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** To understand how ocean-atmosphere feedbacks impact climate predictability in the Intra-America Seas region.

***Strategy*:** Diagnose air-sea feedbacks using lag-lead regression relationships between heat fluxes, rainfall and sea surface temperatures in observations, coupled model simulations and experiments, and coupled model forecasts.

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/CPO **NOAA Technical Contact:** Jin Huang

Research Summary:
This report describes the progress of the project entitled "Atmosphere-Ocean Interactions and Summer Rainfall Variability and Predictability in the Intra-Americas Region" during the period of June 1, 2009-May 31, 2010. The results are described in the following areas:

Biennial relationship of rainfall variability between Central America and equatorial South America and the mechanisms:
We have examined the relationship of boreal summer rainfall over Central America (7.5°-22.5°N, 110°-80°W; CA for short) and boreal winter rainfall in equatorial South America (7.5°S-7.5°N, 70°-40°W; ESA for short) based on the CMAP rainfall data for the period 1979-2008. A clear biennial relationship is found between the CA JJA rainfall and ESA DJF rainfall anomalies. There are 10 cases of in-phase relationship between JJA CA rainfall and DJF ESA rainfall and 7 cases of out-of-phase relationship between DJF ESA rainfall and the following JJA CA rainfall. The correlation coefficient between JJA CA rainfall and DJF ESA rainfall is 0.62, and the correlation coefficient between DJF ESA rainfall and following JJA CA rainfall is -0.33.

To understand the factors and processes for the formation of the above biennial relationship, we have examined the spatiotemporal evolution of SST, rainfall, wind, surface latent heat flux and shortwave radiation anomalies associated with the CA and ESA rainfall variability. The results indicates that the in-phase relationship between JJA CA rainfall and DJF ESA rainfall tends to occur during the developing years of ENSO and the out-of-phase relationship between DJF ESA rainfall and following JJA CA rainfall tends to occur during the decaying years of ENSO.

Local air-sea relationship in the intra-Americas Seas during the rainy season:
We have examined in detail the local correlation of rainfall and surface heat fluxes (latent heat flux, shortwave radiation, longwave radiation) with SST and SST tendency based on different sources of data (CMAP, GSSTF2, OAFlux, COADS, OI V2, CFS simulation, GFS simulation, CFS retrospective forecasts). The analysis is done separately for different seasons with the focus on the intra-Americas Seas (the Caribbean Sea and the Gulf of Mexico). The correlation in the CFS and GFS simulations as well as in the CFS forecasts is compared with observations to evaluate the performance of the model simulations and forecasts.

The local correlation indicates very different air-sea relationship between the Caribbean Sea and the Gulf of Mexico in observations. Over the Caribbean Sea, the atmosphere and ocean interact with each other, whereas over the Gulf of Mexico, the atmospheric forcing dominates. This is the situation for both the early (May-July or MJJ for short) and late (August-October or ASO for short) rainy seasons. The CFS simulation captures basically the observed air-sea relationship. The GFS simulation produces spurious SST forcing over the Gulf of Mexico. The CFS forecasts capture the air-sea relationship in the late rainy season, but have difficulty in reproducing the SST forcing of atmosphere over the Caribbean Sea in the early rainy season.

Leading modes of rainfall variability in the intra-Americas Seas during the rainy season and relationship to contemporaneous SST anomalies:
An EOF analysis is performed for MJJ and ASO mean percent rainfall anomalies, respectively, to obtain the leading modes of rainfall variability in the early and late rainy season. The leading modes of rainfall variability in both the early and later rainy seasons display the largest loading in the southern Caribbean Sea. This feature is captured in the CFS and GFS simulations as well as the CFS

forecasts. The corresponding temporal evolution, however, displays differences between the CFS forecasts and observations and between the GFS and CFS simulations.

The concurrent SST anomalies obtained by regression/correlation with respect to the leading modes suggest different roles of the tropical North Atlantic and eastern equatorial Pacific SSTs on the Caribbean Sea rainfall. The early season Caribbean Sea rainfall variability is mainly due to the tropical North Atlantic SST anomalies in observations, but is mainly due to the eastern equatorial Pacific SST anomalies in the GFS simulation and CFS forecasts. The late season Caribbean rainfall variability is mainly related to the eastern equatorial Pacific SST, with a secondary contribution from the tropical North Atlantic SST.

Research Performance Measure: Applying new techniques to diagnose air-sea feedback in observations and coupled model forecasts and simulations.

Multi-Model Ensemble Climate Prediction with CCSM and CFS

B. Kirtman (UM/RSMAS)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** To improve intra-seasonal to interannual prediction through a mutli-model ensemble prediction strategy.

***Strategy*:** First, document the capability of the National Center for Atmospheric Research (NCAR) Community Climate System Model version 3 (CCSM3.0) to predict ENSO. This model is a natural candidate for inclusion in the U.S. operational multi-model prediction strategy. Second, document how CCSM3.0 can be combined with the current operational National Oceanic and Atmospheric Administration (NOAA) Climate Forecast System (CFS) to produce improved ENSO forecasts. Third, demonstrate how an ocean initial state using one ocean-component model (i.e., the Geophysical Fluid Dynamics Laboratory Modular Ocean Model; MOM) can be used in a coupled system that uses a different ocean-component model (i.e., Parallel Ocean Program; POP).

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/CPO **NOAA Technical Contact:** Dr. Jin Huang

Research Summary:
The four objectives of this study are all related to expanding multi-model seasonal prediction capabilities. First, we document the ENSO predictive capability of the NCAR CCSM3.0 and more recently CCSM3.5. This model is a natural candidate for inclusion in the U.S. operational multi-model prediction strategy (Higgins, personal communication 2006). Second, we document how CCSM3.0 (and CCSM3.5) can be combined with the current operational CFS to produce ENSO forecasts that are superior to either model alone. Third, we demonstrate how an ocean initial state using a particular ocean component (i.e., the Geophysical Fluid Dynamics Laboratory Modular Ocean Model; MOM) can be used in a coupled system that uses a different ocean component model (i.e., the Parallel Ocean Program; POP). This demonstration has the potential to simplify and broaden the multi-model prediction strategy, because institutions that do not have an independent ocean data assimilation system can more easily participate in prediction research. Fourth, we seek to show how an improved land initialization strategy impacts the forecast skill. Kirtman and Min (2009) describe in detail the results from the first three objectives.

The land surface initial conditions are initialized as follows: soil moisture and soil temperature are derived from the Second Global Soil Wetness Project (GSWP-2) daily data. GSWP-2 reports only soil wetness, so the initial soil moisture for a particular layer and column is considered to be either all liquid or all ice, depending on the corresponding soil temperature at that point. Profile data for different column types are restricted in the same manner as in the Common Land Model (CLM), which is the land surface component of the CCSM. We first compute the normalized anomalies of the GSWP-2 soil moisture from a 10-year climatology, and then combine those anomalies with the mean statistics from a 30-year CLM run, after a 100-year spin-up.

The GSWP-2 soil data are reported for six layers, from top to bottom, with depths of 10, 20, 20, 20, 30, and 50 cm, for a total depth of 1.5 m. The CLM soil column consists of 10 layers, and is 3.4 meters deep, with the bottom two layers spanning 2.0 meters. The initial soil data are created by imposing the GSWP-2 anomaly for the layer containing the depth of the CLM layer on the CLM climatology. Where the CLM layer overlaps two GSWP-2 layers, weighted anomalies are used. The bottom CLM layer is set to model climatology, and layer nine is relaxed to climatology. Initial soil data south of 60°S are set equal to the model climatology.

Initial values for the CLM vegetation variables are taken from a seven-day CAM only spin-up forecast, using the same atmospheric initialization as used in the fully coupled forecast. Initial snow depth and snow temperature are taken from daily values of the ERA-40 reanalysis. We have used the same formulation as the CLM in assigning initial snow depth for up to five snow layers. Snow is assigned to each column type according to the proper CLM formulation. Snow water equivalent is computed using the CLM formulation, after computing snow density from a mean of the ERA-40 skin temperature and 2 meter temperature. The impact of the land initialization is described in Paolino et al. (*Mon. Wea. Rev* 2010, submitted).

Research Performance Measure: The performance metric for this project is developing an initialization strategy for CCSM3.0 (and in the future CCSM4.0) that then can be used to perform multi-model intra-seasonal to interannual prediction experiments.

Why do CGCMs have too much ENSO Variability in the Western Pacific?

B. Kirtman (UM/RSMAS)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** To understand how *noise* due to internal oceanic and atmospheric dynamics impacts climate variability and predictability on inter-annual to decadal time scales.

***Strategy*:** Develop new techniques for controlling the amplitude of the atmospheric stochastic forcing within the context of state-of-the-art coupled general circulation models (CGCM). In the past, this has only been possible in simple theoretically motivated coupled models which required *a priori* assumptions regarding the statistics of the stochastic forcing.

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/CPO **NOAA Technical Contact:** James Todd

Research Summary:

Diagnosing how much low frequency climate variability is due to intrinsic coupled (i.e., interactions among the components of the climate system) modes and how much is stochastically forced by internal dynamics (e.g., weather noise forcing ocean variability or ocean dynamics associated with western boundary current forcing atmospheric variability) remains a challenge in climate research. In this project we have developed a methodology for separating the intrinsic coupled modes from the stochastically forced variability that can be applied at the air-sea, air-land, air-ice or ice-ocean interface. Here, we focus on the air-sea interface and apply the approach to the National Center for Atmospheric Research Community Climate System Model. We find that coupled ocean-atmosphere feedbacks contribute to a significant fraction of the sea surface temperature variability worldwide with increasing importance in the tropics. One of the by-products of the experiments developed here is an improved diagnostic tool for understanding atmospheric teleconnections. In this regard, we find that the mid-latitude atmospheric response to tropical forcing is not simply a function of the magnitude of the forcing.

The new modeling strategy interactive ensemble is used to diagnose how noise due to internal atmospheric dynamics impacts the forced climate response during the 20th Century (i.e., 1870-1999). The interactive ensemble uses multiple realizations of the atmospheric component model coupled to a single realization of the land, ocean and ice component models in order to reduce the noise due to internal atmospheric dynamics in the flux exchange at the interface of the component models. An ensemble of so-called climate of the 20th century simulations of the community climate simulation model version 3 (CCSM3) are compared with a similar simulation with the interactive ensemble version of CCSM3. Despite substantial differences in the overall mean climate, the global mean trends in surface temperature, 500 mb geopotential and precipitation are largely indistinguishable between the control ensemble and the interactive ensemble. Large differences in the forced response; however, are detected particularly in the surface temperature of the North Atlantic. Associated with the forced North Atlantic surface temperature differences are local differences in the forced precipitation and a substantial remote rainfall response in the deep tropical Pacific. We also

introduced a simple variance analysis to separately compare the variance due to noise, coupled natural variability and the forced response. We find that the noise variance is decreased when external forcing is included and that the variance due to coupled natural variability is decreased in the interactive ensemble relative to the control. In terms of the forced variance, we find that the interactive ensemble increases this variance relative to the control. These results are described in detail in Kirtman et al. (*Climate Dynamics, 2010, submitted*).

Several recent studies have focused on the importance of *atmospheric* model resolution in the simulations of climate - our emphasis is on ocean model resolution. Three experiments have been completed and the results are being prepared for publication. The first experiment is a 155-year simulation of the 0.5^{o} atmosphere coupled to the 1^{o} ocean. The initial condition is taken from a previous coupled simulation. This is done so that ocean state is fully "spun-up" thus minimizing the initialization shock; however, as will be shown, some climate drift is apparent. The second simulation is a 112-year simulation using the same atmospheric model coupled to the 0.1^{o} ocean. The initial condition is the same of the control simulation except that the ocean state has been interpolated to the higher resolution. This interpolation does lead to a significant period of adjustment. The third simulation begins at year-102 of the high resolution run using the same resolution parameters except in this case the polar winds have been filtered to reduce computational instability. Significant improvements in the high-resolution simulation are worth noting. For example, the resolved Gulf Stream eddies result in much sharper temperature gradients along the coast of North America and in the Gulf Stream separation region. Perhaps most interesting is that the enhanced ocean eddy activity results in a decrease in the coupled feedbacks in the far western tropical Pacific. This decrease in coupling reduces the systematic bias associated with ENSO events that extend too far to the west along the equator.

Research Performance Measure: Developing interactive ensemble versions of the NOAA Climate forecast system (CFS) and the NCAR Community Climate System Model (CCSM). Publishing several papers documenting the impact of climate noise on ENSO predictability and prediction skill, intra-seasonal variability and decadal modulation of ENSO. Quantifying the limit of ENSO prediction skill due to uncertainty as the forecast evolves versus uncertainty in the initial condition. All measures were met without exception.

Understanding Discrepancies between Satellite-Observed and GCM-Simulated Precipitation Change in Response to Surface Warming

B.J. Soden (UM/RSMAS); G. Vecchi (NOAA/GFDL)

Long Term Research Objectives & Strategy to Achieve Them:

***Objectives*:** Understand the cause of discrepancies between observed and model-simulated precipitation variability over the tropical oceans.

***Strategy*:** Compare satellite observations with empirical analyses and climate model simulations to evaluate the veracity and cause of decadal variations in the tropical precipitation.

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: CPO**

Research Summary:
Future substantial changes in the global water cycle are an expected consequence of a warming climate; this is based upon understanding of the governing physical processes and projections made by sophisticated models of the Earth's climate system. Monitoring changes in tropical precipitation is a vital step toward building confidence in regional and large-scale climate predictions and the associated impacts on society.

A number of robust large-scale responses of the hydrological cycle have been identified in models, relating primarily to increases in low-level moisture with temperature, a consequence of the Clausius-Clapeyron equation. Improving confidence in climate projections demands the use of observations, sampling the many aspects of the global energy and water cycles, to evaluate the relevant processes simulated by models. It is important to establish causes of disagreement, for example relating to observing system deficiencies or inadequate representation of forcing and feedback processes in models. There is observational evidence of increased tropical monthly-average moisture and precipitation and an amplification of extreme precipitation events in response to atmospheric as well as a contrasting precipitation response over wet and dry regions of the tropics. While observed precipitation responses appear larger than those simulated by models it is unclear whether this relates to model deficiency, inadequacy in the observing system or is a statistical artifact of the relatively short satellite record.

In Allan et al. (*Envir. Res. Lett.*, 5, doi: 10.1088/1748-9326/5/2/025205, 2010) and Chung et al. (*Geophys. Res. Lett.*, **37**, L02702, doi:10.1029/2009GL041889, 2010) we examine current changes in tropical precipitation and its extremes, and the radiative feedbacks which govern them. In particular we addressed the questions: (1) What are current trends in tropical mean precipitation? (2) Are the wet regions becoming wetter at the expense of the dry regions? (3) Is there an intensification in extreme precipitation with warming in models and observations over the period 1979-2008? (4) How consistent are observed and model-simulated rates of radiative feedbacks?

Current changes in tropical precipitation from satellite data and climate models were assessed. Increased precipitation in moist, ascending regions and reductions in drier descending branches of the large-scale circulation, previously identified, were sensitive to the reanalysis products used to define these regions. To avoid homogeneity issues with reanalysis fields, wet and dry regions of the tropics were defined as the highest 30% and lowest 70% of monthly precipitation values. Observed tropical ocean trends in the wet regime (1.8%/decade) and the dry regions (-2.6%/decade) for the Global Precipitation Climatology Project (GPCP) over the period including Special Sensor Microwave Imager (SSM/I) data (1988-2008) were of smaller magnitude than when including the entire time-series (1979-2008) and in closer agreement with model simulations than previous comparisons. Analyzing changes in extreme precipitation using daily data within the wet regions we found that SSM/I observations indicate an increased frequency of the heaviest 0.2% of events of

approximately 60% per K warming. This is at the upper limit of the model simulations which display a substantial range in responses. However, we find that the radiative feedback processes which govern variations in clear-sky longwave damping are highly consistent between observations and models.

Research Performance Measure: The following research performance measures were accomplished on schedule: 1) Compared observed decadal variations in mean precipitation and extreme precipitation events from multiple satellite observations and GCM simulations. 2) Submitted manuscripts documenting these results to *Geophys. Res. Lett. and Env. Res. Lett*.

Role of Diabetic Heating Profiles in MJO Simulation and Prediction

C. Zhang, R. Chattopadhyey (UM/RSMAS); A. Vintzileos (NOAA/NCEP)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** To identify a possible root cause for reduced prediction skill in NCEP GFS on intraseasonal timescales

***Strategy*:** To diagnose diabatic heating profiles in the model in comparison to 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 (*Primary*)

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

NOAA Funding Unit: OGP **NOAA Technical Contact:** Dr. Jin Huang

Research Summary:

Observations of heating profiles as validation of numerical models have been diagnosed. Samples of model output have been tested. We are in a process of porting a huge amount of data from NCEP to RSMAS for diagnostics.

Research Performance Measure: The project is behind its planned timeline mainly because it took almost a year to hire the postdoctoral associate who is responsible for a major portion of the proposed work. The postdoc arrived at RSMAS in May 2010.

Predicting the Effects of Climate Change on BluefinTuna (Thunnus thynnus) Spawning in the Gulf of Mexico Using Downscaled Climate Models

B. Muhling and S.-K. Lee (UM/CIMAS);
J. Lamkin, W. Ingram and M. Schirripa (NOAA/SEFSC)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** To quantify potential impacts of climate change on bluefin tuna spawning habitat in the Gulf of Mexico.

***Strategy*:** To downscale global climate models to the scale of the Gulf of Mexico, and predict changes in spawning habitat using habitat preference models.

CIMAS Research Theme:

Theme 1: Climate Variability (*Primary*)
Theme 2: Fisheries Dynamics (*Secondary*)

Link to NOAA Strategic Goals:

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

***Goal 1*:** Protect, Restore, and Manage the Use of Coastal and Ocean Resources through an Ecosystem Approach to Management (*Secondary*)

NOAA Funding Unit: SEFSC **NOAA Technical Contact:** John Lamkin

Research Summary:

We will be projecting the impact of climate change on environmental indicators in the northern Gulf of Mexico (GOM). Initially, this project will apply statistically downscaled climate predictions to bluefin tuna habitat models in the GOM. This will allow predictive forecasts to be integrated into stock assessment models under various climate change scenarios, and quantitative forecasts of favorable bluefin tuna spawning habitat.

Our research objectives are to:

1) Downscale IPCC climate models to a regional scale, focusing on the GOM.
2) Formulate seasonal and decadal predictions of sea surface temperature and salinity across the GOM under a range of scenarios, derived from the downscaled model.
3) Use an existing larval habitat model to calculate the increase, or decrease, in the spatial and temporal extent of suitable larval habitat, under conditions predicted by the downscaled model. This will allow us to estimate potential effects of climate change on spawning activity of adult bluefin tuna in the GOM, by use of a simple index (size of suitable habitat across the spawning season).

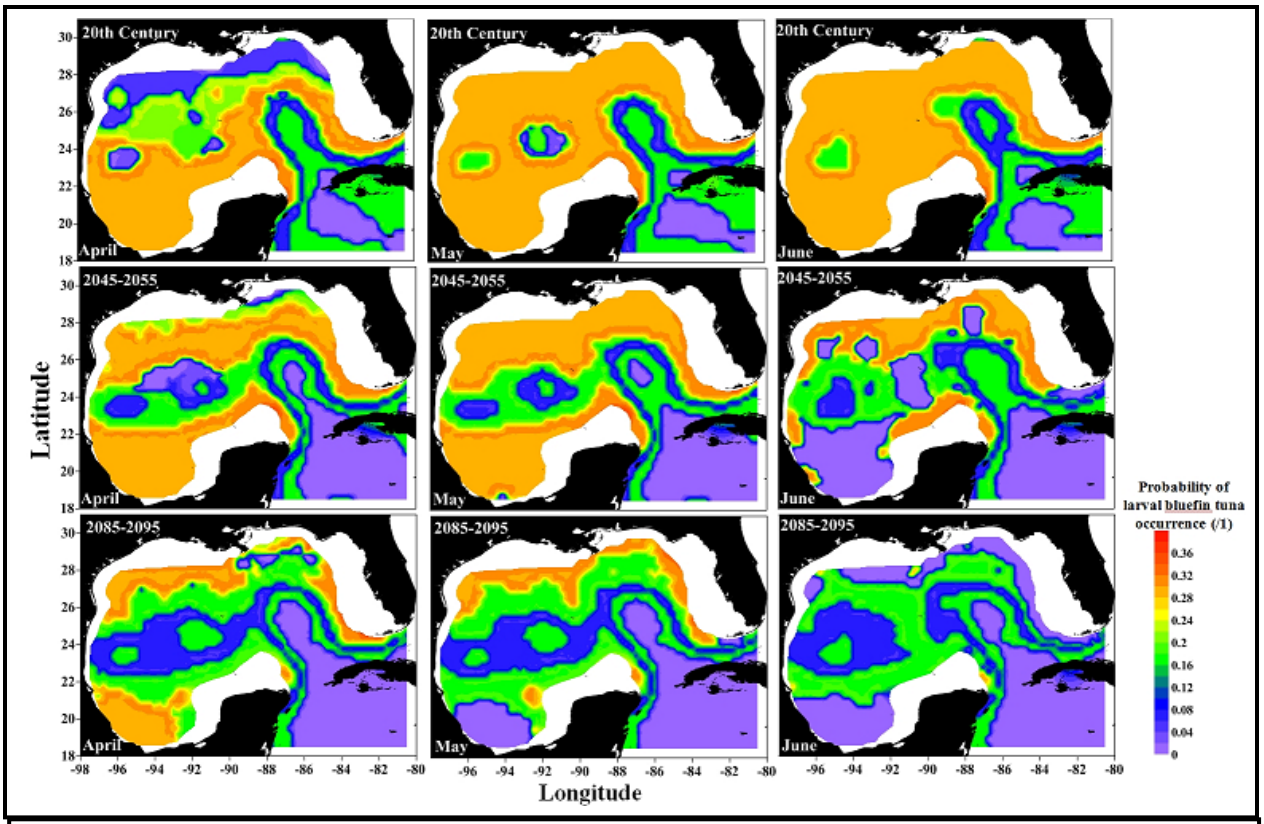


Figure 1: Predicted bluefin tuna spawning habitat extent in April, May and June for the late 20th century (top), 2045-2055 (middle), and 2085 – 2095 (bottom). Habitat suitability is measured by probability of larval occurrence (/1), and is using interpolated temperature data from an ensemble of 19 climate models.

Research Performance Measure: This is a new project that just began a few months prior to the end of the fiscal year. The performance will be evaluated by the degree to which the modeled formulations and predictions prove useful in the mandated assessment process.

THEME 2: FISHERIES DYNAMICS

Development and Evaluation of New Technology for the Remote Identification and Enumeration of Larval Fish

R.K. Cowen and C. Guigand (UM/RSMAS);
G. Tsechpenakis (UM/CCS); J. Hare (NOAA/NEFSC)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** To support the development of imaging technology software for the remote enumeration of larval fish. To evaluate the ISIIS technology in the context of ongoing efforts to improve stock assessments.

***Strategy*:** Since the imaging system produces very high resolution imagery at very high data rates necessitating automated image analysis. Our approach aims at the detection of multiple regions (organisms) of interest automatically, while filtering out noise and out-of-focus organisms, and the classification of the detected organisms into pre-defined categories using shape and texture information. Last year we conducted an initial evaluation of ISIIS as an assessment tool for Atlantic Herring on Georges Bank. Atlantic herring larvae are a dominant component of the ichthyoplankton in the late fall / early winter on Georges Bank and have a unique shape compared to other ichthyoplankton present in the area at that time of year. These factors would, we thought, maximize the ability of ISIIS to image and automatically classify herring larvae and our comparison of traditional and ISIIS sampling is confirming that assumption.

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 an Ecosystem Approach to Management

NOAA Funding Unit: NMFS/Advanced Sampling Technology Working Group (ASTWG)
NOAA Technical Contact: Frank Parrish

Research Summary:

ISIIS is a towed digital imaging system capable of quantifying larval fish *in situs*, via high volume imaging (~70 l s-1) at high resolution (effect <70 µm per pixel). The basic design includes: shadowgraph lighting, a combination of various state-of-the-art digital imaging and computer technologies (i.e. incorporating machine vision technology with line scan cameras), and fiber-optic data communication. The towed vehicle also carries sensors that measure temperature, salinity and depth. Preliminary deployments off the east coast of Florida demonstrate that ISIIS takes clear, identifiable and quantifiable images of larval fish. The major challenge to broad applicability of ISIIS is the development of software that automates target recognition, identification and enumeration. Our first objective addresses this challenge. A second challenge involves evaluating the utility of ISIIS in a fisheries management application. This challenge is addressed by our second objective.

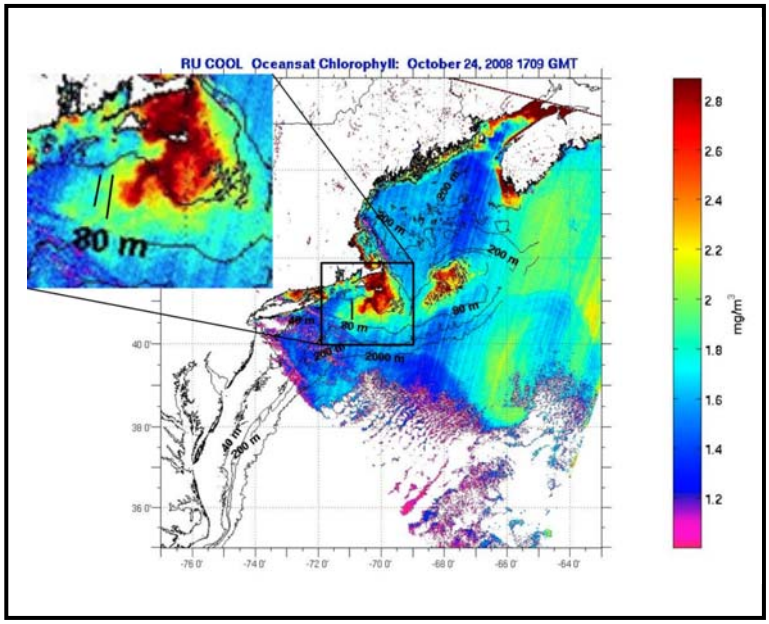


Figure 1 – Oct 2009 NOAA cruise tract overlain on Ocean Color image of study area.

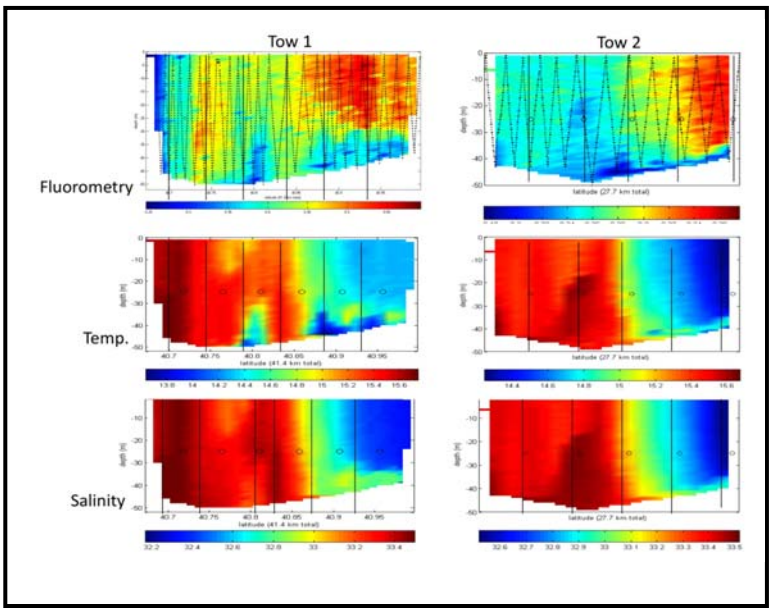


Figure 2: Vertical profiles of fluorometry, temperature and salinity for each of two transects. Note the undulation pathways depicted by the dotted lines in the top panels.

Preliminary sample analyses – During Oct 2008, we used ISIIS in conjunction with a NOAA cruise collaborating with Dr. Jon Hare (NOAA/NMFS). We conducted two ~ 40 km transect south of Rhode Island (SW of Woods Hole), and conducted replicate BONOG tows to collect comparison ichthyoplankton samples. All plankton samples were sorted and identified, and counted. Similarly, all images were manually and automatically counted (using image analysis). Figure 1 shows a satellite (color) image of the study area with the blow-up designating where each ISIIS transect was run. Note the transect moved inshore-offshore and thereby transited from high nutrient to lower nutrient waters. Along each transect, we undulated ISIIS form the surface to ca. 40 m depth or within 10 m of the

bottom (when bottom depth was less than 50 m). Profiles of tempera-ture, fluorometry and salinity reveal both vertical and horizontal structure (see Figure 2).

Actual locations of individual larval fish observed by ISIIS are depicted in Figure 3, overlain on the fluorometry. This visualization gives unprecedented detail on where in the water column different species of larval fish are located.

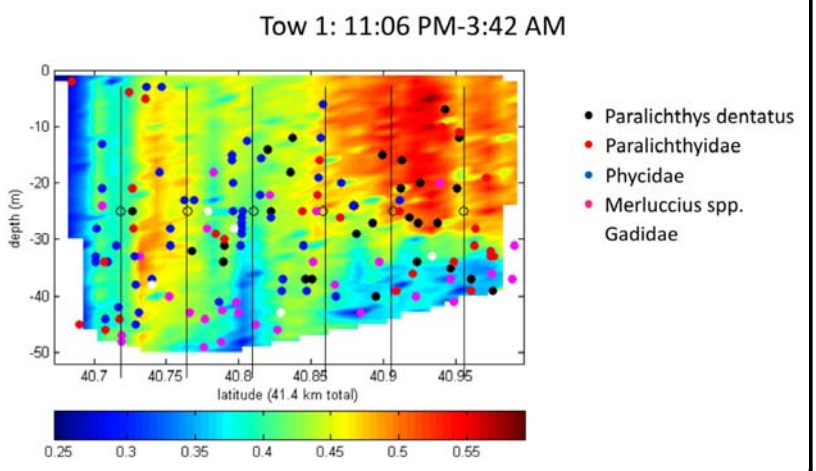


Figure 3: Species-specific, depth-specific occurrences of larval fish along transect, overlain on fluorometry. Individual species are color-coded.

To compare the ability of ISIIS to capture both numerically and with sufficient resolution to identify larval fish at comparable rates as the standard BONOG net method, we compared actual catches of the two methods (Table 1). Overall, while some small larvae were difficult to identify in the imagery, the taxonomic distribution and relative number of each taxon were comparable. The total estimated density, however, was lower with ISIIS. Initially we were not sure what to make of this, but then we realized that the BONGO nets were sampling deeper in the water column than ISIIS – so we examined the trend in catch (density) with depth (Figure 4), and found that it increased with depth such that our interpretation is that had we taken ISIIS into deeper water (i.e. as we did with the BONGO net) we would have collected overall comparable densities.

Table 1: Comparison of catch/imagery by fish taxon for BONGO net and ISIIS

ISIIS vs. Bongo tows

Sample method	ISIIS	Bongo
Volume sampled (m^3)	2406	1506
maximum depth (m)	49	61
Clupeidae	3	1
Etropus spp.	8	10
Gadidae	12	3
Gobiidae	6	3
Lepophidium spp.	34	7
Merluccius spp.	44	48
Paralichthyidae (unable to ID lower than family)	62	1 (damaged)
P. dentatus	65	188
Phycidae (unable to ID lower than family)	83	0
Scopthalmidae	10	31
Urophysis spp.	21	48
Unknown	57	0
Total fish larvae	409	359
Avg. fish density	0.1700	0.2384

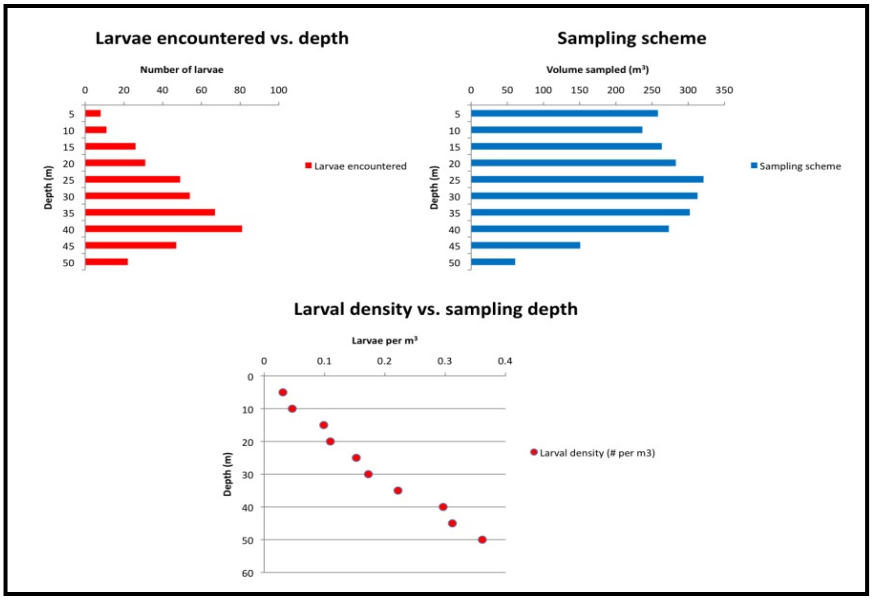


Figure 4: Analysis of number of fish larvae seen by depth stratus in ISIIS imagery. Upper left panel is total number observed by depth, upper right panel is volume of water sampled by depth. Lower panel combines above panels to estimate larval density by depth.

Research Performance Measure: Results are still too preliminary to make any final judgments about objective success with regard to ultimate utility for management. However, the work seems to be progressing very well and the comparison/quantification of techniques is very encouraging.

Development of Biological and Physical Indices for Stock Evaluation in the Dry Tortugas Pink Shrimp Fishery. FATE Project

M.M. Criales, C.B. Paris and L. Cherubin (UM/RSMAS); J.A. Browder (NOAA/SEFSC)

Long Term Research Objectives and Strategy to Achieve Theme:

***Objectives*:** To refine stock assessments of the pink shrimp stock in south Florida in relation to environmental and climatic variation to better inform fishery managers about the factors contributing to stock changes.

Strategy: to develop physical and biological indices for of recruitment from existing data and a biophysical Lagrangian model for the species.

CIMAS Research Theme:

Theme 2: Fisheries Dynamic

Link to NOAA Strategic Plan:

***Goal 1*:** Protect, Restore, and Manage the Use of Coastal and Ocean Resources through an Ecosystem Approach to Management

NOAA Funding Unit: SEFSC **NOAA Technical Contact:** Joan Browder

Research Summary:

A coupled biophysical Individual-Based Model (IBM) has been developed to simulate the life history and migratory movements of pink shrimp (*Farfantepenaeus duorarum*) in south Florida. Pink shrimp migrate from spawning grounds on the southwest Florida shelf off the Dry Tortugas and nursery grounds in Florida Bay. The model will help determine the main environmental factors that affect their journey and successful recruitment to the bay.

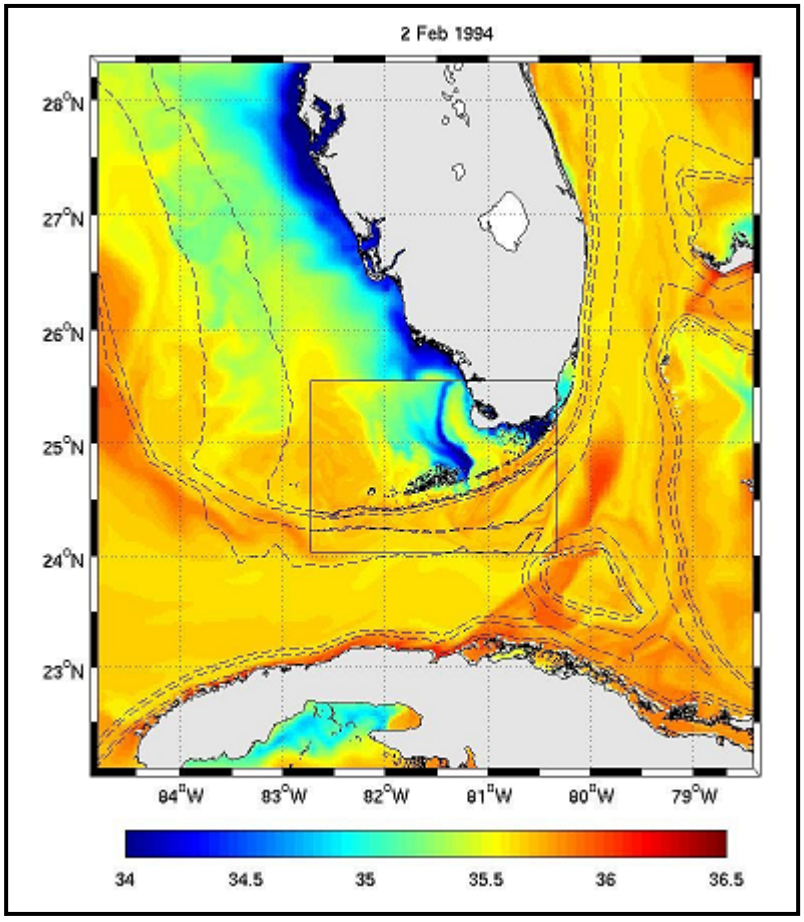


Figure 1: ROMS model output depicting sea surface salinity SST (February 2, 1994), bathymetry and parent and nested models.

The Regional Ocean Modeling System (ROMS), a coastal hydrodynamic model with tidal flux, is the physical hydrodynamic component of the biophysical model. This model has been adapted and tested for the region. A 2-grid-level model was developed for the Florida Keys region. First, a parent circulation simulation grid at 2.8 km horizontal resolution grid was set up and then a 0.7 km horizontal resolution grid was nested within the parent model (Fig. 1). The circulation model is forced at the surface by the NCEP North American Regional Reanalysis (NARR) which provides a very accurate wind speed and direction in the coastal waters of South Florida. The model's lateral boundaries are provided by the HYCOM TOPAZ Atlantic Ocean 1989-to present reanalysis. Freshwater input is a critical component of the regional dynamics and affects the circulation in Florida Bay and the inner SW Florida Shelf. Therefore, the current simulation now includes the southern Florida watersheds up to the Peace and Myakka Rivers, the Big Cypress and Shark Slough drainages, and water flow to Florida Bay from Everglades National Park. Model results are showing a highly dynamic circulation on the SW Florida shelf with spin off eddies traveling along the edge of the Florida Current (Fig 2). The model is also showing that circulation at the middle shelf bifurcates upon approaching the Florida Keys with a portion of the flow turning to Florida Bay and another porting turning further offshore.

The biophysical model simulates the selective tidal stream transport (STST) of pink shrimp larvae on the SW Florida shelf. In STST transport, pink shrimp postlarvae move up in the water column during the flood tide to progress inshore and sink to the bottom of the water column during ebb tide to avoid being carried offshore. Our previous research suggested that STST was important to pink shrimp migration across the SW Florida Shelf. The pink shrimp model is tide driven and based on the phase of the tide and larval developmental stage at each individual particle (shrimp larvae) location. Test-runs of the IBM were conducted with 7 days of hourly outputs of the ocean circulation model. Simulations of particles with a STST behavior showed that larval transport patterns varied substantially in direction and distance, even when starting from nearby locations, compared to passive particles. Longer time scale simulations are ongoing since the literature suggests it takes about 30 days for young pink shrimp to reach the bay. Decadal ROMS simulations coupled with the pink shrimp IBM will be used to assess the effect of environmental factors on pink shrimp stock variability over the 1995-2005 period.

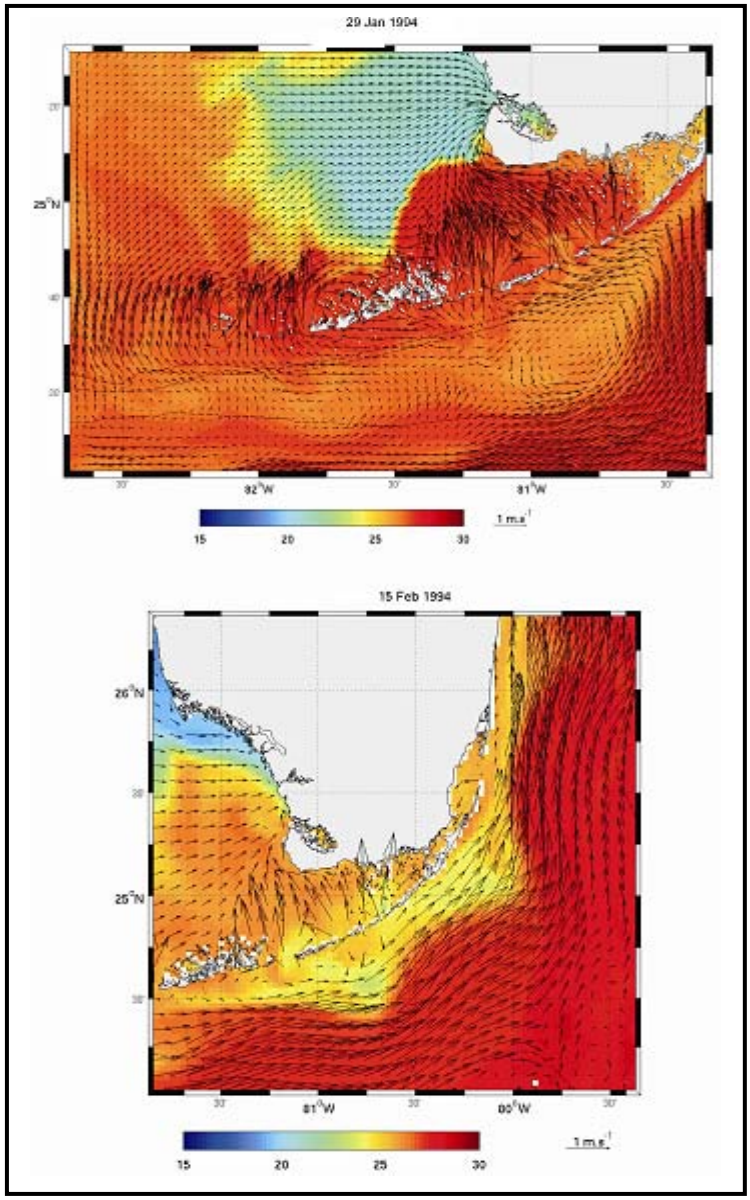


Figure 2: ROMS modeling results (January 29 and February 15, 1994) for sea surface temperature and surface current velocity including tides. Model outputs clearly indicate spin off eddies traveling along the edge of the Florida Current and onshore currents with a strong northward flow on the inner SW Florida shelf.

Research Performance Measure: We have met our primary objectives.

Monitoring Shoreline Fish Assemblages of Biscayne and Florida Bays

D. Johnson, B. Teare and L. Visser (UM/CIMAS);
J. Luo (UM/RSMAS); J. Serafy (NOAA/SESFC)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** Shoreline Fish Community Visual Assessment (SFCVA) monitoring component is part of the REstoration, COordination and VERification (RECOVER) program of the Comprehensive Everglades Restoration Plan (CERP). Specific objectives of the SFCVA monitoring component are: (1) to continue the seasonally-resolved, 12-year visual fish monitoring effort that, for the most part, has focused on southern Biscayne Bay; (2) to expand this effort spatially to include sites in northern Biscayne Bay, Card Sound, Barnes Sound and northeastern Florida Bay; (3) to perform data analyses that evaluate variability in these fish communities before, during, and (ultimately) after CERP-related changes to freshwater flow (and salinity) are implemented; and (4) to correlate changes in salinity with changes in the shoreline ichthyofauna. These objectives are being met via calculation of the minimum numbers of samples required to detect change, review of historical literature and existing datasets, collection of new data, and analyses of the "baseline condition" of shoreline fish assemblages at both the community and taxon-specific levels. Its purpose is to provide long-term baseline data and to evaluate the CERP-related impacts on bay systems which are likely to be the strongest and most easily discerned along the mangrove-lined shorelines of South Florida's mainland.

***Strategy*:** Maintain long-term data monitoring program and develop fish habitat suitability index models with an emphasis on revealing abundance-salinity relationships, through analysis of existing empirical data collected from Biscayne Bay and adjacent systems.

CIMAS Research Theme:

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

Link to NOAA Strategic Plan:

***Goal 1*:** Protect, Restore, and Manage the Use of Coastal and Ocean Resources through an Ecosystem Approach to 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:** Joseph Serafy

Research Summary:

1. Annual trends in Taxon-Specific Abundances

Densities of all taxa have been found to be relatively stable over the time series when plotted against time. All of the taxa examined showed some level of seasonal variation in density and frequency of occurrence and concentration tended to track each other. No clear annual trends emerged within shoreline segments. Densities of the four major taxa were higher at the leeward key shorelines than the mainland shorelines. Along the Mainland shoreline, 75% of the fish community metrics estimated for 2009 fell within the 95% confidence intervals of the historical mean, 25% were higher, and 8% were lower.

2. Habitat Suitability Models

We used a delta approach to generate a triad of habitat suitability index (HSI) models per species. The approach allowed for the testing of three HSI models per combination because three "abundance metrics" are considered: frequency of occurrence, concentration (density when present, exclusive of zeros) and "delta-density" (occurrence x concentration). In the present project, and provide results in both graphic and mathematical form. This was achieved using the 11.5 years of visual census fish monitoring effort.

We detected statistically-significant trends across salinity gradients in one or more abundance metrics six taxa. Where observations under hypersaline conditions were available, most of the statistically-significant salinity trends for individual taxa showed abundance declines beyond 36 psu. The metrics tended to show linear or parabolic relationships with salinity for Biscayne Bay fishes.

3. Community Analyses

We calculated average taxonomic richness across years for the composite and subdivided mainland shoreline and the leeward key shoreline. We examined seasonal and annual variation of yearly indices of taxonomic richness and dominance using multivariate regression and analysis of variance. We found that richness was higher along the Leeward Key where the environment was more stable than along the Mainland Shoreline.

We did not find annual or seasonal differences in richness along the Leeward Key. We found that dry season differences in samples were correlated with temperature, salinity, depth, and the interactions of year x temperature and salinity x depth, while wet season differences were only related to salinity.

We found no significant annual differences in richness in the dry season along the Mainland Shoreline, but there were differences in the wet season. We found that dry season differences were primarily due to salinity, depth, dissolved oxygen, temperature, and the interaction of depth and salinity. Wet season differences were correlated with salinity, depth, dissolved oxygen, and the interaction of salinity and depth.

4. Canal Analyses

We found more taxa near low-flow canals than near high-flow canals, especially in the wet season, suggesting that the quantity of freshwater flow has a negative effect. We found impacts from high-flow canals as far as 2000 m in the wet season.

Research Performance Measure: Our primary objectives were to continue our baseline visual census surveys and develop habitat suitability models to evaluate the impact of salinity on major organisms in Biscayne Bay. These objectives were accomplished. We have completed year 12 of our visual census survey and developed models for the six major species. The modeled relationships were found to be significant.

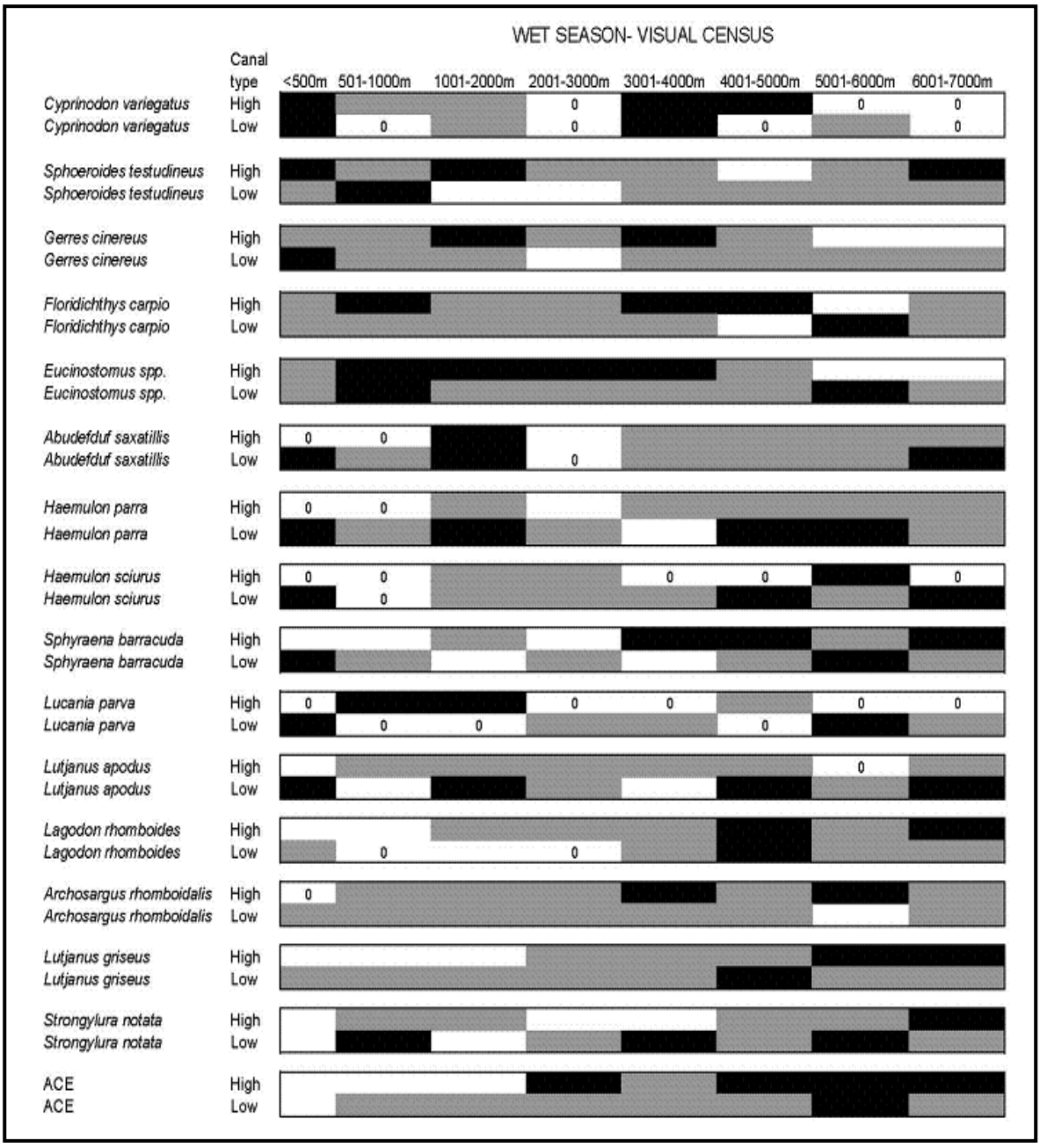


Figure 1: Relative abundance ranked using quartiles of selected wet season Biscayne Bay species sampled in visual census surveys in relationship with distance from high-flow and low-flow canals. Black is in the 75% quartile (high density), gray 25-75% (medium density), and white 25% (low density). Low density bins that are zero are indicated. ACE is a group of silvery fishes composed of athernids, clupeids, and engraulids.

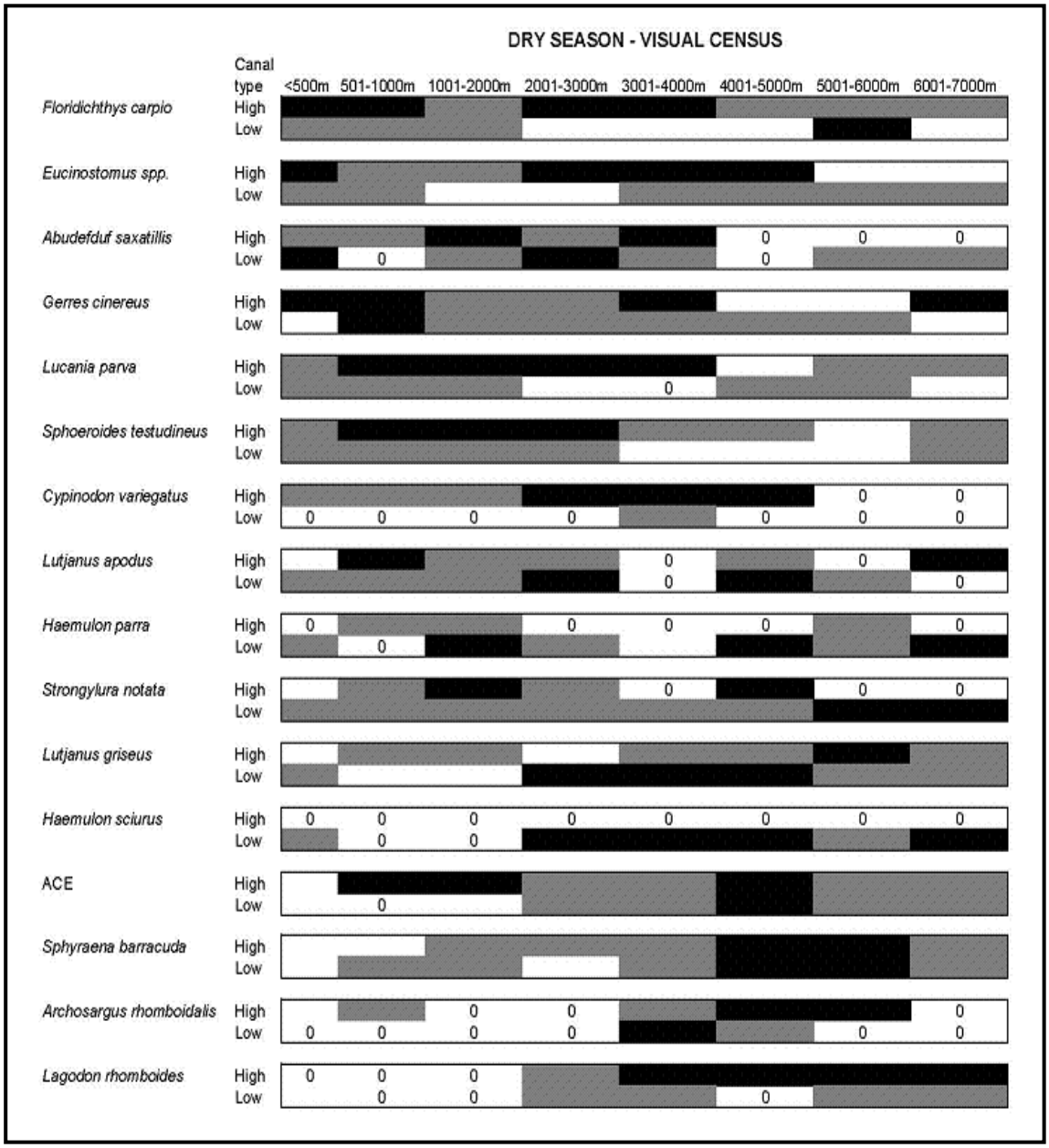


Figure 2: Relative abundance ranked using quartiles of selected dry season Biscayne Bay species sampled in visual census surveys in relationship with distance from high-flow and low-flow canals. Black is in the 75% quartile (high density), gray 25-75% (medium density), and white 25% (low density). Low density bins that are zero are indicated. ACE is a group of silvery fishes composed of athernids, clupeids, and engraulids.

Coral Reef Fish-Habitat Modeling to Support Ecosystem-Based Management

J.S. Ault and S.G. Smith (UM/RSMAS); G.T. Kellison (NOAA/NMFS)

Long Term Research Objectives and Strategy to Achieve Them:

Objectives: To improve understanding of the relationships between habitat characteristics and coral reef fish community structure as a critical step in facilitating the transition to Ecosystem Based Management (EBM), including determining optimal sizes, numbers, and locations of MPAs. This provides improved understanding via the development of multi-species habitat suitability models.

Strategy: To accomplish this we utilize newly available benthic habitat and marine topography data to assess habitat complexity over multiple scales; use spatially-explicit reef fish data to develop predictive models relating seascape variables, habitat complexity, and biophysical processes to coral reef fish community structure in coral reef ecosystems; and, identify potential areas within the Florida Keys coral reef ecosystem for ecosystem management and conservation actions.

CIMAS Research Themes:

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

Link to NOAA Strategic Plan Goals:

***Goal 1*:** Protect, Restore, and Manage the Use of Coastal and Ocean Resources through an Ecosystem Approach to Management

NOAA Funding Unit: NMFS/SEFSC/CRCP **NOAA Technical Contact:** G. Todd Kellison

Research Summary:

Our research in habitat suitability models allows fishery managers to: (1) identify fundamental relationships governing fish community structure, dynamics, and responses to environmental changes and anthropogenic impacts; (2) devise cost-effective sampling strategies to assess the effects of exploitation and management actions; and, (3) predict optimal areas for management actions (e.g., establishment of MPAs). These models are an essential component of successful ecosystem-based fisheries management. Our work utilizes, builds on and compliments ongoing state and

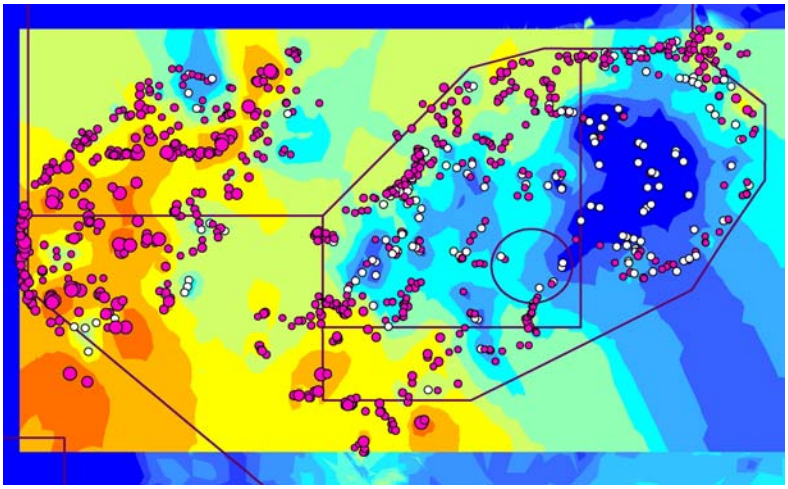


Figure 1: Multivariable spatial statistical model estimate of species abundance as a function of depth and habitat for bicolor damselfish (*Stegastes partitus*) in the Dry Tortugas region. Size of colored (purple) circle indicates relative animal density; open (white) circles indicate no animals were seen with the primary sampling by four replicate diver observations.

federal monitoring efforts in the Florida Keys coral reef ecosystem, and will provide output that will be used to improve sampling design for these monitoring efforts, which in turn will lead to improved data quality to support ecosystem-based management (EBM). Thus, our work will begin a positive feedback loop that will continually improve our ability to perform wise and effective EBM in the Florida Keys coral reef ecosystem.

Our research work supports multiple projects, goals and objectives identified in Local Action Strategies under the Southeast Florida Coral Reef Initiative (SEFCRI) and the FKNMS. From an perspective MPA design and assessment, our work is integral to FKNMS resource management for evaluating likely effectiveness and ecosystem impact of existing marine protected areas (i.e., MPAs or Sanctuary Preservation Areas SPAs in FKNMS) relative to alternate types of traditional management scenarios. Our work is also of considerable value to resource managers in the National Park Service (i.e., Biscayne National Park and Dry Tortugas National Park). For example, Biscayne National Park is currently using results from our research to assist the analysis of establishment of MPAs as part of their General Management and Fisheries Management Plans.

Figure 2: Relationship of a black grouper (*Mycteroperca bonaci*) to preferred coral reef habitat of stony corals, octocorals and sponges in a high rugosity environment in the Dry Tortugas region of the Florida Keys.

Research Performance Measure: The objectives of this program are being met by the extensive monitoring program that is currently underway. This research represents an excellent example of coordination, cooperation, and participation by different government agencies, universities, and private organizations to achieve a common goal.

Monitoring Coral Reef Fish Populations in the Florida Keys

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

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** To provide a comprehensive quantitative evaluation of trends in the Florida Keys coral reef ecosystem, in particular the open and "no-take" zones of the Florida Keys National Marine Sanctuary (FKNMS -- Sanctuary Preservation Areas SPAS; Tortugas Ecological Reserves TERs) and Dry Tortugas National Park (DTNP -- Research Natural Area RNA).

***Strategy*:** Carry out regional multispecies reef fish assessments, map coral reef habitats and to conduct spatially-based monitoring of coral reef fish composition, occurrence, abundance, and size structure on the Florida Keys reef tract. Use these data to assess population changes, ontogenetic habitat associations, and ecosystem responses to fishing, recreational use, pollution, MPA zoning and, eventually, Everglades restoration.

CIMAS Research Themes:

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

Link to NOAA Strategic Plan Goals:

***Goal 1*:** Protect, Restore, and Manage the Use of Coastal and Ocean Resources through an Ecosystem Approach to Management

NOAA Funding Unit: NMFS/SEFSC **NOAA Technical Contact:** James A. Bohnsack

Research Summary:

This research emphasizes assessing the effectiveness and impacts of no-take marine reserves and other resource management measures in Biscayne National Park, the FKNMS, and DTNP towards meeting their marine ecosystem management goals. 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 implemented a 100 km^2 Research Natural Area (RNA) in the western half of Dry Tortugas National Park in January 2007.

We continue to evaluate the performance of the SPAs and TERS in the FKNMS. During the past year we conducted spatially-synoptic sampling of reef fish and coral reef habitats in the Florida Keys. Although still early in the recovery process, our results for the Dry Tortugas and Florida Keys are encouraging and suggest that NTMRs in conjunction with traditional management measures can potentially help rebuild sustainable fisheries while protecting the Florida coral reef ecosystem. This is a win-win scenario; good for the fish, ecosystem, fishermen, and Florida's economy! The black groupers provide a particularly compelling example. Fishing pressure typically results in a shift from larger to smaller animals. If we compare a fished area and two protected areas prior to the establishment of the protected areas (1999-2000) with the same three areas after protection, we see

that there are significantly more larger fish in the two protected areas but not in the fished area where the number of large animals continued to decrease (see Figure 1).

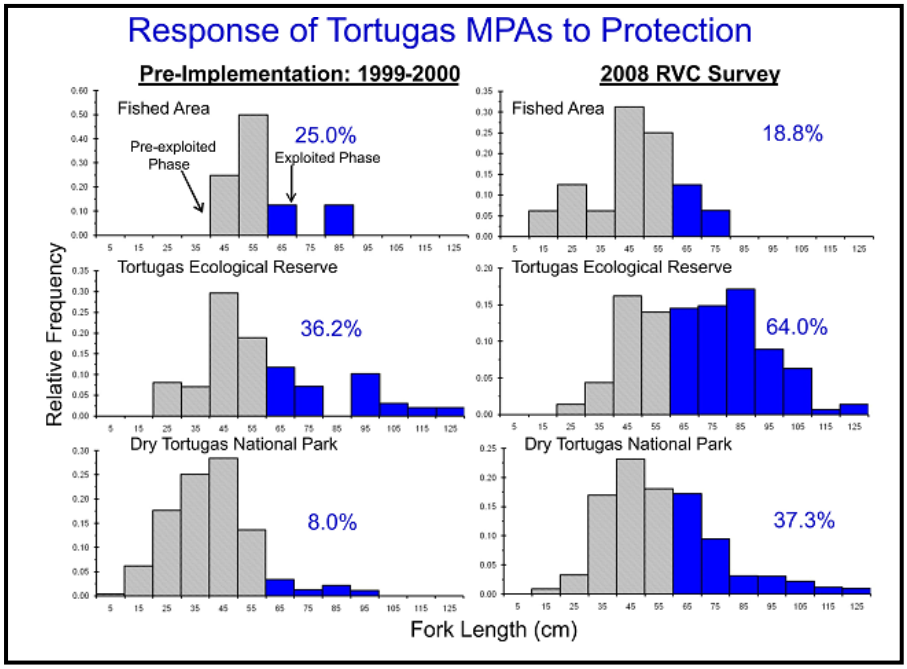


Figure 1: Size frequency distribution of black grouper in a control (fished) area versus two protected areas: Tortugas Ecological Reserve and Dry Tortugas National Park in the pre-implementation period (1999-2000) and the most recent survey (2008).

In Spring-Summer 2010, a team of 46 research divers from the University of Miami (UM) Rosenstiel School of Marine and Atmospheric Science, NOAA Fisheries Service, the Florida Fish and Wildlife Conservation Commission, and the National Park Service completed a successful 20-day biennial census to measure how the protected status of the Florida Keys National Marine Sanctuary's Tortugas Ecological Reserve and Dry Tortugas National Park's Research Natural Area are helping the regional ecosystem rebound from decades of overfishing and environmental changes (Figure 2). The unprecedented collaboration allowed the team to complete more than 1,700 scientific dives, which will now help to further establish a baseline for the state of reef fish stocks and coral reef habitats in Florida's dynamic marine ecosystem. We were very encouraged to see that stocks have slowly begun to recuperate since the implementation of 'no-take' marine protected areas in the region. We noted particular improvements in the numbers of snapper, grouper, and coral recruits. We are currently crunching the data collected to see what adjustments may need to be made in order to help guide future management decisions to address the issues of biodiversity protection, restoration of ecological integrity, and fishery management which are critical to this area. This year, the team documented changes in fish abundance and habitat quality in this region which was hit by six major hurricanes since 2004. By statistically comparing this year's findings to previous baseline survey information collected, scientists can determine what effects intense hurricane activity had on this marine environment. If we again look at black grouper data we can see that the extent of occupancy markedly increased after implementation of the protected areas (between 1999-2000 and 2004) but has since been highly variable albeit at a consistently higher level than prior to protection. The natural variability associated with storms and other factors is superimposed upon the change due to management (Figure 3).

Figure 2: Vortexing school of permit (*Trachinotus falcatus*) seen in a spawning aggregation in the Tortugas Ecological Reserve during the 2010 RVC monitoring survey of the Dry Tortugas

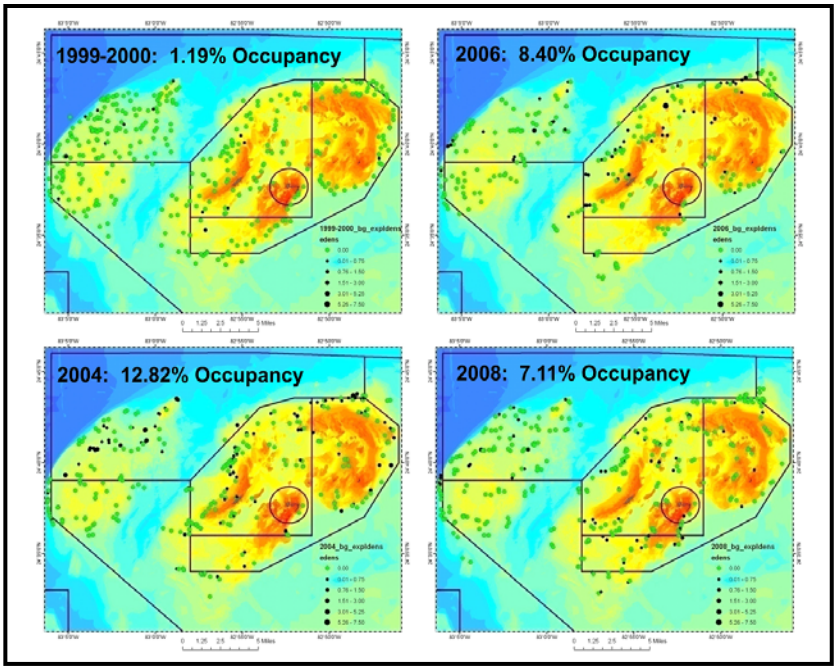


Figure 3: Regional black grouper frequency-of-occurrence (occupancy) during survey years 2004, 2006 and 2008 relative to the pre-implementation baseline measured in 1999-2000.

Research Performance Measure: All of the following objectives were met**:** (1) Conducted spatially-synoptic monitoring surveys of reef fish and coral reef habitats in the Florida Keys coral reef ecosystem; (2) Conducted quantitative assessments of reef fishery sustainability; (3) Evaluated NTMR efficacy.

Simulation of Management Strategies

D.J. Die, E. Babcock (UM/RSMAS); J. Hoenig (VIMS)

Long Term Research Objectives and Strategy to Achieve Them:
***Objectives*:** To provide quantitative evaluation of fishery management strategies.
***Strategy*:** To use an analysis framework to evaluate both theoretical and real fisheries.

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 an Ecosystem Approach to Management

NOAA Funding Unit: SEFSC/NMFS **NOAA Technical Contact:** Clay Porch

Research Summary:
This project continues to develop analytical and simulation methods to evaluate the performance of fisheries management strategies through the collaborative work of students and faculty.

Elizabeth Martin has started building a theoretical mathematical model of the reproductive dynamics of populations of highly migratory fish. She is hoping that the model can then be incorporated to simulation models so as to predict the age and size structure of harvested populations and thus facilitate fishery management strategy evaluation.

William Harford is developing an individual-based modeling framework that will specify the decision rules for fish movement in response to environmental and competitive conditions. He hopes to use this framework to characterize trade-offs in management objectives for spatial management strategies applied to the snapper/grouper species complex. He has also identified the trade-offs between conservation of migratory shortfin mako sharks and multispecies fisheries objectives in the NW Atlantic. He has done so with an EcoPath model of the NW Atlantic emphasized the need for a spatially explicit model to couple North-South migrations of shortfin mako with their trophic interactions. He is now exploring an alternative multi-species model based on a bioenergetic and allometric Bayesian framework.

Mandy Karnauskas is working on quantifying spatial patterns of reef fish abundance to allow for evaluation of spatial management. She has conducted analyses of spatial patterns of reef fish from underwater visual census, CPUE and physical data at 110 sites in Glover's Reef Marine Reserve, Belize. She is untangling natural seascape variation from marine reserve effects using a landscape approach. Furthermore, she is evaluating the influence of pre-existing spatial heterogeneity in fish density on our ability to detect the changes in fishing mortality caused by the implementation of a no-take fishing zone.

Matthew Smith's research represents novel uses of statistical models to quantify mortality rates induced by chronic diseases. Having demonstrated that these diseases are causing significant increases in natural mortality rates, he is now beginning to consider the management implications of the changes.

Lynn Waterhouse has developed an improvement to the standard multi-year (Brownie) tagging model for total mortality rate. Her model allows for the fact that tag visibility can decrease over time as the tag becomes fouled. She is writing up these results while she tries to generalize the model to estimate the fishing and natural mortality components of total mortality.

Elizabeth Babcock continued working on application of Bayesian models to the assessments of Atlantic sharks. She presented a Bayesian surplus production model at the joint ICES/ICCAT porbeagle stock assessment and expects to participate in the large coastal shark assessments in 2010. She also submitted a paper to CJFAS describing a management strategy evaluation of a data poor fishery management strategy that uses the ratio of fish density outside versus inside marine reserves as the metric of fishery impacts for a fisheries control rule. She also completed an analysis using size based indicators of overfishing for the harvested species at Glover's reef, Belize.

David Die continued to work with Kristin Kleisner in the modeling of pelagic fish distribution with the aim to develop better spatially explicit indices of relative abundance. We showed that different species of pelagic fish have different ranges of spatial autocorrelation and that these ranges are related to the spatial structure of the environment they inhabit. Deeper swimming pelagic fish have greater ranges of spatial autocorrelation the same way that deeper water masses.

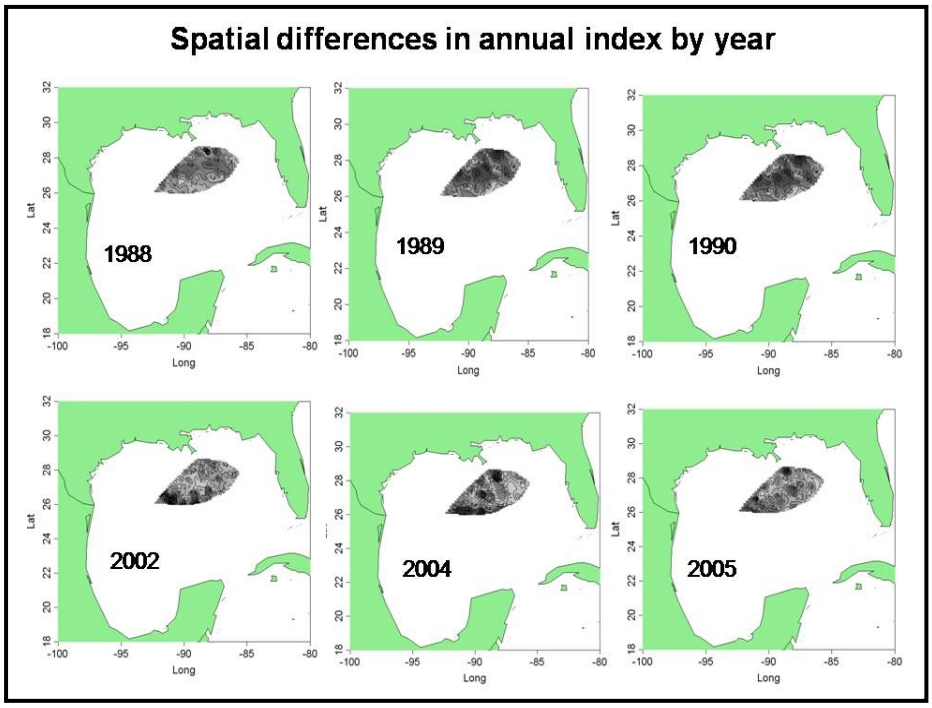


Figure 1: Spatially explicit relative indices of abundance for dolphinfish in the Gulf of Mexico obtained with geo-statistical models of catch per unit of effort data from the US pelagic longline fishery.

Research Performance Measure: All students involved in this project are making the expected progress towards their degree(s), including progress on their graduate research related to this project. Three of the students are pursuing dual degrees: M. Smith and L Watterhouse MSc in Marine Science and MSc Statistics at VIMS and E. Martin a PhD in Marine Biology and Fisheries and MSc in Applied Mathematics at RSMAS. Additionally those students that already graduated (K. Kleisner) have published their work related to this project on peer review journals. The simulation and methodological framework develop with this project is now reaching a broader list of management strategies and resources, ranging from pelagic to demersal fish and from spatial to non spatial management.

Investigation of the Movement of Adult Billfish in Potential Spawning Areas

J.P. Hoolihan (UM/CIMAS); J. Luo (UM/RSMAS); E.D. Prince, D. Snodgrass,
E.S Orbesen (NOAA/SEFSC), C.P. Goodyear (Contractor, Niceville, FL).

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** Characterize the horizontal and vertical movement of istiophorid billfish and other tropical pelagic fishes in potential spawning areas in the context of large marine ecosystems.

***Strategy*:** Utilize electronic tags, plankton nets, and biological samples to describe habitat utilization and spawning state of subject teleosts. Describe depth of pelagic longline gear using electronic monitors and use available oceanography of the study areas from the World Ocean Atlantic web site.

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 an Ecosystem Approach to Management

NOAA Funding Unit: NMFS/SEFSC **NOAA Technical Contact:** Eric D. Prince

Research Summary:

We used a combination of recreational and commercial fishing vessels to (1) catch pelagic fish known to interact with pelagic longline fishing gear, (2) attach pop-up satellite archival tags (PSATs) to them and (3) release them to study their horizontal and vertical movements for periods up to 150 days. Over 300 PSATs have been deployed by the NOAA-SEFSC Migratory Fisheries Biology Branch and about 78% of them reported

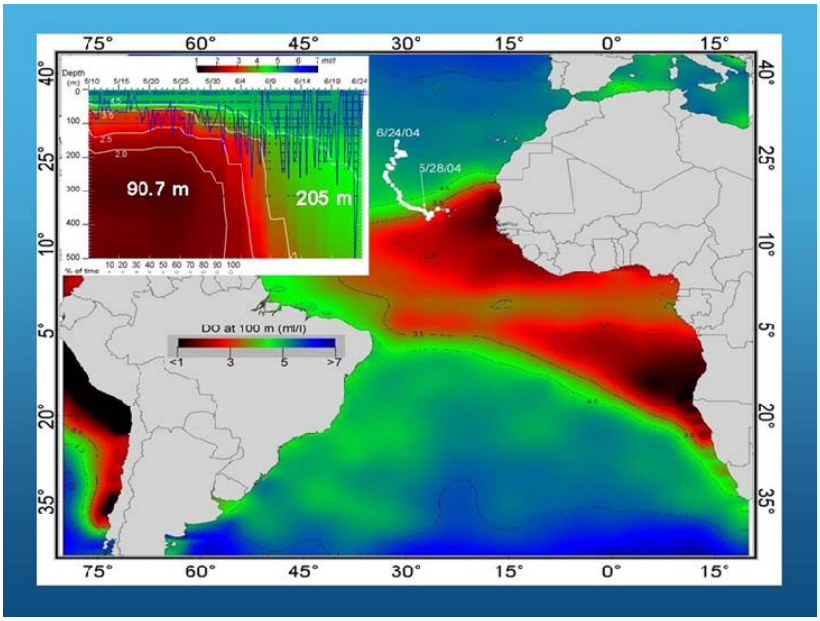


Figure 1: Estimated 43 day horizontal track of a PSAT monitored blue marlin off the Cape Verde Islands. The figure insert shows a cross section of the vertical habitat along the horizontal track, and the oxyclines associated with the oxygen minimum zone (OMZ) present off West Africa (DO $\leq$ 3.5 mL L^{-1} is shown in red fading to black). The blue line in the insert indicates a plot of the maximum depth per day for the 43 day monitoring period. While the marlin was over the OMZ, it stayed relatively shallow (averaging a maximum depth of about 91 m/day) but as it moved outside the OMZ area (5/28/2004) the maximum depth per day increased to over 200 m/day, eventually reaching 500+ m at the end of the track (image courtesy of Fisheries Oceanography, Prince *et al.*, in press).

summarized data via the Argos satellite system. In addition, we have physically recovered 18 PSATs that had previously transmitted summarized data. PSAT's non-volatile memory retains large volumes of high resolution data that is available for download. This augmented the PSAT data base with detailed information that is not available through Argos transmissions. PSAT data has provided the first empirical evidence of how habitat utilization by high oxygen demand large pelagic fishes is restricted by the levels of available dissolved oxygen (Figure 1).

Research Performance Measure: The high recovery rate for data collected by pop-up satellite tags indicates that fish tagging protocols and deployment durations are appropriate. The successful acquisition of high resolution data on pelagic longline gear "behavior" and the effects of gear modifications on animal interactions with pelagic longline fishing gear. Many joint authored (NOAA/RSMAS) peer review papers have resulted over the last few years. Those from 2009-2010 are listed in the Publications section. Other can be accessed at: http://www.sefsc.noaa.gov/ fisheriesbiology.jsp

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

E. Malca, B. Muhling, A. Shiroza (UM/CIMAS)
J. Lamkin, T. Gerard (NOAA/SEFSC); R. Smith and L. Johns (NOAA/AOML)
L. Vasquez-Yeomans, E. Sosa-Cordero and L. Carrillo-Bibriezca (ECOSUR)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** To provide a baseline study of the oceanography and larval distributions of fish species in the western Caribbean during winter spawning to provide a basis for anticipated fisheries management decisions.

***Strategy*:** To carry out large scale synoptic larval and oceanographic surveys to map the larval transport and recruitment pathways in the Mesoamerican reef system upstream of the Florida Keys.

CIMAS Research Theme:

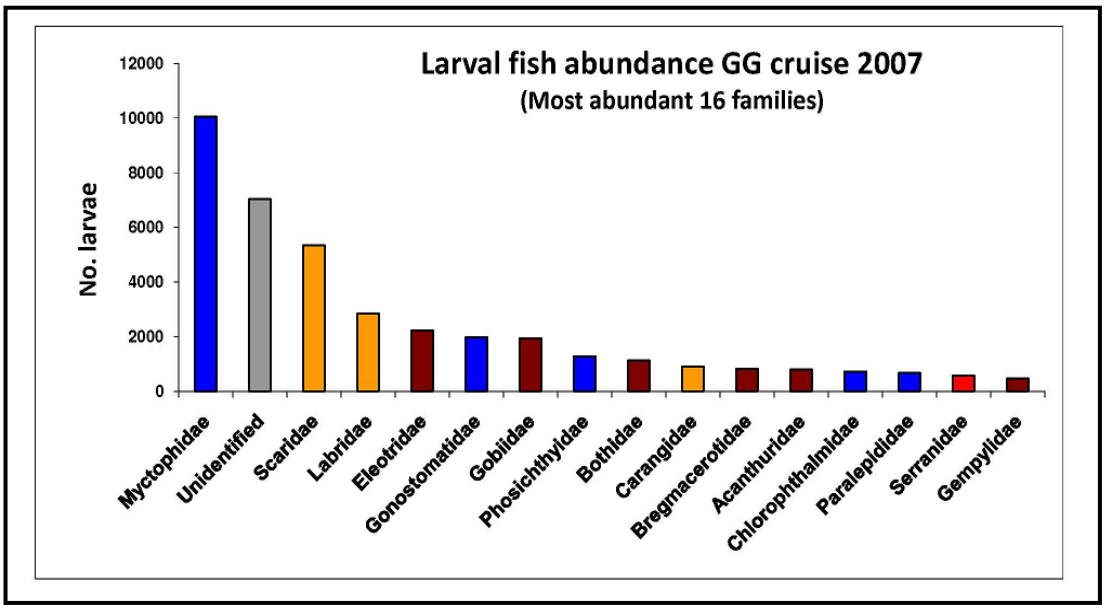
***Theme 2*:** Fisheries Dynamics (*Primary*)
***Theme 3*:** Regional Coastal Ecosystem Processes (*Secondary*)

Link to NOAA Strategic Goals:

***Goal 1*:** Protect, Restore, and Manage the Use of Coastal and Ocean Resources through an Ecosystem Approach to Management

NOAA Funding Unit: NOAA CRCP **NOAA Technical Contact:** John Lamkin

Research Summary:
This research project included two large-scale oceanographic research cruises in 2006 and 2007 aboard the NOAA R/V Gordon Gunter from Yucatan Channel to Mexico and southern Belize in collaboration with ECOSUR, CONANP, the University of Belize, and Conservation International allowed sampling to be extended south into Belize and the Honduran Gyre. Gear utilized included a 1 meter and 10 meter multiple opening and closing net environmental sampling system (MOCNESS) and juvenile trawls were used to collect ichthyoplankton emphasizing sites with known snapper and grouper spawning aggregations. Oceanographic data including currents, temperature, salinity, and oxygen measurements were collected with a lowered CTD and LADCP and shipboard ADCP and flow through system. We also deployed satellite-tracked Lagrangian drifters to measure current flow and identify gyre circulation patterns. In addition, inshore sampling took place, simultaneously, with light trap, settlement trap, and tidal net samplers deployed both in the coastal marine reserves at Xcalak and also at the offshore atoll Banco Chinchorro, Mexico during grouper and snapper spawning periods. Small scale recruitment experiments were conducted from 2004 – 2008 during various sampling efforts at Xcalak, Mexico. Otoliths were removed from a subsample and at three additional sites extending north to Ascension Bay for isotope analysis. Divers monitored spawning aggregations in the vicinity, and ADCP's and current meters were deployed to measure near-shore current fields.



Research Performance Measure: The program is in progress and proceeding on schedule. To date, sorting of ichthyoplankton samples from the 2006 and 2007 research cruises and all inshore collections has been completed and identification to the taxonomic level of family has been 90% completed by our colleagues at the graduate school El Colegio de la Frontera Sur (ECOSUR) Chetumal campus, Quintana Roo, Mexico. Thus far, highest larval abundances (1,000 m^3) were found in the upper 50 meter strata with mean abundance values ranging from 113 to 218 larvae/1000m^3.

Applying Bio-Physical Monitoring and Capacity Assessments to Mesoamerican Reef Marine Protected Areas

S. Whitcraft and E. Malca (RSMAS/CIMAS); J. Lamkin and T. Gerard (NOAA/SEFSC)
E. Sosa-Cordero, L. Carrillo-Bibriezca, L. Vasquez-Yeomans, (ECOSUR)
M.J. González (MARfund)

Long Term Research Objectives and Strategy to Achieve Them:

Objectives: To establish research priorities in the Mesoamerican region in order to provide baseline data (oceanographic and larval fish distributions) to support connectivity and fisheries management decisions in the region.

Strategy: To carry out larval and oceanographic collections to assess larval transport & recruitment pathways in the Mesoamerican reef system. In addition, to carry out an international capacity-building workshop to discuss the topic of connectivity as it relates to research and management with local and regional practitioners in the Mesoamerican Reef.

CIMAS Research Theme:

***Theme 2*:** Fisheries Dynamics (*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 an Ecosystem Approach to Management

NOAA Funding Unit: NOAA/CRCP International & NOAA/SEFSC

NOAA Technical Contact: John Lamkin

Research Summary:

We utilized existing regional capacity-building initiatives (El Colegio de la Frontera Sur, Healthy Reefs Initiative and the Mesoamerican Reef Fund) in order to carry out a capacity building workshop focusing on connectivity along the Mesoamerican Reef this past May 2010. In addition, the research portion of this project is focused in Isla Contoy National Park, ICNP in order to: 1) Assess the critical habitats in the interior lagoons and shallow coral reefs of ICNP as they are identified areas of particular concern for the current revision of their management plan. 2) Determine the biomass and species composition of juvenile coral reef-associated fishes using light-traps, settlement traps, and seine nets. 3) Meteorological and oceanographic data will be collected via the installation of a meteorological station on the island and a current meter off-shore; and 4) spawning aggregations of economically/ecologically important species will be identified using SCUBA along the island's coral reefs utilizing previously established methodologies developed with our academic partners. 4) Part of this research will be submitted as a Master's of Science thesis at the Rosenstiel School of Marine and Atmospheric Sciences, division of Marine Affairs.

Research Performance Measure: The program is in progress and proceeding on schedule. The capacity building workshop was carried out at ECOSUR, Chetumal campus in May 2010 with successful participation of international MPA practitioners and regional/local managers from the countries that make up the Mesoamerican Reef (Mexico, Belize, Guatemala and Honduras). Two websites and an online email group was created in order to facilitate communication between The

research portion is taking place in June, July and in August 2010 with participation of research staff and students from ECOSUR, (El Colegio de la Frontera Sur) CONANP, (Comisionado Nacional de Áreas Naturales Protegidas) and local guides. Preliminary results have been presented at an oral presentation during the International Larval Fish Conference in Santa Fe, New Mexico (May 2010).

Capacity building workshop carried out May 2010 at ECOSUR campus in Chetumal, Mexico with participants (managers/MPA practitioners) from the Mesoamerican Region (Mexico, Belize, Honduras and Guatemala).

Variations in Carbon and Oxygen Stable Isotopes Snapper (Lutjanidae) in Florida Bay and Florida Keys

B. Muhling, E. Malca, S. Privoznik (RSMAS/CIMAS)
J. Lamkin and T. Gerard (NOAA/SEFSC)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** To determine similarities of otolith isotope signatures between four snapper species commonly found in Florida Bay. To examine the connectivity between habitat use of juvenile snapper and adults that utilizes Florida Bay as a nursery.

***Strategy*:** To measure the concentration of $\delta^{13}C$ and $\delta^{18}O$ stable isotopes in the otoliths of four snapper species found in Florida Bay and to use these as an indicator of environmental factors and metabolic activity of these fishes. To measure the concentration of $\delta^{13}C$ and $\delta^{18}O$ stable isotopes in the portion of the otolith that corresponds to the juvenile life history of adult snapper inhabiting the Florida Keys reef track and comparing it to historical values from previous sampling in Florida Bay.

CIMAS Research Theme:

***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 an Ecosystem Approach to Management

NOAA Funding Unit: NOAA Coral Reef Conservation Program
NOAA Technical Contact: John Lamkin

Research Summary:
This study has two components; the first examines the concentration of $\delta^{13}C$ and $\delta^{18}O$ stable isotopes in the otoliths of four snapper species found in Florida Bay as an indicator of environmental factors and metabolic activity of these fishes. Interspecies and temporal analyses were performed on samples taken from seven sites over five years representing 133 km of representative habitat in Florida Bay. Initial results suggest that stable isotope projects involving snapper in Florida Bay should be species-specific to report any future findings with confidence. Collections of fish samples from Florida Bay was continued to extend the temporal extent of the study into summer 2009.

The second component of this study analyzes the juvenile portion of adult gray snapper otoliths collected within the Florida Keys National Marine Sanctuary in order to potentially match them to one of five previously assigned nursery regions (Gerard, PhD dissertation). Adult gray snapper and yellowtail snapper were collected along the Florida reef tract in 2004. Measurements of carbon and oxygen ratios were obtained and compared to existing isotopic signatures of juvenile gray snapper from Florida Bay nursery. Preliminary data analysis shows an overlap in isotope measurements for the juvenile portion of adult otoliths to isotope values for the Florida Bay region, thereby suggesting a migratory connection.

Research Performance Measure:
The program is meeting its goals on schedule. Initial results obtained from this study suggest that stable isotope projects involving snapper in Florida Bay should be species-specific to report any future findings with confidence. Preliminary results of the study were presented as an oral presentation at the International Otolith Symposium in August 2009, Monterrey, California.

Figure 1: Technology transfer via hands on training on otolith removal and preparation methodologies in Mexico.

US Virgin Islands Larval Distribution and Supply Research

E. Malca, N. Melo, B. Muhling, S. Privoznik, G. Rawson and A. Shiroza, (UM/CIMAS);
J. Lamkin, T. Gerard (NOAA/SEFSC); R. Smith and L. Johns (NOAA/AOML)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** To provide essential information required for coral reef ecosystem assessment and a scientifically-based ecosystem approach to fisheries management in the Caribbean region.

Strategy: To carry out large-scale larval and hydrographic surveys with complementary inshore larval collections to map the larval distribution, transport, and recruitment pathways.

CIMAS Research Theme:

***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 an Ecosystem Approach to Management

NOAA Funding Unit: NOAA Coral Reef Conservation Program

NOAA Technical Contact: Trika Gerard

Research Summary:

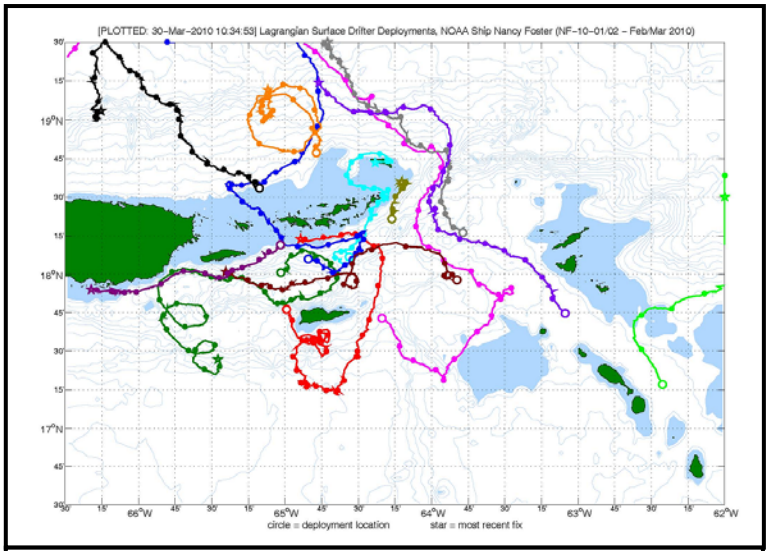


Figure 1: Tracks of satellite tracked drifters deployed during 2010 cruise.

This uniquely collaborative fisheries oceanography research project combines the expertise of fisheries biology, oceanography, and local knowledge from managers to assess the long-term sustainability of coral reef fish populations in the Caribbean, focusing on the U.S. Virgin Islands. Surveys of water properties, currents, dispersal and transport of settlement-stage larvae provide data on and a further understanding of the biological and physical processes that drive production on the Grammanik and Red Hind Banks, which are protected sites of multi-species spawning aggregations for economically important coral reef fish e.g. fisheries management areas established by the Caribbean Fisheries Management Council. Additionally, surveys of inshore juvenile fishes yield an understanding of the spatial variation in the supply of settlement-stage fishes in coastal waters. This is a long term interdisciplinary research project (March 2007, March 2008, April 2009, and February 23 - March 15, 2010) utilizing the NOAA Ship NANCY FOSTER to conduct biological and physical oceanographic surveys of the Virgin Islands' (VI) bank ecosystems and surrounding regional waters. In addition, inshore biological collections of

2007, 2008, 2009 & 2010 took place in St. Thomas using either light traps or seine nets in important nursery habitats targeting juvenile coral reef fishes.

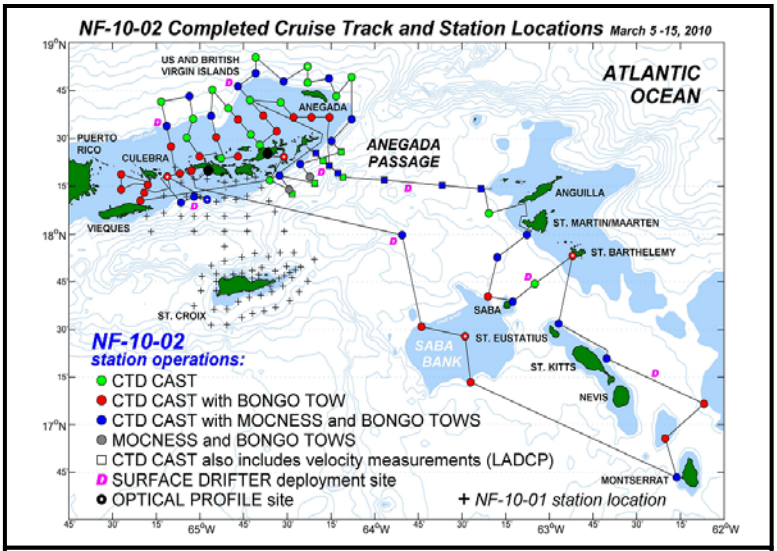


Figure 2: Cruise track showing collection gear and sampling location in 2010.

Research Performance Measure: The research program is on schedule. This study requires a comprehensive understanding of regional larval transport, and overall larval recruitment in the study area. Data analyses are ongoing for all four cruises; 2007-2010. Oceanographic cruise data has been collected and processed for 2007-2009. Biological collections from the 2010 cruise included the use of stratified net sampling with a multiple opening and closing net environmental sampling system (MOCNESS), and subsurface Bongo tows. In addition, the family identification has been completed for 2007 and 2008. Ichtyoplankton sampling in 2009 yielded 314 samples (217 MOCNESS and 97 bongo) from 105 stations. The fourth cruise was successfully carried out earlier this year (23 February – 15 March 2010) replicating collections at historical stations and extending our sampling collections in and around St. Croix and associated MPAs at the request of local managers including the Caribbean Fisheries Management Council. We completed a total of 156 stations of which 20% have been sorted so far. Results from this project have been presented in two oral presentations at the Larval Fish Conference in Santa Fe, NM in May 2010.

Descriptive Geomorphology of Reef Fish Spawning Aggregations in the Florida Keys

A. Gleason (UM/CIMAS), G. T. Kellison (NOAA/Beaufort, NC Laboratory)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** To conserve reef fish spawning aggregations. The particular goal of this project is to determine if there is a consistent relationship between seabed geomorphology and the locations of FSAs in the Florida Keys. Knowledge of any such relationship will help managers in the Florida Keys develop a comprehensive zoning plan in terms of evaluation of the location, size and rezoning of Sanctuary Preservation Areas (i.e., no-take areas).

***Strategy*:** To use a single-beam acoustic seabed classification system to map seabed substrate and detailed bathymetry surrounding sites of known spawning aggregations and then compare maps of different sites to assess whether the aggregations form in consistent locations relative to seabed features.

CIMAS Research Theme:
***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 an Ecosystem Approach to Management

NOAA Funding Unit: NOAA Coral Reef Conservation Program
NOAA Technical Contact: Todd Kellison

Research Summary:
Reef fish spawning aggre-gations (FSAs) are a vital part of the life cycle of many reef fishes. Unfortunately, the act of aggregation makes aggre-gating species particularly vulnerable to overfishing. The protection and conservation of FSAs is critical to the sustainable management of grouper, snapper and other reef fish fisheries, from both fisheries and ecosystem perspectives.

Understanding the relationship between seabed habitat and spawning aggregations is important for the management of fish populations. One example is the design of marine protected area networks. In 1998 a large (~100 individuals) black grouper (*Mycteroperca bonaci*) aggregation was observed less than 100 m outside the Carysfort Sanctuary Preservation Area (SPA) within the Florida Keys National Marine Sanctuary (FKNMS). In 2003 this site was mapped with a single-beam acoustic seabed classification system and the site of the aggregation was observed to fall on the steep slope of the first Carysfort outlier reef, inshore of the deeper outliers. In 2007 four other sites of known historical FSAs in the upper Keys were mapped with the same acoustic system, all of which were found to also be associated with outlier reefs. Additional sites need to be surveyed to determine if this pattern is consistent across the FL Keys coral reef tract.

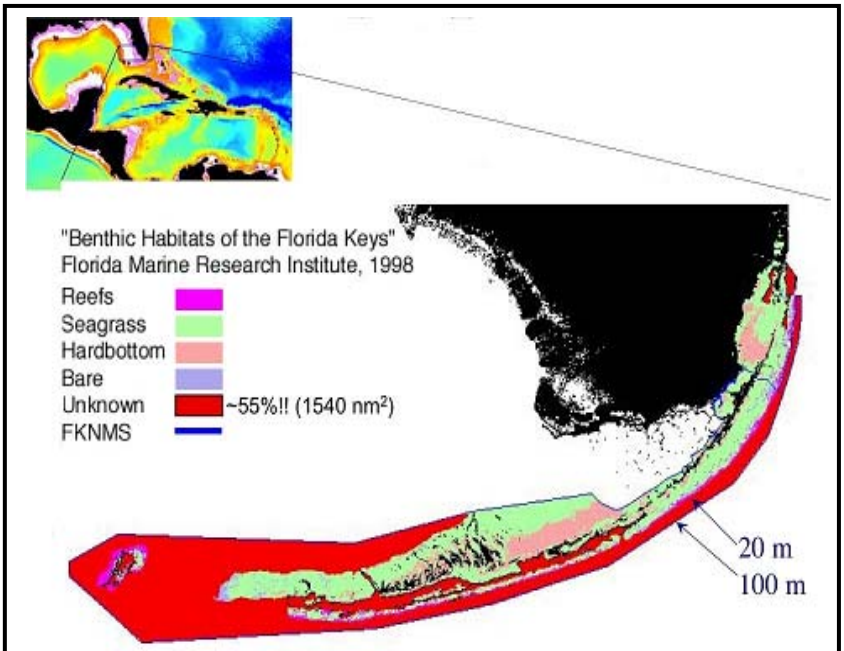


Figure 1: Benthic habitat of the Florida Keys National Marine Sanctuary published by the Florida Marine Research Institute in 1998. Over half of the sanctuary could not be mapped from aerial photographs due to water depth or turbidity constraints thereby highlighting the utility of acoustic mapping technologies for habitat assessment within the Sanctuary.

This year, 4 FSA sites in the lower Florida Keys were mapped with a single-beam seabed classification system. These results, along with those for the areas previously mapped in the upper Keys, were shared with NOAA and Florida Fish and Wildlife Conservation Commission (FWC) partners who used additional hydroacoustic surveys and diver observations to assess the current state of these aggregations. Loose aggregations of mutton and cubera snapper and several non-snapper-grouper species were observed in the upper Keys on predicted summer spawning moons. These observations suggest that spawning still occurs at these sites, all of which are near but outside of areas closed to fishing (SPAs) and all of which were being fished by commercial and recreational fishers (multiple boats on-site). In the lower Keys, aggregations of 100s of gray and mahogany snapper were documented at the mapped historical sites.

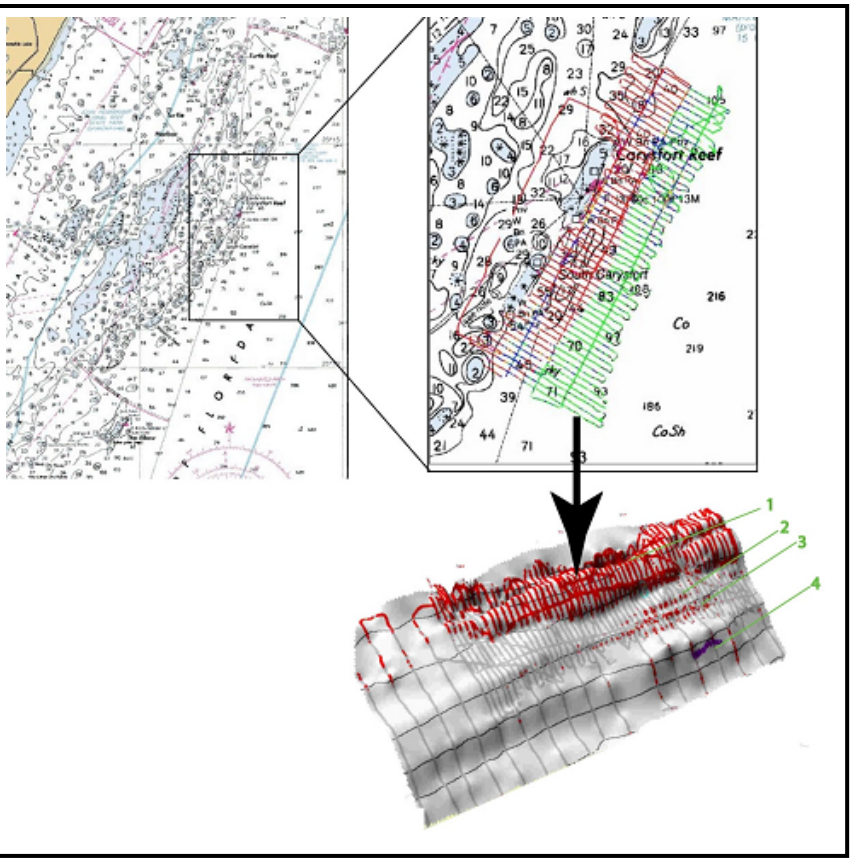


Figure 2: Top left: Portion of NOAA nautical chart 11451 showing the area around Carysfort Reef, FL (soundings in feet). Note lack of bathymetric detail for areas greater than approximately 20 feet deep. Top right: Survey track lines color coded by acoustically-derived substrate: red is hard bottom (reef), green is sediment. Bottom: Oblique view of a shaded three-dimensional surface created by interpolating acoustic soundings with seabed type draped on top: red is hard bottom (reef), gray is sediment. A series of four parallel rocky ridges, numbered 1-4, are apparent on the acoustic data but are not visible on the NOAA charts. These ridges provide important habitat and appear to be associated with grouper and snapper spawning aggregations in the upper Florida Keys.

Research Performance Measure: This year, single-beam echosounder data were acquired over 4 FSA sites in the lower Florida Keys. The data were processed to produce georeferenced maps of bathymetry and substrate type, and analyzed to assess the relationship of the mapped geomorphological features with the locations of the FSAs. All of these activities were as planned, except the number of sites mapped was slightly less than the planned goal of 5 due to an accident involving the FWC vessel being used to do the survey work. (The accident occurred while it was being used for a different project, but was nevertheless serious enough that we could not use the vessel for the last 5 months of the project.)

Coastal Fisheries Logbook Program

J. Diaz (UM/CIMAS); S. Turner, M. Judge, N. Baertlein and J. Hall (NOAA/SEFSC)

Long Term Research Objectives and Strategy to Achieve Theme:

***Objectives*:** To determine the fishing effort of federally-permitted commercial fishers in the South Atlantic and Gulf of Mexico.

***Strategy*:** To collect fisheries dependent catch data by providing trip report logbooks to all federal South Atlantic Snapper/Grouper, Gulf of Mexico Reef Fish, Shark, King Mackerel, Spanish Mackerel, and Dolphin/Wahoo permit holders in the U.S. Atlantic and Gulf of Mexico.

CIMAS Research Theme:

***Theme 2*:** Fisheries Dynamics

Link to NOAA Strategic Goals:

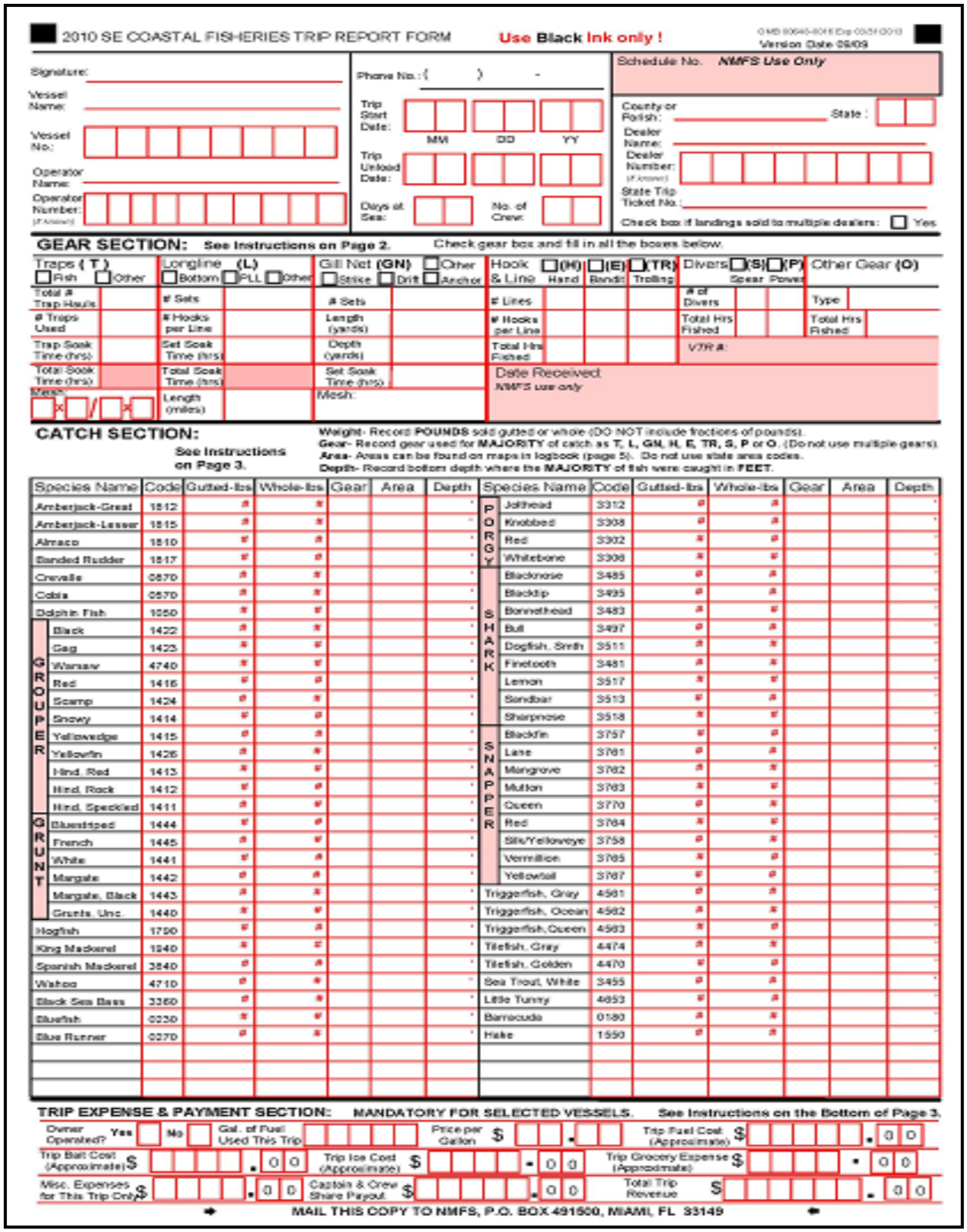
***Goal 1*:** Protect, Restore, and Manage the Use of Coastal and Ocean Resources through an Ecosystem Approach to Management

NOAA Funding Unit: NMFS/SEFSC **NOAA Technical Contact:** Brion Cook

Research Summary:

The Coastal Fisheries Logbook Program is an ongoing fisheries-dependent data collection program that collects statistics for the commercial fisheries found in the South Atlantic (SA) and Gulf of Mexico (GOM). Over the past 20 years, fishers in the SA and GOM who possess federal commercial fishing permits (SA Snapper-Grouper, GOM Reeffish, King Mackerel, Spanish Mackerel, Shark, & Atlantic Dolphin/Wahoo) have been required to submit a trip report form which primarily aims to collect landings and fishing effort data. Data collected is therefore used for fisher permit compliance. Data is also used in conjunction with other fisheries-dependent, and independent, data sets for stock assessments and fisheries management decisions. A recent stock assessment of Gulf of Mexico red grouper utilized a indices of abundance created from logbook data

Research Performance Measure: Our objective, the monitoring of compliance by fisherman by the timely submission of data, has been successfully accomplished.



2010 SE COASTAL FISHERIES TRIP REPORT FORM

Use Black Ink only !

OMB 0648-0016 Exp 03/31/2013
Version Date 09/09

Signature:

Vessel Name:

Vessel No:

Operator Name:

Operator Number:

Phone No.: ( ) -

Trip Start Date: MM DD YY

Trip Unload Date:

Days at Sea:

No. of Crew:

Schedule No. NMFS Use Only

County or Parish:

State:

Dealer Name:

Dealer Number:

State Trip Ticket No.:

Check box if landings sold to multiple dealers: Yes

GEAR SECTION: See Instructions on Page 2. Check gear box and fill in all the boxes below.

Traps (T) Fish Other	Longline (L) Bottom PLL Other	Gill Net (GN) Other Strike Drift Anchor	Hook & Line (H) Hand (E) Bandit (TR) Trolling	Divers (S) Spear (P) Power	Other Gear (O)
Total # Trap Hauls	# Sets	# Sets	# Lines	# of Divers	Type
# Traps Used	# Hooks per Line	Length (yards)	# Hooks per Line	Total Hrs Fished	Total Hrs Fished
Trap Soak Time (hrs)	Set Soak Time (hrs)	Depth (yards)	Total Hrs Fished	VTR #:	
Total Soak Time (hrs)	Total Soak Time (hrs)	Set Soak Time (hrs)	Date Received NMFS use only		
Mesh: x / x	Length (miles)	Mesh:			

CATCH SECTION: See Instructions on Page 3.

Weight- Record **POUNDS** sold gutted or whole (DO NOT include fractions of pounds).
Gear- Record gear used for **MAJORITY** of catch as **T, L, GN, H, E, TR, S, P** or **O**. (Do not use multiple gears).
Area- Areas can be found on maps in logbook (page 5). Do not use state area codes.
Depth- Record bottom depth where the **MAJORITY** of fish were caught in **FEET**.

Species Name	Code	Gutted-lbs	Whole-lbs	Gear	Area	Depth
Amberjack-Great	1512					
Amberjack-Lesser	1515					
Almaco	1510					
Banded Rudder	1517					
Crevalle	0570					
Cobia	0570					
Dolphin Fish	1050					
GROUPER Black	1422					
GROUPER Gag	1423					
GROUPER Warsaw	4740					
GROUPER Red	1416					
GROUPER Scamp	1424					
GROUPER Snowy	1414					
GROUPER Yellowedge	1415					
GROUPER Yellowfin	1426					
GROUPER Hind, Red	1413					
GROUPER Hind, Rock	1412					
GROUPER Hind, Speckled	1411					
GRUNT Bluestriped	1444					
GRUNT French	1445					
GRUNT White	1441					
GRUNT Margate	1442					
GRUNT Margate, Black	1443					
GRUNT Grunts, Unc.	1440					
Hogfish	1790					
King Mackerel	1240					
Spanish Mackerel	3540					
Wahoo	4710					
Black Sea Bass	3360					
Bluefish	0330					
Blue Runner	0370					

Species Name	Code	Gutted-lbs	Whole-lbs	Gear	Area	Depth
PORGY Jolthead	3312					
PORGY Knobbed	3308					
PORGY Red	3302					
PORGY Whitebone	3306					
SHARK Blacknose	3485					
SHARK Blacktip	3495					
SHARK Bonnethead	3483					
SHARK Bull	3497					
SHARK Dogfish, Smth	3511					
SHARK Finetooth	3481					
SHARK Lemon	3517					
SHARK Sandbar	3513					
SHARK Sharpnose	3518					
SNAPPER Blackfin	3757					
SNAPPER Lane	3761					
SNAPPER Mangrove	3762					
SNAPPER Mutton	3763					
SNAPPER Queen	3770					
SNAPPER Red	3764					
SNAPPER Silk/Yelloweye	3758					
SNAPPER Vermilion	3765					
SNAPPER Yellowtail	3767					
Triggerfish, Gray	4581					
Triggerfish, Ocean	4582					
Triggerfish,Queen	4583					
Tilefish, Gray	4474					
Tilefish, Golden	4470					
Sea Trout, White	3455					
Little Tunny	4653					
Barracuda	0180					
Hake	1550					

TRIP EXPENSE & PAYMENT SECTION: MANDATORY FOR SELECTED VESSELS. See Instructions on the Bottom of Page 3.

Owner Operated? Yes No

Gal. of Fuel Used This Trip:

Price per Gallon: $

Trip Fuel Cost (Approximate): $ .00

Trip Bait Cost (Approximate): $ .00

Trip Ice Cost (Approximate): $ .00

Trip Grocery Expense (Approximate): $ .00

Misc. Expenses for This Trip Only: $ .00

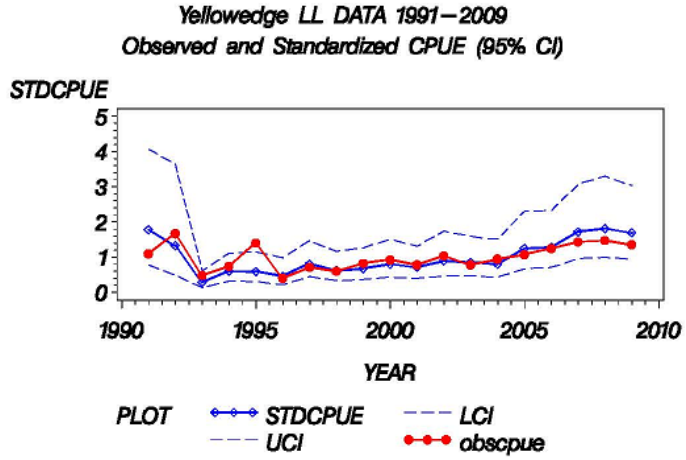
Captain & Crew Share Payout: $ .00

Total Trip Revenue: $ .00

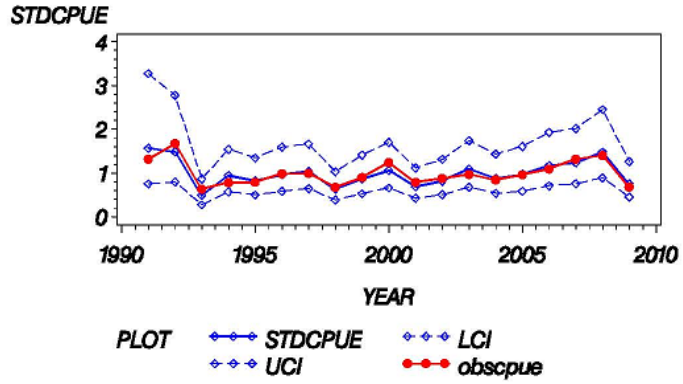
MAIL THIS COPY TO NMFS, P.O. BOX 491500, MIAMI, FL 33149

Figure 1: An example of the trip report logbook that is sent out to Federally permitted fishers in the South Atlantic and Gulf of Mexico. Once trips are completed by the fisher, they are returned to the Southeast Fisheries Science Center via USPS, postage-paid envelopes.

A. Region 1 – Areas 2-5



B. Region 2 – Areas 6-11



C. Region 3 – Areas 13-21

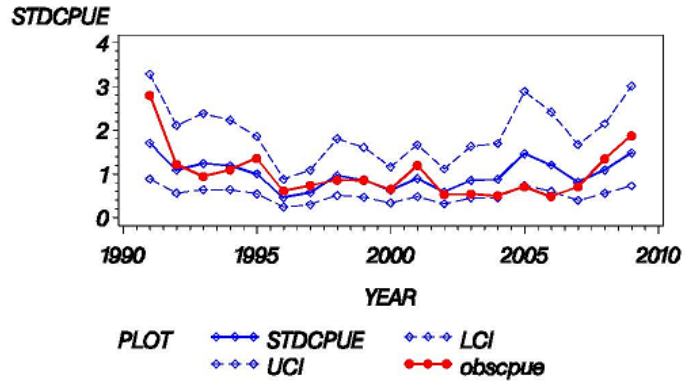


Figure 2. Yellowedge grouper nominal CPUE (solid circles), standardized CPUE (open diamonds) and upper and lower 95% confidence limits of the standardized CPUE estimates (dashed lines) for vessels fishing longline gear in **(A)** region 1 of the Gulf of Mexico, **(B)** region 2 of the Gulf of Mexico, and **(C)** region 3 of the Gulf of Mexico.

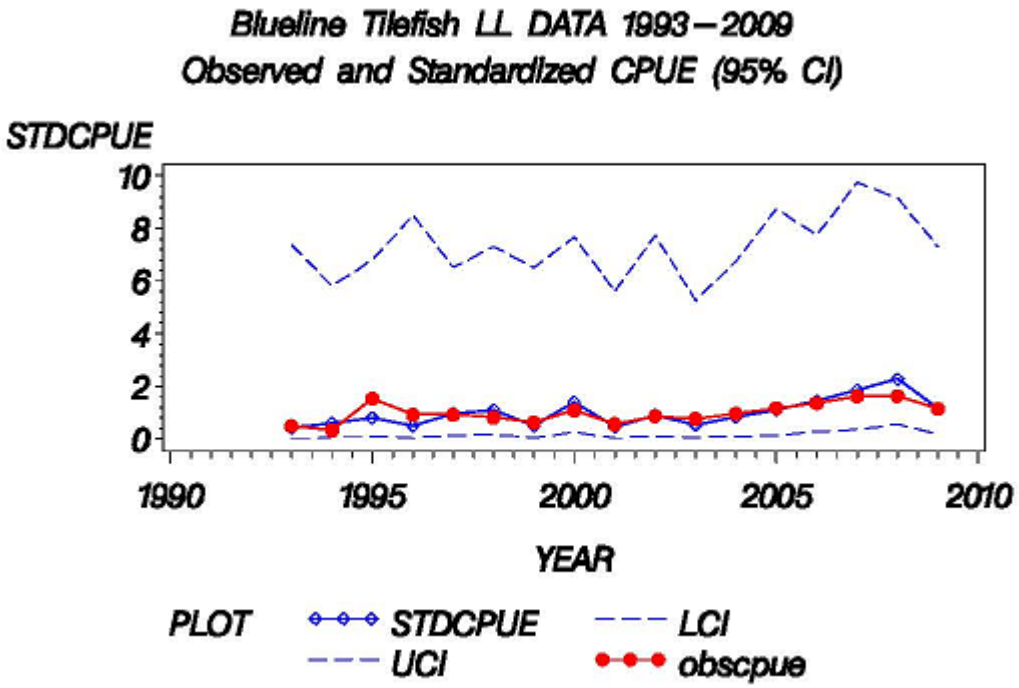


Figure 3. Golden tilefish nominal CPUE (solid circles), standardized CPUE (open diamonds) and upper and lower 95% confidence limits of the standardized CPUE estimates (dashed lines) for vessels fishing longline gear in the Gulf of Mexico.

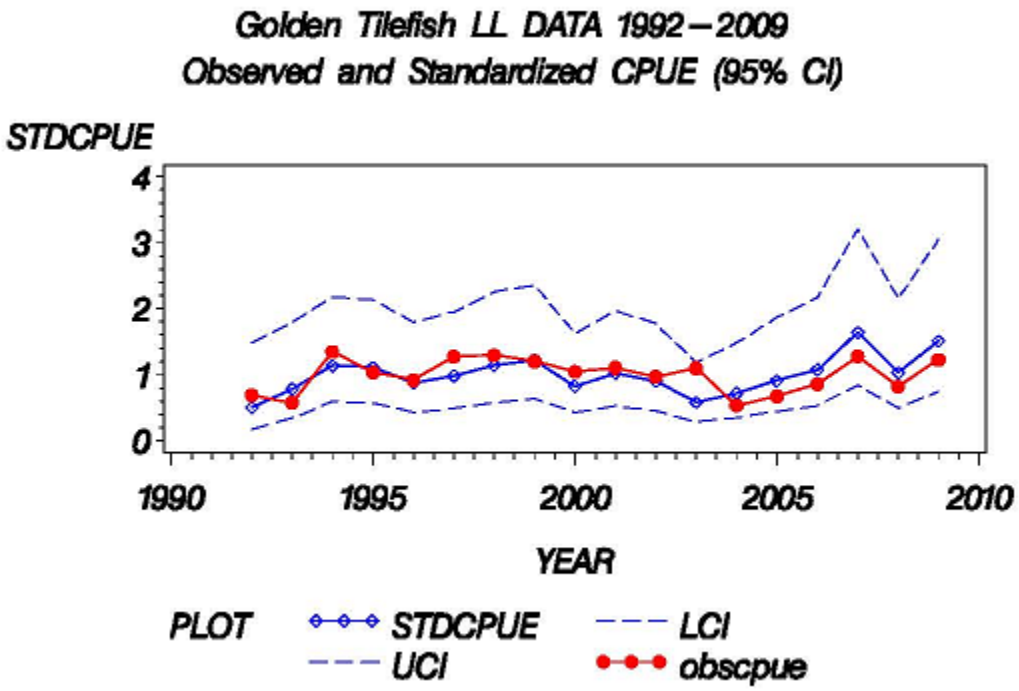


Figure 4. Blueline tilefish nominal CPUE (solid circles), standardized CPUE (open diamonds) and upper and lower 95% confidence limits of the standardized CPUE estimates (dashed lines) for vessels fishing longline gear in the Gulf of Mexico.

Pelagic Fisheries Logbook Program

K. Erickson (UM/CIMAS); S. Turner and M. Maiello (NOAA/SEFSC)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** To assist with all phases of pelagic weigh-out data and longline vessel logbook data processing and quality control for domestic longline data. To take on partial responsibility of two Oracle systems: Fisheries Logbook System (FLS) and Domestic Longline System (DLS) databases including advising on maintenance, improvement and redesign with emphasis on improving work flow and quality control as well as review and maintenance of metadata. To provide support on previous data management responsibilities and provide limited field work support for Dr. Margaret Miller (Coral reef protected resources).

***Strategy*:** Work with co-workers to improve the database systems especially with respect to quality control and maintain metadata about the systems. Assist with yearly audits, weigh out data comparisons, and catch at size data comparisons. Assist with the compiling of monthly swordfish landings that are reported to Highly Migratory Species (HMS) for quota monitoring with supervision of team leader and with compiling annual reports to International Commission for the Conservation of Atlantic Tunas (ICCAT) on landings, catch rates and size composition of Atlantic pelagic species. Answering requests from fishermen and dealers, providing information on the completion of logbook forms, retrieving vessel permit information and updating delinquent vessels' data and permit renewal information. Educate myself on Statistical Analysis Software (SAS) and when time permits to facilitate data requests, assist colleagues in other divisions, and begin working toward stock assessment analysis. Provide Access database management support for Dr. Miller's team. Participate in coral reef field work when time permits.

CIMAS Research Theme:

***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 an Ecosystem Approach to Management

NOAA Funding Unit: NMFS/SEFSC **NOAA Technical Contact:** Patrick Cope

Research Summary:

The Domestic Pelagic Longline Data program is an ongoing program that collects data from various commercial fisheries in the Atlantic Ocean, Caribbean Sea and Gulf of Mexico. The focus of this research program is to continue fisheries-dependent data collection, with an emphasis on improving data quality to provide more reliable fishery analyses and fisheries management decisions.

The primary concern of the Domestic Pelagic Longline Data program is landing data of swordfish and tuna. The landings data is collected to assist with the compiling of monthly swordfish landings that are reported to HMS for quota monitoring and with compiling annual reports to ICCAT on landings, catch rates and size composition of Atlantic pelagic species. The two fishery database systems (FLS and DLS) utilized for pelagic logbook program are critical to NOAA's obligations to the International Commission for the Conservation of Atlantic Tunas. This research involves

collaboration with other scientists and technicians at NOAA Fisheries Southeast Fisheries Science Center (SEFSC) as part of the Sustainable Fisheries Division (Figure 1, Figure 2).

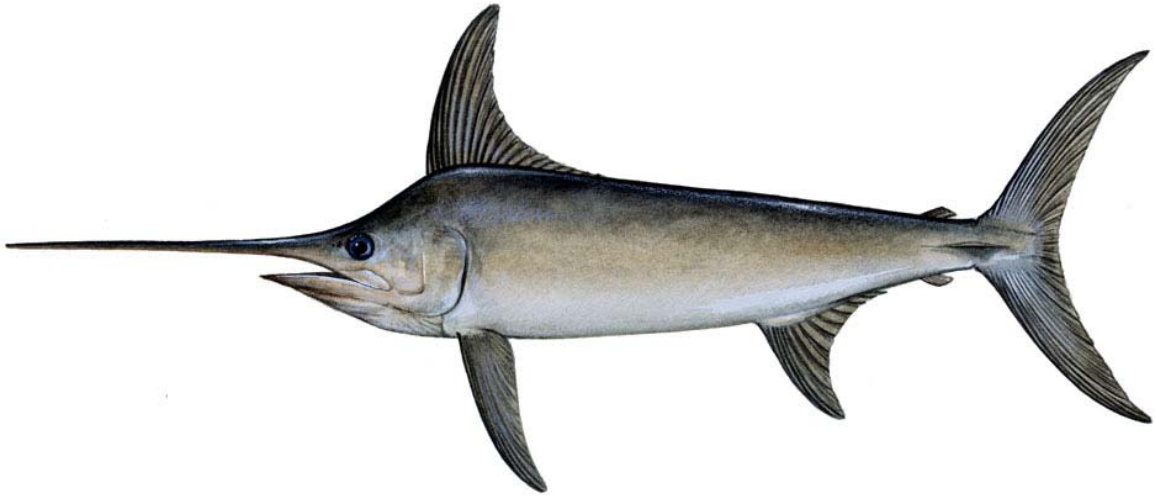


Figure 1: Photo of *Xiphias gladius* the swordfish (www.safmc.net,

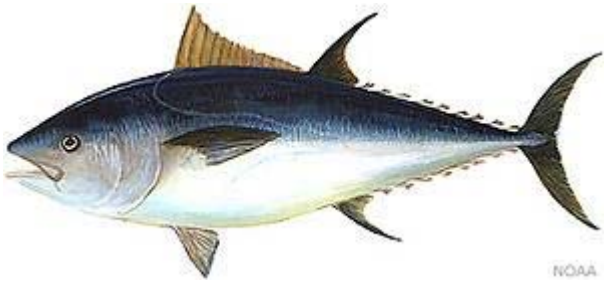


Figure 2: Photo of *Thunnus thynnus* the Atlantic Bluefin Tuna (www.MarineBio.org, 2009).

Research Performance Measure: All major objectives have been met.

Marine Mammal Research

L. Aichinger Dias (UM/CIMAS); L. Garrison (NOAA/SEFSC)

Long Term Research Objectives and Strategy to Achieve Them:

Objectives:

To support the Marine Mammal Health and Stranding Response Program (MMHSRP) at Southeast Fisheries Science Center (SEFSC) in data validation and collection in compliance with the Data Quality Act and Marine Mammal Protection Act.

To assist the SEFSC's Protected Resources and Biodiversity program in management and conservation of protected species during data collection programs within the Marine Mammal Program as amended by the Marine Mammal Protection Act and Endangered Species Act.

Strategies:

To validate the stranding historical data collected by the Southeast Region Marine Mammal Stranding Network from 1996 to 2001 working closely with the SEFSC staff to implement effective data auditing and correction.

To respond and coordinate response actions with the Southeast Region (SER) Stranding Coordinator in case of any cetacean stranding dead or alive as well as entanglement reports of cetaceans along the US Southeast Region (from North Carolina to Texas, Puerto Rico and the U.S. Virgin Islands).

To compile and distribute weekly information about cetacean strandings and entanglement along the SER to NOAA SEFSC's e-mail list.

To support field work and management of data onboard the NOAA Ship Pisces during the Sperm Whale Acoustics and Prey Study in the Gulf of Mexico.

To assist on the Biscayne Bay's bottlenose dolphin population monitoring program by means of photo-identification as well as carcass recovery and necropsy.

To assist on management of data coming from monitoring studies during the Deepwater Horizon Oil Spill Response in the Gulf of Mexico.

To supervise temporary interns at the SEFSC Miami facility, Marine Mammal's division.

CIMAS Research Theme:

***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 an Ecosystem Approach to Management

NOAA Funding Unit: SEFSC **NOAA Technical Contact:** Lance Garrison

Research Summary

Completing the auditing and validation of the historical stranding data improves the accuracy in which the scientific analysis of cetacean strandings can be performed. Similarly, responding to strandings and gathering consistent data also provides the baseline for scientific analysis. This is especially crucial, considering the increasing interest in examining the impacts of military and other human activities on the rate and location of stranding events nowadays. Gathering data from dead animals is important and so is the monitoring of live populations, especially wild population living in highly human influenced areas such as metropolitan areas (Miami) and the Gulf of Mexico.

Given the current circumstances affecting the Gulf of Mexico with the oil spill special attention has been given to the area by means of increased research effort as well as displacement of personnel to the area by the SEFSC.

Figure 1: Bottlenose dolphins in Biscayne Bay.

Research Performance Measure: All objectives proposed are being met. Some strategies, however, were given higher priority due to the actual circumstances affecting the Gulf of Mexico as well as personnel in the SEFSC, specifically, the oil spill data management and the stranding response.

Characterization of Ocean Acidification in Coral Reef Waters

D. Gledhill (UM/CIMAS); C. Langdon (UM/RSMAS); J. Hendee and R. Wanninkhof (NOAA/AOML); C. Sabine (NOAA/PMEL); J. Corredor (UPRM); W. McGillis (CICAR)

Long Term Research Objectives and Strategy to Achieve Them:

***Objective*:** NOAA CRCP and partners are currently developing a means to characterize and monitor the chemical changes in reef environments necessary to assess natural variability and better constrain critical thresholds in the carbonate system.

***Strategy*:** 1) enhance/maintain sustained ocean acidification (OA) observations at the Atlantic OA Test-bed, including advanced sensors and hydrodynamic monitoring and 2) develop new techniques for monitoring community-scale metabolic performance necessary in establishing critical thresholds.

CIMAS Research Theme:

***Theme 3*:** Regional Coastal Ecosystem Processes (*Primary*)
***Theme 6*:** Integrated Ocean Observations (*Secondary*)
***Theme 1*:** Climate Variability (*Tertiary*)

Link to NOAA Strategic Goals:

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

NOAA Funding Unit: NOS/CRCP **NOAA Technical Contact:** Kacky Andrews

Research Summary:
Atmospheric carbon dioxide (CO_2) concentrations are currently at levels greater than, and increasing at a rate faster than, experienced for at least the last 650,000 years. Global oceans serve as the largest natural reservoir for this excess CO_2, absorbing one-third of that emitted each year. As a consequence, dissolved CO_2 in the surface ocean could double over its pre-industrial value by the middle of this century resulting in changes to ocean chemistry more dramatic than in over 20 million years. As CO_2 reacts with seawater, fundamental chemical changes occur causing a pH reduction (or acidification) and a reduced availability of chemical compounds which play an important role in calcification. A growing number of laboratory experiments now demonstrate that OA could hamper reef-building processes. Model estimates suggest that by mid-century, coral reef accretion may be compromised along with ecosystem resiliency to other environmental stresses (e.g., disease, bleaching).

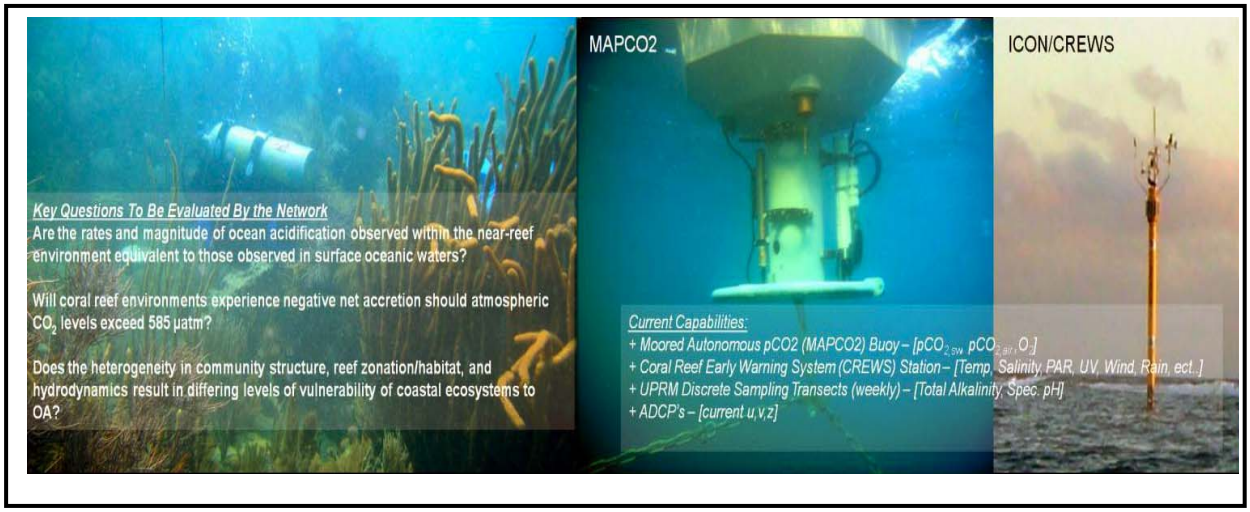


Figure 1: The Atlantic Ocean Acidification Test-bed serves as a nexus of OA monitoring research in the Greater Caribbean Region uniting autonomous and discrete sampling platforms in concert with process and modeling studies.

CIMAS investigator Dr. Dwight Gledhill leads an interdisciplinary team of investigators from NOAA, University of Puerto Rico, University of Miami, Columbia University and the USGS in a five year (FY08 -12) project to 1) establish a standardized approach and methodology for monitoring, assessing, and modeling the impacts of OA on coral reef ecosystems, 2) identify critical thresholds, impacts, and water chemistry trends necessary for developing ecological forecast, 3) characterize the spatial and temporal variability in carbonate chemistry in coral reef environments to better characterize the threat of OA, 4) provide data and information necessary to facilitate an early alert system based on ecological forecasting for OA stress to coral reef ecosystems.

Research Performance Measure: Provide continuous sustained monitoring of ocean acidification relevant chemistry in near-reef waters. – achieved.

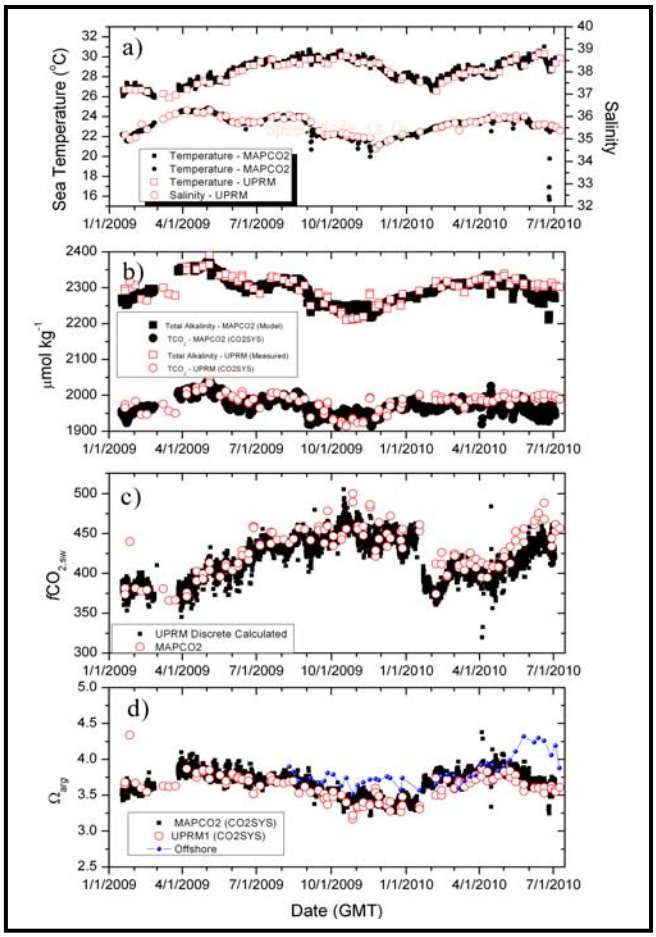


Figure 2: The Atlantic Ocean Acidification Test-bed has provided near-continuous near-reef observations of physical (a) and chemical (b – d) conditions along the Cayo Enrique forereef designed to yields insight into the long-term effects of OA on coral reef ecosystems. The unites both autonomous and discrete measurements to provide a means to track carbonate mineral saturation state (Ω_{arg}) which is a key parameter of concern with regards to OA effects on coral reef (d).

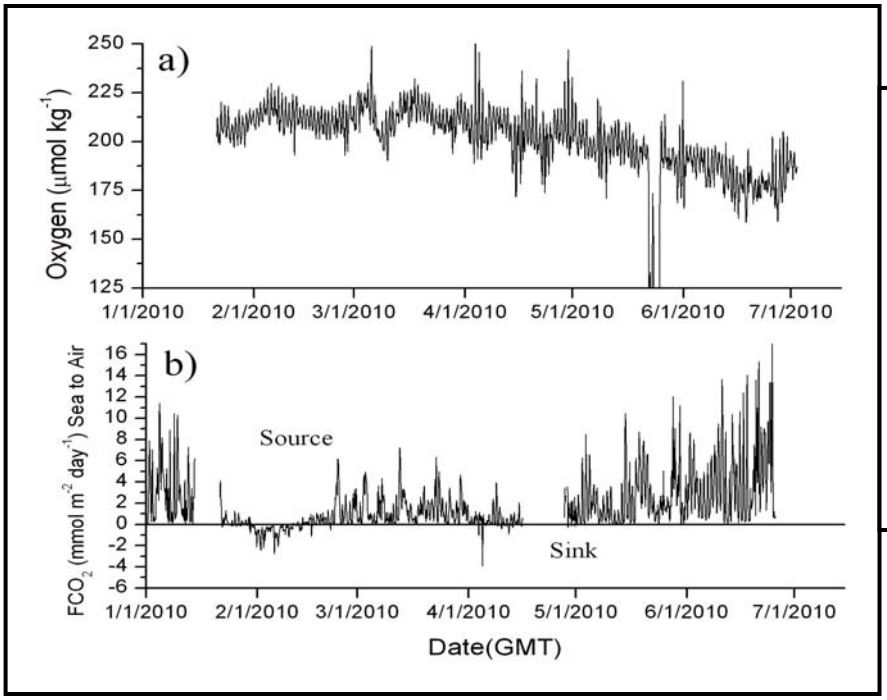


Figure 3: Recent upgrades to the autonomous capabilities at the test-bed provide for near-real-time monitoring of CO_2 flux by merging the data with that of the nearby ICON station and also provide for measurements of oxygen concentrations which is critical to interpreting the biological controls on the local carbonate chemistry.

Florida Area Coastal Environment (FACE)
Water Quality Monitoring and Tracer Study Project

C. Brown, C. Sinigalliano and N. Amornthammarong and L. Visser (UM/CIMAS);
J. Bishop, T. Carsey, J. Craynock, C. Featherstone, C. Fischer, L. Salerno,
J. Stamates and J.-Z.Zhang (NOAA/AOML)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** To quantify impact of nutrient sources, including six treated-wastewater outfalls, on the water quality and coastal ecosystems of SE Florida.

***Strategy*:** Perform extensive water quality monitoring and deliberate tracer experiments in the areas of interest.

CIMAS Research Theme:

Theme 3: Regional Coastal Ecosystem Processes (*Primary*)
***Theme 4*:** Human Interactions with the Environment (*Secondary*)
***Theme 6*:** Integrated Ocean Observations (*Tertiary*)

Link to NOAA Strategic Goals:

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

NOAA Funding Unit: OAR/AOML **NOAA Technical Contact:** Thomas P. Carsey

Research Summary:

The FACE project is primarily concerned with anthropogenic discharges in the Florida's coastal ocean. FACE field operations include a wide range of physical, biological, and chemical oceanographic measurements such as ocean currents nutrients, stable isotopes, acoustic remote sensing of plumes, microbiological monitoring, and coral reef health monitoring. Doppler current profiler (ADCP), meteorology, and seawater characterizing instrumentation was installed at the Port Everglades inlet as described in last year's report. This year, we have continued to generate current flow and seawater parameter data which have lead to more detailed understanding of the flow characteristics. In Figure 1, the flow structure during ebb and flood tide for 4-17-08 is shown. The flow is complex, with considerable variation in flow with depth and across the inlet. In addition, some preliminary nutrient samles were analyzed (Figure 2), which allows us to estimate nutrient flux values for the inlet. During next year, more detailed nutrient studies are planned, leading to a robust value for the nutrient flux into the coastal ocean. The website is:
(http://www.aoml.noaa.gov/themes/ CoastalRegional/projects/FACE/ PtEverg.htm).

Research Performance Measure: ADCP, meteorology, and seawater instrumentation at Port Everglades has been maintained and the data made available on line. Water quality monitoring for the coastal waters adjacent to Broward and Hollywood treated-wastewater outfalls began this summer. (http://www.aoml.noaa.gov/themes/CoastalRegional/projects/FACE/WQ-Survey.htm).

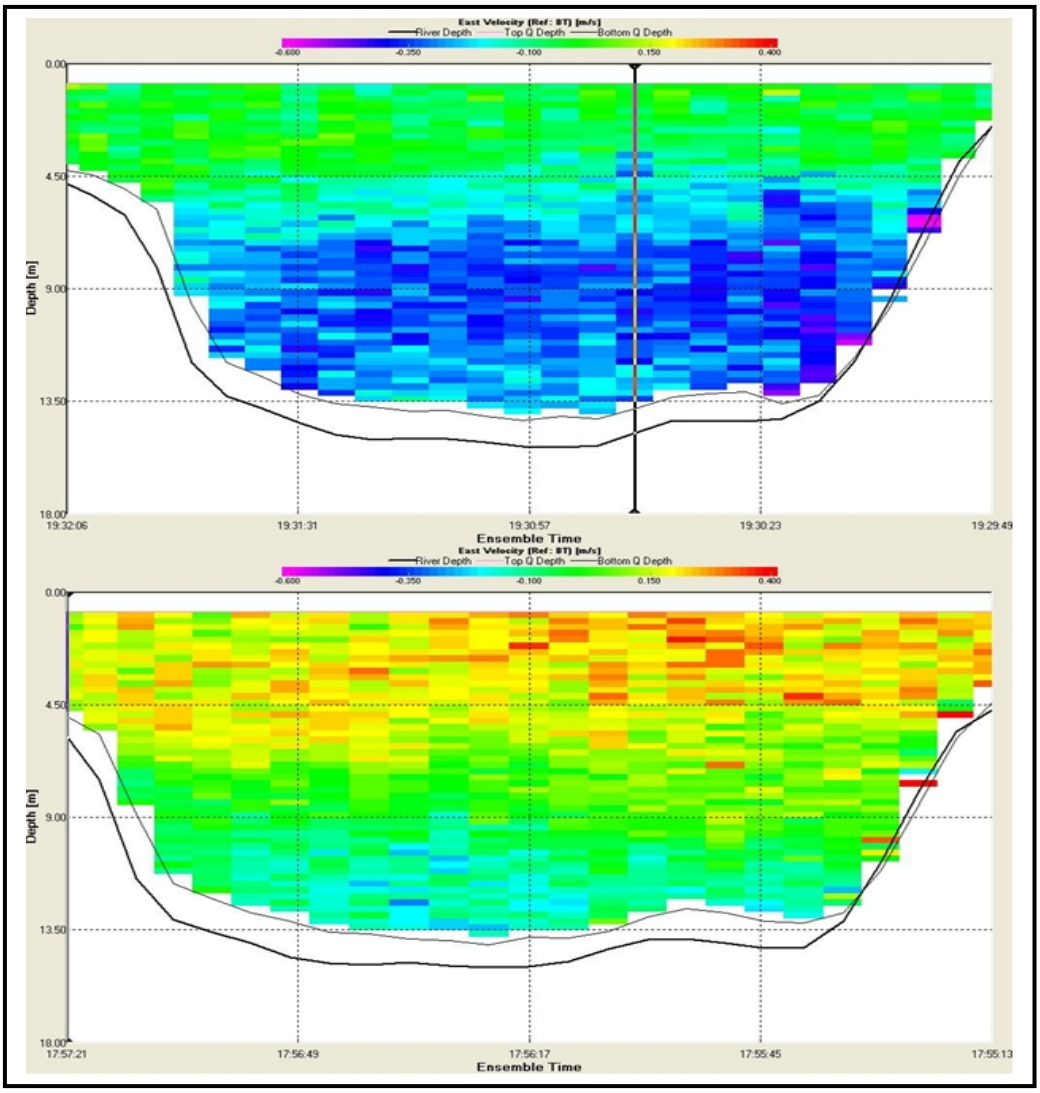


Figure 1: ADCP-derived flow structure during flood (upper) and ebb (lower) tide, through the Port Everglades inlet. Vertical scale has been significantly exaggerated.

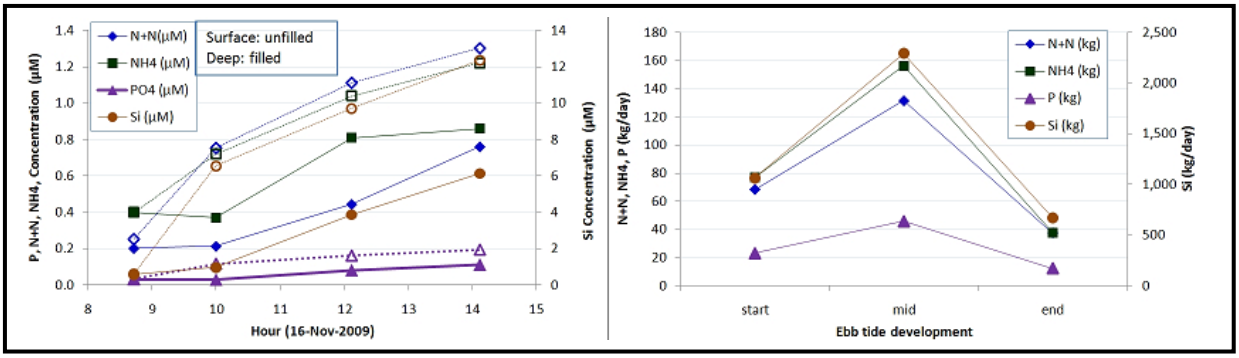


Figure 2: Preliminary estimates of nutrient fluxes, 16-Nov-2009. Left: concentrations of key nutrients during ebb tide. Right: estimates of nutrient fluxes (kg/day) based on measured flow and nutrient data. Silicate values use right-hand vertical axis.

Modeling Connections Among Life Stages and Habitats of Pink Shrimp in South Florida

M.M. Criales (UM/RSMAS); H. Cardenas and I. Zink (UM/CIMAS); J.A. Browder and T.L. Jackson (NOAA/SEFSC); M.B. Robblee (USGS/SESC)

Long Term Research Objectives and Strategy to Achieve Theme:

***Objectives*:** To develop a pink shrimp (*Farfantepenaeus duorarum*) simulation model and performance measure of the impact of the Comprehensive Everglades Restoration Plan (CERP) on water management changes in the Florida Bay

***Strategy*:** Conduct coordinated field and laboratory experiments on different life history stages of pink shrimp in conjunction with water quality and circulation measurements to improve our understanding of the recruitment process of this important fishery species.

CIMAS Research Theme:

***Theme 3*:** Regional Coastal Ecosystem Processes

Link to NOAA Strategic Plan:

***Goal 1*:** Protect, Restore, and Manage the Use of Coastal and Ocean Resources through an Ecosystem Approach to Management

NOAA Funding Unit: NMFS/SEFSC **NOAA Technical Contact:** Joan Browder

Research Summary:

We continue to refine our understanding of the ecology and behavior of this important species in Florida Bay and the SWF shelf of the Gulf of Mexico. Activities during the summer of 2009 and the winter of 2010 consisted of laboratory experiments on survival, growth and behavior of pink shrimp postlarvae and early juveniles.

The pink shrimp is a euryhaline species that tolerates a wide range of salinity, with the degree of tolerance varying with life stage. Early larval stages have a weak tolerance to low salinities but as postlarvae approaching coastal waters, tolerance to low salinities increases. As juveniles in south Florida shrimp are found in different salinity regimes. In western Florida Bay, the main nursery ground of the species, shrimp live at salinities between 30 and 50 ppt. In Whitewater Bay, about 20 km north of western Florida Bay, shrimp live in slightly brackish waters (5-15 ppt). The wide salinity range in which juvenile shrimp live may be related to: *1*) genetic differences among populations, or *2*) internal mechanisms allowing adaptation to salinity conditions. Adaptation to salinity may be achieved by acclimation to salinity conditions encountered as postlarvae settle in nearshore nursery habitats when shrimp have the maximum capacity to osmoregulate and adapt to a wide range of salinities. To test this hypothesis, we conducted laboratory experiments on salinity tolerance and on growth and survivorship of pink shrimp postlarvae (PL). PL20 (age or number of days as postlarvae) were preconditioned (long-term acclimation) to salinities of 15 and 35 at 25±2.5^{0}C for 30 d. After the 30 d period PL50 were transferred to eight salinities treatments (5, 10, 15, 25, 35, 45, 55, 60) and survival rates of PLs were determined between 0.5 and 144 h of exposure to the tested salinity. In the laboratory shrimp were fed a formulated pellet artificial diet. Results indicated that all PL50 acclimated to 35 ppt died at salinities of 5 and 10 after 6 h of exposure; however, survival was over 90% at salinities between 25 and 45 (Fig 1). PL50 acclimated to 15 ppt did not survive more than 12 h at any salinity >35, but their survival at salinities 5 to 25 was over 96%. These results suggest that

the tolerance range (homeostatic range) of PLs preconditioned at a salinity of 15 was 20 ppt lower than that of postlarvae preconditioned at 35 ppm. Results support our hypothesis that salinities as postlarvae may determine the future tolerance range of juveniles.

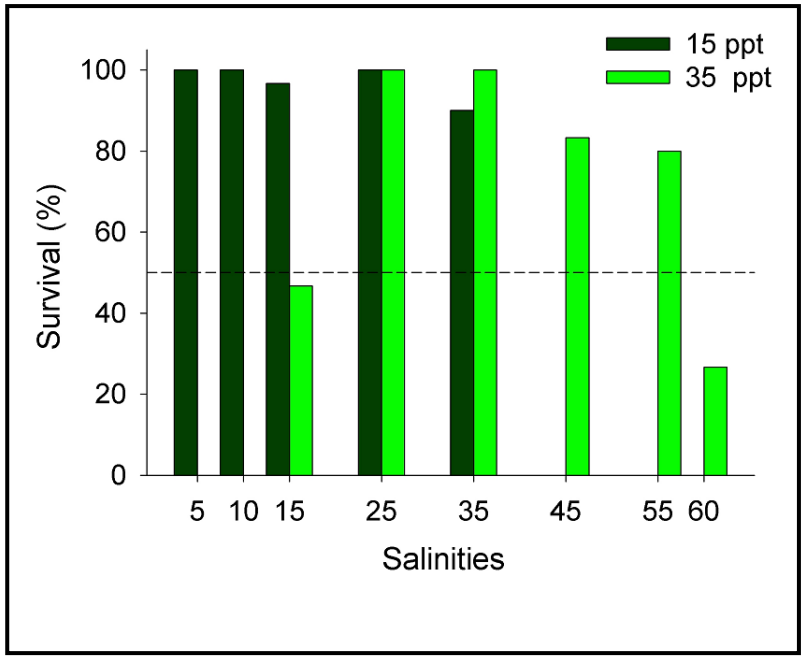


Figure 1: Survival rates (%) of pink shrimp postlarvae (PL50=50 days as postlarvae) previously acclimated in salinities of 15 and 35 ppt for 30 days and then exposed to eight salinity treatments (5, 10, 15, 25, 35, 45, 55 and 60 ppt) for 144 h.

A subsequent growth expe-riment was conducted with juveniles acclimated to salinities of 15 and 35 for 50 days. Juvenile shrimp acclimated to 15 ppt were reared in 5, 15 and 25 ppt and those acclimated to 35 ppm were reared in 25, 35 and 45 ppt. The experiment lasted 30 d at 27±2.0^{0}C. Results indicated that the growth rate of juveniles preconditioned at 35 ppt was higher than that of juveniles preconditioned at 15 (Fig. 2). ANOVA showed neither significant differences in growth between salinity treatments, nor significant differences in growth between salinity controls of 25 ppt in each acclimation group.

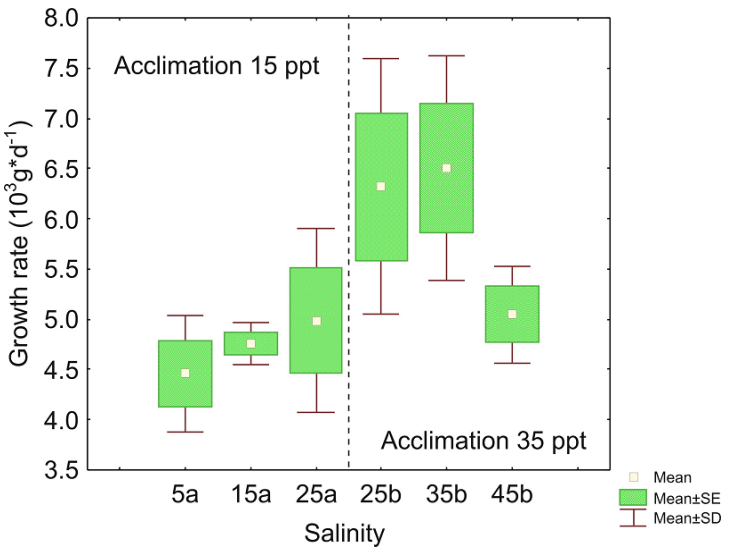


Figure 2: Growth rate (mean ± standard deviation and standard error) of pink shrimp juveniles previously acclimated in salinities of 15 and 35 for 50 days and then reared in different salinity treatments for 30 d. Juveniles acclimated in 15 ppt were reared in 5, 15 and 25 ppt and those acclimated in 35 ppm were reared in 25, 35 and 45 ppt.

One clear result of our prior research has been the strong response of postlarvae and juveniles to tidal currents (CIMAS report 2009). Therefore, behavior has become an important component of this study. To test the hypothesis that pink shrimp postlarvae have an endogenous rhythm we conducted a laboratory experiment in cooperation with Dr. Matt Ogburn of Savannah State University. Postlarvae collected in Florida Bay were placed in a clear Plexiglas column and the vertical position of postlarvae was monitored with a video camera under constant darkness illuminated by far-red light. Preliminary Maximum Entropy Spectrum Analysis (MESA) indicated that shrimp showed two peaks of migration, one at ~ 12.4 h and

another at 24.9 h, but only the 24.9 h peak was significant 15 (Fig. 3). The result suggests that postlarval shrimp have a circadian rhythm but more trials need to be conducted to confirm our hypothesis.

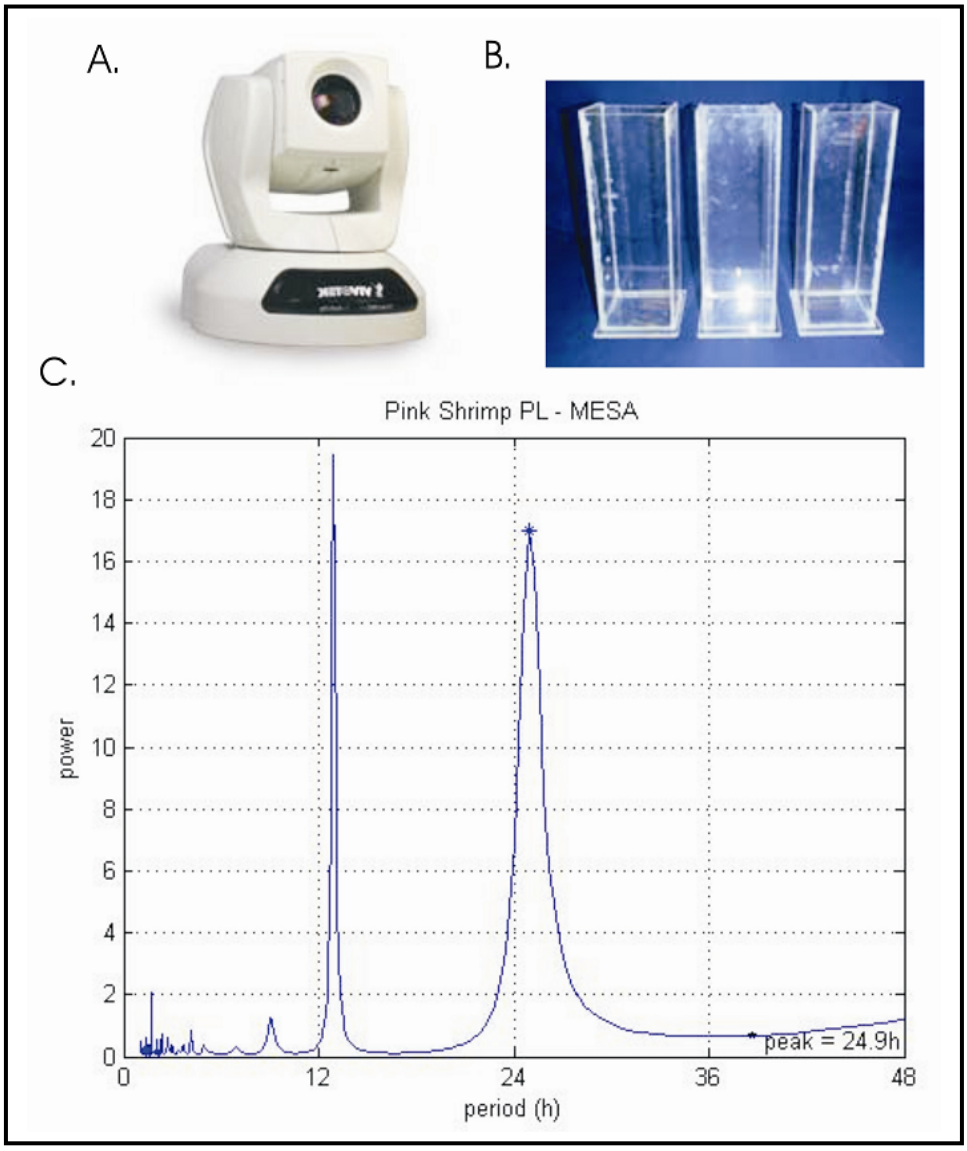


Figure 3: A. Network-compatible digital video camera for recording to a remote computer. **B.** Plexiglas columns. **C.** Maximum Entropy Spectrum Analysis (MESA) of the vertical swimming activity of pink shrimp postlarvae. Asterisks indicate statistically significant peaks in autocorrelation and MESA plots.

Research Performance Measure: The objectives have been accomplished; a unit model has been developed and continues to be refined and extended to add new knowledge. Two manuscripts were completed and accepted for publication in peer-reviewed journals.

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

D. Wanless, J. Bartkowiak, D. Aranda and M. Gidley (UM/CIMAS); K. Goodwin and C. Sinigalliano (NOAA/AOML); H. Coit (UM/RSMAS NSF-REU), J. Joyner (UGA)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** To improve detection of microbial contaminants in coastal waters and to implement these new or modified technologies along with traditional approaches to better characterize microbial contaminants of coastal receiving waters impacted from treated wastewater outfalls, septic field discharge, terrestrial runoff, and other anthropogenic sources.

***Strategy*:** Develop and/or test novel detection methodologies for fecal indicator bacteria, alternative fecal indicator bacteria, human-source microbial markers, and selected pathogens of public and coastal ecosystem health interest, to assess their effectiveness for environmental monitoring of microbial contaminants in coastal waters, and to deploy those molecular technologies found effective along with traditional methods for the assessment of microbial water quality in conjunction with ongoing NOAA water quality monitoring programs.

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 an Ecosystem Approach to Management

NOAA Funding Unit: OAR/AOML (*Primary*); NGI, NOAA OHHI (*Secondary*)

Substantial additional external funding and support provided by NSF, NIEHS, EPA, UM OHH Center, and Source Molecular Corp.

NOAA Technical Contact: Kelly Goodwin & Christopher Sinigalliano

Research Summary:

This research seeks to develop molecular assays for detection of fecal indicating bacteria, source tracking markers and pathogens in coastal waters that impact both human and ecosystem health, and to utilize the developed technologies to assess the microbial water quality of coastal waters and sands.

This project's research focuses on rapid enumeration of bacterial targets in environmental samples through the use of quantitative PCR (qPCR) and has markedly improved these methods applicability to field studies (Figs 1-3). In close collaboration with NOAA/AOML, UM/RSMAS, the UM Oceans and Human Health Center, the Southern California Coastal Water Research Project (SCCWRP), Florida Atlantic University (FAU), Florida Department of Health, Mote Marine Laboratory, Source Molecular Corporation, and the Gulf of Mexico Alliance, we have successfully employed molecular and traditional microbiological technologies to support a wide variety of epidemiology studies and environmental quality assessment studies, including the CDC/UM BEACHES study, Pacific Water Project Avalon, Doheny, and Surfrider studies, and large field programs such as the NOAA Florida

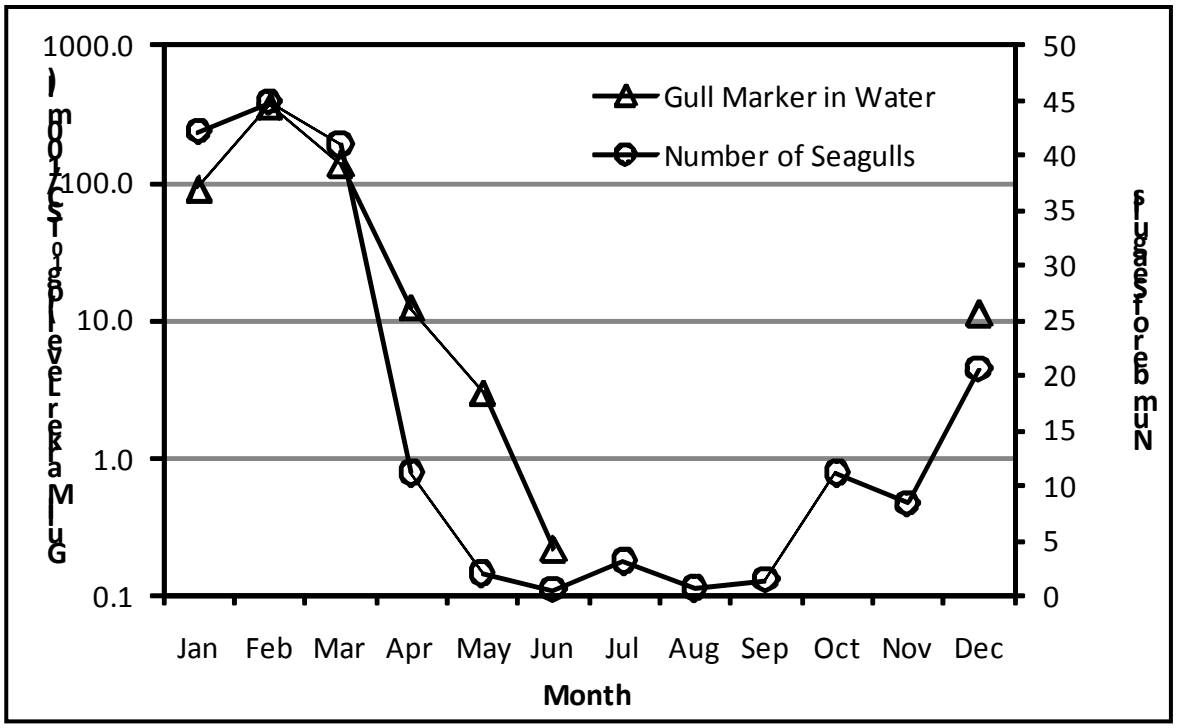


Figure 1: Molecular detection of Gull Fecal Marker (*C. marimammalium*) abundance during a South Florida beach epidemiologic study (BEACHES) shows the same gull seasonality abundance patterns as that observed by an automated hi-resolution camera imaging system at the beach.

Area Coastal Environment Program (FACE), the EPA STREAMS Virtual Beach Program (Figs. 2 and 3), and the Florida Healthy Beaches Program.

For the 2009-2010 period, we have focused on development of zoonotic fecal contamination markers of public health concern. We have added additional source tracking markers to the microbial source tracking toolkit, particularly the development of a real-time PCR assay for the molecular detection and enumeration of *Catellicoccus marimammalium*, a bacterial indicator of fecal contamination by gulls, which can be an important vector of zoonotic disease organisms to beaches and coastal waters (Fig 1). We are in the final stages of multi-lab and specificity studies to validate our zoonotic fecal contamination source tracking markers for dog and gull fecal contamination.

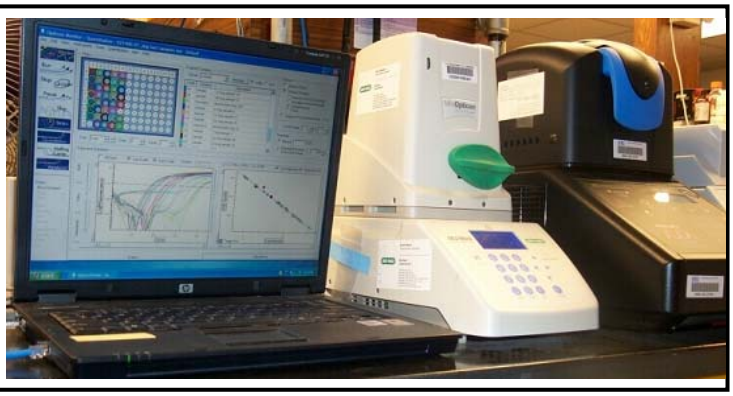


Figure 2: Image of real-time quantitative PCR instrumentation running a molecular assay to measure the amount of canine-source Bacteroides fecal indicator bacteria in beach water samples. This project is developing and testing molecular microbial source tracking methods to assess the potential impact of canine feces, gull and pelican feces, and other animal feces as potential sources of zoonotic pathogens to recreational waters and beaches.

We have also collaborated with Dr. Erin Lipp from the University of Georgia in Athens and members of her lab to develop and field test a real-time PCR assay for the molecular detection and

Figure 3: Elkhorn Coral near Key West, Florida showing White Pox Disease.

enumeration of strains of Serratia marcescens that can potentially cause disease in both humans and coral reefs (causing White Pox Disease in corals, Fig 3). Jessica Joyner, a NOAA Oceans and Human Health Initiative Scholar from Dr. Lipp's lab, spent the summer of 2010 in the Environmental Microbiology Lab of NOAA AOML working closely with CIMAS researchers David Wanless and Maribeth Gidley, and NOAA PI Chris Sinigalliano to develop and field test a series of molecular assays for detecting specific strains of *S. marcescens* causing White Pox Disease in corals, and to detect specific *S. marcescens* virulence genes from contaminated coral mucus. To date these assays appear to be successfully detecting *S. marcescens* in diseased corals, and corals with White Pox appear to have differences in their suite of virulence genes from the strains commonly associated with human disease. Further assay optimization as well as additional specificity and sensitivity testing is on-going in both the UGA and AOML laboratories, and close collaborations between the labs will continue, with CIMAS personnel and AOML lab facilities hosting this UGA project's ongoing field activities and aiding in molecular analyses throughout this next year.

In addition, we have exchanged our protocols and methods with Northern Gulf Institute (NGI) and Gulf of Mexico Alliance (GOMA) researchers, and we have collaborated with engineers at the University of South Florida (USF) to incorporate PCR and electrochemical detection capabilities into the Autonomous Microbial Genosensor (AMG) (Fig 4), and are currently collaborating on a new project lead by Dr. Kelly Goodwin out of the Southwest Fisheries Science Center in association with the Monterey Bay Aquarium Research Insitute (MBARI) on optimization of extraction of genetic material from environmental samples for use with their automated environmental sensor platform (ESP) system.

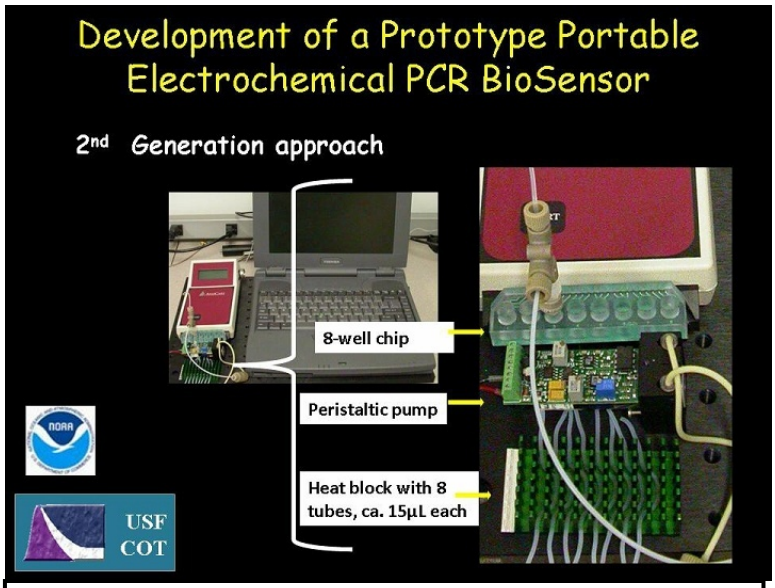


Figure 4: Image of a 2nd generation prototype design for a field-portable electrochemical biosensor utilizing PCR detection of microbial contaminants in environmental samples.

Research Performance Measure: The performance measure of this research is to provide microbiological assessments of coastal waters and sands. All major objectives are being met.

Biscayne Bay Alongshore Epifauna Community

G.A. Liehr, D.R. Johnson (UM/CIMAS); E. Buck, H. Cardenas, A. Griefen,
L.H. Petteway, J.A. Browder and T.L. Jackson (NOAA/SEFSC)
M.B. Robblee (USGS/CWRS)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** Characterize the epifaunal community of nearshore Biscayne Bay and relate distribution, abundance, and community characteristics to salinity, benthic habitat (e.g. seagrass and algae cover), and other environmental factors

***Strategy*:** Conduct a twice-yearly (dry and wet season) spatially intensive epifaunal sampling survey along the western shoreline of South Biscayne Bay and analyze data to relate epifaunal attributes (species abundance, community composition, condition factors, etc.) to salinity and other environmental factors

CIMAS Research Theme:

Theme 3: Regional Coastal Ecosystem Processes

Link to NOAA Strategic Plan:

Goal 1: Protect, Restore, and Manage the Use of Coastal and Ocean Resources through an Ecosystem Approach to Management

NOAA Funding Unit: NMFS/SEFSC **NOAA Technical Contact:** Dr. Joan Browder

Research Summary:

Our study supports the ecological objectives of the Comprehensive Everglades Restoration Plan (CERP) which include restoring the estuarine habitats of southern Biscayne Bay and the diversity and abundance of the component of the fauna associated primarily with salinities ranging from near zero to 20 psu. The purpose of our monitoring project is to characterize the epifaunal community along the shoreline of south Biscayne Bay from Shoal Point to Manatee Bay and to develop performance measures and restoration targets based on this community for use in assessing the effectiveness of restoration efforts.

We used faunal density-weighted salinities to screen for salinity affinities: those species whose center of density was less than the average site salinity might be considered estuarine and those whose center of density was greater than average site salinity might be considered marine. However, we found that the confidence limits on most species extended on both sides of the line of neutrality (i.e., average site salinity) indicating great variability in species affinities (Figures 1A and 1B). For sites 1-47 just a few species such as clown goby, rainwater killifish, gulf toadfish, pink shrimp, common mud crab, caridean shrimp spp., dwarf seahorse, snapping shrimp, and some pipefish spp. had confidence limits on the same side as their density-weighted average salinity. For sites 48-72, confidence limits were shorter, and fewer crossing confidence limits from negative to positive density-weighted salinity appeared. Figure 2 shows species (based on individuals) distributions in relation to salinity, disregarding the average salinity across sites. We found that most of the fish species, some crabs, and pink shrimp are distributed within the polyhaline range (18-30), while other crab species, the caridean (incl. snapping) shrimp, and all echinoderms are distributed within the euhaline range (30-40).

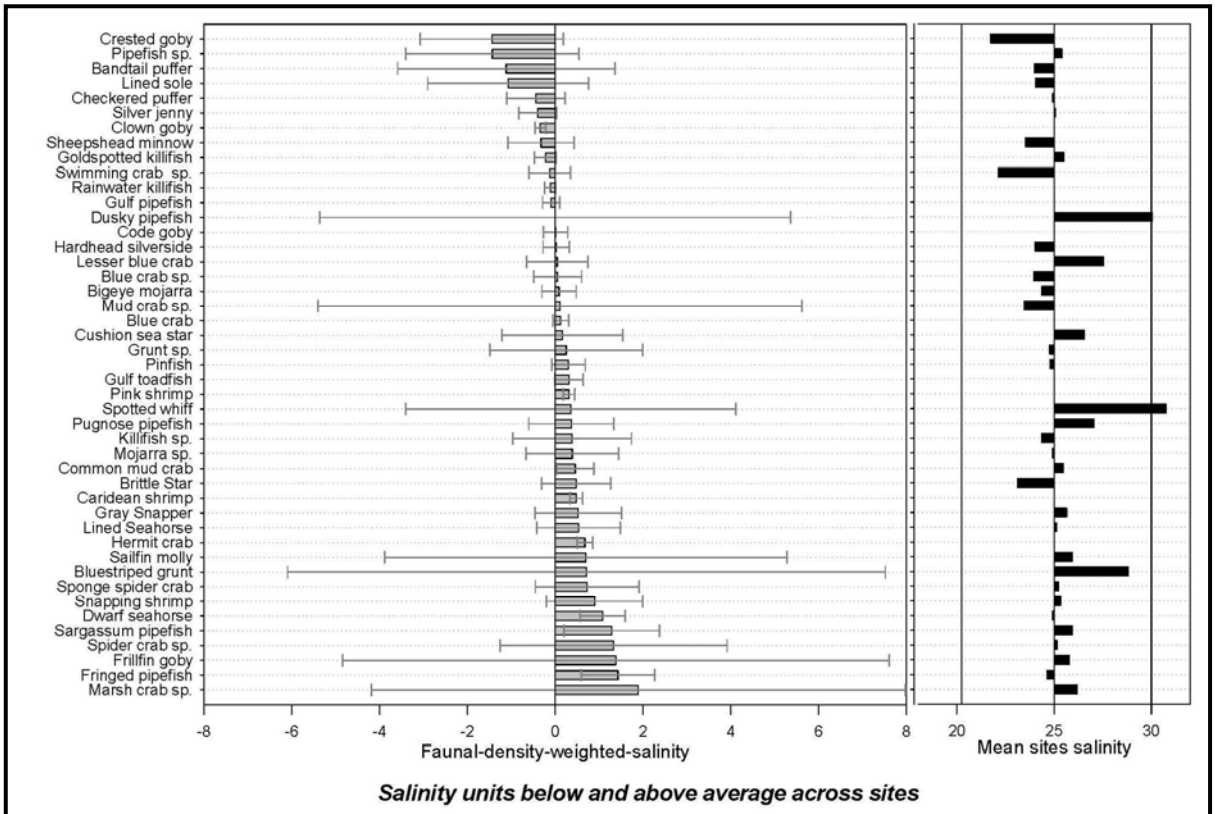


Figure 1A. Mean faunal-density weighted salinity, and average salinity across sites (1-47), for collections in which species was present, 2005-2009

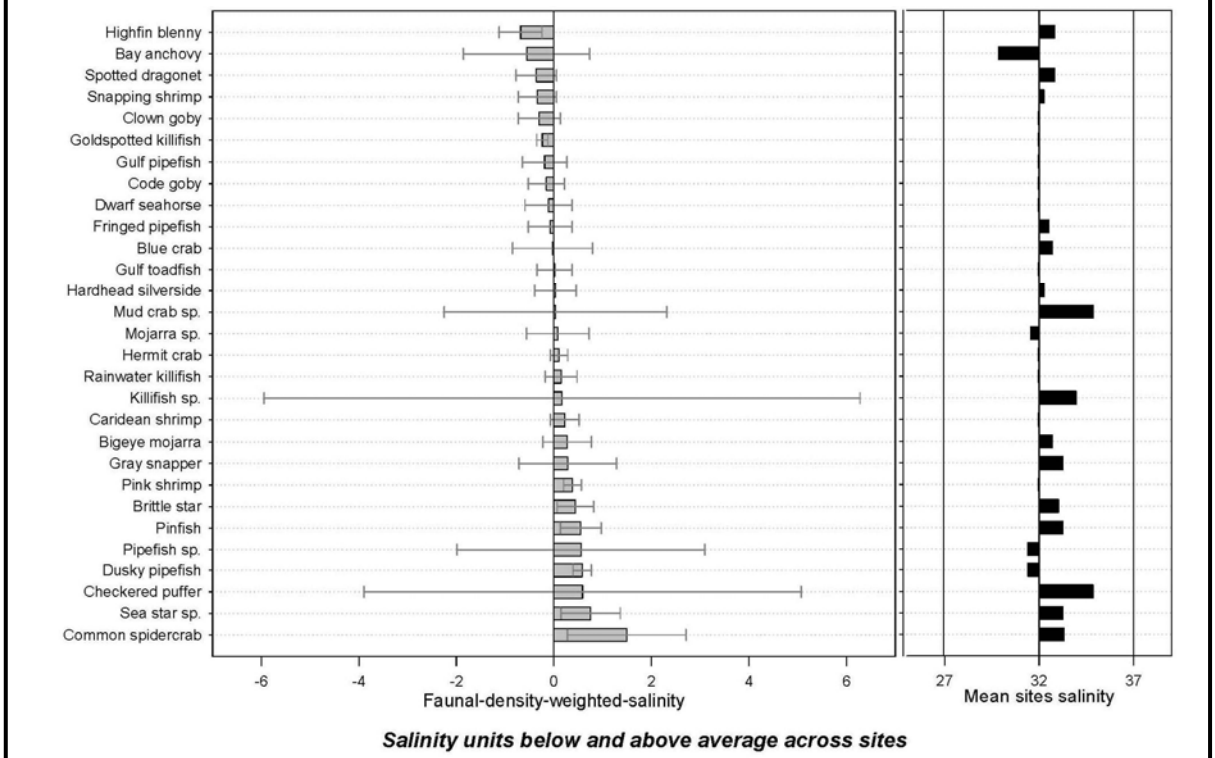


Figure 1B. Mean faunal-density weighted salinity, and average salinity across sites (48-72), for collections in which species was present, 2007-2009

We then used salinity-bin analyses to explore species/salinity relationships and found that relationships were similar to those found using other techniques. Maximum frequency of occurrence was at 30-35 psu for shrimp, crabs, and echinoderms. The highest occurrence of fish was in salinity bins 20-25 to 30-35. Clearly the fish were dispersed over a larger salinity range than the mobile macro-invertebrate fauna.

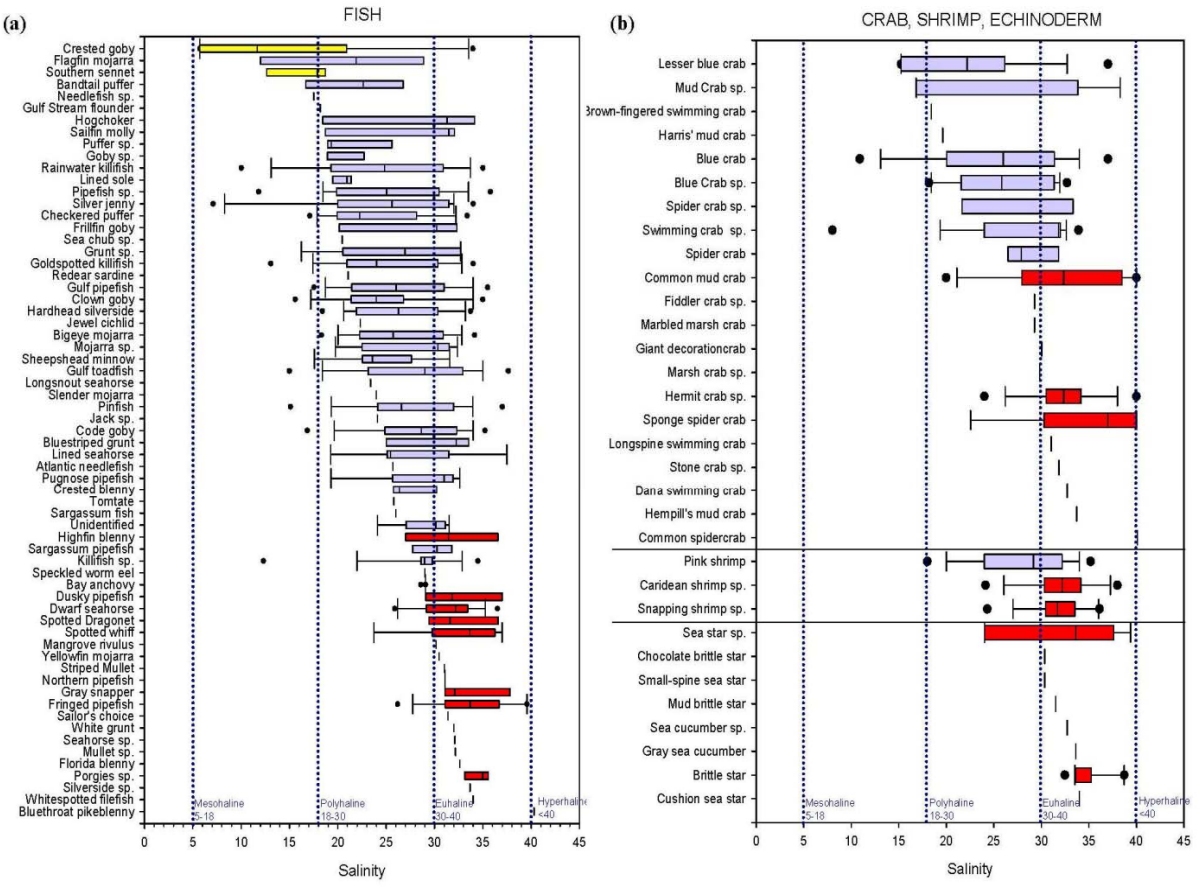


Figure 2. Box plot of species distribution in relation to salinity: (a) fish and (b) crabs, shrimp, and echinoderms, by collection, 2005-2009

The affinity of dominant species with environmental variables was explored using principal component analysis (Figure 3). In analyses that combined all years and seasons, we found that salinity was the most important environmental parameter, followed by temperature and dissolved oxygen (DO). Pink shrimp and caridean shrimp were positively correlated with salinity. Other species increased in density as salinity decreased. These included rainwater killifish (*L. parva*), goldspotted killifish (*F. carpio*), gulf pipefish (*S. scovelli*), clown goby (*M. gulosus*), code goby (*G. robustum*) and blue crab (*C. sapidus*). Rainwater killifish, goldspotted killifish, mojarra sp. were positively correlated with DO. Brittle star sp. (*Ophioderma sp.*), and gulf toadfish (*O. beta*) were positively correlated with canopy height and salinity.

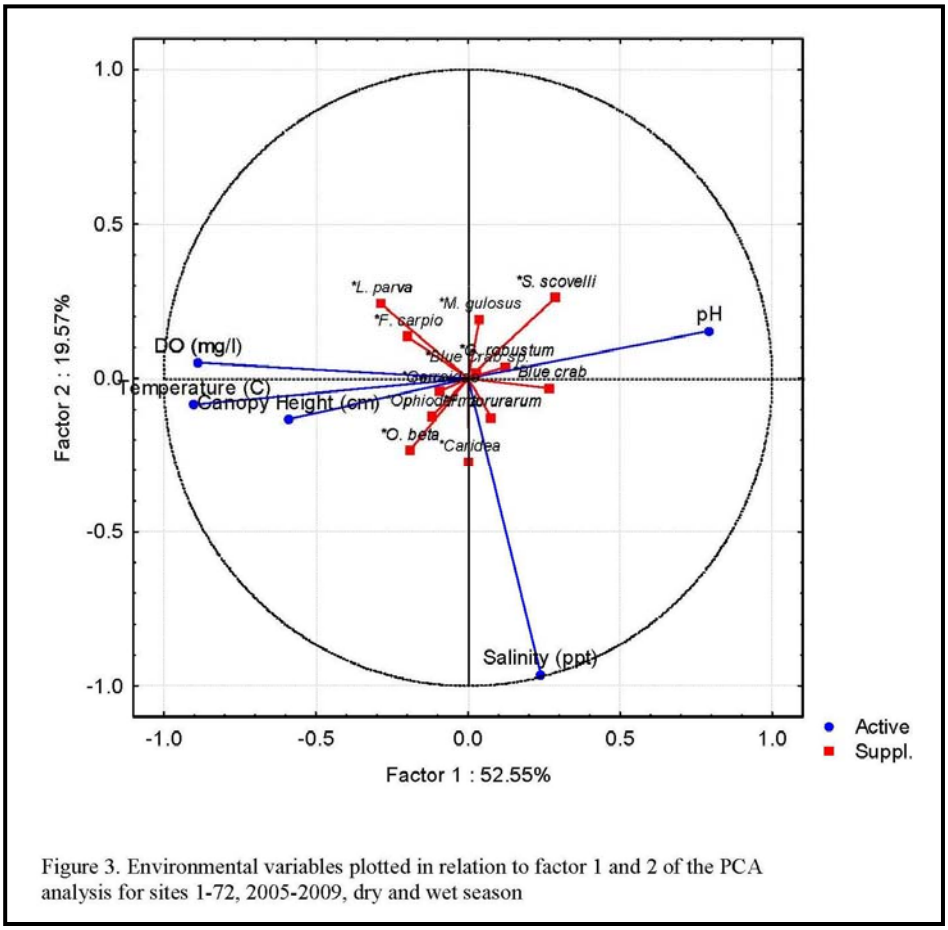


Figure 3. Environmental variables plotted in relation to factor 1 and 2 of the PCA analysis for sites 1-72, 2005-2009, dry and wet season

Based on the new information from this project, we were able to assign a greater number of species to halo-habitat in 2009 than in 2005 (Table 1). The number of unknown ("O") halo-habitat species decreased from a count of 48 to 12, poly-haline species increased by 25, and estuarine-polyhaline species increased by 18. The changes are due both to reassignments and the addition of new species. In other work, we used Bray-Curtis dendrograms and MDS plots to explore similarity in species composition among sites. MDS plots of data from all years (2005-2009) and collections (wet and dry) showed a distinct separation by season (Figure 4).

Table 1. Overview over the total count of species found in 2005 and 2009 and their assigned habitat. 2005 assignments are based on the literature and 2009 assignments are based on an integration of the literature and results of this project.

	Salinity (ppt)	2005	2009
Polyhaline	±18 - >±30	2	27
Euhaline	±30 - ±40	0	3
Estuarine		12	3
Estuarine-polyhaline		1	19
Non-Estuarine	±30 - >±40	33	21
Non-Estuarine-polyhaline		1	13
Other/Unknown	???	48	12

We explored the influence of canal distance on densities of dominant epifauna (Figures 5 and 6). Group patterns of quartiles (<25%, 25-75%, and >75%) of the statistical distribution of density, by species, suggest movement towards canals in the dry season (medium to high densities for all species), and away from canals (lower densities) in the wet season. Canals were classified to high flow or low flow based on average annual flows for the period 1998-2009.

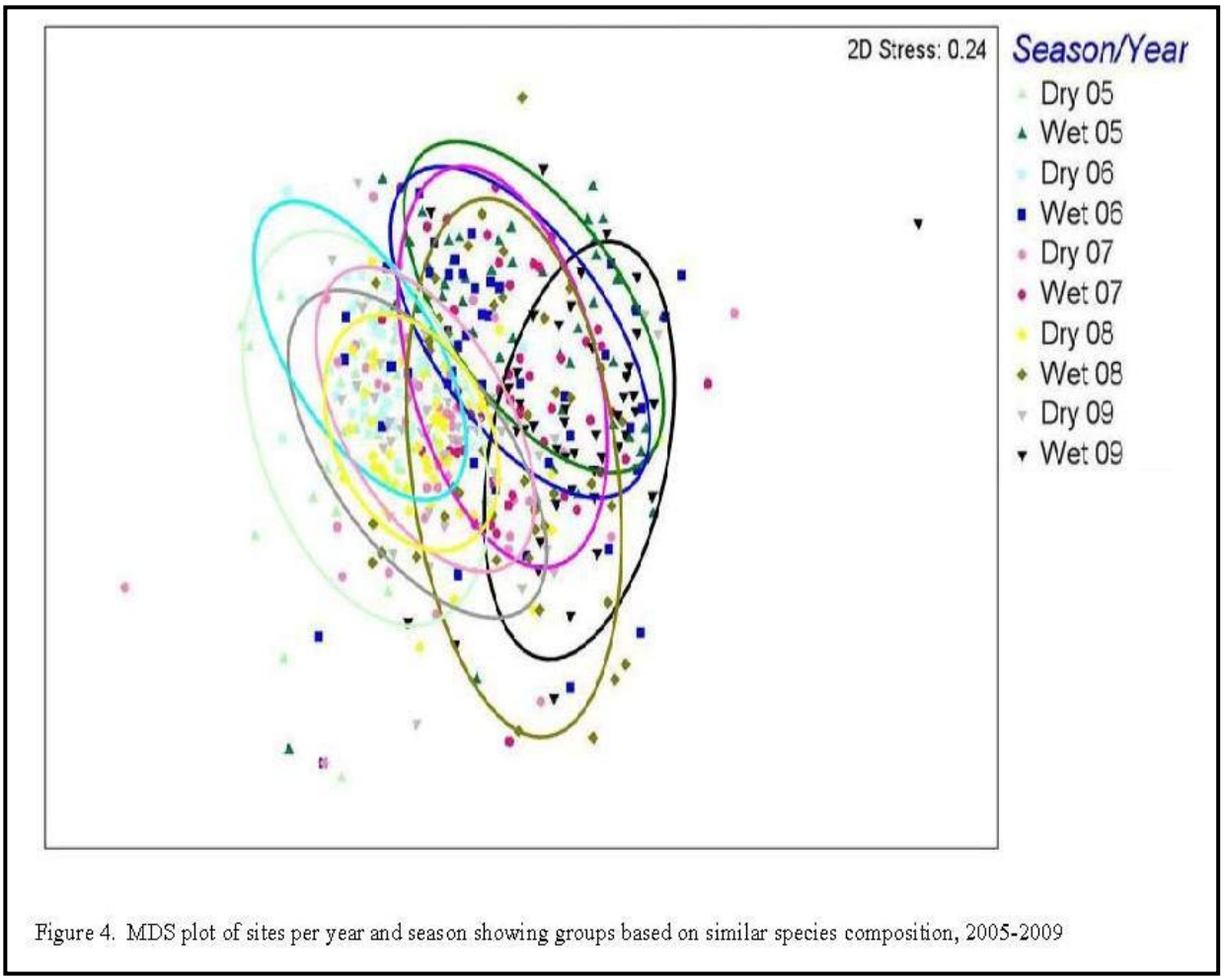


Figure 4. MDS plot of sites per year and season showing groups based on similar species composition, 2005-2009

Research Performance Measure: The primary purpose of our work is to characterize the epifaunal community, determine relationships with halo-habitat, and explore analytical means to develop species-based and community-based performance measures. We have made substantive progress in exploring analytical approaches to addressing our objectives.

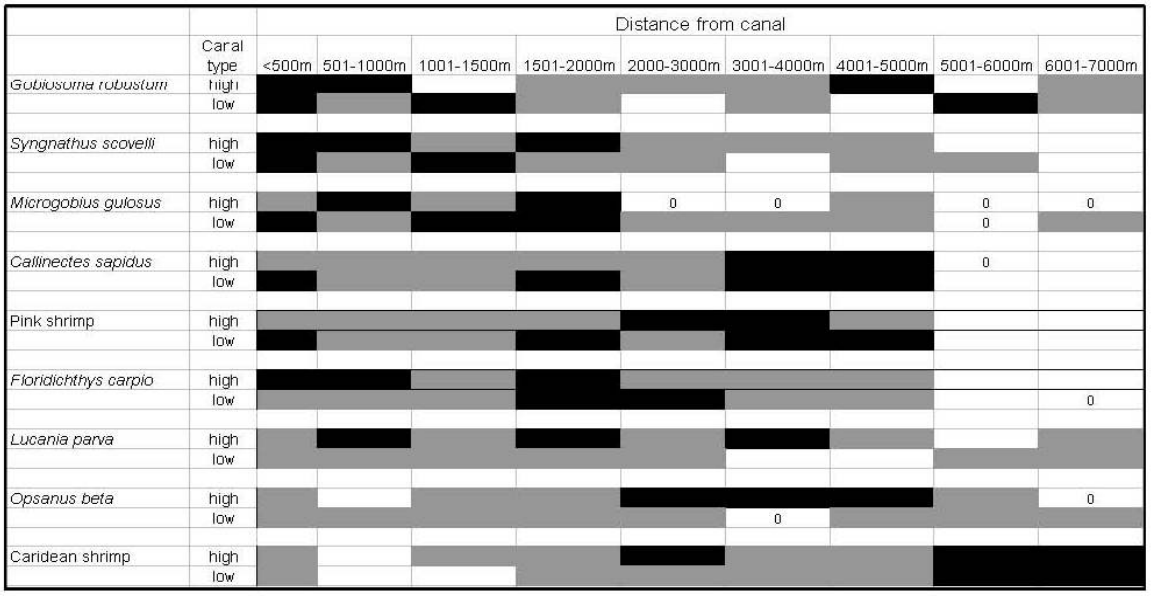


Figure 5. Relative abundance ranked using quartiles of selected dry season Biscayne Bay species sampled in throw-trap in relationship with distance from high-flow and low-flow canals. Black is in the 75% quartile (high density), gray 25-75% (medium density), and white 25% (low density). Low density bins that are zero are indicated.

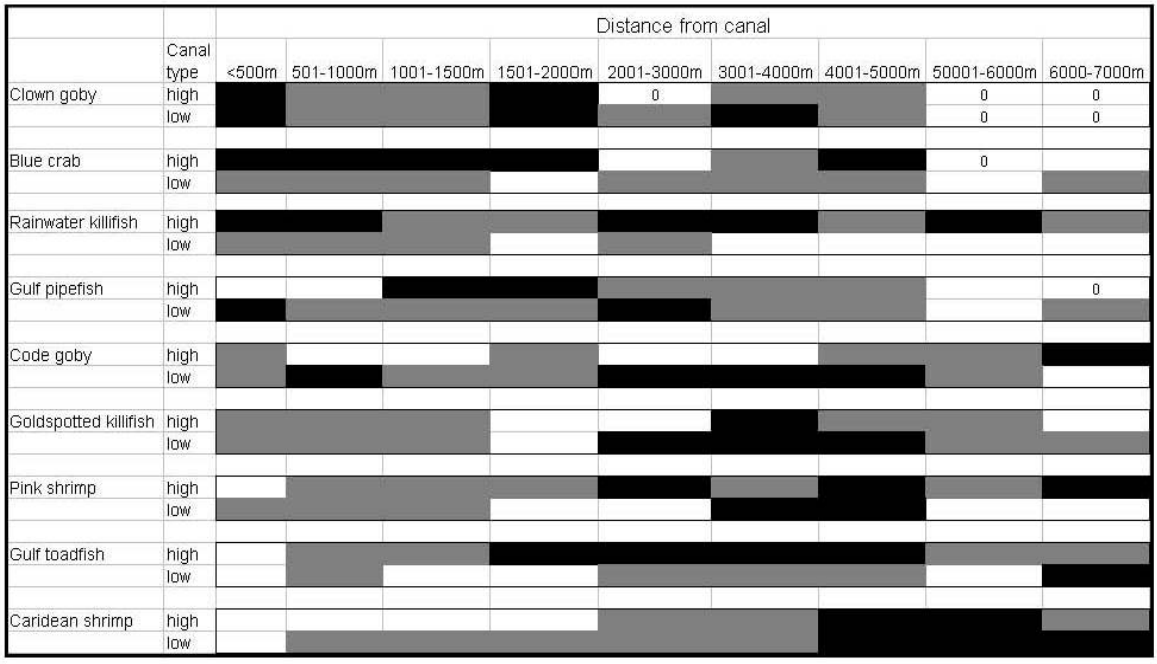


Figure 6. Wet-season density of selected species, ranked using quartiles in relationship with distance from high-flow and low-flow canals. Black is in the 75% quartile (high density), gray 25-75% (medium density), and white 25% (low density). Low density bins that are zero are indicated

Documenting Everglades Restoration Impacts on Biscayne Bay's Shallowest Benthic Habitats

D. Lirman (UM/RSMAS); J. Serafy (NOAA/NMFS)
G. DeAngelo (NOAA/National Geodetic Survey)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** To characterize the seasonal and spatial abundance of the submerged aquatic vegetation (SAV) of western Biscayne Bay and monitor these communities as changes to freshwater flow are implemented as part of the Comprehensive Everglades Restoration Plan (CERP).

***Strategy*:** Conduct seasonal SAV surveys with a Shallow Water Positioning System (SWaPS,) that collects geo-tagged images of the bottom with sub-meter spatial accuracy.

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 an Ecosystem Approach to Management

NOAA Funding Unit: NMFS/SEFSC **NOAA Technical Contact:** Joe Serafy

Research Summary:

This project concentrates on the shallow (< 1.5 m in depth), near-shore (< 500 m from shore) bottom habitats along Biscayne Bay's western margin. These habitats are important nursery grounds for key fisheries species and, due to their location, are likely to be highly impacted by changes in hydrology and water quality caused by Everglades restoration activities. Surveys in this project are conducted with the image-based Shallow Water Positioning System (SWaPS), a methodology that collects geo-tagged, high-resolution digital images of the bottom with high spatial accuracy. These images are analyzed to extract information on abundance, diversity, and distribution of seagrasses and macroalgae, key components of the submerged aquatic vegetation (SAV) community. In addition to these photographic surveys, we conduct remote sensing surveys of these shallow habitats using aerial imagery to evaluate whether salinity patterns influence the landscape ecology (e.g., patch size, habitat fragmentation) of seagrass beds.

Over the past several years, we have collected abundance and distribution information for SAV communities in > 2000 sites in central and southern Biscayne Bay. These surveys have revealed that the abundance and distribution of seagrasses and macroalgae are tightly linked to water quality and, more specifically, to salinity patterns. Near-shore habitats with low and variable salinity are dominated by the manatee seagrass *Halodule wrightii*, a species with a wide tolerance for salinity fluctuations, while habitats with more constant and higher salinity are dominated by the turtle seagrass *Thalassia testudinum*, a species known to be favored under constant salinity conditions (Fig. 1). The documented relationships between seagrass abundance and distribution and salinity are important to the understanding and forecasting of potential future impacts of changes in the hydrology of the Everglades watershed as the activities and projects of the Comprehensive Everglades Restoration Plan proceed.

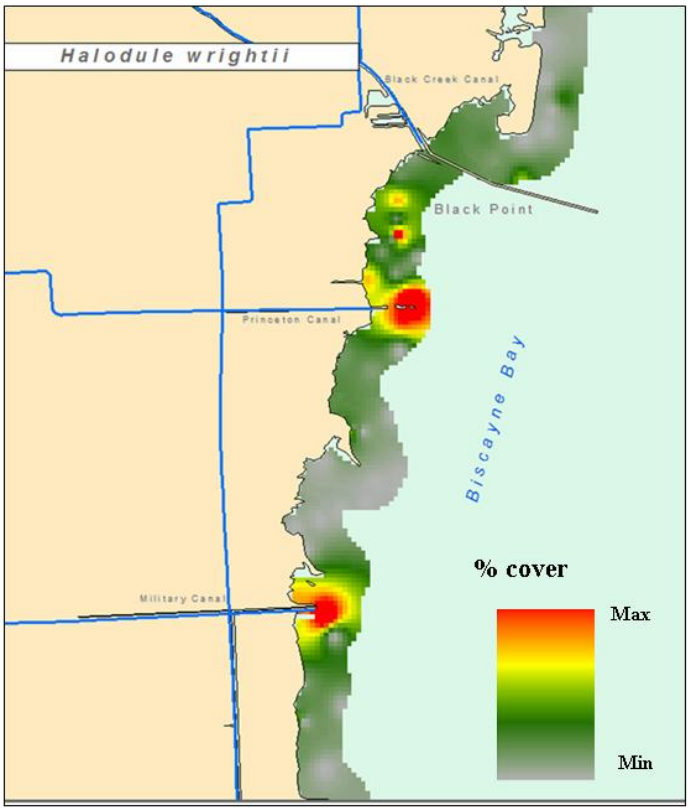


Figure 1: Abundance contour for the manatee seagrass *Halodule wrightii* in Biscayne Bay in relationship to the inflow of freshwater from canals (in blue). Note the highest abundance of this species in areas of freshwater discharge.

Results of our remote sensing studies have revealed, for the first time, that salinity patterns can influence the landscape structure of seagrass patches (Fig. 2). In Biscayne Bay, near-shore shallow habitats in close proximity to water management canals that discharge freshwater into the bay exhibit significant signs of habitat fragmentation. These areas, characterized by low and variable salinity, have seagrass landscapes dominated by a large number of small seagrass patches interspersed within a sediment matrix. In contrast, bottom habitats further away from points of discharge of freshwater and characterized by higher and more constant salinity are dominated by large continuous seagrass landscapes. Habitat fragmentation is a common characteristic of stressed terrestrial ecosystems and it appears that seagrass communities exposed to pulses of freshwater may be responding in similar fashion. In general, fragmented habitats are more susceptible to future disturbances and have limited recovery capabilities. Further research will concentrate on determining the relationship between habitat fragmentation and associated fauna in these valuable littoral habitats.

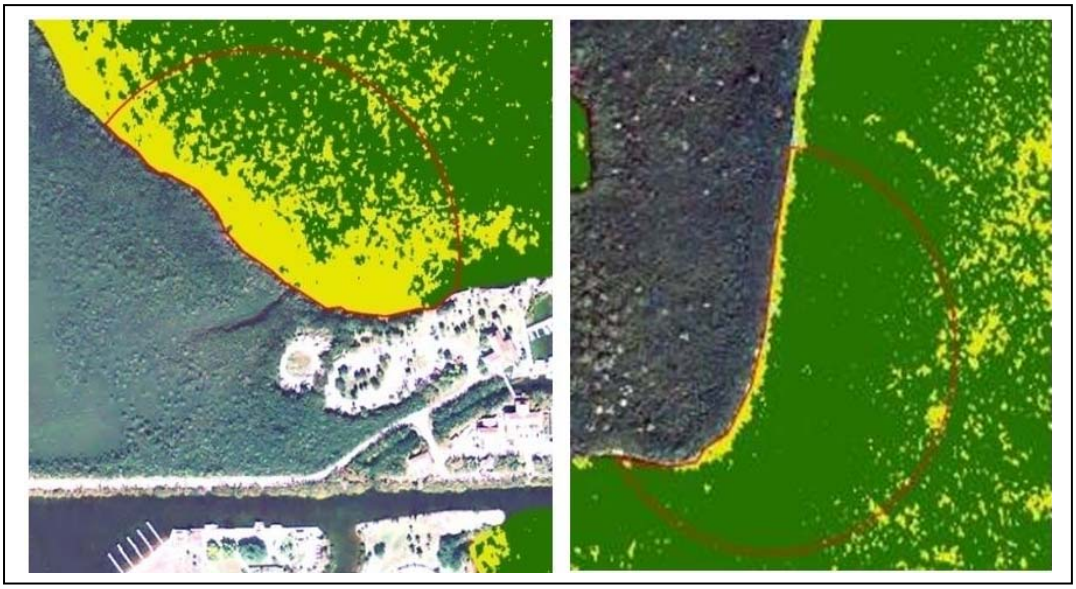


Figure 2: Landscape structure of SAV communities in near-shore habitats of Biscayne Bay (seagrass in green, sediment matrix in yellow, shore in grey). The image on the left shows a highly fragmented SAV landscape and the image on the right shows a continuous SAV landscape.

Research Performance Measure: All major objectives have been met for the report period and the approach tested is now being considered for application in other similar CERP domains. Our research demonstrates that SWaPS is particularly suitable in the very near-shore habitats that are difficult to sample with other approaches and that SAV landscape patterns can be effectively studied using aerial images and remote sensing tools .

Development of an Autonomous Ammonium Fluorescence Analyzer (AAFA) with a View towards in situ Application

P.B. Ortner and N. Amornthammarong (UM/CIMAS); J.-Z. Zhang (NOAA/AOML)

Long Term Research Objectives and Strategy to Achieve Theme:

Objectives: To develop a portable autonomous ammonium analyzer with a detection limit in the nM range and a sampling frequency of 6 samples per hour.

Strategy: To design, assemble, and develop a analyzer based on a novel fluorescence technique in conjunction with a simple photodiode detector and UV-light emitting diode (LED) excitation sources building upon technology and chemistry we have already published upon.

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 an Ecosystem Approach to Management

NOAA Funding Unit: N/A

Funding for this project provided through CIMAS Task IV from the National Ocean Partnership Program

NOAA Technical Contact: Jia-Zhong Zhang

Research Summary:

Ammonium is the most rapidly cycled nitrogen compound in coastal and marine waters. The concentrations of ammonium in oceanic waters are usually below 1 μM but exhibit considerable temporal and spatial variability. Current indophenol blue methods using auto-analyzers are limited in sensitivity and rarely detect the low ammonium concentrations in ocean surface waters. Fluorescence techniques are inherently more sensitive than colorimetric methods. Moreover methods requiring discrete water samples are not suitable for measuring a parameter so highly variable in both time and space. In addition, sample contamination is always a concern when water samples are analyzed for ammonium. An automated potentially in-situ analyzer/sampling system would not only better assess the actual environmental variability but also eliminate this source of systematic error.

We are developing such an analyzer based on a novel fluorescence technique and chemistry we have already published upon. The shipboard system was tested on a cruise of the Florida Area Coastal Environment (FACE) Program on November 1-9, 2009. Results in the nM range are shown in Figure 1. Moreover, a new design enhancing mixing (and sensitivity) in flow analysis has was developed and has already been accepted for publication (Amornthammarong *et al.*, 2010). Currently, a small inexpensive fluorescence detector is being incorporated to replace the large and expensive (>$13,000) commercial fluorescence detector currently being used in the shipboard system. The new detector also consumes much less energy, which is essential if it is to be powered by batteries in *in situ* applications.

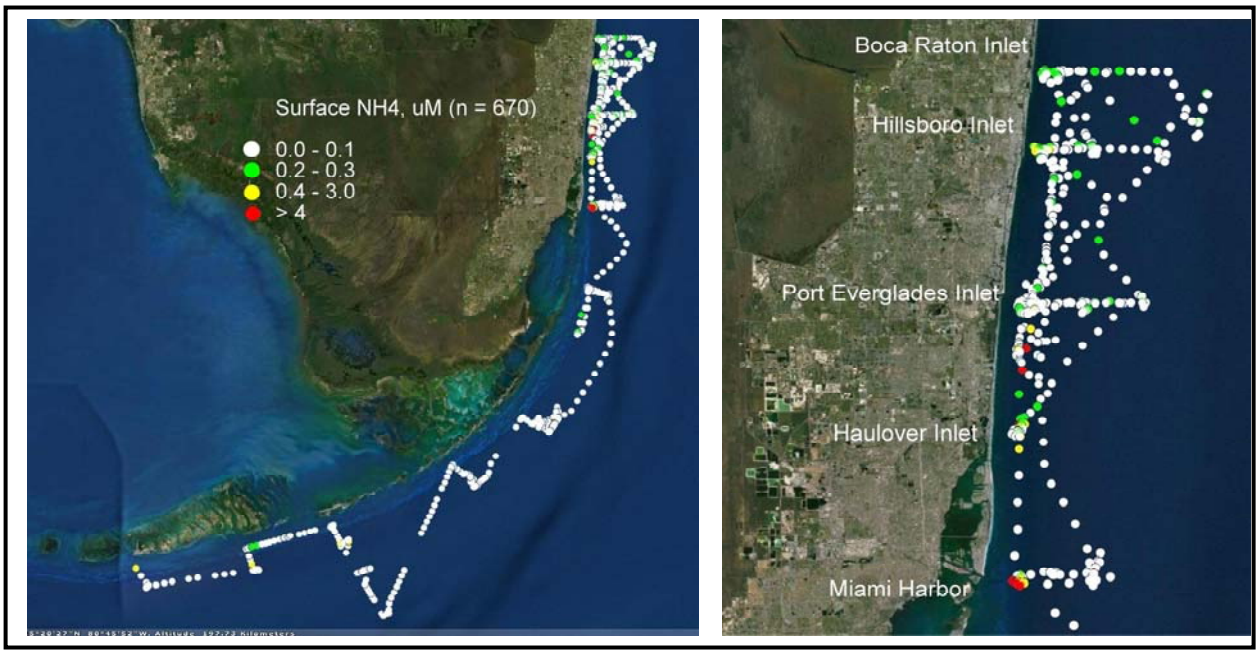


Figure 1: The underway measurement of ammonium in the surface seawater from Key West to Boca Raton Inlet, FL (November 1-9, 2009). (a) Total data plotted, n = 670 samples and (b) Data from Miami Harbor to Boca Raton Inlet.

Research Performance Measure: Our objective in Year 1 of this three year project was to finalize the chemistry, mechanical and optical components required for an in situ autonomous system. The first step (the shipboard system) has been completed and tested and with the enhanced mixing chamber and improved fluorescence detector also in hand, the project is ahead of schedule.

Juvenile Sportfish Monitoring in Florida Bay

C. Kelble, L. Petteway (UM/CIMAS); J. Browder, J. Contillo
and P. Cope (NOAA/SEFSC); B. Huss (NOAA/AOML)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** To determine the baseline distribution and current variability of juvenile spotted seatrout within Florida Bay including quantification of the potential mechanisms that may limit this distribution; to provide the basis for distinguishing future changes that may occur as a result of the Comprehensive Everglades Restoration Plan (CERP).

***Strategy*:** Conduct regular sampling of juvenile spotted seatrout throughout Florida Bay and incorporate these results along with ancillary water quality and habitat data into statistical analyses and models to determine the underlying cause for the current distribution. Produce predictive, testable hypotheses regarding the effect of CERP projects on juvenile spotted seatrout distribution.

CIMAS Research Theme:

***Theme 3*:** Regional Coastal Ecosystem Processes (*Primary*)

***Theme 2*:** Fisheries Dynamics (*Secondary*)

Link to NOAA Strategic Goals:

***Goal 1*:** Protect, Restore, and Manage the Use of Coastal and Ocean Resources through an Ecosystem Approach to Management

NOAA Funding Unit: DOD thru NMFS/SEFSC **NOAA Technical Contact:** Joan Browder

Research Summary:

The Comprehensive Everglades Restoration Program (CERP) is the largest and most expensive ecosystem restoration ever attempted. The primary goal is to restore the quantity, quality, timing, and distribution of freshwater to as near historic levels as feasible in the greater Everglades Ecosystem. Restoration activities will have a significant effect on the downstream coastal ecosystem that supports a significant portion of south Florida's economy, including the recreational fishery within Florida Bay. The spotted seatrout, *Cynoscion nebulosus*, is an important recreational sportfish in Florida Bay that spends its entire life history within the Bay (Rutherford et al., 1989). This life history pattern makes juvenile spotted seatrout a good indicator to assess the effect of CERP on Florida Bay's recreational fishery.

Juvenile spotted seatrout display a large degree of interannual variability throughout Florida Bay. The population oscillates between "high-population" and "low-population" years, which are statistically distinct. The variability in population is in part a result of a strong relationship with salinity. The spatial distribution of juvenile spotted seatrout expands during years with lower salinities and contracts in years with severe, persistent hypersalinity. Years with high annual abundances and frequency of occurrence are more common when salinity is low and near the restoration target for salinity. In each of the four sub-regions of Florida Bay, at least one aspect of the juvenile spotted seatrout population is significantly correlated with salinity (Fig. 1). Moreover, only in the west is there not a significant correlation of salinity with frequency of occurrence, and this is the only sub-region within which seatrout have been observed at salinities greater than 50. The development of a generalized linear model corroborated this relationship with salinity. Salinity

along with water temperature had the greatest impact on juvenile spotted seatrout distributions, with seagrass biomass providing a lesser contribution.

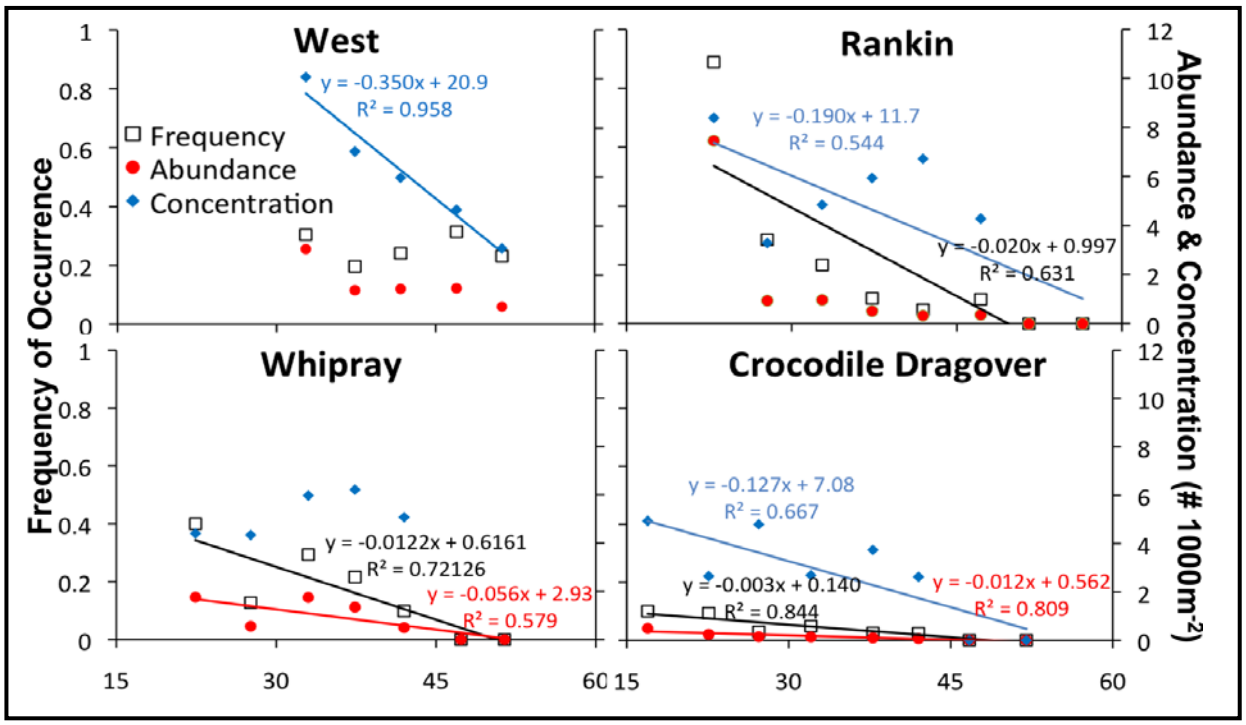


Figure 1: Scatter plots depict the correlation of the juvenile spotted seatrout population to salinity within each sub-region. The black boxes are frequency of occurrence, the blue diamonds are concentration, and the red circles are delta-density. Only significant linear regressions are depicted.

These complementary results indicate that if CERP is successful at lowering salinity in Florida Bay, it is likely to increase the population of juvenile and possibly adult spotted seatrout. This increase will likely be due to both an expansion of the spatial range and an increase in abundance within the range where we consistently observe juvenile spotted seatrout. Current research includes a closer examination of the relationship to salinity and preliminary investigation into the role of the food environment via gut content analysis. Our understanding of the existing variability in the system provides the capability to develop sound working hypotheses regarding the effect of restoration projects on the fish populations of the downstream coastal ecosystem. The development of testable hypotheses will lead to a rigorous methodology to assess the effect of Everglades Restoration on the coastal fisheries and provide the feedback necessary to successfully implement iterative adaptive restoration.

Research Performance Measure: We have quantified a significant relationship with juvenile spotted seatrout to salinity that has allowed for the development of testable hypotheses regarding the effect of CERP on juvenile spotted seatrout distributions. This project data (and the Project Principal Investigator) provided critical contributions to the relevant components of the congressionally mandated 2009 CERP System Status Report**.**

Coral Ecological Restoration in the Florida Keys National Marine Sanctuary

D.E. Williams, R. Wilborn, A. Bright and L. Johnston (UM/CIMAS)
M.W. Miller (NOAA/SEFSC)

Long Term Research Objectives and Strategy to Achieve Them:

***Objective*:** To enhance scientific basis for implementing restoration and recovery of coral populations in the Florida Keys National Marine Sanctuary (F.K.N.M.S.).

***Strategy*:** To (a) culture larvae of reef-building coral species including *Acropora palmata* (E.S.A. Threatened) and *Montastraea faveolata*, conduct experimental studies to elucidate factors affecting success of early life stages and b) undertake experimental studies to evaluate risks/benefits of different coral sources for coral transplant/restocking projects.

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 an Ecosystem Approach to Management

NOAA Funding Unit: NOS/CRCMP

NOAA Technical Contact: Margaret Miller

Research Summary:

During the research year (09/10) we continued ongoing research efforts to address recruitment failure by reef-building coral species in the Florida Keys via experiments on how substrate conditioning and placement affects the settlement success and early survivorship of larval reef-building corals. We had a successful coral spawning season in 2009 with no storm impairments. We were successful in collecting and rearing larvae of *Acropora palmata* (elkhorn coral), *Montastraea faveolata* (mounding star coral) and, for the first time, documented spawning by nursery-reared, outplanted *A.cervicornis* (staghorn coral). We conducted short-term field survivorship experiments with M.fav and A.palm to examine differential survivorship of lab-cultured spat at two field sites in the Florida Keys (Fig.1). The two coral species and two reef sites examined in this experiment showed markedly contrasting survivorship patterns over the crucial first six weeks post-settlement. These results will guide future experiments and attempts at larval seeding in the Florida Keys. This project component is also gradually cumulating spawning obser-vational records for genotyped A.palmata colonies at two FKNMS sites. These observations are showing marked asynchrony (distinct genets spawning on different nights, precluding effective fertilization and larval production), implying greater reproductive impairment of these threatened populations that their abundance and clonal structure suggest.

A second, ongoing project component was begun in summer 2008, the Aquarius Coral Restoration/Resilience Experiments (ACRRE). This study involves a controlled transplant experiments to explicitly compare the performance of coral transplants of two primary reef-building species (*Montastraea faveolata* and *Acropora cervicornis*) from different source populations (including lab-cultured, field nurseries, and wild-collected) when transplanted to a common fore-reef environment, the Aquarius undersea lab site in the Florida Keys National Marine Sanctuary. Performance of the different-source fragments are being evaluated at organismal and molecular levels over a long time frame. Mortality rates of the transplants have been high over the two years of the experiment, with both corallivores and disease as visually obvious sources of mortality among all source groups. Pending analyses of mechanistic samples including surface microbial communities and stress gene expression patterns will hopefully provide additional insights on transplant performance. Graduate student Johnston has also conducted ancillary field experiments on corallivorous snail dynamics under this project component which have shown that the density and species identity of coral transplants can significantly affect their attraction of corallivores and subsequent transplant mortality.

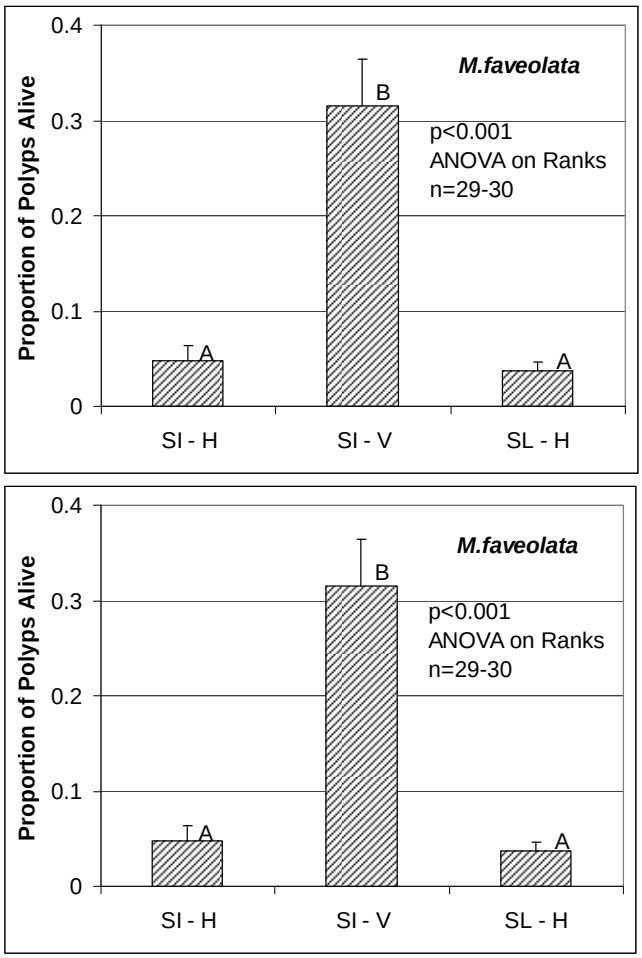


Figure 1: Results of short term field survivorship experiment (deployed in field on 21 Aug, scored on 28-29 Sept 2009). Panels show the proportion of initial polyp counts present at the end of the experiment in each of the three site/position treatments (initial densities pooled) for A.palmata and M.faveolata. Consistently low survivorship was observed at the Snapper Ledge site. Ap and Mf showed contrasting survivorship in different positions (Horizontal vs. Vertical) at Sand Island.

Research Performance Measure: Field work milestones are being completed appropriately, with the exception of NOAA-cancelled Aquarius saturation diving mission in June 2010 which impaired planned supplemental experiments on corallivory in the transplant experiment. Laboratory analyses of additional ACRRE experimental parameters are underway. Additional larval survival experiments are on track to be completed in Aug-Sept 2010.

Photo-Identification of Bottlenose Dolphins in Biscayne Bay, Florida

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

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** To understand and describe the parameters of the bottlenose dolphin population in Biscayne Bay and monitor and observe their role in the south Florida ecosystem. To inform decision-makers and the general public on the status of the bottlenose dolphins in Biscayne Bay, and to investigate the impacts of human activities on this population.

***Strategy*:** Develop and maintain a long-term database on individual bottlenose dolphins using photographic identification techniques. These data can be used to estimate abundance, monitor short-term and long-term movement patterns, investigate population structure, and contribute to knowledge of the overall health of the Biscayne Bay ecosystem. In addition, we will facilitate sharing of bottlenose dolphin photo-ID information and images among research groups in adjacent study areas in south Florida.

CIMAS Research Themes:

***Theme 3*:** Regional Coastal Ecosystem Processes

Link to NOAA Strategic Plan:

***Goal 1*:** Protect, Restore, and Manage the Use of Coastal and Ocean Resources through an Ecosystem Approach to Management

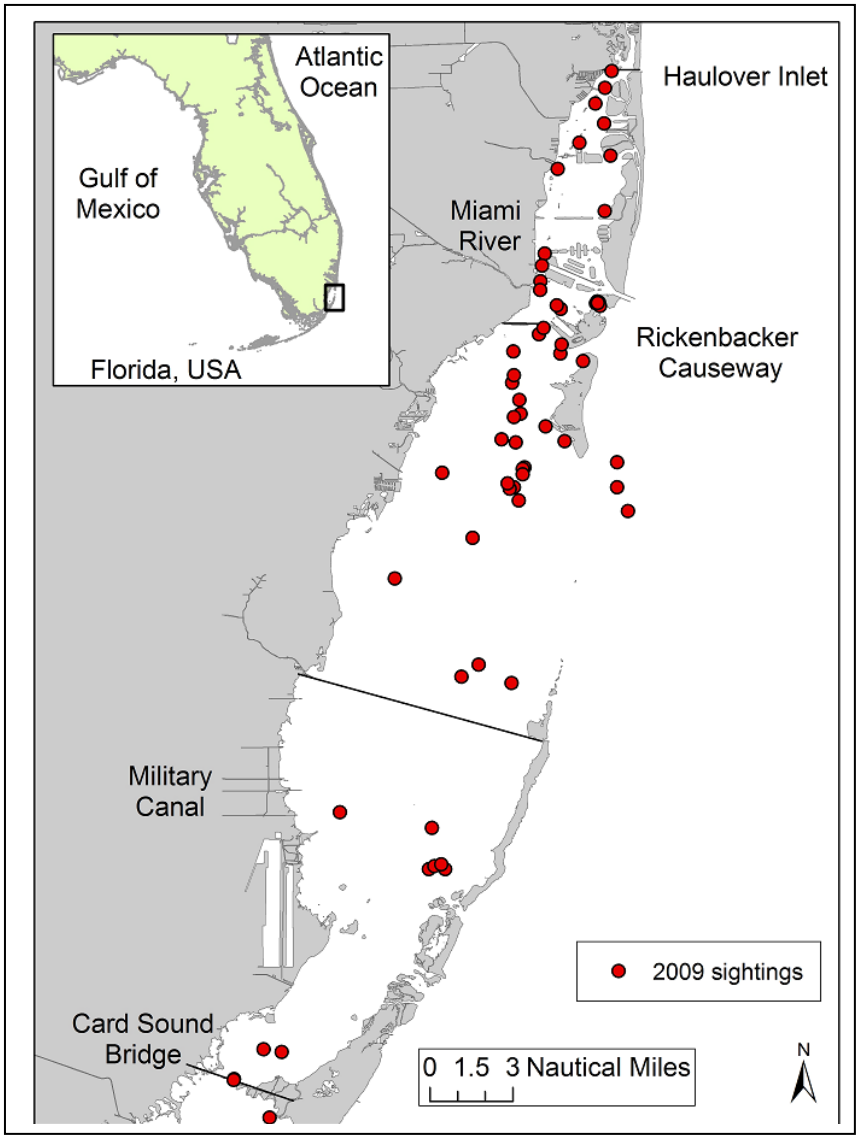
NOAA Funding Unit: NMFS/SEFSC **NOAA Technical Contact:** Lance Garrison

Research Summary:

The National Marine Fisheries Service (NMFS) is responsible for monitoring the populations of bottlenose dolphins (*Tursiops truncatus*) in the southeastern United States waters. The main goals of this monitoring are detection of large-scale changes in bottlenose dolphin abundance and establishment of archival databases for long-term trend detection. Biscayne Bay has been greatly influenced by development of the Miami area in the past 75 years. Data from 15 years of photo-ID surveys have confirmed the presence of a relatively large, long-term resident 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 Daniel 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 1990-2007, survey effort was conducted monthly in North, Central and South Biscayne Bay throughout the year. In 2008 sampling methods changed to a quarterly system for three weeks per quarter in each of two areas of Biscayne Bay, North and South. These surveys have defined the basic parameters of the Biscayne Bay bottlenose dolphin population, including abundance, distribution, natality and mortality. In May 2002, a genetics based stock-structure program was initiated, and involves a remote biopsy-sampling program to collect skin and blubber samples from dolphins that reside in Biscayne Bay. To date, a total of 70 skin and 50 blubber samples have been collected. Continuation of the established photo-ID sampling regimen and integration of photo-ID and genetic data will provide the framework for defining biologically based management units. To improve data management of photo-ID information, FinBase was added in the

fall 2008, which helps in image management and analysis. The principal aim of this program is to calculate population abundance by using mark–recapture methods and photo-identification data.



2009 Dolphin Sightings

Research Performance Measure: All major objectives have been met with the Biscayne Bay Photo-identification project. As a result of this program bottlenose dolphins in Biscayne Bay have been identified as a separate stock from neighboring populations and can be used as an indicator species with respect to Biscayne Bay ecosystem health and water quality. We have assembled a database that will enable future monitoring of changes in population structure and investigation of the consequences of anthropogenic contamination upon the well characterized bottlenose dolphin population in Biscayne Bay.

Evaluation of Acropora Status for Management and Recovery

D.E.Williams, A. Bright and R. Wilborn (UM/CIMAS); M.W. Miller (NOAA/SEFSC)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** To document the threats (disease, predation etc.) impacting the remaining elkhorn (*Acropora palmata)* populations in the upper Florida Keys and determine the relative importance of each 'threat'. To document and identify demographic variables (recruitment, mortality etc.) in the Florida Keys *Acropora* spp. population. To continue annual assessment of *Acropora palmata* in Curacao for comparison to local populations.

***Strategy*:** To assess on a quarterly basis the status of individually-tagged colonies of coral at several sites in the upper Florida Keys. Periodic assessments of other Caribbean *Acropora* spp. populations.

CIMAS Research Theme:

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

Link to NOAA Strategic Goals:

***Goal 1*:** Protect, Restore, and Manage the Use of Coastal and Ocean Resources through an Ecosystem Approach to Management

NOAA Funding Unit: NOAA Coral Reef Conservation Program via NMFS/SEFSC

NOAA Technical Contact: Dana E. Williams

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. Acroporid corals are listed as 'Threatened' species under the U.S. Endangered Species Act. NMFS is in the process of designating critical habitat and developing a recovery plan based on the current status and threats to these corals in U.S. waters. Data collected for this project are directly supporting the critical habitat designation and recovery plan development by NMFS. Additionally, the protocol developed based on this project is being implemented to other reef areas through state and territorial partners. The design of this ESA Section 6 effort is contingent upon our existing monitoring effort and assistance in implementing the protocol in a consistent manner.

The overall objectives of this project are to document the dynamics of the remaining Elkhorn populations in the upper Florida Keys and compare its performance to other Caribbean locations. The surveys also aim to determine the relative importance of the various 'threats' (disease, predation, etc.) present in those populations.

Individually tagged *Acropora palmata* colonies are surveyed periodically 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 sources of recruitment (asexual or sexual). These data are directly used in a population model being developed by a colleague at Scripps Institute of Oceanography and the projections will assist in the development of a recovery plan by NMFS. Data from the Florida Keys population indicates continued decline of the

adult *A. palmata* population, and an alarming failure of asexual and sexual recruitment. This decline was the direct result of the 2005 hurricane season. Recovery from this disturbance has been slow and the population continues to suffer losses from disease and predation. *Acropora palmata* in Curacao suffered losses due to Hurricane Omar in 2008 but is showing signs of a more robust recovery with evidence of greater inputs from recruitment. Additionally our data allows us to estimate that in the Florida Keys population most common source of tissue loss on *Acropora palmata* is white disease, followed by breakage and feeding by the corallivorous snail *Coralliophila abbreviata* (Fig. 1).

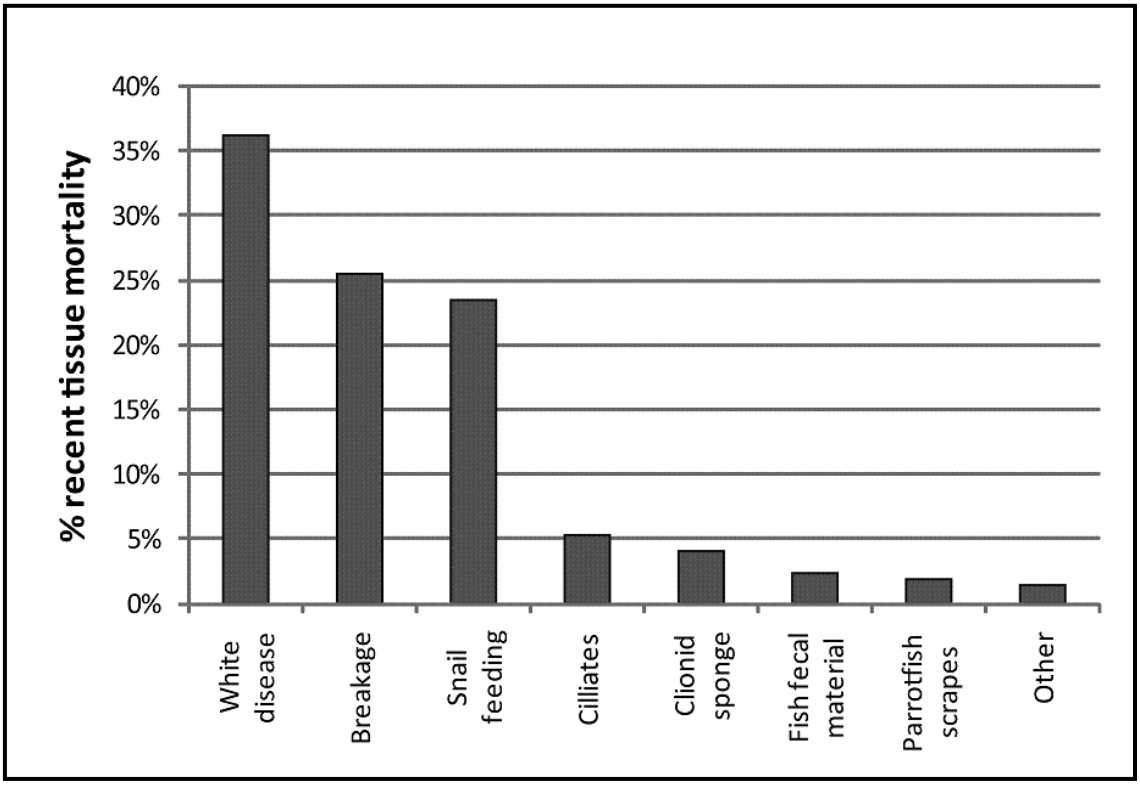


Figure 1: Percent of *Acropora palmata* tissue mortality associated with various threats observed in the Florida Keys population. Percentages are based on the estimated surface area of tissue lost for each monitored colony between 2004 and 2009. The 2 surveys during the 2005 hurricane season are excluded due to the anomalously high breakage and tissue loss observed during this unusually active season. More than one third of the mortality was associated with white disease, followed by breakage and feeding by *Coralliophila abbreviata*. Other sources of mortality were relatively inconsequential (see Williams et al. 2006 for explanation of these threats).

Research Performance Measure: All major objectives of this project are ongoing and progress is on schedule. Three surveys of the Florida Keys sites were conducted. An additional survey of selected sites was done following the cold temperatures that occurred in January. Survey sites around Curacao were re-surveyed in May 2010. Data has been processed for use in population models by our research partner at Scripps Institute of Oceanography. A manuscript reporting on sources of mortality in *Acropora palmata* is in preparation for submission to a peer reviewed journal.

Small Boat pCO_2 Equilibrator and Gradient-Flux Measurements of Calcification

C. Langdon (UM/RSMAS); W. McGillis (Columbia University)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** To develop instrumentation and methodsto facilitate the observation and quantification of the response of coral reef calcification to rising CO_2 levels in the atmosphere and the surface ocean.

***Strategy*:** Develop at set of instrumentation that can easily be deployed from a small boat to observe the partial pressure of CO_2 and its effect on the calcification rate of reef corals utilizing the boundary-layer gradient flux method.

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 an Ecosystem Approach to Management

NOAA Funding Unit: Coral Reef Conservation Program

NOAA Technical Contact: Kacky Andrews

Research Summary:

During a cruise on the RV Walton Smith in Dec09 a small boat equilibrator was successfully used to map the pCO_2 of the surface waters of the Florida Reef Tract. During this cruise the system was run in parallel to the General Oceanics system installed on the ship. The agreement between the two systems over the five days of the cruise averaged +/- 2 uatm, indicating the small boat system was performing up to expectations. We found that during this cruise reef waters were considerably supersaturated with respect to pCO_2 with levels as high as 450 uatm observed. This in turn resulted in the aragonite saturation state of the reef waters being considerably depressed relative to the oceanic water immediately offshore of the reefs. We believe that the high pCO_2 is explained by net ecosystem respiration that prevails at this time of year. We are planning to repeat the measurements in 2010.

The second part of this project is to conduct a proof of concept of a new method for measuring calcification rates on coral reefs. The method is based on measuring the concentration gradient of total alkalinity in the boundary layer between the corals on the seafloor and the overlying reef waters and multiplying that gradient by the vertical eddy diffusivity coefficient computed from turbulent energy dissipation to get the flux of the total alkalinity into or out of the seafloor, i.e. the rate of calcification or dissolution. Variants of this method have been used to estimate fluxes of other dissolved constituents at the seafloor and across the air-water boundary. The method has the advantage of making the flux measurement under completely natural and unconfined conditions. Langdon and McGillis have been conducting trials of the method at several different reef environments in La Parguera, Puerto Rico. These trials have focused on making measurements of community photosynthesis and respiration. The results have been very promising. In Mar09 an intercomparison experiment was conducted between the Boundary Layer Gradient Flux method and

the enclosure method. We were able to show that the rates of oxygen production and consumption that we measured by the boundary layer-gradient method agreed well with measurements made in a nearby enclosure of a portion of the reef that were made by a group from the USGS led by Kim Yates. This work has led to a talk that was given by C. Langdon at the ICDC8 meeting held in Jena, Germany Oct 2009 and in a manuscript that has been submitted to Geophysical Research Letters (McGillis, Langdon et al.).

During 13-20 January 2010 we conducted our first trials to see if we could measure total alkalinity gradients just above the reef floor and if those gradients would reflect calcification and vary over the day as we would expect. As can be seen from Figure 1, that answer is yes. The vertical gradients measured during the day were negative implying a flux of alkalinity and hence a positive rate of calcification. The magnitude of the rates were also reasonable and they varied over the morning and early afternoon was would be expected for a process that is known to be light-enhanced. In future work I will be trying to improve the analytical precision of the TA analysis in order to shrink the size of the error bars. In conjunction with Co-PI Wade McGillis, more tests will be carried out in different reef environments to see if the method is generally applicable in a range of reef settings.

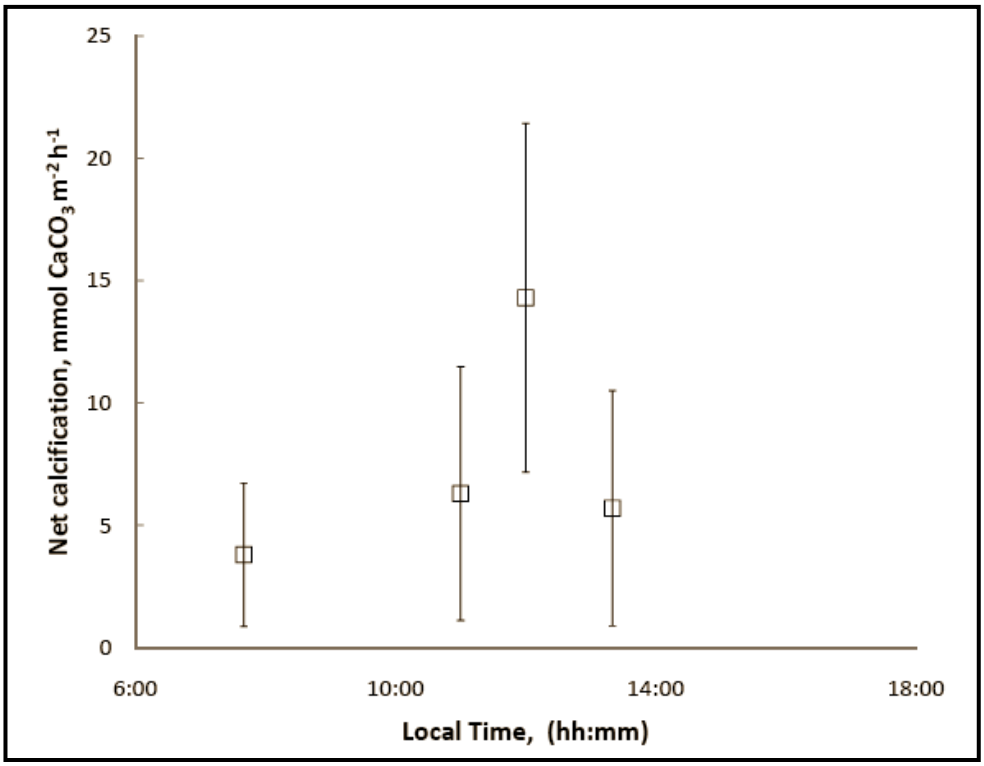


Figure 1: Net calcification rate calculated from vertical TA gradient just above the reef floor at Enrique Reef, La Parguera, Puerto Rico on January 20, 2010. Error bars are 1 SE.

Research Performance Measure: All objectives have been met to date.

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

C. Kelble, N. Melo, G. Rawson, S. Dolk, K. Seaton, L. Visser and P. Ortner (UM/CIMAS)
E. Johns, R. Smith, J.-Z. Zhang, C. Fischer and S. Cummings (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 times scales; to quantify the variability in these parameters so as to provide a historical basis for distinguishing future changes that may occur as a result of the Comprehensive Everglades Restoration Plan (CERP).

***Strategy*:** Conduct regular and supplemental event-focused monitoring cruises (with charter ship-time from provided to CIMAS by NOAA/NMAO) in conjunction with a moored instrument array and targeted drifter releases and to incorporate these results into system models supporting management decisions.

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 an Ecosystem Approach to Management

NOAA Funding Unit: NOAA/AOML/NMAO **NOAA Technical Contact:** Elizabeth Johns

Research Summary:

The Comprehensive Everglades Restoration Program (CERP) is the largest and most expensive ecosystem restoration ever attempted. The primary goal is to restore the quantity, quality, timing, and distribution of freshwater to as near historic levels as feasible in the greater Everglades Ecosystem. Restoration activities will have a significant effect on the downstream coastal ecosystem that supports a significant portion of south Florida's economy and includes the Florida Keys National Marine Sanctuary, as well as the Rookery Bay National Estuarine Reserve. The effect of restoration on the coastal ecosystem remains unclear and some have hypothesized that the end result could be eutrophication of specific areas within the coastal ecosystem. This concern along with others in the terrestrial system has resulted in the adoption of iterative adaptive restoration, whereby each project will be undertaken individually and management decisions will be altered if it is found they are likely to cause detrimental ecological effects. In order to effectively implement Everglades Restoration with this capability it is necessary to quantifiably understand the distribution and variation of the relevant physical, chemical, and biological water column properties in the South Florida coastal ecosystem.

The underlying focus of this multi-disciplinary project is to understand the present-day variability in south Florida's coastal marine ecosystem and thereby to gain insights into how the Everglades' restoration might impact on this ecosystem. Recent research has included quantifying the relative contribution of chlorophyll *a*, CDOM, and tripton to the attenuation of photosynthetically available radiation (PAR) in Florida Bay along with investigating the potential for light availability to limit primary producers in this system. This understanding has enabled the development of predictive, mechanistic model to estimate light attenuation, mesozooplankton, and bay anchovy (*Anchoa*

mitchilli). The long-term variability in salinity was examined to determine the impact of meteorological phenomena on the physical environment of Florida Bay and subsequently to partition the sources of salinity variation (precipitation, runoff, and evaporation) throughout the different sub-regions of Florida Bay. An analysis of the mesozooplankton community in conjunction with the juvenile and small adult fish community found evidence of strong top-down effects, including a potential trophic cascade that could have important consequences both to the health of fisheries that use Florida Bay as a nursery and the magnitude of algal blooms.

Our research, combined with information on circulation in Florida Bay, suggests possible restoration approaches that might mitigate the magnitude, extent, and duration of hyper-salinity in north-central Florida Bay. Current research has observed low abundances of mesozooplankton at low salinities; however, this appears to reflect top-down predation control by the planktivorous fish community that is more abundant at these low salinities. Model results suggest that lowering salinities via restoration will increase the abundance of *A. mitchilli* (Figure 1). This increase in *A. mitchilli* would likely increase the amount of food available to the pelagic fish community. Understanding the current variability of the system in this manner, results in the development of sound working hypotheses regarding the effect of restoration projects on the water column of the downstream coastal ecosystem. These hypotheses can be verified via modeling exercises, as is currently being done to validate the hypothesis that top-down predation control is more prevalent at lower salinities (Figure 1). Verifying these hypotheses via modeling not only provides further scientific basis for restoration, but also enables the capability to quantitatively predict the effect of an altered salinity regime on ecological components of the ecosystem. Moreover, the development of testable hypotheses will provide a rigorous way in which to assess the effect of Everglades Restoration on the coastal ecosystem and provide the feedback necessary to successfully implement adaptive management.

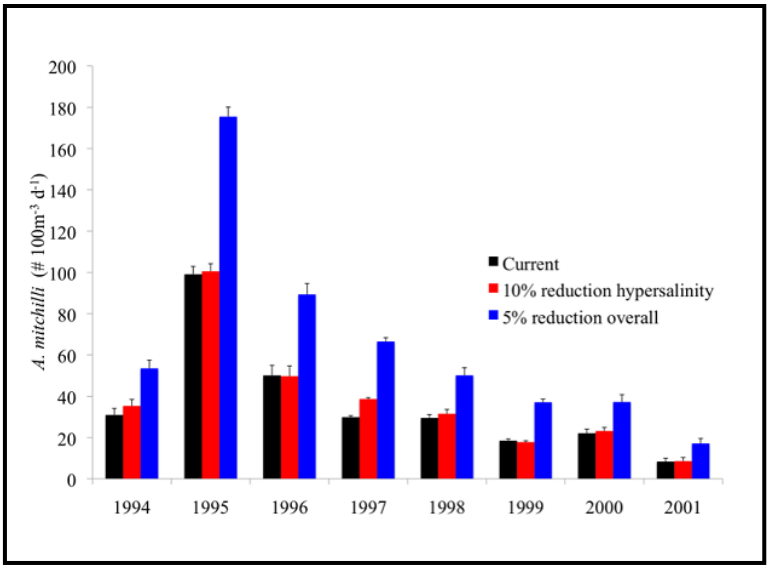


Figure 1: Annual median abundance of *A. mitchilli* from model runs with current salinity (black), a 10% decrease in salinity during hypersaline periods (red), and a 5% decrease in all salinities (blue). The 5% decrease in salinity results in up to a two-fold increase *A. mitchilli*.

Research Performance Measure: Our research objectives are being met on schedule. The primary measure of performance is the degree to which the data and analyses are incorporated into the scientific basis and adaptive management for CERP. With respect to this project year, the project data (and the Project Principal Investigator) provided critical contributions to the relevant components of the congressionally mandated 2010 System Status Report.

Climate Information System for Agriculture and Water Resources Management in Southeastern USA

D. Letson, N. Breuer, D. Solis and K. Broad (UM/RSMAS)
J.W. Jones, C.W. Fraisse, C. Porter and K.T. Ingram, (UF/Agricultural & Biological Engineering); J. O'Brien, D. Zierden, T. LaRow (FSU/COAPS); G. Hoogenboom, D. Stooksbury, and P. Knox (Univ. Georgia/ Biological & Agricultural Engineering)
C. Roncoli (Univ. Georgia/Anthropology); J. Christy (Univ. Alabama-Huntsville)

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*:** Develop generic tools for the production and dissemination of relevant climate information (diagnostic and forecasts)

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: OAR/CPO **NOAA Technical Contact:** Caitlin Simpson

Research Summary:

The mission of the Southeast Climate Consortium (SECC) is to use advances in climate sciences, including improved capabilities to forecast seasonal climate and long-term climate change, to

provide scientifically sound information and decision support tools for agricultural ecosystems, forests and other terrestrial ecosystems, and coastal ecosystems of the SE USA. As a multidisciplinary, multi-institutional team, the SECC conducts research and outreach to a broad community of users and forms partnerships with extension and education organizations to ensure that SECC products are relevant, reliable, and delivered to the public by these organizations through their networks and mechanisms.

SECC research and extension activities focused mostly on the agricultural sector until about four years ago when we started activities to develop climate information for water resource managers. Then, following the publication of the Stern Review (Stern 2006) and IPCC AR4 (IPCC, 2007) demands for climate change information has grown rapidly. These demands have come not only from the agricultural sector, but also from local governments, public health, environmental engineering firms, and others. We have also received numerous requests from scientists in other areas, particularly in coastal and other terrestrial ecosystems. A common challenge to meeting these requests is the need for reliable, probabilistic information at the local level regarding climate change. In order to meet this need, the proposed activities are designed to build on the successes of past SECC work in agriculture by broadening out into other sectors and by adding research and extension programs that respond to demands for information on climate change.

An important factor contributing to SECC success in agriculture has been a strong partnership with Cooperative Extension, which provides a boundary organization linking research to users for broad applications. The SECC also includes among its members the state climatologists for all SECC states. For the agricultural sector, we will shift much of our effort to providing information related to climate change and to developing methods to help sustain *Agro*Climate, our on-line climate information and decision support system [http://AgroClimate.org]. An important aspect of our work in this project will be to develop an open source version of *Agro*Climate that will help to assure the sustainability of this system.

A further aspect of the SECC is that it leverages funding from diverse sources in order to maximize is impact. In addition to USDA-NIFA, principal sources of funding include the National Oceanic and Atmospheric Administration, Regional Integrated Sciences and Assessments program, the USDA Risk Management Agency, and other competitive funding sources.

OBJECTIVES

Our long-term goal is to design, develop, and implement a prototype comprehensive information and decision support system. The purpose of this system is to inform farmers, ranchers, foresters, water resource managers, industry, and policy makers about climate risks and to identify management practices that can reduce risks and increase benefits by using this climate information. This system has been implemented on the Internet at http://AgroClimate.org. The system includes:

- State and regional outlooks for climate-related risks to agriculture and water resources
- Commodity-based information and decision support for local users
- Watershed-based forecast applications to water resources management
- Feedback and evaluation of forecast tools and information products

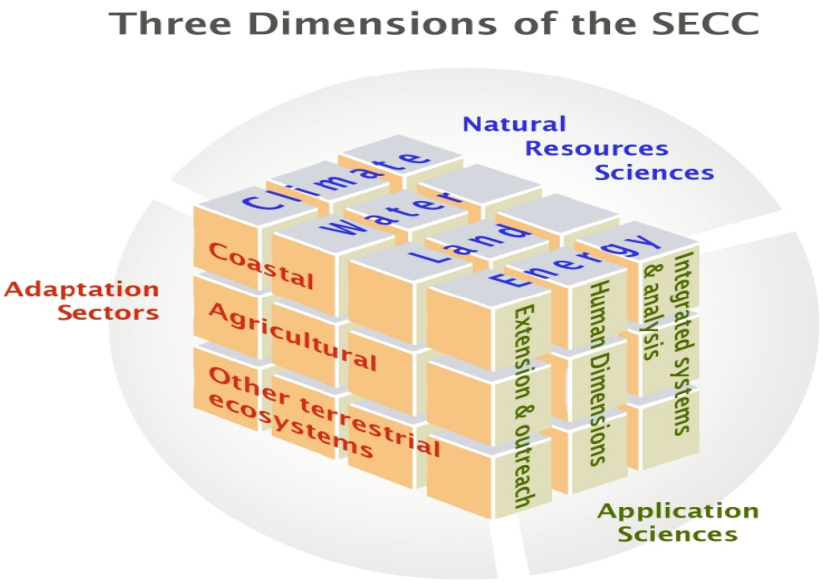
This project is a long-term undertaking, which began in 1998. Our initial focus was the design of the system, implementation of a prototype system on the web, development and implementation of example information and decision aids, and evaluation of the overall design and potential value to users in the Southeastern USA. In 2004 we opened *Agro*Climate to the public and in 2008 we transferred the operational version of the site, now called *Agro*Climate, to the Florida Extension Services, though this project will continue to update the databases and improve the tools on *Agro*Climate.

Specific objectives are:

1. Design and develop prototype climate forecast information
2. Design and develop prototype state and regional agricultural and water resource outlooks
3. Design and develop prototype commodity-based decision support system
4. Design and develop prototype watershed-based decision support system
5. Educate producers and their advisors on the applications of climate–based decision
6. Support systems and evaluate the design and potential value of decision support tools and systems

PROCEDURES

In order to meet the growing and changing demands for local climate change information, including information needs for sectors other than agriculture, to understand what information stakeholders need and their decision environments, and to develop accessible decision support tools, the SECC is reorganizing using a three-dimensional structure that is designed to promote collaboration among scientists and our partners (Figure 1). The three dimensions are: 1) ecosystem-based adaptation sectors; 2) natural resources sciences; and 3) application sciences. This project will not support all components of the structure, but we present the structure to show how these activities fit into the overall SECC program, which is leveraged with other funds.



This diagram shows the three dimensions of the new SECC structure and their components. Though shown separated to emphasize that each cell includes all three dimensions, in operation,

the cells are linked and projects may address multiple cells as will be clear from the examples in the Methodology section

Ecosystem-based adaptation sectors each have different boundary organizations. In agriculture we have worked closely with Cooperative Extension and have begun working with other boundary organizations that provide targeted outreach to socially disadvantaged farmers, such as the Federation of Southern Cooperatives, which works primarily with black farmers, and the North South Institute, which works with Spanish-speaking, Asian, and black farmers. For coastal ecosystems, we will work closely with Sea Grant Extension, the Association of County Governments, Florida Oceans Coastal Council, Gulf of Mexico Alliance, and others depending on the findings of our assessments. For other terrestrial ecosystems, we will work in partnership with diverse boundary organizations, including Fish and Wildlife Service, Natural Resource Conservation Service, US Geological Service, and others to be identified in our scoping activities.

While agriculture will remain our largest program, we will also address the needs of other ecosystems. For coastal ecosystems, we plan to conduct stakeholder assessments and to strengthen CoastalClimate.org, our on-line prototype information system for coastal ecosystems. Work in the other terrestrial ecosystems will begin with scoping activities.

Climate data gathering and analysis
Raw weather data updated will continue to be collected and data made available to all SECC members and other interested parties. Of particular import will be the collection and accessibility of daily weather data to allow high frequency updates of climate indices. FSU, UAH, UGA

Provision of updates for forecasts and other climate data
We continue to provide regular updates of forecasts and other climate information as requested by decision makers. Of particular emphasis, are daily weather data that are needed for real-time updates of climate indices. This activity includes the development of web services to process, store, and transform climate data. These web services would serve as intermediaries between the climate database for the SECC and AgroClimate applications, containing libraries of useful routines.

Most SECC research has emphasized seasonal crop forecasts based on ENSO phase or using dynamic models. Stakeholders have requested local climate projections for the next 5 to 30 years. We use several approaches to provide this information, including, analysis of extremes and scalar changes of extremes from the historical record, downscaling global forecasts using statistical and dynamic methods. FSU, UAH

Linkage of crop and climate models
Develop downscaled ENSO climate information and forecasts for the SE USA
Climate information only has value when there is a clearly defined benefit, once the content of the information is applied in the decision making process. *Agro*Climate is a response to the need for information and tools on proactive adaptations to seasonal climate variability forecasts in the southeastern US. Extension agents, agricultural producers, forest managers, crop consultants, and

policy makers may use this decision support system to aid in decision making concerning management adjustments in light of climate forecasts. Adaptations include those that might mitigate potential losses as well as maximize yields. The tools section contains two applications that allow a user to examine the climate forecast for his/her county based on the ENSO phase and to evaluate yield potentials for certain crops. FSU, UF

Dynamically downscaled regional forecasts for agriculture

In order to build a firm bridge between the numerical climate model and crop simulation model, the following details must be studied. First, we investigated the performance of the Community Land Model 2 in the seasonal dynamical downscaling of surface fields (maximum and minimum temperatures, precipitation, and solar radiation) through the FSU regional climate model and explored the suitability of these surface fields for crop yield estimations using a state-of-the-art process-based crop model (e.g., DSSAT 4.0 family of crop models). These models are able to simulate between 2.5 and 10% of the observed yields when accurate data for crops, soils, and weather are available. Preliminary finding indicate a skillful prediction of peanut yield was achieved using a crop model forced with ten years of daily data from the FSU model. The average rainfall amount was similar to that observed, resulting in similar water stresses during the reproductive phases of peanut growth.

Monitoring and Forecasting Drought

The Office of the Alabama State Climatologist has developed a simple drought index, the Lawn and Garden Moisture Index (LGMI) that is updated daily at a 4 km x 4 km resolution. Based on ENSO phase, we have developed a forecast for LGMI for all coop climate stations in the region. We will combine these forecasts with daily monitoring to show recent and projected values of LGMI on *Agro*Climate.

Using high-resolution, daily climate data as inputs to DSSAT crop simulation models, we will monitor drought impacts on crops during the growing season and display as relative yield loss in GIS format.

The Agricultural Reference Index for Drought (ARID) was developed to quantify water stress for crops and to estimate relative crop yield losses associated with drought. This index adequately represents water stress for crops with full canopy cover as compared with the water stress computed by the widely used DSSAT crop model. Yields of corn, peanut, soybean, and cotton are highly correlated with ARID. Work in progress shows that ARID accurately simulates soil water availability under pastures. In this activity, we will complete analyses of the performance of ARID as compared with other drought indices and will develop methods to forecast ARID for the southeast USA and disseminate ARID monitoring and forecast data. UF, UAH, UGA, FSU

Incorporate generic crop model in DSSAT

The current DSSAT suite of crop models includes many of the crops cultivated in the southeast USA, but not all. In order to remedy this problem, a new relatively simple, generic crop model is being adapted to facilitate the use of the model for other crops, such as pasture and vegetable crops. This model is needed so that agricultural land use can be more accurately represented in the coupled crop-climate model. One available generic crop model that closely matches the

inputs and interfaces of the DSSAT suite of models is SALUS. In this activity, we develop an interface between SALUS with DSSAT models, assure that SALUS is compatible with an integrated crop model, and calibrate SALUS for 4 crops, including documentation of the procedures needed to calibrate the model for other crops. UF

Modify existing crop models for linkage with regional climate models

Soil evaporation and plant transpiration are highly variable during a growing season, and this needs to be taken into account when predicting climate at the regional scale. The dynamic energy balance at the land-atmosphere interface is modeled differently in the cropping system model than in the land surface models used in the regional climate models. The cropping system model has much more detail in its computations of evapotranspiration, including a separate treatment of soil water evaporation vs. plant transpiration. However, the land surface models use a finer temporal resolution. These current incompatibilities must be resolved in order to properly couple these two types of models and allow dynamic interactions between the land and atmosphere. These interactions provide feedback to the regional climate model, which affect regional climate forecasts and in turn affect forecasts of crop growth and yield. In this activity, we study the land-atmosphere interface of each model and make modifications to the cropping system model as needed to couple it with the land surface model used in the FSU Regional Spectral Model. This model coupling allows a better understanding of the interactions between land use and local and regional climate and how these interactions affect forecasts of the climate in the region and also crop responses at that scale. UF, FSU

Characterizing spatial variability of rainfall for downscaling

Climate forecasts need to be downscaled to points for some applications, and historical weather data are typically used to train downscaling procedures. Historical daily weather data are available in our region at approximately county scales, with distances between rain gauges of 25 miles or more. One of the limitations of using point-based models, like crop models, to predict possible responses at watershed, county or other areas is that rainfall varies considerably over short distances (e.g., 1 mile or more). In order to downscale rainfall forecasts to a finer spatial resolution, information is needed on spatial variability of daily rainfall at distances of less than one mile. We have installed 40 additional gauges to complement the 10 already installed and 11 that were in the area when this project started. Results have been provided to cooperating farmers and extension agents in the 3-county area from monthly data downloads. A geostatistical analysis has been performed to produce parameters needed by GiST. During the second year, GiST will be implemented in this area to evaluate its ability to downscale rainfall, temperature, and solar radiation using area-wide observed "hindcasts" and climate forecasts. Spatially-generated weather data will be input into crop models to compare aggregate crop forecasts for yield, irrigation requirements, and maturity dates with those using historical data. UF, UGA, FSU

Coupling crop and land surface models for the FSU regional climate model

The objective of this research is to couple a dynamic crop model from DSSAT 4.5 to the Community Land Model 2 (CLM2) already coupled to the Florida State University/Center for Ocean-Atmospheric Prediction Studies (FSU/COAPS) nested regional spectral model (NRSM). The DSSAT version 4.5 CSM was translated to the LINUX operating system for linkage with the CLM2 model that runs in this operating system.

The models will be coupled in the biophysics (energy flux: momentum, heat and radiation), hydrology (soil moisture: evaporation, run off, drainage, precipitation and interception, and canopy), dynamic vegetation (replacing prescribed monthly values retrieved from satellite by crop model realizations), biochemistry (processes associated with ecosystem and carbon dioxide that are not incorporated yet), and sub-grid land cover types (glacier, lake, wetland, urban and vegetated areas replaced by vegetated portions of a grid box divided into patches of plant functional types, each with its own leaf and stem area index and canopy height). Remaining issues to solve are related to the spatial and temporal scales from both separate and integrated models and to integrate and evaluate these models. UF, FSU

Open-Agro-Climate

An open source version of AgroClimate will enhance its development, use, and sustainability. One goal of this work is to facilitate the development of tools for AgroClimate by other researchers who wish to implement a version in their own state or region.

In this activity, we will develop additional tools to enhance the ability of Open-AgroClimate and evaluate the capabilities of new initiatives to contribute to Open-AgroClimate. We will adapt an existing climate change tool from Australia for incorporation into Open-Agro Climate. UF, UGA, FSU

Development of general disease index for Open AgroClimate

For many plant diseases, control measures must be implemented prior to appearance of visible disease symptoms. The climate data stored on the CRONOS system can be used to calculate general disease risk indices. As with soil moisture, relative humidity is recorded for only a limited number of sites. We will work with investigators at UF to develop algorithms for estimating relative humidity and leaf wetness from available information. In this project, we will continue development of a decision aid to accumulate disease favorable hours up to the present time and to project disease development into the future using historical climate information and climate forecasts. Web services will be developed to extract needed climate and weather data from CRONOS and the National Weather Service, and to store, transform, and utilize these data to calculate disease indices. UF, FSU, UGA

Develop climate education materials for agriculture, K-12, and the general public

The Climate Education will continue to develop and improve the 80 modules which have been created for inclusion on the *Agro*Climate website. Web changes will be made by a student with climate content knowledge as well as web development expertise. Content will be stored in a database so that modules can be easily modified to meet the needs of different audiences. FSU, UF

Evaluate ENSO classification schemes

This research examines alternative ENSO-phase forecasts to yield predictions for spring-summer crops in the Southeastern USA. Previous work shows that increased accuracy of crop yield forecasts is possible by using alternative categorizations of ENSO phase relative to the JMA index, which has been used for most SECC work. County-level annual yield residual data for corn, cotton, and peanut were grouped using two different monthly ENSO classifications (COAPS and NOAA-ONI), and the results were compared with those based on the JMA yearly

ENSO classification. The monthly classification system used looks at the monthly ENSO category for each May and August of the year in question, and uses both to characterize the crop season according to ENSO. UF, FSU

Survey farmers, farm advisors, and farmer representatives

A survey has been conducted in North Florida and Southern Georgia, focusing on field crop production. A second survey has been conducted in Central and Southern Florida focusing on vegetable and fruit crops. This information will be used to help determine key entry points for expanded SECC activities that address multiple year climate variability and scenarios that farmers may face and need information to enhance their preparedness for those situations. Our aim is to provide information that will help the agricultural community in the SECC develop strategies that enhance their resiliency and adaptive capacity to climate variability and climate change. UF, UGA, UM

Economic modeling to quantify impact of climate variability

Refining agricultural risk management strategies using regional and global climate indices helps mitigate climate (systemic) risk and increase producer welfare by reducing uncertainty. This area of research is particularly important as, in national and international policy making, weather index based insurance and other risk hedging strategies are becoming increasingly popular. So far, the value of climate forecasts for use in area yield index insurance has not been researched.

As part of new work in this area, similar analyses will be performed for new pilot insurance products, such as rainfall and vegetation index insurance, to reveal how much efficiency gains are available from accommodating additional climate information (forecasts) in production decisions and in contract design. This activity benefits from recent research by SECC climatologists and agronomists justifying crop yield and climate connection. In addition, benefits from accommodating climate information in insurance and re-insurance contracts will be evaluated, as insurance and re-insurance companies are also important users in the potential market for climate information. UM, FSU

Managing risks to water quantity and quality

This activity addresses water quality impacts resulting from anticipated climate change in the Southeast, municipal water supply and demand of small rural municipalities, water quality impacts resulting from climate variability and water withdrawal for irrigation, and water quality issues resulting from land application of farm animal waste. Since all of these issues are affected by climate variability and climate change, use of climate information in decision-making is pertinent. Results will be made available to end users (farmers, certified animal waste vendors, and extension agents) to help reduce water quantity and quality impacts from water withdrawal, animal waste application, and other land use activities under various climate variability and change scenarios. UA, UF, UGA

Quantifying impact of climate variability on crop production and aflatoxin

This study incorporates data from field research conducted at three different locations throughout Alabama as well as modeling and simulation of the impact of climate variability on Corn and Wheat. Previously, results from field research were used for model calibration as a first step on the simulation of the impact of ENSO phases on corn and wheat production. This work is being

extended to incorporate corn and wheat growth and yield data by ENSO phases under potential agricultural adaptations (e.g. irrigation, planting date, crop mix). In addition, those impacts and potential adaptations will be studied based on extreme historic weather events.
As a complement, data from these studies will be integrated for use by producers and Extension agents and specialists in extension programs and advisory roles and for other end users of AgroClimate forecasts.

Additionally, research will be conducted to quantify and reduce risk of aflatoxin contamination in corn production. Rainfed corn production in Alabama (91%), with inherent on-farm aflatoxin contamination risk, is evidence of the need to develop and implement cost-effective site-specific management strategies that can minimize contamination. Therefore, the identification of the relationship between climatic conditions and aflatoxin contamination can be used as a first step on the identification and characterization of risk scenarios for contamination. UAH, UGA, UF

Farm risk models to evaluate climate information
The SECC has developed a framework to study the value of the climate information under federal farm programs in the SE USA. This framework integrates climate, biophysical, economic, 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. Our goal is to include a wider range of risk management approaches, more farm enterprises, more farm programs, and other locations. Also, the model framework will be adapted to respond new research questions in collaboration with extension agents and other stakeholders. UM, FSU

Assessment and evaluation
We will continue to assess the potential use of seasonal climate forecasts by different groups of potential users, including case studies with particular groups of agricultural producers, including resource-limited or marginalized communities. Comments and responses will regularly be tabulated and analyzed to strengthen the SECC research and development effort. UM, UGA, UF

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

Marine and Estuarine Goal Setting for South Florida (MARES)

P. Ortner and C. Kelble (UM/CIMAS); P. Fletcher (UF/FSG); L. Johns (NOAA/AOML)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** To reach a science-based consensus about the defining characteristics and fundamental regulating processes of a South Florida coastal marine ecosystem that is both sustainable and capable of providing the diverse ecological services upon which our society depends.

***Strategy*:** Develop ICEM models for critical subregions, and based upon these through series of subsequent meetings and briefings identify quantitative ecosystem indicators and establish an annual South Florida coastal ecosystem report card.

CIMAS 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 an Ecosystem Approach to Management

NOAA Funding Unit: NOS/CSCOR **NOAA Technical Contact:** Larry Pugh

Research Summary:

MARES (www.sofla-mares.org) is a three year project funded by NOS/CSCOR whose goal is to reach a science-based consensus about the defining characteristics and fundamental regulating processes of a South Florida coastal marine ecosystem that is both sustainable and capable of providing the diverse ecological services upon which our society depends. MARES represents a unique collaboration amongst academic and government natural and human dimensions scientists working with public and private stakeholders. The first step in the MARS process is to sequentially develop Integrated Conceptual Ecosystem Models (ICEMs) for critical sub-regions (SW Florida Shelf, Florida Keys and SE Florida shelf. Figure 1 is the ICEM for the Florida Keys and Dry Tortugas. It is a modification of the DPSIR (Drivers/Pressures/Stresses/Indicators/Responses) used by the EPA in ecological risk assessment contexts. These models and a series of subsequent meetings and briefings are being used to identify quantitative ecosystem indicators. The process is proceeding on schedule. Specifically, a rollout workshop was held this last Fall at UM/RSMAS immediately after the project was initiated in October 2009. This was followed by two workshops for the first of the sub-regions to be characterized: the Florida Keys and Dry Tortugas. The first workshop in December, 2009 at FIU was used to develop the Integrated Conceptual Ecological Model for this domain. A cartoon of the model and sub-models included in the ICEM (and their spatial relationship) is provided in Figure 2. The second workshop in early April 2010 was to begin the process of developing the quantitative indicators for the same domain. At the same time MARES leadership has held briefings for the SFER Science Subgroup, the CERP/RECOVER RLG and the Florida Keys National Marine Sanctuary Technical Advisory Committee.

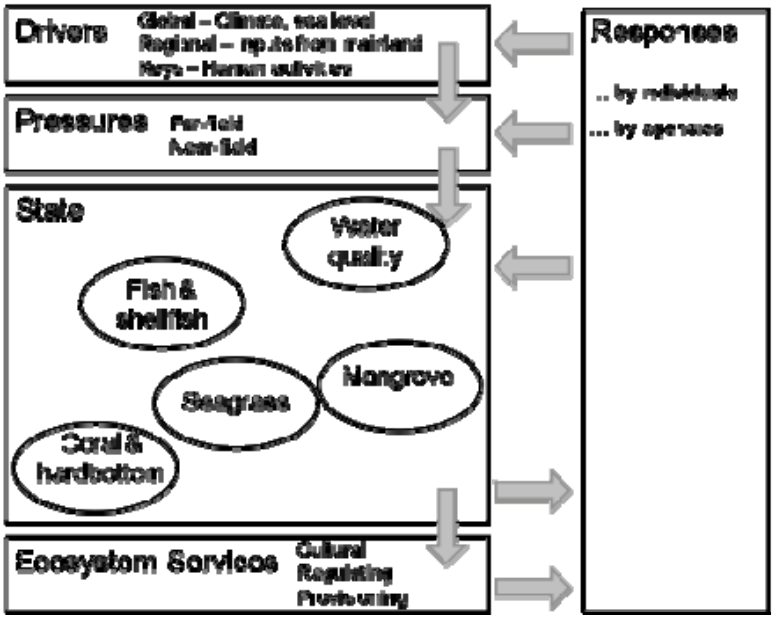


Figure 1: Integrated Conceptual Ecological Model (ICEM) for the Florida Keys and Dry Tortugas: a modification of EPA's DPSR (Drivers-Pressures-States-Responses) framework.

MARES will eventually yield a South Florida Marine Ecosystem Report Card that will assist natural resource and environmental managers of South Florida to effectively implement ecosystem based management (EBM). The need to conduct EBM has become the focus of several new NOAA initiatives, Integrated Ecosystem Assessments (IEAs) and Coastal and Marine Spatial Planning (CMSP). Both initiatives are aimed at integrating human- and natural-system needs for the development of effective EBM. MARES hopes to provide a model process for integrating the human- and natural-system to; 1) develop ICEMS, 2) develop indicators, 3) assess the ecosystem and 4) set ecosystem goals. All four are key components of IEAs and likely CMSP. The development and subsequent utilization of science-based ecosystem goals that incorporate both the human- and natural-systems will represent significant progress towards enacting EBM in south Florida. This MARES process can be emulated in other regions for IEA and CMSP purposes.

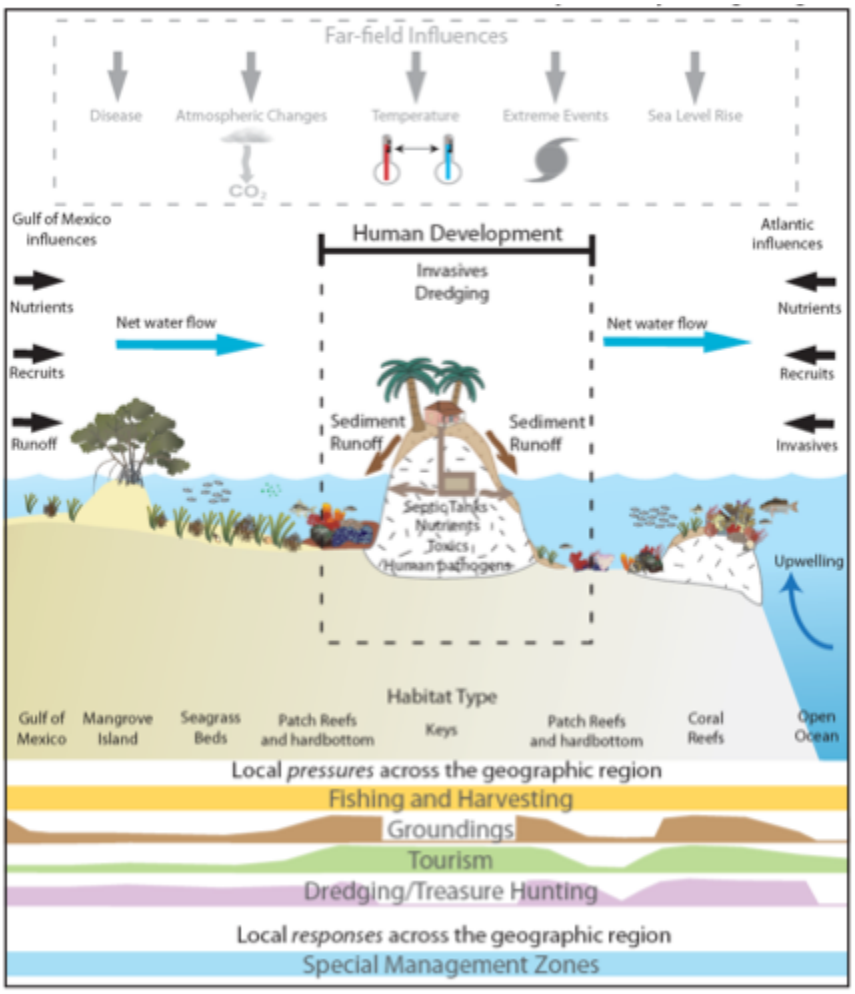


Figure 2: Near-field and far-field influences on the Florida Keys and Dry Tortugas Region.

Research Performance Measure: The project is on schedule with the next MARES sub-region meeting organized and scheduled. The SW Florida ICEM meeting will be held at Florida Gulf Coast University on August 19 and 20. The ICEM for the Florida Keys and Dry Tortugas will be used as model and prototype for the Southwest Florida subregion.

Scientific, Technical, Research, Engineering and Modeling Support (STREAMS) Virtual Beach Project – Miami Hobie Cat Beach

M. Gidley, D. Wanless, M. Lara, M. Gonzalez, K. Herleman, J. Jans, J. Bartkowiak, F. Tonioli and D. Aranda (UM/CIMAS); C. Sinigalliano (NOAA/AOML)
S. Tomoyuki (UM/MBF), L. Plano (UM/Miller School of Medicine)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** To assist the EPA to improve remote forecasting and coordination for the detection of microbial indicators and contaminants in coastal waters and beaches, and thus limit risk of human exposure to potential microbial pathogens and contaminates. ("ground-truthing" for predictive modeling of pathogen indicators at recreational beaches.) This project is now completely finished and concluded.

***Strategy*:** Determine microbial indicator levels along a sub-tropical beach during an intensive ninety day sampling period to be correlated with EPA physical data (air/water temp., currents, UV, wind) collected throughout the same study timeframe, and provide EPA with water filter samples for independent molecular analysis of microbial indicators.

CIMAS Research Theme:

Theme 4: Human Interactions with the Environment *(Primary)*
Theme 3: Regional Coastal Ecosystem Processes ***(****Secondary****)***
Theme 6: Integrated Ocean Observations (*Tertiary*)

Links to NOAA Strategic Goals:

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

NOAA Funding Unit: N/A (funded by EPA directly through ERD contract)
NOAA Technical Contact: Christopher Sinigalliano

Research Summary:

This project has been successfully concluded, all funded work has finished, all required deliverables delivered, and the final report has been finished and turned in. However, the sample archive and data archive generated by this project continue to be utilized by several other independent projects, including methods development and validation for the CIMAS project "Assay and Sensor Development to Identify, Detect and Quantify Microbial Contaminants" (PIs K Goodwin and C. Sinigalliano), and analysis of samples for pathogenic Staphylococcus aureus with the CIMAS project "Potential Human Contribution and Exposure to Staphylococcus aureus, including Methicillin-Resistant Staphylococcus aureus (MRSA), to the beach and coastal environment" (PIs M. Gidley and L. Plano).

Significant progress has been made in water quality and recreational water quality protection during the past several decades, but many of the nation's coastal beaches still periodically fail to meet national standards. Contamination by fecal indicators and/or pathogens is the primary cause of impairment in most regions, with fecal pollution believed to be the major source of such microbial contamination in recreational waters; with both point and non-point sources possibly being involved. In addition, current culture-based testing methods may result in a delay of a day or more in reporting

results that exceed regulatory exposure levels to beach managers and the public, leading to a potential for human exposure to microbial contaminants during that time frame.

Figure 1: CIMAS employee collects water samples from Hobie Beach to test for Fecal Indicator Bacteria as part of ground-truthing for the EPA-STREAMS Virtual Beach Project.

Currently, microbial water quality standards are judged by assessing the abundance of Fecal Indicator Bacteria (FIB). The FIB traditionally assayed includes enterococci and *Escherichia coli*. However there is wide and growing consensus in the scientific community that these current indicator organisms and the culture-based methodology currently used to detect them may be inaccurate and inappropriate indicators of human fecal contamination in subtropical and tropical coastal waters where they may persist or even re-grow in the environment (particularly when associated with sand, sediments, or biofilms), and that more rapid and sensitive molecular-based assays need to be employed in the monitoring of these indicators and alternative indicators that may better represent the actual public health risks in these environments. The EPA has been mandated to update their water quality criteria from traditional culture-based methods of total coliforms and enterococci to include new molecular based methods for rapid detection of FIBs, and to develop water quality criteria utilizing alternative FIBs. In addition, there is a need to determine not just the presence of fecal indicator bacteria, but also their origins, in particular the determination of human-origin indicators, as human-source fecal contamination may pose the greatest public health risks.

Figure 2: RSMAS student learns how to conduct traditional culture-based confimative tests for enterococci during the EPA-STREAMS Virtual Beach Project.

The EPA-STREAMS Virtual Beach Program seeks to develop predictive computer modeling utilizing a combination of in situ physico-chemical and meteoro-logical measurements at recrea-tional beaches to predict the putative levels of FIBs in near-real-time to generate "Now-Casts" of beach water quality. Pilot demonstrations of this approach have met with some success, and the EPA is now trying to adapt this predictive modeling to other types of beach environments. The project reported here served to support this EPA program by "ground-truthing" their predictive modeling work at Hobie Beach on Virginia Key in Miami, Florida. The CIMAS-AOML work conducted for this

project included intensive sampling throughout the summer of 2008, collecting water samples from shin and waist depth along three transects three times a day, four days a week for three months. FIBs were enumerated by traditional culture-based methods, replicate water samples were filtered to harvest the bacterial population and these filters were sent to the EPA ERD laboratories for molecular analysis of FIBs, and sample filters were also collected to generate a filter archive for molecular analysis at NOAA AOML.

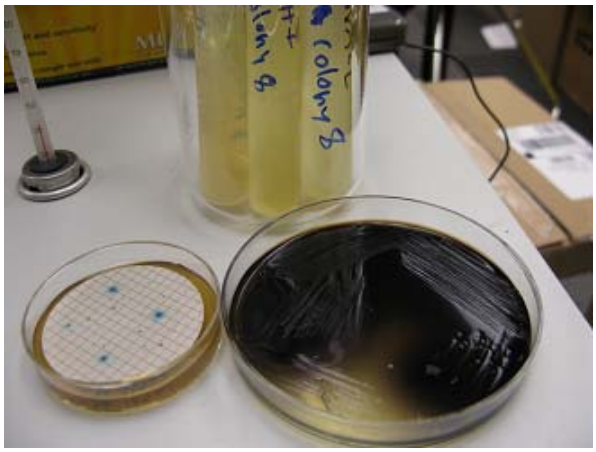


Figure 3: Membrane filtration plate count and confimative culture-based tests indicating the presence of enterococci fecal indicator bacteria.

Figure 4: CIMAS graduate student filters beach water samples for molecular analysis of fecal indicator bacteria and pathogens as part of ground-truthing for the EPA-STREAMS Virtual Beach Project.

Research Performance Measure: This project is now completely finished. To date we have accomplished all of our objectives for this project, and all required deliverables have been provided to ERG and the EPA. This includes culture-based enumeration of enterococci for the project sample set, replicate polycarbonate filters for molecular analysis sent to the EPA's ERD lab in Athens, GA, and replicate filtered water samples also sent to the ERD labs for nutrient and volatiles analysis. Final reports have been sent to ERG and EPA and all required contractual work on this project has been finished. In addition, an in-house genetic archive of all samples collected has been established at NOAA-AOML, and additional in-house molecular characterization of indicators, alternative indicators, and pathogens is on-going. Note that this analysis is beyond the scope of this project as funded by EPA and the in-house analysis is value-added work that is being leveraged by funding from other NOAA and OHH projects. This genetic archive and its analysis should provide a wealth of data on indicators and pathogens at non-point source recreational beaches, and indeed has already yielded significant new insights on presence of skin pathogens such as Staphylococcus aureus through collaborative analysis with the University of Miami Oceans and Human Health Center. The genetic archive generated by this project will continue to be utilized for a variety of analyses by future projects.

EPA/FIU Molecular Microbial Source Tracking for the Florida Keys Little Venice Service Area

D. Aranda, D. Wanless, J. Bartkowiak and M. Gidley (UM/CIMAS)
C. Sinigalliano (NOAA/AOML); H. Coit (UM/RSMAS, NSF-REU)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** Utilization of molecular microbial source tracking tools to assess potential improvements of surface water quality in residential canals and near-shore coastal waters of the Florida Keys National Marine Sanctuary (FKNMS) in the region of the Little Venice Service Area (Vaca Key, Florida) following the implementation of a new sewer infrastructure in the region. This study is part of a larger integrated on-going water quality assessment of the FKNMS, and the impacts of this water quality on both human health and coastal ecosystem and coral reef health.

***Strategy*:** To measure fecal indicator bacteria load (specifically Enterococcus and Bacteroidales sp.), microbial source tracking genetic markers, and selected pathogens in surface waters of the study area during the course of a year following transition from residential septic fields and/or cess pits along the Little Venice residential canals to a regional sewer system. Multiple species and strains of fecal indicator bacteria (FIB) are measured by both traditional culture-based methods and quantitative molecular methods for comparison of their abundance before and after the sanitary infrastructure improvements. The host-sources of various FIB source tracking genetic markers are measured by the molecular approach of quantitative PCR (qPCR) targeting host-specific gene sequences to determine the relative loading of human-source FIBs (indicative of human sewage contamination) and domestic animal-source FIBs (indicative of terrestrial runoff and stormwater discharge).

CIMAS Research Theme:

Theme 4: Human Interactions with the Environment *(Primary)*
Theme 3: Regional Coastal Ecosystem Processes ***(****Secondary****)***
Theme 6: Integrated Ocean Observations (*Tertiary*)

Link to NOAA Strategic Goals:

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

NOAA Funding Unit: The project funded by the U.S. EPA via a subcontract from FIU to UM (*Primary*); OAR/AOML (*Secondary***)**

NOAA Technical Contact: Christopher Sinigalliano

Research Summary:

The coastal residence canal area of Vaca Key known as the Little Venice (LV) service area, FL (Fig. 1) has been observed to contain elevated levels of fecal indicator bacteria in the surface waters of the canals and the near shore coastal waters. This region has previously been identified as one of the fecal indicator bacteria (FIB) "hot spots" within the Florida Keys National Marine Sanctuary, (FKNMS). Until very recently, the sanitary infrastructure of the Little Venice Service Area has consisted of individual septic fields or even old cess pits. These aging sanitation structures along the Little Venice area residential canals were subject to significant leakage to the surrounding coastal

waters and have recently been replaced with a municipal area sewer system with the expectation of improving water quality.

Figure 1: Vaca Key, Florida, showing the sampling sites of the Little Venice Service Area

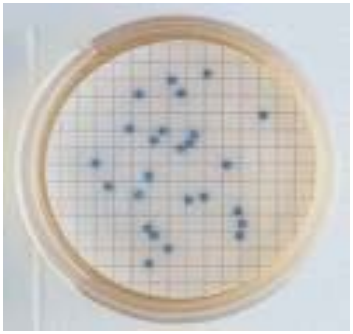


Figure 2: mEI agar filter showing diagnostic enterococci type colonies

Surface water samples were taken at four residential canals (head and mouth of each canal and at a nearshore coastal station) at a total of nine sampling stations. All water samples were tested for the presence of viable fecal indicator bacteria of the enterococci group and the bacteroidales group using standard traditional filtration and culture-based incubation methods on mEI agar (Fig 2) and BBE agar respectively. Our method is as follows. Microorganisms from the water are collected by filtration on membrane filters and the total microbial community DNA and RNA from the water samples are extracted from replicate water sample filters. These purified environmental nucleic acid extracts are stored long-term in ultra-cold -80°C freezers providing a valuable cyropreserved genetic archive representing microbial community from the Little Venice canals and coastal waters during this time of sanitary infrastructure improvement to the region. This genetic archive is utilized for a variety of molecular genetic assays of this changing microbial community both by this study and by other ongoing independent research projects.

The abundance of total enterococci and Bacteroides fecal indicator bacteria are assessed by real-time quantitative PCR (qPCR), and the abundance of a variety of human-host-specific FIB strains are also measured by qPCR. This project is investigating the seasonal and diurnal patterns of FIBs and microbial source tracking markers by conducting bi-weekly samplings of these sites, and by conducting two intensive diurnal 48 hour sampling events, one in Jan of 2010 during the dry winter season, and one in July of 2010 during the wet summer season respectively. During the intensive studies, samples are automatically collected every two hours for 48+ hours with automated ISCO autosamplers (Fig 4) and the water samples are processed on location in the Florida Keys at the host

Figure 3: extraction of microbial community DNA from filtered water samples.

Figure 4: Dr. Maribeth Gidley, an environmental public health physician with CIMAS, collects water samples for culture and genetic analyses from an autosampler at the head of a Little Venice residential canal.

lab facilities of the Keys Marine Lab (operated jointly by the Florida Institute of Oceanography and the Florida Wildlife Research Institute).

The relative abundance of fecal indicator bacteria, as measured both by culture-based and molecular based methods, appears to be significantly decreased as compared to preliminary base-line studies of the area conducted two years prior to this project's surveillance period, although molecular measurements still show periodic spikes for total enterococci and Bacteroides. During the surveillance period so far (Sept. 2009 through May 2010), there has been one seasonal average exceedence of viable enterococci above the EPA recommended 104 CFU / 100 mL, and these elevated total enterococci levels could be correlated to elevated human-source Bacteroides as measured by qPCR (Fig 5).

The results to date of this microbial source tracking study suggest that the implemented infrastructure improvements in the Little Venice area is having a positive impact on reducing human-source microbial fecal indicator levels and so presumably in reducing human fecal contamination in the canal and nearshore coastal waters. The reason for the ongoing periodic spikes and the observed regulatory exceedence incident are not clear. Canal sediments may be one potential source of the continued persistence of enterococci and other fecal indicators in these canals due to sediment resuspension, and further studies are planned to investigate the role of these sediments as potential environmental reservoirs for FIBs. These continued monitoring efforts aid in regional water quality management. Measuring the relative abundance of multiple human-source fecal indicator markers can help researchers and water quality managers better assess if the implemented sanitary improvement activities of the region are having an impact on the microbial population composition and thus resulting in reduced potential risk to humans and the ecosystem from human fecal contamination of the local coastal waters.

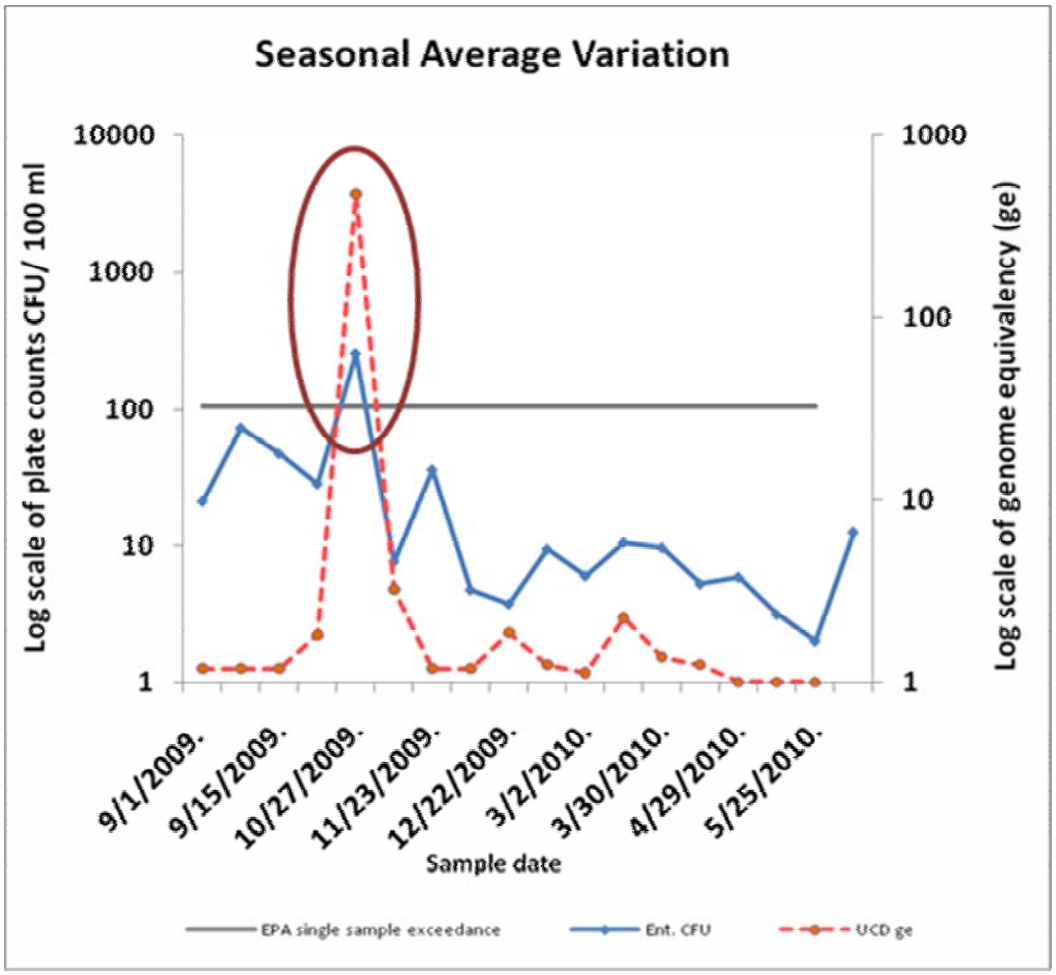


Figure 5: Average seasonal variability of enterococci colony forming units (CFU) and human bacteroides genome equivalency. Enteroccoci CFU / 100 ml plate counts (blue) on the primary axis (log scale) on the left shows seasonal variability, with one exeeedence incident on 10/27/2009. The genome equivalency of the human –specific Bacteroides marker on the secondary axis (log scale) to the right shows seasonal variability with a spike also on 10/27/2009. Circled in red is the sample date were the Enterococci counts and the human fecal source-tracking marker peaked together, indicating the presence of human fecal contamination above regulatory levels. The grey line denotes enterococci exceedences above this 104 CFU / 100 mL level.

Research Performance Measure: The performance measure of this research is to provide microbiological assessments of the relative abundance of total viable enterococci and Bacteroides sp., and the relative abundance of multiple human-source-specific microbial source tracking markers in the surface waters of the Little Venice canals over a period of one year on a bi-weekly basis, including two 48 hours intensive sampling events, one in the wet summer season and one in the dry winter season. All major objectives are being met.

Improvement in the NOAA Rapid Intensity Index by Incorporation of Inner-Core Information

J.P. Dunion (UM/CIMAS); J. Kaplan and J. Cione (NOAA/AOML);
M. DeMaria and J. Knaff (NOAA/NESDIS); J. Dostalek (CIRA);
T. Lee and J. Hawkins (NRL-Monterey)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** Develop and test Rapid intensification (RI) predictors from three new sources of inner-core information for possible implementation in NOAA's operational Atlantic basin SHIPS Rapid Intensity index (RII).

***Strategy*:** Submit a successful proposal to NOAA's Joint Hurricane Testbed Program (JHT) to test and develop new predictors for improving the NOAA Rapid Intensity Index forecast model.

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 (*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:** Frank Marks

Research Summary

NOAA's Rapid Intensity (RI) Index (RII) is currently utilized by the National Hurricane Center as guidance for the possible onset of tropical cyclone rapid intensification. The goal of this project is to develop new predictors for this forecast model to improve the detection of tropical cyclone RI events. RI predictors from three new sources of inner-core information were developed for testing in a revised version of the operational Atlantic basin SHIPS RI index (RII). These three sources are the

time evolution of tropical cyclone inner-core structure as deduced from GOES infra-red (IR) satellite imagery, total precipitable water (TPW) derived from microwave SSM/I satellite imagery and boundary-layer temperature and moisture differences and sensible and latent heat fluxes derived from NOAA Global Forecast System (GFS) model analyses. Figure 1 shows that relative to climatology, the new RII index shows significant skill at predicting the onset of tropical cyclone RI at three selected thresholds [25 kt (12.5 m s^{-1})/day, 30 kt (15 m s^{-1}/day, and 35 kt (17.5 m s^{-1}/day in both the North Atlantic and eastern North Pacific basins.

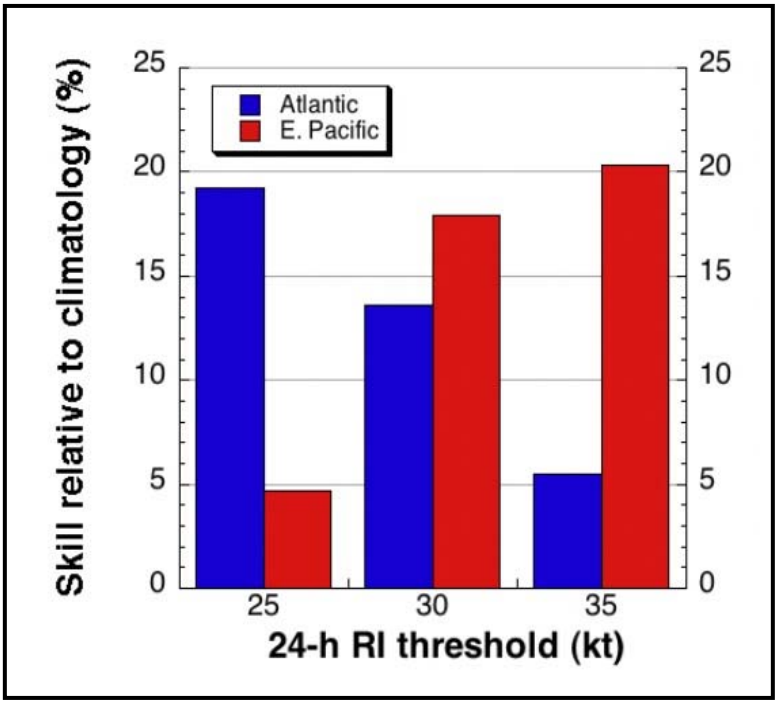


Figure 1: The skill of the operational Atlantic and eastern North Pacific 2008-2009 tropical cyclone Rapid Intensity Index forecasts.

Research Performance Measure: Results from this project were presented at the AMS Tropical Conference in Tucson, AZ (April 2010). Additionally, a manuscript describing the results of this work has been published in Weather & Forecasting [Kaplan, J., M. DeMaria, and J. Knaff, 2010: A revised tropical cyclone rapid intensification index for the Atlantic and eastern North Pacific basins, *Wea. and Forecasting,* 25(1), 220-241].

Ensemble-Based High-Resolution, Vortex-Scale Data Assimilation for Hurricane Model Initialization

A. Aksoy, K. Sellwood and S. Lorsolo (UM/CIMAS); S. Majumdar (UM/RSMAS)
S.D. Aberson (NOAA/AOML); F. Zhang (Pennsylvania State University)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** improve hurricane intensity and track forecasts through improved representation of hurricane vortex structures in the initial conditions of hurricane forecast models.

***Strategy*:** To better utilize high-resolution observations (dropsonde, radar, flight level, surface wind speed, etc.) collected during the Hurricane Field Program run by NOAA/AOML/HRD by taking advantage of flow-dependent covariance structures that can be obtained from an ensemble of model forecasts that will form the basis of an ensemble Kalman filter data assimilation system.

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:** Sim D. Aberson

Research Summary:
An ensemble Kalman filter (EnKF) data assimilation system has been built to assimilate high-resolution, vortex-scale observations that are routinely collected and transmitted real-time, during NOAA's annual Hurricane Field Program and regular reconnaissance flights. Coined Hurricane Ensemble Data Assimilation System (HEDAS), it will be tested in semi-real-time as part of NOAA's Hurricane Forecast Improvement Project (HFIP) during the 2010 hurricane season. Various observation types that will be assimilated include Doppler radar radial winds, dropwindsonde wind, pressure, temperature, and humidity, flight-level wind, pressure, temperature, and humidity, and stepped-frequency microwave radiometer (SFMR) surface wind speed. The system will also make it possible to evaluate impacts of other potential observation platforms through observing system and observing system simulation experiments (OSE and OSSE, respectively). The EnKF is a state-of-the-art data assimilation system first proposed for geophysical applications by Evensen (*JGR*, 1994). In this specific application, we implement the "ensemble square root" filter of Whitaker and Hamill (*MWR*, 2002) and covariance localization by Gaspari and Cohn's (*QJRMS*, 1999) compactly supported fifth-order correlation function.

HEDAS has been developed within the framework of AOML/HRD's experimental Hurricane Weather Research and Forecast (HWRFx) model. Data assimilation will be performed on a 3-km nest, while HWRFx will run in a nested 9/3-km configuration during cycling. Initial ensemble perturbations are obtained from NOAA/ESRL's EnKF system, which will run with NCEP's Global Forecast System (GFS) modeling framework and Gridpoint Statistical Interpolation (GSI) system's forward operators.

Currently, there are two major research directions with HEDAS. In one approach, a detailed diagnostic of HEDAS performance is being carried out in an OSSE environment. For this purpose, a higher-resolution version of HWRF-x, at 4.5/1.5-km horizontal resolution with explicit convection in all domains, is used to obtain a nature run, which will be the basis for simulating various observation platforms. The case of interest is Hurricane Paloma of 2008. The nature run is initialized from one ensemble member of the GFS-EnKF analysis valid for 7 November 2008 12Z. The availability of a nature run enables detailed diagnostics of a data assimilation system when observations simulated from that nature run are assimilated. The fact that such observations are obtained from a model run also eliminates non-meteorological noise from them so that the performance of a data assimilation system entirely depends on the underlying modeling and data assimilation characteristics. The OSSE aspect of the project is motivated by these factors and will be completed in the near future using the Paloma 2008 nature run presented here.

In Figure 1, some characteristics of the nature run are presented for a 24-h period. In panel (a), a general northeasterly track of the simulated storm is apparent. The 10-m radius of maximum wind speed (10-m RMW, measured as the distance of the azimuthally-averaged 10-m tangential wind speed maximum from the center), the distance of absolute maximum 10-m horizontal wind speed from the center, and the azimuthal standard deviation of distance of maximum tangential wind to center (coined "10-m RMW standard deviation" hereafter) are shown in panel (b). While the distance of actual 10-m wind maximum is not expected to exactly follow the RMW pattern (because of potential vortex asymmetries), a general agreement within one 10-m RMW standard deviation is evident beyond 6 h. Meanwhile, a large fluctuation (relative to 10-m RMW standard deviation) between the two quantities within the first 6 h likely points to an imbalance within the vortex as the simulation spins up from the much-coarser-resolution GFS-EnKF initial conditions. It is also evident in this panel that RMW fluctuates at ~30 km 6 h and beyond. Panel (c) shows the RMW slope (as approximated from the linear regression between RMW and height at each time) as a proxy for eyewall slope. During the 6-24 h of simulation, a general decreasing trend is evident. Finally, panel (d) depicts estimations of intensity from minimum central surface pressure and maximum 10-m horizontal wind speed. While minimum pressure appears to be steadily decreasing in the simulation, maximum-wind intensity is steady between 6-18 h and then increases by ~10 m s^{-1} during the last 4 h of simulation. This intensity increase is preceded with an increase in RMW and decrease in RMW slope.

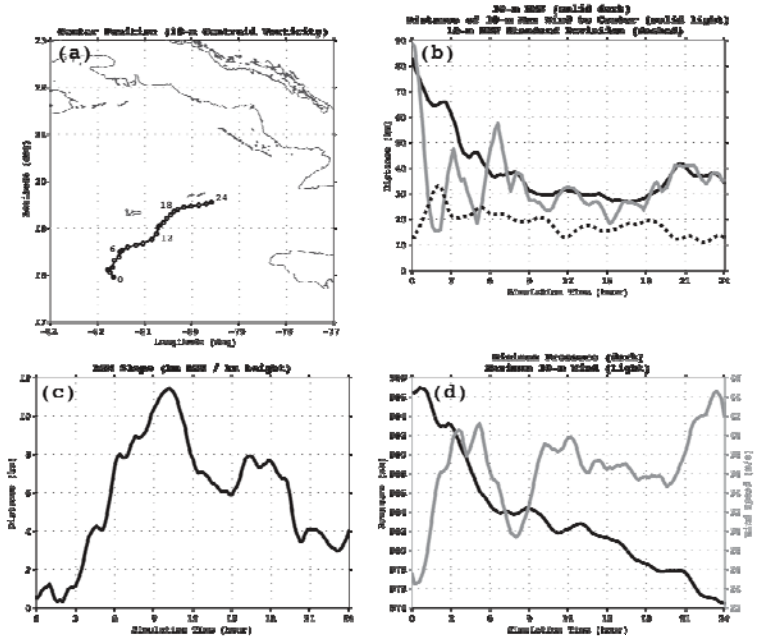


Figure 1: 24-h nature run simulation for Hurricane Paloma (2008), initialized at 7 November 2008 12Z. (a) Hourly center position as obtained using the 10-m centroid vorticity method, (b) 10-m RMW (solid dark, km), distance of absolute 10-m maximum horizontal wind to storm center (solid gray, km), and 10-m RMW standard deviation (dashed, km), (c) vertical slope of RMW (km RMW km^{-1} height), and (d) minimum central surface pressure intensity (dark, mb) and maximum 10-m horizontal wind intensity (m s^{-1}).

In parallel work, the performance of HEDAS has been evaluated with real observations for the case of Hurricane Bill (2009), using inner-core Doppler radar, dropwindsonde, SFMR, and flight-level data that were collected by NOAA and Air Force. The HWRFx model is initialized from the same GFS-EnKF ensemble as the OSSE experiment, for 30 ensemble members, at 9/3-km horizontal resolution and the aircraft data are assimilated on the 3-km inner nest. In these experiments, the impact of assimilating the different data types into the model background forecast is assessed by examining the model diagnostic variables and the evolution of their associated error statistics over the 5-h interval in which observations were available. Additional experiments are being performed

to study the effect of varying certain HEDAS parameters in order to determine the optimal configuration for real-time data assimilation. This configuration is planned to be utilized for the near-real-time HEDAS runs during the 2010 hurricane season.

In Figure 2, the ensemble-mean horizontal fields of wind and sea-level pressure are shown for the model forecast/analysis with no data assimilation (a, b) and the analysis produced after 5 forecast-assimilation cycles (c, d). The forecast without data assimilation produces a weaker, less symmetric vortex, while the analysis which incorporates the aircraft data is more consistent with the observed structure and intensity of Hurricane Bill.

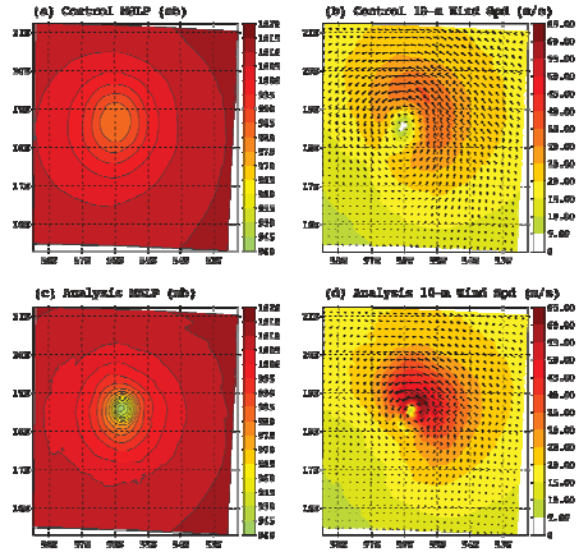


Figure 2: Mean sea-level pressure (MSLP) and 10-m horizontal wind speed for Hurricane Bill valid at 13Z on August 19, 2009. Top row: Control ensemble mean forecast without data assimilation. Bottom row: Ensemble mean analysis after five data assimilation cycles.

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

Ensemble Kalman Filters and OSSEs in Hurricane Models

S.J. Majumdar (UM/RSMAS); A. Aksoy and K.J. Sellwood (UM/CIMAS); R. Atlas, S.D. Aberson, F.D. Marks and T. Vukicevic (NOAA/AOML); M. J. Brennan (NOAA/NHC)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** To explore the utility of ensemble methods in data assimilation and Observing System Simulation Experiments, in support of NOAA's Hurricane Forecast Improvement Project (HFIP).

***Strategy*:** To collaborate on the development of an Ensemble Kalman Filter with NOAA, and to exploit existing information in ensemble forecasts of tropical cyclones.

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:** Bob Atlas

Research Summary:

***Ensemble-based data assimilation*:** As part of NOAA's Hurricane Forecast Improvement Project (HFIP), the PI has begun collaborating with Vukicevic, Aksoy and Sellwood, the latter of whom is entering the Ph.D. program at RSMAS in August 2010. The Ensemble Kalman Filter (EnKF) for tropical cyclones is being prepared on NOAA's computer system, and initial results have been promising (see corresponding report by Aksoy).

***Observing System Simulation Experiments (OSSEs) for hurricanes*:** The PI has been involved in multiple virtual conferences with Dr Bob Atlas (AOML Director), and Dr Steven Koch (ESRL Global Systems Division Director) and his staff with respect to enabling OSSEs in global and regional models of hurricanes. The calibration for the global model OSSE has been completed, and the PI is working on designing potential unmanned aircraft tracks to determine their potential for improving forecasts of hurricane track.

***Evaluating Ensemble Forecasts*:** The PI has published an article on the evaluation of ensemble forecasts of hurricane track, together with Peter Finocchio, an undergraduate student at UM. It was found that the ensemble from the European Centre for Medium-Range Weather Forecasts (ECMWF) was able to produce competitive 1-5 day forecasts of hurricane track, and furthermore probabilities of the track falling within a specific region.

Errors in Forecasting Hurricane Ike: This research grant has also permitted the extension of modeling and ensemble studies to a new collaboration with Dr Michael Brennan, a Senior Hurricane Specialist at NOAA/NHC. The study focuses on the errors in the global model track forecasts of Hurricane Ike (2008), four days prior to its landfall in northern Texas. Through a sensitivity study with NOAA's operational Global Forecast System (GFS), it was found that the mid-level ridge to the immediate north of Ike was forecast to be too strong in the models, and that there was also sensitivity of Ike's track to the strength of a shortwave trough off California (Fig. 1). Similar sensitivities were found in NOAA's operational Global Ensemble Forecast System.

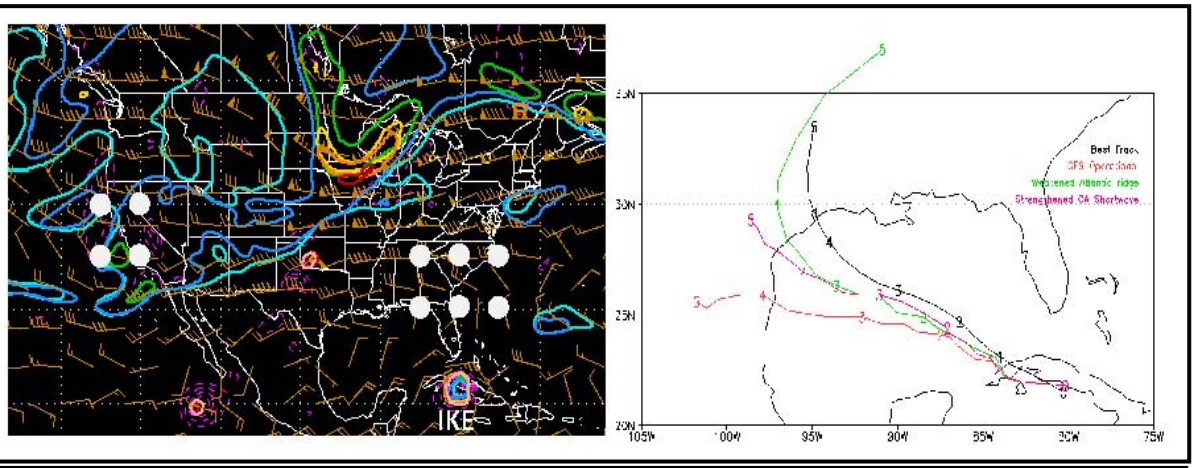


Figure 1: Left: NCEP GFS analysis field illustrating the location of Hurricane Ike, and two regions in which perturbations are made to the GFS data assimilation, at 00 UTC, 9th September 2008. In the western region, a shortwave trough over California is deepened. In the eastern region, a mid-level ridge to the north of Ike is weakened. Right: Response of the 5-day GFS forecasts of Ike to these perturbations, illustrating improved forecasts (green and magenta) compared against the original operational forecast (red).

Research Performance Measure: The accomplishments have met the original objectives.

Characterization of Turbulent Energy in Hurricanes Using Doppler Measurements

S. Lorsolo and J. Zhang (UM/CIMAS); J. Gamache, P. Dodge and F. Marks (NOAA/AOML)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** To estimate the distribution and evolution of hurricane boundary layers' turbulent kinetic energy (TKE) for a better understanding of the processes that influence hurricane intensity change and for a more accurate parameterization in numerical weather prediction models.

***Strategy*:** To analyze Doppler radar and *in-situ* measurements from various instruments from an extensive data set to provide a comprehensive evaluation of the turbulent structure of hurricanes. To develop methods to estimate low-level turbulent parameters that will provide an accurate assessment of hurricane turbulent energy to use in numerical weather prediction parameterization.

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:** John Gamache

Research Summary:

One of the main challenges of hurricane research is to better understand the processes that influence hurricane intensity change, which could ultimately lead to improved intensity forecasts. Among the various parameters believed to impact hurricane intensity change are air-sea interaction and turbulent energy transport within the hurricane boundary layer (HBL). An accurate estimate of hurricane turbulent energy is crucial to identify the role of turbulent processes in the energy transport within a storm in general and in the hurricane boundary layer (HBL), in particular.

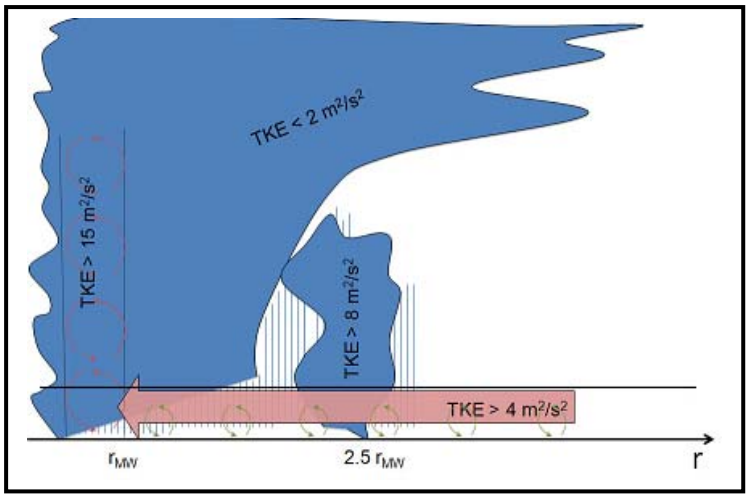


Figure 1: Lorsolo_T5_ Conceptual model of TKE distribution in hurricanes.

The goal of this research project is to characterize turbulent parameters of hurricanes, especially in the HBL, using remote sensing observations as they are difficult to assess from direct measurements in high wind regions such as the eyewall and the HBL. Turbulent data retrieved from instruments such as Doppler radars are crucial to identify turbulent processes impacting hurricane intensity and to evaluate models.

The activities of the past year have focused on continuing processing and analyzing the data to improve the robustness of the results, completing the manuscript related to the study and developing a new method to retrieve turbulent dissipation rate from Doppler measurements to help model evaluation. A new algorithm is being developed to test the method.

The TKE study was refined by providing general results from the combination of data from multiple hurricanes and by the realization of a conceptual model of the TKE distribution with a tropical cyclone.

Research Performance Measure: The objectives regarding the TKE study were met. The manuscript related to the study was accepted for publication and is currently in press. Some preliminary results of the dissipation method have been presented at the AMS hurricane conference. During the conference requests were made for TKE data and the recently accepted paper was cited in presentations.

A Composite Study of the Atmospheric Boundary Layer Structure in Hurricanes Using GPS Dropsondes

J. Zhang (UM/CIMAS); F. Marks and R. Rogers (NOAA/AOML)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** To study the mean and turbulence structure of the hurricane boundary layer in order to provide knowledge to evaluate the boundary layer parameterization schemes used in hurricane models.

***Strategy*:** Conduct a composite study of the kinematic and thermodynamic boundary layer profiles using the 10-year Global Positioning System (GPS) datasets.

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:** Frank Marks

Research Summary:

Given the attention being paid to developing high-resolution numerical models and coupled atmosphere-ocean models in order to improve the hurricane intensity forecast, improving understanding of the small-scale boundary layer processes becomes increasingly important. However, understanding the hurricane boundary layer has been limited by a lack of in-situ observational studies. This project aims to provide better knowledge of the boundary layer structure using the 10-year dropsonde datasets collected by NOAA research aircraft.

The first part of this project focuses on the investigation of the mean boundary layer structure. The dropsonde data are grouped into several categories according to the mean wind speed of the lowest 150 m data (W_{L150}). The Contoured Frequency by Altitude Diagram (CFAD) is used to study the vertical distribution of the statistical characteristics of the key variables such as tangential and radial wind speeds, potential temperature, and humidity (Fig. 1). The dropsonde are also grouped and analyzed according to the distance from the storm center that is normalized by the radius of maximum wind speed (Fig. 2). The characteristic height scales such as the height of the maximum wind speed, the mixed layer depth and height of the inflow layer are examined.

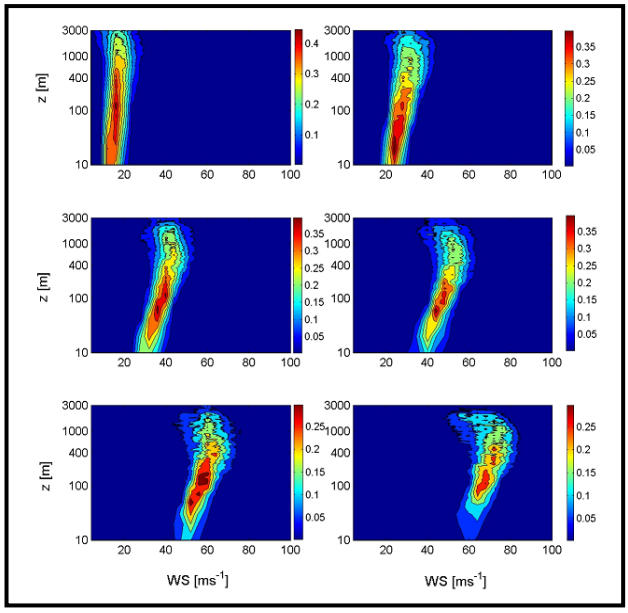


Figure 1: Contoured Frequency by Altitude Diagram (CFAD) plots of the wind speed in six groups according to the W_{L150} which is defined as the mean wind speed of the lowest 150 m data. The vertical scale is in log space.

The second part of this project is to use the composite analysis results a to evaluate the surface layer and boundary layer schemes used in the high-resolution Experimental Hurricane Weather and Research Forecast System (HWRFx).

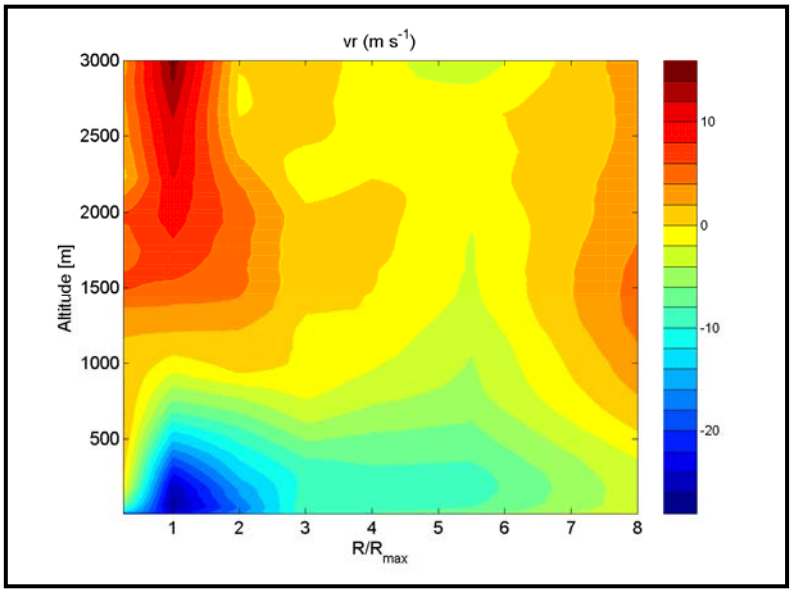


Figure 2: A composite analysis of the radial wind velocity as a function of the radius to the storm center normalized by the radius of maximum wind speed. The data used to create this plot are from 8 major

Research Performance Measure: The program is on schedule.

Advanced Modeling and Prediction of Tropical Cyclones

X. Zhang and K.-S. Yeh (UM/CIMAS); S.G. Gopalakrishnan, T. Quirino,
S. Goldenberg and F. Marks (NOAA/AOML)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** To guide and accelerate improvements in hurricane intensity forecasts with emphasis on rapid intensity (RI) change and the reduction of false alarms.

***Strategy*:** Improve hurricane forecasts through the development of numerical modeling and data assimilation techniques valid for scales of motion down to about 1-km resolution.

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: Sundararaman G. Gopalakrishnan

Research Summary:

In the last ten years, errors in hurricane track forecasts were reduced by about 50% through improved models, observations, and forecaster expertise. However, little progress was made in intensity forecasts over the same period of time. The National Oceanic and Atmospheric Administration (NOAA) initiated the Hurricane Forecast Improvement Project (HFIP) to reduce both track and intensity forecast errors by 50% in the following ten years, with an emphasis on rapid intensity change. To this end, the High Resolution Hurricane (HRH) tests were proposed to quantify the impact of increased model resolution on hurricane intensity forecasts. To enhance the confidence in model performance, we have been implementing real-time forecasts, in collaboration with the Hurricane Research Division (HRD) at the Atlantic Oceanographic and Meteorological Laboratory (AOML) and the Physical Sciences Division (PSD) at the Earth System Research Laboratory (ESRL).

We have achieved several research goals during the period of July 2009 to June 2010:

(a) We have established the experimental Hurricane Weather Research and Forecast (HWRFx) system (Fig. 1) and performed real-time forecasts at 9/3 km resolution during the 2009 hurricane season. The results indicate that the performance of the HWRFx is generally comparable to those of the NOAA operational models.
(b) We have developed a new nesting algorithm and moving algorithm and implemented in HWRFx3.0 version.
(c) We have transferred the code of both new algorithms to EMC.
(d) The multiple nesting code and 3 nesting system with new code are under testing.

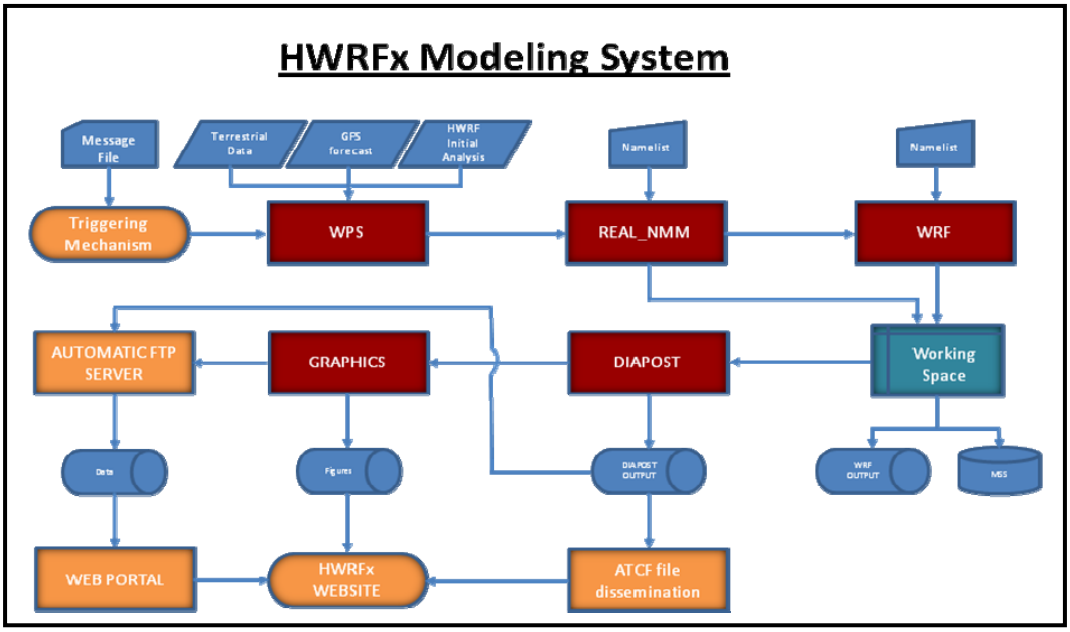


Figure 1: Schematic flowchart of the HWRFx modeling system. Red color indicates executable modules, blue color indicates input data and data storage disk, and orange color indicates controlling scripts. Working space is the high performance parallel file system on the NJET cluster. The ATCF file dissemination is through automatic email system on the cluster.

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

Ocean Observing System Simulation Experiments to Improve Ocean Model Initialization for the Hurricane Forecast Improvement Project

D. Willey (UM/CIMAS); G. Halliwell and R. Atlas (NOAA/AOML)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** To design optimal ocean observing system strategies to improve initialization of ocean models in coupled hurricane forecast models.

***Strategy*:** To develop the capability of performing Observing System Simulation Experiments (OSSEs) and Observing System Experiments (OSEs) at NOAA/AOML and use these systems for designing observing system enhancements, both operational and targeted, that will improve ocean model initialization and potentially more-accurate hurricane intensity forecasts.

CIMAS Research Theme:

***Theme 5*:** Air-Sea Interaction and Exchanges
***Theme 6*:** Integrated Ocean Observations

Link to NOAA Strategic Goals:

***Goal 2*:** Serve Society's Needs for Weather and Water Information

NOAA Funding Unit: USWRP/HFIP **NOAA Technical Contact:** Frank Marks

Research Summary:
For a coupled tropical cyclone (TC) prediction model to correctly forecast intensity evolution, it must accurately predict the magnitude and pattern of sea surface temperature (SST) cooling over the region directly forced by the storm, particularly beneath the storm's inner core. The ocean model component must therefore accurately predict the magnitude and pattern of temperature cooling within the ocean mixed layer (OML) under intense TC forcing. SST evolution is sensitive to the initial temperature-salinity and associated density profiles provided to the ocean model because between 70 and 90% of OML cooling typically results from the entrainment of colder water into the OML. Initial errors in the thickness of the surface warm layer can produce large errors in the predicted SST cooling rate. This places a high premium on accurate initialization of ocean model fields. Basin-scale and global data-assimilative ocean hindcasts produced by the Global Ocean Data Assimilative Experiment (GODAE) are an attractive choice for ocean model initialization because they provide balanced ocean fields to the nested regional ocean model. However, these products still contain significant errors and biases that will potentially degrade the ocean thermal response in coupled forecast models and reduce the accuracy of intensity forecasts.

This project consists of two components: (1) quantify the upper-ocean temperature (and density) errors in present-day ocean analysis products with respect to their impact on coupled hurricane forecasts, and (2) devise ocean observing strategies that will reduce the errors in data-assimilative ocean analyses and potentially improve forecast accuracy. We have made substantial progress on the first component as described below. Our strategy for the second component will be to use Observing System Experiments (OSEs) and Observing System Simulation Experiments (OSSEs) to evaluate existing ocean observations (OSE) and new ocean observations (OSSE). We are now in the late stages of developing our data assimilation and OSE/OSSE toolbox. In the meantime, we report on our evaluation of existing ocean model products.

Research Performance Measure: The evaluation of GODAE ocean products has been greatly facilitated by the emergency P3 observations over the eastern Gulf of Mexico taken in response to the Deepwater Horizon oil spill. Comparisons of upper ocean temperature between the P3 AXBT observations and three ocean models that did not assimilate the P3 observations demonstrate that significant errors still exist in these products (Figure 1). The biases and errors in the NOAA/NCEP/EMC RTOFS Atlantic Ocean analysis is substantially larger than for the other two models. To further investigate why this is so, sea surface height maps derived from satellite altimetry, the NRL/NAVO global HYCOM analysis (which has the smallest errors and biases in Figure 1), and the RTOFS analysis are presented in Figure 2 on the dates of four of the P3 missions. On 21 May and 9 July, significant differences in the structure of ocean features exist in the eastern Gulf between the RTOFS analysis and both the altimetry and HYCOM analyses. These errors in feature location probably contribute to the larger errors shown in Figure 1. We intend to add other models to this evaluation. After completion of this evaluation phase, we will focus our efforts on OSE and OSSE efforts to evaluate how observing system enhancements can further reduce these errors.

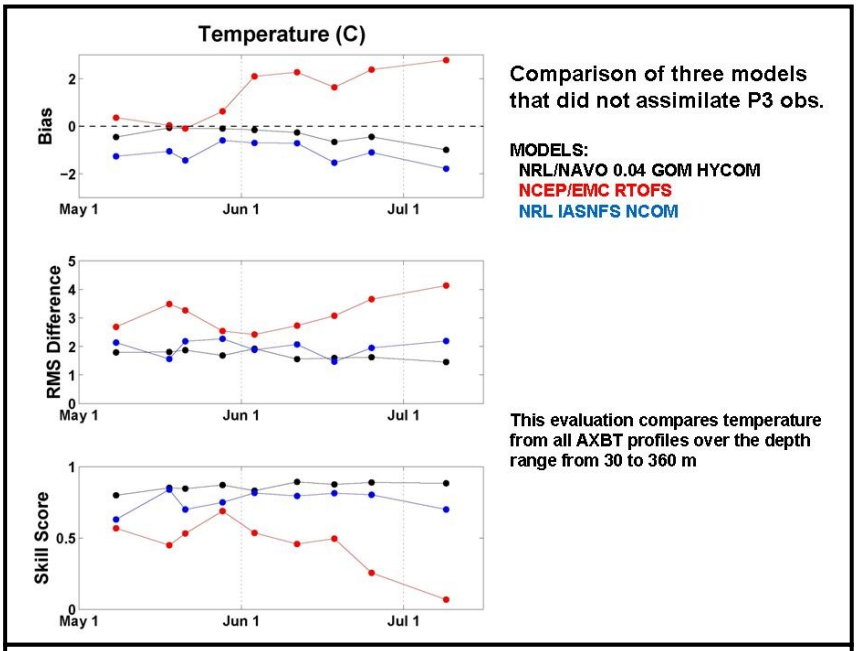


Figure 1: Comparison of three GODAE data-assimilative ocean model analyses against the P3 AXBT profiles. Shown are the mean bias, RMS difference, and skill score for subsurface temperature between 30 and 360 m between each model product and the P3 observations. The largest bias and RMS errors exist for the NOAA/NCEP/EMC RTOFS Atlantic Ocean analysis.

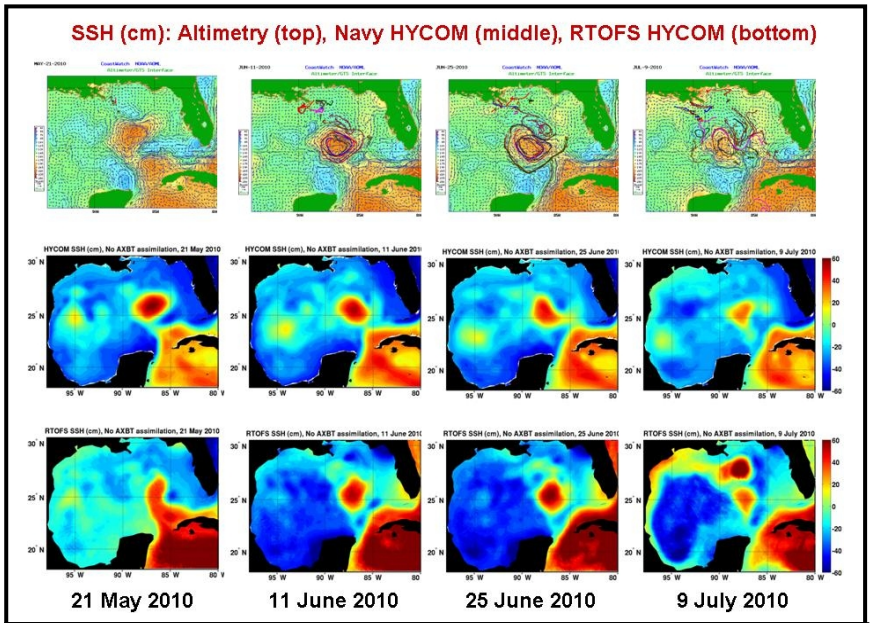


Figure 2: Comparison of SSH from satellite altimetry (from G. Goni, NOAA/AOML) (top panels), from the NRL/NAVO global HYCOM analysis (middle panels), and from the RTOFS analysis (bottom panels) on the dates of four of the P3 missions.

Joint Center for Hurricane Research

S.S. Chen (UM/RSMAS)

Long Term Research Objectives & Strategy to Achieve Them:

***Objectives*:** To work toward establishing a research center for hurricane research.

***Strategy*:** To improve the understanding of the physical processes that lead to extreme winds and heavy rain in hurricanes and to develop an integrated hurricane forecasting system that is based on state-of-the-art numerical models, observations, and data assimilation techniques.

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 (*Primary*)

***Goal 4*:** Support the Nation's Commerce with Information for Safe, Efficient, and Environmentally Sound Transportation (*Secondary*)

NOAA Funding Unit: NWS **NOAA Technical Contact:** Sam Cortono

Research Summary:

The overall objective of this project is to work toward establishing a research center for hurricane research. The goals are to improve the understanding of the physical processes that lead to extreme winds and heavy rain in hurricanes and to develop an integrated hurricane forecasting system that is based on state-of-the-art numerical models, observations, and data assimilation techniques. The benefits will include much improved warnings to the public of when and where damaging winds and heavy rain will occur, thereby enabling emergency planners to provide for the appropriate level of preparedness and minimizing the costs of unnecessary preparation and evacuations.

During the first year initial start-up period of Sept 09-June 10, the principal investigator and collaborating researchers at UM/RSMAS have focused on development of the basic modeling system and diagnostic tools. There are three main areas of research activities:

1) ***Development of the fully coupled atmosphere-wave-ocean models for hurricane research and forecasting.*** We have developed coupled code for the Weather Research and Forecasting (WRF) model The Center will play a leading role in developing and testing these physical parameterizations and applications in high-resolution, fully coupled models for hurricane research and prediction. Professors Chen, Srinivasan, and Iskandarani have been working on the development of coupled WRF with HYCOM. We are in the process of testing the coupled model in the Gulf of Mexico and the West Pacific. These initial tests are expected to be completed in the summer 2011.

2) ***Data assimilation using NOAA AOML/HRD airborne Doppler radar data.*** To improve the hurricane intensity forecasts, Prof. Chen and a graduate student at RSMAS/UM, Ronald Gordon, are working on improving the model initial condition by assimilating the 3D wind data derived from the airborne Doppler radar data using the four-dimensional variational (4DVar) data assimilation technique. Using the data provided by Dr. J. Gamache of NOAA/AOML/HRD, we have conducted a number of experiments for Hurricane Ike (2008). Preliminary results show that the WRF 4DVar data assimilation is able to improve the initial vortex in Hurricane Ike. We are in the process of

conducting model forecasts using multi-nested grids with 12, 4, and 1.3 km resolution to examine the impact of the 4DVar data assimilation on 3-5 day forecasts.

3) ***Initialization of ocean component model in the coupled modeling system***. A major challenge of the modeling effort is the initialization of coupled models with accurate storm and environmental conditions in both the ocean and atmosphere. The lack of in situ ocean observations make it difficult to initialize the ocean model, especially in hurricane conditions when both satellite IR and Microwave derived SST are not accurate in cloudy and heavy rain conditions. Dr. Brandon Kerns, a post-doctoral investigator, has developed a new methodology of initializing the upper ocean model using a technique of merging the satellite SST with global analysis products as well as the operational ocean model output to initialize the high-resolution coupled model.

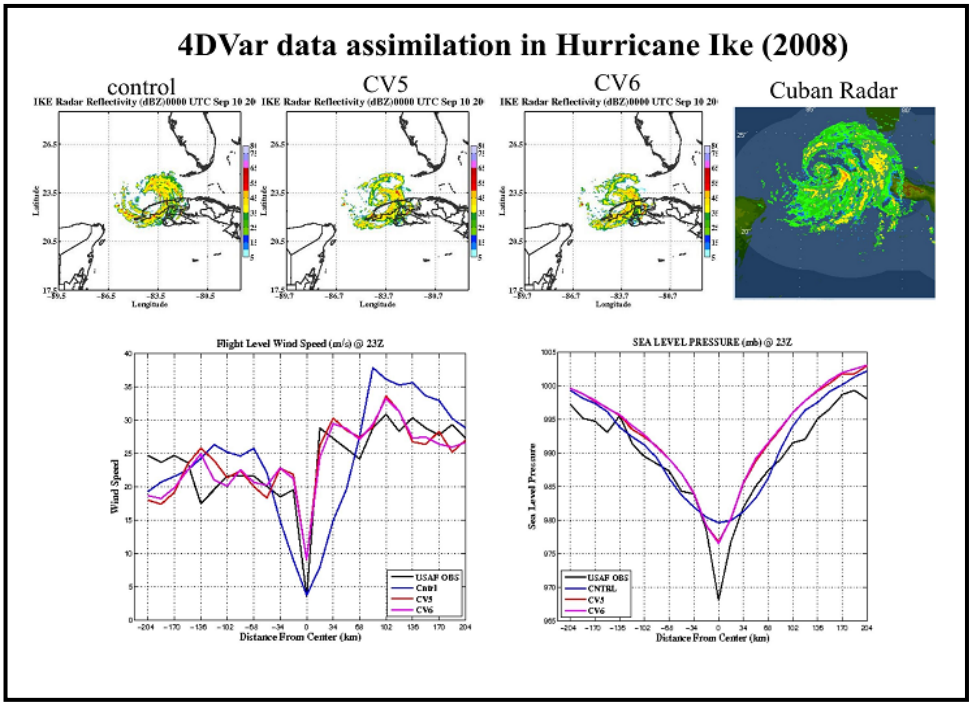


Figure 1: (Upper panels) Impact of 4DVar data assimilation using various background error covariance and airborne Doppler winds in Hurricane Ike at 0000 UTC 10 September 2009: model forecasts and observed radar reflectivity from the Cuban radar. (Lower panels) Model forecasted (color) and observed (black) hurricane eye and eyewall in Ike.

Research Performance Measure: 1) Drs. Kerns and Chen have presented the work on ocean model initialization with merging satellite data at the AGU Ocean Science Meeting in February 2010 in Portland, Oregon, and 2) Gordon and Chen reported the results on "4DVar Data Assimilation of Airborne Doppler Radar Winds in Hurricane Ike (2008)" at the 10th WRF User Workshop in June 2010, Boulder, CO.

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 assessment of risk to insured residential and commercial properties 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: N/A

Funding provided by the State of Florida through the International Hurricane Center at FIU

NOAA Technical Contact: Mark Powell

Research Summary:

As a team member of scientists, we served as members of a group that helped develop the new Florida Public Hurricane Loss Model (FPHLM). It is an open, transparent computer model used by the State Office of Insurance Regulation to provide a baseline for evaluating rate change requests for windstorm insurance. The FPHLM is the first model that enables all of the results and details from the modeling approach to be open to scrutiny. To date, all other models used for rate making in Florida have been proprietary.

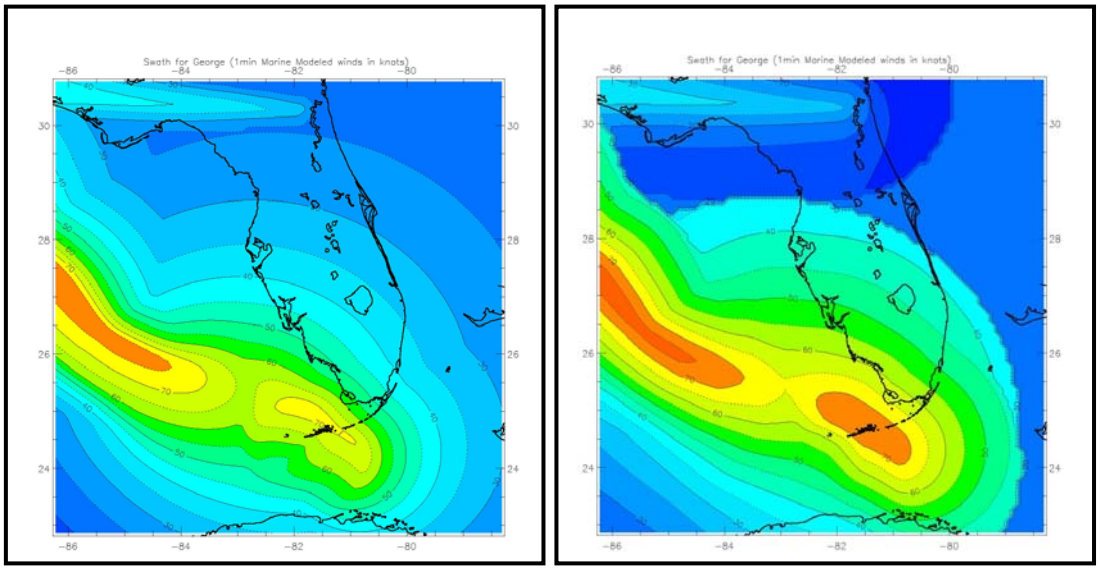
FPHLM comprises atmospheric science, engineering, and actuarial components. The atmospheric component includes modeling the track and intensity life cycle of each simulated hurricane within the Florida threat area. When a model storm approaches within a damage threshold distance of a Florida zip code 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 maximum open terrain surface wind is then recorded 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 passed to an engineering model that estimates the damage to residential structures within the zip code, followed by an actuarial model that estimates the insured loss. The average annual loss is then estimated statewide for every zip code in Florida.

The Florida Public Hurricane Loss Model provides estimates of future insured losses that can be used by insurance companies as input in determining homeowner's windstorm rates. Insurance rates in Florida have been rapidly rising in recent years because of eight hurricanes striking the State in a 14-

month period of 2004-2005. The FPHLM can also provide immediate estimates of losses from specific hurricane events like Dennis, Katrina, Wilma, and Charley.

The activities of the past year have focused on updating the residential model to make use of the latest climatic data and to provide wind risk information at 1 km resolution. Also our focus was to meet the standards of the 2009 Report of Activities of the Commission on Hurricane Loss Projection Methodology. The Florida Commission on Hurricane Loss Projection Methodology employs a professional team of experts to review hurricane loss models according to a book of standards. The FPHLM passed the "pro team" review in June and received a unanimous acceptance vote from the Commission on Monday, June 2, 2009. The model is certified and is available for insurance rate making purposes in Florida.

Also, a first version of a commercial model was developed and a linear wind field model was evaluated for the atmospheric science component. We compared 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 life cycle. We also compared 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. The validation suite included the following storms: Charley, Frances, Jeanne, Ivan, Dennis, Katrina, Rita, and Wilma. The validation makes use of the Hurricane Research Division's Surface Wind Analysis System (H*Wind).



The two figures (above) show two swaths for hurricane George (1998). The one on the left is a product of the residential model; the one on the right is a product of the commercial model.

Research Performance Measure: All objectives were met on schedule.

Windfield Reconstruction of Hurricane Ike and Gustav for Storm Surge and Wave Hindcasting

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

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** To improve our understanding of the wind distribution in tropical cyclones.

***Strategy*:** 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

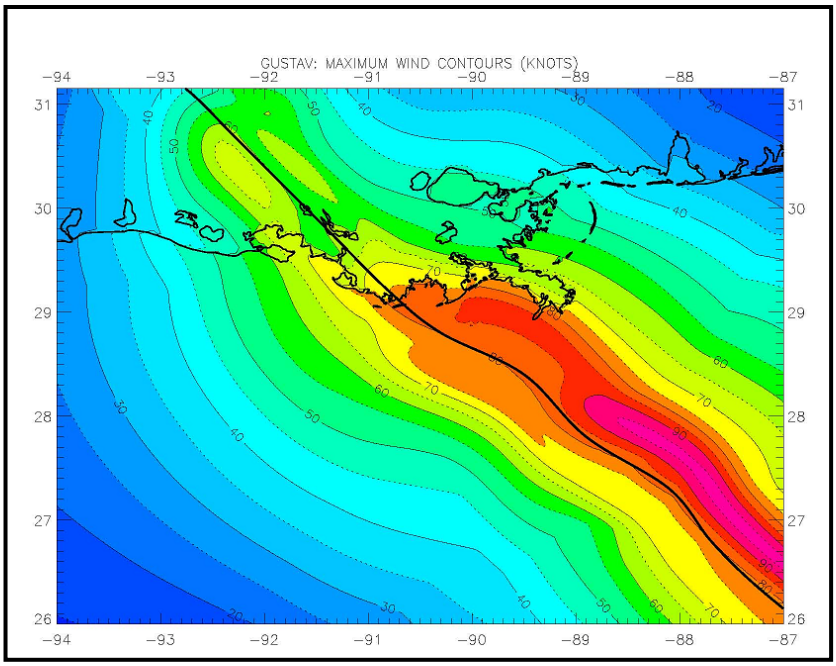
Research Summary:

In order to understand the performance of flood control systems during Hurricane Gustav and Ike it was essential to model the forces associated with winds, waves, and storm surge. Since the surface wind stress provides the forcing for the waves and surge, accurate wind field information is necessary to model realistic storm surge and waves. We collaborated with other universities to reconstruct the wind fields of Hurricane Gustav and Ike.

Observations from a large number of air-, land-, sea-, and space-based measurement platforms were obtained, standar- dized, evaluated and analyzed in order to provide a mesoscale analysis of record to serve as the best available depiction of Gustav's and Ike's wind field for use in wave and surge modeling. Wind field analysis was first conducted in real-time as part of NOAA's research to understand and predict hurricane impacts. A limitation of the real-time analyses is that they were based on data collected 4–6 h before the analysis time. Months later, the analyses were improved with additional data that were not available in real-time. The post-storm analyses are more accurate due to the availability of more observations with more detailed standardization processing and quality control. The post-storm analyses are more representative of storm conditions since they use all observations within 3 h of the analysis time. The post-storm analyses are the basis for winds used by the storm surge and wave model components of this study.

We aquired mesonet data from landfall teams; Texas Tech University and Florida Coastal Monitoring Program. After doing a quality control of mesonet data in combination with data from SFMR, buoys, ships, C-MAN stations, GPS sondes, METAR stations, ASOS stations, MADIS stations, airborne Doppler radar, GOES cloud drift winds, QuikScat, and A-Scat, we conducted a post-storm wind analyses at 3 h intervals for the period of time corresponding to the entry of each storm into the gulf of Mexico;

1. Gustav for the time period 0000 UTC 31 August - 0300 UTC 2 Sept. 2008.
2. Ike for the time period 1800 UTC 9 Sept. - 1800 UTC 13 Sept. 2008.



The figure (above) shows wind swath for hurricane Gustav.

Research Performance Measure: All objectives were met on schedule.

Validation and Improvement of Planetary Boundary Layer Parameterizations Used in High-Resolution Hurricane Simulations for Forecasting and Research

D.S. Nolan (UM/RSMAS); J.A. Zhang and M.D. Powell (NOAA/AOML)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** To evaluate and improve the parameterizations of atmospheric boundary layer processes as represented in numerical simulations of hurricanes used for forecasting and research.

***Strategy*:** To directly compare in-situ measurements of wind, temperature, and humidity near the surface in observed hurricanes to the same variables as generated by computer simulations of the same hurricanes, at approximately the same times and locations as the original observations.

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 (*Primary*)

***Goal 4*:** Support the Nation's Commerce with Information for Safe, Efficient, and Environmentally Sound Transportation (*Secondary*)

NOAA Funding Unit: OAR/AOML **NOAA Technical Contact:** Frank Marks

Research Summary:
The first year of support for this project led to the completion of a substantial study of the representation (that is, the reproduction) of the atmospheric boundary layer in a numerical (computer) simulation of a mature hurricane over the open ocean. This study was achieved through the careful comparison of the three-dimensional wind, temperature, and moisture fields in the boundary layer of a simulation of Hurricane Isabel (2003) to the same fields directly observed by NOAA research aircraft and instruments in the same storm.

We examined the results of simulations using two widely used, yet conceptually distinct methods for representing vertical mixing processes in the boundary layer, the so-called Yonsei University (YSU) scheme and the Mellor-Yamada-Janjic (MYJ) scheme. Given the extreme conditions of the hurricane boundary layer, both schemes were found to perform surprisingly well, generating vertical profiles of wind, temperature, and humidity that compared quite well to observations. Both schemes were substantially improved when the formula for the wind-speed-dependent surface roughness of the ocean was modified to be more consistent with other recent studies. Overall, the YSU scheme was shown to provide a consistently more realistic inner-core structure for the wind field. The MYJ scheme was found to be overly diffusive (i.e., generating too much friction with the surface), leading to an exaggeration of the frictionally induced flow into the center of the storm and unrealistically large values of the wind speed at 1 km height above the surface.

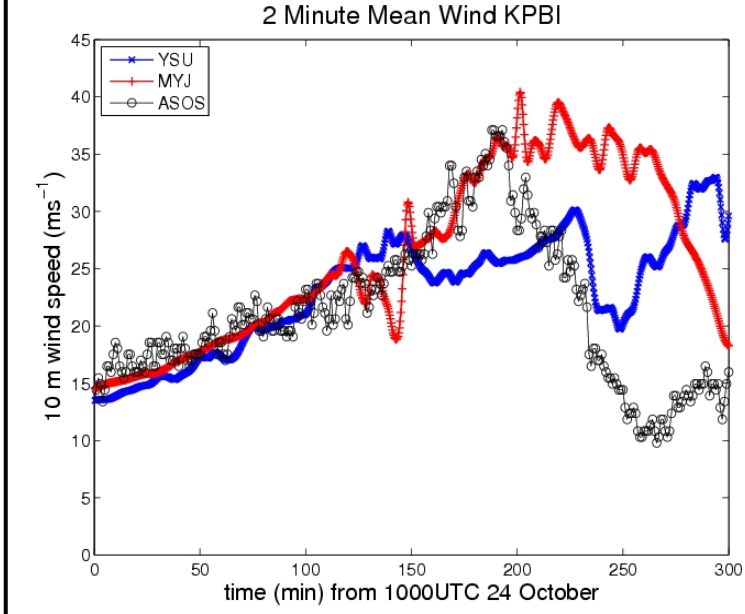


Figure 1: Time series of surface wind speeds observed at Palm Beach International Airport (KPBI) during the passage of Hurricane Wilma (2005) (black circles), and simulated time series of wind speeds at KPBI from WRF simulations of the same event. The red and blue curves show the surface wind speeds as simulated

In the second year of this project, this work has been continued with the same strategy, but for a hurricane at landfall. Hurricane Wilma (2005) has been chosen for this purpose since, as for Isabel, simulations with the WRF model reproduce the track and intensity of Wilma quite well, and there is an abundance of surface observations and radar data than can be used for evaluation of the simulations. A large number of simulations of the landfall of Hurricane Wilma have been performed, and a variety of surface data sets have been obtained. Preliminary comparisons between the data sets and the simulations have been performed.

Research Performance Measure: The first objective of this project is to complete a comprehensive study and comparison to in-situ observations of the boundary layer of Hurricane Isabel (2003) as it is represented in numerical simulations using the research version of the Weather

Research and Forecasting Model (WRF). This objective has been entirely achieved, resulting in the production, submission, and publication of two papers in *Monthly Weather Review*. The second objective is a study and comparison to observations of the boundary layer in a landfalling hurricane. Hurricane Wilma (2005) has been selected for this purpose. Substantial progress has been made on the second objective. Preliminary results were presented at the 29th AMS Conference on Hurricanes and Tropical Meteorology in May of 2010.

Real-Time Hurricane Wind Analysis

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

Long Term Research Objectives and Strategy to Achieve Them:
***Objectives*:** To improve our understanding of the wind distribution in tropical cyclones.
***Strategy*:** 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 adjusting 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, ASCAT, WINDSAT satellites and the AMSU satellite product, METAR, C_MAN, Buoys, Ships, mobile Towers, MESONET data from FSL MADIS Group and WeatherFlow. Currently based on research performed, the packages developed to bring data into the H*Wind database are being ported to Python, a platform independent language similar to Java. The effort will lead to a wider use with in other systems and tools and further promotes the software paradigm of code reuse endorsed by the H*Wind project.

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 basic product of this analysis is a colored and annotated wind contour plot. In the last year, we expanded to generate vorticity, divergence and google products. Each analysis is now published with a self-explanatory metadata file compliant with FGDC (Federal Geographic Data Committee).

Increasing research was concentrated on fine tuning the framework that rates the destructive wind and surge potential of tropical cyclones based on integrated kinetic energy (IKE). By taking into account the size of the wind field and magnitude of the winds, it offers a more relevant metric of the physical forces that contribute to damage, as opposed to relying on the guidance by a single value representing the maximum surface wind speed. A new web page, https://storm.aoml.noaa.gov/ss/ike, reflects these efforts, with a) a calculator tool that lets the interested community roughly estimate IKE and surge destructive potential by providing the radii of 34, 50, 64kt winds at each quadrant, and b) a forecast time series tool combining IKE calculated from official forecasts' radii and from H*Wind analysis gridded fields (Fig. 1). For the last 3 years, IKE has been computed for each gridded H*Wind surface wind analysis.

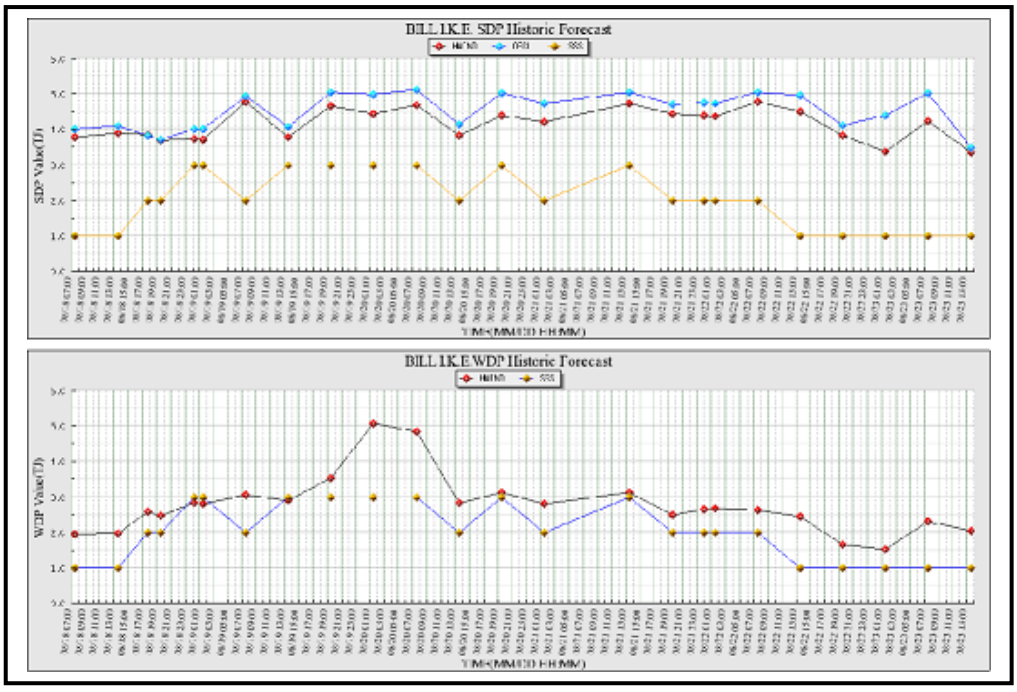


Figure 1: Time series of Integrated Kinetic Energy (IKE) Wind Destructive Potential (WDP) and Surge Destructive Potential (SDP) for Hurricane Bill 2009.

A new initiative for the H*Wind system is for its infrastructure to become fully duplicated at the Center for Ocean Atmospheric Prediction Studies (COAPS), Florida State University, in Tallahassee. Initial assessment and action plan were drafted. The goal is to provide redundancy of operations if AOML were to shut down due to a storm evacuation or due to a hardware failure, while supporting teaching and research activities at FSU.

Figure 1: Pilot Carl Newman, aboard a NOAA P3 aircraft, making some in-flight navigational adjustments**.**

Finally, the team also closely collaborates with a CIMAS project, led by Dr. Mei-Ling Shyu, "Data Integration and Data Mining Support for Tropical Cyclone Integrated Observing Systems".

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

A Fourteen-Year Tropical Cyclone Global Positioning System Dropwindsonde Dataset

K. Sellwood (UM/CIMAS); S. Aberson (NOAA/AOML)

Long Term Research Objectives and Strategy to Achieve Theme:

***Objectives*:** To gather, organize, quality control, and make available to the broader community all GPS dropwindsonde data in and around tropical cyclones, and to provide support for other scientists who wish to use the data for research.

***Strategy*:** Systematically organize data from past years and incorporate new data as it arrives.

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:** Sim Aberson

Research Summary:

Since 1996, NOAA, the United States Air Force, and other international agencies have been releasing drop-windsondes in and around tropical cyclones to obtain wind velocity, temperature, humidity, and mass observations from flight level to the ocean surface. These observations are used operationally

by meteorological centers to diagnose current conditions and to improve initial conditions of numerical weather prediction models. After the fact, these data are invaluable to researchers in studies of tropical cyclone dynamics and thermodynamics, and in studies of targeted observations and predictability, as well as in climate research.

Hundreds of these profiles are obtained annually in the Atlantic and northern Pacific Oceans, and may soon become available in the Indian Ocean. In this project, we gather, organize, and quality control, all GPS drop-windsonde data in and around tropical cyclones. We subsequently make these data available to the broader community and we provide support for other scientists who wish to use the data for research. These data are organized and made freely available on an ftp site. Additionally we are in the process of developing computer programs to extract the environmental data that is transmitted, in real time, from the various aircraft. The programs will produce estimates of the missing fields and format the information in a manner that provides a quick look at the data and can be easily ingested into numerical models. The codes will be made available to the public in an effort to meet the growing needs of the scientific community that is focused on computer modeling of tropical cyclones and the assimilation of observational data.

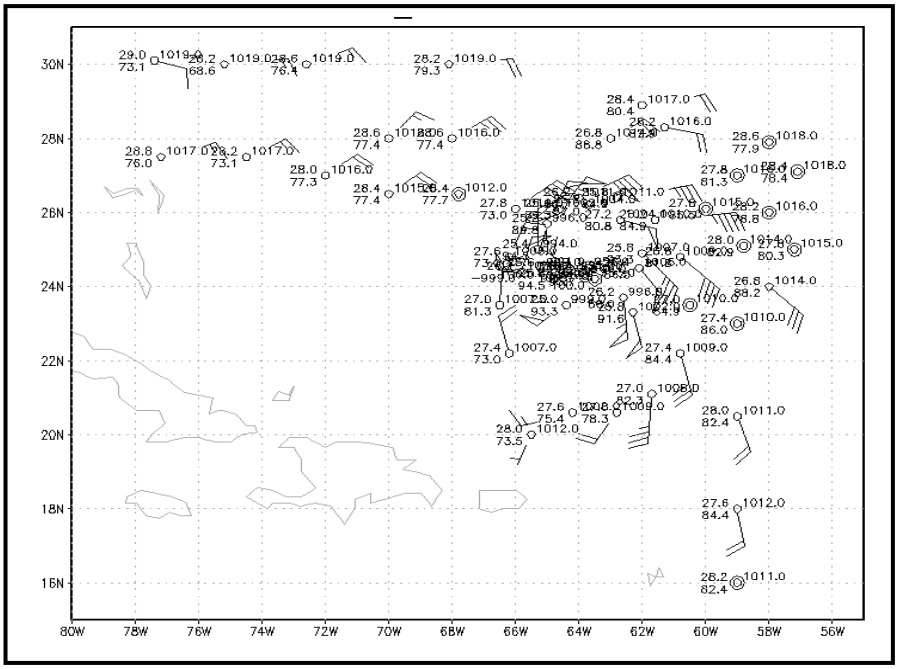


Figure 2: Dropwindsonde wind temp-erature and humidity data from NOAA P3 and GIV flights into hurricane Bill, at 12Z August 19, 2009 plotted in "station" format.

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

Studies in Support of NOAA's Operational Oceanic Heat Content Analysis at NESDIS

L.K. Shay and J.K. Brewster (UM/RSMAS), E. Maturi and J. Sapper (NOAA/NESDIS/STAR)

Long Term Research Objectives and Strategy to Achieve Theme:

***Objectives*:** To provide a high resolution OHC product (0.25°) from altimeter derived fields for the North Atlantic Ocean Basin to NOAA NESDIS for 24/7 operations. A key aspect of this product is that the isotherm depths (20 and 26°C), and OHC will be carefully evaluated from *in-situ* data from floats, drifters, expendable bathythermographs (XBT), long-term PIRATA moorings and airborne XBTs (AXBTs).

***Strategy*:** Systematically organize data from past years and incorporate new data as it arrives. To build a realistic regional climatology in the Atlantic Ocean Basin for a two-layer model and evaluate a daily OHC product based on satellite altimetry-derived sea surface height anomalies (SSHA) with observations from various in situ platforms. This product will be transitioned to NOAA NESDIS for 24/7 operations.

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: NESDIS **NOAA Technical Contact:** Eileen Maturi

Research Summary:

Over the first few months of the grant (since 1 April), we have built a daily Systematically Merged Atlantic Regional Temperature and Salinity (SMARTS) climatology from the US Navy Generalized Digital Environmental Model (GDEM 3.0) and the latest World Ocean Atlas (WOA) for the two-layer model using a 15-day running mean to insure continuity between the months for mean isotherm depths and reduced gravities. Temperature profiles were acquired from various platforms including ARGO floats, XBT transects (see Figure 1), PIRATA moorings and AXBTs for a twelve-year period. Altimeter-derived SSHA were blended and objectively analyzed from various satellites using the Mariano and Brown (1992) approach to estimate space based values of isotherm depths and OHC values. Based on these measurements, we have found high correlations and low RMS differences between observed and space-based estimates of the product fields that use the SMARTS climatology for the North Atlantic Ocean basin.

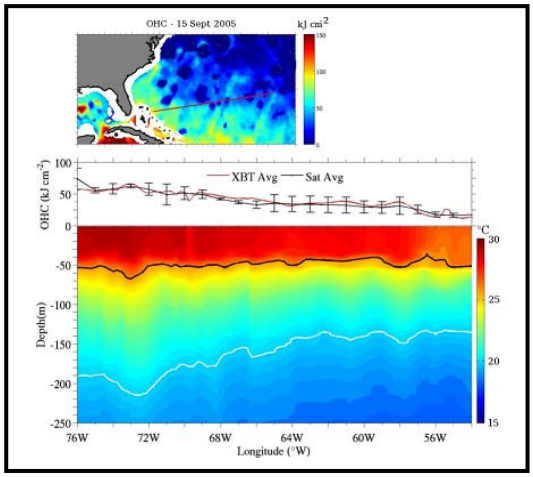


Figure 1: NOAA XBT transect (inset) in the North Atlantic Ocean superposed on OHC (kJ cm^{-2}: color) on 15 Sept 2005. Lower figure shows the corresponding OHC from coincident satellite altimetry-derived data (black line) and the XBT temperature profiler data (red line) averaged from 2004 to 2006 (upper panel) with the appropriate error bars for the OHC. The corresponding averaged temperature profiles (°C: color) are shown in the lower panel where the solid black (white) lines represent the depths of the 26 and 20°C isotherms, respectively.

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

Evaluation of Hurricane Surface Wind Measurements by Air Force Reserve Command WC-130J Stepped Frequency Microwave Radiometers

B. Klotz (UM/CIMAS); E. Uhlhorn (NOAA/AOML)
J. Carswell (Remote Sensing Solutions, Inc.)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** To evaluate and monitor SFMR sea-surface wind retrieval accuracy from Air Force Reserve Command WC-130J hurricane reconnaissance aircraft and provide a quality-controlled wind product to the research community.

***Strategy*:** Examine SFMR surface wind data for all 2008 operational hurricane reconnaissance flights in order to identify potential anomalies. Based on these findings, a set of quality-control procedures were developed to provide an improved product which can in the future be implemented in real-time. In addition, SFMR data from future seasons will continue to be monitored through use of the quality control process.

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:** Eric Uhlhorn

Research Summary:

Hurricane forecasters rely on accurate surface wind speed data to provide estimates of storm intensity. In preparation for the 2008 hurricane season, SFMRs were installed on the entire fleet of Air Force Reserve Command (AFRC) WC-130J hurricane reconnaissance aircraft. With the large increase in SFMR-equipped hurricane-penetrating aircraft came a surge in real-time surface wind data available to forecasters. Due to installation configuration and real-time data processing algorithm differences, an extensive data validation effort was required to ensure consistency among all aircraft and instruments. As 2008 was the first season of real-time operations, anomalous behavior was expected, and indeed was identified on a number of occasions.

As a number of QC procedures have been implemented for the NOAA WP-3D SFMRs, a goal of this project was to identify specific reasons for questionable surface wind retrievals being transmitted from the WC-130J aircraft due to little real-time QC procedures. Mentioned in the 2009 Annual Report, several of the issues included contamination from land-based microwave emission and interference from non-natural radar sources. Even instrument failure occurred on occasion with these instruments.

To correct these anomalies with the exception of instrument failure, a number of QC checks were applied to the raw microwave data prior to computing winds. Measurements over land are identified by a land mask. Radio frequency interference (RFI) that contaminates one or more SFMR channels, for example from a ground-based radar, is eliminated using a statistical filtering technique.

During the 2009 hurricane season, the fleet of AFRC WC-130J aircraft were routinely monitored for questionable data with some of the solutions listed being used during post-processing. Several flights still showed questionable data, but these were often in the presence of heavy precipitation. An

example of this occurred during Tropical Storm Claudette wherein an AFRC WC-130J SFMR sampled a wind speed of nearly 60 knots while the wind speed reported from a nearby buoy was 35 knots. This example is shown in Figure 1. Further research was and continues to be conducted on this issue, which is not limited to the AFRC SFMR. A separate report covers the details of this problem and its research.

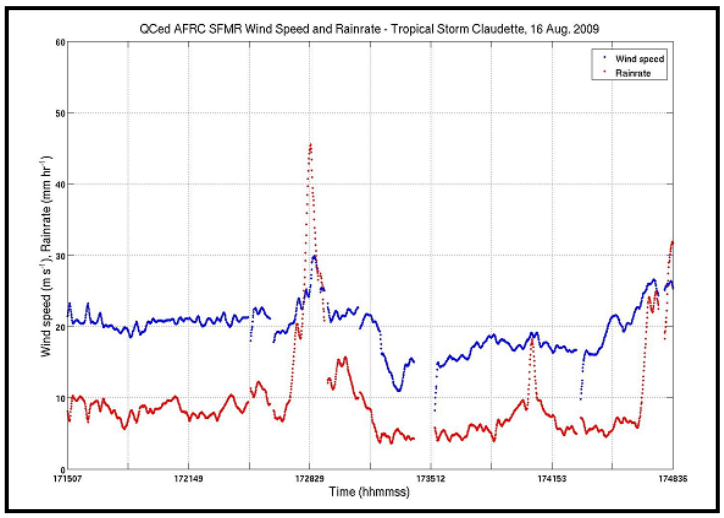


Figure 1: Quality Controlled USAF SFMR wind speed (blue) and rain rate (red) are shown for a flight segment into Tropical Storm Claudette during the 2009 hurricane season. A sharp increase in rain rate seen near the center of the image contributes to a similar increase in the wind speed. A buoy wind speed measurement nearby reported winds of about 12 m s^{-1} less than the SFMR.

Research Performace Measure: All major research objectives have been met. This research is mentioned in this annual report mainly because the investigators continued to monitor the AFRC SFMR observations through much of the 2009 hurricane season.

Stepped Frequency Microwave Radiometer Algorithm Improvements Addressing Rain Contamination of Surface Wind Speed Measurements in Tropical Cyclones

B. Klotz (UM/CIMAS); E. Uhlhorn (NOAA/AOML)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** To determine necessary changes to the current SFMR algorithm that will correct the overestimation of sea-surface wind speeds in the presence of moderate to heavy rain and provide more reliable data to tropical cyclone forecasters.

***Strategy*:** To use various surface wind speed and rain data from the NOAA WP-3D aircraft in order to develop improved absorption versus rain and wind speed versus emissivity models. Using the new models, statistical comparisons will be used to show the algorithm improvement in the heavy rain conditions.

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:** Eric Uhlhorn

Research Summary:

Reliable surface wind speed data must be readily available in order for hurricane forecasters to produce the best tropical cyclone intensity forecasts. Since the late 1990's, a joint effort between CIMAS and NOAA/HRD scientists has produced improved methods of attaining wind speed estimates by using the NOAA Stepped Frequency Microwave Radiometer (SFMR). These improvements allowed the SFMR to become an integral operational tool for researchers and forecasters alike.

Over the past few years, the SFMR's use expanded from strictly NOAA research and observation into Air Force Reserve Command (AFRC) operational reconnaissance flights with the WC-130J aircraft. By outfitting these aircraft with an SFMR, the amount of useable sea-surface wind speed data grew quickly and allowed for improved tropical cyclone coverage.

A current issue affecting wind speed estimates is observed with both the AFRC and NOAA SFMR data. During weak wind (i.e. tropical depression to tropical storm force) and moderate to heavy rainfall conditions, SFMR wind speeds were overestimated anywhere between 10 to 25 knots. This drastic difference represents a condition where reliable wind speed data within the tropical cyclone are needed but are likely unavailable. Several approaches to correct the algorithm for such conditions are used and include:

- Develop an empirically derived absorption versus rain (κ-R) model using rain data from a Precipitation Imaging Probe (PIP), shown in Figure 1.
- Pair SFMR emissivities and GPS dropwindsonde surface-adjusted wind speeds to empirically derive a new wind versus emissivity model
- Statistically compare the combination of the new models with those of the current algorithm and determine if the wind speeds are reduced in heavy rain

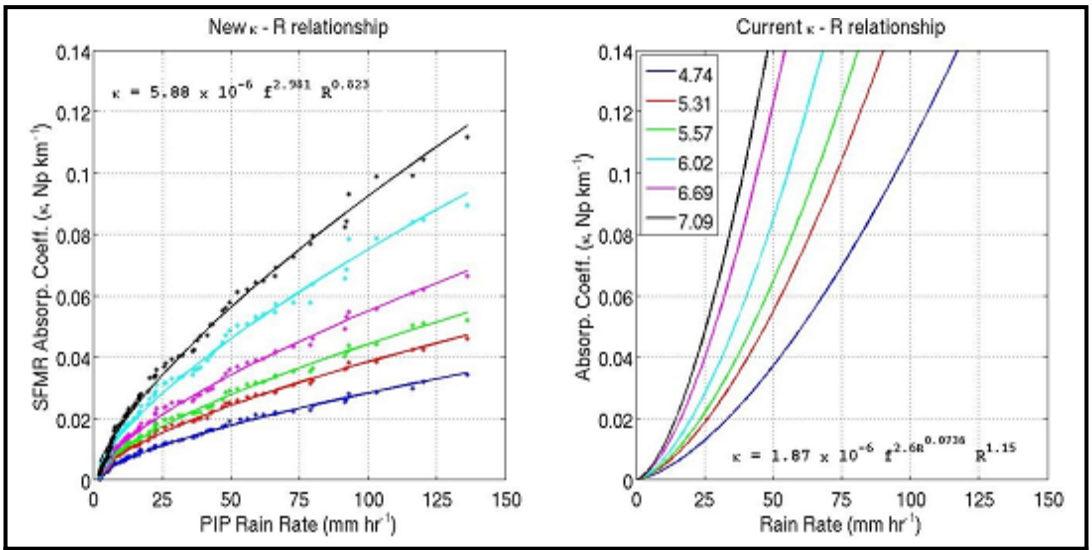


Figure 1: Absorption coefficient (κ) versus rain rate (R) for the preliminary derived relationship (left) and the current relationship (right). The κ-R relationship is plotted for each frequency (f) and the representative model equation is given for the current and the new preliminary models.

The first set of preliminary results show that in some cases, the wind speed overestimation was reduced to reasonable values on the order of 10 knots. However, there were also situations that produced very unrealistic reductions in the wind speeds. An example of these wind speed reductions is provided in Figure 2. The new κ-R model shown in Figure 1, which is used to produce the results in Figure 2, appears to have moved too far in the opposite direction wherein wind speeds are reduced too much in the presence of heavy precipitation. Rainrate data from the PIP were used in this example, but incorporating the Tail Doppler radar from the NOAA aircraft could provide a more accurate estimate of the rain rate. This would also provide a more accurate independent measurement to use in the κ-R model. Despite the wide range of wind speed reductions produced, the methods used show that the new, preliminary model is capable of producing reduced wind speeds but is not always consistent.

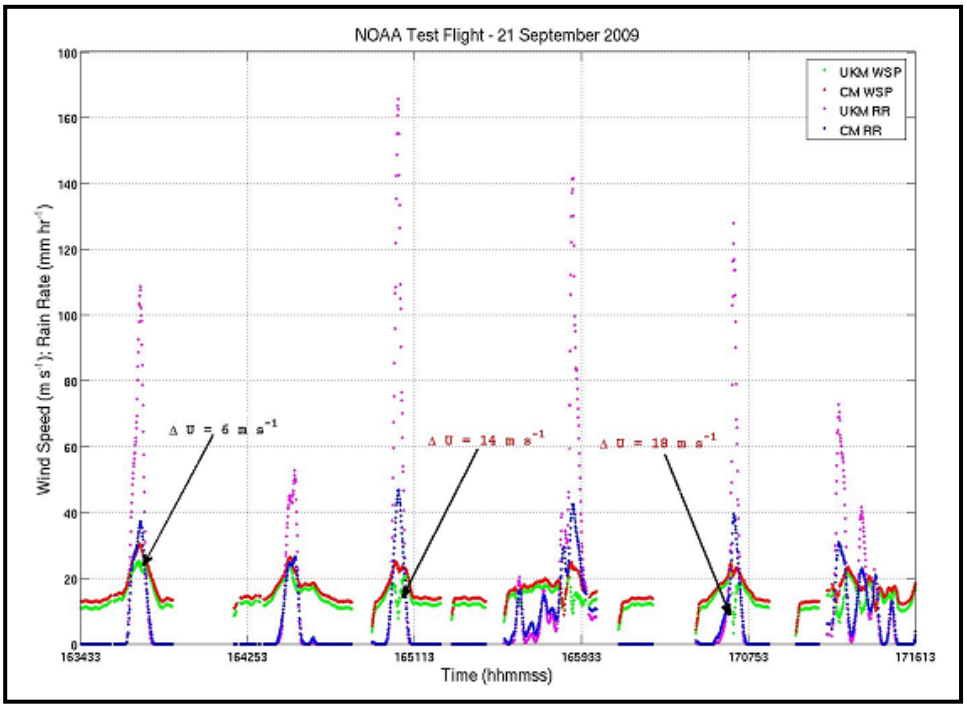


Figure 2: Wind speeds and rain rates determined by the current model (CM) and the new model (UKM) conditions. This time series is taken from a 21 September 2009 NOAA test flight and provides examples of realistic wind speed reductions (i.e. first rain spike) and unrealistic reductions (i.e. third and fifth rain spike). The current model (CM) wind speeds and rain rates are shown with red and blue asterisks, respectively, while the new (UKM) wind speeds andrain rates are shown with green and magenta asterisks, respectively.

Research Performance Measure: All major research objectives are currently being met and remain on schedule.

Microphysics of Deep Convection

P. Willis (UM/CIMAS); F. Marks (NOAA/AOML); A. Heymsfield (NCAR)

Long Term Research Objectives & Strategy to Achieve Them:

***Objectives*:** To improve the understanding and prediction of tropical cyclone genesis, intensity change, rainfall, water content, as well as the microphysical schemes in tropical cyclone simulations.

***Strategy*:** Evaluate and compare microphysical fields from in situ data and from NOAA-WP3D's and NASA DC-8 aircraft and high resolution numerical 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:** Frank Marks

Research Summary:

Work has centered on the study of the microphysics of a deep convective cloud system over the tropical Atlantic. A cloud particle image data set, and derived water and ice contents and concentrations, has been reduced, sorted, and analyzed in relation to the vertical shear of the horizontal wind and high resolution measurements of updraft/downdraft velocities in this cloud system. Fresh young updrafts are found to occur preferentially on the up-shear side of the cloud, and older mixed parcels in the down-shear portions of the cloud. Figure 1 shows a vertical radar slice through the cloud system. A seminar on this work was presented at AOML on 16 May 2010. A draft manuscript has been prepared on this work. Some preliminary pertinent results are summarized below:

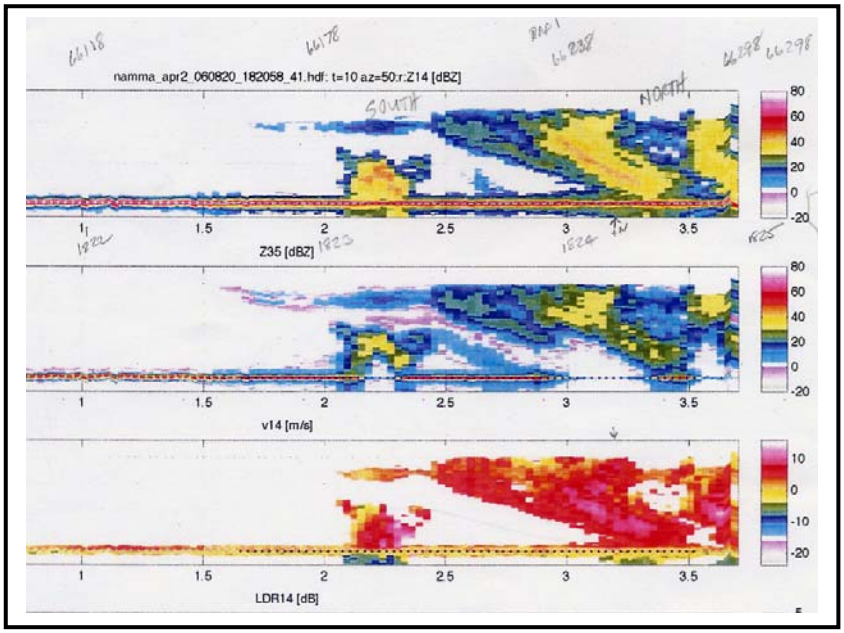


Figure 1: Vertical radar slice through the cloud system-upshear to right.

Copious ice concentrations are found in a cloud transect at the -2 deg C level in the cloud system. These are illustrated in Figure 2 showing the vertical velocity measurements and a sampling of image data on the cloud pass.

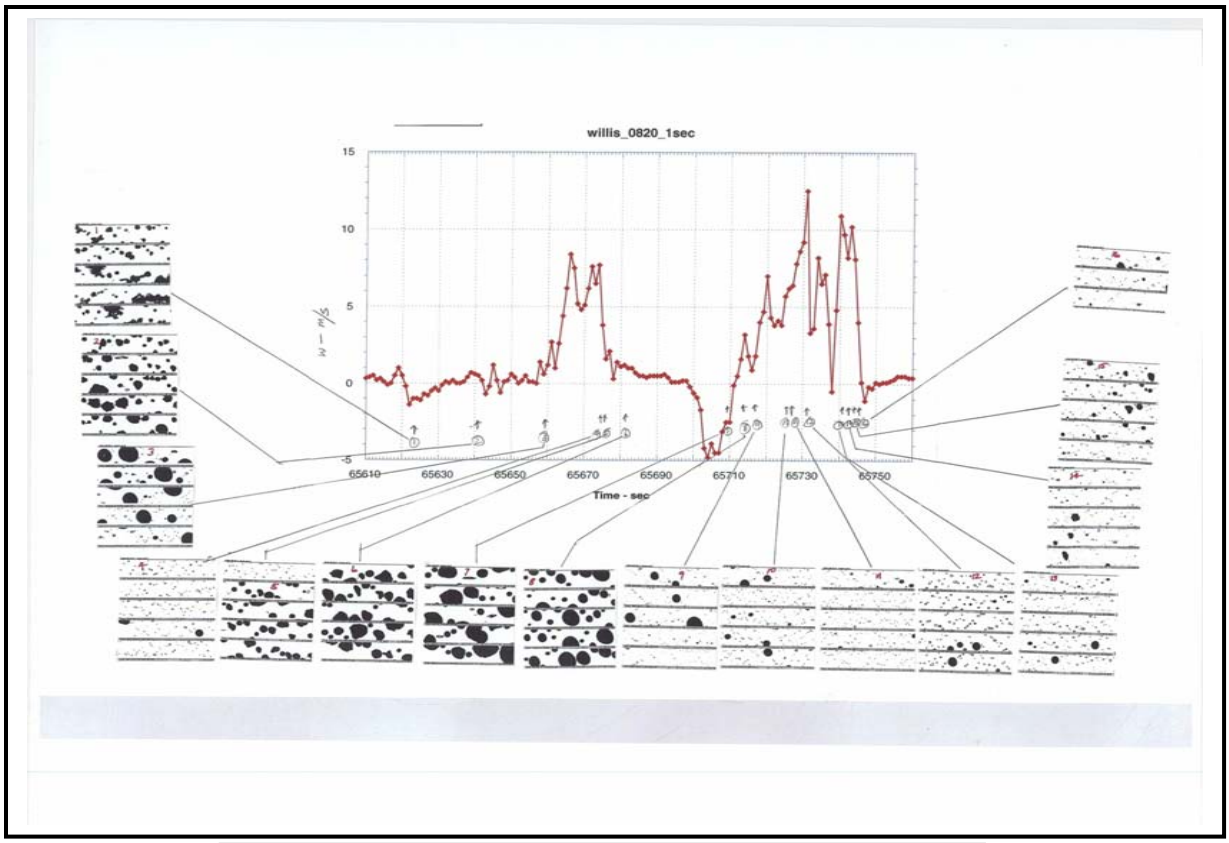


Figure 2: Vertical velocity and sample images for transect at -2C.

- The ice evolution in this deep convection cloud system is not well described by current ice parameterizations used in numerical models of hurricanes and tropical deep convective clouds. The ice nucleation schemes developed for use in numerical models are largely based on measurements in mid-latitude, often non convective clouds, and do not fit observed conditions in tropical oceanic convective clouds.
- Strong evidence is found that the initial ice formation in this cloud system is by freezing of drops which often fragment upon freezing.
- Direct evidence is found that a Hallett-Mossop type ice multiplication is very operative in this cloud system – very high concentrations of columnar ice crystals at, or near the -10C level. This is illustrated in Figure 3, showing the distributions and a sample of image data.
- Some fraction of the liquid does occasionally transport through the ice multiplication zone (0 to -10C) in the new fresh active up-shear updrafts.

Work has started on an investigation of the role of active deep convection on the formation of vortices, and the intensification or vortices. To this end, the plan is to participate in the PREDICT(NSF), GRIP(NASA), IFEX(NOAA) tri agency field program in the summer of 2010.

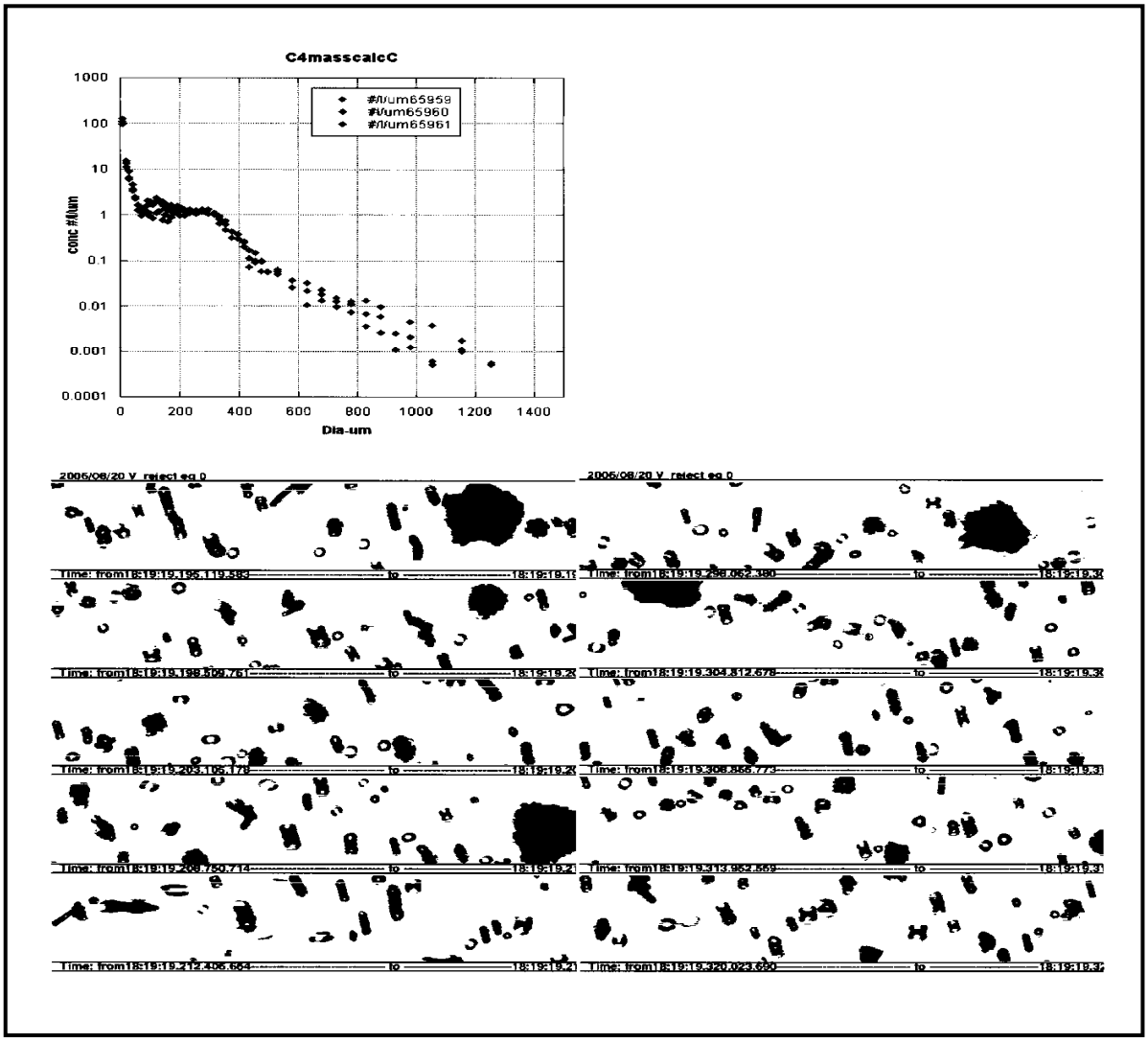


Figure 2: Distributions and 2D-S image sample in ice multiplication region near -10C.

Research Performance Measure: Considerable progress has been made on the reduction and analysis of these data. JPL radar data are planned to be further incorporated into the analysis.

Studies of Cloud, Drizzle, Turbulence, and Boundary Layer Variability over the Eastern Pacific in Support of the VOCALS Regional Experiment

B. Albrecht (UM/RSMAS)

Long Term Research Objectives and Strategy to Achieve Theme:

***Objectives*:** To contribute to our understanding of the dynamical, turbulence, microphysical, and drizzle properties of extensive boundary layer cloud decks in the southeasterly trade winds.

***Strategy*:** Continue collaborative observing and analysis efforts with Dr. Chris Fairall at NOAA ESRL on the deployment and operation of cloud radars and the collection and the analysis of data from other remote and *in situ* observing systems. Observations from these systems operating on the *R/V Ron Brown* during VOCALS-REx (VAMOS Ocean-Cloud-Atmosphere-Land-Study Regional Experiment, 2008) and from a buoy operated by Woods Hole form the basis for cloud and boundary layer studies.

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: OAR/CPO **NOAA Technical Contact:** Jin Huang

Research Summary:

During work completed prior to VOCALS-Rex, we used observations (2001-2005) from the Wood Hole Ocean Reference Station (WORS) located at 20°S and 85°W to develop a surface flux and cloudiness climatology of the South-East Pacific region around the buoy. A simple one-dimensional model was used to estimate monthly cloud fraction using the observed surface down-welling longwave flux and surface meteorological parameters. The fractional cloudiness derived along with the surface fluxes and meteorology for the buoy region provide a critical set of characterizations than provide a basis for evaluating forecast models in representing the clouds and boundary layer structure in this region of climate sensitive region. large-scale clime models. These results appear in Ghate et al. (*J. Climate*, 22, 5527-5540, 2009).

In support of NOAA's component of VOCALS-REx, (2008) the University of Miami W-Band and X-Band radars were prepared, deployed, and operated on the R/V Ron Brown with University of Miami graduate students helping with the data collection. Following the cruise we have collaborated with Chris Fairall and other VOCALS investigators to analyze and synthesize observations made on the cruise. These analyses have concentrated on examining the conditions under which the boundary layer becomes decoupled — a process that can be associated with a substantial reduction in cloudiness. This study used observations obtained from the VOCALS 2008 cruises along with observations from 5 previous cruises to the WHOI buoy area (20ºS, and 85 ºW). In addition to the boundary layer structure analysis, observations of the turbulence structures in the cloud layer obtained from the NOAA Doppler cloud radar and in the sub-cloud layer from the NOAA Doppler lidar have been developed and combined. An example of one-day of retrieved vertical velocity variance from the NOAA radar and lidar is shown in Figure 1. Although the scheme used to derive the variance does not apply to regions in the cloud where there is precipitation, work is in progress to

examine the Doppler spectra from these observations to develop schemes for retrieving turbulence estimates. The goal will be to provide turbulence characteristics in the cloud and the subcloud layer that can be compared with those form cloud resolving and large eddy simulations.

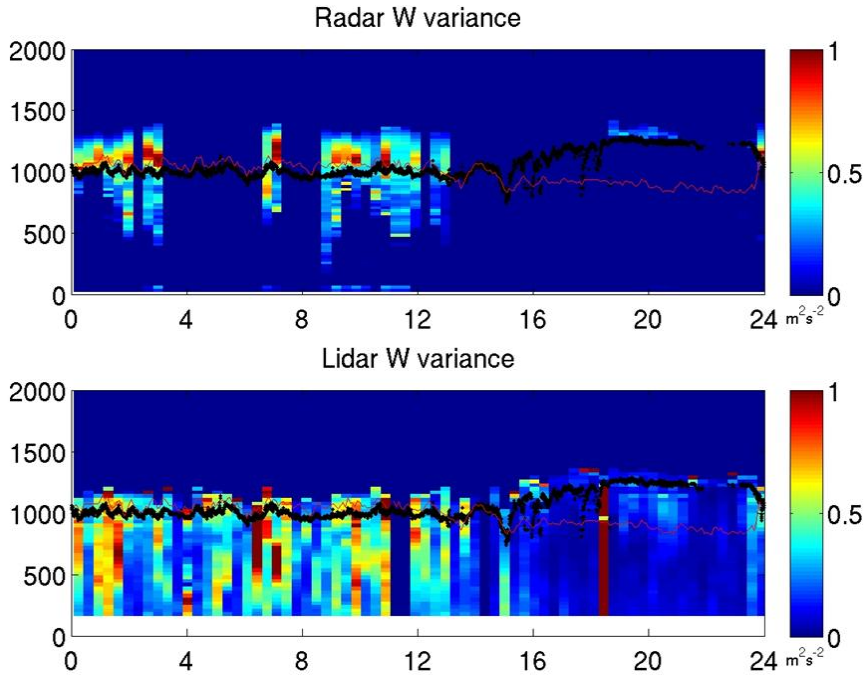


Figure 1: Radar observed vertical velocity variance (turbulence) and lidar observed variance with ceilometer cloud base height and the Lifting Condensation Level estimated for a . Both were calculated for the same 10 min periods. Radar W variance was calculated only for periods when maximum reflectivity was non-precipitating (radar reflectivity < -15 dBZ at all levels).

Observations from this study have been instrumental in documenting surface flux and cloud variability in the marine stratocumulus regimes over the southeast Pacific. Accurate simulation of these atmospheric features is critical for understanding of climate variability and the role of air-sea interaction in this variability. These observations provide a key baseline for evaluating boundary layer models and simulations from large-scale models. The boundary layer structure and the turbulence characteristics from a ship-borne Doppler lidar and radar provide a detailed description of the stratocumulus cloud structure during the VOCALS 2008 cruise. These observations will be critical for evaluating cloud resolving and large eddy models that can then be used in a bootstrap fashion to improve the representation of these critical cloud systems in climate models.

Research Performance Measure: The research completed during second first two years of the grant was consistent with the expectations outlined in the proposal. The next year will focus on completing analyses and publishing results from the VOCALS observations.

Evaluation and Improvement of Ocean Model Parameterization for NCEP Operations

L.K. Shay (UM/RSMAS); G. Halliwell (NOAA/AOML) C. Lozano (NOAA/NCEP)

Long Term Research Objectives & Strategy to Achieve Them:

***Objectives*:** To evaluate and improve ocean model parameterizations in NOAA National Center for Environmental Prediction (NCEP) coupled hurricane forecast models in collaboration with the NOAA Tropical Prediction Center (TPC) and NOAA/NCEP Environmental Modeling Center (EMC).

***Strategy*:** To initialize the Hybrid Coordinate Ocean Model (HYCOM) with realistic ocean conditions, force it with realistic ocean fields, and then evaluate model performance against high-quality ocean observations, emphasizing the impact of vertical resolution, horizontal resolution, vertical mixing, air-sea flux parameterizations (drag coefficients), ocean dynamics, and the accuracy of the ocean initialization.

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 Joint Hurricane Test-bed
NOAA Technical Contact: Jiann-Gwo Jiing

Research Summary:

The initial work focused on testing model initialization schemes primarily in the Gulf of Mexico (GOM) and processing data required for model evaluation. This dataset includes *in situ* Naval Research Laboratory (NRL) Acoustic Doppler Current Profiler (ADCP) data from Ivan (Teague et al., JPO, 2007) and during Katrina and Rita (courtesy of Minerals Management Service) as well as measurements acquired during NOAA Hurricane Research Division Intensity Fluctuation Experiments (IFEX) in pre and post Rita in 2005 (Rogers *et al.*, BAMS, 2006) and Gustav and Ike in 2008.

The model evaluation completed to date has focused on hurricane Ivan in the GOM, where high-quality *in-situ* moored current measurements have been acquired, focusing on the impact of the Loop Current (LC) and associated warm and cold rings, along with the complex bathymetry of the continental shelf/slope region. Objectively analyzed fields from multiple space-based platform data such as radar altimeter measurements and SST fields are also used in the evaluation. Fifteen experiments have been performed to date emphasizing ocean model sensitivity to vertical resolution, horizontal resolution, vertical mixing, air-sea flux parameterizations (drag coefficients), ocean dynamics, and the accuracy of the ocean initialization.

During Ivan, the model accurately reproduces the upper-ocean near-inertial velocity shear response as illustrated in a comparison to one of the NRL ADCP velocity profilers over the continental slope of the northern Gulf of Mexico (Fig. 1). At mooring 9, simulated velocity shear magnitudes are compared to the observed shear profiles over the upper 150 m. Good agreement exists between observed and simulated current shears from KPP with the Donelan *et al.* drag coefficient over the first two inertial periods. These observations and simulations suggest vertical energy propagation out

of the surface mixed layer and into the thermocline consistent with surface intensified flows (Jaimes and Shay, JPO 2010). Velocity shear comparisons clearly reveal differences among the three drag coefficient parameterizations and vertical mixing schemes. Central to the momentum flux issue (e.g., surface drag coefficient), the Donelan *et al*. drag coefficient seems to produce the most realistic shear profile in the upper 150 m compared to the Powell and the Large and Pond formulations. Based on these comparisons, KPP mixing scheme with the Donelan *et al.* drag coefficient formulation (control experiment) seem to accurately simulate the observed current shears from the Ivan data set. We are in the process of making such comparisons for all the ADCP records during storm forcing given differing distances from the storm track and over differing time intervals. The import of this surface drag cannot be over stated in that the surface stress drives the current and its shear that will lead to enhanced shear instabilities and entrainment mixing. So these schemes are clearly linked in obvious and subtle ways (Halliwell *et al*., *Mon. Wea. Rev*., 2010). Coupled models seem to be overlooking this very important point.

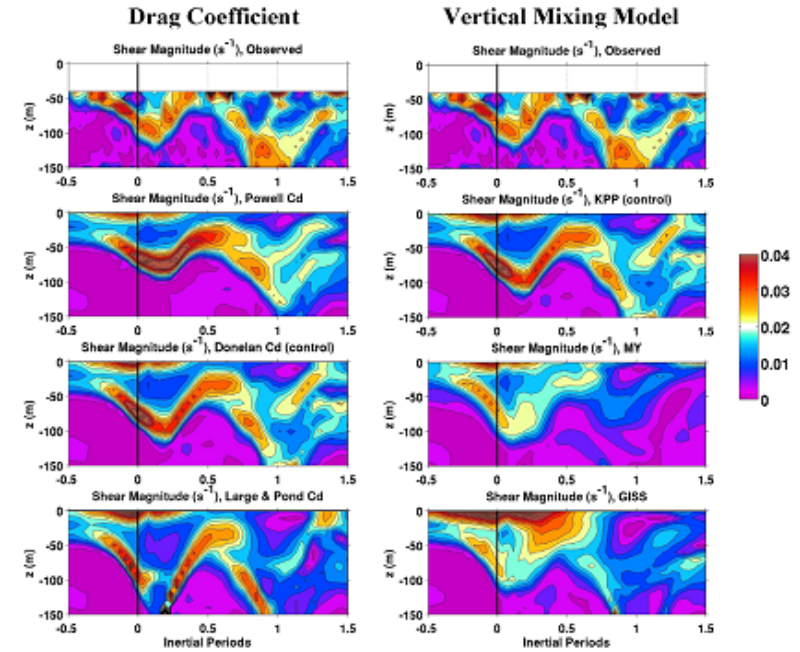


Figure 1: Time series of the magnitude of vertical current shear (s^{-1}) comparing observations from SEED mooring 9 (upper panels) to three three wind stress drag coefficient choices (left) and vertical mixing choices (right) over two inertial periods. The black line represents the time of Ivan's closest approach to.the mooring (t=0). The combination of KPP mixing scheme and Donelan *et al.* drag coefficient parameterization produce the most realistic shear structure and maximum OML depth relative to the data. Note that the quality ADCP data started at about 40 m which avoids surface interference effects.

Analyses of the ocean response to hurricanes Katrina and Rita have commenced using the oceanic measurements acquired from research aircraft in support of IFEX and MMS moorings (Jaimes and Shay, MWR, 2009; Jaimes and Shay, JPO, 2010). Analysis of these storms along with the major storms Gustav and Ike from 2008 are now high priorities. G. Halliwell has moved from RSMAS to NOAA/AOML, and part of his duties is to lead an effort with the AOML/HRD modeling group in the development and evaluation of an experimental coupled TC forecast model (HWRFX) based on the operational NCEP HWRF model. Strategies for ocean model improvement developed under this project will then be tested in HWRFX at AOML to quantify the impact on actual coupled forecasts and refined based on these results before recommendations are communicated to NOAA/NCEP/EMC.

Research Performance Measure: The objectives of this program have been delayed as Shay's and Halliwell's time has been directed toward the oil spill given their fairly extensive knowledge of

observing and modeling the Loop Current and its eddy field and the implication of the ocean response on the dispersion of the oil in surface and subsurface layers in the Gulf of Mexico.

WISDOM Field Operations

S.J. Majumdar (UM/RSMAS); S.D. Aberson (NOAA/AOML)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** To coordinate balloon launches for NOAA's Weather In-Situ Deployment Optimization Method (WISDOM) program.

***Strategy*:** In advance of a hurricane that may become a significant threat to land, teams of students at UM/RSMAS are organized to deploy to the Florida Keys to launch "super-pressure" balloons. The balloon data are made available for assimilation into numerical forecast 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: AOML/HRD **NOAA Technical Contact:** Bob Atlas

Research Summary:

The primary purpose of this small grant was to provide travel funds for UM/RSMAS students to be deployed to Islamorada in the Florida Keys, to launch balloons for the WISDOM program. Due to the relatively inactive hurricane season in 2009, only one storm was targeted: Tropical Storm / Hurricane Ida in November 2009. Three UM/RSMAS students were deployed to Islamorada over a 3-day period, when Ida was in the central Gulf of Mexico and threatening the northern Gulf states.

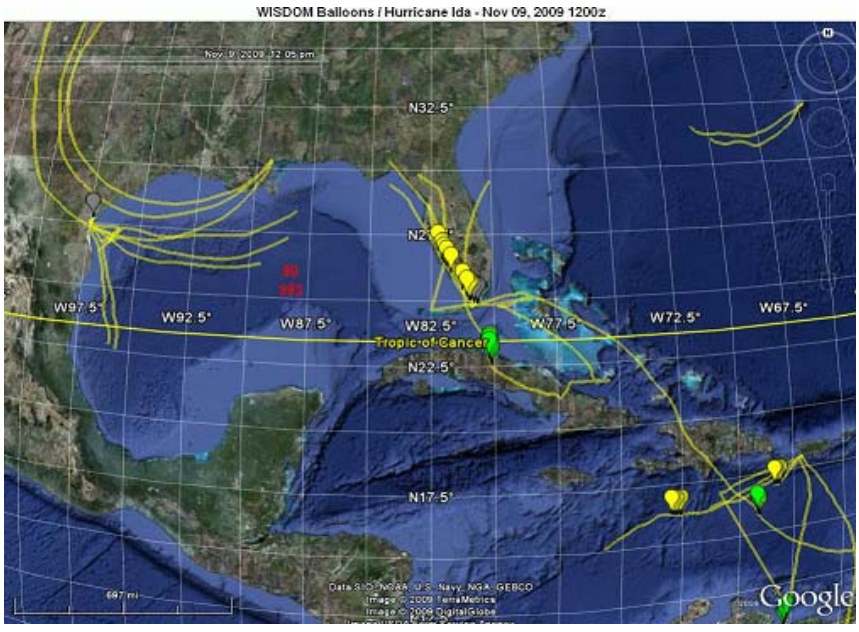
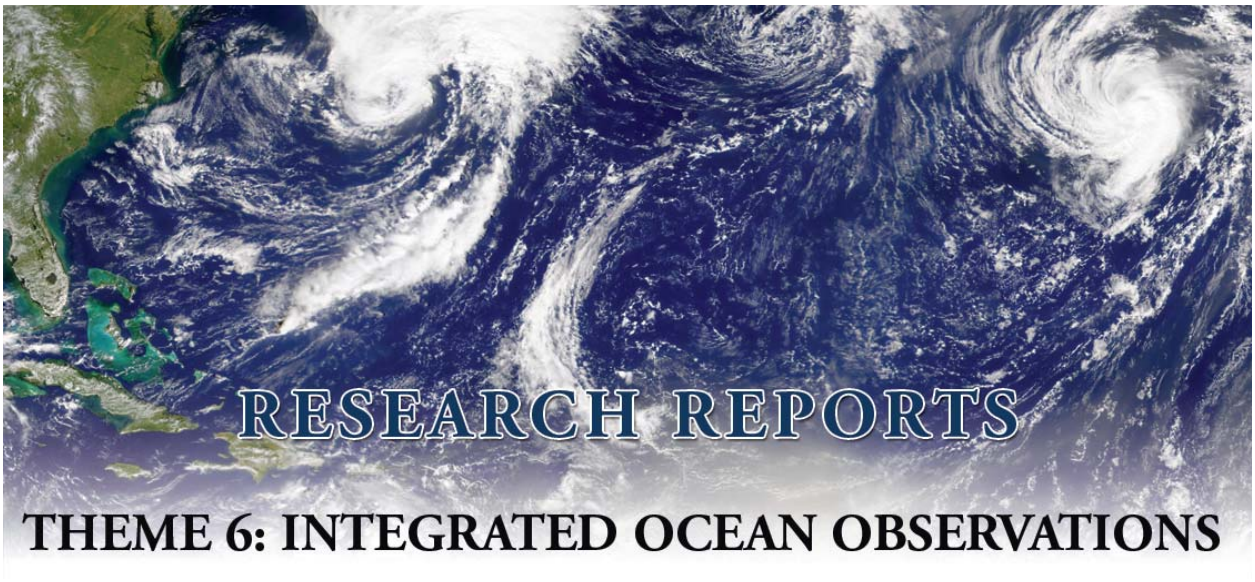


Figure 1: WISDOM balloon tracks near Hurricane Ida.

Research Performance Measure: The goals of the original proposal were met.



Synoptic Estimates of Sea Surface Ocean Acidification

D. Gledhill (UM/CIMAS); R. Wanninkhof (NOAA/AOML);
C.M. Eakin (NOAA/CRW); Shari Yvon-Lewis (TAMU)

Long Term Research Objectives and Strategy to Achieve Them:

***Objective*:** To provide monthly synoptic (near-real-time & retrospective) estimates of changing sea surface carbonate chemistry in response to ocean acidification.

***Strategy*:** Utilize regionally specific algorithms applied to satellite data and synoptic geochemical models to estimate sea surface carbonate chemical parameters.

CIMAS Research Theme:

***Theme 6*:** Integrated Ocean Observations (*Primary*)
Theme 1: Climate Variability (*Secondary*)
Theme 5: Air-Sea Interactions and Exchanges (*Tertiary*)

Link to NOAA Strategic Goals:

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

NOAA Funding Unit: NOS/CRCP **NOAA Technical Contact:** Kacky Andrews

Research Summary:

AOML/OCD and CIMAS are advancing the development of regionally synoptic maps of surface carbonate chemistry in near-real-time. A quasi-operational product is being currently distributed by NOAA Coral Reef Watch (CRW). That product delivers a monthly x 0.25 degree synthesis of satellite and modeled environmental datasets to provide a synoptic estimate of the distribution sea surface carbonate chemistry throughout Greater Caribbean Region (GCR). The general approach is to fully describe the carbonic acid system and solve for aragonites saturation state (Ω_{arg}) through the application of regionally specific satellite-based algorithms. The satellite-based algorithms that drive this experimental model are derived from underway and discrete geochemical survey data. The

details of the original model are presented in Gledhill et al. [2008, *J. Geophys. Res.*, *113*, C10031, doi:10.1029/2007 JC004629]. Ongoing efforts seek to improve the constraint and performance of these algorithms.

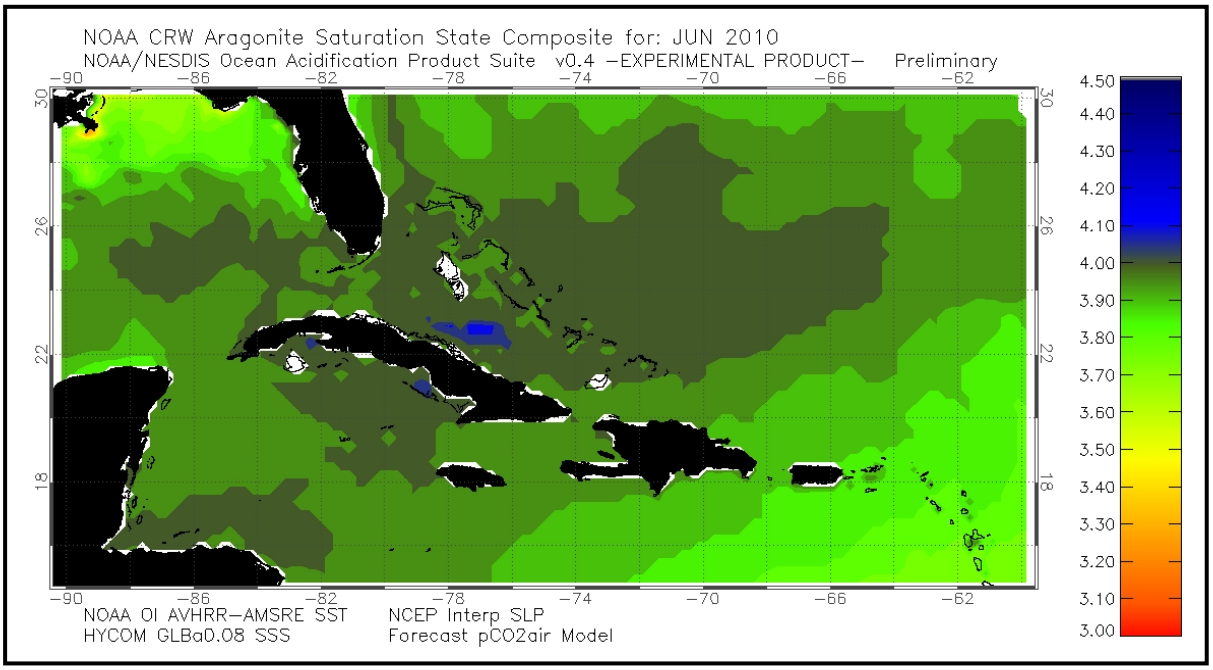


Figure 1: Example output from the Experimental Ocean Acidification Product Suite v0.4 showing the distribution of aragonite saturation state (Ω_{arg}) across the Greater Caribbean Region for July, 2010.

To achieve this, surface carbonate chemistry (A_T, total inorganic carbon, $pCO_{2,sw}$) are routinely measured aboard a series of VOS and research cruises throughout the GCR to evaluate the OAPS v0.4 model performance in estimating surface Ω_{arg}. We have discovered that in cases where satellite derived chlorophyll estimates are low, the model performs well particularly throughout the Western Tropical Atlantic and Lesser Antilles Region. However, in the northern Gulf of Mexico (NGOM) in the presence high concentrations of chlorophyll the model tends to underestimate the Ω_{arg} values. In particular, the model significantly underestimates Ω_{arg} for waters very near the Mississippi River outlet where satellite estimates of chlorophyll concentration are very high. The underestimation of Ω_{arg} throughout much of the northern Gulf of Mexico is largely attributed to the model's dependence on the Lee et al. (2006) subtropical algorithm for alkalinity. Where surface alkalinity data is available within the oceanic oligotrophic waters of the Caribbean region, the OAPS data generally show good agreement with Lee et al. (2006). In contrast, waters in the northern Gulf of Mexico region are more complex and exhibit a strong riverine influence (particularly that of the Mississippi River) that can export considerable alkalinity to the northern Gulf of Mexico and thus export carbonate to the shelf off Louisiana and Texas. Total alkalinity values for the Mississippi River values sometimes exceed those of seawater which can serve to increase local Ω_{arg}-values. Within the NGOM region, we have developed a means to inform the OAPS model using satellite estimates of chlorophyll to readily distinguish appropriate application of specific A_T-SSS relationships greatly enhancing the models performance within these complex waters.

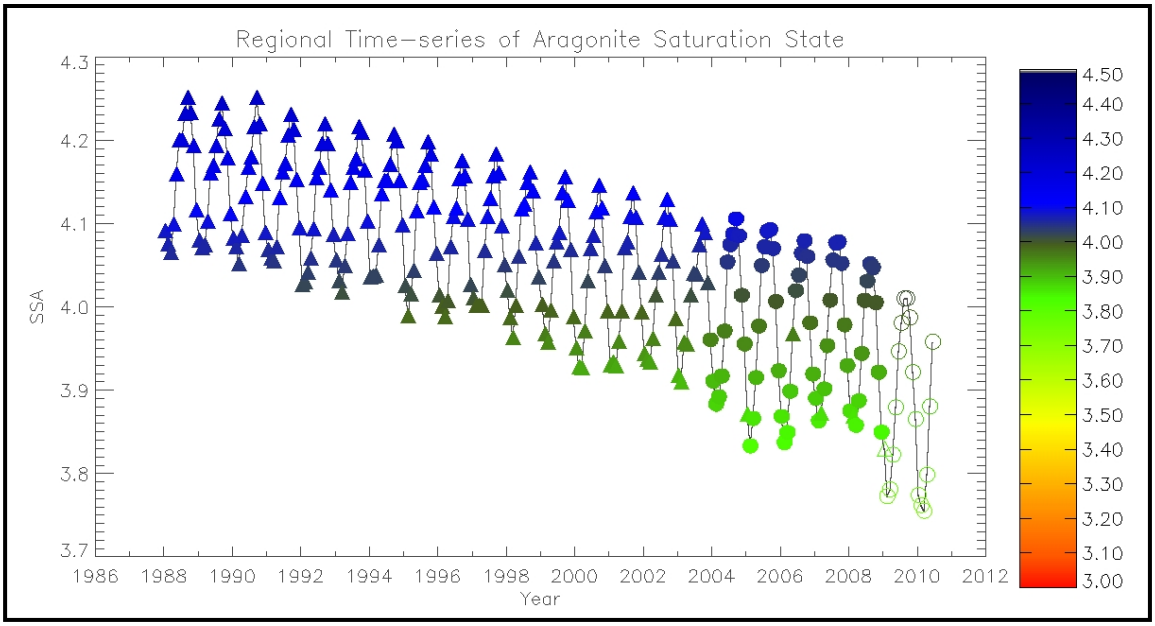


Figure 2: Time-series (b) of the regional mean Ω_{arg} for the Greater Caribbean Region derived from the Experimental Ocean Acidification Product Suite v0.3.

Research Performance Measure: Provide monthly estimates of changes in surface ocean chemistry throughout the Greater Caribbean Region in response to ocean acidification. – achieved.

Western Boundary Time Series Project

C. Fonseca, R. Garcia, G. Berberian, Q. Yao, G. Rawson, N. Melo, K. Seaton,
P. DiNezio, R. Roddy, J. Molina, E. Valdes and F. Bringas (UM/CIMAS)
M. Baringer, C. Meinen and S. Garzoli (NOAA/AOML)

Long Term Research Objectives and Strategy to Achieve Theme:

***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 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 and OAR/CPO

NOAA Technical Contact: Molly Baringer

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 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. 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. 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 25 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 on research vessels. 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 27ºN. 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, we have continued to improve the monitoring and data distribution systems for the Florida Current cable program, providing Florida Current transports in near real time via the web page www.aoml.noaa.gov/floridacurrent/ (See Figure 1). Through a collaboration with the National Science Foundation-funded Meridional Overturning Circulation Heat-flux Array experiment and the United Kingdom National Environmental Research Council funded RAPID-Meridional Overturning Circulation program, this program executes two hydrographic cruises each year to monitor water mass changes along 26.5ºN east of Abaco Island in the Bahamas. These cruises usually involve collaborations with scientists from RSMAS/University of Miami and from the National Oceanographic Centre, Southampton, United Kingdom. Quarterly 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 and small sport fishing boats charter from Sailfish Marina in West Palm Beach.

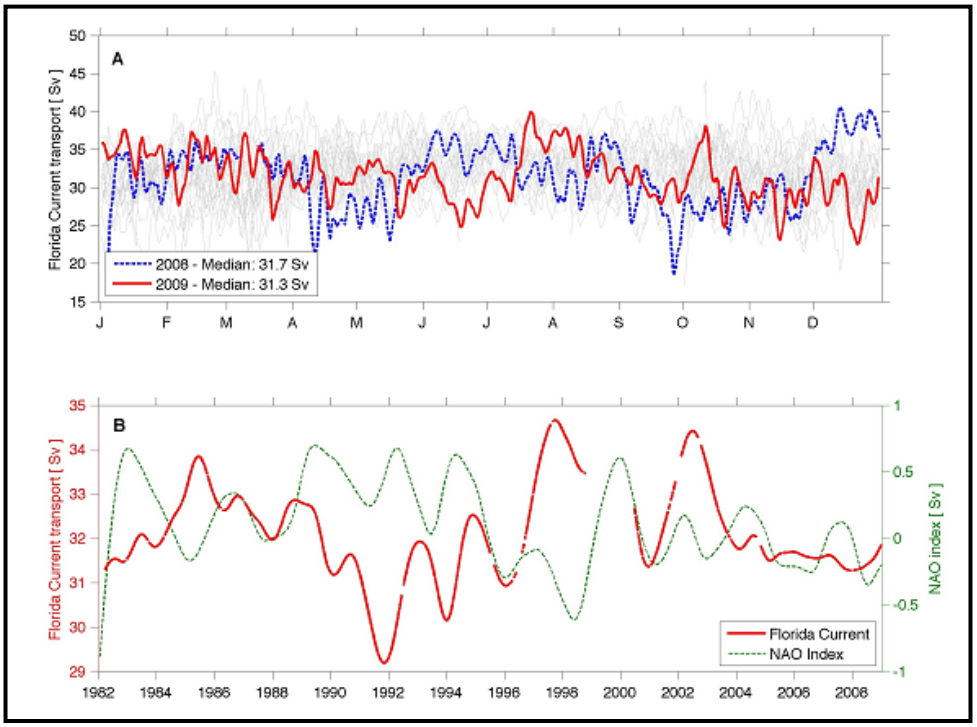


Figure 1: (A, top) Daily estimates of the transport of the Florida Current for 2009 (red solid line) compared to 2008 (dashed blue line). The daily values of the Florida Current transport for other years since 1982 are shown in light grey. The median transport in 2009 decreased slightly relative to 2008, and is slightly below the long-term median for the Florida Current (32.2 Sv). (B, bottom) Two-year smoothed Florida Current transport (red) and NAO index (dashed green). The daily Florida Current transport values are accurate to 1.1-1.7 Sv (Meinen *et al.*, 2010) and the smoothed transport to 0.25 Sv (a priori estimate using the observed 3-10 day independent time scale).

Research Performance Measure: All research goals were met during this last year. We continue to achieve our major long term objective – to maintain the continuity of this long term data set and to continually improve the calibration of the data obtained.

Ship of Opportunity Program

Q. Yao, F. Bringas, P. DiNezio, S. Pochan G. Rawson, N. Melo, T. Casal,
E. Muñoz, S. Dong, J. Molina and C. Gonzalez (UM/CIMAS)
G. Goni, M. Baringer and S. Garzoli (NOAA/AOML)

Long Term Research Objectives and Strategy to Achieve Them

***Objectives*:** To characterize the upper ocean thermal structure and to investigate the large-scale, low-frequency modes of climate variability using observations of ocean and atmospheric properties obtained, transmitted and quality controlled within the Ship of Opportunity Program (SOOP) using volunteer merchant ships.

***Strategy*:** Make routine observations along major shipping routes throughout the global ocean including design, development and maintenance of a system for the merchant fleet to acquire ocean and meteorological information and transmitted in real-time to users worldwide called SEAS (Shipboard Environmental Acquisition System). Make upper ocean temperature observations using expendable bathythermographs (XBTs) deployed both broadly across large ocean regions along repeated transects (the frequently repeated/low-density XBT program) and more closely spaced to measure the mesoscale ocean temperature structure (the high-density XBT program) and to combine these observations with those from other platforms, such as satellite altimeters, floats, drifters and moorings, to enhance the global ocean observing system and provide estimates of the meridional heat transports and upper ocean heat content.

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 / CPO **NOAA Technical Contact:** Molly Baringer

Research Summary:

This project is designed to measure the upper ocean thermal structure along major shipping lines globally with low resolution and in key regions of the Atlantic Ocean with high resolution. Approximately 8000 XBTs are deployed annually in all three modes (low density, frequently repeated and high density; Figure 1). Approximately 14000 XBT data, from NOAA and non-NOAA operations, are quality controlled every year. The global atmospheric and oceanic data from Ships of Opportunity (SOOP) serve as the foundation for understanding long-term changes in marine climate. This project is a component of the NOAA's Program Plan for building a sustained Ocean Observing System for Climate and directly addresses one of its milestone*: Occupy transects of the Ship Of Opportunity Program (SOOP) for high accuracy upper ocean observations.*

The SOOP program currently maintains the following transects in low-density/frequently repeated mode: AX07, AX08 and AX10 in the Atlantic Ocean, and PX08, PX10, PX13, PX37 and PX44 in the Pacific Ocean. Five high-density XBT lines have been chosen to monitor properties in the upper layers of the Atlantic Ocean (AX07, AX08, AX10, AX18 and AX25). 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 are the only means to measure subsurface temperature fields on spatial and temporal scales designed to map the mean and fluctuating components of the ocean thermal structure. Data obtained from these lines 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.

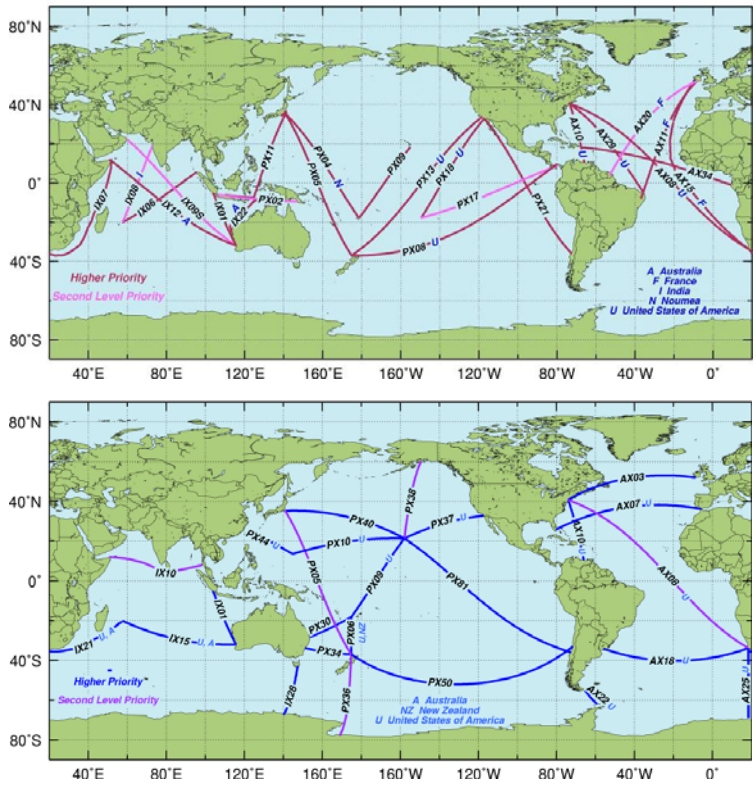


Figure 1: (top) Location of Frequently Repeated and Low Density XBT network and (bottom) the High Density network recommended by the 1999 Upper Ocean Thermal Review Panel. The blue letters indicate the country that leads the effort of each transect.

This project includes extensive operations that collect, organize and distribute the data which are gathered from as many as eighteen cruises conducted each year, including in excess of 225 days at sea and more than 8000 XBTs deployed in all modes. Data obtained from these transects are provided to the scientific community to investigate the thermal structure of the subtropical gyres, equatorial system and the Antarctic Circumpolar Current and 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 more details). In addition, satellite altimetry data are being used to complement the observations provided by the XBT transects and together provide estimates of Tropical Cyclone Heat Potential.
Tropical cyclones occur in seven ocean basins: tropical Atlantic, northeast Pacific, northwest Pacific, southwest Indian, north Indian, southeast Indian, and south Pacific. The intensification

of TCs includes very complex mechanisms, such as TC dynamics, upper ocean interaction, and atmosphere circulation. In general, the accuracy of TC intensity forecast has lagged behind the TC track because of the complexity of the problem and because many of the errors introduced in the track forecast are translated into the intensity forecast. While sea surface temperature (SST) plays a role in the genesis of TCs, the ocean heat content (OHC) contained between the sea surface and the depth of the 26°C isotherm (D26), also referred as Tropical Cyclone Heat Potential (TCHP), has been shown to play a more important role in TC intensity changes. The TCHP shows high spatial and temporal variability associated with oceanic mesoscale features. TC intensification has been linked with high values of TCHP contained in these mesoscale features, particularly warm ocean eddies, provided that atmospheric conditions are also favorable. Since sustained *in situ* ocean observations alone cannot resolve global mesoscale features and their vertical thermal structure, different indirect approaches and techniques are used to estimate the TCHP. Most of these techniques use sea surface height observations derived from satellite altimetry, a parameter that provides information on the upper ocean dynamics and vertical thermal structure. This manuscript highlights the importance of integrated data and, particularly, of satellite derived observations, for tropical cyclone intensification studies.

During 2008 five intense (category 4 and 5) TCs were identified to have gained strength when traveling into regions of very high or higher values of TCHP. These TCs were Gustav in the Gulf of Mexico, Ike in the Caribbean Sea, Sinlaku in the western Pacific, Nargis in the northern Indian, and Ivan in the southwest Indian region. Additionally, the cooling associated with the wake of the TCs, which can reach values of 30 $kJcm^{-2}$ in tropical cyclone heat potential and 3°C in sea surface temperature, is important since it influences the upper ocean thermal structure on regional scales within weeks to months after the passage the cyclones.

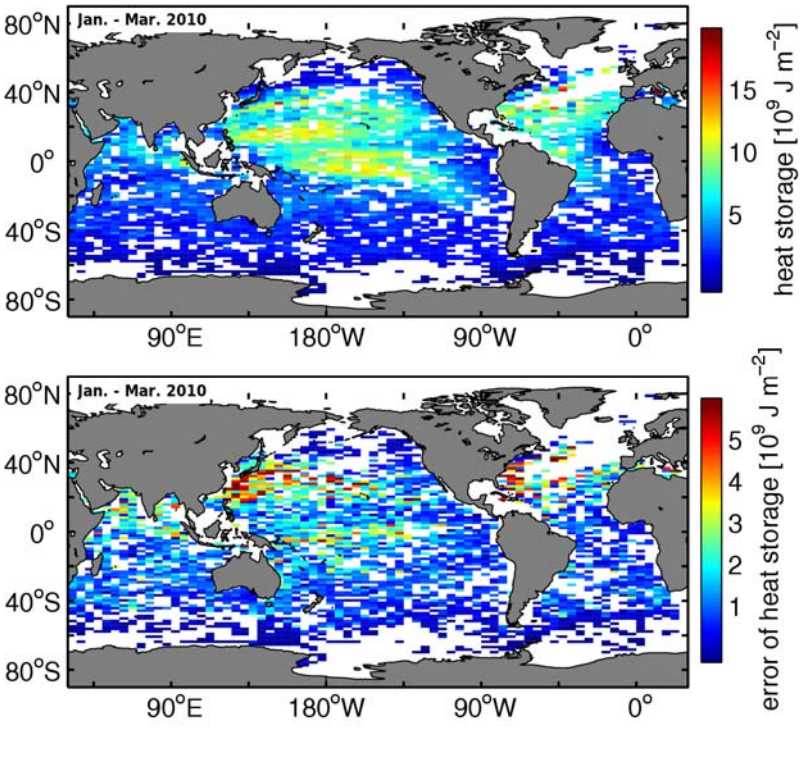


Figure 2: (top) Global map of in situ estimates of heat storage of the mixed layer and (bottom) error of these estimates for the period January – March, 2010. Available online at: *www.aoml.noaa.gov/phod/soto/ghs/reports*.

Storage and transport of heat in the ocean are central to other aspects of climate such as El Niño, the North Atlantic Oscillation, sea level rise, and global warming. Global integrals of upper ocean heat content for the last several years have reached values consistently higher than for all

prior times in the record, demonstrating the dominant role of the oceans in the Earth's heat budget. Changes in mixed layer depth can have large impacts on the heat content in the mixed layer (Figure 2) even if there is no change in the mixed layer temperature.

The Meridional Overturning Circulation (MOC) is the main mechanism for global redistribution of heat in the ocean. The Atlantic Ocean is the major ocean basin involved in large-scale northward transports of heat typically associated with the MOC, where warm upper layer water flows northwards, and is compensated for by southward flowing North Atlantic Deep Water. This large-scale circulation is responsible for the northward heat flux through the entire Atlantic Ocean. Historical estimates of the net northward heat flux in the vicinity of its maximum, which occurs in the North Atlantic roughly at the latitude of the center of the subtropical gyre, range from 0.9 PW to 1.6 PW, while estimate in the 30°S to 35°S band are even more uncertain, ranging from negative to more than 1 PW. While much of this variability may be a consequence of the different methods used to estimate the heat transport, natural variability cannot be ruled out. Quarterly reports of heat storage (Figure 2; *http://www.aoml.noaa.gov/phod/soto/ghs/reports.php*) and heat transport (Figure 3; *http://www.aoml.noaa.gov/phod/soto/mht/index.php*) are created to provide an overview of the current state of knowledge about ocean climate, including anomalies, placed in historical context. Climate applications are presented along with an explanation of how the observing system needs to be enhanced to improve ocean analysis and reduce present uncertainties.

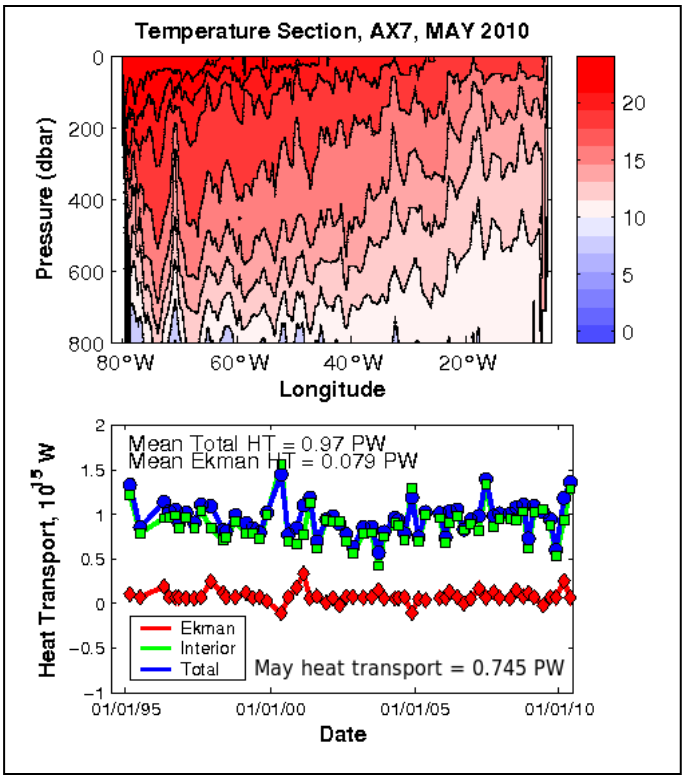


Figure 3: (top) Temperature section obtained with the XBT data from the high density AX07 cruise on May, 2010. (Bottom) Ekman, Interior and Total heat transport in the North Atlantic obtained using the May 2010 AX07 XBT data. Available online at *http://www.aoml.noaa.gov/phod/soto/mht/ax7/report.php*.

Research Performance Measure: All operational research goals were met during this year with respect to the percentage recovery of good data based upon rigorous internal quality control. All scientific goals were met with respect to timely assimilation of the data generated into operational NOAA modeling efforts.

Marine Optical Buoy (MOBY) Hardware Refurbishment

K. Voss (UM/Physics); M. Yarbrough (Moss Landing Marine Laboratory)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** To enable the MOBY system to continue acquiring daily measurements of the water leaving radiance for vicarious calibration of ocean color sensors.

***Strategy*:** In this work we are replacing several large, key, system subcomponents required for the continued operation of MOBY into the next Decade.

CIMAS Research Theme:

Theme 6: Integrated Ocean Observations

Link to NOAA Strategic Goals:

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

NOAA Funding Unit: NESDIS **NOAA Technical Contact:** Kent Hughes

Research Summary:

The Marine Optical Buoy (MOBY) is the primary ocean measurement site for vicarious calibration of satellite ocean color. Since late 1996, the time series of normalized water-leaving radiances $L_{WN}(\lambda)$, obtained with MOBY has been the basis for calibrating various US and international ocean color sensors (**US;** SeaWiFS, MODIS Terra and Aqua, **International;** Japan: OCTS and GLI, French: POLDER, German: IRS1-MOS and EU: MERIS). The MOBY vicarious calibration $L_{WN}(\lambda)$ reference is an essential element in the international effort to develop a global, multi-year time series of consistently calibrated ocean color products using data from a wide variety of independent satellite sensors.

This system is now over a decade old, and many components are no longer manufactured and are obsolete. With the upcoming launch of VIIRS on the NPP satellite, it is important to maintain this site to bridge between old and

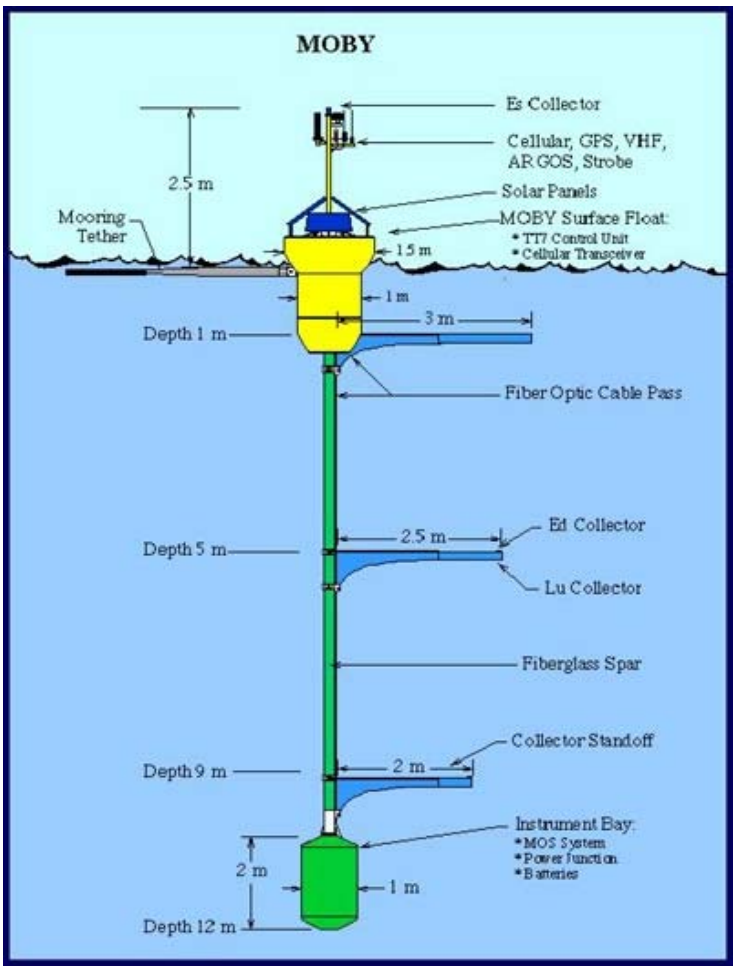
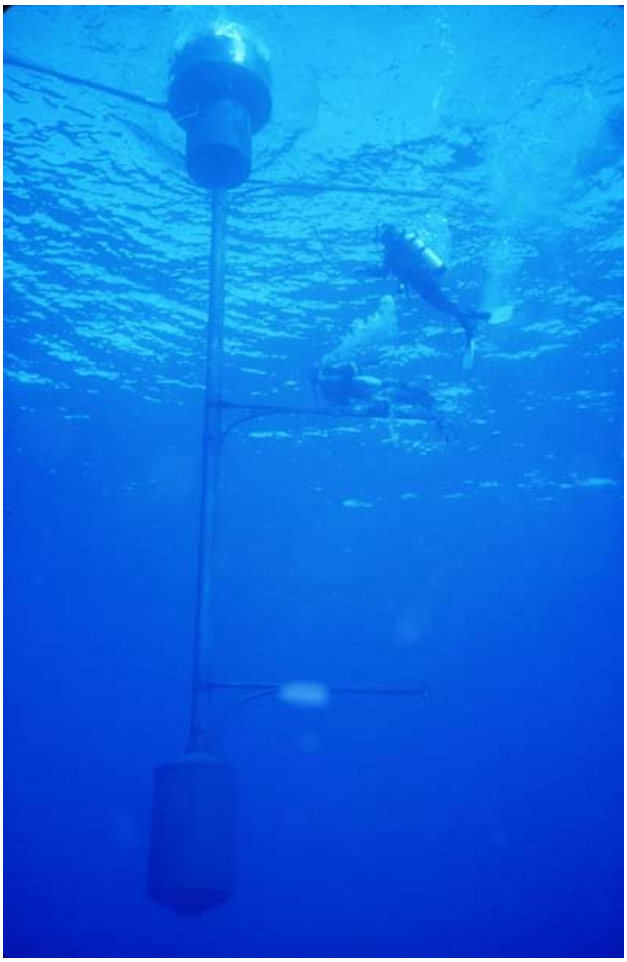


Figure 1 Schematic of current MOBY system.



new satellite sensors. During the past decade of operation MOBY has received upgrades and continual replacement of minor system components. But some of the larger, more durable system components are now over 12 years old. Extensive periodic maintenance has kept these components going, however this only works for a certain period of time. In this work the MOBY surface floatation frame will be replaced, the solar panels replaced and upgraded, new collector standoff "arms" fabricated, a new lower instrument bay fabricated, and we will redesign and fabricate a new mooring buoy solar panel array. All of this effort is designed to allow the continued operation of this important asset for vicarious calibration.

Research Performance Measure: This project has only recently been funded (April, 2010), the subcontract with Moss Landing Marine Laboratories is just being completed (the main organization doing the work), and so we have not had sufficient time to have completed any goals.

Figure 2: MOBY system as deployed in Hawaii.

Global Drifter Program

S. Dolk and E. Valdes (UM/CIMAS)
R. Lumpkin and M. Pazos (NOAA/AOML)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** To maintain a global 5x5 degree array of 1250 satellite-tracked surface drifting buoys to meet the need for an accurate and globally dense set of in-situ observations of mixed layer currents, sea surface temperature (SST), atmospheric pressure, winds and salinity; to provide, archive, and disseminate a uniform quality-controlled data set of SST and surface velocity.

***Strategy*:** To produce an annual plan for the global distribution and deployment of 1000-1050 drifters through interaction with international partners; to coordinate drifter objectives with NOAA field personnel, contractors, shipping companies and various ship personnel; to verify deployment status and update the Drifter Database and to monitor on a daily basis systems status.

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: Rick Lumpkin and Mayra Pazos

Research Summary:
The Global Drifter Program (GDP) at AOML is one of the principal components of the Global Surface Drifting Buoy Array, a branch of NOAA's Global Ocean Observing System (GOOS) and a scientific project of the Data Buoy Cooperation Panel (DBCP). There are two major activities in this program.

- *Drifter Operations Center (DOC)* whose task is to maintain a global 5x5 degree array of 1250 ARGOS-tracked surface drifting buoys to meet the need for an accurate and globally dense set of in-situ observations of mixed layer currents, sea surface temperature (SST), atmospheric pressure, winds and salinity.
- *Drifter Data Assembly Center (DAC)* whose tasks are: to arrange data dissemination to the Global Telecommunications System (GTS); to provide uniform quality-controlled data from the historical data sets of SST and surface velocity, web access, archival and distribution. These data support short-term (seasonal to interannual) climate predictions as well as climate research and monitoring.

The design of the Global Drifter Program drifter has continued to evolve - as demonstrated by the recent introduction of hurricane drifters with wind measurements - while its qualitative characteristics and water-following properties have remained relatively stable since the earliest deployments. Incremental improvements in design and manufacturing continue to increase drifter lifetime, and alternative methods for detecting drogue presence (such as tether strain) are being evaluated. We continue to develop new methodologies for drifter data analysis, aided by increasing information from the ever-growing drifter array and from other sources of complimentary observations. Dense deployments in eddy-rich, frontal regions will help us improve our understanding of eddy fluxes and their role in modifying air-sea heat fluxes and water mass formation.

The major challenge facing AOML's DOC, which coordinates drifter deployments, is to arrange deployments in regions of surface divergence and areas infrequently visited by research or voluntary observation vessels. This logistical challenge is being addressed by increased international cooperation, and the development of tools to predict global drifter array coverage based on its present distribution and historical advection/dispersion. As the array grows, it provides invaluable observations of ocean dynamics, meteorological conditions and climate variations, and offers a platform to test experimental sensors measuring surface conductivity, rain rates, biochemical concentrations, and air-sea fluxes throughout the world's oceans.

The AOML's DAC is responsible for processing data from all drifters in the 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 has four primary objectives: Global Telecommunications System (GTS) data distribution, data quality control, web access, and instrument performance evaluation. The DAC inserts and deletes drifters onto the GTS distribution. The accuracy of data is monitored and data are removed from the GTS once sensors fail or a drifter runs aground. The DAC also notes drifters that have lost their drogue so that this information can be relayed in the GTS message.

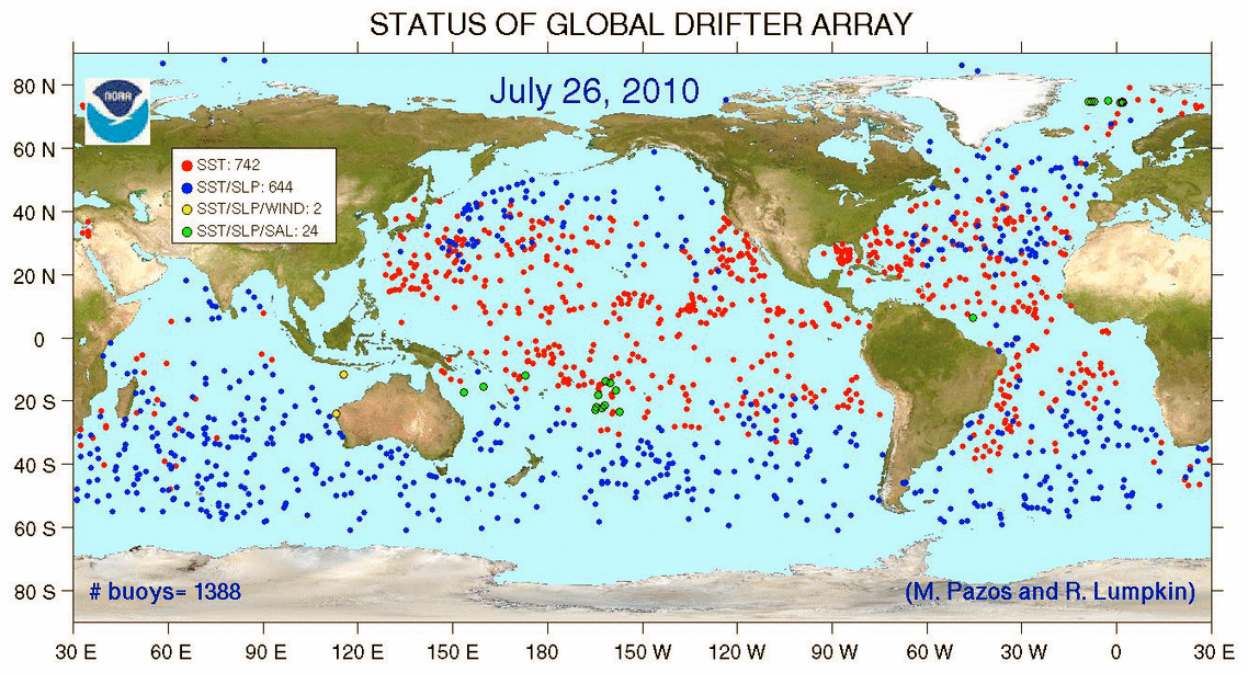


Figure 1: Status of the Global Drifter Array (updated weekly).

A major activity as an added task under this program is titled "Evaluating the Ocean Observing System: Surface Currents, an Add-task to the Surface Drifter Program" (Pedro DiNezio, CIMAS; Rick Lumpkin and Gustavo Goni, NOAA/AOML). In this study, the status of the observing system for surface currents obtained from quality-controlled, drogued Lagrangian drifter observations is derived. Sea height anomaly data are used to match with those from the drifters to evaluate the correlation between along-track sea height anomaly gradients and across-track drifter-derived geostrophic velocity anomalies. Global fields of correlations and eddy kinetic energy are computed and differences between estimates from both observations are evaluated. High correlations indicate where altimetry observations can be calibrated by the in-situ measurements to provide a good proxy for surface currents. On the other hand, low correlations may indicate where errors in the winds or Ekman model are problematic, where ageostrophic ocean dynamics are contributing significantly to the surface momentum budget, where the signal-to-noise ratio is low, or where there are depth-compensating effects in the upper layer causing the sea height to have low variability.

Research Performance Measure: All goals were met in that the array was both maintained and markedly enhanced and timely quality-controlled data made available to the research and operational communities.

Observing System Simulation Experiments for the Atlantic Meridional Overturning Circulation

C. Thacker and H. Yang (UM/CIMAS); G. Halliwell (NOAA/AOML)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** To design optimal observing system strategies to monitor changes in the Atlantic Meridional Overturning Circulation (AMOC), particularly changes that are potentially related to rapid climate change.

***Strategy*:** To develop the capability of performing Observing System Simulation Experiments (OSSEs) and Observing System Experiments (OSEs) at NOAA/AOML and use these systems for observing system design; to perform "virtual OSSEs" to conduct preliminary assessments of AMOC observing strategies.

CIMAS Research Theme:

***Theme 6*:** Integrated Ocean Observations
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/CPO **NOAA Technical Contact:** James F. Todd

Research Summary:

Although our eventual goal is to design and execute viable OSSEs to evaluate and recommend AMOC monitoring strategies, work during the first two years has emphasized the development of the required software toolboxes. The most recent work completed was to set up and produce a "demonstration" OSSE using a sub-optimal low-resolution ocean model that enables efficient testing of the software. Simultaneously, work has also continued to identify suitable choices for the nature run model and the operational model that will be required to execute viable OSSEs for the AMOC. From May through July, progress was substantially interrupted due to emergency work required for the response to the Deepwater Horizon oil spill.

The demonstration OSSE effort employed the "fraternal twin" approach, which uses one model type (HYCOM) as both the nature run and operational ocean models. The key is to run the model run in two substantially different configurations that reproduce the same level of uncertainty in the representation of the AMOC that is achieved by other model types. For the demonstration OSSE, HYCOM was run in its standard configuration with hybrid vertical coordinates with a 30-year climatological spinup followed by a multi-decadal (1948-2004) realistic run forced by monthly-averaged NCEP reanalysis forcing. This run was repeated with the second model configuration (fixed sigma-z coordinates with different vertical mixing parameterizations). Based on inspection of model fields, including the AMOC transport and associated meridional heat flux, the sigma-z run was selected as the nature run and the standard-configuration HYCOM was chosen as the operational model. The multi-decadal run was then repeated using the operational model, but with synthetic satellite altimetry sampled from the nature run assimilated into the operational model. A fixed-basis variant of the SEEK filter was used to perform the assimilation. Figure 1 shows sea surface height (SSH) maps from the end of the three multi-decadal runs. The SSH field from the data-assimilative run displays a pattern that is intermediate between the nature run and the non-assimilative operational

run as expected. Further analysis and evaluation is now being conducted on this first demonstration run before more-optimal OSSEs are designed and executed.

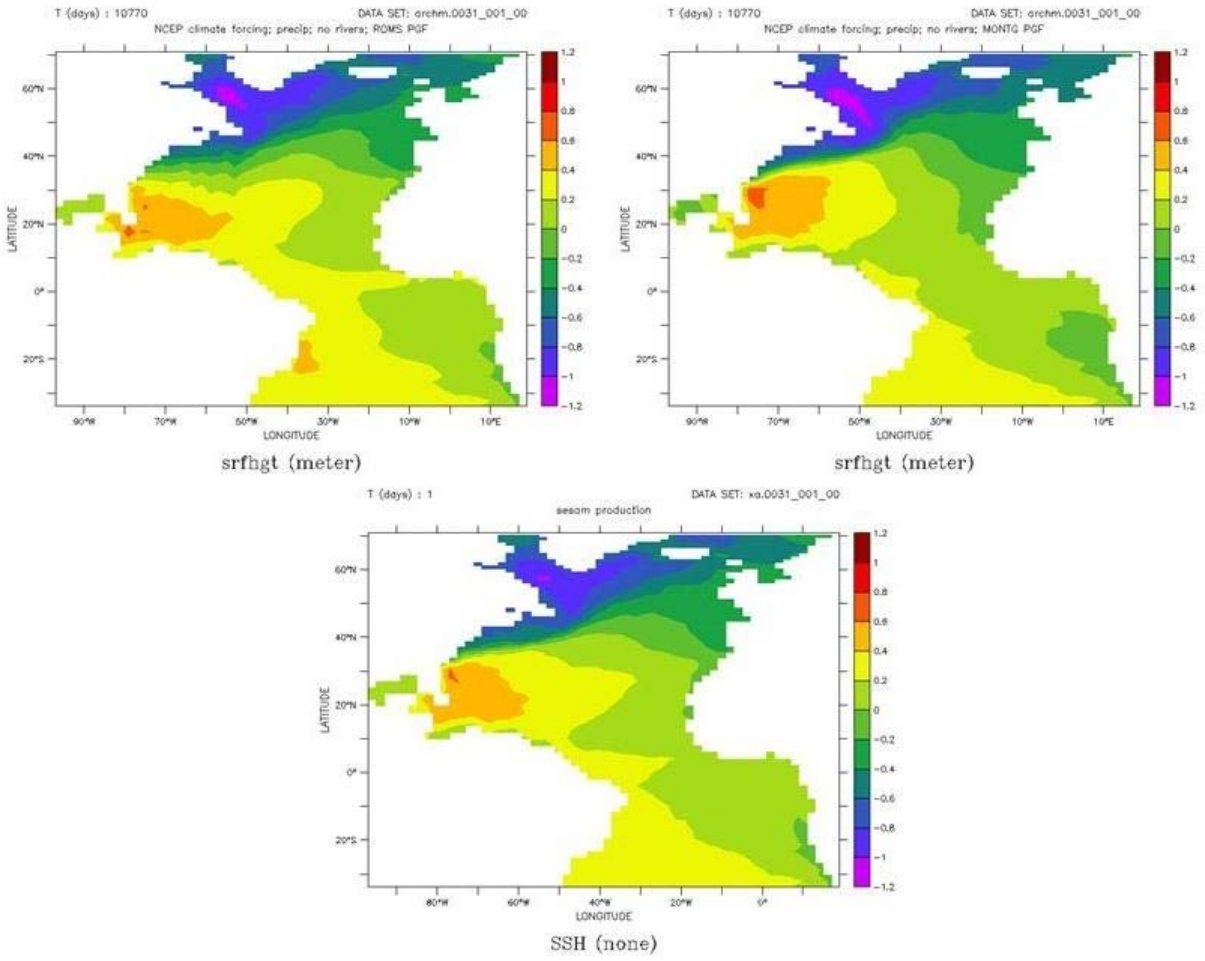


Figure 1: Results from the first test of the SEEK filter data assimilation system on the low-resolution (2-degree) Atlantic HYCOM. The three panels all show sea surface height in meters from the nature run (sigma-z HYCOM; upper left), the operational model run without data assimilation (standard hybrid HYCOM, upper right), and the operational model run with the assimilation of synthetic altimetry data from the nature run (bottom).

Research Performance Measure: We finally achieved our first major goal of conducting a demonstration OSSE that is now under evaluation. During the final year of the project, our goal will be conduct a more-optimal OSSE. For this purpose, a medium resolution (0.72-degree) global HYCOM run is being performed within which we will nest medium-resolution (0.32 to 0.72 degrees) Atlantic basin models for this purpose. These are necessary steps to eventually perform optimal eddy-resolving OSSEs for the purpose of improving our capability to monitor the AMOC.

Developing the Operational Calibration/Validation Components for VIIRS SST Retrievals

R. Evans and P. Minnett (UM/RSMAS)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** To provide consistent, accurate SST fields derived from VIIRS infra-red observations.

***Strategy*:** To incorporate VIIRS data and SST retrievals algorithms in the SEADAS processing framework currently supporting AVHRR and MODIS, acquire radiometric in situ observation to validate VIIRS SST retrievals.

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: NESDIS/DNIP **NOAA Technical Contact:** Heather Kilcoyne

Research Summary:

The VIIRS sensor will be first launched on the NPP satellite in Fall, 2011. Our activities are focused on providing at launch SST retrieval algorithms and associated coefficients based on radiative transfer (RT) code simulations and MODIS-in situ matchups transformed to VIIRS band-pass specifications. Following launch, radiometric measurements of in situ SST will be used to validate VIIRS retrievals. Initial implementation of the VIIRS retrieval codes have been tested using MODIS observations and RT simulations. Initial post launch SST retrieval coefficients will be estimated using the NOAA Optimal Interpolation global SST fields derived from in situ, AVHRR infrared and AMSR microwave retrievals.

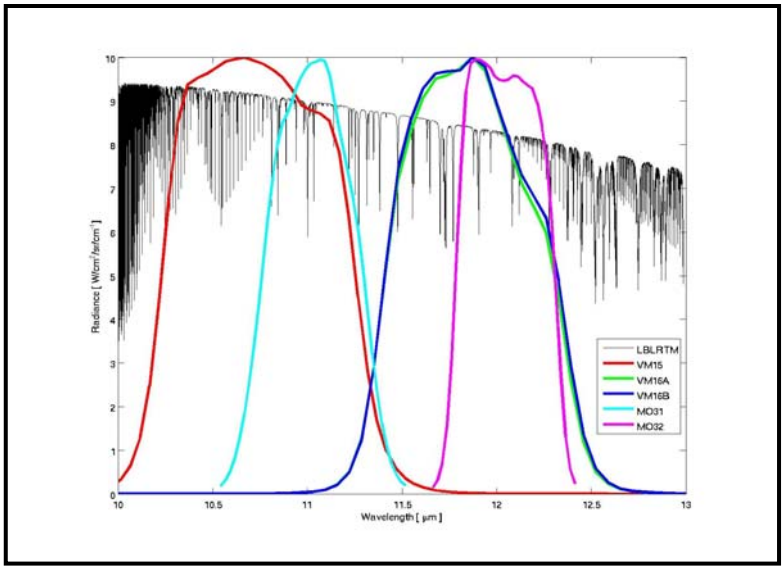


Figure 1. Simulated spectrum of top-of-atmosphere emergent radi-ance (black) for an example marine atmosphere. The AQUA MODIS relative spectral response functions are shown for Band 31 (aquamarine) and Band 32 (purple); and for NPP VIIRS Band 15 (red) and Bands 16 a and b (green and blue).

Research Performance Measure: Delivery of the initial VIIRS algorithms has been completed.

Simulation of the Argo Observing System

I. Kamenkovich (UM/RSMAS); and Z. Garraffo (UM/RSMAS and SAIC)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** To examine how well the Argo observing system determines the state of the global upper ocean, and to understand factors that control accuracy of the reconstruction of the oceanic state.

***Strategy*:** To employ a suite of observation system simulation experiments (OSSE) in ocean general circulation models, to sub-sample oceanic fields in these experiments in ways similar to how the Argo float array samples the ocean, to quantify errors in reconstructions of the oceanic state, and to study factors that control these errors.

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/CPO **NOAA Technical Contact:** Joel M. Levy

Research Summary:

The aim of this study is to evaluate effects of the mesoscale variability on the expected accuracy of reconstruction of temperature, salinity and velocities from the Argo measurements and trajectories. For this purpose, we carried simulations of Argo measurements in: (i) a coarse-resolution global ocean model; (ii) a high-resolution ocean circulation model of the North Atlantic.

In coarse-resolution simulations, we have analyzed the expected accuracy of the Argo system in reconstructing such important oceanographic variables as temperature, salinity, upper ocean heat content and mixed layer depth. For each of the variables, the analysis is carried for the annual-mean values, the amplitude of the annual cycle, and the amplitude of the interannual difference. The results, which demonstrate an overall good performance of the simulated Argo system, but emphasize the importance of sustained measurements in the regions of strong advection, are described in *Kamenkovich et al.* (2009).

The activities during the reported period have been focused on high-resolution simulations (1/8^o resolution in latitude/longitude), which permit simulation of mesoscale eddies. We analyze and contrast simulations with and without mesoscale variability, and explicitly separate the effects of the time-

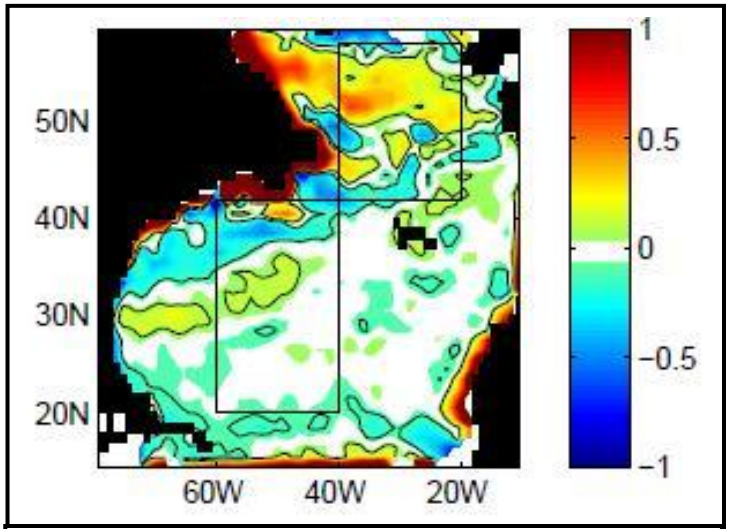


Figure 1: Reconstruction errors – the difference between the reconstructed and actual GCM-simulated values – for the sea-sruface temperature (SST, unit: degrees). The contour interval is 0.05K, the contour lines show the +/-0.1K line.

mean and mesoscale-eddy-induced advection. The results demonstrate that eddies help to achieve more uniform spatial sampling coverage, but can also cause gaps in the coverage due to the dispersion of the floats. The resulting affects of eddy advection on reconstruction errors are complex, but moderate in the most of the domain (Fig.1). High-frequency variability in temperature and salinity leads to enhancement of the reconstruction errors, especially if the Argo sampling is carried only for a few years. Reconstruction of horizontal velocities from profiler trajectories is capable of detecting detailed multiple zonal jets (Fig. 2), but the reconstruction of the meridional velocities is significantly less reliable.

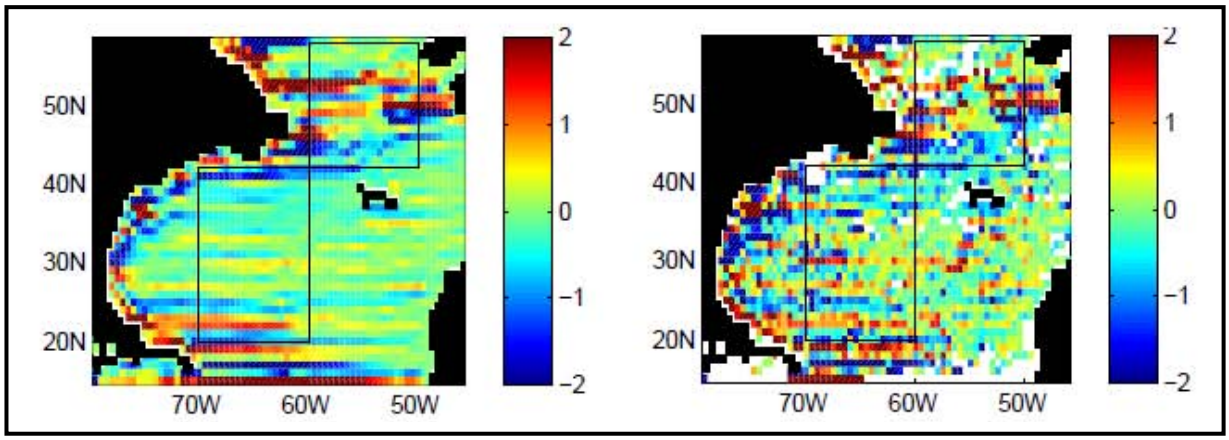


Figure 2: Time-mean zonal velocities at 1500 meter depth on a 1x1-degree grid: a) GCM-simulated values; b) values reconstructed from the float trajectories Units are 10^{-2} m sec^{-1}. Locations with fewer than 5 datapoints (over the 9 year period) are masked (white). Topography is shown at 1500 meter depth.

Research Performance Measure: The project achieves the original objectives, by analyzing the factors that affect the expected accuracy of the Argo-based reconstructions of the oceanic state.

Observing System Simulation Experiments (OSSEs) in the Gulf of Mexico

V. Kourafalou (UM/RSMAS); M. Le Hénaff and P. Ortner (UM/CIMAS)
R. Atlas and G. Halliwell (NOAA/AOML)

Long Term Research Objectives and Strategy to Achieve Them:

Objectives **:** Observing *System Simulation Experiments (OSSEs)* are a tool to evaluate the impact of specific observation systems on our ability to accurately hindcast and forecast important physical processes prior to actually collecting observations. Since observing systems are expensive to deploy and maintain, a-priori understanding of the impact of different observing strategies is a crucial component of NOAA's Integrated Ocean Observing Systems initiative. The goal of the OSSE prototype in the Gulf of Mexico (GoM) is to assess the expected performances of various network systems to monitor the Loop Current (LC) dynamics.

***Strategy*:** The development of high resolution, data evaluated models that can perform reliable simulations of the GoM mesoscale variability and be integrated with observations toward data assimilative forecasts.

CIMAS Research Theme:
***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 an Ecosystem Approach to Management (*Primary*)
***Goal 3*:** Serve Society's Needs for Weather and Water Information (*Secondary*)

NOAA Funding Unit: AOML **NOAA Technical Contact:** Robert Atlas

Research Summary:
This project has focused on the development of a regional ocean OSSE methodology, in collaboration with AOML (R. Atlas and G. Halliwell), where a parallel methodology for large scale (in space and time) ocean OSSEs is being developed. In particular, we advanced a "toolbox" that can be shared by the RSMAS and AOML ocean OSSE research groups and we have been working toward a nature run in the Gulf of Mexico with suitable data evaluation and performance metrics. In addition, this project is connected to an international initiative on nested, data assimilative coastal and regional models, namely the Global Ocean Data Assimilation Experiment (GODAE) through the Coastal and Shelf Seas Task Team activities of the GODAE/OceanView.

The LC is the main dynamical feature in the GoM. It is highly variable in time, from a retracted position where it flows directly from the Yucatan Strait to the Straits of Florida, to an extended position where it flows far north into the GoM before turning southeastward towards the Straits of Florida. When extended, the LC eventually sheds a large, warm-core anticyclonic eddy or ring (Loop Current Eddy, LCE) that drifts westward in the GoM. The LC then returns to its retracted position. This variability appears to be highly determined by the LC frontal dynamics. Small cyclonic eddies at the edge of the LC (Fig. 1) play an active role in the variability of the LC and in the LCE shedding. This role has been highlighted during the recent Deepwater Horizon oil spill, when such a small cyclonic eddy advected pollutants southward, before they were trapped within LCE Franklin that formed at that time. OSSEs need to address a specific question that the monitoring and prediction systems will address. We are interested in better understanding, representing and predicting the interactions between the LC and the frontal eddies, especially during the LCE shedding process.

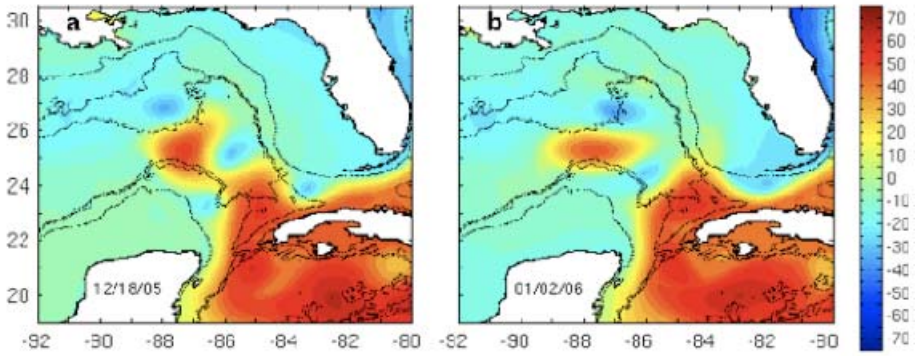


Figure 1: Daily model Sea Surface Height (SSH) on (a) December 18, 2005, (b) January 2, 2006, depicting the synergy between the cyclonic eddies (low SSH, blue colors) and the formation/separation of an anticyclonic Loop Current Eddy (hiugh SSH, red colors). Black dotted lines indicate 200, 2000 and 3000 m isobaths.

To address this issue, we have set up a high-resolution model of the circulation of the Gulf of Mexico (GoM-HYCOM). This model has been run to simulate five years of this circulation, giving us insights on the full 3D dynamics. This has allowed us to better characterize the interactions between the LC and its associated frontal eddies, which lead to the LCE separation from the LC. In addition, an ensemble of 40 simulations with different forcing conditions in the boundary inflow has been run during an LCE shedding episode. This ensemble of simulations has allowed us to understand our model uncertainty regime, associated to the growth of frontal eddies and their migration. Observations from surface drifters in the LC have confirmed some of our results.

In parallel, an advanced data assimilation (DA) scheme has been set up for use with our ocean model. It will be used to integrate simulated observations within the model; this will allow us to assess the expected performance of hypothetical observation networks, thus helping in array design. The networks to be tested will be dedicated to the observation of the LC frontal eddy dynamics.

After the recent Deepwater Horizon oil spill event, we have also performed numerical experiments to model the displacement of water particles initiated at the observed oil spill patch. These simulations are based on the Lagrangian drift module from a tool originally developed to study fish larvae dispersion. We are now working on improving the modeling of the oil within this tool, to better describe the distribution of oil and gas at depth.

Research Performance Measure: The model has been successfully evaluated with several observational data sets. Mean Absolute Dynamical Topography (MADT) maps from Aviso, Reynolds analyzed SST maps from AVHRR and AMSR satellites and NODC/MMS hydrographic data. In addition, a wealth of observations became recently available, as part of academia and government response to the Deepwater Horizon oil spill accident in spring-summer 2010; preliminary evaluation using these data has also commenced.

Integrated Coral Observing Network (ICON) Project

L.J. Gramer, K.P. Helmle, M. Jankulak and D.P. Manzello (UM/CIMAS)
J.C. Hendee, M. Shoemaker and J. Craynock (NOAA/AOML)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** To: 1) Facilitate *in situ* observations at coral reef areas, 2) integrate *in situ*, remote-sensing, and other environmental data so as to better understand the physical and biogeochemical processes that affect the health and life cycles of organisms in the reef ecosystem, 3) compile ecological forecasts for coral reef ecosystems to help to understand them, and to aid in decision support for Marine Protected Area management.

***Strategy*:** Construct and operate meteorological and oceanographic monitoring platforms near key coral reef areas; provide data archiving and artificial intelligence tools to facilitate the acquisition and integration of high-quality data from these and other reef areas worldwide; and, enable rapid

science-based assessment of the physical and biogeochemical environment at these reefs. Such an assessment will enable better ecosystem-based management of resources.

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 an Ecosystem Approach to Management.

NOAA Funding Unit: CRCP and AOML **NOAA Technical Contact:** J.C. Hendee

Research Summary:
Through continuous data collection, real-time monitoring, and ongoing research, ICON provides scientists and managers with data critical to understanding the complex physical, chemical, and biological processes influencing coral reef ecosystems. For the 2009-2010 year, the ICON project has focused its efforts in two existing areas of research, and three new areas. Ongoing research topics are: (1) development and field verification of real-time inference models about ecological and physical events on the basis of integrated *in situ* and remotely sensed data; and (2) continued deployment of new, and maintenance of existing stations and *in situ* sensors, with emphasis on field-testing and integration of innovative sensor technologies. Research areas that are new for the project as of FY2010 are, (3) field and paleo-climate research on the effects of ocean acidification (OA) on reef building and loss; (4) analysis of long (decadal) time records of coral growth and physical environmental variables, for evidence of climate impacts on coral reef ecosystems; and (5) research on dominant physical forcing processes for sea temperature variability on shallow reefs. ICON/CREWS stations continue to operate at Salt River, St. Croix in the U. S. Virgin Islands ("SRVI2") and La Parguera, Puerto Rico ("LPPR1"). This year ICON installed a new ICON/CREWS station in the Cayman Islands, working in close cooperation with the Central Caribbean Marine Institute (CCMI). The new station, designated "LCIY2", is situated just off the north coast of Little Cayman, adjacent to the Bloody Bay Marine Park. The station has now been continuously transmitting since July 2009, and these near real-time data are shared with both the Cayman Islands Weather Service and US National Weather Service (please see Fig. 4). A bottom plate was placed, and a new station pylon and suite of monitoring instruments have been configured and shipped to Saipan, awaiting final deployment of ICON/CREWS station "LLBP7" at a site in Laolao Bay on the southeastern coast of Saipan (15N, 146E) in fall/winter of 2010. Additional *in situ* reef monitoring stations continue to be jointly operated by ICON and the Florida Institute of Oceanography SEAKEYS project at Molasses Reef in Florida Keys National Marine Sanctuary (FKNMS); by ICON, SEAKEYS and the NOAA Great Lakes Environmental Research Lab (GLERL) at Tennessee Reef in FKNMS; and by ICON and the AOML Florida Area Coastal Environment (FACE) project in Port Everglades inlet, Broward County, Florida. The existing station at Tennessee Reef and that being deployed in Saipan both make novel use of 2G/3G cellular communications for increased bandwidth. The result of this innovation is a richer set of environmental monitoring data, delivered in a more timely and reliable way, than has been done on U.S. coral reefs to date. A further cooperative effort between ICON and the NOAA Pacific Marine Environmental Laboratory (PMEL) has continuously operated a Moored Autonomous Profiler for Carbon Dioxide (MAPCO2) buoy at the La Parguera embayment since January 2009. Combined with physical sensors deployed at the LPPR1 ICON/CREWS station nearby, this system provides

both extended and near real-time data, for modeling and process studies of ocean acidification and its impact on coral reef ecosystems. Finally, data acquisition and collection procedures have now been normalized at all ICON stations, allowing near real-time quality assurance and archiving of ICON data by the NOAA National Data Buoy Center. This has now facilitated use of these data by the National Weather Service and other entities in numerical modeling and forecasts, and by the satellite research community in "match-ups" for remote sensing algorithm verification.

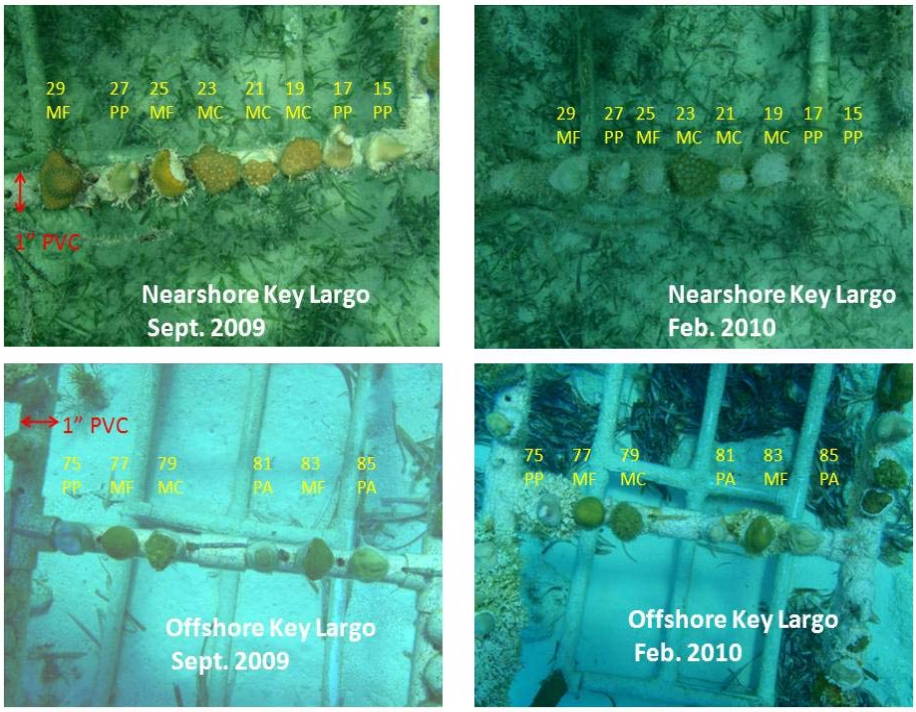


Figure 1: Corals deployed for repeat calcification measurements at nearshore patch reef and offshore coral reef off Key Largo. Due to unseasonably cold weather in the winter of 2010, 78% of the 36 deployed corals at this nearshore site died. Note that only one coral colony is still alive in upper right image. Conversely, just 5% or two (2) of the 40 individual corals at an adjacent site just offshore suffered mortality.

Research utilizing data from ICON/CREWS and SEAKEYS stations has progressed in 2009-2010. Biological monitoring of coral reefs at each CREWS and SEAKEYS site continues to form an integral part of the ICON mission, with both visual and photographic surveys, and beginning with this year, field experiments in the Florida Keys and Puerto Rico, throughout the year (please see Figs. 1 and 2). Furthermore in 2009, research into oceanographic and air-sea pro-cesses impacting the coral reef environment over time scales from hourly to interannual was under-taken by the ICON team. A coastal ocean heat budget modeling reef sea temperature variability based on air-sea fluxes and small-scale dynamical pro-cesses has been developed with promising initial results for SEAKEYS sites in the Florida Keys (please see Fig. 3). Development has also continued on the suite of data integration and ecological forecasting tools for researchers, with stable releases in 2009-2010 of both a MATLAB toolkit for environmental data analysis and ecoforecast model development, and

of ICON/G2, an expert systems platform designed to implement ecoforecast models in a quasi-operational mode. These tools combines station observations from instruments such as multi-spectral light, meteorological, ocean-current and hydrographic instruments, with data from remote sensors including NOAA GOES, MODIS, AVHRR, AMSR-E, TRMM and the WERA High Frequency ocean surface current radar. The resulting high spatio-temporal resolution, near real-time integrated data streams are used to predict conditions conducive to coral bleaching, to upwelling and other hydrodynamic events affecting ecosystem productivity, and to reproductive activities of corals and other reef organisms such as coordinated spawning. These ecological forecasts are then distributed via email to researchers, and Marine Protected Area managers, and to the public via the Web site http://ecoforecast.coral.noaa.gov. Continuous collection of baseline data, combined with real-time monitoring tools allow 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. Another ongoing collaboration between ICON and RSMAS and industry remote sensing researchers, is the development of a Multi-sensor Improved Sea Surface Temperatures (MISST) product, using optimal interpolation and diurnal warming models to estimate daily sub-surface sea temperature profiles on coral reefs. This project is funded by the NASA National Oceanographic Partnership Pro-gram (NOPP) for FY2010 and FY2011.

Figure 2: Thriving Pacific coral reef ecosystem within Laulau Bay, Saipan/CNMI, near the site of a new ICON/ CREWS autonomous reef monitoring station planned for deployment in 2010. ICON monitoring activities at this site, together with those already ongoing at Little Cayman in the Caribbean, will provide insight into the environmental parameters dominant in relatively undisturbed, so-called baseline coral reef ecosystems.

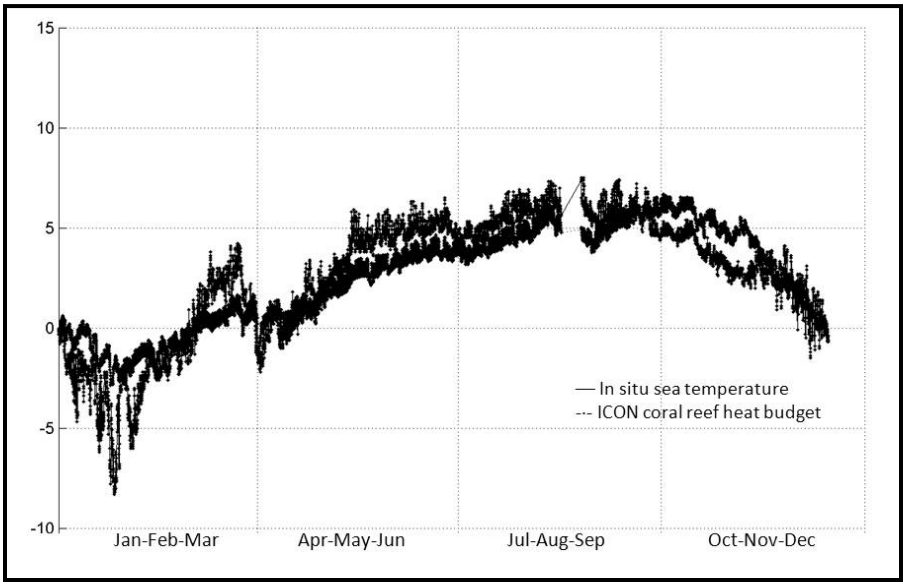


Figure 3: Oceanic heat budget for 2003 at the SEAKEYS reef monitoring station on Sombrero Key Reef, Florida, with comparison to quality-controlled, hourly *in situ* sea temperature variability. The heat budget models sea temperature variability by combining *in situ* data with products from high-resolution regional atmospheric reanalysis, ocean modeling, and satellites. Turbulent fluxes are estimated with TOGA-COARE 3.0a bulk algorithms, while a small-scale *horizontal convective* process – not previously reported in reefs of Florida or the Caribbean – is modeled using the scaling analysis of Monismith et al. (2006).

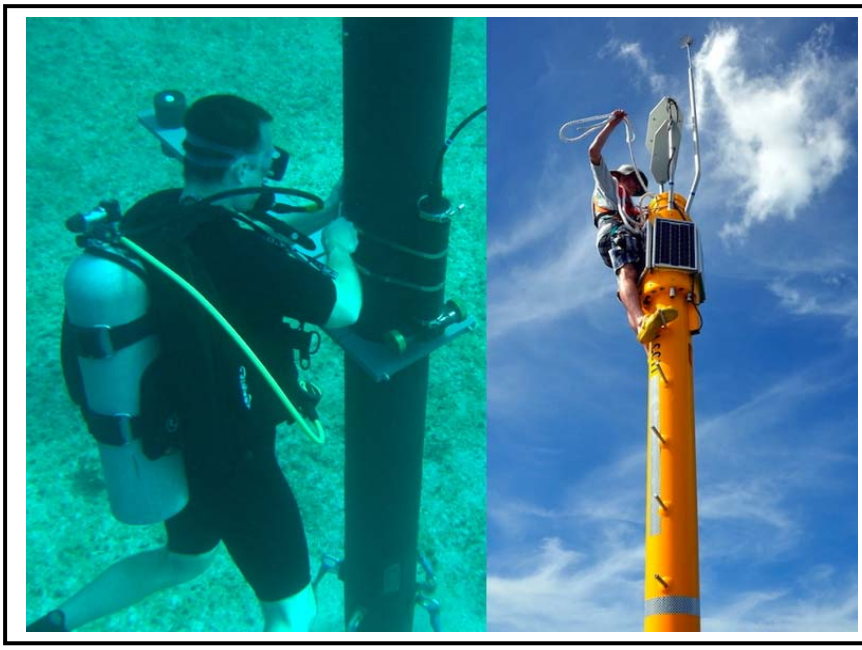


Figure 4: CIMAS researchers install monitoring instruments on the new Little Cayman ICON/CREWS station "LCIY2".

Research Performance Measure: All objectives were reached.

The CLIVAR CO_2 Repeat Hydrography Program

K. Sullivan, G. Berberian and Geun-Ha Park (UM/CIMAS)
C. Langdon (UM/RSMAS); R. Wanninkhof (NOAA/AOML)

Long Term Research Objectives and Strategy to Achieve Them:

***Objective*:** To determine decadal changes in ocean interior and to constrain ocean CO_2 inventories to 2 Pg C/ decade.

***Strategy*:** To reoccupy transects on a decadal timescale to quantify the uptake of anthropogenic CO_2 by the ocean.

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/CPO **NOAA Technical Contact:** Joel Levy

Research Summary:

The CLIVAR/CO_2 Repeat Hydrography Program is a global re-occupation of select hydrographic sections to quantify changes in storage and transport of heat, fresh water, carbon dioxide (CO_2), oxygen, nutrients, chlorofluorocarbon tracers and related parameters. The effort started in 2003 and to date, sections have been completed in the Atlantic, Pacific and Indian Ocean.

Data from these cruises are being compared to data from previous surveys (e.g., World Ocean Circulation Experiment (WOCE)/Joint Global Ocean Flux Survey (JGOFS) during the 1990s) to measure changes in the physics and biogeochemistry of the oceans, and to determine where/how much excess atmospheric CO_2 is entering the oceans on decadal timescales. The program is designed to assess changes in the ocean's biogeochemical cycle in response to natural and/or man-induced activity. Global warming-induced changes in the ocean's transport of heat and freshwater, which could affect the circulation by decreasing the thermohaline overturning, can be followed through long-term interior measurements. The program also provides data for continuing model development that will lead to improved forecasting skill for oceans and global climate. During FY-2010 we completed occupation of a meridional line in the Atlantic from 5° N to 54° S (A-13.5) with full physical and chemical characterization of 129 water column profiles. Kevin Sullivan and Geun-Ha Park were responsible for the discrete pCO_2 measurements on the cruise, quality control and data reduction. A contoured cross-section is shown in Figure 1. Chris Langdon and George Berberian performed all the oxygen analysis and the results are presented in Figure 2.

In order to assess the impact of fossil fuel CO_2 on climate, we must be able to make an accurate inventory of the carbon stored in the atmosphere and the oceans. The most robust way to accomplish this goal is by measuring changes in atmospheric and ocean carbon inventories over time to quantitatively track the changes in these two reservoirs. While atmospheric changes have been accurately measured for many decades, this has not been possible for the oceans until now. In our program we have been able to accurately quantify the changes in the water column carbon in the Atlantic, Pacific, and Indian oceans by comparing data from recent cruises with those from WOCE

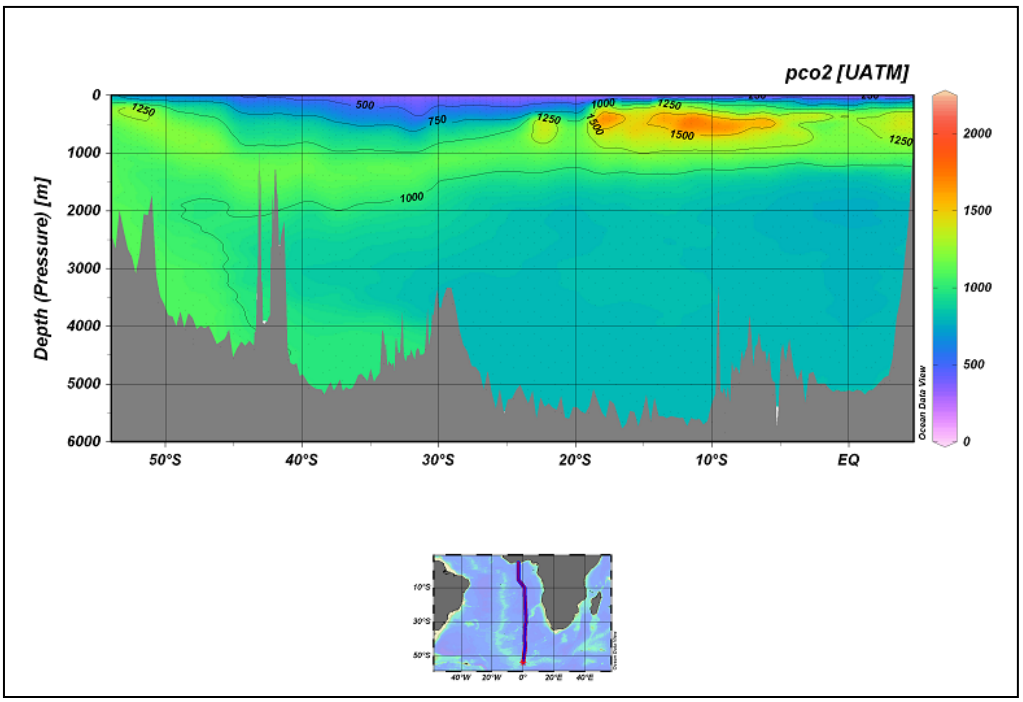


Figure 1: Section of partial pressure of CO_2 at 20˚C ($pCO_2(20)$) (µatm) nominally along the prime meridian in 2010. The cruise was part of the CLIVAR/CO_2 Repeat Hydrography program.

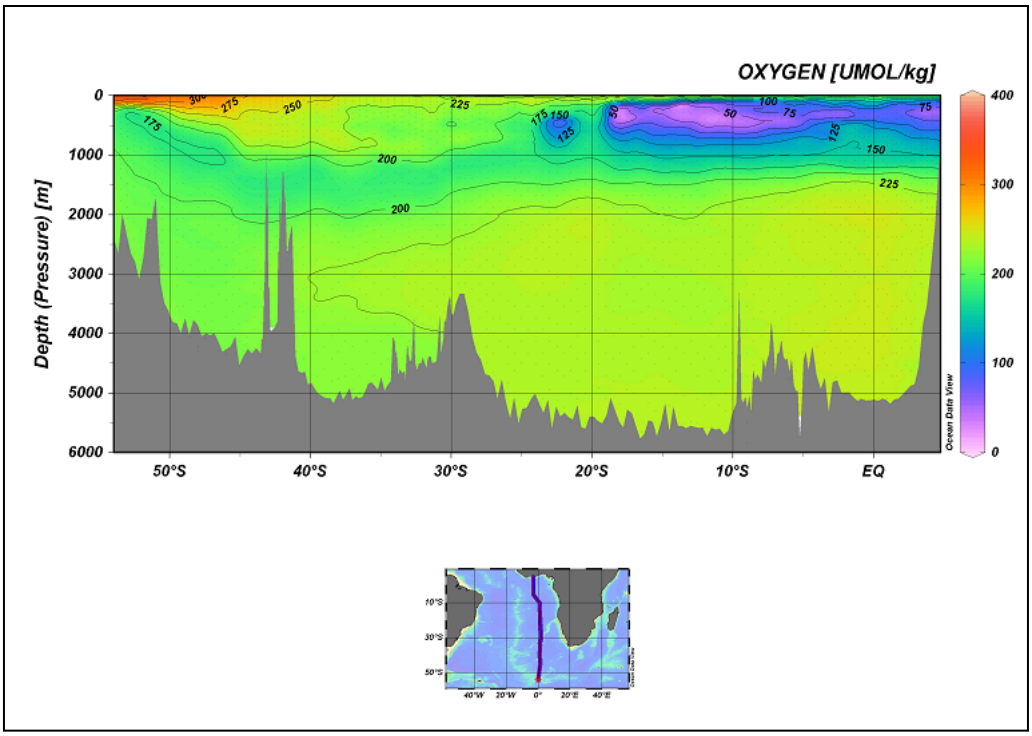


Figure 2: Section of oxygen concentration (O_2) (µmol kg^{-1}) nominally along the prime meridian in 2010. The cruise was part of the CLIVAR/CO_2 Repeat Hydrography program.

cruises that occupied the same transect lines in the late 80's and early 90's. Besides clearly showing the anthropogenic CO_2 input, our data also shows large changes in the biogeochemical properties of the upper water column. The estimated changes in anthropogenic carbon inventory in the Atlantic Ocean are shown in Table 1. These values will be updated based on the recently completed cruise A13.5 described above. The large uptake in the Atlantic corresponds to the downwelling component of the Meridional Overturning Circulation (MOC) that enhances transport of carbon into the deep waters.

Table 1. Comparison of Specific Inventories for the Atlantic Ocean along the A16 Section (64°N-54°S) in mol m^{-2} a^{-1} (from Wanninkhof et al. 2010)

Method	N. Atlantic	Eq. Atlantic	S. Atlantic	Full Section
	(> 15°N)	(15°N-15°S)	(> 15°S)	
ΔDIC	0.82	0.23	0.56	0.58
ΔDIC_{O2}	0.92	0.60	0.86	0.82
ΔDIC_{NO3}	0.59	-0.28	0.66	0.39
ΔDIC_{eMLR}	0.59	0.68	0.78	0.68
$\Delta DIC_{eMLR\text{-}sectional}$	0.69	0.17	0.96	0.65
$\Delta DIC_{eMLRdens}$	0.57	0.20	0.76	0.53
$\Delta DIC_{C\text{-}13}$[a]	0.63 ± 0.16			
ΔDIC[b]			0.71 ± 0.1	

[a]From *Quay et al.* [2007].

[b]From *Murata et al.* [2008]: From the zonal A10 cruise along 30°S, between 35°W-15°W, 1993-2003

Research Performance Measure: The Repeat Hydrography Sections are progressing according to timeline of the CLIVAR CO_2 Repeat Hydrography Committee (http://ushydro.ucsd.edu/cruises). Our performance measure has been augmented in that we are actively interacting with modelers at Princeton, GFDL and WHOI to compare our observed decadal changes with model trends.

Biogeochemical Measurements

C. Langdon (UM/RSMAS)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** To: 1) Determine decadal changes in ocean interior and to constrain ocean CO_2 inventories to 2 Pg C/ decade. 2) Determine decadal changes of dissolved oxygen in the ocean interior in response t

***Strategy*:** Reoccupy transects on a decadal timescale and use the observed changes in dissolved oxygen and nutrients to determine what fraction of the observed change in dissolved inorganic carbon is due to natural processes and what is due to invasion of anthropogenic CO_2.

CIMAS Research Themes:

***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/CPO **NOAA Technical Contact:** Mike Johnson

Research Summary:

This project encompasses the participation of Dr. Langdon on A13.5 Cape Town to Accra, Ghana cruise that is separately detailed in CIMAS project "The *CLIVAR CO_2 Repeat Hydrography Program"*. The background on this project and the highlights from 2010 can be found in corresponding sections of this report. Specifically this project supports Dr. Langdon to oversee the dissolved oxygen measuring capacity of the Ocean Chemistry Division of AOML. This involves the maintenance of the equipment, chemicals and calibrated flasks, the training of personnel, processing and QCing of the data, reporting the final data and going to sea to assist in the sampling. Dissolved oxygen is proving to be sensitive indicator of the effects of climate change on the ocean. Changes in ocean circulation, ventilation of subsurface waters, changes in biological productivity and remineralization all impact the dissolved oxygen concentration of a parcel of water. Estimates of the amount of dissolved inorganic carbon taken up since the start of the industrial revolution (so called anthropogenic carbon) requires precise measurements of dissolved oxygen and nutrient concentrations. In 2008 two publications resulted from this research (Sabine et al. 2008, Mecking et al. 2008). In 2010 Dr. Langdon wrote a chapter on the measurement of dissolved oxygen using the amperometric endpoint method for the new GO-SHIP Hydrographic Methods Manual that is intended to supplant the 15 year old WOCE Hydrographic Methods Manual.

Research Performance Measure: This program is attaining all its goals on schedule.

Surface Water pCO_2 Measurements from Ships

F.J. Millero (UM/RSMAS); K. Sullivan, D. Pierrot, J. Trinanes, F. Bringas, G.-H. Park and S. Pochan (UM/CIMAS); R. Wanninkhof and G. Goni (NOAA/AOML)

Long Term Research Objectives and Strategy to Achieve Them:
***Objectives*:** Constrain regional air-sea CO_2 fluxes to 0.2 Pg C/yr
***Strategy*:** Sustained observations using automated pCO_2 systems on ships of opportunity

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: COD **NOAA Technical Contact:** Joel Levy

Research Summary:
The ship-based surface pCO_2 program is designed to provide sustained measurements of regional oceanic carbon sources and sinks on seasonal timescale by measuring surface water and marine boundary pCO_2 on ships of opportunity. It is a collaboration of investigators at the NOAA laboratories AOML and PMEL; and the following academic institutions: Columbia University, the University of Miami, and the Bermuda Institute of Ocean Sciences. 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. The near-term focus is on development of the Northern Hemisphere ocean carbon observing system, which is closely linked to anassessment of the carbon dioxide sources and sinks over the coterminous United States through the North American Carbon Program (NACP). In FY-10, the NOAA funded participants maintained instrumentation and reduced data from twelve ships and posted the data. Flux maps, based on extrapolation routines using remotely sensed wind and sea surface temperature (SST) have been created to estimate global seasonal air-sea CO_2 fluxes (Fig. 1).

An increasing emphasis is put on observations in marginal seas as the fluxes in these regions are very poorly constrained. To address this, new generation pCO_2 systems were installed on the methanol carrier LAS CUEVAS and container ship BARCELONA EXPRESS. They are currently making measurements in the Atlantic Ocean, Caribbean Sea, and Gulf of Mexico.

An appreciable focus continues to be global coordination of similar efforts. We have taken the lead in providing uniform autonomous instrumentation for installation on ships of opportunity. Through a successful technology transfer and continued guidance, General Oceanics, Inc. in Miami is now producing units for the community at large. We also are leading an effort for uniform data quality control procedures and data reduction that now is used as a standard for the International Carbon Coordination project (IOCCP) of UNESCO/IOC. A major product, the Surface Ocean Carbon Atlas (SOCAT) containing over 6 million pCO_2 data points, is slated to be released in the fall of 2010. Our NOAA funded effort is the single largest contributor of data to SOCAT.

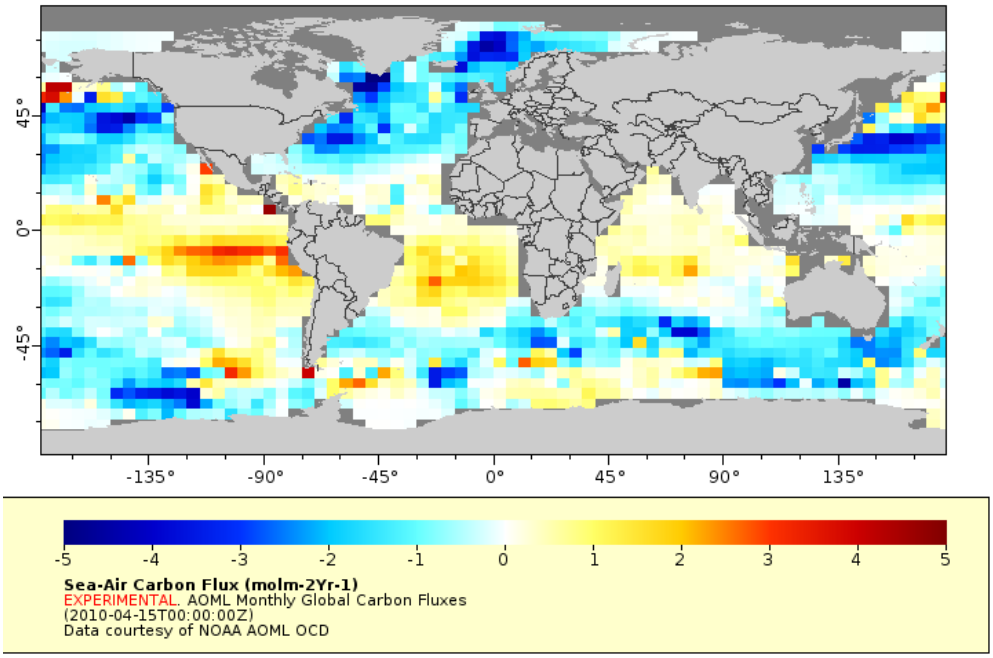


Figure 1: Air-sea CO_2 flux map for April 2010 using the algorithms described in Park et al. 2010.

As part of the effort, improvements in auxiliary data such as sea surface temperature (SST) and sea surface salinity (SSS) from thermosalinographs (TSG) have been made. Currently as part of this project, the NOAA ships BROWN and GUNTER, and the container ship BARCELONA EXPRESS are transmitting TSG data. The NOAA ship BROWN also sends complete daily files of pCO_2 to shore via internet.

Research Performance Measure: Create flux maps of the Global oceans. Assess seasonal variability of air-sea CO_2 fluxes.

Global Carbon Data Management and Synthesis Project

F.J. Millero, F. Huang and G. Ingram (UM/RSMAS); K. Sullivan, D. Pierrot, J. Trinanes, F. Bringas and G.-H. Park (RSMAS/CIMAS); R. Wanninkhof and T.-H. Peng (NOAA/AOML); C.L. Sabine, R.A. Feely and S. Hankin (NOAA/PMEL); A. Kozyr (CDIAC); R. Key (Princeton); A. Dickson (UCSD)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** NOAA's Office of Climate Observations (OCO) funds researchers from NOAA laboratories, Pacific Marine Environmental Laboratory (PMEL) and Atlantic Oceanographic and Meteorological Laboratory (AOML), as well as the Carbon Dioxide Information Analysis Center,

Princeton University, University of California San Diego and the University of Miami to participate in a project to manage, synthesize and interpret data in an endeavor to understand how the ocean carbon cycle changes over time. NOAA's Office of Climate Observations (OCO) oversees this group project and recognizes the need for proper data management and synthesis.

***Strategy*:** As a member of this global carbon data management and synthesis project, principal investigators participate in national and international planning efforts to evaluate and improve the global ocean observing system. The principal investigators of this multi institutional project gather data and bring it together. They collaborate to discuss and provide tools and methods to manage the data, insure accuracy and facilitate easy access.

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/CPO

NOAA Technical Contact: Mike Johnson and Joel Levy

Research Summary:

The goal of the Global Carbon Data Management and Synthesis Project is to work together with the OCO carbon measurement projects to take the fundamental carbon observations and turn them into products that are useful for scientists and the public for understanding the ocean carbon cycle and how it is changing over time. This effort ranges from ensuring that the observations are of the highest quality and are mutually consistent with each other to combining the observations into a common data set that is available and easy for the community to use and explore to evaluating the time rate of change in global ocean carbon uptake and storage. This project brings together ocean carbon measurement experts, information technology experts and data managers to ensure the most efficient and productive processing possible for the OCO carbon observations.

Millero and Huang (2009) have made new measurements to expand the equation of state of seawater to a wider range of temperature and absolute salinity. A new equation of state has been used to calculate a number of thermal and caloric parameters. Safarov et al. (2009) present new (p, p. T) measurements for standard seawater samples over the extended temperature interval (T=(273.14 to 468.06)K and for pressure up to p=140 Mpa. The results are used to derive an equation of state of seawater that is valid for higher temperatures and pressures than previously possible. The new equation of state puts all of the physical properties in one equation. This makes it convenient for modelers to calculate various properties of seawater.

Spectroscopic measurements of the pH in NaCl brines were made by Millero et al. (2009) in an article in *Geochimica et Cosmochimica Acta*. In another publication, South Pacific Ocean waters were examined on the P18 CLIVAR (Climate Variability and Predictability) cruise to determine the effect of composition on the density of the waters (Millero et al., 2009).

Millero (2010) published a paper on the carbonate constants for estuarine waters. Another by Millero and DiTrolio (2010) will be published in October on the effects of ocean acidification due to CO_2 dissolution in *Elements*.

A RSMAS cruise report on the pH and total alkalinity measurements in the Pacific Ocean P18 was prepared and the data was sent to CDIAC for standardization of all measurements. CDIAC has prepared a report from all the participating investigators on the chemical data obtained during the *R/V Knorr* Repeat Hydrography Cruises in the North Atlantic Ocean during 2003. The report is a compilation of all the data obtained during the cruise and briefly describes the methods of obtaining data consistent with community standards, issues with the data and the resulting quality data.

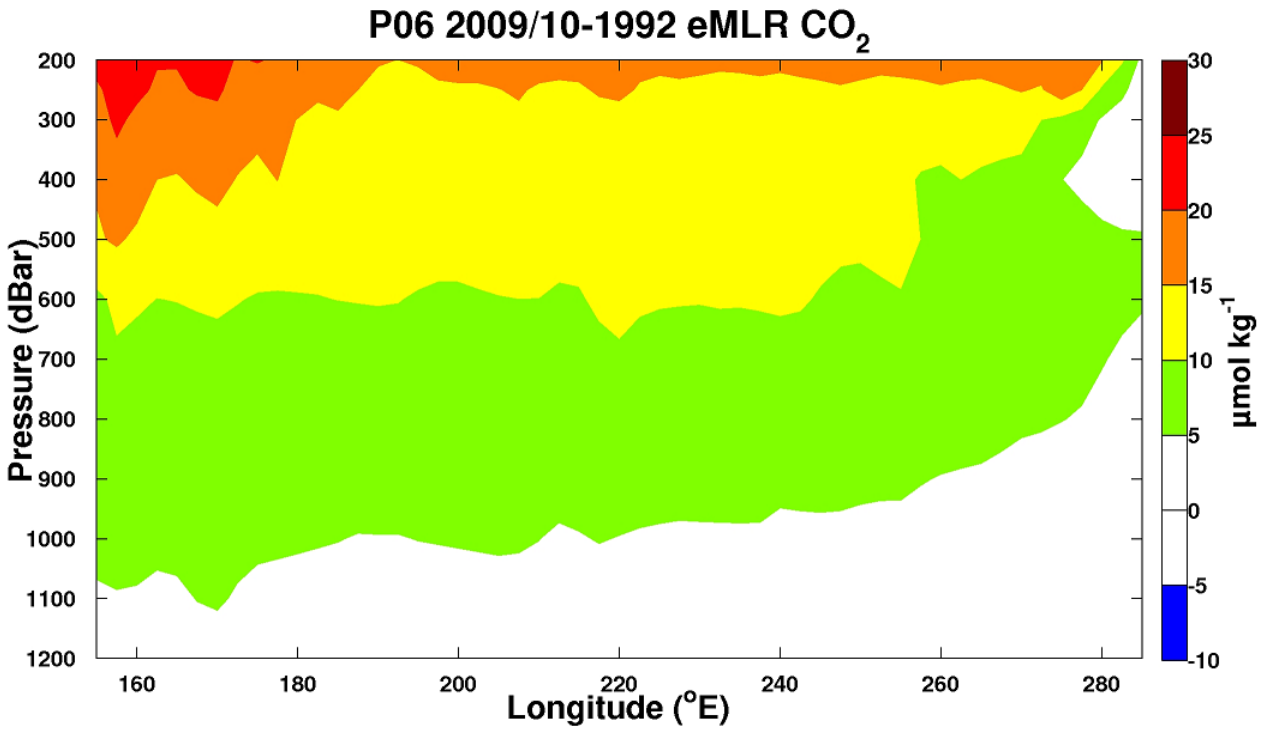


Figure 1: Accumulation of anthropogenic CO2 on P06, along 32oS in the Pacific, from WOCE, 1992, to CLIVAR, 2009/10.

Research Performance Measure: All objectives have been met.

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

C. Chen, S. Dong, E. Forteza, V. Halliwell, L. Lin and R. Sabina (UM/CIMAS)
S.L. Garzoli, E. Ramos and C. Schmid (NOAA/AOML)

Long Term Research Objectives and Strategy:

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 aintenance of an array 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:** Claudia Schmid

Research Summary

The Argo array is part of the Global Climate Observing System/Global Ocean Observing System (GCOS/GOOS). Argo profiling floats 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, including meteorology, climatology and oceanography, use data collected from the floats. The Argo array achieved its goal of a total of 3000 floats in November 2007 and is maintaining the number of floats.

The US Argo Data Assembly Center (US DAC) at AOML is responsible for deploying floats, and for acquiring and processing the data. We have 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:

- 265 floats were deployed by the USA
- 38 of these floats were deployed by AOML
- 2156 US floats are actively reporting.
- 71919 profiles have been sent to Global Data Centres
- 55084 profiles were sent to GTS by the US DAC
- US DAC is processing 84 Argo-equivalent floats (i.e. not funded by Argo) from different institutions and organizations (Florida State University, NAVOCEANO, University of Hawaii); 5 floats were donated to Kenya.

The US DAC is maintaining a website: http://www.aoml.noaa.gov/phod/argo/index.php that provides documentation and information about the operations at the US Argo DAC.

The quality control steps are nearly finalized. All Argo profiles undergo the standard scientific Delayed-mode Quality Control (DMQC) process, which is performed at the institution that provided the float. The last stage of the quality control (Post-DMQC) is based on various consistency checks and is intended to identify profiles or even entire floats that may need further attention. This Post-DMQC analysis involves comparing each Argo profile to four separate data sets: 1) the monthly Levitus World Ocean Atlas 2005 climatology, 2) the Navy GDEM3 ocean climatology, 3) a monthly climatology composed from the global monthly means of Argo-derived temperature and salinity (from 1992 forward), and 4) a data set consisting of all available temperature and salinity profiles from all sources (CTD, XBT, Argo profiles, etc.), where each Argo profile is compared to any other profile in close proximity (~100km in space and 10 days in time). These comparisons are made at multiple levels from 400m to 2000m, and are used to derive difference statistics for each float. A set of web pages is used to display time series of the difference statistics, profiles and their location for each float, and individual profiles together with the profiles are then used in the comparisons. Summary plots compare overall statistics from all floats, highlighting floats that may have larger deviations from the comparison data sets with or without time dependence. The latter could be caused, for example, by inadequate correction of sensor drift. This quality control system will facilitate the detection of floats with potentially erroneous corrections performed during the DMQC.

Also during this last year, a new product was added to the products web page of the South Atlantic Regional Argo Center (http://www.aoml.noaa.gov/phod/sardac/products/index.php). It depicts annual and semi-annual sections of temperature, salinity and dynamic height at every 5 degrees of latitude between 45S and 20N together with maps of the profile positions (Fig. 1).

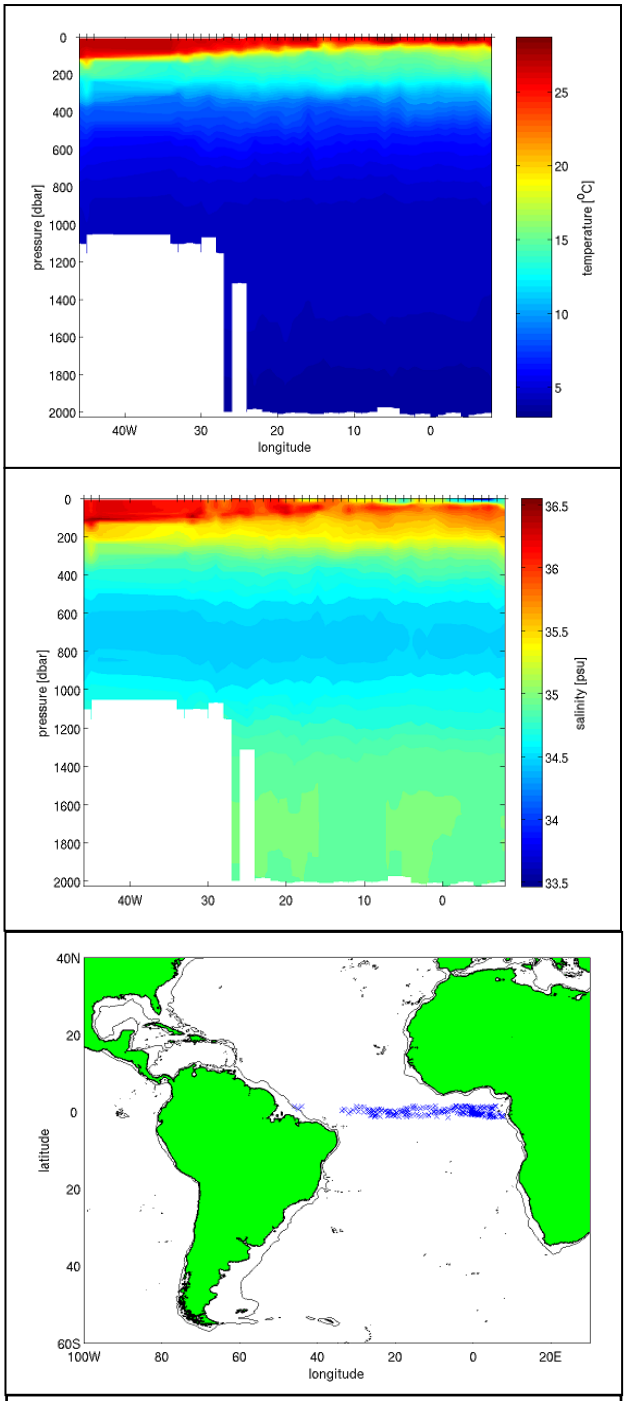


Figure 1: Annual mean temperature and salinity section across the Atlantic at the equator. The map shows the positions of the profiles used to generate the section. from WOCE, 1992, to CLIVAR, 2009/10.

Quality controlled Argo profiling data are used to calibrate thermosalinograph (TSG) data. Float data have to be measured within one week and 150km distance from the TSG measurement for this purpose. These data and that from other instruments are then used to study the mixed layer salinity in the eastern tropical Atlantic. Figure 2 shows the mean distribution of the mixed layer salinity as well as the standard deviation, as derived from data collected in 2006 to 2009. Relatively low salinity predominates around 5N, with the lowest values near Africa (at about 10W). In the former area which is strongly influenced by the annual migration of the Inter-tropical Convergence Zone (ITCZ) the standard deviation of the salinity is very high, as expected. In the latter area the standard deviation is quite low, thus indicating that the annual migration of the ITCZ has little impact in this region.

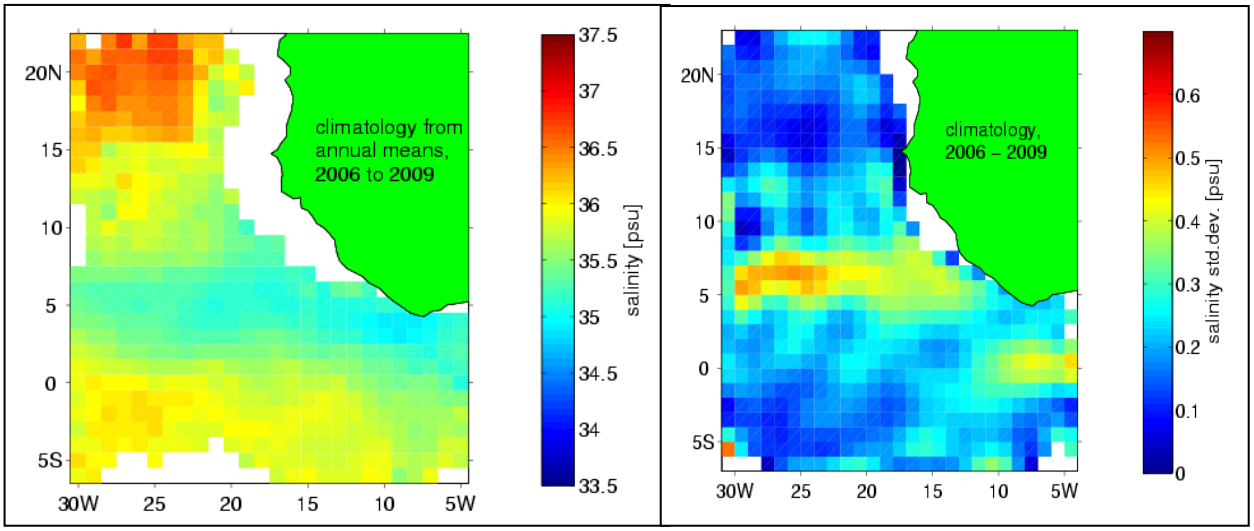


Figure 1: Mean mixed layer salinity (top) and standard deviation (bottom) based on Argo and other profiles collected in 2006 to 2009.

The time series derived from these data shows clearly that the salinity has a minimum in about 3-8N that is strongest in the fall (Figure 3). A secondary minimum exists in late spring. The minimum in fall is significantly stronger in 2006 and 2008, when compared with 2009 and (to a lesser extent) with 2007. North and south of this minimum the annual cycle is weaker, with a minimum in spring near the equator and a winter minimum near 15N.

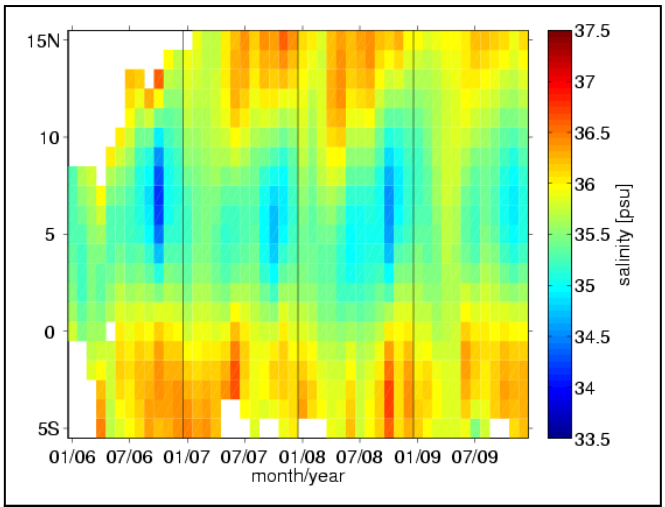


Figure 3: Latitude-time diagram of the mixed layer salinity at 23W based on Argo and other profiles.

Most seasonal-to-interannual variations in the ocean are confined to the upper 1,000 m. Thus, a combination of the monthly temperature/salinity maps from Argo floats and sea surface height (SSH) from satellite altimeter provides the potential to estimate the net northward heat transport. Willis and Fu (2008) have shown that altimeter SSH

anomalies and the anomalous subsurface velocity are strongly related. We are using the Argo temperature/salinity maps to examine the seasonal-to-interannual variations in the AMOC and northward heat transport and contributions from various processes (Ekman, geostrophic, overturning, and horizontal circulations). Our analysis will yield an assessment of the extent to which the sustained large-scale long-term observational projects can be used in AMOC-related studies. Our preliminary tests at 33°S suggest some promise with regard to determining the AMOC and the net northward heat transport from the monthly Argo climatology (Fig. 4). The seasonality of both the AMOC and northward heat transport derived from the Argo temperature and salinity climatologies are consistent with those from high-density XBT measurements along AX18 (Dong et al., 2009).

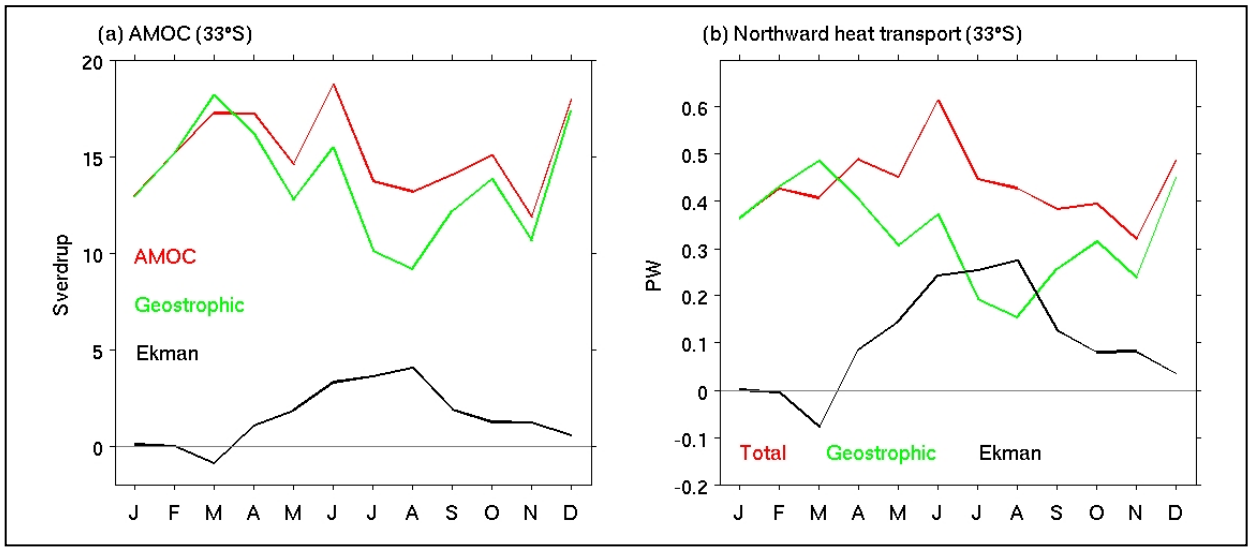


Figure 4: Monthly variations in (a) the strength of the AMOC (red) and contributions from the geostrophic (green) and Ekman (black) components, and (b) the net northward heat transport (red) and contributions from the geostrophic (green) and Ekman (black) transports at 33°S derived from the Argo temperature and salinity monthly climatologies.

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

Automating Explorer-of-the-Seas Oceanographic and Meteorological Sampling: the Next Generation "Ship of Opportunity".

P. Ortner and K. Sullivan (UM/CIMAS); S.Cummings (NOAA/AOML)
R. Findley and E. Williams (UM/RSMAS)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** The extensive regions of the ocean interior continue – despite their enormous climate and biochemical importance - to be extremely difficult to probe and monitor on a regular basis due to the high cost of research vessels and fixed moorings, and hence the very low density of marine measurements, especially in horizontal dimensions. Measuring ocean currents, temperature, and a wide suite of biochemical properties concurrently at high resolution in the horizontal remains a fundamental challenge. The objective of this project is to explore the potential of an alternative approach to sampling the ocean.

***Strategy*:** The solution is to develop mechanisms of sampling along cruise tracks during the regular course of business of cruise and merchant ships plying regular routes and this requires new technological approaches and new business models. The Explorer of the Seas has been operating as such a vessel (with a permanent technician aboard and regular visiting scientists) for more than six years. However, not only is this model is no longer financially viable but advances in technology make it no longer necessary. It is now possible to fully automate data collection, quality control and dissemination.

CIMAS Research Themes:

***Theme 6*:** Integrated Ocean Observations

Link to NOAA Strategic Goals:

***Goal 1*:** Understand Climate Variability and Change to Enhance Society's Ability to Plan and Respond Protect, Restore, and Manage the Use of Coastal and Ocean Resources through an Ecosystem Approach to Management. (*Primary*)

***Goal 3*:** Protect, Restore, and Manage the Use of Coastal and Ocean Resources through an Ecosystem Approach to Management. (*Secondary*)

NOAA Funding Unit: N/A
Funding provided to CIMAS through the Royal Caribbean's Ocean Fund

NOAA Technical Contact: Shailer Cummings

Research Summary:

Figure 1 below depicts the fully automated system that was finally completed. It includes the following fully networked components:

- A central computer system that can provide "virtual machines" substituting for up to ten individual computers (this system is "mirrored" for data security) and a virtual data server.
- A wireless connection to download large volumes of data during in the port in New Jersey.
- A connection to the university virtual private network so that small volumes of data can be offloaded automatically on an hourly basis to assure all components are fully functional (and if not to schedule in port maintenance visits) and to satisfy bridge reporting requirements for environmental observations

- A compact integrated flow through water sampling system with its own microprocessor control yielding temperature, salinity, chlorophyll and additional optical parameters.
- An optical sensor suite assessing the ambient light field
- Two Acoustic Doppler Current Profilers yielding not only ambient current structure from the surface to greater than 1000m but also the vertical distributions of mesopelagic fishes and zooplankton.
- A high resolution rapid response positioning system (ADU-5) required to obtain high quality velocity data
- A set of individual principal investigator supported instrumentation supporting ongoing research programs (MAERI, Wake Camera and pCO_2). Two of these (MAERI and pCO_2 are aspects of other CIMAS programs within Theme 6. The WAMOS wave measurement system was also successfully integrated into the system but subsequently removed by the principal investigator.

The system was designed for maximum flexibility. Any ancillary system can be incorporated that can be adapted to the virtual machine control environment and be networked into the system. Installing the core on multiple vessels will create "research opportunities" to piggy-back upon these systems and obtain cost-effective data in a fully characterized oceanographic context. Another key feature of this approach (and engine room installation) is that a system could comparatively easily be moved from ship to ship and could be installed after-the-fact with the ship in the water. The original *Explorer of the Seas* systems were so complex they required extensive work (and expensive change-orders) during the shipyard construction phase.

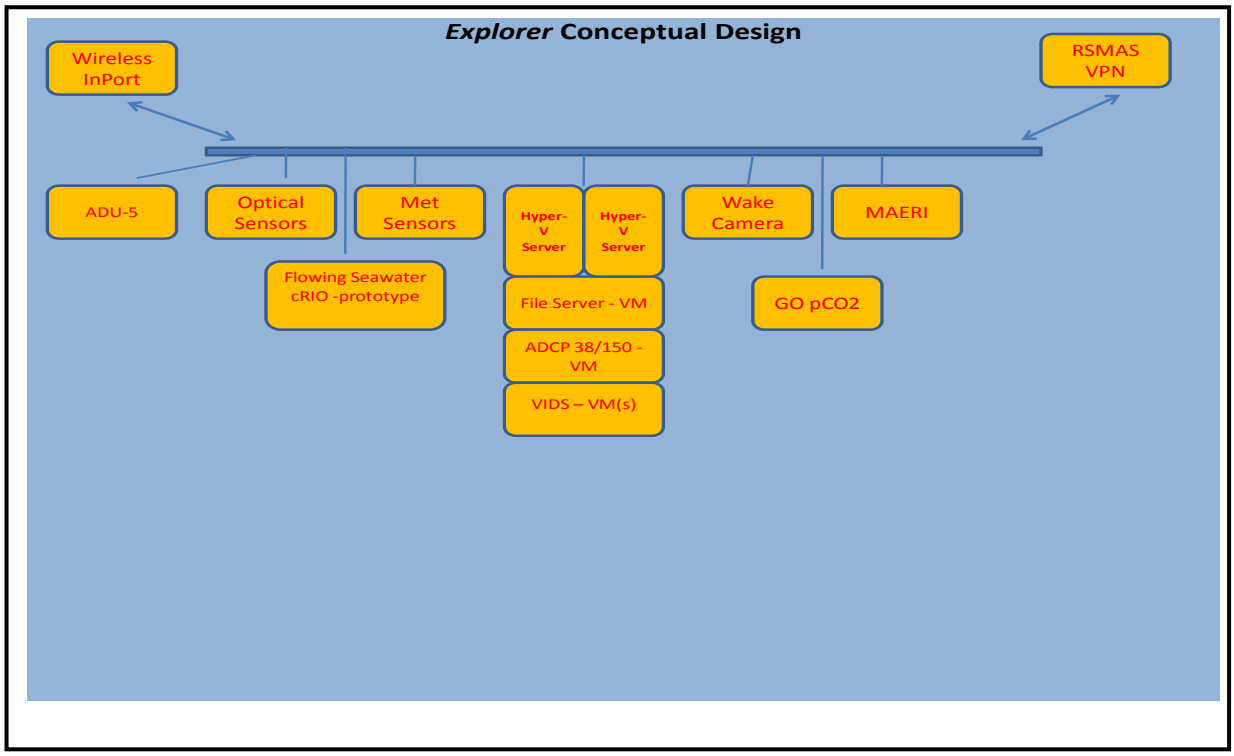


Figure 1 – The Conceptual Design of the Fully Automated Highly Flexible Oceanographic and Meteorological Sampling System now in operation aboard the EXPLORER.

Progress in Advancing the *Explorer* Model:
The other significant area of progress has been in regard to advancing the international OceanScope project. The Scientific Committee on Oceanic Research (SCOR) and International Association for the Physical Sciences of the Oceans (IAPSO) have teamed up to establish the OceanScope Working Group, a way to bring science and industry together for the systematic study of the oceanic water column. OceanScope's overall objective is to establish a global network of ocean observation platforms on commercial ships. The *Explorer of the Seas* project principal (Dr. Ortner) is one of two U.S. Working Group members and co-author of the OceanScope proposal.

At the first OceanScope meeting, representatives from academia, ship owners and operators, naval architecture, government agencies and ocean technology companies gathered in Montreal, Canada in July 2009 to begin to develop a plan to systematically collect data that will allow us to better understand the ocean's interior dynamics and its impact on climate. Not only was the Explorer project description one of the meeting highlights but agreement was reached on phased implementation plan for OceanScope. In the first phase (reliant primarily upon existing technologies), the *Explorer of the Seas* would serve as a prototype and instrument test bed.

OceanScope is chaired by Professors Thomas Rossby (University of Rhode Island) and Kuh Kim (Seoul National University). Results of the first meeting were reported by Dr. Ortner to the international scientific community at OceanObs09 in Venice, Italy in September 2009. The next Working Group meeting was hosted by the International Chamber of Shipping and took place in London in April 2010. This was followed by presentations at the American Bureau of Shipping meeting in London in May 2010 and the World Ocean Council Sustainable Ocean summit in Belfast in June 2010. The Draft implementation is currently being finalized and will be distributed for public comment in September 2010.

The SCOR-approved terms of reference, core membership and a growing list of Associate Members is available at: http://www.scor-int.org/Working_Groups/wg133.htm.

Research Performance Measure: Successful automated operation of all core shipboard systems and addition of individual subsystems (pCO_2, MAERI and Wake Camera) in an automated mode.

PIRATA Northeast Extension (PNE)

G. Berberian, S. Dolk, R. Perez, G. Rawson (UM/CIMAS)
R. Lumpkin, C. Schmid and C. Meinen (NOAA/AOML)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** PIRATA stands for "Prediction and Research Moored Array in the Tropical Atlantic". PIRATA is a multinational observation network, established to improve our knowledge and understanding of ocean-atmosphere variability in the tropical Atlantic. It is a joint project of Brazil, France and the United States of America. PIRATA is motivated by fundamental scientific issues and by societal needs for improved prediction of climate variability and its impact on the countries surrounding the tropical Atlantic basin.

***Strategy*:** To improve the description of the intra-seasonal to inter-annual variability in the atmospheric and oceanic boundary layers of the tropical Atlantic Ocean. To improve our understanding of the relative contributions of air-sea fluxes and ocean dynamics to variability in sea surface temperature and sub-surface heat content. To provide a set of data useful for developing and improving the predictive models of the ocean-atmosphere coupled system. To document interactions between tropical Atlantic climate and extra-regional variability such as ENSO and the North Atlantic Oscillation. To design, deploy, and maintain an array of moored oceanic buoys and collect and transmit a set of oceanic and atmospheric data, via satellite in near-real time, to monitor and study the upper ocean and atmosphere of the tropical Atlantic Ocean.

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:** Rick Lumpkin

Research Summary:

PIRATA is a three-party project involving Brazil, France and the United States that seeks to monitor the upper ocean and near surface atmosphere of the Tropical Atlantic via the deployment and maintenance of an array of moored buoys and automatic meteorological stations.

NOAA's contribution, the PIRATA Northeast Extension (PNE), is an effort to expand the PIRATA array of tropical Atlantic ATLAS moorings into the northern and northeastern sectors of the Tropical Atlantic Ocean. This region has strong climate variations from intraseasonal to decadal scales, with impacts upon rainfall rates and storm strikes for the surrounding regions of Africa and the Americas. Important processes in this region include formation of Cape-Verde type hurricanes, seasonal migration of the Intertropical Convergence Zone (ITCZ) and the Guinea Dome, interannual variations of the ITCZ migration associated with rainfall anomalies in Africa and the Americas, off-equatorial eddy heat advection by Tropical Instability Waves, and overturning-related ventilation of the oxygen minimum zone.

The PNE buoys and moorings are serviced by annual cruises, during which opportunistic oceanographic and meteorological observations are collected. Post-cruise processing and distribution on the PNE web site (http://www.aoml.noaa.gov/phod/pne/index.php) adds value by making the data available to the broader scientific research community. This research, including research conducted by CIMAS researchers, is aimed at improving our understanding and numerical simulation of climate signals in the tropical Atlantic.

The array consists of a backbone of ten moorings that run along the equator and extend southward along 10ºW to 10ºS, and northward along 38ºW to 15ºN. Given the widely varying dynamics of various subregions of the Tropical Atlantic, future extensions of the array had been anticipated by the PIRATA Science Steering Group to further the scientific scope of the observing system and improve weather and climate forecasts. In August 2005 a Southwest Extension of three moorings was added off the coast of Brazil (PIs: P. Nobre, E. Campos, P. Polito, O. Sato and J. Lorenzzetti).

The northeastern and north central Tropical Atlantic (TA; Fig.1) is a region of strong climate variations from intraseasonal to decadal scales, with impacts upon rainfall rates and storm strikes for the surrounding regions of Africa and the Americas. In 2004, Lumpkin et al. proposed a formal PIRATA Northeast Extension (PNE), to consist of four moorings (see Fig. 1). This extension was approved and funded by NOAA's Climate Program Office for implementation starting in June 2006.

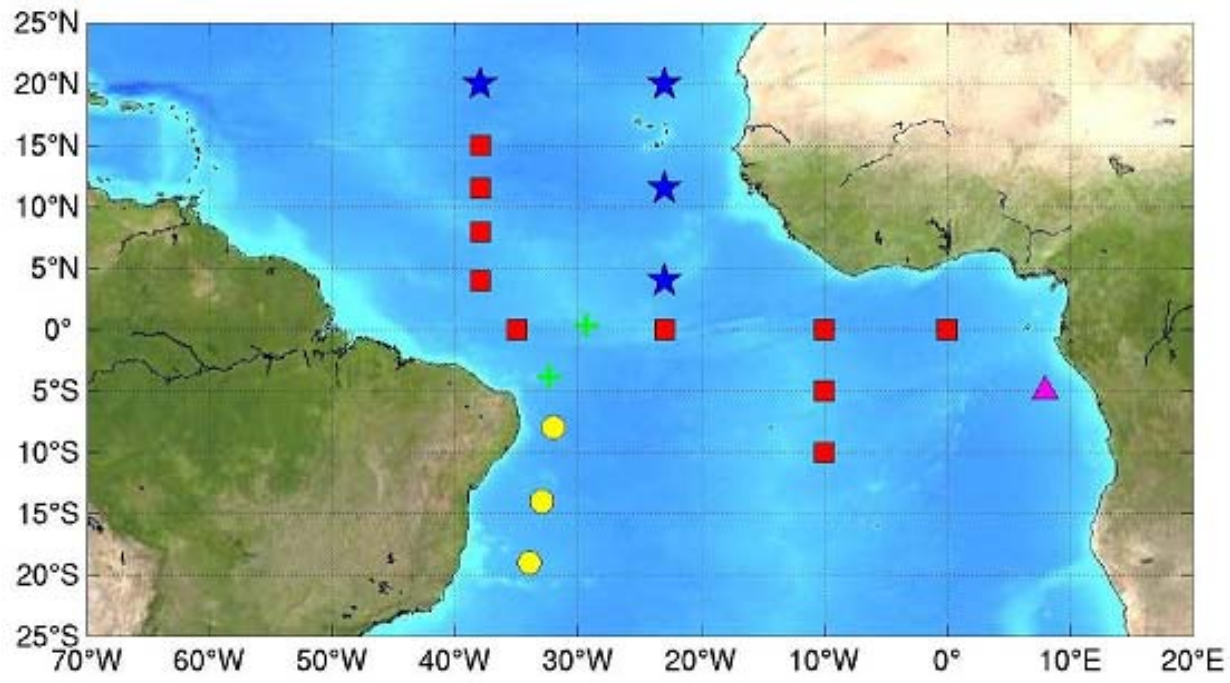


Figure 1: The Tropical Atlantic, showing the PIRATA backbone (red squares), automatic meteorological stations (green +), southwest extension (yellow circles), southeast extension pilot site (magenta triangle), and NOAA's northeast extension (blue stars).

In April-May 2010, the PNE servicing cruise was conducted aboard the NOAA ship Ronald H. Brown, along the way from Takoradi, Ghana to Charleston (Fig. 2). In addition to servicing the 4 moorings of the PIRATA NE extension the French mooring on the equator at the Greenwich Meridian was chased and recovered because it had gone adrift, and tube swap was performed at the French equatorial mooring at 23ºW. Two additional components of the cruise were (1) the collection of CTD/O2/LADCP and XBT data along 23ºW, and (2) the AEROSE project which collects and analyzes aerosol data to improve the understanding of their impact on, for example, heat fluxes into the ocean.

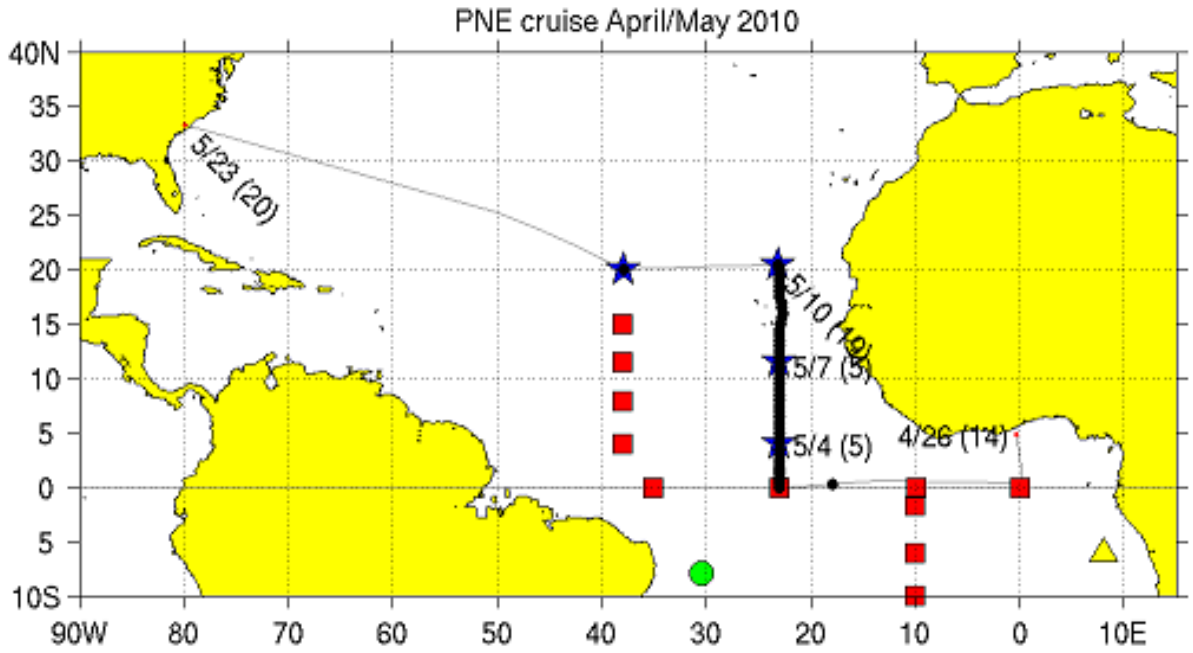


Figure 2: Map showing the cruise track of the PNE cruise in April/May 2010 on the R/V *Ronald H. Brown*. Track (black line) with CTD stations (dots), PNE recovery and deployment sites (blue stars) and the PIRATA backbone moorings (red squares), the Southeast extension (yellow triangle) and one of the Southwest extension moorings (green circle) superimposed.

The salinity sections collected in the PNE cruises during July 2009 and May 2010 are quite similar at intermediate depth, where the salinity minimum of the Antarctic Intermediate Water is found (Fig. 3). In the upper layer, some significant differences exist. In July 2009, the salinity maximum at the equator covers a larger area, but it does not reach as deep, when compared with May 2010. The surface salinity minimum farther north is found at different latitudes during the two cruises (it is farther north in July 2009 than in May 2010). These differences are mainly caused by the migration if the Intertropical Convergence Zone. This migration is reflected in the record of the PIRATA mooring at 4N, 23W (Fig. 4), which shows that the precipitation tends to exceed the evaporation around the time of year when the 2009 cruise was done, while this is not the case during the time of year when the 2010 cruise took place. Near the northern end of the sections, the differences in the vertical extent of the salinity maximum are likely due to changes in the circulation pattern caused by shifts in the wind field that drive the subtropical gyre (Fig. 3).

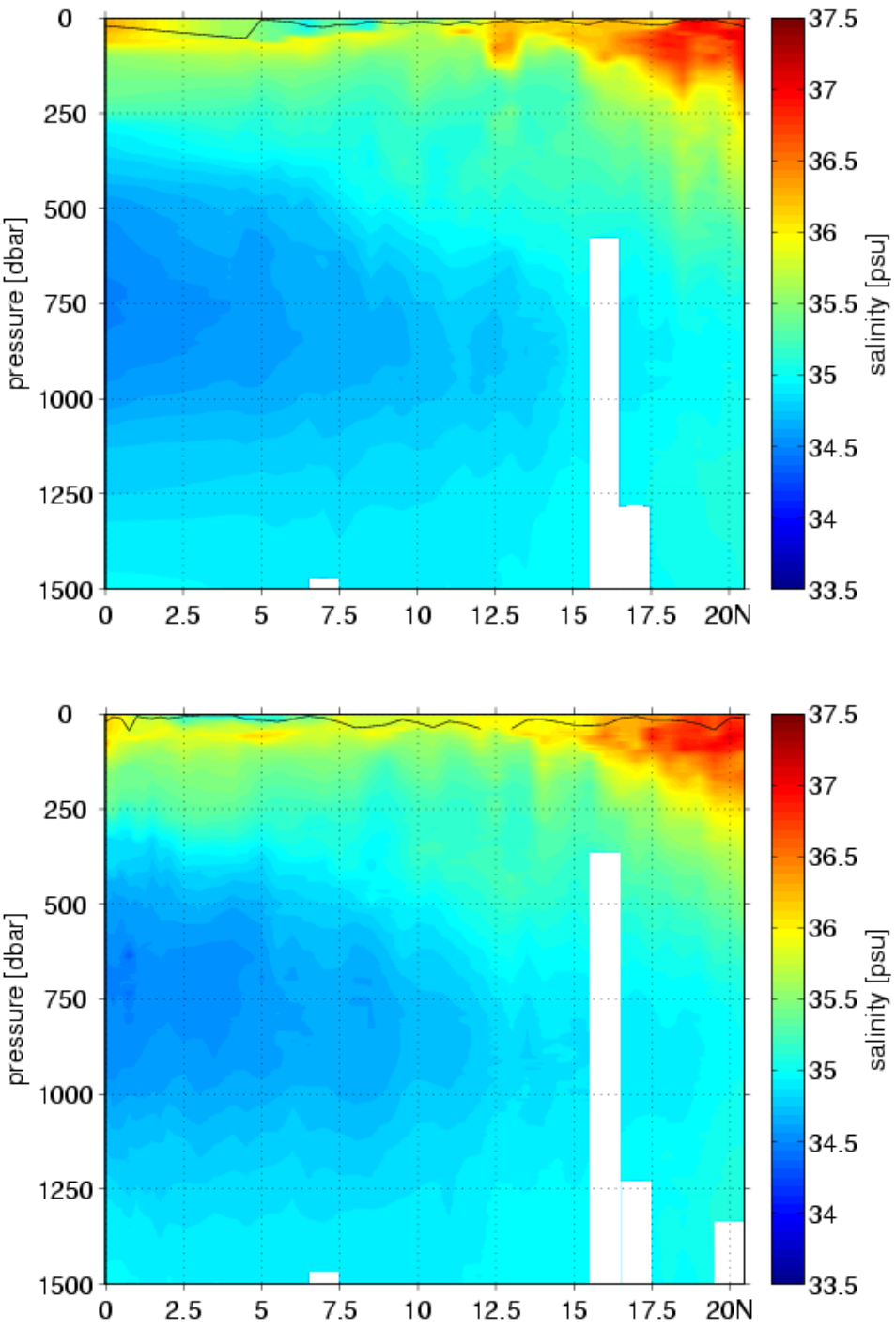


Figure 3: CTD salinity (psu) along 23ºW. From the PNE cruises in 2009 (top) and 2010 (bottom). The black line indicates the mixed layer.

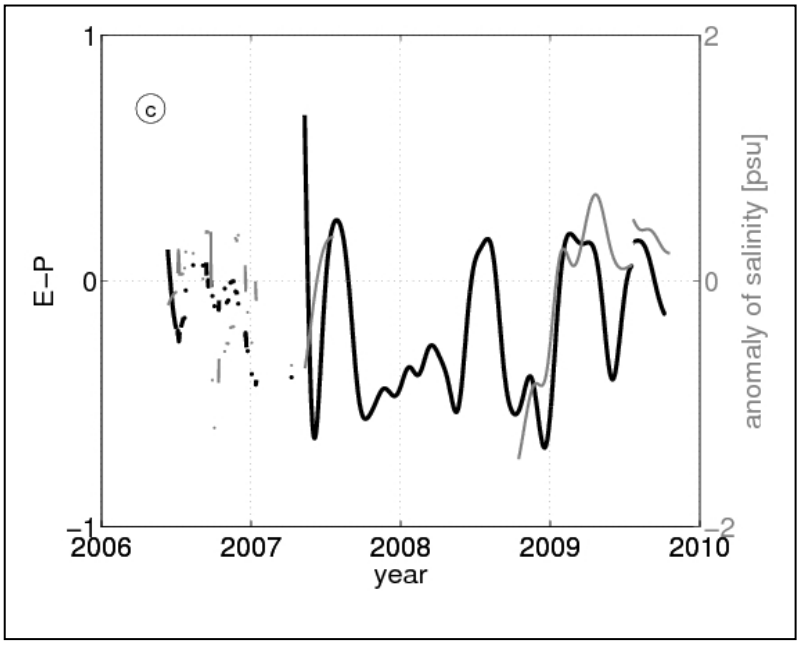


Figure 4: Salinity anomaly and evaporation minus precipitation at 4N, 23W from the PIRATA mooring.

Research Performance Measure: Research objectives are being met.

Data Analysis and Near-real-time Quality Control in Support of the International ARGO Project (Phase I)

M.-L. Shyu (UM/ENG); R. Sabina (UM/CIMAS); C. Schmid (NOAA/AOML)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** To investigate, develop, and implement innovative methodologies to perform a near-real-time quality control of ARGO profiling float data using a diverse set of oceanographic measurement systems.

***Strategy*:** To analyze differences between recently collected data from Argo floats and publicly available long-term climatologies as well as newly derived climatologies.

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

NOAA Funding Unit: OAR/AOML **NOAA Technical Contact:** Claudia Schmid

Research Summary:

This project supports Argo, an international program, which calls for the deployment of more than 3,000 drifting profiling floats distributed over the global oceans. It facilitates the generation of data products to increase the usefulness of Argo data and the improvement of data quality control in real-time. To achieve these objectives, we have developed, implemented, and maintained software for the decoding, processing, and adjustment of the float data. We have also fixed and existing profile numbering error by developing a new profile number checking program to monitor the profile numbers. Figure 1 shows the real-time data processing. Figures 2 and 3 demonstrate the salinity adjustment program and real-time pressure adjustment program procedures, respectively.

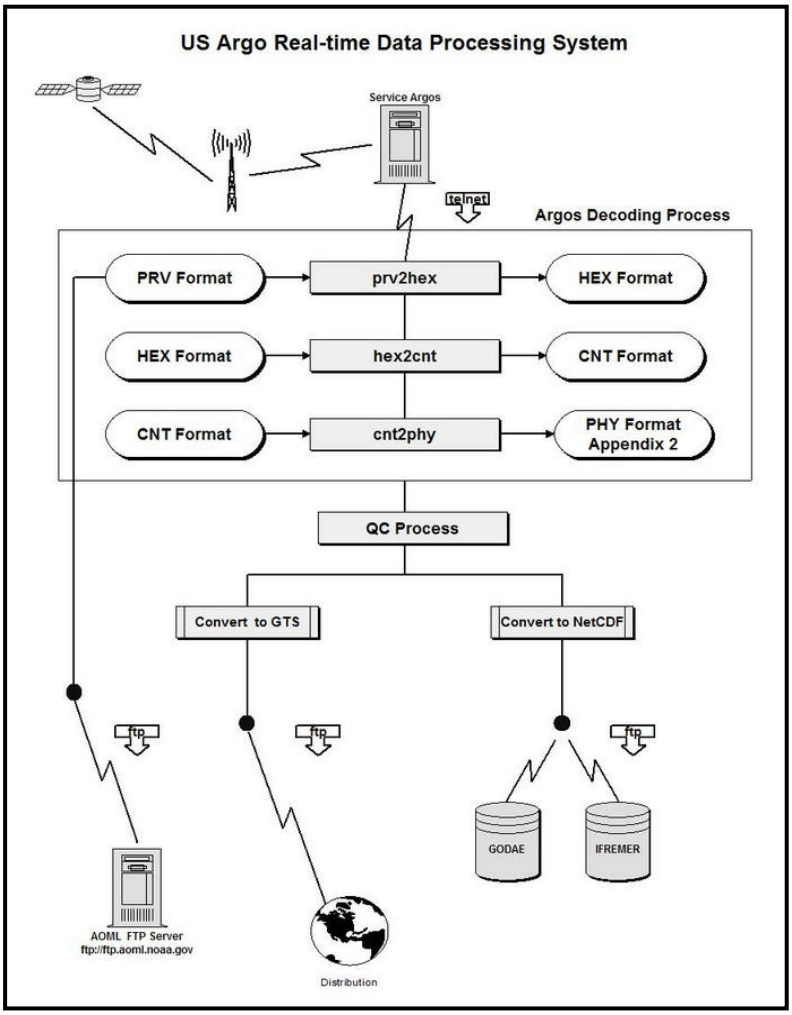


Figure 1: Real-time Data Processing

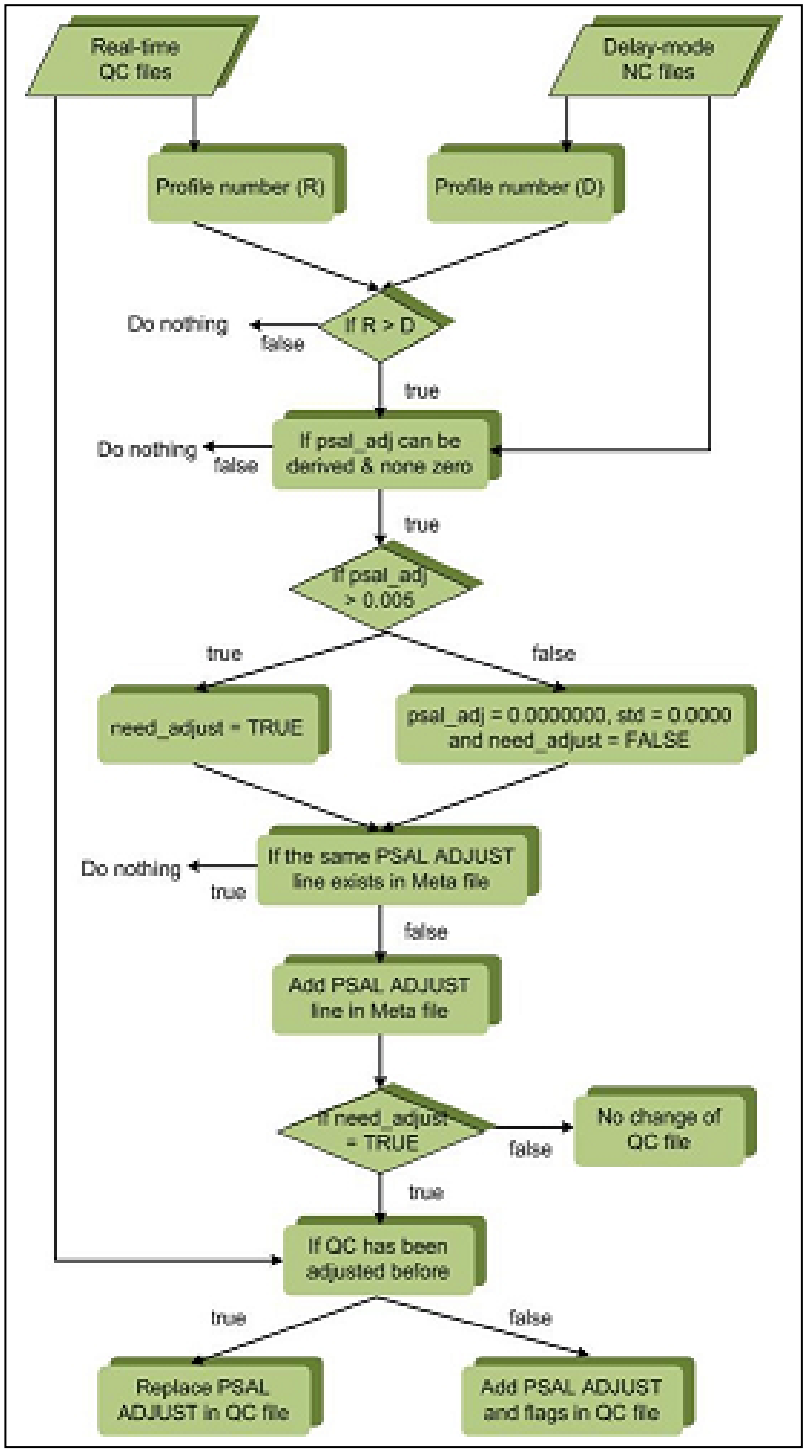


Figure 2: Salinity Adjustment Algorithm

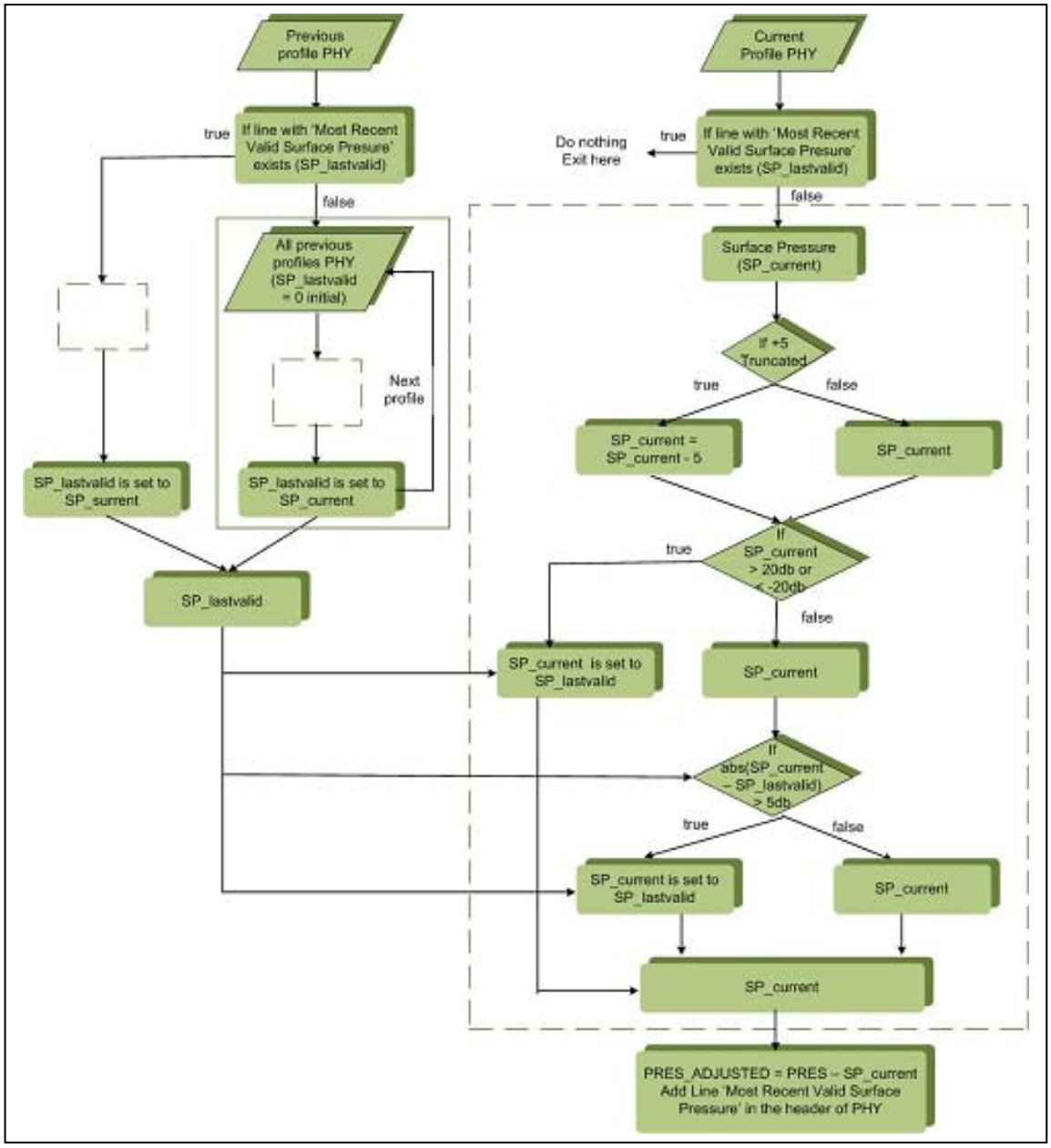


Figure 3: Real-time Pressure Adjustment Algorithm

Research Performance Measure: All objectives were reached.

Research and Implementation of a Hydrographic Database in Support of the Operational and Research Community

M.-L. Shyu (UM/ENG); R. Sabina (UM/CIMAS); C. Schmid (NOAA/AOML)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** To design, develop, and implement a hydrographic data management system (HYDRO) in support of the International Argo project and community researchers at the Atlantic Oceanographic and Meteorological Laboratories, NOAA (AOML).

***Strategy*:** To develop and implement data integration methodologies to facilitate transparent data access.

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

NOAA Funding Unit: OAR/AOML **NOAA Technical Contact:** Claudia Schmid

Research Summary:

For the hydrographic data management system (HYDRO), the following components were designed and developed: (1) Upgraded all PL/SQL based code into JDBC-based code; (2) checked duplicated data within the database; (3) developed a Java-based NetCDF reader; and (4) designed a ghost transmission detection algorithm able to detect the ghost transmission within the ARGO float files. These efforts support the US-ARGO real-time processing system as shown in Figure 1. More specifically:

(1) all PL/SQL based code was upgraded into JDBC-based code. JDBC-based code was able to adapt to different platforms. Since different platforms (Windows and Linux/Unix) are used in the working environment, JDBC-based code provides more flexibility than the previously PL/SQL based code.

(2) addresses the duplicate data record problem in the database. Any duplicated records would result in redundant retrievals and might cause potential problems in the future. Programs were developed to check for duplication using SQL/Query and deleting redundant records.

(3) a Java-based NetCDF reader was developed. This reader, unlike the prior one, was able to fix the display bugs for NaN numbers. It can also render only the sections of greatest interest based on scientists' requests.

(4) ghost transmission problems were addressed. These occurs in float data during the cycle time (as shown in Figure 2), which also causes problems in later analyses. A new ghost-detection algorithm was developed to solve this problem. We applied our ghost-detection algorithm on 800 floats with 100% success in precision and 25% in recall.

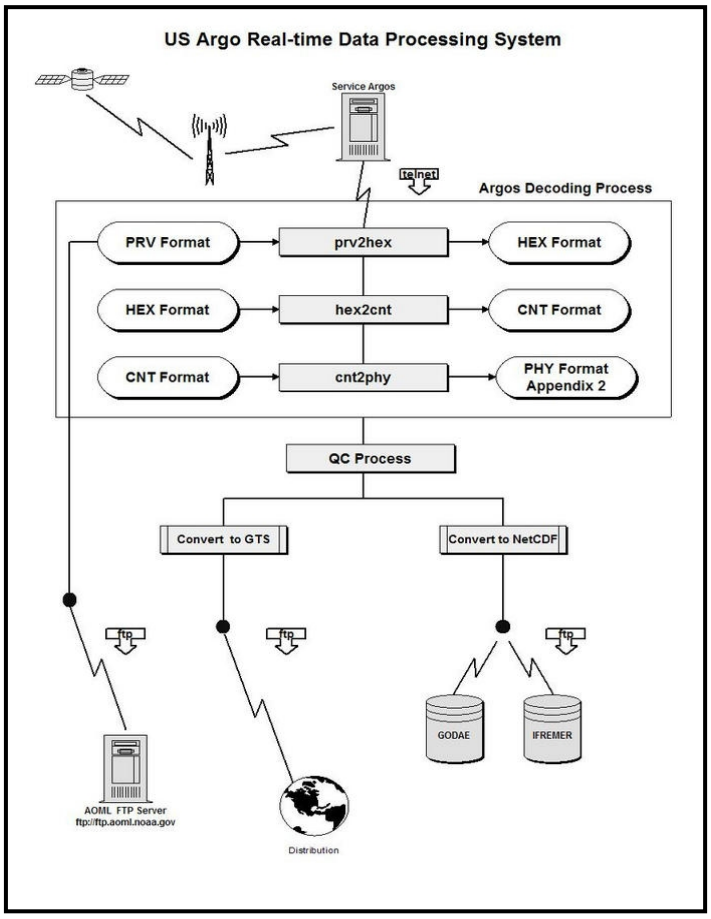


Figure 1: US-AROG real-time processing system.

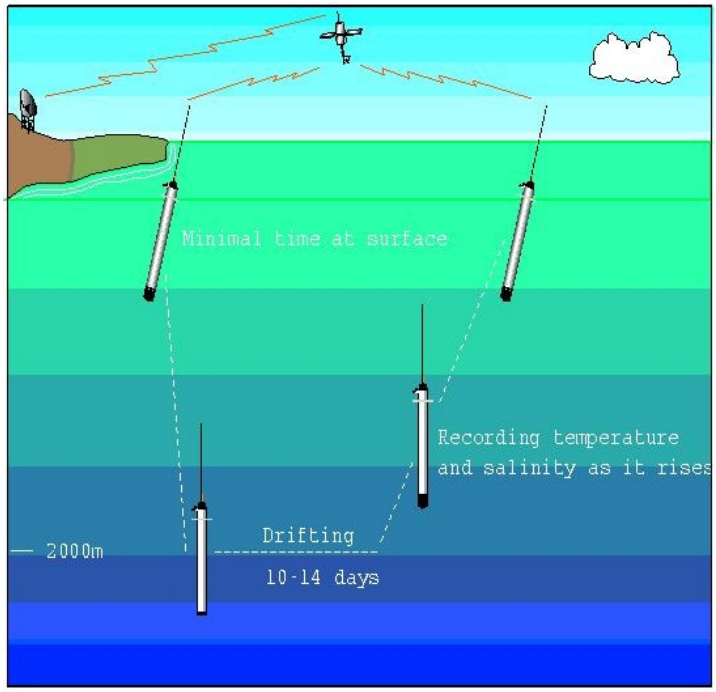


Figure 2: Semantics of a single cycle in the mission of a profiling float.

Research Performance Measure: All objectives were reached.

Data Integration and Data Mining Support for Tropical Cyclone Integrated Observing Systems

M.-L. Shyu (UM/ENG); F. Marks and M. Powell (NOAA/AOML)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** To design, develop, and implement a "HRD Web Portal" that combines data from several sources (geographical and non-geographical), enables researchers and scientists to connect to the database via the web portal platform to integrate, mine, and analyze raw and post-processed Tropical Cyclones data, and display the results in order to improve the public's awareness of the dangers that may be imposed by Tropical Cyclones.

***Strategy*:** To integrate wind field contour images generated by H*Wind together with relevant videos taken from YouTube and display them to the user in a web interface using Google Earth API, JavaScript, and PHP, and to utilize Google Web Toolkit (GWT) and Google Maps APIs for the development of a "lightweight" web-based interface dubbed the "HRD Web Portal".

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

NOAA Funding Unit: OAR/AOML **NOAA Technical Contact:** Frank Marks and Mark Powell

Research Summary:

Raw point-observational data (land, atmosphere, and ocean) and graphical products derived from observational and model data are stored in a centralized database. The "HRD Web Portal" was designed, developed, and implemented as a bridge to integrate wind data originating from diverse sources (and in different formats) with geographical information into multiple visualization maps, as well as synchronized animations, geared toward comprehensive forecast and model evaluation. Figure 1 shows the HRD Forge framework for improving access to NOAA's hurricane data, the "HRD Web Portal" is on the left-hand side of the figure. The visualization interface is specifically tailored toward tropical cyclone (e.g., hurricane) forecast and model diagnostics. The design and implementation included the following features key to comprehensive data inter-comparison: 1) lightweight architecture (i.e., runs on a web-browser), and 2) a multi-map interface capable of side-by-side animations of diverse model and observational data products (geo-referenced and non-geo-referenced). The portal serves as an example of potential visualization applications built to take advantage of the Web Services Layer as the data source. It allows users to overlay different types of tropical cyclone data, including their own KML documents with proprietary data. Figure 2 shows a snapshot of one of the Web-Based portal interface, it helps users search HWind XY Plot Data in the database for visualization.

Furthermore, videos are collected from YouTube based on location and date information of a storm extracted from the H*Wind system. The YouTube videos are then ranked based on relevancy to the weather event using a concept detection algorithm. Google Earth is then used to display the storm track and wind field contour images created by H*Wind along with the highest ranked YouTube

videos available at each day and time. A web-based prototype has been implemented using PHP, JavaScript, and the Google Earth API to display the different information to the user. Figure 3 shows a visualization example of data taken from H*Wind and YouTube.

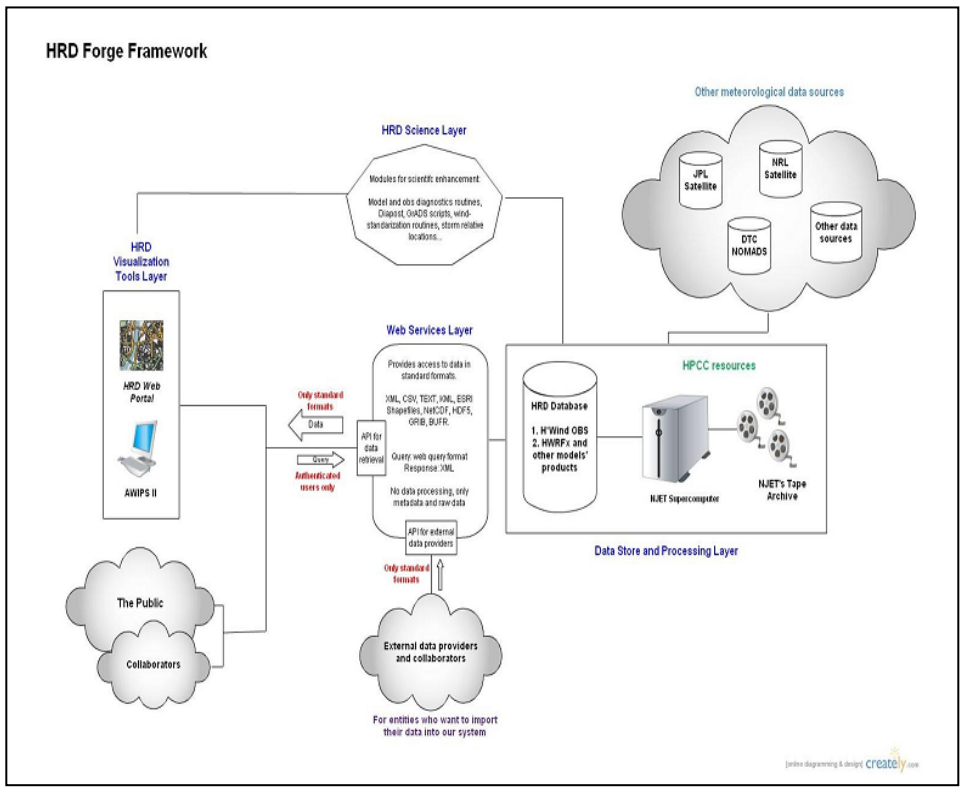


Figure 1: The proposed HRD Forge framework for improving the utility of NOAA's hurricane data.

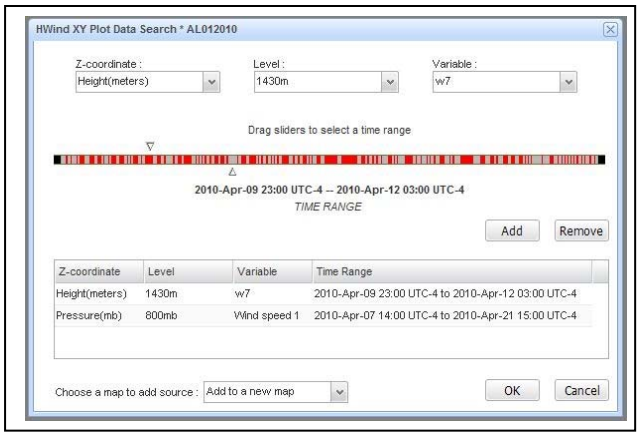


Figure 2: A snapshot of the Web-Based interface helps user search HWind XY Plot Data in the database.

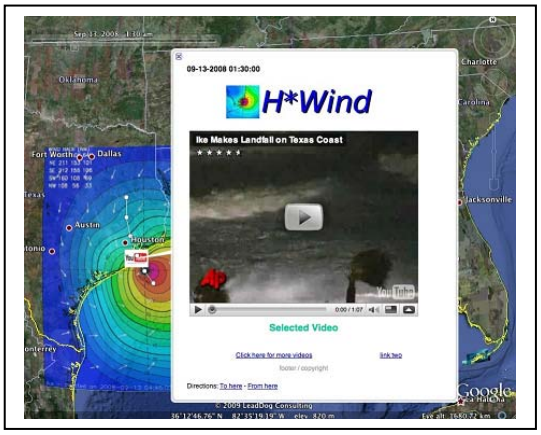


Figure 3: A Snapshot of H*Wind and YouTube Data Visualization in Google Earth.

Research Performance Measure: All objectives were reached.

System Support for the Development and Simulation of Tropical Cyclone Numerical Models in a Linux Cluster System

M.-L. Shyu (UM/ENG); F. Marks, S. Gopalakrishnan and R. Rogers (NOAA/AOML)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** To investigate and develop innovative data mining tools and methodologies for studying rapid intensity changes in Tropical Cyclones, and to build a centralized database and a user friendly interface to facilitate the access of data from different sources for NOAA scientists.

***Strategy*:** To study structure and dynamics of tropical cyclones (TCs) and analyze specific hurricane cases using model and observational data sets, the Experimental Hurricane Weather and Research Forecast (HWRF-X) System has been developed and maintained. To build a centralized database and interface integrating data from the H*WIND relational database, HRD's operational flights (radar, dropsondes, AXBT, UAS), satellites, and both operational and research models to verify and validate the HWRF-X 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 (*Primary*)
***Goal 3*:** Serve Society's Needs for Weather and Water Information (*Secondary*)

NOAA Funding Unit: OAR/AOML

NOAA Technical Contact: Frank Marks, Sundaraman Gopalkrishnan, and Robert Rogers

Research Summary:

Many factors are involved in predicting Tropical Cyclone (TC) track, intensity and impact. For example, in the case of TC intensity and rainfall, one must consider factors such as magnitude and direction of vertical shear, upper oceanic temperature structure, and low- and mid-level relative humidity. All these parameters were analyzed in data sets collected from model runs on 60 hurricane cases. Currently, hurricane researchers have no ability to synthesize *model* and *observation* data in a centralized and comprehensive manner. The worlds of modelers and observers have not united in an efficient way to access and share data for the sake of inter-comparison, verification or validation. Nevertheless, advances in hurricane modeling depend upon the ability to quickly evaluate model output against a diverse set of observations to determine (and correct) deficiencies in model forecasts.

In this project, a centralized database which stores hurricane data from different data sources such as the H*WIND relational database and satellites was designed and implemented. A user friendly interface was implemented so that the scientists could access different real-time and historical hurricane data easily. Figure 1 shows the overall design of the whole system. Figure 2 shows a sample webpage in the interface. Figure 3 shows the visualization manager which organizes different components of the web interface.

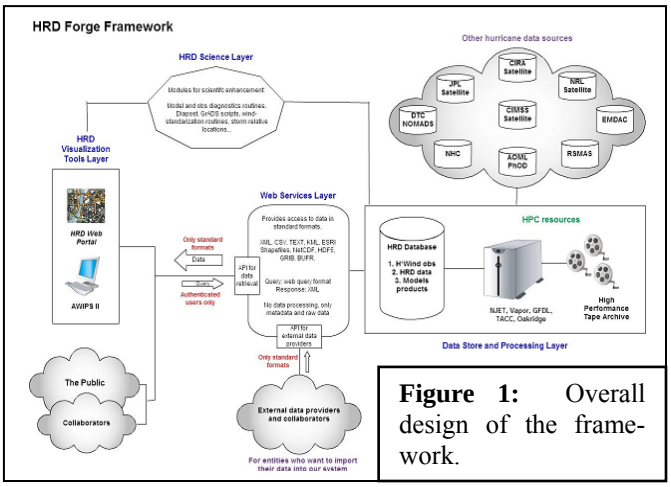


Figure 1: Overall design of the framework.

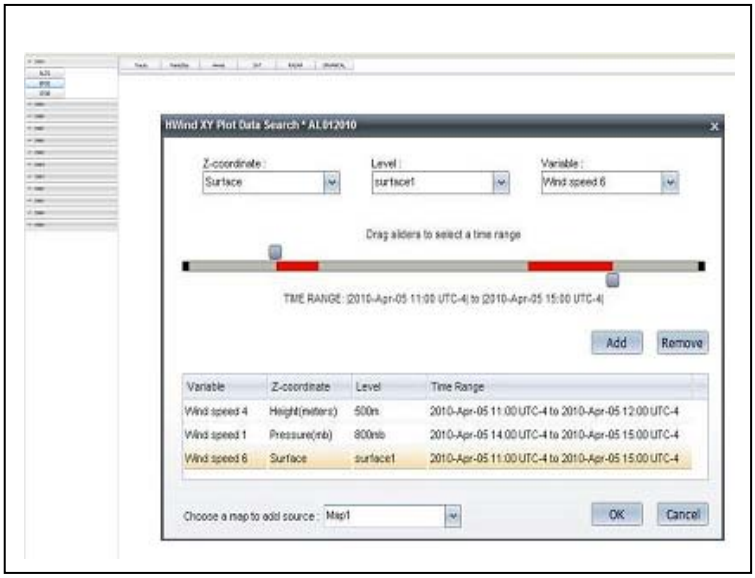


Figure 2: Sample webpage in the web interface.

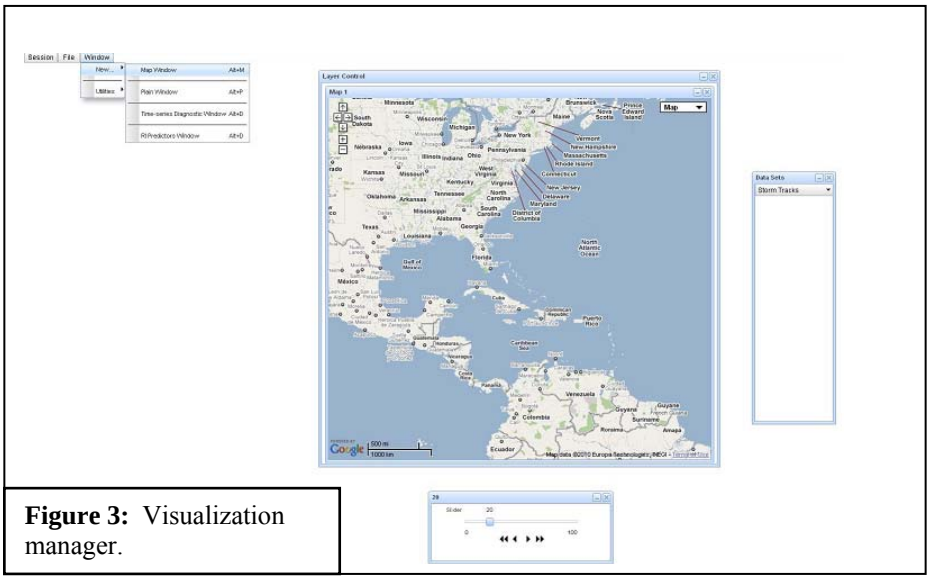


Figure 3: Visualization manager.

Research Performance Measure: All objectives were reached.

Determining Information Content in Repeat Low-density XBT Transects

R. L. Molinari (UM/CIMAS)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** To determine information content (e.g., dominant signals, propagation of anomalies, etc.) in individual eXpendable BathyThermograph (XBT) lines occupied since the late 1960's. To evaluate time dependent uncertainties in depth estimates from XBT data.

***Strategy*:** Verify published corrections to XBT depth calculations by comparing XBT data to more accurate observations. Select XBT lines in the Pacific and Atlantic oceans that have been occupied for greater than 35 years and perform statistical analyses on resulting time-series of upper layer temperature structure. Compare with model results to search for dynamical processes responsible for upper layer temperature variability.

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 Units: OAR/AOML **NOAA Technical Contact:** Gustavo Goni

Research Summary:

As a test case, this study was directed at decadal variability of upper layer temperature structure in the North Atlantic. Data from XBT lines that crossed the subtropical and subpolar Atlantic were reviewed. A manuscript was submitted to PROGRESS IN OCEANOGRAPHY in April 2010.

A time-dependent depth correction, including uncertainty estimates, developed by Australian scientists has been applied to historical XBT data. The method was verified in the subtropical Atlantic by comparing bottle and CTD observations taken at the Bermuda Time Series Station with corrected XBT depths taken within a 5-degree radius of the nominal position of the former location. The method was verified in the subpolar Atlantic by comparing bottle and CTD data from a weather ship to XBTs collected within a 5-degree radius of the ship. Both comparisons indicated that the XBT data corrected using this time-dependent relationship is accurate to 0.2C, which is assumed to be the minimal reliable signal addressed in the subsequent analyses.

In addition, results from a study using different combinations of the components of XBT systems were addressed. The study showed that newer components produced comparable results to older components (i.e., a false 'climate signal' was not being introduced by the change in instrumentation). In addition, comparison of the XBT data with CTD measurements demonstrated that the depth estimation formula for XBTs continues to change and appropriate corrections made. Recently manufactured XBTs have a formula similar to the original manufacturer's formula.

Scientifically, in the subpolar Atlantic, although lines do not extend over long periods they do show the presence of strong decadal signals. The decadal signals are related to variability in the atmospheric North Atlantic Oscillation and there are model results that suggest the SST variability

could impact on atmospheric climate. In the subtropics the data show that models that attribute decadal signals to only planetary wave propagation may not be correct.

Research Performance Measure: Research objectives have been met with respect to XBT lines in the North Atlantic. This project was originally to be supported for 3 years, but year-3 funding was not provided because of funding agency shortfalls. Thus, lines in other basins will not be addressed.

South Atlantic Meridional Overturning Circulation ("SAM") Project

R. Garcia, R. Perez (UM/CIMAS); C. Meinen, S. Garzoli,
M. Baringer and G. Goni (NOAA/AOML)

Long Term Research Objectives and Strategy to Achieve Theme:

***Objectives*:** To initiate a sustained time series measurement system for the western boundary component of the meridional overturning circulation at 34.5°S.

***Strategy*:** To use moored instruments and hydrographic observations collected in partnership with international collaborators to study the Brazil Current and the Deep Western Boundary Current systems.

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 and OAR/CPO

NOAA Technical Contact: Christopher Meinen

Research Summary:

Studies using numerical climate models have suggested that variations in the transport of the Meridional Overturning Cell (MOC) are correlated with significant changes in surface air temperatures and precipitation both regionally and globally. NOAA has maintained a crucial long-term array measuring the western boundary components of the MOC in the Atlantic near 27˚N since 1982; the SAM project represents an effort to start a similar program in the South Atlantic near 34.5°S. Observations and modeling studies have indicated that water mass transformations occurring in the South Atlantic alter the waters circulating in the global MOC resulting in changes to the global circulation system. The SAM project represents a collaborative effort working with partners in France, Argentina, Brazil, and South Africa to begin to monitor the MOC-related flows in the South Atlantic to improve our understanding of the key processes occurring in the South Atlantic Ocean. Specifically the NOAA component of this international effort is focused on the western boundary

currents, specifically the Brazil Current in the upper layer and the Deep Western Boundary Current (DWBC) at depth. The DWBC is of particular import because it is believed to carry a significant percentage of the lower limb of the MOC. Long-term observations of these key flows will be required to understand the mechanisms leading to changes in the MOC system in the South Atlantic.

This project began in March 2009 with the deployment of four moored instruments near the western boundary at 34.5°S. Collaborators from France have a pair of moored instruments deployed along the same line of latitude off the western coast of South Africa, providing a initial effort at observing the western and eastern boundary flows. Ultimately the goal of the NOAA SAM program and the international collaborating programs is to expand to develop a truly trans-basin measuring array from South America to Africa along 34.5°S.

The SAM project is essentially still in its early phase, with the moored instruments (three pressure-equipped inverted echo sounders and one current-and-pressure-equipped inverted echo sounder) just deployed in March 2009. During the past year, the first 5 months of data were collected acoustically from a research ship in August 2009 during a cruise sponsored jointly by NOAA and the Argentine Naval Hydrographic Service. The next approximately six months of data are to be collected in July 2010.

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

Climate Data Records of Sea-Surface Temperature

P.J Minnett and E. Williams (UM/RSMAS)

Long Term Research Objectives & Strategy to Achieve Them:

***Objectives*:** To determine the uncertainty characteristics of sea-surface temperature (SST) fields using ship-board radiometers with calibration traceable to national reference standards, thereby fulfilling the requirements of a Climate Data Record; recommend improved algorithms, and provide meta-data to contribute to the NOAA Scientific Data Stewardship Program.

***Strategy*:** To compare co-located and contemporaneous retrievals of satellite-derived sea-surface temperatures with measurements of skin sea-surface temperatures from well-calibrated Fourier-Transform infrared spectroradiometers and filter radiometers; analyze the resulting data bases to determine the error characteristics in the satellite measurements and determine improvements to retrieval algorithms and procedures.

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/CPO

NOAA Technical Contact: William L. Murray

Research Summary:
In the second year of the project effort has been directed at continuing the collection of ship-based radiometric measurements of the skin SST and deriving the matchups between these and the most recent version of the AVHRR Pathfinder SST retrievals. Extractions of the sub-scenes that cover the positions of the ships carrying the radiometers have been done for the AVHRRs on the NOAA-16, -17 and -18 satellites for most of 2001 to 2006.

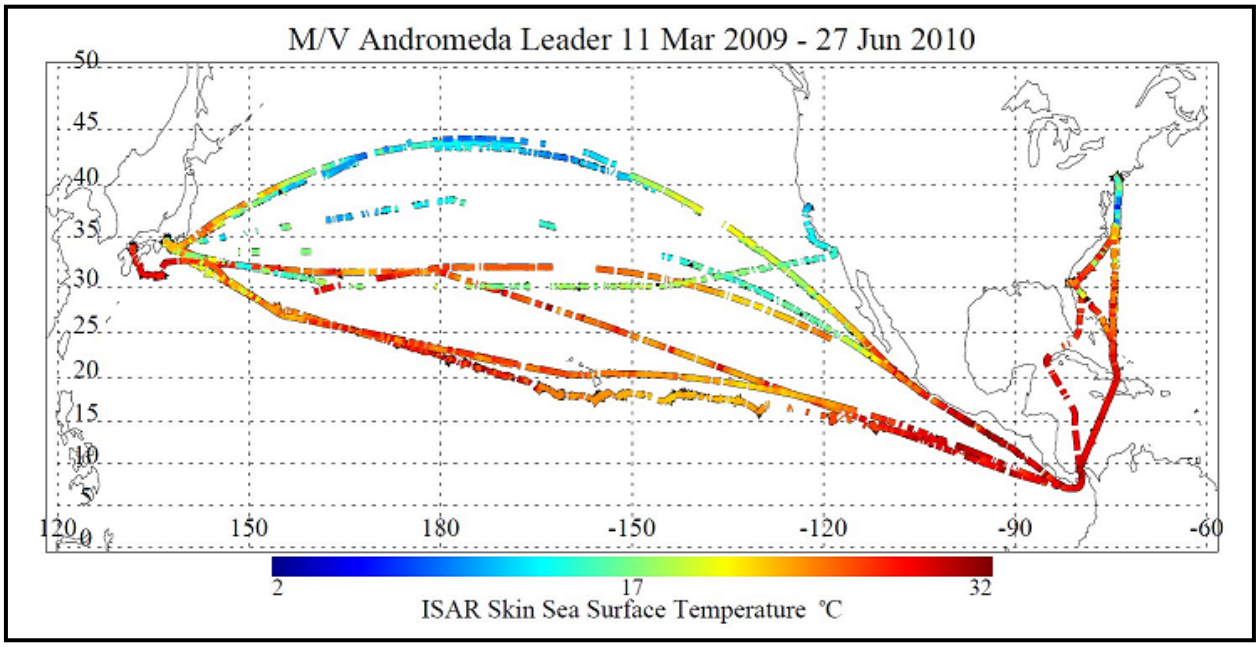


Figure 1: The tracks of the NYK Lines Ship *Andromeda Leader* from 11 March 2009 to 27 June 2010, with the colors indicating skin SST measured by an ISAR.

Research Performance Measure: Two ISAR's have been mounted on the NYK Lines Ship *Andromeda Leader* throughout the performance period, with one being refurbished while the other has been deployed, and following the recovery of the shipping industry following the economic recession, a large amount of data has been taken (Figure 1). An M-AERI was deployed on the RCCL cruise liner *Explorer of the Seas* for autonomous operations. Unattended operations render both the ISARs and the M-AERI susceptible to data loss because of failures that require visits to the ships in port by technical staff. But under normal operations, the data are available from these radiometers in near real-time by satellite links. In the third year of the project the PI plans to visit Dr LeBorgne of Metéo-France to work on the SEVIRI (Spinning Enhanced Visible and IR Imager) data from the Eumetsat Meteosat Second Generation satellite over the Atlantic Ocean. The project is largely on schedule.

VIII. EDUCATION AND 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 some of the outreach activities at the School in which CIMAS is 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., fishermen), 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. These sites are often designed to serve as an outreach function. We only list those that have a specific broadly-based educational component.

Graduate Education

The Rosenstiel School of Marine and Atmospheric Science offers graduate instruction leading to the Doctor of Philosophy (PhD) and Master of Science (MS) degrees through academic divisions that include Marine Biology and Fisheries, Marine and Atmospheric Chemistry, Marine Geology and Geophysics, Meteorology and Physical Oceanography, and Applied Marine Physics. Though graduate students typically concentrate in one of these curricular areas, interdisciplinary study is encouraged and coursework can be tailored to the individual student. In addition, we offer the Master of Arts (MA) and MS degrees in Marine Affairs and Policy for students who wish to pursue careers in marine policy and management. Currently there are about 200 students enrolled in the RSMAS graduate program, two thirds of which are PhDs.

To assist in attaining our main objectives, a sub-unit was created within CIMAS, the Cooperative Unit for Fisheries Education and Research (CUFER). CUFER was established in 1992 in response to a need for the development of improved methods for quantitative assessment of fishery populations, and as a source of advice for a range of topics concerning resource sustainability. These activities complement the NOAA/NMFS mission of resource stewardship. CUFER offers the opportunity to work on research issues with long-time horizons, an advantage afforded by academic research. The educational goal of CUFER is to train students (graduate and post-doctoral) in state-of-the-art theory and applications of quantitative fishery science, a critical expertise area to support management for sustainability of US fishery resources.

Many graduates of these UM/RSMAS programs have joined the NOAA workforce, mainly at the NOAA AOML and SEFSC laboratories and at NOAA headquarters but also at other NOAA laboratories throughout the US. This training pipeline for NOAA jobs was greatly facilitated by CIMAS activities such as 1) collaborative research teams between NOOA Scientists, and CIMAS faculty and graduate students; 2) funding of graduate students with the support of NOAA fellowships and graduate research assistantships; and 3) participation of NOAA scientists from Miami laboratories in student mentoring and teaching.

The University of Miami has recently developed Masters of Professional Science (MPS) intended for students who seek advanced training in marine and atmospheric science, while also cultivating a blend of team-building and communication skills, legal and regulatory knowledge, and business savvy, that should be highly valued by potential employers. In addition to two semesters of intensive course work this degree will offer internship in government NGOs and business to their graduates.

The MPS foci especially relevant to NOAA are the ones developed for Meteorology and Fisheries science.

Undergraduate Education

The Rosenstiel School offers two undergraduate degree options, a Bachelor of Science in Marine and Atmospheric Science with majors in Marine Science and Meteorology and a Bachelor of Arts in Marine Affairs. For academic year 2009, a record number of 248 students enrolled in the program. The MSC curriculum is designed to take full advantage of the University's subtropical location, with year-round access to a variety of specialized marine environments including the deep ocean waters offshore, the coral reef tracts of the Florida Keys, and the estuarine sea grass beds and mangrove shoreline of South Florida. The transfer of the administration of this program to RSMAS has created a more vibrant undergraduate experience for students and enhanced opportunities for undergraduate research. Many of these research experiences take advantage of the collaborative research links between RSMAS and the AOML and SEFSC NOAA labs that are available through CIMAS.

NOAA recently announced that six Rosenstiel School students were selected as 2010 NOAA/Ernest F. Hollings Scholars. UM recipients are among 119 Hollings Scholars selected from colleges and universities across the country. With six recipients, UM was one of only two universities achieving this many prestigious grants this year. See http://www.rsmas.miami.edu/pressreleases/20100820-hollings.html.

The MAST Academy and High School Student Education

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. In past 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.

MAST is one of three schools involved with the South Florida Student Shark Program (SFSSP). The SFSSP is a collaborative, multi-disciplinary research and education program that exposes students to

marine science field research. They focus on the study and conservation of coastal Florida shark species, mangrove fish habitats, and the Florida watershed through in-service learning, education and research (see below). MAST students have also participated in other field programs, for example in a comprehensive habitat study of Biscayne Bay. In this way, the School and CIMAS scientists 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 the NMFS-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. Students worked on the development of a microbial contaminant database using FileMaker Pro Software.

University of Miami (UM), 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. UM participates under the leadership of Dr. D. Letson, a CIMAS Fellow. This program is lead by 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.

The goals of the science center are to increase the number of under-represented 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 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 capability building in the partner 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.

Public outreach and informal educational activities associated with specific CIMAS projects include:

Intra-Americas Studies of Climate Processes (IASCLIP)

For the past two summers, D. Enfield (UM/CIMAS) has served as a mentor to mentor to Hollings Scholars from outside Miami that are working at AOML: Brittany Perrin (2009) and Sarah Larson (2010).

Re-Writing the Climatology of the Tropical North Atlantic and Caribbean Sea Atmosphere

J. Dunion (UM/CIMAS) gave the following invited presentations:

- Guest speaker, National Geographic JASON Project, live event (January 2009)
- Guest Lecturer, University of New Hampshire Florida Alumni Association (February 2009)
- Guest Lecturer, University of SUNY Albany seminar series (April 2009)
- Guest Lecturer, Western CT State University seminar series (November 2009)
- Guest Speaker, Gulliver Prep Academy, Miami, FL (November 2009)
- Invited Seminar, NOAA/National Hurricane Center (November 2009)
- Guest Speaker, Newington High School, Newington, CT (November 2009)
- Guest speaker, National Geographic JASON Project, West VA Hidden Promise Program (November 2009)
- Guest Speaker, Marlborough Elementary School, Marlborough, CT (February 2010)
- Guest Lecturer, Massachusetts Institute of Technology seminar series (March 2010)
- Guest Lecturer, University of Wisconsin-Madison seminar series (April 2010)

Diagnostic and Modeling Studies on Impacts, Mechanisms and Predictability of the Atlantic Warm Pool

Beginning in June 2010, Sarah Larson, an undergraduate Hollings Scholar from the University of South Alabama worked with S-K. Lee and D. Enfield(UM/CIMAS) on the impact of central Pacific warm events and Atlantic warm pool on Atlantic hurricane activity.

Monitoring Shoreline Fish Assemblages of Biscayne and Florida Bays

D. Johnson participated in the following scientific meetings.

- Greater Everglades Ecosystem Restoration Conference 2010.
- Talk - Mangrove Shoreline Fishes of Biscayne Bay and adjacent waters
- Poster - Canal-Related Influences on Biscayne Bay Seagrass and Mangrove Fishes and Invertebrates

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

E.Malca and B. Muhling(UM/CIMAS) have shared results shared with local managers including CONANOP, several academic institutions and NGOs such as TNC. This project has benefited from substantial participation (both at sea and in the laboratory) of undergraduate students from the University of ECOSUR and University of Miami. Moreover multiple open house events where held during which local scientific personnel and the general public were invited to tour the ship and observe operations. Part of this project was submitted and accepted as an undergraduate Senior Thesis by Christine Quigley to the Biology Department at the University of Miami, her project was titled: Spatial Isotopic Variability of *Lutjanus griseus* in the Dry Tortugas and Mexico where she used some data collected during inshore sampling in Quintana Roo, Mx.

Variations in Carbon and Oxygen Stable Isotopes Snapper (Lutjanidae) in Florida Bay and Florida Keys

B. Muhling, E. Malca and S. Privoznik(UM/CIMAS) carried an otolith workshop in the Chetumal campus of ECOSUR (University in Mexico) in order to provide technology transfer via hands on training on otolith removal and preparation methodologies to faculty and students as well as CONANP staff. Part of this data was prepared as a Hollings Summer Scholar project by undergraduate student Latreese Denson, her project was titled: The Use of Otolith Chemistry to Compare Sources of Snapper Recruits from Southern Florida where she used some data collected during inshore sampling.

US Virgin Islands Larval Distribution and Supply Research

E. Malca, N. Melo, B. Muhling, S. Privoznik, G. Rawson and A. Shiroza(UM/CIMAS) have shared preliminary results have been shared with local managers including the Caribbean Fisheries Management Council, University of the Virgin Islands, Virgin Island's Department of Planning and Natural Resources Department of Fish and Wildlife and the British Virgin Islands Conservation and Fisheries Department. This project has had participation (both at sea and in the laboratory) of undergraduate students from the University of Miami and from the University of the Virgin Islands since 2007. In addition multiple open house events were held during which local scientific personnel and the general public were invited to tour the ship and observe operations.

Biscayne Bay Alongshore Epifauna Community

G.A. Liehr and D.R. Johnson(UM/CIMAS) contributed the following presentations: ***Biscayne Bay Regional Restoration Team, July 9, 2010***

Presentation: Epifauna Community of South Biscayne Bay in Relation to Salinity

- ***Greater Everglades Ecosystem Restoration Conference 2010***
  Presentation: Epifauna Community of South Biscayne Bay in Relation to Salinity
  Poster: Canal-Related Influences on Biscayne Bay Seagrass and Mangrove Fishes and Invertebrates

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

The education/outreach components of this project have been integrated into the larger outreach programs of the UM Oceans and Human Health Center, NOAA AOML, and the Gulf of Mexico Alliance. This has included training and support of student interns through UM and NOAA, public informational presentations, and participation in the National Ocean Sciences Bowl program and incorporation and data and information from project in educational brochures and products by NOAA, UM OHH Center, and GOMA. Professional outreach has also involved technology transfer training of techniques developed by the project with other labs, such as the EPA labs in Puerto Rico and Athens, and other NGI collaborator labs, local FDOH facilities, other collaborating GOMA-associated and OHH-associated labs, as well as local academic partners such as the UM OHH Center, the Applied Research Center and the Southeast Environmental Research Center of Florida International University, and the Odum School of Ecology, University of Georgia in Athens.

Coral Ecological Restoration in the Florida Keys National Marine Sanctuary

D.E. Williams, R. Wilborn, A. Bright and L. Johnston (UM/CIMAS) have over this last year conducted a series of outreach activities including:

- Fairchild Challenge: half day program with visiting MDPSC middle school students at SEFSC focused on coral transplanting and restoration (23 March 2010)
- Past project larval seeded corals featured in Earth Day outreach event sponsored by The Nature Conservancy, attended by NOAA Administrator Dr. Jane Lubchenco
- Participation by undergraduate intern in field experiments (June-July 2010)
- Two oral presentations at Marine Benthic Ecology Meetings (March 2010, Wilmington NC)
- Collaborated with SCUBAnauts (high school scientific dive team) to involve them in coral spawning research, including documentation of first staghorn spawning from nursery-raised transplants in the FKNMS. This garnered press coverage.
  (see: http://www.tampabay.com/news/environment/article1026766.ece)

Evaluation of Acropora Status for Management and Recovery

D.E. Williams, A. Bright and R. Wilborn (UM/CIMAS):

- Presented seminar on *Acropora* spp. population ecology as part of a 'Sanctuary Science course offered by Florida Keys Community College.
- Gave presentation to local civic group on *Acropora* spawning and restoration.

Small Boat pCO_2 Equilibrator and Gradient-Flux Measurements of Calcification

C. Langdon (UM/RSMAS) contributed to ONE OCEAN a four-part series produced by David Suzuki and the Canadian Broadcasting Co. "Exploring the Past, Present and Future of the World's Oceans and Our Race Against the Clock to Save Them." Part four is "The Changing Sea" and covers ocean acidification and includes footage of my work in the Florida Keys and an interview filmed at RSMAS. It will air on the Discovery Channel in the US some time in Dec. 2010.

EPA/FIU Molecular Microbial Source Tracking for the Florida Keys Little Venice Service Area

D. Aranda, D. Wanless, J. Bartkowiak and M. Gidley (UM/CIMAS) and R.Coit (UM/RSMAS, NSF-REU) have integrated the education/outreach components of this project into the larger outreach programs of the UM Oceans and Human Health Center, NOAA AOML, and the Gulf of Mexico Alliance. This has included training and support of student interns through UM and NOAA, public informational presentations, and participation in the National Ocean Sciences Bowl program and incorporation and data and information from project in educational brochures and products by NOAA, UM OHH Center, FIU, and GOMA.

Global Drifter Program

S. Dolk and E. Valdes (UM/CIMAS) got out the word about their program through:

- World Oceans Day '10: in this project, the importance of SST and Ocean Currents were used to explain the goals of the Global Drifter Program and how gathering this data was made possible by using a drifter.
- NOAA deployed four drifting buoys from the coasts of California, one of which was modified to emulate a "message in a bottle." To make this possible, the barometer port was hallowed out, to provide space for student messages. Along with their classmates, family, and friends, these students track the movement of their drifters throughout the Pacific. Now, in addition to tracking these buoys online, these students will await the response from whoever finds their buoy/messages.

Observing System Simulation Experiments (OSSES) in the Gulf of Mexico

M. Le Hénaff (UM/CIMAS) and V. Kourafalou (UM/RSMAS) gave:

- Presentations at the *14th Symposium on Integrated Observing and Assimilation Systems for the Atmosphere, Oceans, and Land Surface (IOAS-AOLS)*, Atlanta, GA (January 2010)
- Presentations at the *AGU Ocean Sciences Meeting*, Portland, OR (February 2010), and
- Served as invited scientist panelists during the public hearing debate on "legislation regarding opening waters offshore of Florida to oil drilling" organized by the Sanctuary Advisory Council to the Florida Keys National Marine Sanctuary
- They also presented project findings on the role of eddies in the Loop Current variability in several interviews with the local, national and international press and were interviewed by the Natural Resources Committee in the U.S. House of Representatives, as part of the House hearings on the BP Deepwater Horizon oil spill environmental impacts (May 2010).

Integrated Coral Observing Network (ICON) Project

The ICON data are fundamental to the success of the Coral Literature, Education and Outreach (CLEO) Program, where expertise in oceanographic instrumentation and coral reef processes is transferred from the field and laboratory to the classroom in the form of educational modules developed for middle school-level students. Additional information is available on the CLEO website at http://www.coral.noaa.gov/cleo.

IX. CIMAS FELLOWS

The Fellows provide guidance to the Director on matters concerning the ongoing activities and future direction of CIMAS. There are currently 17 Fellows, 10 from RSMAS, 5 from the local NOAA laboratories, 1 from the National Hurricane Center and 1 from Florida International University. 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 nominally to meet on a quarterly basis although scheduling has been difficult because of the extensive travel schedules. Many Fellows-related matters are now addressed and implemented by means of email exchanges. Finally, because of the close proximity of the three Institutions and the frequent social activities, there are also many ad hoc meetings and discussions. During Year 9 there were few formal meetings in that the focus of the academic Fellows and CIMAS Administration was upon the Recompetition Process and a distinct separation needed to be maintained between academic and federal Fellows during the lengthy RFP development, proposal response, proposal review and proposal modification processes to avoid even the appearance of a conflict-of-interest.

FELLOWS	AFFILIATION
Dr. Bruce Albrecht	UM/RSMAS Meteorology and Physical Oceanography
Dr. Molly Baringer	NOAA/Physical Oceanography
Dr. James Bohnsack	NOAA/Southeast Fisheries Science Center
Dr. David J. Die	UM/RSMAS Marine Biology and Fisheries
Dr. Nelson Ehrhardt	UM/RSMAS Marine Biology and Fisheries
Dr. Rana A. Fine	UM/RSMAS Marine and Atmospheric Chemistry
Dr. Silvia Garzoli	NOAA/AOML/ Physical Oceanography
Dr. William E. Johns	UM/RSMAS Meteorology and 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. Donald B. Olson	UM/RSMAS Meteorology and Physical Oceanography
Dr. Edward N. Rappaport	NOAA/National Weather Service
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. Hugh E. Willoughby	Florida International University, Dept. of Earth Sciences

Ex Officio

Dr. Robert M. Atlas	NOAA/AOML, Office of the Director
Dr. Roni Avissar	UM/RSMAS Dean
Dr. Bonnie.Ponwith	NOAA/Southeast Fisheries Science Center

X. AWARDS AND HONORS

Re-Writing the Climatology of the Tropical North Atlantic and Caribbean Sea Atmosphere
J.P. Dunion (UM/CIMAS)

- Recipient of the 2009 Editors' Citation for Excellence in Refereeing for *Geophysical Research Letters*

Small Boat pCO_2 Equilibrator and Gradient-Flux Measurements of Calcification
C. Langdon (UM/RSMAS); W. McGillis (Columbia University)

- 2009 University of Rhode Island Distinguished Achievement Award to C. Langdon.

Synoptic Estimates of Sea Surface Ocean Acidification
D. Gledhill (UM/CIMAS); R. Wanninkhof (NOAA/AOML); C.M. Eakin (NOAA/CRW); Shari Yvon-Lewis (TAMU)

- Dwight Gledhill - Contributor to NOAA 2009 Silver Medal
- Dwight Gledhill - CIMAS Silver Medal Award for Scientific Excellence

Surface Water pCO_2 Measurements from Ships
F.J. Millero (UM/RSMAS); K. Sullivan, D. Pierrot, J. Trinanes, F. Bringas, G.-H. Park and S. Pochan (UM/CIMAS); G. Goni and R. Wanninkhof (NOAA/AOML)

- The M/V Oleander, a ship of SOOP that performs pCO_2 measurements between New York and Bermuda obtained the 2010 NOAA Environmental Hero Award, for its work done in support of sustained ocean observations, including those made with the pCO_2 system.

Global Carbon Data Management and Synthesis Project
F.J. Millero, F. Huang and G. Ingram (UM/RSMAS); K. Sullivan, D. Pierrot, J. Trinanes, F. Bringas and G.-H. Park (RSMAS/CIMAS); R. Wanninkhof and T.-H. Peng (NOAA/AOML); C.L. Sabine, R.A. Feely and S. Hankin (NOAA/PMEL); A. Kozyr (CDIAC); R. Key (Princeton); A. Dickson (UCSD)

- Symposium in Honor of Frank J. Millero's 70th Birthday, 237th ACS National Meeting, Salt Lake City, UT, March 22-26, 2009.

XI. POSTDOCTORAL FELLOWS AND GRADUATE STUDENTS

CIMAS-Supported Postdoctoral Fellows and Graduate Students

Postdoctoral Fellows

Amornthammarong, Natchanon
Casal, Tania
Helmle, Kevin
Jones, David L.
Le Henaff, Matthew
Liu, Hailong
Lorsolo, Sylvie
Muñoz, Ernesto
Park, Geun-Ha
Yang, Haoping
Zhang, Jun

Graduate Students

Task I
Buck, Eric
Ebanks, Dwight
Helms, Joshua
Johnston, Lyza
Karnauskas, Mandy
Lazarre, Dominique
Quirino, Thiago
Saul, Steven
St. Hilary, Sandra

Task III
Greer, Adam
Hans, Jonathan
Harford, Bill
Lin, Lin
Martin, Elizabeth
McCaskill, Claire
Meyers, Patrick
Ravitz, Guy

Employees
Aranda, Diana
DiNezio, Pedro
Forteza, Elizabeth
Kelble, Christopher
Malca, Estrella
Wanless, David

Other Participants in CIMAS Projects

Postdoctoral Fellows

Chattopadhyey, Rajib
Chatzis, Sotirios
Jaimes, Benjamin
Kerns, Brandon
Loose, Brice
Min, Dughong
Trapp, J. Michael

Graduate Students

Chanson, Mareva
Chen, Chao
DiTrilio, Benjamin
Ghate, Virendra
Gordon, Ronald
Huntington, Brittany
Joyner, Jessica
Judt, Flako
Komaromi, William
Kough, Andrew
Liu, Dianting
Melendez, Melissa
Meng. Tao
Miller, Matthew
Ravitz, Guy
Rodriguez, Carmen
Sainani, Varsha
Santos, Rolando
Smith, Matt
Standohar, Christine
Stern, Daniel
Trapp, J. Michael
Vasquez-Yeomans, Lourdes
Waterhouse, Lynn
Waters, Jason
Woosley, Ryan
Zheng, Xue

XII. RESEARCH STAFF

Aksoy, Altug	Assistant Scientist
Amornthammarong, Natchanon	Postdoctoral Associate
Annane, Bachir	Senior Research Associate III
Aranda, Diana	Research Associate I
Berberian, George	Research Associate II (PT)
Bright, Alan	Research Associate II
Bringas Gutierrez, Francis	Research Associate III
Brown, Cheryl	Research Associate II
Cardenas, Hernando	Research Associate I
Carrasco, Hector N.	Senior Research Associate I
Casal, Tania	Postdoctoral Associate
Di Nezio, Pedro N.	Research Associate III
Dias, Laura	Research Associate I
Diaz, Jose E.	Research Associate II
Dolk, Shaun	Research Associate II
Dong, Shenfu	Assistant Scientist
Dunion, Jason	Senior Research Associate III
Enfield, David	Scientist (PT)
Erickson, Kristin L.	Research Associate III
Festa, John	Senior Research Associate III (PT)
Fonseca, Carlos A.	Research Associate III
Forteza, Elizabeth	Research Associate III
Garcia, Rigoberto F.	Research Associate III
Gidley, Maribeth	Assistant Scientist
Gledhill, Dwight	Associate Scientist
Gonzalez, Caridad	Research Associate II
Gramer, Lewis J.	Research Associate III
Halliwell, Vicki	Senior Research Associate III
Helmle, Kevin	Postdoctoral Associate

Hoolihan, John	Assistant Scientist
Jankulak, Michael L.	Research Associate III
Johnson, Darlene R.	Scientist
Jones, David	Postdoctoral Associate
Kelble, Christopher R.	Senior Research Associate II
Klotz, Bradley	Research Associate III
Le Henaff, Matthieu	Postdoctoral Associate
Lee, Sang-Ki	Associate Scientist
Liehr, Gladys	Senior Research Associate I
Liu, Hailong	Postdoctoral Associate
Lorsolo, Sylvie	Postdoctoral Associate
Malca, Estrella	Research Associate III
Manzello Derek	Assistant Scientist
Melo, Nelson	Senior Research Associate II
Molinari, Robert	Scientist (PT)
Molina, Jonathan	Research Associate I
Muhling, Barbara	Assistant Scientist
Muñoz, Ernesto	Postdoctoral Associate
Otero, Sonia	Research Associate III
Park, Geun-Ha	Postdoctoral Associate
Perez, Renellys	Assistant Scientist
Pierrot, Denis P.	Assistant Scientist
Pochan, Sommyr D.	Research Associate I
Rawson, Grant T.	Research Associate III
Sabina, Reyna	Research Associate III (PT)
Seaton, Kyle	Research Associate I
Sellwood, Kathryn J	Research Associate III
Shiroza, Akihiro	Research Associate I
Sinigalliano, Christopher	Assistant Scientist
St. Fleur, Russell	Programmer Analyst II
Sullivan, Kevin F.	Senior Research Associate III
Teare, Brian	Research Associate I
Thacker, Carlisle	Scientist (PT)

Tonioli, Flavia	Senior Research Associate I
Valdes, Erik	Research Associate I
Valdivia, Abel	Senior Research Associate I
Visser, Lindsey	Research Associate I
Wanless, David R.	Research Associate II
Whitcraft, Samantha R.	Senior Research Associate III
Wicker, Jesse A.	Research Associate II
Wilborn, Rachel	Research Associate II
Willey, Debra	Senior Research Associate I
Williams, Dana E.	Assistant Scientist
Willis, Paul	Research Associate II (PT)
Yang, Haoping	Postdoctoral Associate
Yao, Qi	Senior Research Associate I
Yeh, Kao-San	Scientist
Zhang, Jun	Postdoctoral Associate
Zhang, Xuejin	Assistant Scientist

XIII. VISITING SCIENTISTS PROGRAM

Dr. Matt Ogburn
Associate Graduate Faculty
NOAA Living Marine Resources Cooperative Science Center
Savannah State University
Savannah, Georgia
11 September, 2009

11 September, 2009 *"Estuarine Invasion: How Crab and Shrimp Postlarvae Ride in on Currents and Conquer Low Salinity"*

Dr. Elizabeth Fulton
Australian Life Scientist of the Year 2007
Principal Research Scientist
CSIRO Marine and Atmospheric Research – Hobart
Castray Esplanade
Hobart, TAS 7000, Australia
28 October, 2009

28 October, 2009: *"The Atlantis Ecosystem Modeling Framework :Applications for Ecosystem-Based Fishery Management"*

Professor Dudley B. Chelton
Distinguished Professor of Oceanic and Atmospheric Sciences
College of Oceanic and Atmospheric Sciences
Oregon State University
Corvallis, Oregon
9 – 11 November, 2009

10 November, 2009: *"Global Satellite Altimeter Observations of Westward Propagating Nonlinear Eddies"*

Dr. Song Gao
Assistant Professor Chemistry
Farquhar College of Arts 8 Sciences – MST
NOVA Southeastern University
Ft. Lauderdale, FL
21 January, 2010

21 January 2010: *"Organic Compounds in Atmospheric Aerosols: Identity Origin and Evolution"*

Dr. Thomas Rossby
Graduate School of Oceanography
University of Rhode Island
Narragansett, Rhode Island
18 – 29 January, 2010

27 January, 2010: *"On the Variability of Gulf Stream Transport from Seasonal to Decadal Timescales"*

29 January, 2010: *"OceanScope, A New Paradigm for Sustained Observation of the Global Water Column"*

Professor Michael Ghil
Distinguished Professor of Climate Dynamics
University of California, Los Angeles
Distinguished Professor of Geosciences
Ecole Normale Superieure
Paris France
1 – 3 March, 2010

2 March, 2010: *"Data Assimilation, OSSEs, and Parameter Estimation"*

3 March, 2010: *"Toward A Theory of the North Atlantic Oscillation"*

Dr. Michael Dagg
Louisiana Universities Marine Consortium
Defelice Center
Chauvin, LA 70344
24 – 26 March, 2010

Professor Da-Ling Zhang
Department of Atmospheric and Oceanic Science
University of Maryland
College Park, Maryland
9 March – 8 May, 2010

31 March, 2010: *"On the Rapid Intensification of Hurricane Wilma (2005)"*

Professor U.C. Mohanty
Centre for Atmospheric Sciences
Indian Institute of Technology, Delhi
Hauz Khas, New Delhi-110016, India
23 June – 24 June, 2010

24 June, 2010 – *"Prediction of Tropical Cyclones over India Seas with Mesoscale Modeling Systems: Data Impact Studies"*

XIV. PUBLICATIONS

We list all publications for the years 2009-2010, 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 2009 – 2010, 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 2009-2010

	Institute Lead Author	**NOAA Lead Author**	**Other Lead Author**
	2009-2010	**2009-2010**	**2009-2010**
Peer Reviewed	60	16	30
Non-Peer Reviewed	11	10	10

Refereed Journal Articles

Abdelzaher, A., M. Wright, C. Ortega, H. Solo-Gabriele, G. Miller, S. Elmir, X. Newman, P. Shih, J.A. Bonilla, T.D., Bonilla, C.J. Palmer, T., Scott, J. Lukasik, V.J. Harwood, S. McQuaig, C. Sinigalliano, M. Gidley, L. Plano, X. Zhu, J.D. Wang and L. Fleming (2010), Presence of Pathogens and Indicator Microbes at a Non-Point Source Subtropical Recreational Marine Beach, *Applied and Environmental Microbiology*, 76(3), 724-732.

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APPENDIX A

NA08OAR4320889
Currently funded Competitive Shadow Awards - Year 9/10

7/13/09	Soden	$	148,990	Understanding Discrepancies between Satellite-Observed and GCM-Simulated Precipation change…
7/13/09	Kirtman	$	124,991	Why Do CGCMs Have Too Much ENSO Variability in the Western Pacific?
7/13/09	Minnett	$	136,544	Climate Data Records of Sea Surface Temperature
8/13/09	Kirtman	$	24,998	Atmosphere-Ocean Interactions and summer rainfall Variability and Predictability in the Intra-Amerigcas Region
8/19/09	Zhang	$	130,000	Role of Diabetic Heating Profiles in MJO Simulation and Prediction
8/24/09	Shay	$	121,642	Evaluation and Improvement of Ocean Model Parameterizations for NCEP Operations
10/2/09	Ortner	$	128,506	SFL08: Marine and Estuarine Goal Setting for South Florida (MARES)
05/19/10	Albrecht	$	120,000	Studies of Cloud, Drizzle, Turbulence, and Boundary Layer Variability over the Eastern Pacific…
05/24/10	Kirtman	$	25,000	Atmosphere-Ocean Interactions and summer rainfall Variability and Predictability in the Intra-Amerigcas Region
05/24/10	Ortner	$	124,732	SFL08: Marine and Estuarine Goal Setting for South Florida (MARES)
05/25/10	Zhang	$	135,000	Role of Diabetic Heating Profiles in MJO Simulation and Prediction
06/10/10	Minnett	$	148,567	Climate Data Records of Sea Surface Temperature
06/10/10	Kirtman	$	134,952	Multi-Model Ensemble Climate Prediction with CCSM and CFS
06/18/10	Soden	$	157,083	Understanding Discrepancies between Satellite-Observed and GCM-Simulated Precipation change…
	TOTAL	**$**	**1,661,005**	