The Cooperative Institute for Marine and Atmospheric Studies

CIMAS
Cooperative Institute for Marine and Atmospheric Studies

Eighth Year Annual Report

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RSMAS
ROSENSTIEL SCHOOL
OF MARINE AND ATMOSPHERIC SCIENCE

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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 2008 - 2009, Year 8 under the Cooperative Agreement (CA), continued at a high level. Total expenditures in FY 8 were $10.49M, somewhat higher than the previous year, $9.9M. The average expenditure of the past two years (Years 7 and 8) is more than $4.5M greater than in 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 FY 8 totaled ca. $4.7M, almost triple that in Year 1.

Additional research funding (Tasks III and IV) in Year 8 totaled ca. $3.9M. This is a decrease in funding from FY07 of ca. 17%. In contrast to Task II funding, this funding has exhibited no long term trend over the past five years of the CA with an annual average of $4.0M. Nonetheless, the total remains 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 in Theme 1, Climate Variability, which accounts for 28% of the total. The smallest portion was in Theme 3, Regional Coastal Ecosystem Processes, 8%. The remaining four themes were roughly comparable, ranging from 13 to 19%.

During FY 2008-2009 a total of 141 persons were associated with CIMAS in various capacities. Of these, 98 received over 50% of their support from NOAA through CIMAS. Of the 98 research employees who received over 50% NOAA support, 64 worked with AOML and 34 with SEFSC.

The employees in the Research Associate and Research Scientist ranks have a diverse demographic profile. The population is 33% female. Foreign-born individuals make up 53% of the personnel. Of these, Hispanics make up 28% of the ranks; Asian and Pacific Islander, 18%. The population of CIMAS is relatively young with an average age of 38.

The research program in CIMAS continues to be productive. In FY 8 CIMAS employees were lead authors on 27 peer-reviewed publications and were co-authors on 44 additional peer-reviewed publications and lead authors or co-authors on another 34 technical reports. Here we highlight some of results of individual projects. The titles are selected from each of themes to be representative of the wide range of activities carried out within CIMAS. A more detailed description of these results can be found in the body of the Report under individual project summaries sorted alphabetically by first author within each of the six Themes.

RESEARCH HIGHLIGHTS

Climate

Seawater Density Variations in the North Atlantic and the Atlantic Meridional Overturning Circulation (AMOC): Data analysis and models indicate that because of the opposite effects of temperature and salinity upon density over both long-term trend and multi-decadal timescales the AMOC has become stronger (not weaker) over the past five decades.

Why do CGCMs have too much ENSO Variability in the Western Pacific: Coupled ocean atmosphere feedbacks contribute to a significant fraction of sea surface temperature variability worldwide with increasing importance in the tropics. We cannot dismiss the possibility that the coupled feedbacks are unstable. Even in the tropical Atlantic there is a sizable region where the ratio of standard deviations is relatively large and even a small region where the ratio exceeds 1.0.

Understanding Discrepancies between Satellite-Observed and GCM-Simulated Precipitation Change in Response to Surface Warming: Based on 20 years of satellite observations, we found a distinct link between tropical rainfall extremes and temperature, with heavy rain events increasing during warm/moist periods and decreasing during cold/dry periods. The observed amplification of rainfall extremes was found to be larger than predicted by models, implying that projections of future changes in rainfall extremes due to anthropogenic global warming may be underestimated.

Climate Impacts of the Western Hemisphere Warm Pool on the Americas: The global climate model simulations forced by future greenhouse warming predict that the North Atlantic will warm at a slower rate than the North Indo-Pacific in the 21st century. Our analysis indicates that the preferential warming of the North Indo-Pacific over the North Atlantic will increase vertical wind shear and static stability over the tropical North Atlantic (TNA), and thereby decrease (not increase) Atlantic hurricane activity.

Fisheries Dynamics

Development and Evaluation of New Technology for the Remote Identification and Enumeration of larval fish: ISIIS is a towed digital imaging system capable of quantifying larval fish *in situ*, via high volume imaging (~70 l s-1) at high resolution (effect <70 μm per pixel). Deployments off the east coast of Florida demonstrate that ISIIS takes clear, identifiable and quantifiable images of larval fish. Subsequent semi-operational tests in conjunction with NMFS survey cruises indicate the technology may have utility in fisheries management applications

Reef Fish Recruitment Dynamics: Integration and Analysis of Long-Term Visual Fish Surveys to Examine Environmental Influences: Connectivity between mangroves and coral reefs may be crucial for the replenishment of adult populations on the reef. Direct evidence has been lacking. Our results indicate that habitats within the bay and on the reef are definitely connected through ontogenetic migrations of fishes from their juvenile to their adult habitats.

Juvenile Spotted Seatrout Monitoring in Florida Bay: The Comprehensive Everglades Restoration Program (CERP) is the largest and most expensive ecosystem restoration ever attempted. Our results indicated that if CERP is successful at lowering salinity in Florida Bay, it is likely to increase the population of juvenile, and possibly that of adult, spotted sea-trout.

Regional Coastal Ecosystems

Characterization of Ocean Acidification in Coral Reef Waters: A growing number of laboratory experiments indicate 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. In collaboration with AOML, PMEL, UPR and USGS we have initiated a five year project and established La Parguera, PR as an Atlantic OA Test-bed.

Coral Ecological Restoration in the Florida Keys National Marine Sanctuary (F.K.N.M.S): A new, ongoing project component was begun in summer 2008, the Aquarius Coral Restoration/Resilience Experiments (ACRRE). Preliminary results indicate substantial variation in survivorship of *A.cervicornis* fragments from different sources. Source needs to be considered with respect to reef restoration.

Human Interactions

Climate Information System for Agriculture and Water Resources Management in Southeastern USA: While there is much information available about global climate change, there is far less information available on the probable local impacts of climate change. Rational adaptation strategies require local or regional information. Along with model downscaling, the SECC is now focusing not only upon the agricultural sector but also upon the needs for climate information of both local governments and businesses.

Scientific, Technical, Research, Engineering and Modeling Support (STREAMS) Virtual Beach Project – Miami Hobie Cat Beach: An in-house genetic archive of all samples has been established and in-house molecular characterization of indicators, alternative indicators, and pathogens is ongoing. This genetic archive and its analysis is expected to provide a wealth of data on non-point source pathogen threats at recreational beaches in Florida.

Air-Sea Interactions

Application of Satellite Surface Wind Data to Ocean SurfaceAnalysis and Numerical Weather Prediction: The operational NCEP GFS currently uses a Gridpoint Statistical Interpolation (GSI) data assimilation scheme. A primary conclusion of our synthetic observation experiments is that the NCEP GSI system is able to produce only limited modifications to the dynamic and thermodynamic fields above the lower troposphere.

Advanced Modeling and Prediction of Tropical Cyclones: The High Resolution Hurricane (HRH) test is designed to quantify the impact of increased model resolution on hurricane intensity forecasts. Preliminary results indicate that the increased model resolution has significantly improved five-day forecasts of both track and intensity.

Integrated Ocean Observations

Synoptic Estimates of Sea Surface Ocean Acidification*:* A quasi-operational product is being distributed through NOAA Coral Reef Watch (CRW) that provides a synoptic estimate of the distribution of sea surface carbonate chemistry parameters throughout Greater Caribbean Region (GCR).

Automating Explorer of the Seas (EoS) Oceanographic and Meteorological Sampling: the Next Generation Ship-of-Opportunity: EoS is now fully automated. SCOR and the IAPSO have formed an OceanScope Working Group to establish a global network of ocean observation platforms on commercial ships. At the WGs first meeting preliminary agreement was reached on phased implementation plan for OceanScope during the first phase of which the EoS would serve as a prototype and instrument test bed.

The CLIVAR CO_2 Repeat Hydrography Program: Our updated estimates of changes in the anthropogenic carbon inventory indicate: a) a large uptake in the Atlantic corresponding to the down-welling component of the Meridional Overturning Circulation (MOC) that enhances transport of carbon into the deep waters; and, b) high rates in the Indian Ocean corresponding to enhanced intermediate water formation in the Southern Indian Ocean.

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 about fifteen such Cooperative Institutes located in seventeen states.

The CIMAS Vision:

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

The CIMAS Mission:

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

How CIMAS Carries Out Its Mission

CIMAS serves as a mechanism to promote synergisms between University scientists and those in NOAA. Most of our research is related to 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 are guided by the general objectives of NOAA's *Strategic Plan for FY 2005-2010*. NOAA identifies four mission goals:

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

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

The Administration and Governance of CIMAS

The organization of CIMAS is designed to reflect the joint interests of the University and NOAA in carrying out the CIMAS Mission. In accordance with the MOU, the Director of CIMAS must be a faculty member of the University. Many aspects of the governance of CIMAS are dealt with in consultation with the CIMAS Fellows who act much like a Board of Directors. Fellows are scientists of established national or international standing who hold regular teaching or research faculty appointments in the University (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 carried out at NOAA's Miami laboratories. The expertise of these CIMAS employees complements that present in NOAA and the University. CIMAS employees provide support that is essential to the success of specific activities or projects under the collaborative research themes of the Institute.

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 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 which are either not directly linked to activities in a NOAA laboratory or 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 FY 08 a total of 141 persons were associated with CIMAS in various capacities. Of these, 98 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 98 who received over 50% NOAA support, 64 are associated with AOML and 34 with SEFSC.

Table 1: CIMAS Personnel 2008 – 2009

Personnel				
Category	**Number**	**BS**	**MS**	**Ph.D**
Research Associate/Scientist	48	22	15	11
Part Time Research Associate/Scientist	7	2	2	3
Postdoctoral Fellow	12			12
Research Support Temporary Staff	31	4	1	3
Total (> 50% NOAA support)	98	28	18	29
Full Time Administrative Staff	5			2
Task I Undergraduates Students	11			
Task I Graduate Students	22	16	6	
Visiting Scientist	5			
Location of Lab	64-AOML 34-SEFSC			
Obtained NOAA employment within the last year	1			

Research Associates, Research Scientists and Postdoctoral Associate are those employees under Task 2 who work closely with the local NOAA laboratories. A total of 67 persons in these categories were employed under Task 2 in FY 8. 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 FY 08 there were a total of twelve Postdoctoral Fellows, the largest number in CIMAS history. 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. These faculty are not counted in the listing of the 141 not even the 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.

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.

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.

Transition to Federal Positions

Since the start of the current Cooperative Agreement a total of 19 CIMAS employees have assumed Federal positions in the local laboratories. During the past year 1 CIMAS employee assumed a position as a Federal Employee in the local NOAA laboratories.

Demographics of CIMAS Employees

The employees in the Research Associate and Research Scientist ranks have a rather diverse demographic profile. The CIMAS population is 33% female. Foreign-born individuals make up 53% of the personnel; of these Hispanics make up 28% of the ranks; Asian and Pacific Islander, 18%. Only one African-American has been recruited, despite our efforts to expand this demographic. The population of CIMAS is relatively young with an average age of 38. The largest age group is the 30s decade, a total of 27. As noted in various NOAA workforce analyses this is a much younger and more diverse group than the overall federal NOAA workforce.

CIMAS and Students

There are currently 22 graduate students supported through CIMAS Task I, the largest number ever supported in any one year under the current Cooperative Agreement. In addition eleven 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 2008 – 2009, Year Eight of the Cooperative Agreement (CA), was similar to the preceding year. In FY 8, funding from all sources totaled ca. $10.5M compared to ca. 9.9M in FY 7. A summary of CIMAS funding under the four Tasks in FY 8 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

The history of funding through CIMAS is shown graphically in Figure 1. Total funding in FY 7 and FY 8 was substantially greater than in the first five years of the CA. The average of the last two years of the CA is approximately $4M greater than the first two years, an increase of almost 100%.

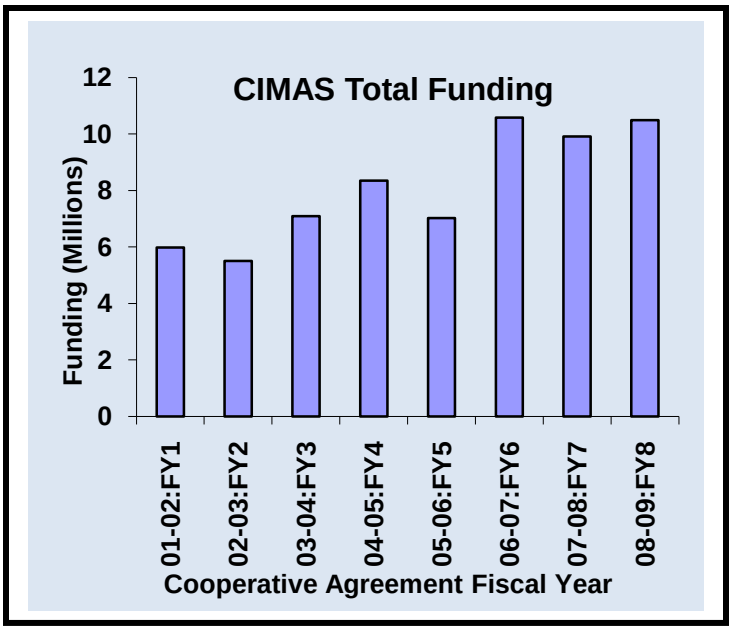


Figure 1: CIMAS funding

The sources of funding in CIMAS are shown in Table 2. The major source of funding is OAR which provided 71% of the total. NMFS and NOS are second at 13% and 6% respectively. Over the course of the CA about 85% of CIMAS funds have come from two NOAA sources: OAR and NMFS (as was true this year) although the relative proportions have changed in different years. Of the total OAR funding most comes from the Climate Program Office (CPO), a competitive grants program in OAR. The funding through CPO increased sharply in FY 7 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 - FY 8

1July 2008 – 30 June 2009		
Line Office	**Funding $M**	**% Total**
OAR	7.40	71%
NMFS	1.39	13%
NOS	0.62	6%
NESDIS	0.07	1%
Other	1.0	9%
Grand Total	10.48	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 competitive grants programs under Climate Program Office (CPO) and previously through the Office of Global Programs (OGP) has been increasing sharply over the past few years.

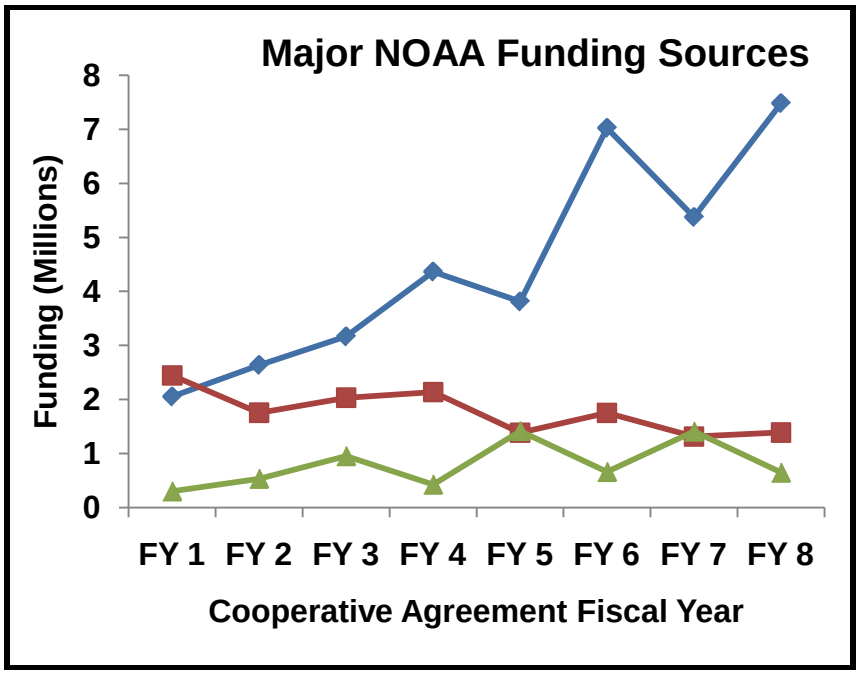


Figure 2: Trends in funding from the major sources under the current Cooperative Agreement

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 and includes support for graduate students and limited-term collaborating research scientists from outside Miami. The University contributes to the administrative support of CIMAS in its role as a Division 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 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 goals but fall outside the scope of Tasks 1, 2 and 3. The indirect cost rate for Task 3 is 40% and Task 4 is 51%. The different rates for these two tasks are in recognition of the direct funding support that CIMAS receives from the local NOAA laboratories under Task 1.

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 last year reflects an increase in other aspects of Task I since there continues to be no Postdoctoral Fellows in Task 1.

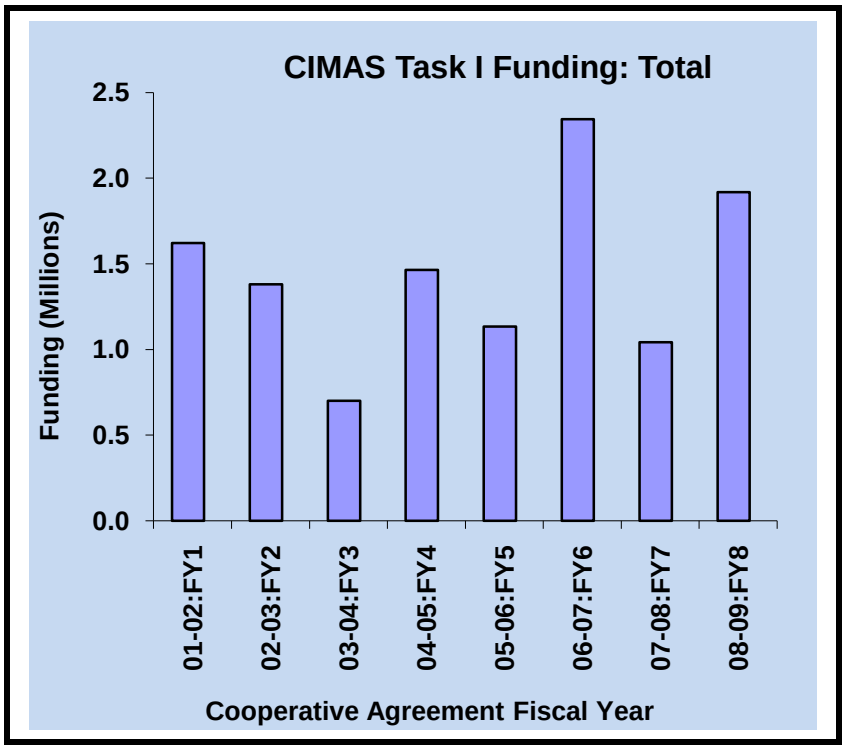


Figure 3: History of Task 1 Funding

The distribution of NOAA Task 1 expenditures is shown in Figure 4. The total NOAA-supported Task 1 budget was $1.9M. The category “Administrative Staff” (25%) covers only a portion of the salary of CIMAS staff including its Director and Associate Director. In addition, the University of Miami FY08 contribution was $0.247M to Task I.

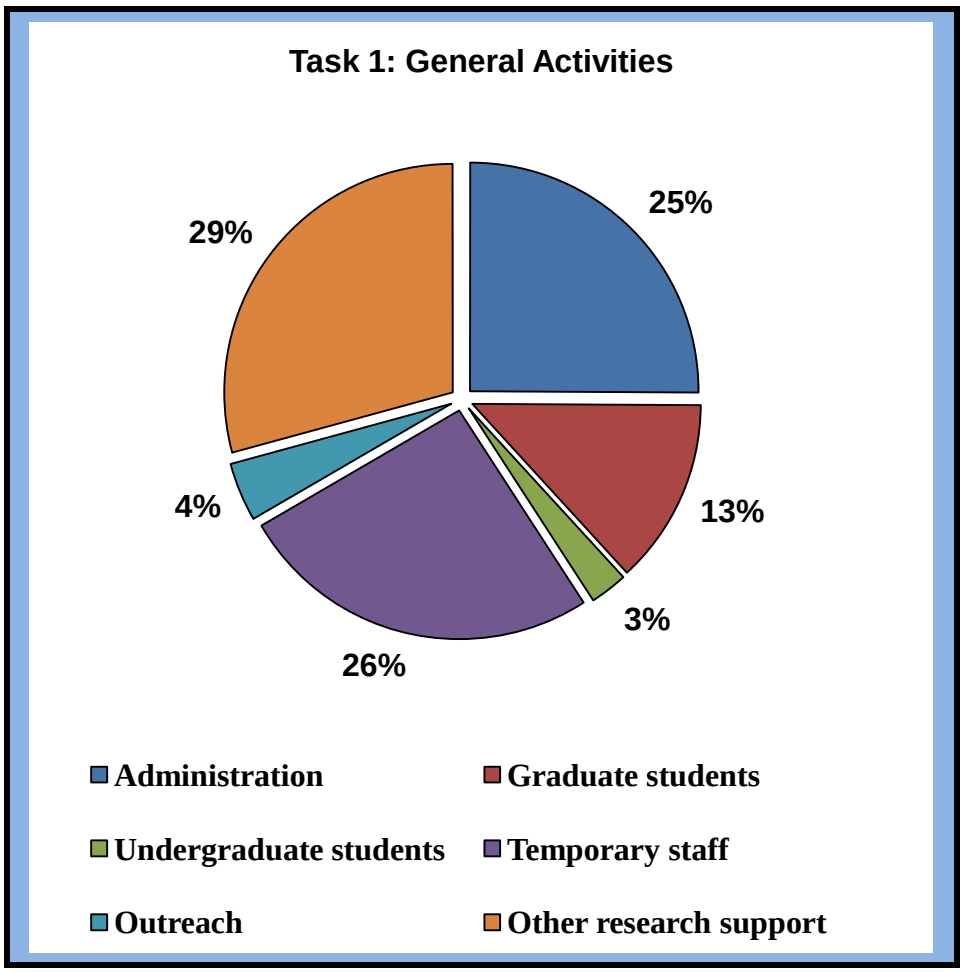


Figure 4: Distribution of Task 1Funding

The category "Other" (29%) 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 (26%) 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 8, Task 2 totaled $4.7M, slightly higher than FY7. There has been strong and steady growth in funding for Task 2 over the CA, essentially tripling 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.

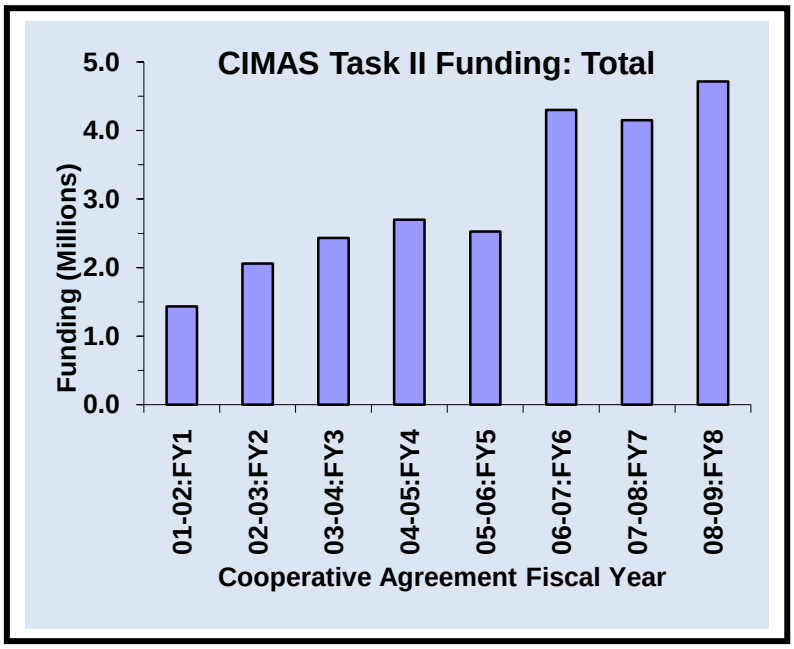


Figure 5: History of Task 2 Funding over the Cooperative Agreement

The history of other research funding (Task 3 and Task 4 combined) is shown in Figure 6. This funding has remained relatively unchanged over the past six years of the Cooperative Agreement with an annual average of $3.9M. Nonetheless, this rate is substantially greater than that in the first two years which averaged $2.5M and that under the previous CA. That said, there is no evidence of any substantial increasing trend in recent years. This contrasts sharply with the strong increases in Task 2 budgets but is consistent with the overall level of research funding available in the last five years.

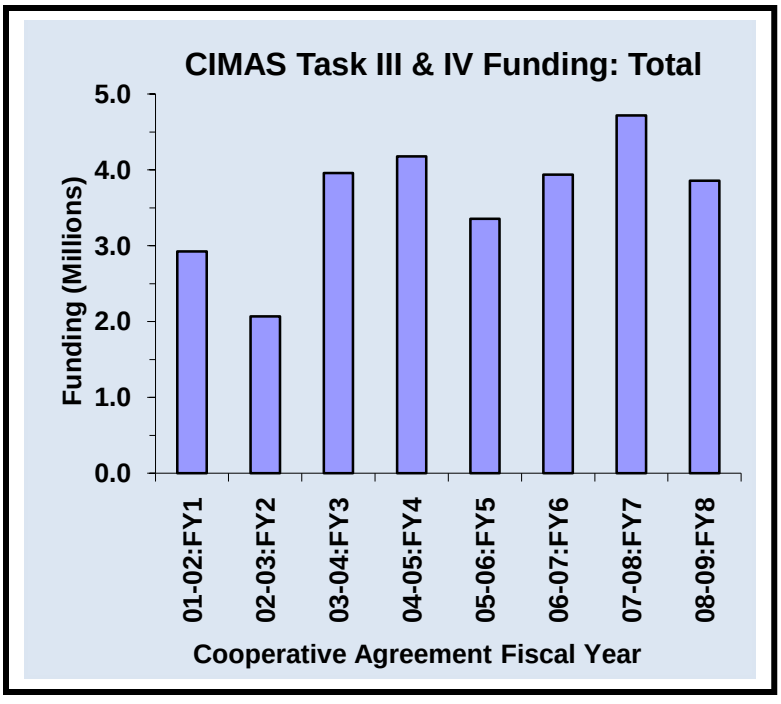


Figure 6: CIMAS Research Funding (Task 3 and Task 4)

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 1, Climate Variability, accounts for the largest portion of the funding - 28%. The smallest funding were in Theme 3, Regional Coastal Ecosystem Processes - 8%. Funding in the remaining four themes was roughly comparable, ranging from 13 to 19%.

The distribution of research funding by Theme as shown in Figure 7 is based upon the scientists' own assessments of the major focus of their research. In truth nearly all the activities are highly interdisciplinary and could reasonably be assigned to more than one Theme – e.g., much of research categorized as Theme 1: Climate Variability could with equal plausibility have been assigned to Theme 5: Air-Sea Interactions and Exchanges. To reflect this we asked scientist to optionally note secondary (or tertiary) theme assignments.

Note that this figure only shows the distribution of funding under Themes 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 the other costs for those research projects are budgeted directly within NOAA.

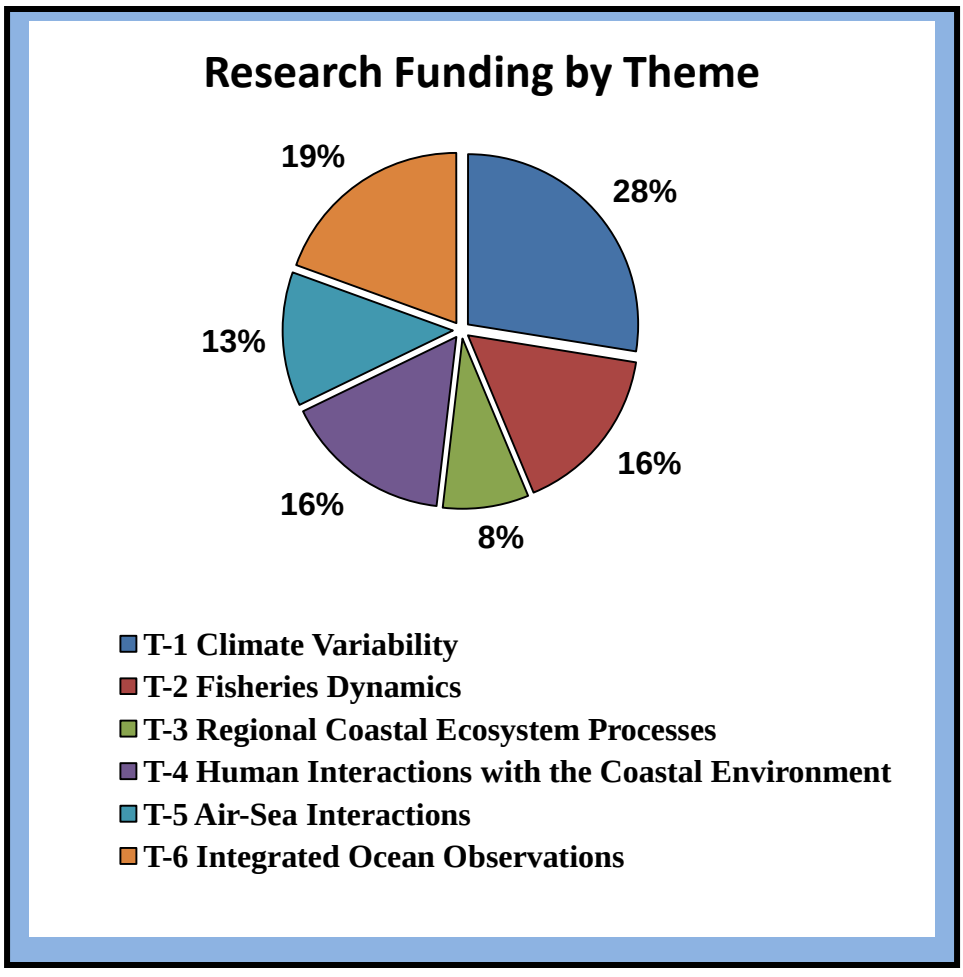


Figure 7: Percentage of Task 3 and Task 4 (Research) funding in the CIMAS Themes

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. 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

Seawater Density Variations in the North Atlantic and the Atlantic Meridional Overturning Circulation (AMOC)

S. Dong and E. Muñoz (UM/CIMAS); C. Wang (NOAA/AOML)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** To understand the long-term variability of upper ocean temperature, salinity, and density fields, and their association with the Atlantic Multi-decadal Oscillation and AMOC.

***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:** Chunzai Wang

Research Summary:

The AMOC plays an important role in climate change since its variability affects the global heat transport. In fact, the AMOC has been identified as a near-term priority in the Ocean Research Priorities Plan by the U.S. Joint Subcommittee on Ocean Science and Technology. In addition, the North Atlantic also hosts a climate phenomenon known as the Atlantic multi-decadal oscillation (AMO), a fluctuating climate mode wherein the sea surface temperature (SST) can vary on multi-decadal timescales of 30-80 years with the largest variations centered in the high latitudes of the North Atlantic. The SST variability of the AMO is associated with changes of climate and extreme weather events such as rainfall and drought/flood in North America and Atlantic hurricane. Thus, improving our understanding of North Atlantic variability important both scientifically and socially in that a better understanding of the AMOC mechanism will improve our ability to predict long-term climate change.

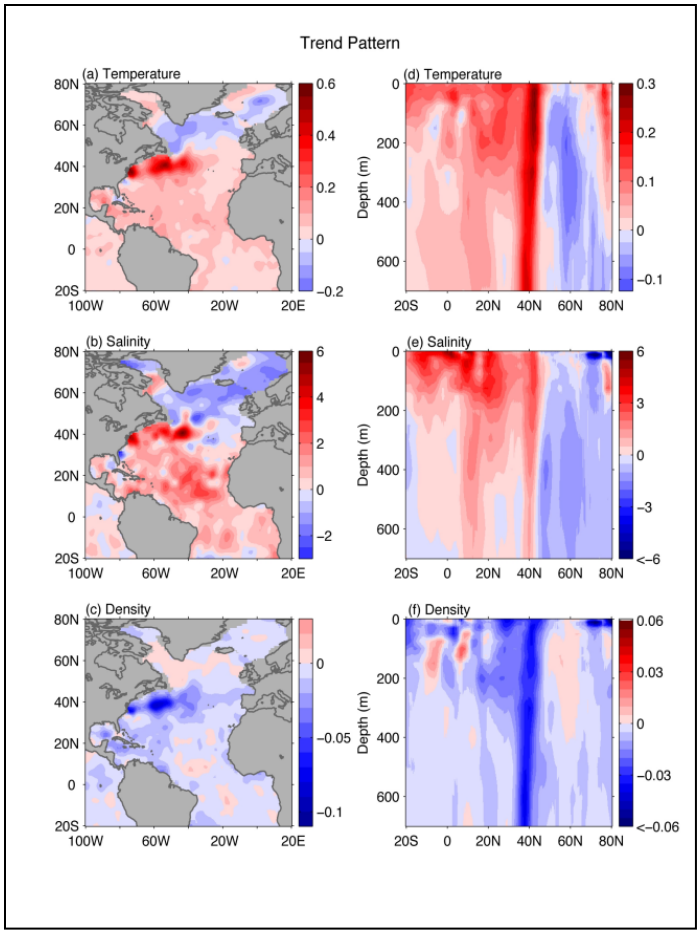


Figure 1: The long-term linear trend patterns of the temperature (°C/decade), salinity (10^{-2} psu/decade) and potential density (kg/m^3 per decade) anomalies in the North Atlantic. The temperature, salinity, and potential density trends averaged over depths of 0-700 m are shown in (a), (b) and (c), and the zonally-averaged (between 80°W-20°E) temperature, salinity and potential density trends are in (d), (e), and (f).

Changes of seawater properties in the North Atlantic Ocean are closely linked to AMOC variability. Previous observational studies have focused on salinity and freshwater variability in the sinking region of the North Atlantic, and it has been argued that a freshening North Atlantic basin would slow down or halt the flow of the AMOC. In contrast we focus upon how density patterns over the upper ocean of the North Atlantic can affect the strength of the AMOC. As a long-term trend, the upper ocean of the sub-polar North Atlantic is becoming cooler and fresher, whereas the subtropical North Atlantic is becoming warmer and saltier. On a multi-decadal timescale, the upper ocean of the North Atlantic has been warmer and saltier since 1995. The heat and salt content in the sub-polar North Atlantic lags that in the subtropical North Atlantic by about 8-9 years, suggesting a lower latitude origin for the temperature and salinity anomalies. Because of the opposite effects of temperature and salinity on density for both long-term trend and multi-decadal timescales, these variations do not result in the proposed density gradient reduction in the sub-polar North Atlantic that would slow down the AMOC. Rather, the changes in the meridional density gradient between the sub-polar and subtropical North Atlantic indicate that the AMOC has become stronger over the past five decades. These observed results are supported by and consistent with oceanic reanalysis products.

Research Performance Measure: The main object is to investigate multi-decadal variations in the oceanic temperature/salinity/density fields and understand their influence on long-term climate variability (such as AMO and AMOC) using available observational data and numerical model outputs. This objective has been accomplished.

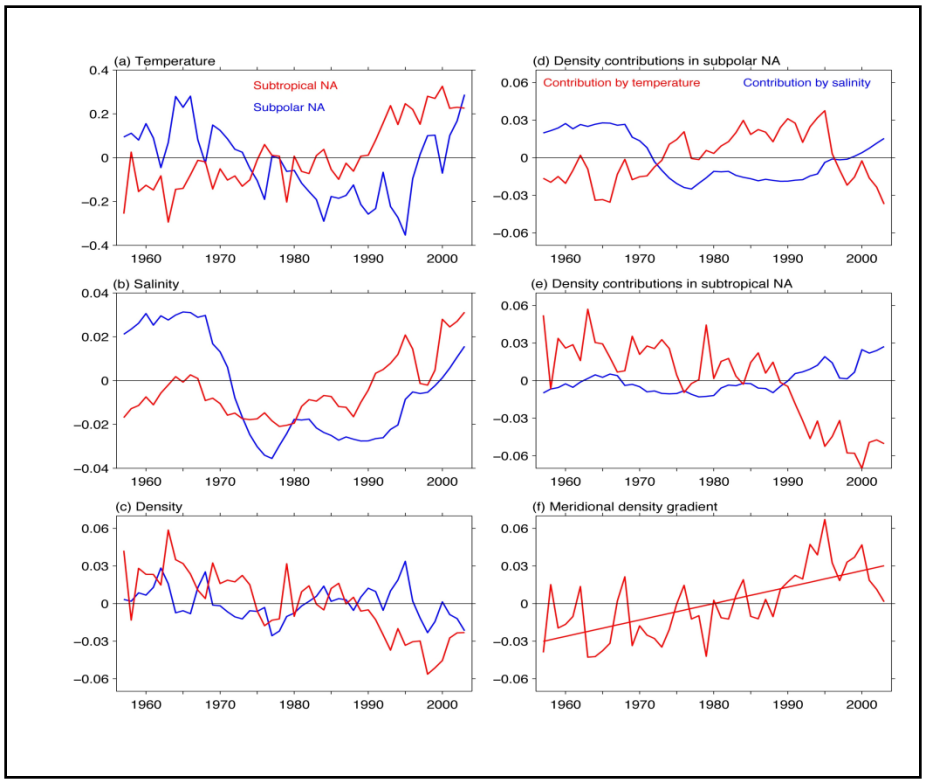


Figure 2: The time series of the temperature (°C), salinity (psu) and potential density (kg/m3) anomalies in the upper ocean (0-700 m) of the North Atlantic. Shown are (a) the temperature anomalies in the subtropical (red) and subpolar (blue) North Atlantic, (b) the salinity anomalies in the subtropical (red) and subpolar (blue) North Atlantic, (c) the potential density anomalies in the subtropical (red) and subpolar (blue) North Atlantic, (d) the potential density anomalies contributed by temperature (red) and salinity (blue) in the subpolar North Atlantic, (e) the potential density anomalies contributed by temperature (red) and salinity (blue) in the subtropical North Atlantic, and (f) the meridional potential density gradient between the subpolar and subtropical North Atlantic. The straight line in (f) is the linear trend which exceeds the 99% significance level. The subpolar and subtropical North Atlantic are defined in the regions of 50°N-75°N, 60°W-10°E and 25°N-50°N, 60°W-10°E, respectively.

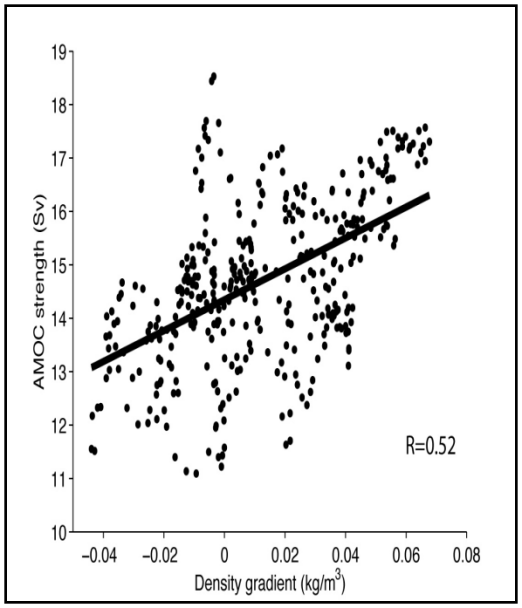


Figure 3: The scatter plot of the AMOC strength (Sv; 1 Sv=106 m3/s) versus the meridional potential density gradient (kg/m3) between the subpolar and subtropical North Atlantic Ocean, calculated from the SODA reanalysis from 1974-2005. The AMOC strength is measured by the maximum streamfunction at 30°N. The meridional potential density gradient is computed by the potential density anomaly (after removing seasonal cycle) difference between the regions of 60°W-10°W, 52°N-75°N and 70°W-10°W, 25°N-50°N. An 11-month running mean is applied to both indices before the scatter plot. The straight line represents the linear regression.

Intra-Americas Studies of Climate Processes (IASCLIP)

D. Enfield (UM/CIMAS)

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 predictdions 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:** Silvia Garzoli

Project 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) begins 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 2009, illustrating the development of a small WHWP (cool tropical North Atlantic) in response to very active convection and heavy rainfall over the Amazon Basin during the late winter and spring of 2009. The link between the convection and small warm pool size is the energizing of the Northern Hemisphere Hadley circulation, intensifying the North Atlantic Subtropical High and NE trade winds and evaporation. The mantra of IASCLIP is that by emulating this and other warm pool development mechanisms (e.g., ENSO), improved numerical models can produced useful summer climate forecasts.

Since retiring from NOAA in December 2008 and joining CIMAS in January 2009, Dr. Enfield has devoted approximately 70% of his time to the task of orchestrating the launch of IASCLIP. This has involved (1) working with other IASCLIP scientists to organize the efforts of several working groups; (1) organizing the preparations and execution of the IASCLIP workshop held in San Juan, Puerto Rico in June 2009, in conjunction with the 12th Annual VAMOS Panel Meeting; and now,

(3) preparing to address the CLIVAR Summit Conference (July 2009) regarding the progress and future plans for IASCLIP.

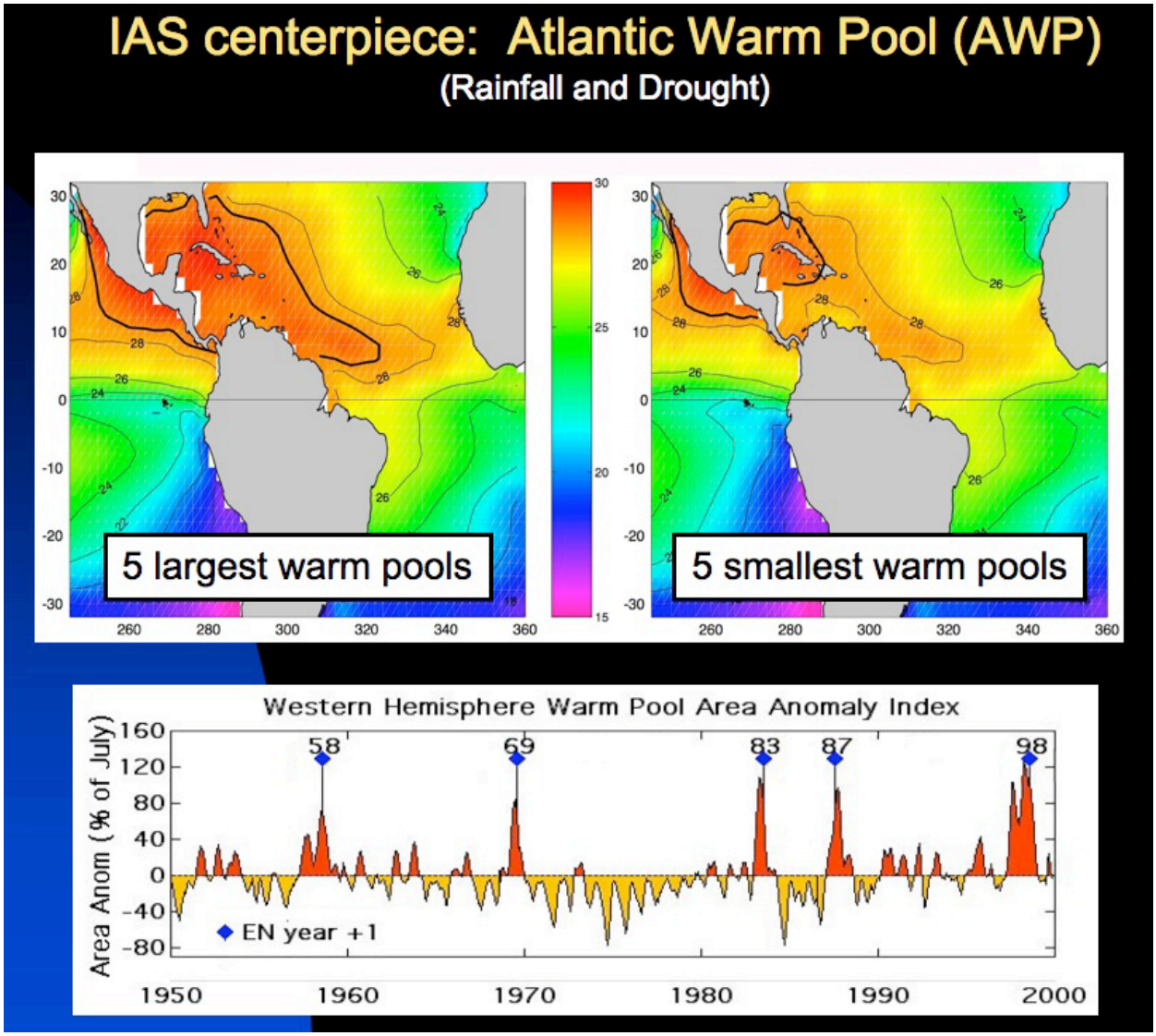


Figure 1: (a) Difference between the largest and smallest wrm pools since 1950 (heavy contour = 28.5°C). (b) Time series index of WHWP size (% of climatological July value).

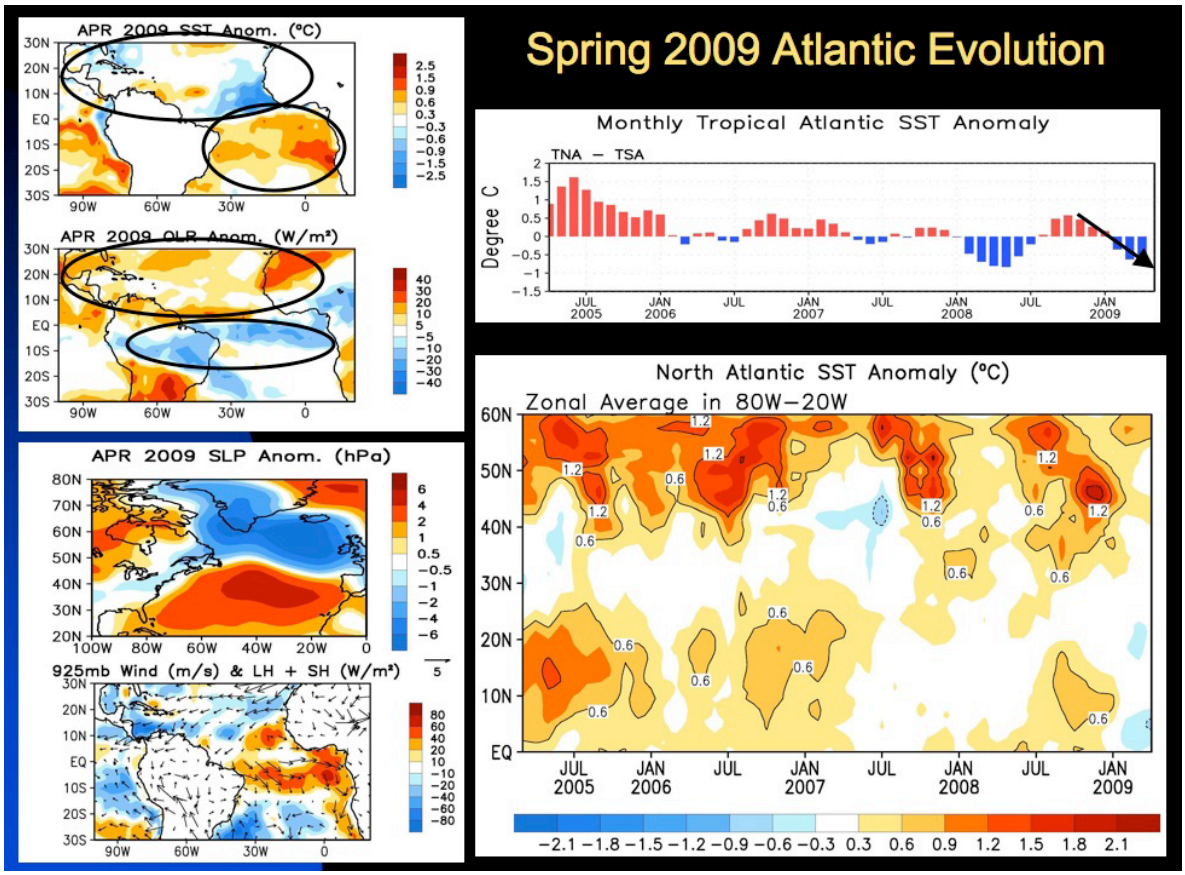


Figure 2: The evolution of the Atlantic warm pool (AWP) in spring 2009 is an excellent illustration of the importance of the Amazon convective heating to AWP growth. There is a cooling in the tropical North Atlantic and warming in the tropical South Atlantic (negative meridional SSTA gradient) and southward displacement of the ITCZ evidenced by negative outgoing longwave radiation (OLRA) near the equator (upper left). These are associated with a stronger-than-normal NASH and easterly low-level winds over the TNA (lower left). Note that the meridional SSTA gradient index (TNA-TSA) is clearly trending downwards as a result (upper right) and that the Hovmuller (lower right) shows 2009 to be the contiinuation of a decreasing trend in SSTA since 2005 in the main development region for tropical cyclones (10-20 N).

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.

Evaluating the Mean and Variability of the Meridional Overturning Circulation and Interocean Exchanges in the South Atlantic, Through the Output of High Resolution Global Numerical Models

Z.D. Garraffo (UM/RSMAS)

Long Term Objectives and Strategy to Achieve Them:

***Objectives*:** 1) To describe the Atlantic Meridional Overturning Circulation (AMOC), and obtain the pathways of the water masses and their variability in the South Atlantic using output from global 1/12º simulations with the Hybrid Coordinate Ocean Model (HYCOM), and 2) To obtain mass, heat and salt budgets for the South Atlantic from the models' output, to compare with and complement observed estimations.

***Strategy*:** Analyze the mean and daily product of existing global 1/12º simulations run with the HYCOM model to obtain: 1) Mass and heat transport for sections delimiting the South Atlantic; 2) Pathways for the upper and lower limbs of the flow; and 3) To compare with observations.

CIMAS Research Theme:

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

NOAA Strategic 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:** Silvia Garzoli

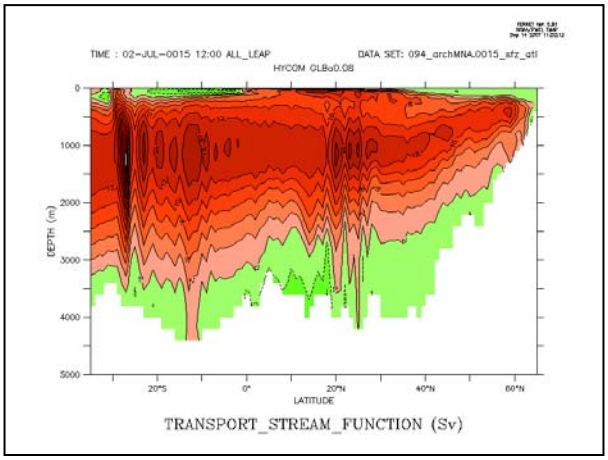
Research summary:

The product of three global 1/12º simulations with HYCOM produced at National Research Laboratory (NRL) and available through the NOPP consortium were analyzed: a) climatological simulation, b) interannual simulation 2003-2006, c) hindcast, 2003-2006. The time mean upper, deep, and lower transports in the South Atlantic were obtained, together with the transport-derived mean pathways. The main currents and locations are well reproduced in all the simulations. The South Equatorial Current reaches the South American coast at 15°S in the upper 100 m, and at 18°S at 1000m. The upper branch of the AMOC transport ranges from 11 to 14Sv in all simulations, with maximum values at 1200m depth (climatological and interannual simulations) and 1000m depth (hindcast).

The Brazil current -the subtropical gyre western boundary current- intensifies southwards in the climatological and in the interannual simulations. The northward flow of the upper branch is 14Sv for the climatological model, and 11Sv for the interannual and for the data assimilative models.

The deep flow shows the deep western boundary current breaking into deep eddies at about 8°S, part of the deep flow seems to migrate to the eastern boundary near 20ºS, while the rest diverts from the western boundary following a topographic feature at 22ºS and recomposes in the western boundary.

a)



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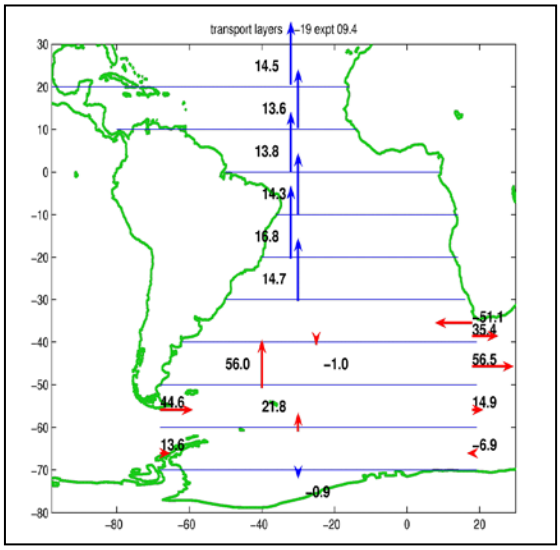

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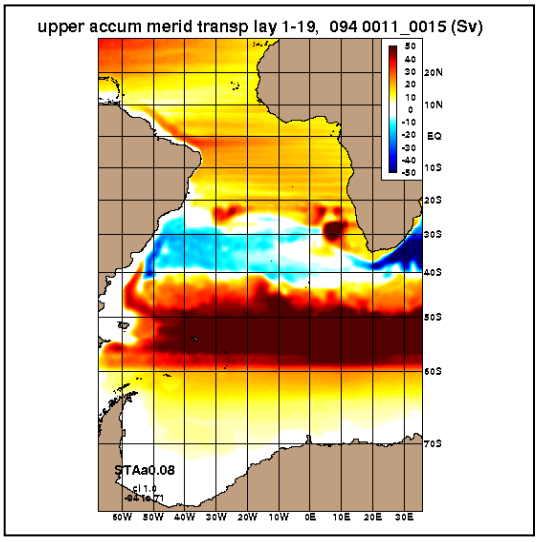

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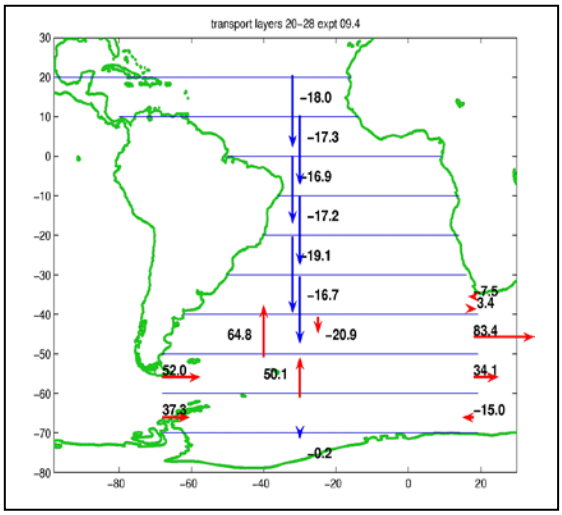


e)

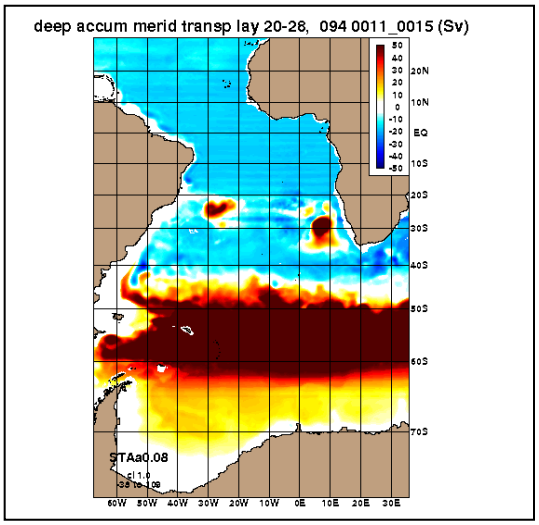


Figure 1: For the climatological simulation (year 15): a) Atlantic transport stream function (AMOC) in Sv; b) transport for the upper branch (layers 1-19, approximately upper 1200m) for Atlantic and Atlantic boundary sections (Sv): c) transport of the upper branch integrated from the western boundary, as a function of longitude; d) same as b but for the lower branch (layers 20-28); e) same as c but for the lower branch.

The climatological simulation, at year 15 of spin-up, has the AMOC maximum at 1200m (Fig. 1a). For this simulation the northward-flowing upper branch, north of 35ºS, has a transport of 14 to 15 Sv (Fig. 1b), and the southward-flowing deep transport is about 17Sv (Fig.1 d), while the bottom transport is about 1Sv northward, resulting in a total net Atlantic transport of about 1Sv southwards. The total Drake Passage transport is 147 Sv, and the Agulhas upper input is about 50Sv. The longitudinal distribution of the upper and lower branch meridional transports, depicting the mean pathways, shows the upper branch western boundary currents (Malvinas, Brazil), the South Equatorial Current and its bifurcation (Fig 1c), and the lower branch (Fig 1e) with southward transport near the western boundary for latitudes north of about 40ºS.

A regional model for the South Atlantic nested to the climatological model was setup and ran for a few months. The objective of this model is to save extra diagnostics that were not saved in the global simulations. In addition, a new climatological simulation is being spun up at NRL in which the output is saved as daily averages instead of daily snapshots, avoiding aliasing of nearly daily motions (this simulation is at year 6 of spin-up).

Research Performance Measure: The first objectives of the proposal were met by describing the mean circulation from several high resolution global simulations. Our focus continues to be upon the mean circulation and less so upon its variability.

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:

Figures 1a-e show the correlation coefficients for the six-member CCSM ensemble mean forecasts (blue curve), the ensemble mean 5-member CFS sub-ensemble (red curve) and the multi-model ensemble mean (black curve). The multi-model ensemble mean is the average of all 11 members of the ensemble with no weighting applied. The correlation coefficients are calculated separately for each initial condition month (i.e., 1a-d) and the average correlation is shown in Fig. 1e. There are several points to note:

(i) The correlation coefficients are quite comparable for all lead times and initial months and are almost indistinguishable for the July cases. Arguably, CCSM performs more skillfully for the January cases and CFS performs more skillfully for the April cases. In terms of a multi-model average, the fact that the models have similar skill levels is a positive attribute. The most desirable feature would be similar but complimentary skill;

(ii) The multi-model ensemble mean (black curve) has the highest correlation for most lead times independent of initial month;

(iii) Most notably the large drop in skill for January CFS forecasts for lead times 4-6 (i.e., spring prediction barrier see also Wu et al., 2009) has only a small impact on the multi-model skill.

(iv) The correlation coefficient is largest for the July forecasts as expected from previous studies.

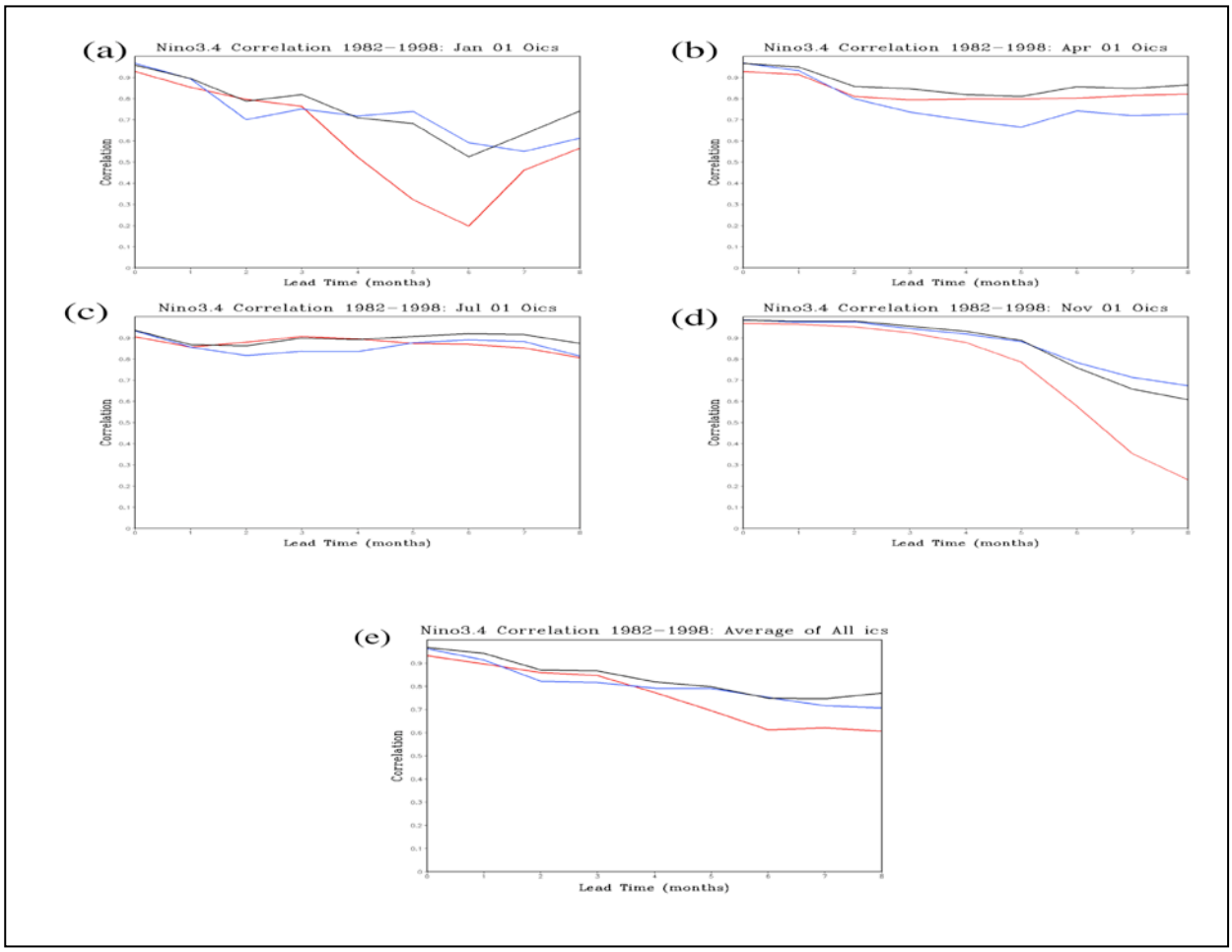


Figure 1: NINO3.4 correlation coefficient for ensemble mean forecasts initialize in (a) January, (b) April, (c) July and (d) November. Panel (e) is the correlation coefficient calculated over all the cases. The red curves correspond to CFS, the blue curves correspond to CCSM and the black is the multi-model ensemble.

These results are further examined in Kirtman and Min (2009) and Wu et al. (2009).

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 SST standard deviation of monthly means from the control and the ratio (IE/control) are shown in Figure 1. This ratio is a useful diagnostic for measuring the strength of coupled feedbacks. For example, based on the Kirtman et al. (2005, *J. Atmos. Sci.*, 62, 2220-2233) when the ratio of standard deviation is less than 0.4 (i.e., variance ratio less than 1/6) the SST variability is largely noise forced from the atmosphere. This critical variance ratio (1/6) or standard deviation ratio (0.4) is based on using six atmospheric ensemble members. When the ratio is greater than 0.4 but less than 1.0 unstable coupled feedbacks, non-linearity or ocean dynamics may play a significant role. When the ratio exceeds 1.0 unstable coupled feedbacks and non-linearity are likely to be significant. In the COLA implementation there were significant regions in the western Pacific and Indian Ocean where the ratio exceeded one, but in much of the tropical Pacific the ratio was less than 1.0 but greater than 0.5. In the CCSM implementation the ratio remains less than 1.0 throughout the Pacific and Indian Oceans. However, in much of the tropical Pacific, well beyond regions where ocean dynamics is likely to play a role, the ratio exceeds 0.5. This suggests that we cannot dismiss the possibility that the coupled feedbacks are unstable. In the tropical Atlantic, although the overall variability is weak, there is a sizable region where the ratio of standard deviations is relatively large and even a small region where the ratio exceeds 1.0. These results are discussed in detail in Kirtman et al. (2009).

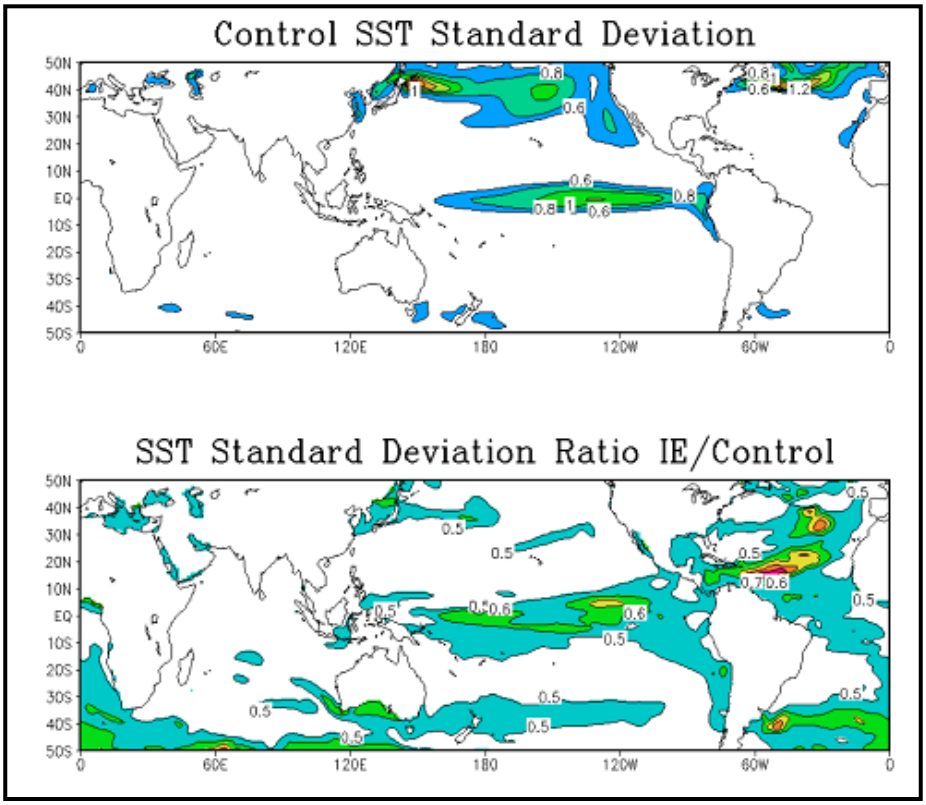


Figure 1: (a) Control SST standard deviation (monthly means) contour interval of 0.2^{o} C. In (b) the ratio (interactive ensemble divided by control) of the standard deviation is plotted with a contour interval of 0.1.

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.

CLIvar MOde Water Dynamic Experiment (CLIMODE)

S.-K. Lee and S. Elipot (UM/CIMAS); R. Lumpkin (NOAA/AOML)

Long Term Research Objectives and Strategy to Achieve Theme:

***Objectives*:** To explore the cross-scale connection between water mass formation associated with wintertime convection on the rim of the subtropical gyre, subduction into the stratified interior, and dispersal and dissipation around the gyre, and to address the interaction of geostrophic eddies with mixed layers which is at present poorly understood and inadequately represented in climate models.

***Strategy*:** A synthesis of field observations and modeling studies.

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:** Rick Lumpkin

Research Summary:

The CLIMODE program, fully funded by the NSF excepting NOAA participant salaries, is a multi-institution field campaign that occurred in a 2-yr period (2006 and 2007). Two winter cruises (Fig. 1) were timed to sample (year 1) the time of the greatest ocean heat loss to the atmosphere, and (year 2) the time when the 18°C layer outcrop was largest. Observations were collected at high spatial resolution over the top 500 m of the ocean to capture the processes associated with mode water formation in the context of the meandering Gulf Stream front. Simultaneously, we measured the evolving marine atmospheric boundary layer above and the air–sea fluxes that drive the two fluids. On longer time scales, the subsequent capping and initial injection of the mode water into the subtropical thermocline was also observed, as well as its eventual dispersal. The CLIMODE field program also involved a synergistic deployment of moorings, profiling floats, surface drifters, and shipboard studies (Fig. 2). These are more fully explained online (www.climode.org).

The CLIMODE field campaign has successfully produced a unique suite of diverse observations of the coevolution of the atmospheric and oceanic boundary layers undergoing vigorous convection in the vicinity of the separated Gulf Stream and placed that evolution in the context of the larger-scale circulation of the subtropical gyre. The focus of the seagoing wintertime component was the mode water formation process itself: much effort was devoted to quantifying the driving air–sea fluxes and studying the detailed dynamical response of the ocean through convection and baroclinic instability. However, these small-scale wintertime processes were embedded in a larger-scale circulation revealed through the deployment a variety of autonomous floats. These are being used in conjunction with models to map the fate of the convectively modified waters and the evolution of the upper ocean over the seasonal cycle.

Figure 1: (left) During the CLIMODE Knorr cruise on 9 Feb 2007, the surface meteorological buoy, which had broken loose from its mooring, was recovered near 39°N, 60°W. In the foreground the ASIS can also be seen (photo by T. Joyce). (right) During mooring recovery we experienced periods of snow, sleet, hail, and rain, and also observed a waterspout amid the near-surface sea smoke (photo by A. Plueddemann). At this time sea surface temperatures of 19°–20°C contrasted with air temperatures of 1°-2°C.

The CLIMODE program has also provided the necessary ocean circulation context to collect and interpret observations of the role of mode waters in the nutrient, carbon and oxygen cycles in the subtropical gyre. A complementary biogeochemical modeling program is also underway. Ongoing foci are addressing air–sea fluxes in extreme middle-latitude conditions and their representation by bulk formulas for use in models, the relative role of wind and buoyancy forcing in driving the wintertime convective process, the nature of convection occurring in a region of strong lateral and vertical shear, the physics of the restratification phase and particularly the role of the mesoscale, the resolution of the EDW formation/dissipation conundrum, and the role of subtropical mode water in the nutrient, CO_2, and O_2 cycle of subtropical gyre.

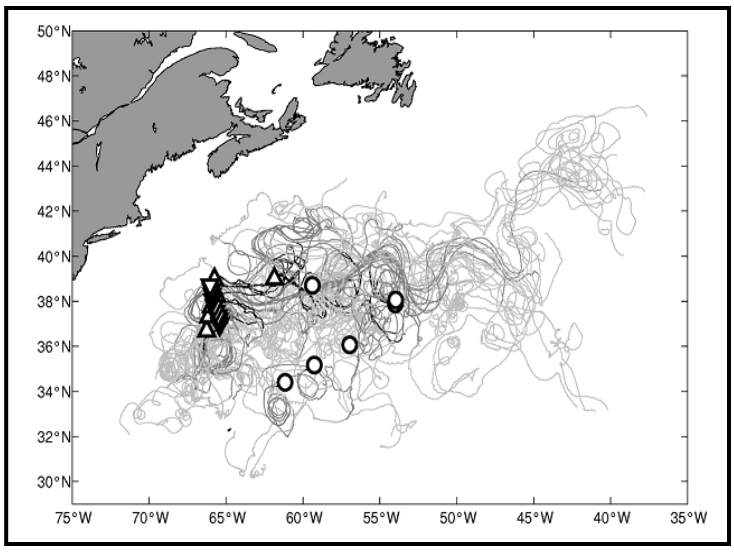


Figure 2: The CLIMODE drifter array. Deployment positions are shown for pairs (circles) andtrios (upward triangles) during leg 1 of the cruise (February 2007) and trios (downward triangles) during leg 2 (March 2007). Subsequent drifter trajectories are shown in black (February), darkgray (March) and light gray (April 1July 7, the final data analyzed here).

Research Performance Measure: Our role in this multi-institution experiment was to release an array of drifters and to measure the dispersion and eddy fluxes of heat across the Gulf Stream front. These tasks are completed as planned. The data have been quality controlled, interpolated to regular hourly intervals, and placed in the CLIMODE data repository hosted by WHOI. Lumpkin participated in the winter 2007 CLIMODE cruise aboard the R/V Knorr, in which he was a watch leader and help collect numerous hydrographic observations via CTD and SeaSoar.

Climate Impacts of the Western Hemisphere Warm Pool on the Americas

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

Long Term Research Objectives and Strategy to Achieve Theme:

***Objectives*:** To understand the climatic impacts (rainfall and tropical storms) of Western Hemisphere warm pool on the Americas.

***Strategy*:** Use both data and a model (NCAR Community Atmospheric Model: CAM3) to elucidate relationships between the WHWP and regional climate parameters.

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

Research Summary:

The global climate model simulations forced by future greenhouse warming predict that the North Atlantic warms at a slower rate than the North Indo-Pacific in the 21st century, consistent with their projection of a weakening Atlantic thermohaline circulation. We use an atmospheric general circulation model to advance a consistent physical rationale that the preferential warming of the North Indo-Pacific over the North Atlantic increases vertical wind shear and static stability over the tropical North Atlantic (TNA), and thus decreases Atlantic hurricane activity in the 21st century (Fig. 1). The preferential warming of the North Indo-Pacific accelerates the warming of tropical troposphere over the North Atlantic, via a tropical teleconnection mechanism, and thus increases the static stability and decreases the convection over the TNA. The anomalous diabatic-cooling, in turn, forces the formation of a stationary baroclinic Rossby wave northwest of the forcing region, consistent with Gill's simple model of tropical atmospheric circulations, and thus induces a secular increase of the vertical wind shear over the TNA.

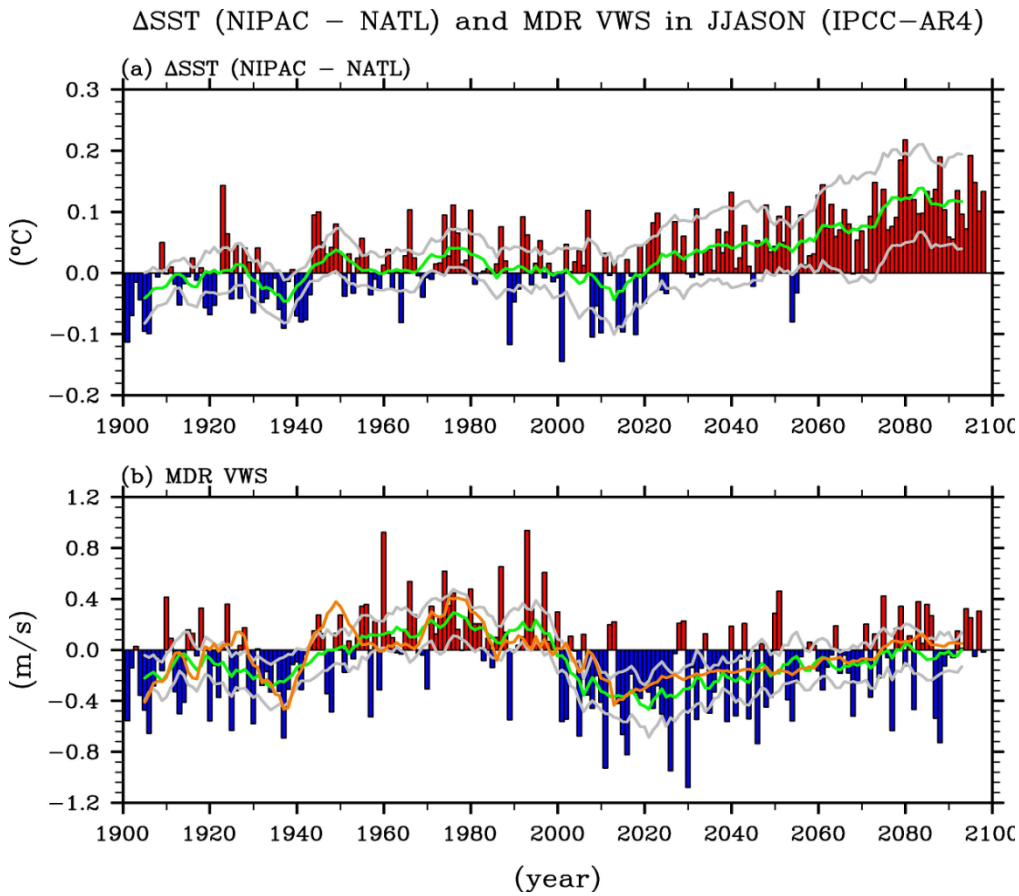


Figure 1: (a) Time series of the tropical (from equator to 30°N) SST difference in JJASON between the North Indo-Pacific and North Atlantic basins (inter-basin SST difference index), and (b) vertial wind shear (200mb minus 850mb) anomaly averaged in the MDR (85°W-15°W, 10°N-20°N) for the period of 1900-2100 obtained from the ensemble average of 24 IPCC-AR4 climate model simulations under the 20C3M (1900-1999) and SRESA1B (2000-2100) scenarios. Green lines are 11-year running averaged MDR SST and MDR VWS. Gray lines in (b) represents 95% significancy, which is computed based on a bootstrap technique. The orange line is the 11-year running averaged inter-basin SST difference index multiplied with a factor of 10 for 1905-2012 periods, and multiplied with a factor of 3 and subtracted with a constant of 0.3 for 2013-2095 periods.

We also investigated the inter-hemispheric influence of the Atlantic warm pool on the southeastern Pacific. During the boreal summer and fall, a strong Hadley-type circulation is established, with ascending motion over the AWP and subsidence over the southeastern tropical Pacific. This is accompanied by equator ward flow of the lower troposphere over the southeastern tropical Pacific, as dynamically required by the Sverdrup vorticity balance. We use observational data and NCAR community atmospheric model simulations to show that an anomalously large (small) AWP during the boreal summer and fall results in a strengthened (weakened) Hadley-type circulation with enhanced descent (ascent) over the southeastern tropical Pacific (Fig. 2). 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.

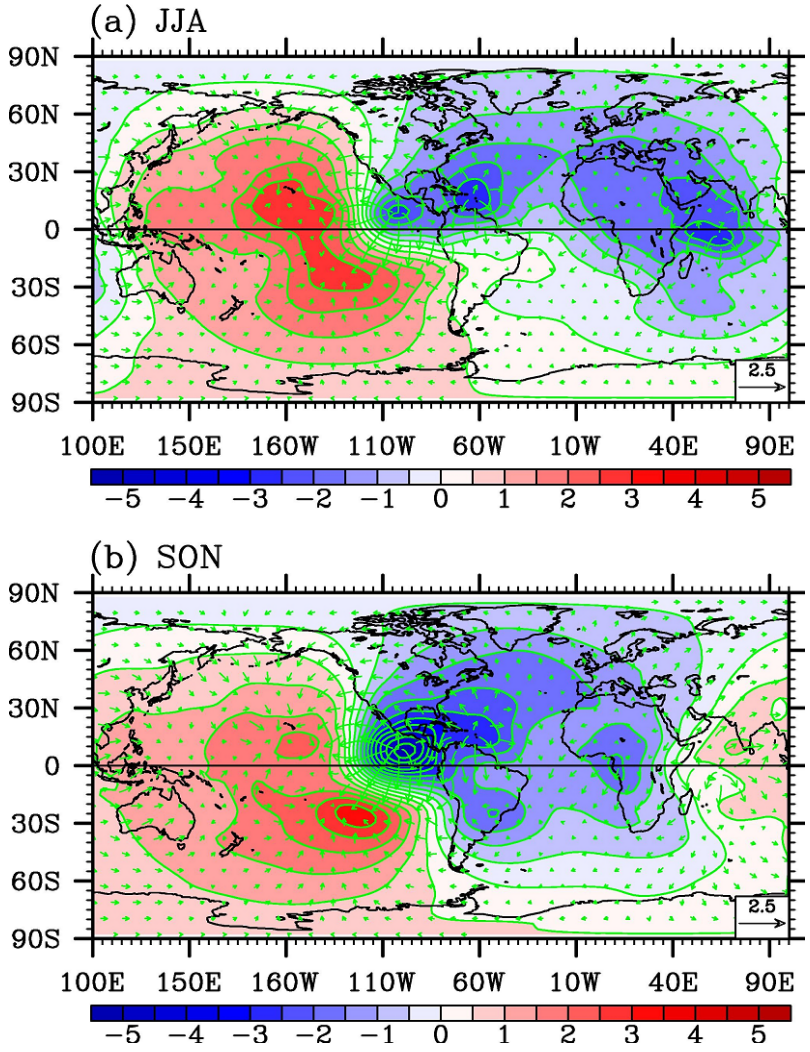


Figure 2: The 200-mb velocity potential (10^6 m^2/s) and divergent wind (m/s) difference between the large AWP (LAWP) and small AWP (SAWP) CAM3 ensemble runs in (a) June to August (JJA) and (b) September to November (SON). The negative velocity potential difference is shaded and the contour interval is 0.5×10^6 m^2/s.

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 then investigated other climate related linkages.

Intra-Americas Sea Climate Variability During Boreal Spring and Summer

E. Muñoz and D. Enfield (UM/CIMAS); C. Wang (NOAA/AOML)

Long Term Research Objectives and Strategy to Achieve Theme:

***Objectives*:** To understand the forcing mechanisms of Intra-Americas Sea (IAS) climate variability. To acquire prognostic understanding of those IAS springtime anomalies which extend into summertime.

***Strategy*:** Combine available gridded observational datasets and re-analysis products and simulate IAS variability with numerical models.

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 (*Primary*)

***Goal 3*:** Serve society's needs for weather and water information (*Secondary*)

NOAA Funding Unit: OAR/AOML

NOAATechnical Contact: Chunzai Wang

Research Summary:

The influence of tele-connections on the Intra-Americas Sea (IAS; Gulf of Mexico and Caribbean Sea) has been mostly analyzed from the perspective of the El Niño Southern Oscillation (ENSO) on the Caribbean Sea overlooking 1) the influence of other tele-connections on the IAS and 2) affects on the Gulf of Mexico variability. We analyze the different fingerprints that the major tele-connection patterns have on the IAS during boreal spring. Our approach so far has been on utilizing re-analyses and COADS data to accomplish our objective. This study contributes to a greater understanding of how the different Pacific and Atlantic tele-connections affect the Intra-Americas Sea.

We find that the Pacific tele-connections that influence the IAS do so by affecting the Gulf of Mexico SSTs in an opposite manner to the SSTS of the Caribbean Sea. For example, during the positive phase of the Pacific North American (PNA) oscillation the Caribbean warms whereas the Gulf of Mexico cools. The dipole forms mostly in response to changes in the air-sea heat fluxes. In the Gulf of Mexico the dominant mechanisms are the air-sea differences in humidity and temperature. The changes in shortwave radiation are linked, in part, to increased cloudiness triggered by the air-sea

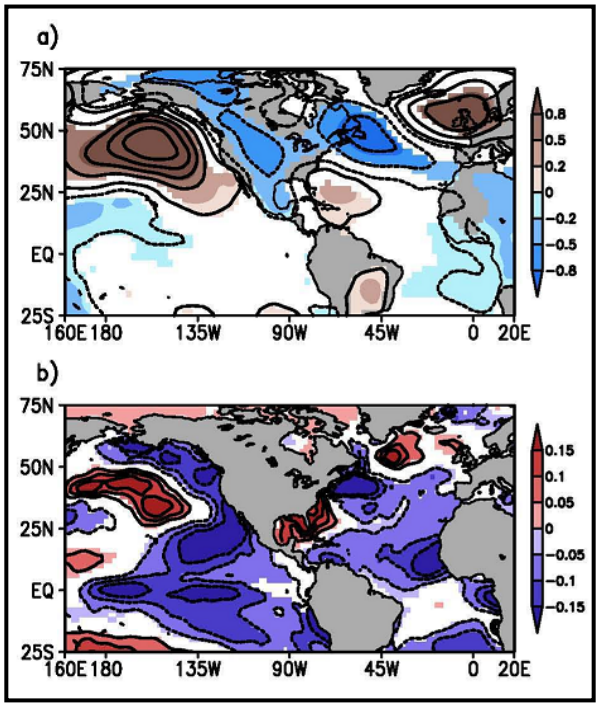


Figure 1: Regression onto the tornado index of (a) mean sea level pressure (MSLP) and (b) sea surface temperature (SST) anomalies. The MSLP contour interval is 0.4 hPa starting at ±0.4 hPa. The SSTA contour interval is 0.05ºC starting at ±0.05ºC. Dashed contours indicate negative values and solid contours indicate positive values.

differences in humidity, and also by the changes in the convection cell that connects the Amazon basin to the IAS.

The springtime variability of the Intra-Americas low-level jet (IA-LLJ) is also analyzed. The IA-LLJ variability is mostly influenced by the PNA oscillation. A stronger IA-LLJ increases the moisture availability in the region of the Mississippi and Ohio river basins. Tornado variability is also influenced by the IA-LLJ moisture transport. But the variability of major tornadoes (F2-5) has a stronger influence from the Pacific Decadal Oscillation (PDO).

Research Performance Measure: We have accomplished much of our goal: we analyzed and characterized the relation of different tele-connections to the Intra-Americas Sea SSTs and LLJ. The next steps will be to simulate (via numerical models) the tele-connection influence on the IAS and perform further numerical experiments.

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);
P.S. Schopf (GMU/COLA)

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).

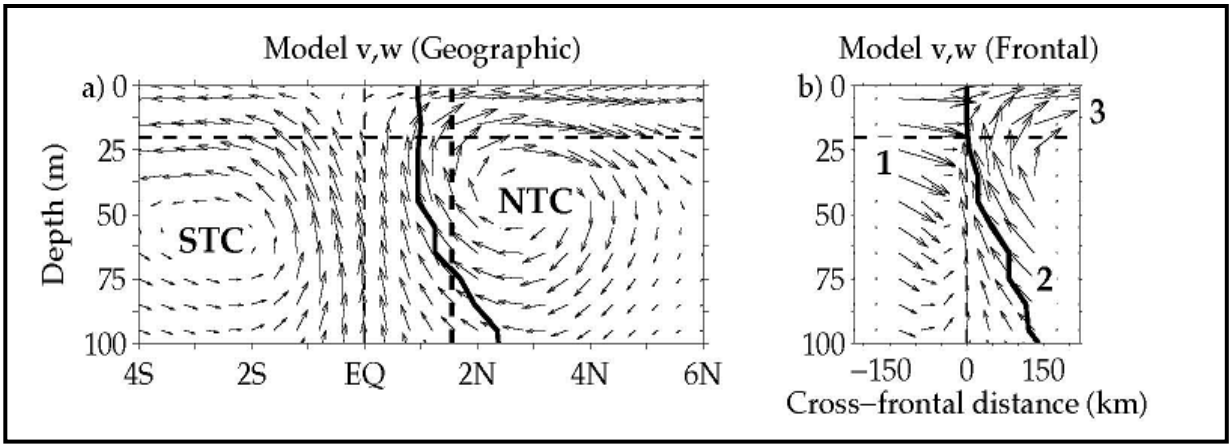


Figure 1: Model mean meridional and vertical velocity structure. Panels compare zonally and temporally-averaged velocity vectors in a) geographic and b) frontal coordinates at the central meridians. Frontal means are plotted relative to the mean position of front (thick dashed line). Thick solid line 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 being revised for J. Phys. Oceanogr.

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

B. Soden and E.-S. Chung (UM/RSMAS), G.A. Vecchi (NOAA/GFDL)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** To understand the cause of precipitation differences between observations and GCM simulations.

***Strategy*:** Use a forward radiance approach to simulate microwave radiances from GCM simulations of cloud water and 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: NOAA/CPO **NOAA Technical Contact:** James Todd

Research Summary:

One of the most serious challenges humanity will face in response to global warming is adapting to changes in extreme weather events. Of utmost concern is that heavy rainstorms will become more common and more intense in a warmer climate due to the increased moisture available for condensation. More intense rain events increase the risk of flooding and can have substantial societal and economic impacts.

Climate models have long predicted that global warming will increase the intensity of extreme precipitation events. To understand how precipitation responds to a warmer climate, we used naturally-driven changes associated with El Niño as a laboratory for testing climate model simulations. On interannual time scales, the tropical atmosphere warms and moistens during El Niño events, and cools and dries during La Niña events. Based on 20 years of satellite observations, we found a distinct link between tropical rainfall extremes and temperature, with heavy rain events increasing during warm/moist periods and decreasing during cold/dry periods.

Furthermore, the observed amplification of rainfall extremes was found to be larger than predicted by models, implying that projections of future changes in rainfall extremes due to anthropogenic global warming may be underestimated. This research was published in the journals Science (Allan and Soden, 2008) and Geophysical Research Letters (John et al., 2009).

In Vecchi et al. (2008), we examined the link between model projected changes in global precipitation and the weakening of the tropical atmospheric circulation. We demonstrate that the strength of the atmospheric overturning circulation decreases as the climate warms, and that this decrease is a robust result of all models. The weakening occurs preferentially in the zonally-asymmetric (i.e., Walker) rather than zonal-mean (i.e., Hadley) component of the tropical circulation and is shown to induce substantial changes to the thermal structure and circulation of the tropical oceans.

As the climate warms, model-projected changes in both the atmospheric and ocean circulation over the tropical Pacific Ocean resemble "El Niño"-like conditions; however, the mechanisms are shown to be distinct from those of El Niño. The consensus of model results was also shown to be consistent with recently detected changes in the tropical circulation during the 20th Century.

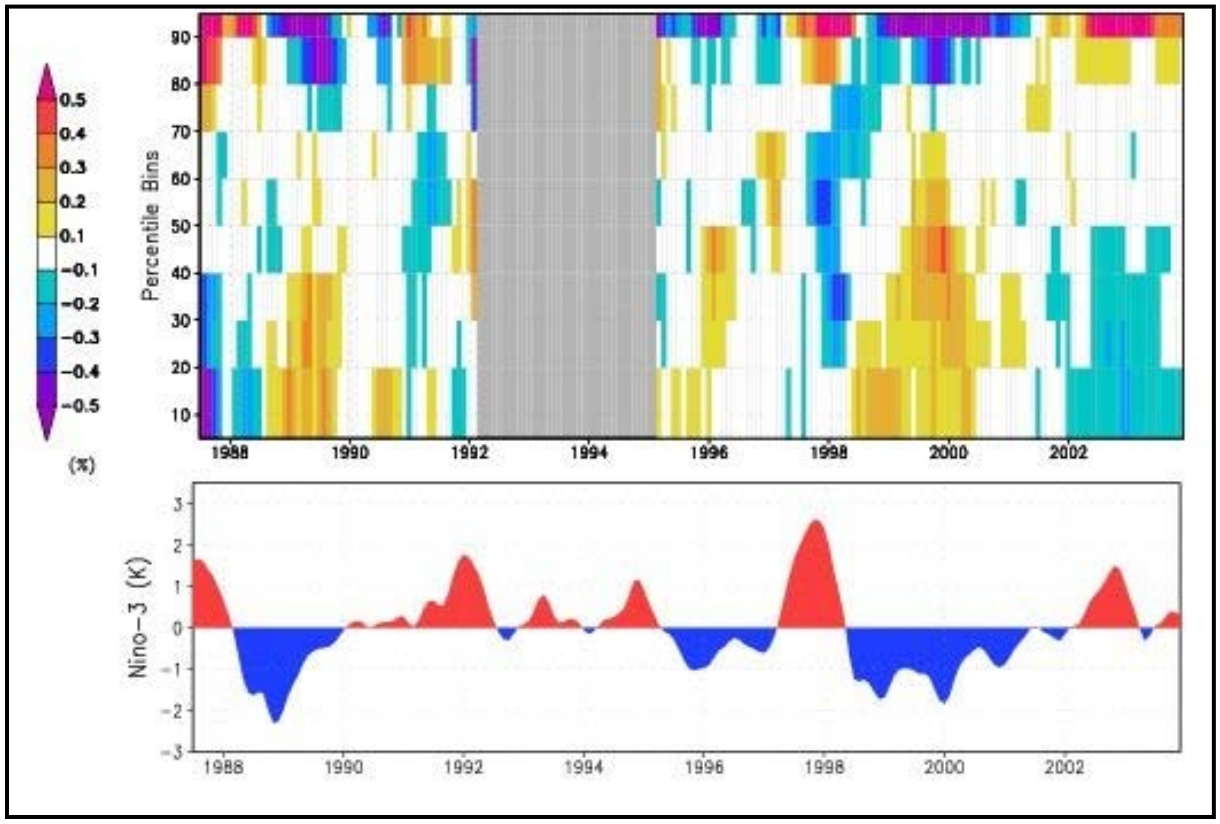


Figure 1: The upper panel depicts the percentage anomalies of tropical precipitation frequency expressed in percentile bins of rainfall intensity from satellite observations over the period 1987-2003. Gray regions depict periods of missing data. The lower panel shows the corresponding Niño-3 SST index for the same period.

Research Performance Measure: The following were accomplished on or ahead of schedule: 1) Compared GCM simulations and satellite observations of sensitivity of extreme precipitation events to ocean warming. 2) Examined consistency of satellite observations of precipitation variability. 3) Identified anthropogenic signatures in HIRS spectral radiance trends. 4) Manuscripts documenting these results were submitted to *Science, Geophys. Res. Lett., and Eos.*

Re-analysis of the Atlantic Basin Tropical Cyclone Database in the Modern Era

B. Soden (UM/RSMAS); Chris Landsea (NOAA/NHC).

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** To produce a high quality database of historical hurricane activity.

***Strategy*:** Collect and analyze historical hurricane data to produce a complete database of all raw observations of gale force winds or stronger, track maps for individual years, and specific detailed listing of U.S. tropical storms and hurricanes.

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

Research Summary:

The North Atlantic basin tropical storm and hurricane database (or HURDAT) has been extensively utilized for meteorological applications as well as climate variability and change studies ranging from intraseasonal, interannual, decadal, and multidecadal timescales.

HURDAT currently extends back from present to 1851. However, this cornerstone database contains many systematic and random errors that need to be corrected. Additionally, as our understanding of tropical cyclones has advanced, analysis techniques have evolved over the years at NOAA's National Hurricane Center, leading to biases in the historical database that have not been addressed. Another difficulty in applying HURDAT to studies concerned with tropical cyclone events is the lack of exact location, time and intensity information for landfalling systems. Finally, due to incomplete observations in past hurricane seasons, tropical storms and hurricanes that existed over the open Atlantic may not have been included in the database. The comprehensive collection and analysis of historical observations that is proposed in this work will result in the addition of many of these "missing" storms to HURDAT.

By spring of 2008, work had been completed on the re-analysis for the years from 1851 to 1920 with preliminary reassessments complete through 1943. This proposal details research that will focus on storms occurring in the latter half of the 20th Century and will result in the completion of the hurricane re-analysis project. Products to be provided include: the revised HURDAT; metadata files providing details about the individual changes to the database; a complete database of all raw observations of gale force winds or stronger; the Best Track Change Committee's comments and our team's responses; track maps for individual years; and specific detailed listing of U.S. tropical storms and hurricanes. At least three peer-reviewed papers should be published that will describe the new datasets/methodologies employed and resulting changes to trends in tropical cyclone activity that have been associated with anthropogenic climate change.

Research Performance Measure: The following research performance measures were accomplished on schedule: 1) Raw observations of tropical storms and hurricanes have been collected for the period of

1944 (the first year of aircraft reconnaissance) through 1947. 2) A separate database has been developed for each tropical storm. These historic data were then reassessed using methodologies and tropical cyclone understanding available today. 3) A draft revised HURDAT and metadata write-up have been accomplished for the years 1944 to 1946. The results for the1944 hurricane season have also been formally submitted to the National Hurricane Center Best Track Change Committee for official inclusion into HURDAT

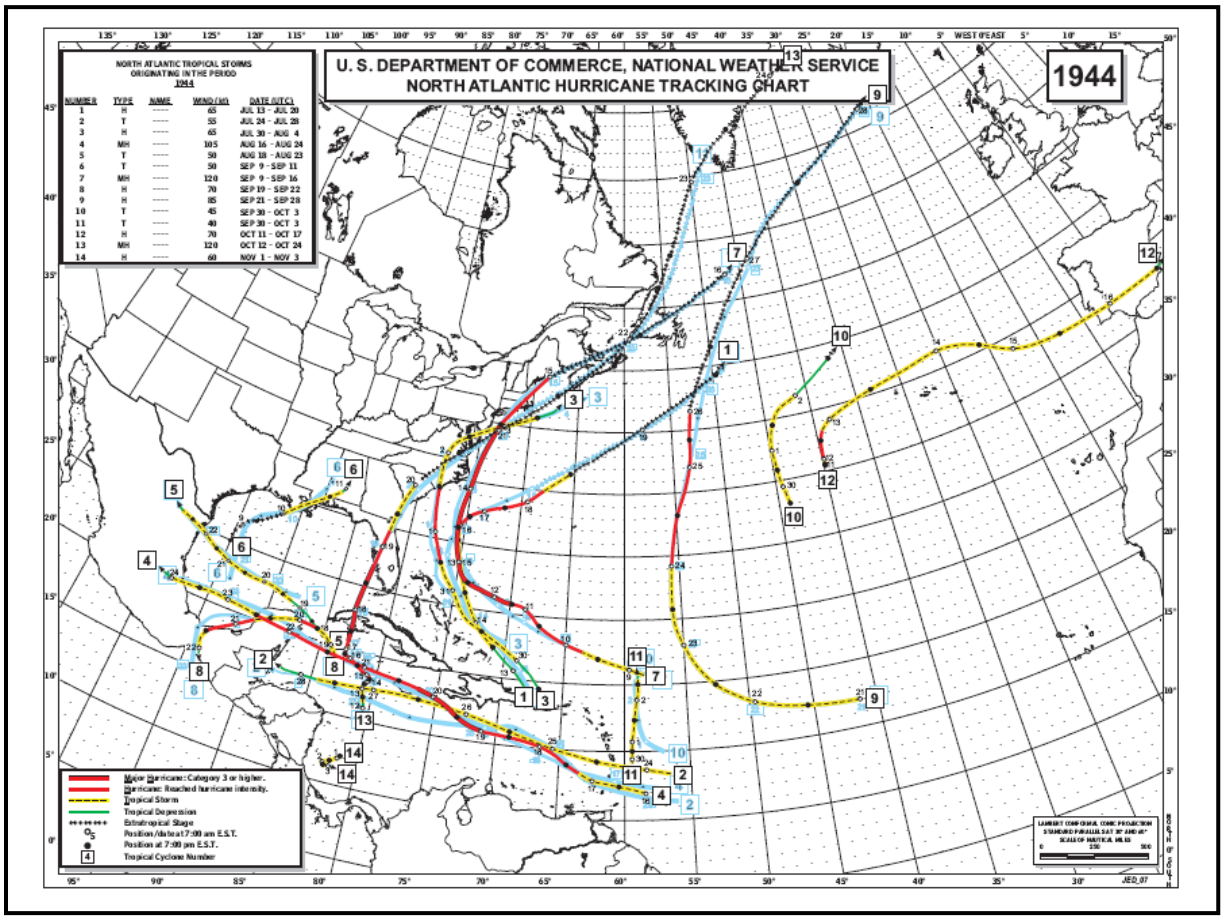


Figure 1: A revised map of hurricane activity for the year 1944 based upon the reanalysis of historical data.

THEME 2: FISHERIES DYNAMICS

Monitoring Coral Reef Fish Populations in the Florida Keys

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

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** To 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].

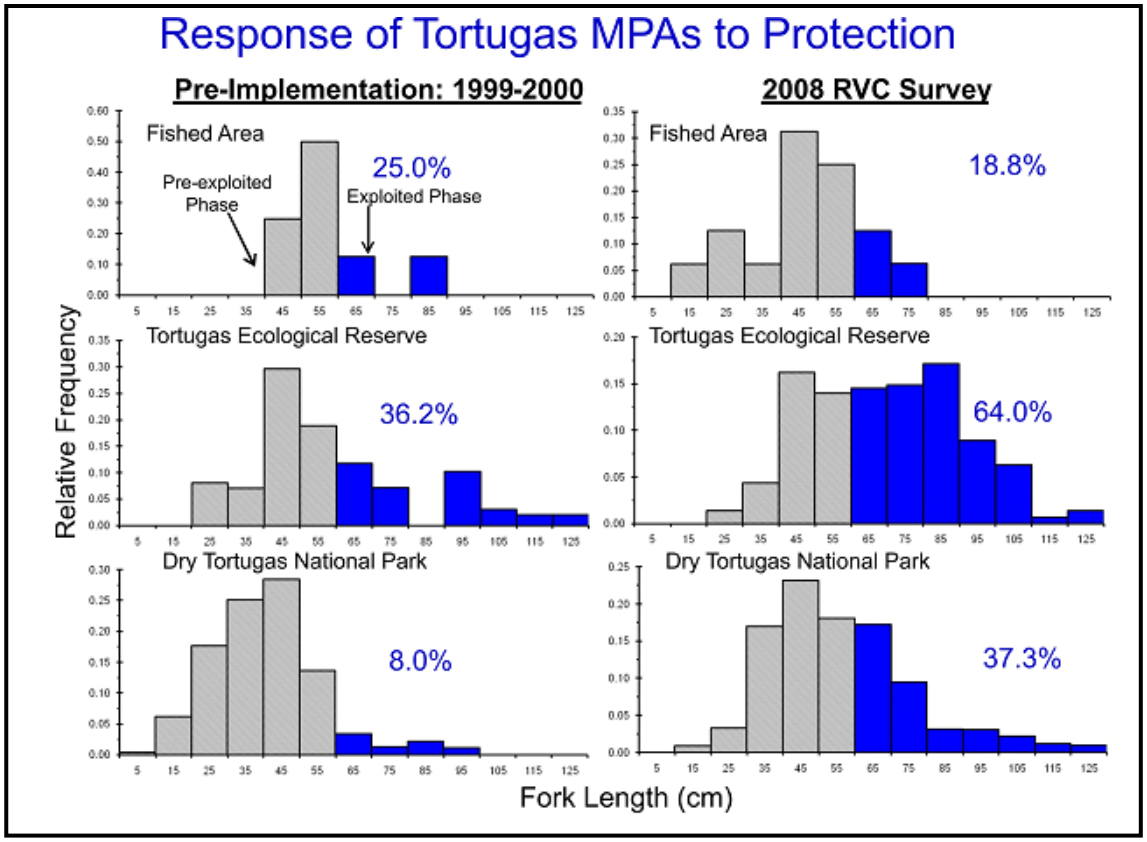


Figure 1: Size frequency distribution of black grouper in a control (fished) area versus two protected areas: Tortugas Ecological Reserve and Dry Tortugas National Park in the pre-implementation period (1999-2000) and the most recent survey (2008).

In late Spring 2008, a team of 38 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, the National Park Service, REEF, and the University of North Carolina at Wilmington 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. 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 2].

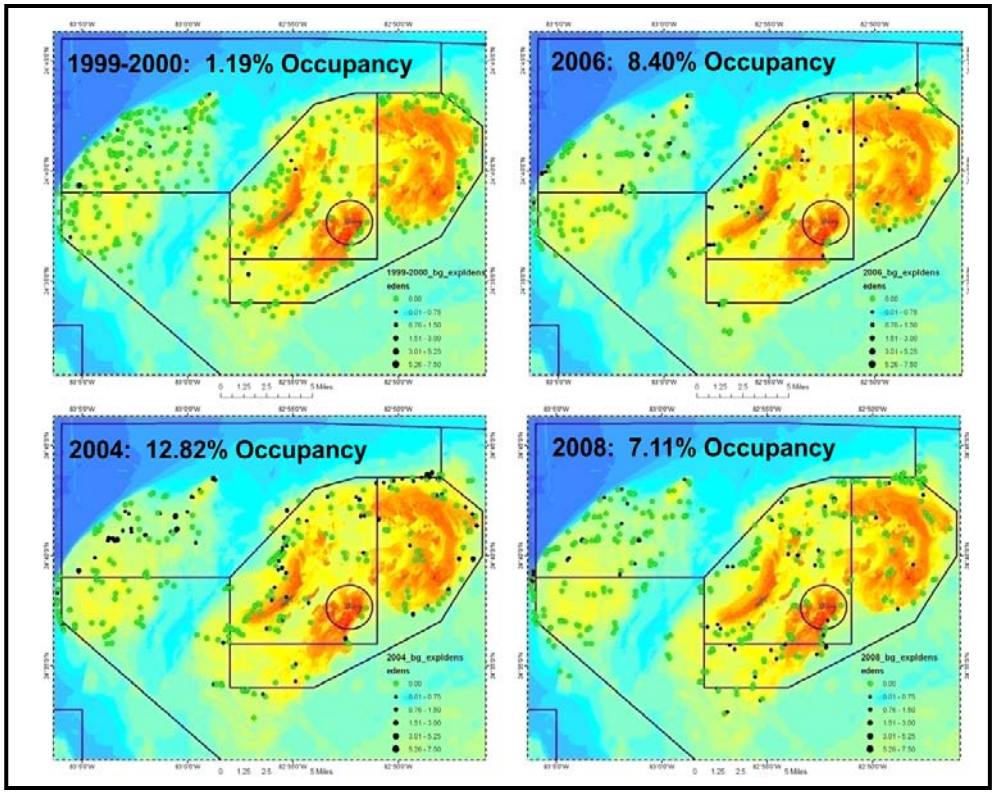


Figure 2: Regional black grouper frequency-of-occurrence (occupancy) during survey years 2004, 2006 and 2008 relative to the pre-implementation baseline measured in 1999-2000

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.

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**:** (1) To support the development of imaging technology software for the remote enumeration of larval fish. (2) 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. Conduct an initial evaluation of ISIIS as an assessment tool for Atlantic Herring, we are conducting trial deployments of ISIIS on Georges Bank. The deployment was accompanied by standard survey sampling, which includes CTD and bongo nets. 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 will maximize the ability of ISIIS to image and automatically classify herring larvae.

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 situ*, 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.

Image analysis is progressing with algorithm development providing strong results for classification. In preliminary trials using up to five different classes of organisms (e.g. fish larvae, copepods, chaetognaths, larvaceans, *Tricodesnium*) – our success (correct identifications) ranged from 72-93%. We are now working on improving this by reducing error due to poor image quality caused by incomplete images. Effort is also being spent on developing algorithms to automatically segment (i.e. extract) regions of interest from the entire image (for later classification as well as image storage).

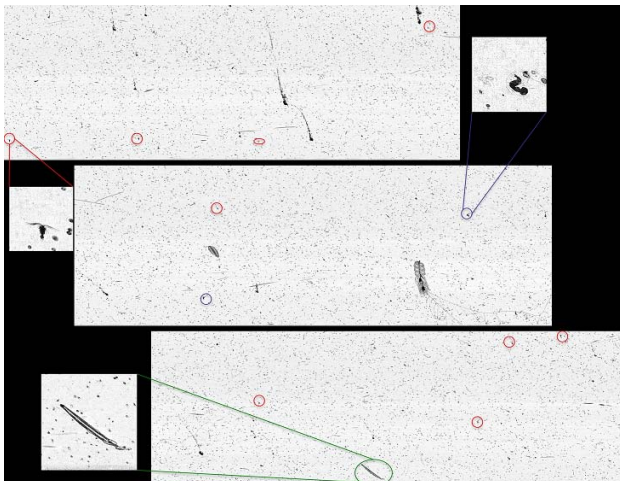


Figure 1: Consecutive imagery (broken into three separate frames) taken with ISIIS in November 2008 – off of Narragansett/Woods Hole. Image dimension of each frame is 42 X 14 cm. Note small particle (diatoms) are very abundant but too small for clear resolution. Copepods, larvaceans, marine snow, chaetognaths and siphonophore are clear.

Evaluation of ISIIS as a survey tool was initiated with a trial cruise last November (2008) on board the NOAA vessel – DELAWARE. We conducted two transects (~ 40 km long) running across the shelf from near Narragansett/Woods Hole (50 – 80 m isobaths). The ISIIS was towed at 5 knots and undulated from near surface to ~40 m deep. Each line was also sampled every 10 km using a standard paired Bongo net for quantification of ichthyoplankton and other major plankton groups for comparison with ISIIS results. Imagery worked very well (see Fig. 1-3). All images are being manually evaluated, then they will be evaluated via the image analysis algorithms for comparison. Finally, once the plankton samples are sorted and ID'd, ISIIS/BONGO samples will be compared.

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

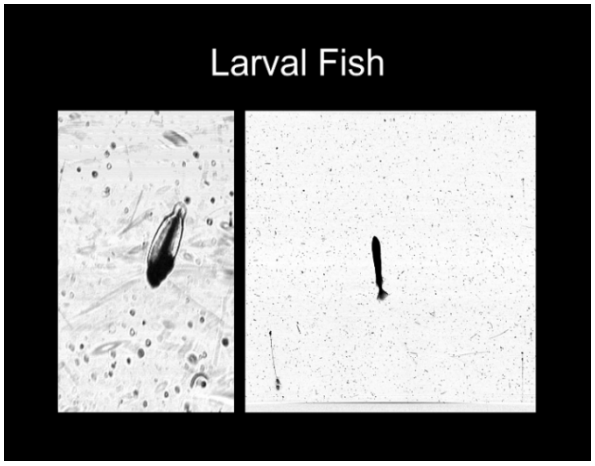


Figure 2: Close-up of two fish larvae; left - *Paralichthys dentatus* (summer flounder), right – *Merluccius* sp.

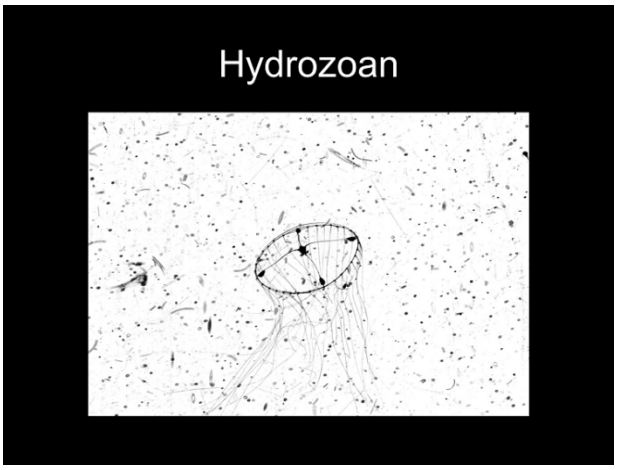


Figure 3: Close up of hydrozoan.

Investigation of the Movements of Adult Billfish in Potential Spawning Areas

R.K. Cowen, J.P. Hoolihan and J. Luo (UM/RSMAS); E.D. Prince, D. Snodgrass and E.S. Orbesen (NOAA/SEFSC); J.E. Serafy (NOAA/SEFSC and UM/RSMAS) P.l Goodyear (Contractor, Niceville, FL); D. Schultz (UM/Medical School)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** To characterize the horizontal and vertical movements of Istiophorid billfish and other pelagic fishes in potential spawning areas in a large marine ecosystem context.

***Strategy*:** Use electronic tags, plankton nets, and biological samples to describe habitat utilization and spawning state; to describe effective depths of pelagic long-line gear using electronic monitors and to relate the distribution to oceanographic information.

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 Prince

Research Summary:
Over this last year, we used recreational fishing vessels to catch pelagic fish. We Attached pop-up satellite archival tag (PSAT) sensors to them, and re-released them, allowing us to record their (horizontal and vertical) movements for periods up to 150 days.

To date, a total of 249 fish have been deployed with PSATs, with about 78% of deployments successfully reporting back via the Argos satellite system. For the 2008-09 fiscal year, these included deployments on two swordfish (Figure 1) and ten yellowfin tuna (Figure 2). Data from these PSATs are currently being analyzed. In addition, we have physically recovered a total of 22 PSAT tags that had previously transmitted summary data sets through the Argos Satellite System. Detailed archived data, accessed from the recovered PSAT's non-volatile memory, are currently being analyzed and compared to the corresponding Argos summary data.

Figure 1: Pop-up satellite archival tag deployed on swordfish off Miami, Florida (photo-Eric Orbesen).

During 2008 a two year collaborative project with Texas A&M University was initiated to monitor movements and behavior of yellowfin tuna in the Gulf of Mexico using PSATs. Ten fish have been tagged so far. Three of these were physically recovered. Additional deployments are scheduled for the summer of 2009.

Figure 2: Attaching pop-up satellite archival tag to yellowfin tuna in the Gulf of Mexico (photo-Mark Lyons).

Marlin and sailfish vertical habitat use data in the western and eastern Atlantic sectors will contribute to the second of a series of papers on hypoxia-based habitat compression. This will provide a mechanistic basis for employing habitat standardization techniques in analyzing Atlantic long-line catch rates.

Research Performance Measure: All objectives are being met on schedule: We obtained a high recovery rate for data collected by pop-up satellite tags indicating that fish tagging protocols and deployment durations are appropriate.

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

Research Summary:

With sources from the FATE program we have begun developing a biophysical Lagrangian model for pink shrimp in south Florida. The ROMS, a coastal hydrodynamic model with tidal flux, is the foundation of the biophysical model and is being adapted to the study area. We are using two embedded grids, the parent grid with a 2-km resolution and the child grid with a 700-m resolution (Fig. 1). Available models for providing boundary conditions were reviewed for spatial and temporal coverage and resolution. Then model predictions were examined in relation to observations to select the model that could provide the most accurate boundary conditions. Although the most accurate model was GOM-HYCOM $1/12^{o}$ its temporal coverage starts in 2003 instead of 1995, which is not compatible with our plans for a decade-long simulation, 1995-2005. Therefore the first 8 years will be simulated using the new JPL ECCO ocean data assimilation product (released in June 2009), which was started in 1980 and has a lower resolution than the GOM-HYCOM simulation. The boundary models provide temperature, salinity, and currents at the boundary of the parent grid once each week. Data to use in model calibration are being acquired. These include especially current, wind, water temperature, and salinity. Current velocity and direction data from two buoys on the inner southwest Florida shelf have been analyzed for spatial and temporal patterns. Data on influx of postlarvae into Florida Bay and larval stages collected in previous research at the SWF shelf and the Florida Keys region are being analyzed in terms of abundances and predominant behavior. Data on juvenile density in Florida Bay are already compiled. Previous pink shrimp stock assessment reports and fisheries catch and effort data from NMFS are being reviewed in terms of potential stock assessment approaches. Approaches are being reviewed for suitability of incorporating any information that the biophysical model or other analytical results suggest might improve stock assessments.

The ocean model will be coupled to a behavioral model using selective tidal stream transport (STST), a vertical migratory behavior that has been observed in pink shrimp postlarvae and myses (see Criales et al., in CIMAS report 2007). With this behavior postlarvae ascend into the water column

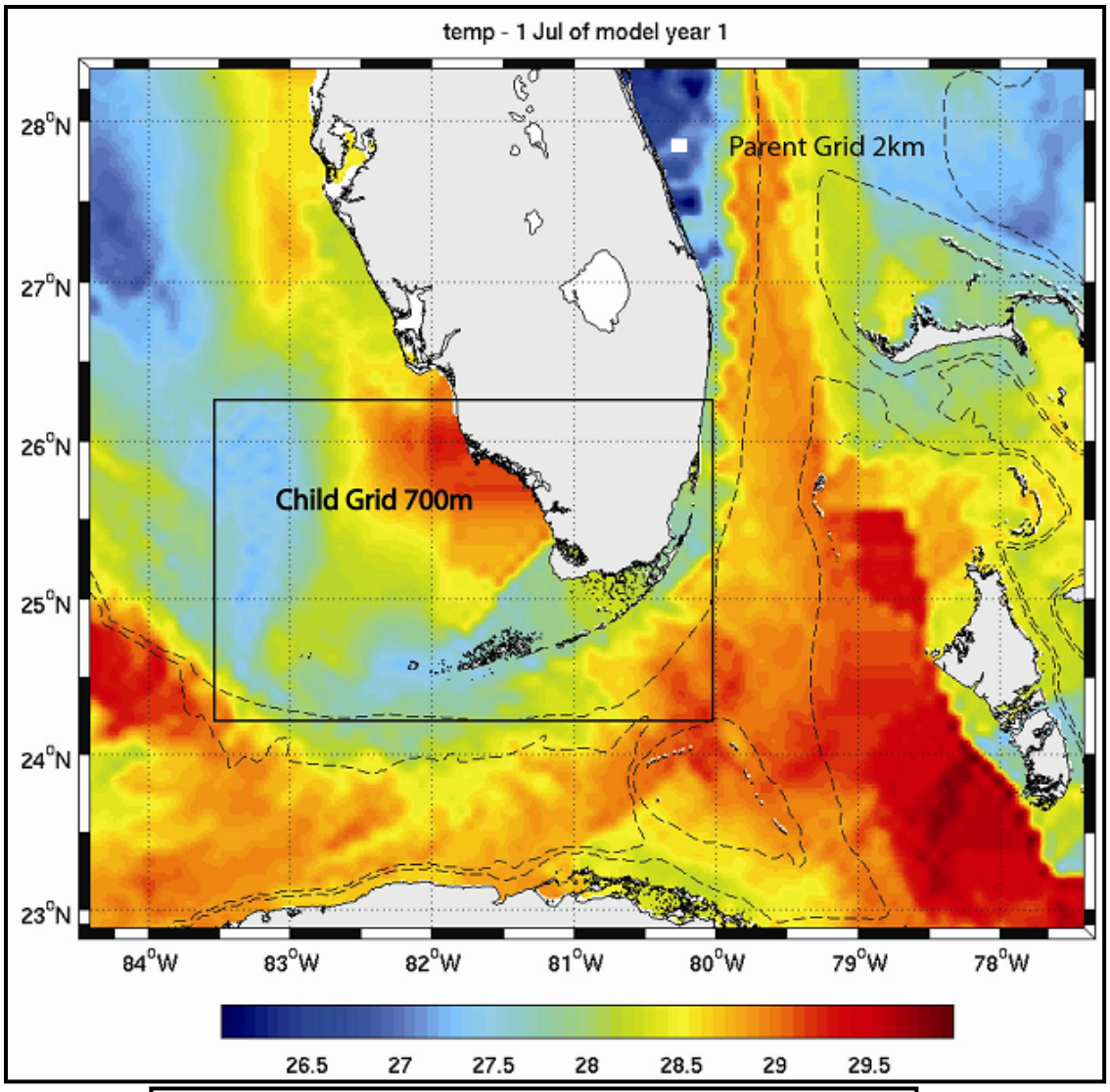


Figure 1: Map depicting SST from the hydrodynamic model indicating the parent and child grid.

during the flood tide to take advantage of the current flow in the direction of the nursery grounds of Florida Bay and rest near the bottom during the ebb tide. We will examine the interconnections between behavior and local, mesoscale, and regional scale processes in the migration of pink shrimp from larvae to answer questions that will help refine stock assessments by improving predictions of recruitment to the fishery. Some of these questions to answer are as follows: What are the survival implications of alternative spawning locations? What is the behavior and transport during the first development stages? Is flood tidal transport the dominant onshore transport mechanism of this species in south Florida? Are there other relevant migration paths and transport mechanisms than the one we have identified? What is the origin of anomalous water column conditions found at that Marquesas that appeared to promote larval recruitment, and is the occurrence of these conditions predictable?

Research Performance Measure: We met all our primary objectives on time.

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*:** 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

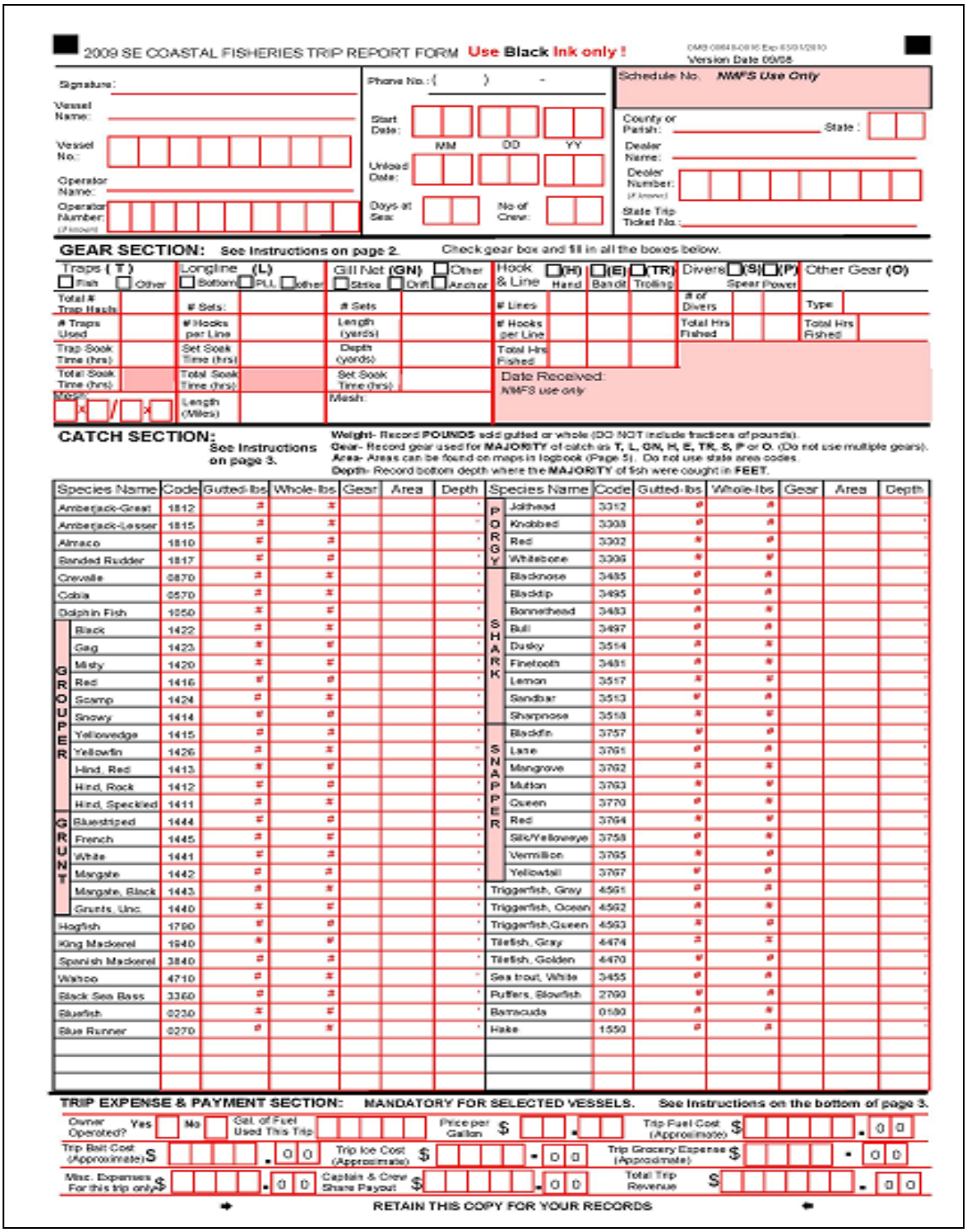
NOAA Funding Unit: NMFS/SEFSC **NOAA Technical Contact:** Brion Cook

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 19 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 an indices of abundance created from logbook data.

Research Performance Measure:

Our objective, the monitoring of compliance by fisherman has been successfully accomplished with respect to the timely submission of data,.



2009 SE COASTAL FISHERIES TRIP REPORT FORM **Use Black Ink only !**

Version Date 09/08

Signature:

Vessel Name:

Vessel No.:

Operator Name:

Operator Number:

Phone No.: ( ) -

Start Date: MM DD YY

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.:

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) Strike Drift Anchor Other	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		
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	1812					
	Amberjack-Lesser	1815					
	Almaco	1810					
	Banded Rudder	1817					
	Crevalle	0870					
	Cobia	0570					
	Dolphin Fish	1050					
GROUPER	Black	1422					
GROUPER	Gag	1423					
GROUPER	Misty	1420					
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	1540					
	Spanish Mackerel	3840					
	Wahoo	4710					
	Black Sea Bass	3360					
	Bluefish	0230					
	Blue Runner	0270					

	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	Dusky	3514					
SHARK	Finetooth	3491					
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	4591					
	Triggerfish, Ocean	4592					
	Triggerfish,Queen	4593					
	Tilefish, Gray	4474					
	Tilefish, Golden	4470					
	Sea trout, White	3455					
	Puffers, Blowfish	2790					
	Barracuda	0190					
	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

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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.

Figure 6.1.1-1. Red grouper 2006 and updated 2009 standardized indices of abundance constructed using commercial vertical line (handline and bandit rig) self-reported logbook data. Indices were scaled to the mean CPUE of the common years.

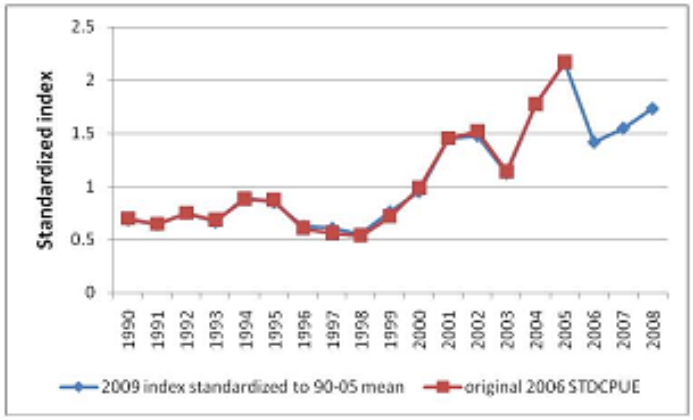


Figure 6.1.1-2. Red grouper 2006 and updated 2009 standardized indices of abundance constructed using commercial longline self-reported logbook data. Indices were scaled to the mean CPUE of the common years.

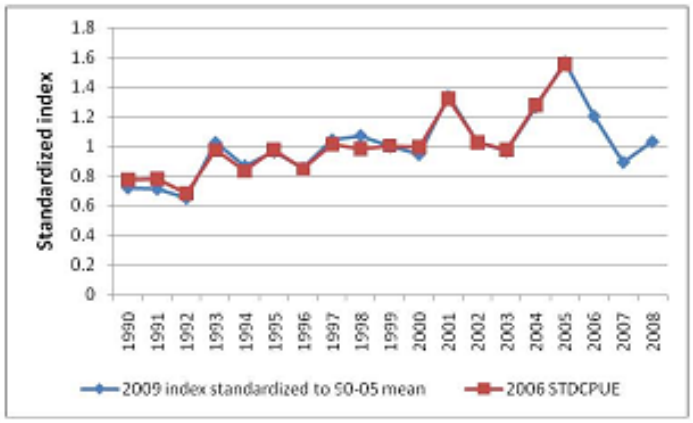


Figure 2: A recent SEDAR (SouthEast Data, Assessment, and Review) assessment of red grouper utilized indices of abundance created using logbook data. Figure 2 shows draft figures (assessment still in progress) of standardized indices for vertical and longline gear.

Shallow-Water Grouper Distribution, Habitat Characteristics and Spawning Behavior

D.J. Die and V. Koch (UM/RSMAS)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** To quantify habitat preferences for black groupers.

***Strategy*:** Use an array of self-contained autonomous acoustic devices to triangulate the position of individual tagged fishes and track them for periods up to several months.

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:** Todd Kellison

Research Summary:

This research is designed to augment our knowledge of black grouper ecology, to improve the effectiveness of management of this ecologically and economically important species.

This project is a multi-year study designed to assess the distribution and abundance patterns of shallow-water groupers in the Florida Keys by using acoustic telemetry. We tagged, around Conch reef, sixteen black groupers in 2006 and monitored them until 2007. We tracked fish movement with the help of 25 self-contained data logging receivers deployed on the seafloor around the no-take reserve of the Aquarius habitat and surrounding reefs.

Black groupers show high site fidelity around the Aquarius Habitat and that the majority of detections occurred within the protected areas surrounding it (Fig. 1). Time at liberty (detection of individual fish by the array during the experiment) ranges from 3 months to the duration of the study; and only 1 fish was reported as caught during the study period. Analyses of telemetry detections indicate that groupers move more frequently outside the protected area during the crepuscular period. Moon phase does not seem to have a detectable effect on activity but season does, with spring being the season where fish were more active.

Figure 1: Black grouper (*Mycteroperca bonaci*) hiding underneath the Aquarius Habitat in Conch Reef, Florida Keys.

Research Performance Measure: Currently we are completing the analyses of telemetry data and preparing publications. Analyses of the interviews conducted with stakeholders suggest that additional interviews will have to be conducted to provide the information originally intended to be collected. Collections of these interviews will take place during the second half of 2009.

Simulation of Management Strategies

D.J. Die and 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*:** 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: NMFS/SEFSC **NOAA Technical Contact:** Clay Porch

Research Summary:
The framework's architecture is designed to facilitate access to its analytical tools to fishery scientists with limited modeling capabilities. We used the framework as one of the evaluation tools for highly migratory fish in the Atlantic and for coastal demersal species in the Mid- Atlantic and the Caribbean.

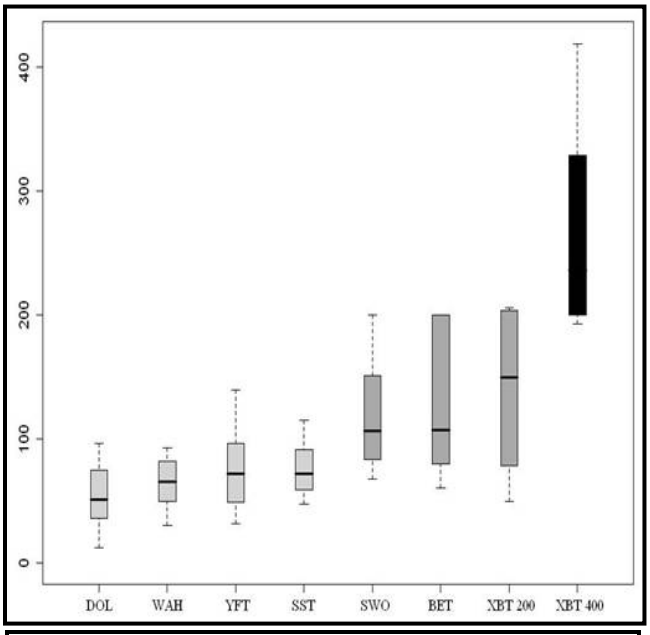


Figure 1: Boxplot of the distribution of the range parameter of spatial autocorrelation from the variogram models of abundance of different pelagic fish (DOL= Dolphinfish, WAH= Wahoo, YFT= Yellowfin tuna, SWO = Swordfish and BET= Bigeye tuna) and of temperature at depth (SST = Surface, XBT200 = 200 m and XBT400 = 400m), in the Gulf of Mexico. The letters reflect significant groupings by depth from the ANOVAs and post-hoc tests (A = shallow, B = mid-depth, C = deep).

Last year we developed an individual-based model for the migration of marlins in the Atlantic that enhances the ability to incorporate realistic movement patterns in operating models for migratory fish. We also completed a study of the spatial correlation of pelagic fish abundance (Fig. 1) that provides guidance on which types of standardization models may be more appropriate for such fish (Kleisner, 2008). We applied Bayesian population models to the assessments of Atlantic blue and mako sharks (Babcock and Cortes in press) and contributed to the development of an integrated approach to determine the risk of over-exploitation for sharks (Simpfendorfer et al., in press).

Research Performance Measure: We continued to develop new components of the framework and used the framework to evaluate stocks of pelagic sharks in the Atlantic. The work on spatial indices of abundance of pelagic fish was completed and accepted as a dissertation for K. Kleisner. The new individual-based models for migratory fish will now be applied to movements of Atlantic tarpon. Work on tagging models of Caribbean conch has ended because the Government of Turk and Caicos has withdrawn their logistical support for the study due to local political upheaval.

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) 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.

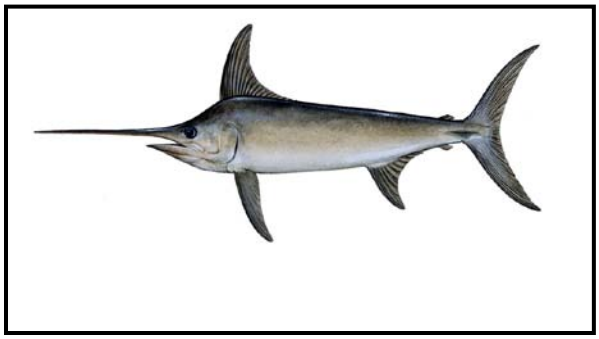


Figure 1: Photo of *Xiphias gladius* the swordfish (www.safmc.net, 2009).

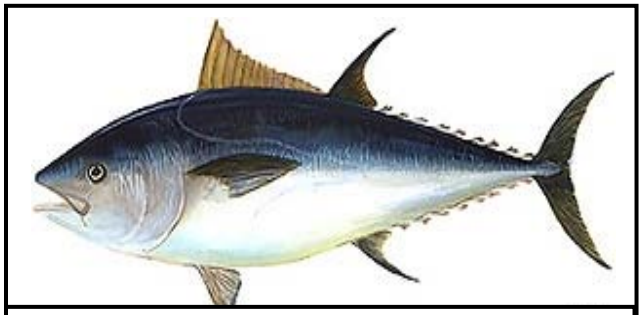


Figure 2: Photo of *Thunnus thynnus* the Atlantic Bluefin Tuna (www.MarineBio.org, 2009).

Research Performance Measure: All major objectives have been met.

Monitoring Shoreline Fish Assemblages of Biscayne and Florida Bays

D. Johnson and B. Teare (UM/CIMAS); 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, >10-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.

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 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

Average taxonomic richness was calculated across years for the composite and subdivided mainland shoreline and the leeward key shoreline. Seasonal and annual variation of yearly indices of taxonomic richness and dominance were examined using multivariate regression and analysis of variance.

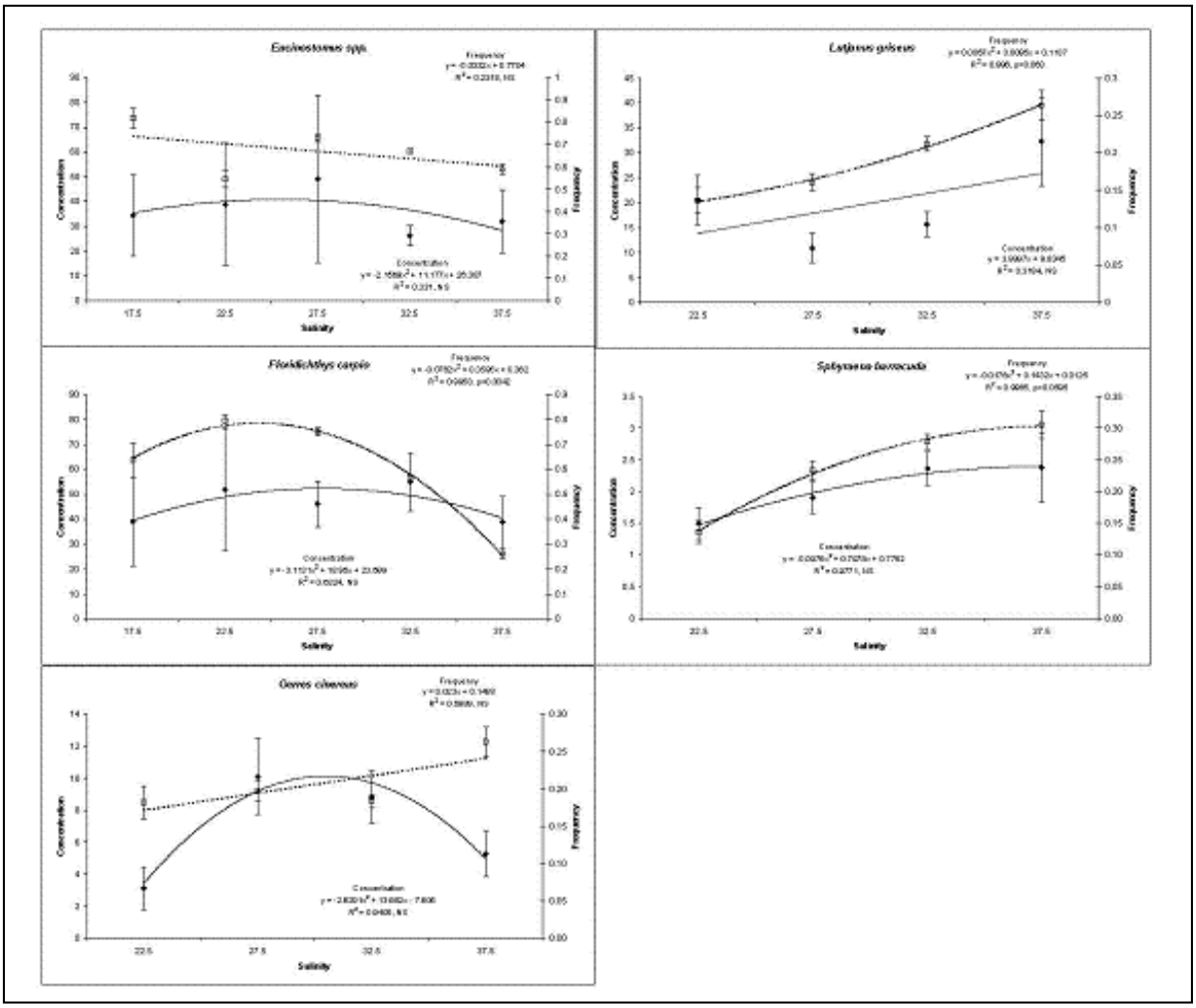


Figure 1: Dry season salinity-abundance patterns obtained by plotting the frequency of occurrence (dotted line) and the concentration of individuals per 60 m2 (solid line) over 5-psu salinity intervals. Regression are for each taxon. Error bars are 95% confidence intervals. NS= not significant.

We found no significant difference between years during the wet season species richness along the mainland shoreline and found that differences were primarily due to temperature and the interaction of salinity and depth. There were annual differences between years in the dry season richness but this was found to be related to temperature, depth, dissolved oxygen, salinity, and the interactions of temperature and year and salinity and depth. We detected no difference in species richness between years along the leeward key shoreline in the wet season but there was differences in dry years species richness which was correlated with temperature, salinity, depth, and the interactions of year x temperature and salinity x depth.

4. Power Analysis

We investigated the minimum sample size requirements for detecting changes (10-90%) with as alpha=0.05 and various power of detection (0.95, 0.9, 0.8, and 0.7) in fish community and taxon-specific for our three abundance metrics. We found that the level of current sampling was (1) more than adequate for detecting small changes in taxonomic richness and dominance along the mainland on an annual basis; (2) for five of six taxa ≤40% change in their seasonal occurrences was readily

detectable on an annual basis (3) for most focal taxa, combination of five years of seasonal samples will allow 20% change detection (alpha=0.05, beta=0.8) in all three of their abundance metrics.

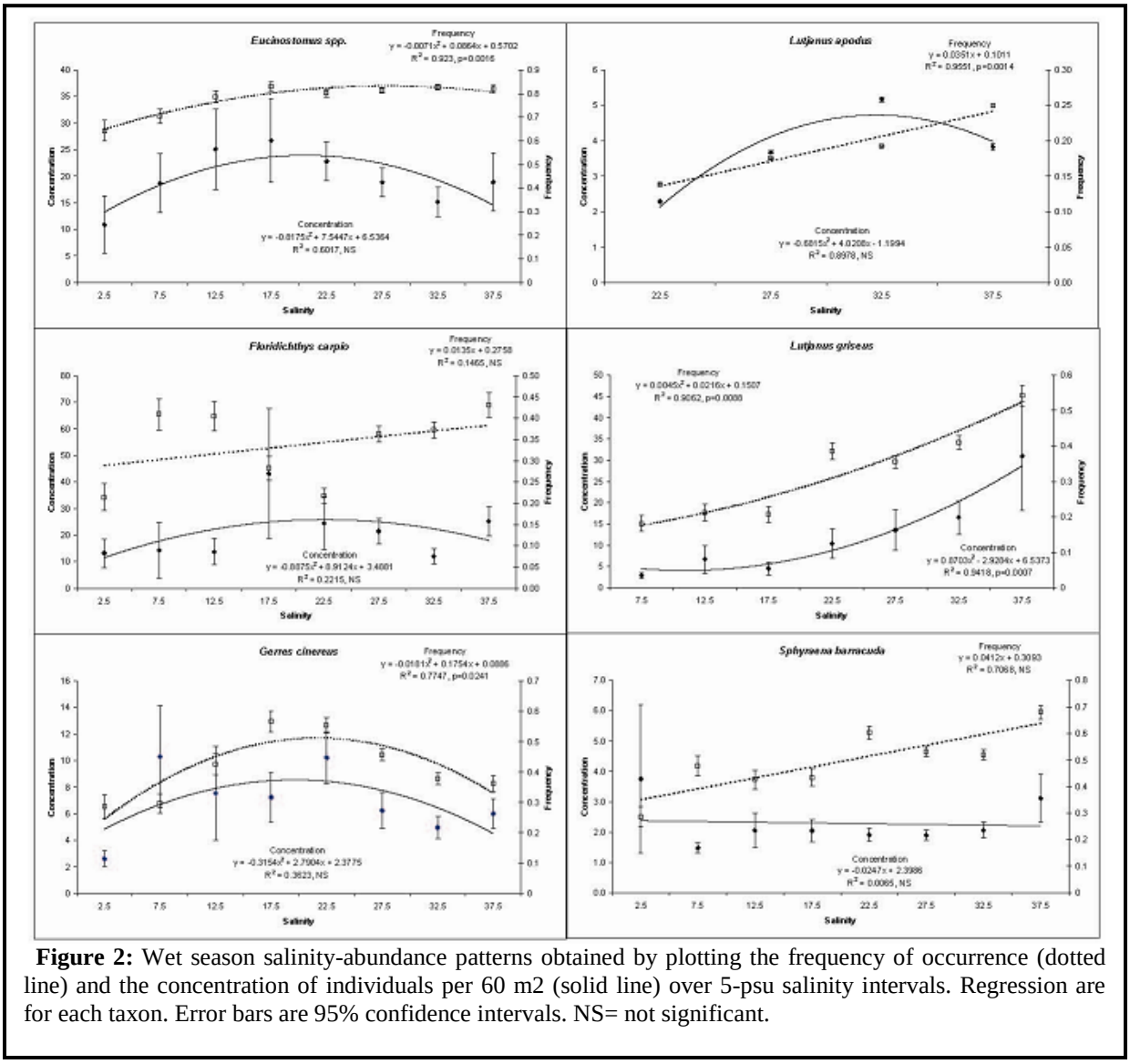


Figure 2: Wet season salinity-abundance patterns obtained by plotting the frequency of occurrence (dotted line) and the concentration of individuals per 60 m2 (solid line) over 5-psu salinity intervals. Regression are for each taxon. Error bars are 95% confidence intervals. NS= not significant.

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 completed year 11 of our visual census survey and developed models for the six major species. The modeled relationships were found to be significant.

Reef Fish Recruitment Dynamics: Integration and Analysis of Long-Term Visual Fish Surveys to Examine Environmental Influences

D.L. Jones (UM/CIMAS); J.F. Walter and J.E. Serafy (NOAA/SEFSC)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** To establish the nature and extent of the linkage between fish populations on the Florida Keys reef tract and those in adjacent inshore mangrove nursery habitats.

***Strategy*:** Construct predictive models of recruitment dynamics which incorporate ontogenetic habitat shifts (i.e., mangrove to reef), account for environmental variation, and allow estimation of adult reef fish stock size. Develop an annual, abundance-based index of recruitment that will allow identification of essential fish habitat and provide a basis for stock assessment and fishery management.

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:** John F. Walter

Research Summary:

Connectivity between mangroves and coral reefs, mediated by ontogenetic migrations of reef fishes that exploit the former for juvenile habitat, may be crucial for the replenishment of adult populations on the reef. However, direct evidence of this linkage and an understanding of the influence variability of juveniles within mangroves has on the dynamics of adjacent adult reef fish populations is lacking. This is because previous work has focused only on juvenile or adult habitats and life-history stages, precluding direct comparisons between the two. Our goal was to evaluate mangroves as functional nurseries for reef fishes by examining inter-habitat connectivity between the inshore mangroves and offshore coral reefs of Biscayne National Park (BNP) in southeastern Florida. Data were analyzed from two independent, visual survey based efforts that have monitored fishes in this region for over a decade (1998-2009) in: (1) the mangrove shorelines of Biscayne Bay (J. Serafy, Univ. of Miami/NOAA Fisheries) and the adjacent Florida Keys reef tract (J. Bohnsack, NOAA Fisheries).

Predictive models of reef fish recruitment dynamics incorporating ontogenetic habitat shifts and accounting for environmental variation were developed for 10 species of fishes that were frequently abundant in both habitats. Spatial segregation of life history stages were found in a number of species of reef fishes that reside in BNP, with juveniles occupying mangroves in the bay and adults inhabiting the reef. Our results also indicate that habitats within the bay and on the reef are connected through ontogenetic migrations of certain fishes from their juvenile to their adult habitats. Statistically significant correlations between juvenile abundances in mangrove habitats and adult abundances on the reef tract one to two years later emerged for four of the 10 target species. The congruence of year-class strength found among bay and reef fish populations is indicative of the nursery role mangroves play in annual population replenishment. This is one of the few long term studies that used juvenile abundance indices to test mangrove-reef ontogenetic connectivity. Our results have potential utility for nursery-habitat assessment, marine reserve design, and for forecasting species-specific year-class strength on the reef, where most fishing is directed.

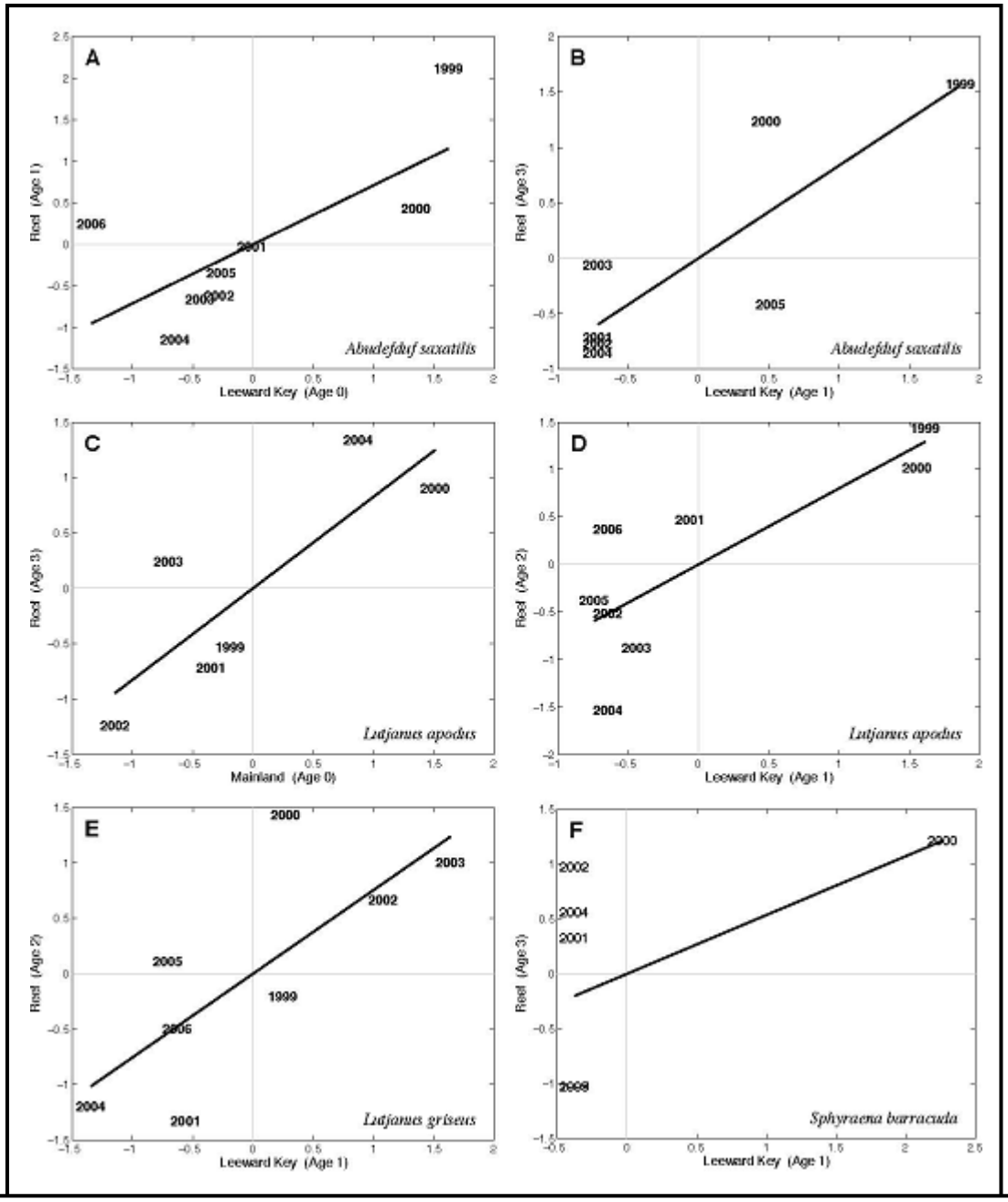


Figure 1: Regression plots of significant correlations (r, where $p<0.05$) between annual mangrove and reef abundance-based indices for ten species of fishes encountered in visual surveys of the mangrove shorelines of Biscayne Bay and the coral reefs of Biscayne National Park, Florida, USA. Data points are labeled with the sampling year associated with the abscissa (mangrove fishes); sampling years corresponding to the ordinate (reef fishes) equal those of the abscissa incremented by the temporal lag (years) associated with each plot as follows: A) sergeant major *Abudefduf saxatilis* (r2 = 0.50, lag = 1); B) *A. saxatilis* (r2 = 0.71, lag = 2); C) schoolmaster *Lutjanus apodus* (r2 = 0.69, lag = 2); D) *L. apodus* (r2 = 0.64, lag = 1); E) gray snapper *L. griseus* (r2 = 0.58, lag = 1); F) great barracuda *Sphyraena barracuda* (r2 = 0.30, lag = 1).

Research Performance Measure: Our objectives to assess the nursery role of mangroves and construct predictive models of adult reef fish stock size have been met and a summary of the results have been submitted for peer-review: *Jones, D. L., J. F. Walter, E. N. Brooks, and J. E. Serafy Connectivity through ontogeny: Fish population linkages among mangrove and coral reef habitats. Mar. Ecol. Prog. Ser., (submitted).*

Juvenile Spotted Seatrout Monitoring in Florida Bay

C. Kelble (UM/CIMAS); J. Browder, J. Contillo and P. Cope (NOAA/SEFSC)
B. Huss, L. Moore (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 2*:** Fisheries Dynamics (*Primary*)
Theme 6: 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: 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 and spends its entire life history within the Bay (Rutherford et al., 1989). Therefore, juvenile spotted seatrout are a good indicator to assess the effect of CERP on Florida Bay's recreational fishery.

A dual power analysis (one population based methodology and one based solely on frequency of occurrence) was undertaken to optimize the sampling design for detecting change as a result of CERP projects. Juvenile spotted seatrout display a large degree of interannual variability throughout Florida Bay. This is in part a result of their 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. 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 no 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 smaller effect.

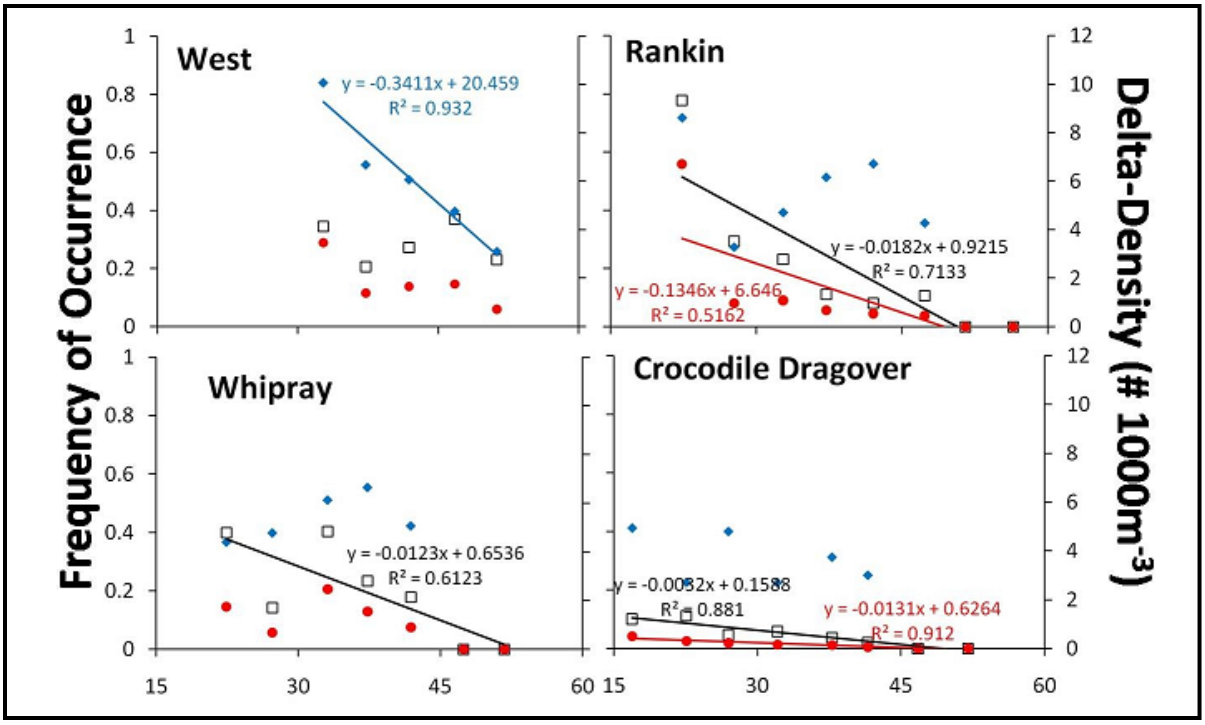


Figure 1: Scatter plots depict the correlation of the juvenile spotted seatrout population to salinity within each sub-region. The black boxes are frequency of occurrence, the blue diamonds are concentration, and the red circles are delta-density. Only significant linear regressions are depicted.

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**.**

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

E. Malca and A. Shiroza, N. Melo and G. Rawson (UM/CIMAS); J. Lamkin and T. Gerard (NOAA/SEFSC); R. Smith and L. Johns (NOAA/AOML); L. Vasquez-Yeomans, E. Sosa-Cordero and Laura 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*:** 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

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:** 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, 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

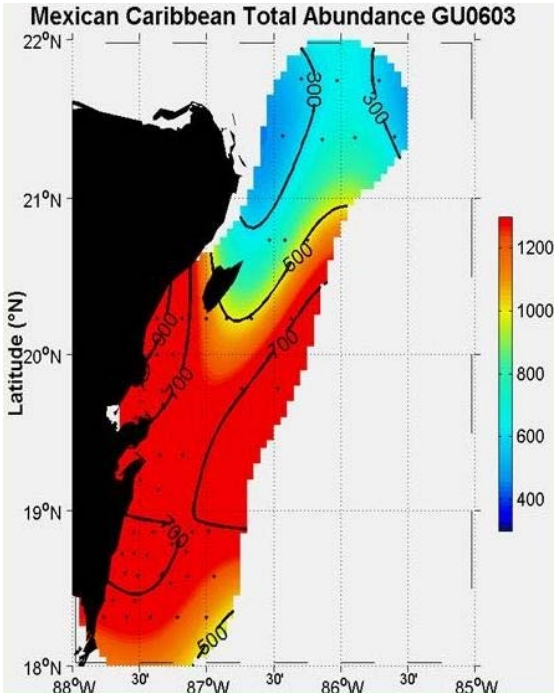


Figure 1: Total abundance of collected ichthyological samples along the Yucatan Peninsula during shipboard collections.

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. To date, sorting of ichthyoplankton samples from the 2006 and 2007 research cruises and inshore collections has been completed and identification to the taxonomic level of family has begun (see figure 1). 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. Family identification of the 2007 research cruise samples has recently been initiated with priority on coral reef fishes with our colleagues at the graduate school El Colegio de la Frontera Sur (ECOSUR) Chetumal campus, Quintana Roo, Mexico.

Research Performance Measure: The program is proceeding on schedule. The primary measure of the success of this newly initiated program will be the extent to which the physical and biological data complement each other and enrich the analysis and the degree to which the results obtained factoring into management decisions being made by NOAA/NMFS and the corresponding Mexican agency. The research program integrates many types of activities; this collaboration will markedly enhance the probability of success. In order to present and discuss the major outcomes of the research cruises a workshop was carried out in Miami, FL, September 30, October 1st - 2nd, 2008 to discuss the scientific publication objectives and set up a timeline for the remaining biological and oceanographic data processing. In addition, results from these cruises were presented by our ECOSUR colleagues at the VIII International Meeting of the Mexican Society of Planktology in Mexico City, April 2009.

US Virgin Islands Larval Distribution and Supply Research

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

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

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/Coral Reef Conservation Program (CRP)
NOAA Technical Contact: Trika Gerard

Research Summary:

This uniquely collaborative fisheries oceanography research project combines the expertise of fisheries biology, oceanography, and local knowledge from managers to focus on 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. We are presently conducting a three-year interdisciplinary research project (March 2007, March 11-24, 2008 and April 7-20, 2009) utilizing the NOAA Ship NANCY FOSTER to conduct biological and physical oceanographic surveys of the Virgin Islands' (VI) bank ecosystems and surrounding regional waters. Inshore biological collections of 2007 and 2008 took place in St. Thomas using light traps and seining close to important nursery habitats for coral reef fishes. These samples have been sorted and family identification has been completed (1,878 fish in 2007 and 342 fish in 2008).

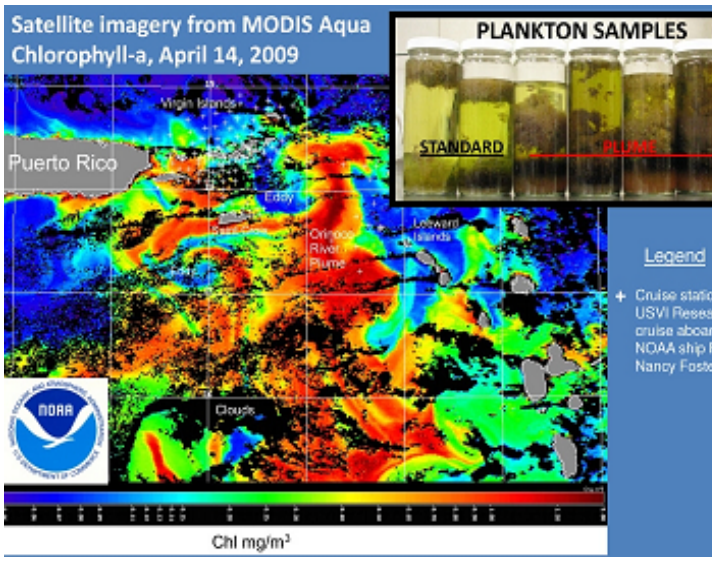


Figure 1: MODIS Aqua satellite imagery during USVI larval fish cruise reflecting unusually extended river discharge into the Caribbean. Sample bottles reflected denser plume samples when compared to standard samples

Data analyses are ongoing for all three cruises; 2007, 2008, and 2009. Operational success is evident in that oceanographic cruise data from 52 stations from the first year and 79 stations in the second year have been collected and processed. Biological collections from the 2007 cruise included the use of stratified net sampling with a multiple opening and closing net environmental sampling system (MOCNESS), and subsurface Bongo tows have been sorted obtaining 23,177 larval fish. In addition, the family identification has been completed for 2007 and samples from the 2008 cruise have been sorted yielding 29,967 fish and family identification is more than 50%. The third cruise took place earlier this year (April 7 – April 20, 2009) replicating collections at historical stations and extending our sampling collections south into St. Croix at the request of local managers including the Caribbean Fisheries Management Council. During the cruise, we began to notice areas of low surface salinity and very high chlorophyll values. Confirmed by satellite ocean color imagery, this large "green water" could be traced back to its source, the Orinoco River. *In situ* observations of this remote riverine signal revealed a surface layer approximately 20 meters thick, relatively high in temperature, low in salinity, and rich in plankton and other biological content (see Figure 1).

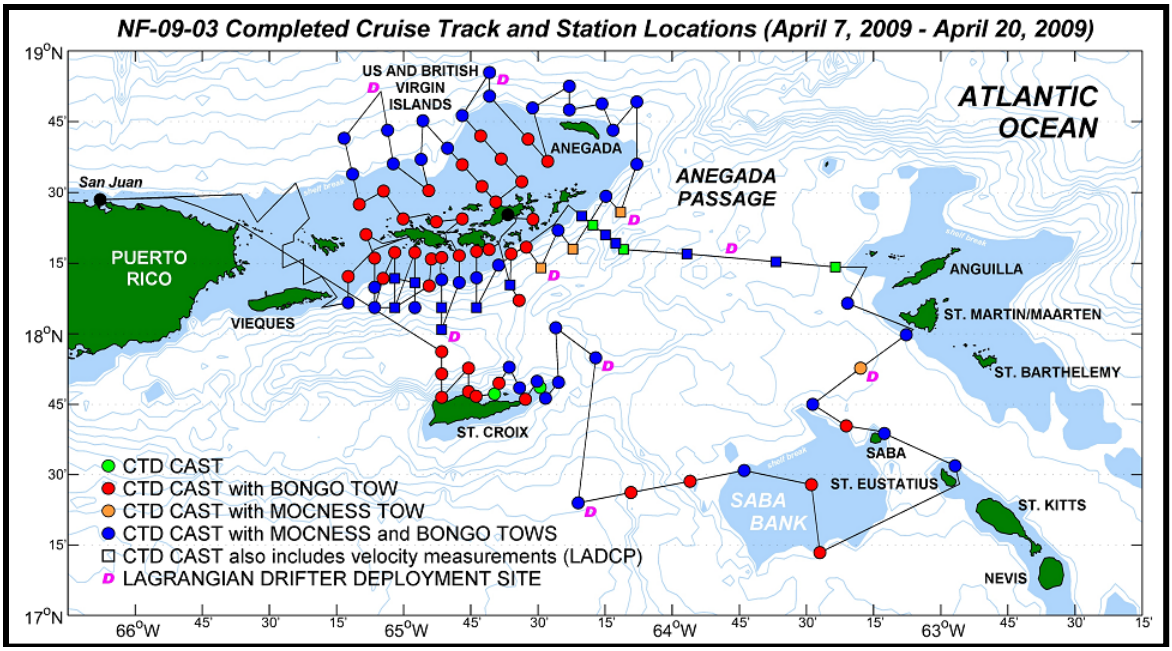


Figure 2: Cruise track showing collection gear and sampling location in 2009.

Research Performance Measure: The research program is on schedule. Our goal is comprehensive understanding of regional spawning aggregations, larval transport, and overall larval recruitment in the study area. The primary measure of the success of this program will be the extent to which the physical and biological data complement each other and enrich the analysis and the degree to which the results obtained are factored into management decisions being made by NOAA/NMFS. This study, when completed, will contribute to the long-term sustainability of fisheries in the Virgin Islands and surrounding regions.

Preliminary Evaluation of Larval Fish Assemblages and Distributions in the Waters of Kuwait

A. Shiroza (UM/CIMAS); J. Lamkin (NOAA/SEFSC)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** Describe the early life history stages of fishes in Arabian Gulf, use available data to monitor the impacts of over-fishing in the region.

***Strategy*:** Trace the development of larval fish for identification, prepare and conduct courses on larval fish identification.

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: NOAA/SEFSC **NOAA Technical Contact:** John Lamkin

Research Summary:

This project is part of the 15 survey cruises carried out between July 2002 and June 2005 at 24 locations off the Kuwait coast. Neuston samples were taken from the Arabian Gulf bi-monthly from April 2004 to June 2005, on 7 cruises at 8 spatially separated stations. Six samples were collected per station; three tows before sunset and three tows after sunset for total of 336 samples. Of these, 322 samples were found positive for fish larvae and total of 43,893 fish were collected; 12079 yolk-sac larvae and 1,066 damaged larvae were left unidentified along with 140 unidentifiable fish larvae. The remaining 30,608 larvae were identified to 35 different families; and, whenever practicable larvae were classified to lowest possible taxonomic level.

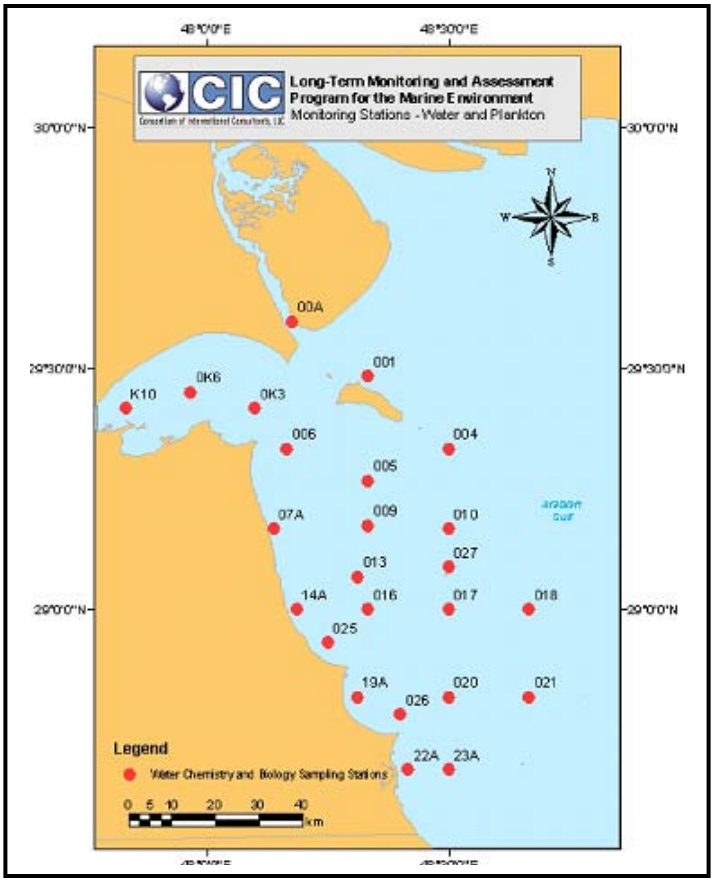


Figure 1: Map of the plankton sampling stations.

The purpose of the research is to assess the recovery of ichthyoplankton from the environmental damage during the Gulf War in 1991 when the largest oil spill in history (approximately 1.7 million tons of oil) and toxins were released in the atmosphere. This research will also contribute to understanding the early life history of fishes in Arabian Gulf that are currently not identified and/or, which in turn may assist in monitoring the impacts of over-fishing of in the region. By preparing and conducting courses on larval fish identification, the project also serves an important educational purpose. The report from this project supplements William J Richard's book on Guide to Arabian Fish.

The surveys were carried out under a PAAC (Public Authority for the Assessment of Compensation for Damages Resulting from Iraqi Aggression) Marine and Coastal sampling program, implemented by CIC (Consortium of International Consultants), and under the technical supervision of KISR.

Research Performance Measure: A poster to be presented at the Joint Meeting of Ichthyologists and Herpetologists in Portland Oregon. NOAA technical reports on families of fish identified. Both efforts are on schedule.

Juvenile Snapper Acoustic Tagging & Tracking Project (J-SATT)

S. Whitcraft (UM/CIMAS); J. Lamkin (NOAA/SEFSC)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** To clarify and quantify the foraging and movement patterns of recreationally and commercially important reef-associated juvenile snappers between their nursery, juvenile and adult habitats in South Florida.

***Strategy*:** Surgically implant acoustic tags in juvenile and sub-adult snappers and, over a two-year period, acoustically track their movements within and between specific habitats, including oyster reefs, mangroves, seagrass beds, and man-made structures in the Loxahatchee Estuary and adjacent coastal habitats.

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: NOS/Coral Reef Conservation Program
NOAA Technical Contact: John Lamkin

Research Summary:

Forty-four sub-adult grey snapper (*Lutjanus griseus*) were tracked in the lower, marine-influenced Loxahatchee Estuary for approximately six months to allow for comparison with the movement of younger age classes from the previous year/study. Preliminary results suggest a set sunrise/sunset movement pattern, greater site fidelity, and tighter schooling behavior in the mangrove habitat than in the man-made habitat supporting earlier findings. The 36+ acoustic receiver array is also tracking snook in partnership with FIU and FWC.

Six new 'acoustic gates' were installed at all the estuary outlets to record any departing fish. One tagged sub-adult snapper was caught/speared two miles south of Jupiter Inlet on an artificial reef. Efforts were made to locate additional fish on the artificial reef using manual acoustic tracking. However, no additional tagged fish were found. Another snapper, tagged a year earlier, was caught at the marina cleaning station after moving 6+ miles downstream. These data, along with other initial results suggest a gross down-stream movement of both juvenile and sub-adult snapper, often in association with increased fresh-water flow in the spring.

In October 2008, a Vemco training and data-workshop, including SAS and Vemco VUE training, was arranged for a Florida Atlantic Coast Telemetry (FACT) meeting with all 13 coordinated projects attending to allow for more efficient data-sharing. Data-sharing protocols were established.
Technical transfer and capacity building, via training in established surgical methodologies and procedures was completed for the Bahamas for snapper tagging and tracking and education outreach in partnership with FIU. Educational outreach was also included via a local Race-to-the-Reef program for participating school groups.

Experimental design for a mesocosm experiment was completed to test for any behavior effects or impacts of tagging surgery and implantation. Additionally, a draft manuscript about the Florida Atlantic Coast Telemetry Project (FACT) was submitted for internal NOAA review. An extended report about coordinating FACT research and data between state, Federal and local agencies was also submitted to RSMAS in completion of a Masters of Marine Affairs and Policy.

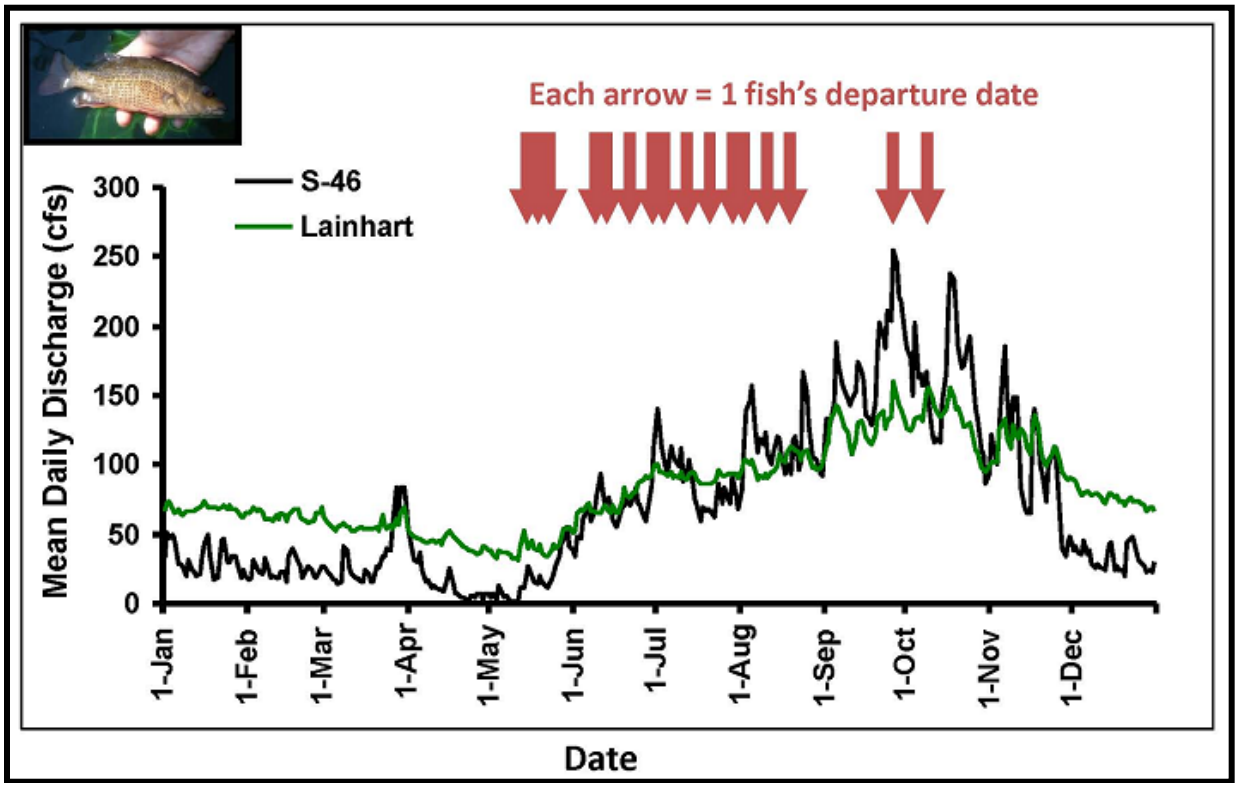


Figure 1: Downstream movement of juvenile gray snapper as determined by departure date from an upstream receiver. These data are overlaid with a 30-year average of freshwater flows through two water control structures at the head of the Loxhatchee River – Lainhart Dam and the S-64 structure

Research Performance Measure: We accomplished our objectives for the past year: to maintain the Loxahatchee Estuary acoustic receiver array and to complete preliminary data analyses of all tagged fish movements. A project overview and initial results were presented at the International Coral Reef Symposium, July 2008. Additionally, we downloaded the entire array (36+ receivers covering 8+ miles) every month for on-going data analyses. Objectives are being met; and as a result of establishing a remarkably successful federal, state, local and academic partnership fish movements are now being continuously and successfully tracked across multiple habitats both in and offshore of the Loxahatchee estuary and along Florida's east coast.

Liquid-Waveguide Spectrophotometric Measurement of Low Silicate in Natural Waters

N. Amornthammarong (UM/CIMAS); J.-Z. Zhang (NOAA/AOML)

Long Term Research Objectives and Strategy to Achieve Them:
***Objectives*:** To measure low silicate in surface ocean waters
***Strategy*:** Apply liquid waveguide technology to spectrophotometric nutrient analysis methods.

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 (*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:** Jia-Zhong Zhang

Research Summary:
We have developed a robust, sensitive method for the measurement of low silicate concentrations in natural waters. The method shows no refractive index effect and a small salinity effect that can be corrected for seawater samples. The sensitivity of this method is substantially enhanced by using a liquid-waveguide capillary cell. The method can be used for both freshwater and seawater samples and has been used to study the distribution of silicate in surface seawater of Gulf Stream in Florida straight.

The method was tested aboard on a cruise from Miami, Florida to the Bahamas coast during July 2008. The results indicate that the silicate concentration is lower in the Gulf Stream, which flows

northward along the east coast of Florida peninsula, in comparison with the open ocean surface waters near Bahamas. Detected levels are well below that measurable by traditional autoanalyzer methods.

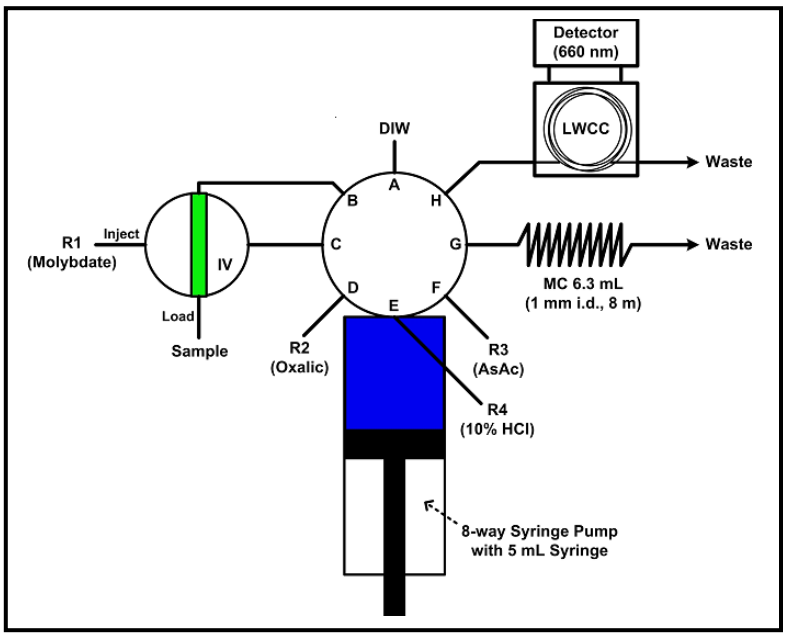


Figure 1: Liquid-waveguide analyzer for silicate determination: LWCC, liguid-waveguide capillary cell; MC, mixing coil; AsAc, ascorbic acid; IV, injection valve; DIW, deionized water; R1, molybdate solution; R2, oxalic acid solution; R3, ascorbic acid solution; R4, 10%HCl (v/v).

Research Performance Measure: All objectives have been accomplished and the method now being routinely used.

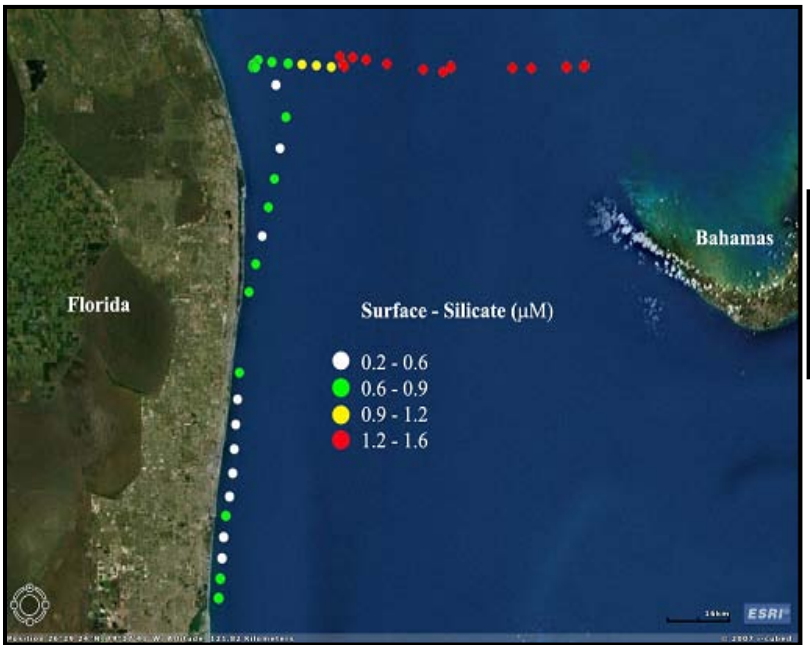


Figure 2: Shipboard measurements of silicate concentrations in surface waters during a cruise from Miami, Florida to the Bahamas in July 2008.

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

C. Brown, C. Sinigalliano and N. Amornthammarong (UM/CIMAS); J. Bishop, T. Carsey, J. Craynock, C. Featherstone, L. Salerno and J. Stamates (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

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. We have previously made careful flow measurements at the Boynton Inlet using side-looking acoustic Doppler current profiler (ADCP) instrumentation. This year, we have installed similar instrumentation at the Port Everglades inlet (Fig. 1), as a part of the Port Everglades Shipping Channel (PESC) study (http://www.aoml.noaa.gov/themes/CoastalRegional/projects/FACE/PtEverg.htm). The instrumentation package also includes seawater temperature and meteorological measurements. The station is a part of NOAA's Integrated Coral Observing Network (ICON) and the data can be viewed on the ICON website (http://ecoforecast.coral.noaa.gov/index/0/PEVF1/station-sensors); it is also station PEVF1 of NOAA's National Buoy Data Network (http://www.ndbc.noaa.gov/station_page.php?station=pvgf1). The instrumentation is located on the south side of the inlet at the Navy base. Preliminary results from the ADCP indicate a complex flow pattern, with significant variations with depth and across the channel.

The FACE project has recently obtained a new small boat, the R/V Hildebrand, from the NOAA Beaufort Laboratory (Fig. 2). The boat will be used in upcoming water quality monitoring in the coastal waters of SE Florida.

Research Performance Measure: Installation of instrumentation at Port Everglades has been accomplished according to schedule, and will be in operation for at least one year. Acquisition of the R/V Hildebrand fulfills a major requirement of a projected FACE project to investigate water quality in coastal Florida from Miami to Palm Beach counties.
(http://www.aoml.noaa.gov/themes/CoastalRegional/projects/FACE/WQ-Survey.htm).

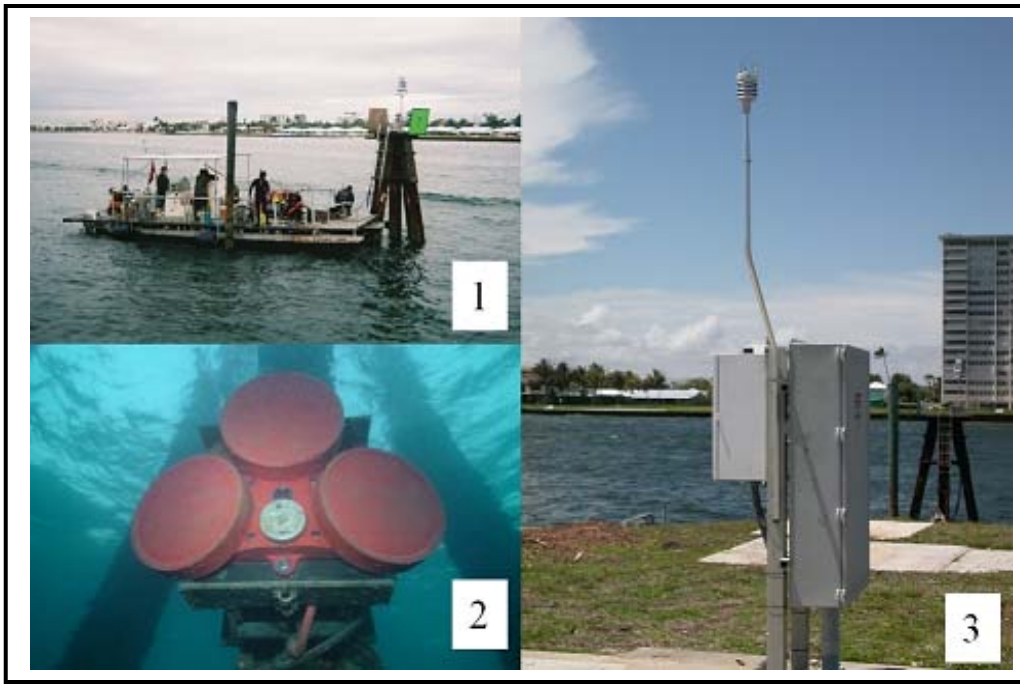


Figure 1: Installation of instrumentation at Port Everglades Inlet. 1) Divers prepare underwater instrumentation for mounting onto a channel marker structure. 2) The ADCP unit, mounted for near-horizontal operation. 3) Power supply, meteorological instrumentation, and communications package with channel marker in background.

Figure 2. Side view of the NOAA R/V Hildebrand, a 41-foot Coast Guard utility boat formerly at the NOAA Beaufort laboratory. The boat will be used for the upcoming FACE water quality monitoring project in the waters off of SE Florida

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

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

Long Term Research Objectives and Strategy to Achieve Theme:

***Objectives*:** To develop a pink shrimp (*Farfantepenaeus duorarum*) simulation model and performance measure (an indicator) of the impact of Greater Everglades ecosystem restoration related upstream water management changes upon the Florida Bay ecosystem.

***Strategy*:** Conduct coordinated field experiments on different life history stages of pink shrimp in conjunction with water quality and circulation measurements so as 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:

Our research on pink shrimp dynamics supports the Comprehensive Everglades Restoration Plan (CERP). We continue developing an understanding of the movements and behavior of early stage larvae and post-larvae in Florida Bay and the SWF shelf of the Gulf of Mexico. One of the most remarkable results of our research is the strong effect of a tidal behavior on the transport of the different life history stages of pink shrimp. Therefore, behavior has become an important component of this study.

Field experiments conducted in the northwestern Florida Bay indicate that post-larvae use flood-tide transport (FTT) to enter Florida Bay and to move inside the estuary. To achieve this horizontal transport, post-larvae ascend from the bottom into the water column during the nocturnal flood tide and remain swimming there until current reversal with the ebb-tide, when they return to the bottom. We

Figure 1: Sampling methods used in northern Florida Bay to collect early settlement stages of pink shrimp: Renfro trawl and settlement traps with artificial sea-grass.

also determine that post-larvae move into the Bay's interior by a cumulative flood tidal process, advancing onshore during successive nights as far as they can go with the tide (CIMAS report 2008). Beyond the location of the highest concentrations, post-larval numbers decline drastically and the displacement curve flattens, suggesting that tidal currents may not be sufficient to generate substantive further eastward transport. While tidal transport appears to be insufficient for post-larvae to reach north-central Florida Bay, salinity and winds may also contribute to the observed distribution patterns of early pink shrimp recruits.

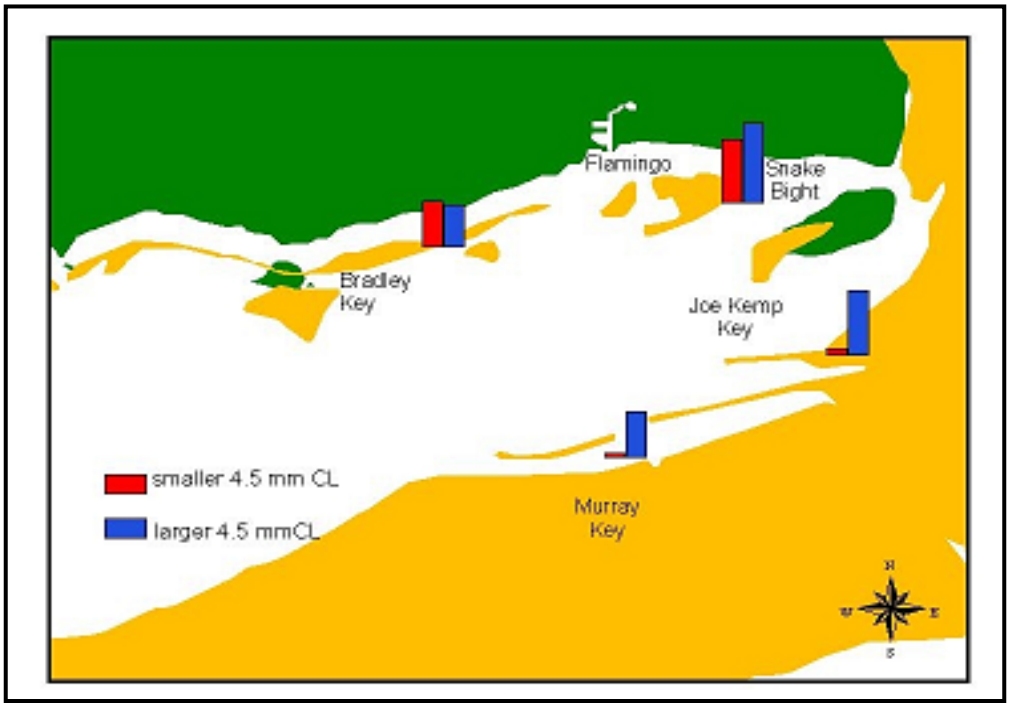


Figure 2: Map of northern Florida Bay depicting sampling stations of pink shrimp juveniles collected during summer 2008. The histograms sizes are proportional to the number of shrimp collected at each station representing two sizes classes of carapace length, CL in mm.

More striking results revealed that even younger stages (myses and early post-larvae) also perform rhythmic vertical migrations synchronized with the semidiurnal tide on the SWF shelf. Myses and post-larvae were found in large concentrations near the surface at the end of the flood tidal period every 12 hours. This behavior was observed near the Marquesas Keys about 80 km from the nursery grounds (Criales et al., 2007 - *Mar. Ecol. Prog. Ser*. 345:167-184), constituting the first evidence of tidal behavior in shrimp larvae migrating across the shelf shoreward from the spawning grounds toward coastal nursery grounds. This behavior was observed under conditions of strong density gradients and strong shear. However, it is not clear if these special conditions have an effect on the larval behavior. We also confirmed that juveniles move seaward by positioning themselves at the surface layer during the ebb tide on moonlit nights.

During summer 2008 we focused upon the settlement process of this species. We conducted exploratory work in northern Florida Bay collecting early settlement stages of pink shrimp using a Renfro trawl and settlement traps with artificial sea-grass (Fig. 1). However captures with settlement

traps were extremely low and were not considered for analysis. We sampled at two onshore stations near Bradley and Snake Bight and at two offshore stations near the seagrass-covered banks of Joe Kemp and Murray Key (Fig. 2). Our target size was small shrimp < 4.5 mm in carapace length (CL) because settlement occurs at 3-4 mm CL. Preliminary analysis testing the effect of location on the number of shrimp indicated that large shrimps are found in about the same numbers at the two onshore stations as well as the two stations near the seagrass banks. In contrast, small shrimps were significantly more abundant at the two onshore stations near Bradley and Snake Bight (Fig. 2). Analysis testing the effect of light on the number of shrimp indicated that large shrimps were captured in about the same magnitude in twilight, daylight, and darkness. In contrast, small shrimps were significantly more abundant during the dark hours (Fig. 3). An ANOVA indicated that small shrimp were significantly more abundant in samples collected in darkness than in daylight. These results suggest that there is a marked difference in behavior and probably habitat selection between these two size classes of shrimp. Further investigation would be desirable to determine the specific seagrass or microhabitat in which early settlement stages settle for better protection of these fragile and vulnerable life stages.

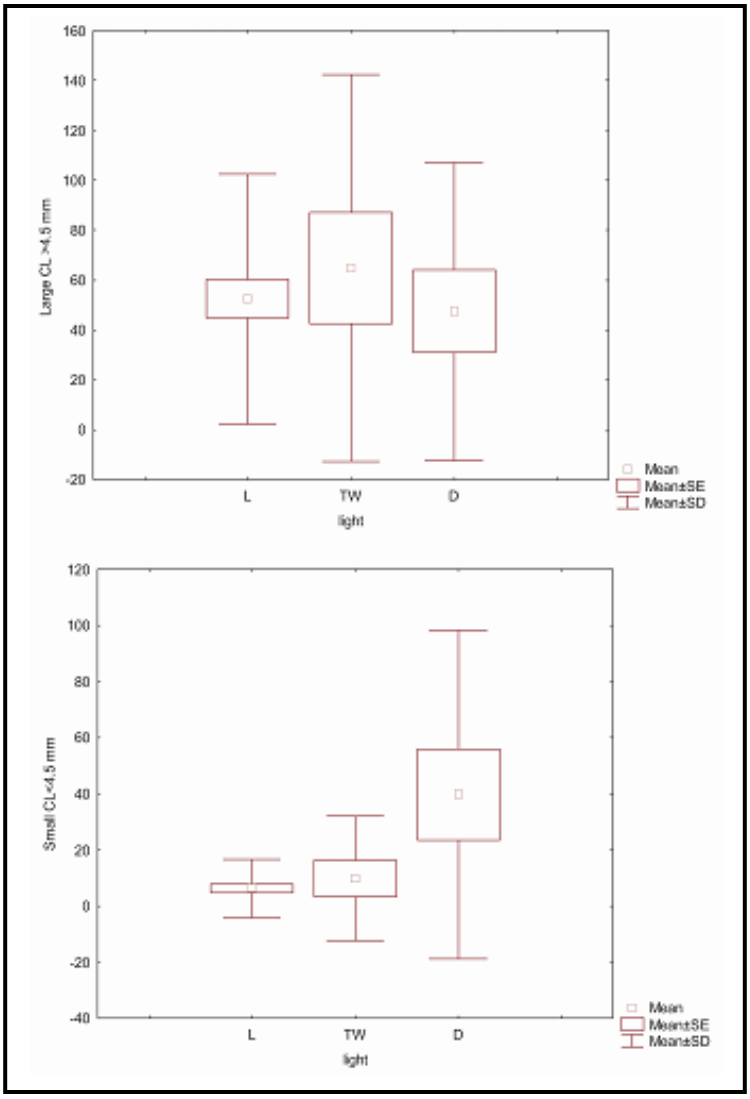


Figure 3: Mean ± standard deviation and standard error of the number of pink shrimp juveniles collected in northern Florida Bay in relation to light (daylight, twilight and darkness) separated into two sizes. Upper figure is for large shrimp (carapace length > 4.5 mm) and lower figure for small shrimp (carapace length < 4.5 mm).

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.

Characterization of Ocean Acidification in Coral Reef Waters

D. Gledhill (UM/CIMAS); C. Langdon (UM/RSMAS); J. Hendee, R. Wanninkhof (NOAA/AOML); R. Brainard (NOAA/PIFSC); R.Feely (NOAA/PMEL)

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; 2) develop new techniques for monitoring community-scale metabolic performance necessary in establishing critical thresholds; and 3) extend Pacific OA base-line characterizations into the NWHI allowing examination the large-scale latitudinal variations in near-reef carbonate chemistry.

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).

This project partners NOAA, USGS, University of Miami, and the University of Puerto Rico initiated 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. FY08 – FY09

activities have established La Parguera, PR as an Atlantic OA Test-bed leveraging considerable NOAA, USGS, and local university partnership investment. The NOAA CRCP contribution provides for high quality carbonate chemistry monitoring at the site complete menting USGS and UM process study efforts thus encompassing four elements: mapping and modeling, monitoring, experimentation, and educational outreach. Reef metabolic processes are being modeled from discrete habitat experiments conducted by the USGS. Up-scaling these processes to the reef scale is being facilitated by geochemical modeling driven by sustained high quality monitoring of water column carbonate chemistry. Furthermore, current models that attempt to establish critical thresholds for OA are based only on changes to oceanic carbonate chemistry and do not accurately account for the dissimilarity between oceanic and coastal chemistry since no comprehensive carbonate chemistry survey of these systems exist. This project has also integrated into the existing Pacific RAMP network a carbonate chemistry survey across various coral reef zones and habitats establishing such a base-line characterization. Together, these efforts are working to better prepare NOAA for implementing an ecological OA forecasting system to inform society of the long-term viability of these ecosystems under continued OA.

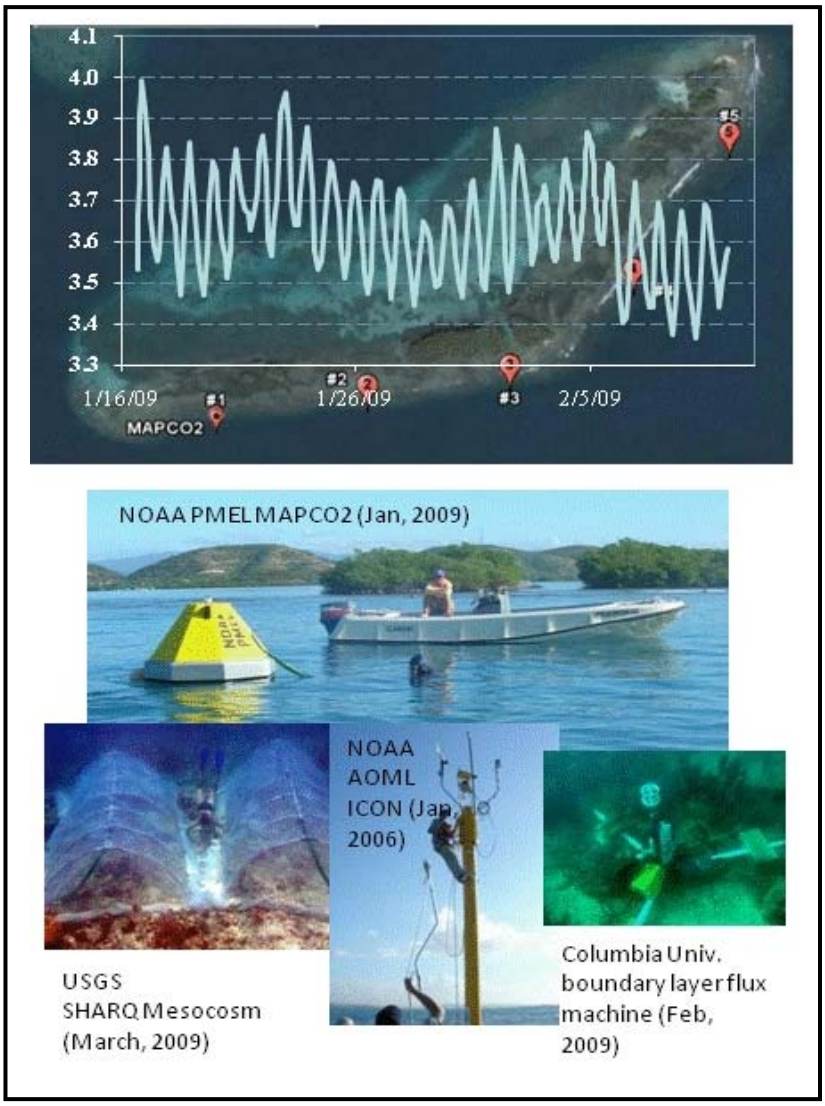


Figure 1: The Atlantic Ocean Acidification Test-bed serves as a nexus of OA monitoring research in the Greater Caribbean Region uniting autonomous and discrete sampling platforms in concert with process and modeling studies.

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

Sediment-Water Exchange of Dissolved Organic Phosphorus in Florida Bay

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

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** To quantify the partitioning of organic phosphate at the sediment/water interface in Florida Bay.

***Strategy*:** Conduct systematic laboratory experiments upon field collected samples to quantify organic P exchange across the sediment/water interface.

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/CSCOR **NOAA Technical Contact:** Jia-Zhong Zhang

Research Summary:

Dissolved organic phosphorus (DOP) is recognized as a dominant component of the total dissolved phosphorus pool in many coastal waters and the exchange of organic phosphorus across the sediment/water interface as one of the important biogeochemical processes. We conducted the following studies to characterize the role of sediments in DOP exchange across sediment/water interface in Florida Bay.

1. The sorption of different organic phosphorus compounds, including the phosphate ester (e.g. AMP, adenosine diphosphate, adenosine triphosphate, glucose-6-phosphate, glycerol-2-phosphate) and phosphonate (e.g. 2-aminothylphosphonoic acid, and phosphonoformic acid) was measured for selected sediments in Florida Bay.
2. A model organic phosphorus compounds, adenosine monophosphate (AMP), was used to study the spatial pattern of sediment-seawater exchange of DOP in Florida Bay and explore its relationship with sediment composition.
3. The methodology of total dissolved phosphorus determination was optimized.

For most of the organic phosphorus compounds we used sorption can be described by a modified Freundlich equation. A considerable amount of the organic phosphorus can be absorbed by the sediments. However, the behavior of sorption is compound-specific. For example, FPA can release native absorbed organic phosphorus in the sediments and the desorbed organic phosphorus from sediment was proportional to the concentration of FPA in the solution.

The results of AMP and phosphate sorption across Florida Bay indicated that distribution coefficients with respect to both total dissolved phosphorus ($K_{d\text{-}TP}$) and phosphate ($K_{d\text{-}IP}$) were a function of degree of P saturation (IPS) and the molar ratio of the surface reactive phosphorus to the surface reactive iron oxide content in the sediments. However, the zero equilibrium phosphorus concentration of total phosphorus was directly related to the total content of sedimentary phosphorus only in the eastern and central Florida Bay. Sediments in western Florida Bay can act as a source of phosphorus in the exchange process, since almost no DOP sorption can be detected (high $EPC_{0\text{-}TP}$ and

low $K_{d\text{-}TP}$); whereas the sediments in the eastern and central Florida Bay act as a sink of phosphorus (low $EPC_{0\text{-}TP}$ and high $K_{d\text{-}TP}$) since a considerable amount of DOP have been found to absorb. These results demonstrate that the important role of the sediment re-suspension for cycling of phosphorus at least in western Florida Bay confirming previous field observations of mixing events.

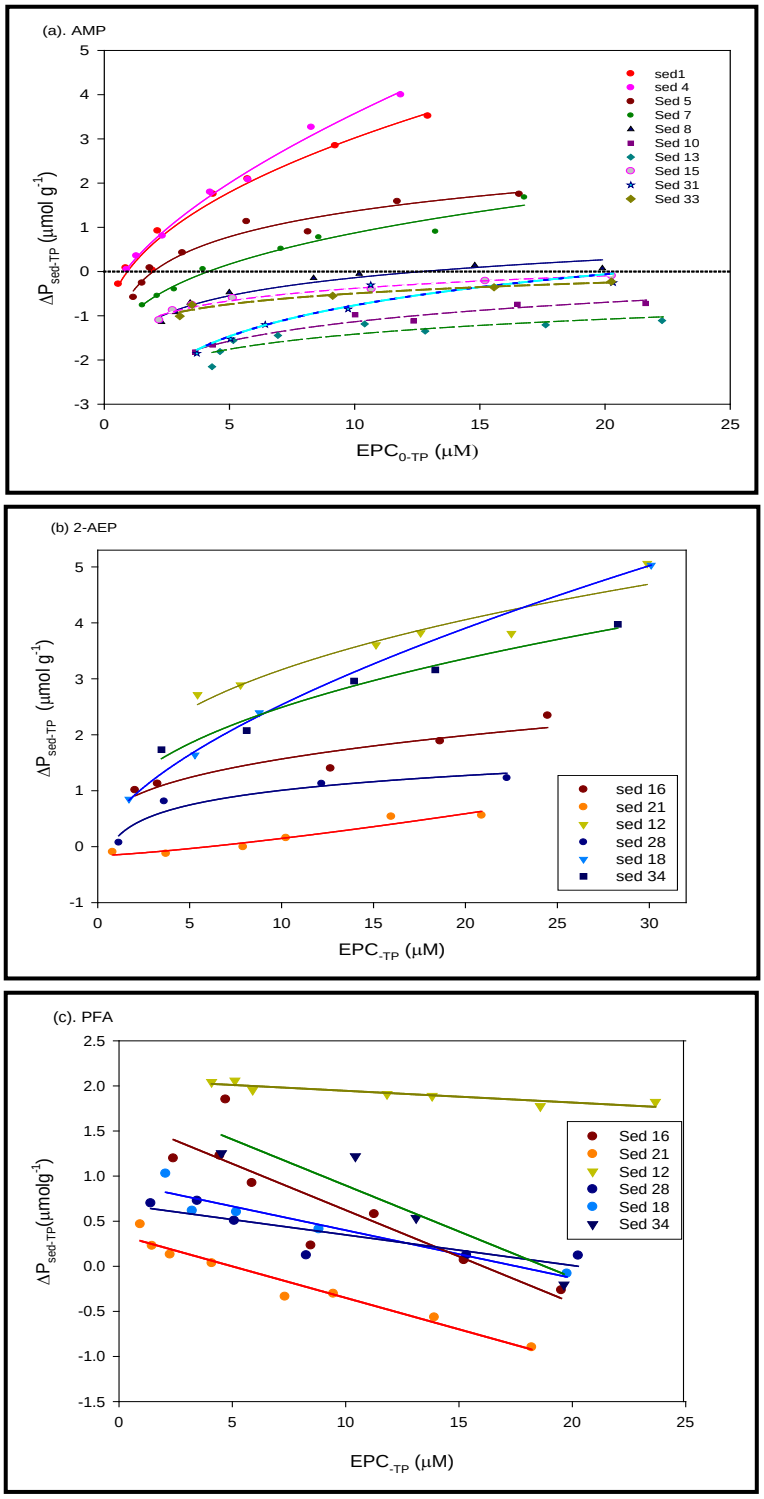


Figure 1: Typical total phosphorus sorption isotherms of sediments in the Florida Bay. (a) AMP (b) 2-AEP (c) PFA.

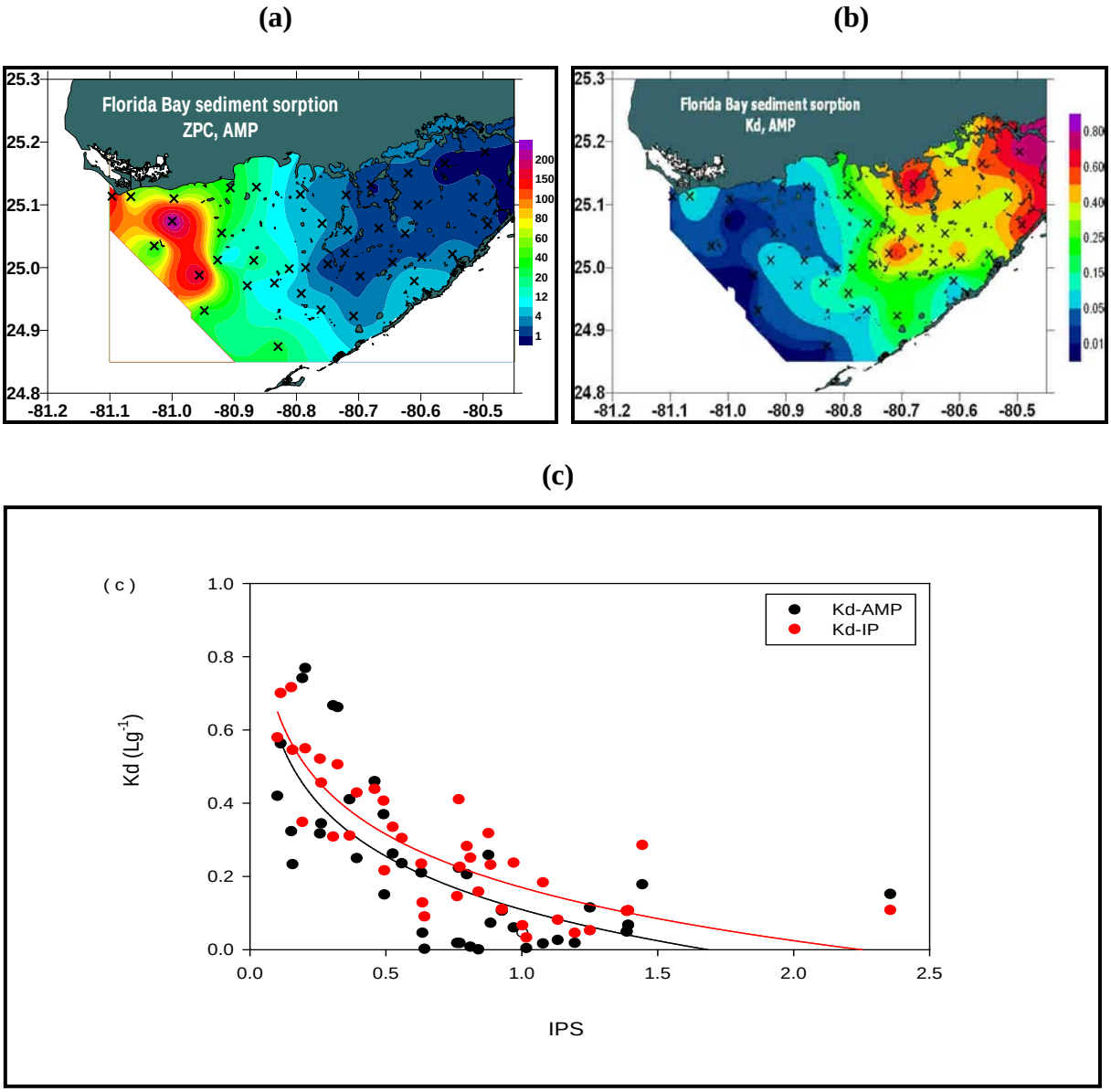


Figure 2: Spatial distribution of (a) $EPC_{0\text{-}AMP,}$ (b) $K_{d\text{-}AMP}$ in the Florida Bay and (c) the function of K_d with the degree of P saturation (IPS), the molar ratio of the surface reactive phosphorus to the surface reactive iron oxide content in the sediment across the whole Florida Bay. $K_{d\text{-}IP}$ = -0.2096 ln(IPS) +0.17 (n =40, r^2=0.748, p<0.001, red solid line, Fig c); $K_{d\text{-}AMP}$ = -0.21 ln(IPS) +0.11 (n = 40, r^2=0.547, p<0.001, black solid line, Fig c).

Research Performance Measure: The research program is on schedule and all performance objectives are being met.

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 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*:** Integrated Ocean Observations (*Primary*)
***Theme 6*:** Region 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: AOML- NOAA/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 a predictive, mechanistic model to estimate light attenuation. The long term variability in salinity was examined

to determine the impact of meteorological phenomena on the physical environment of Florida Bay (Figure 1) 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 meso-zooplankton community in conjunction with the juvenile and small adult fish community found evidence of strong top-down effects in the pelagic food web that could have important consequences both to the health of fisheries that use Florida Bay as a nursery and the magnitude of algal blooms.

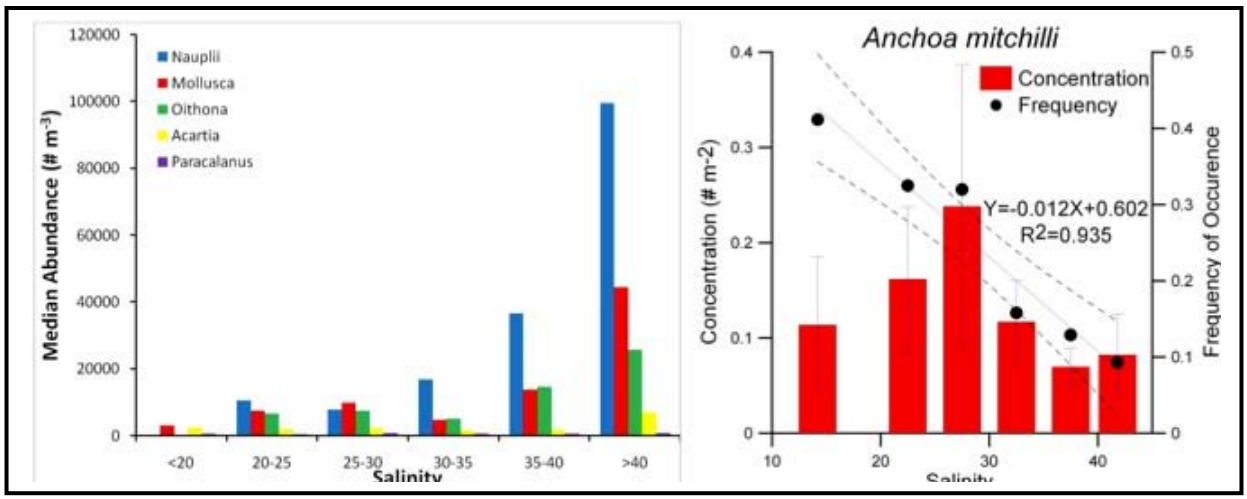


Figure 1: The median abundances of the 5 dominant mesozooplankton taxa binned by salinity (left panel) and the median abundance and frequency of occurrence for *Anchoa mitchilli*, bay anchovy, binned by salinity (right panel).

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 meso-zooplankton 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. This has led us to hypothesize that lowering salinities via restoration is likely to be beneficial in getting more energy 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 results in low meso-zooplankton abundances at low salinities. 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.

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 2009 System Status Report.

Biscayne Bay Alongshore Epifauna Community

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

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** To characterize the epifaunal community of near-shore Biscayne Bay and relate distribution, abundance, and community characteristics to salinity, benthic habitat, and other potential influencing environmental factors.

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

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: DOD through NMFS/SEFSC
NOAA Technical Contact: Joan Browder

Research Summary:

The epifaunal community along the western shoreline of South Biscayne Bay will be the first to change when the Biscayne Bay Coastal Wetland Project of the Comprehensive Everglades Restoration Program is implemented. This monitoring and assessment project (MAP) is developing a dynamic characterization of the epifaunal community and its variation along the shoreline to provide baseline information for evaluating the ecological effects on Biscayne Bay of water management changes associated with the Comprehensive Everglades Restoration Project (CERP) and its two near-bay components, the Biscayne Bay Coastal Wetland Project and the C-111 Spreader Canal Project. Analyses to develop species-based and community-based restoration performance measures and targets are the topic of this report.

Analyses were based on four years of data, each for two seasons, dry (January-February) and wet (July-August). Our sampling sites and sampling dates correspond to the sites of the fish visual survey (Serafy et al. 2009), another MAP project, and our project is designed to interrelate with visual survey results. The data were collected with a 1-m^2 throw-trap; three throw-trap samples were collected at each of 47 (05-06) to 72 (07-08) sites along the shoreline. Various statistical techniques are being used to determine (1) whether species with the same salinity affinities, as suggested by the literature, would have similar geographic distributions; (2) whether the average density-weighted salinity of occurrence of specific faunal species could help determine their preferred salinity habitat (i.e., "halo-habitat"); (3) whether salinity is an important variable for explaining species relative abundance; and (4) whether sites with similar species composition are nearer to each other when the coherence of salinity patterns along the coastline is less disrupted by canal discharges.

The dominant taxa in our samples were caridean shrimp (several species) and rainwater killifish, however several other species made up a substantial component of the fauna, and pink shrimp was well distributed across the sites. Our multiple dimensional scaling (MDS) plots showed pink shrimp,

rainwater killifish, and caridean shrimp (the last as a group not identified to species) consistently (across all years and seasons) formed a central group with one or more other species, including some pre-classified as estuarine (Table 1). Non-estuarine (i.e., marine) species, on the other hand, were scattered near the margins of the plots. The three central taxa may have taken this position in the plots because they best represented the distribution of the estuarine faunal community with respect to habitat needs or affinities.

Table 1: Overview of taxa found in the central areas of the MDS graphs, by collection (listed are taxa that occurred in the central areas of at least one MDS graph; numbers show the total count of that species in a given collection; numbers in bold type indicate species found in the central area of the MDS graph for a given collection).

Species	Dry 2005	Dry 2006	Dry 2007	Dry 2008	Wet 2005	Wet 2006	Wet 2007	Wet 2008
Clown Goby	*71*	*45*	*10*	124	*4*	*45*	10	*18*
Code Goby	159	252	*10*	35	*24*	*252*	10	*47*
Goldspotted Killifish	*19*	*26*	100	154	*66*	26	100	63
Gulf Pipefish```	113	164	14	201	*3*	*164*	14	122
Gulf Toadfish	55	*22*	*36*	*7*	150	22	36	9
Rainwater Killifish	656	1204	1696	1439	1371	1204	1696	1043
Blue crab	57	63	23	71	*8*	*63*	23	18
Blue Crab sp.			*1*	*2*			*1*	*13*
Hermit Crab	159	*91*	*66*	*3*	70	91	*66*	*1*
Caridean Shrimp	3653	3680	2563	1127	640	3680	2563	906
Pink Shrimp	189	291	202	306	101	291	202	153

Figure 1, based on data from sites 1-47 in up to eight collections, 2005-2008, both dry and wet seasons, shows, for each species, the mean and confidence limits of standardized species density-weighted salinity over all collections in which the species occurred. Negative density-weighted salinity values indicate that species abundance was centered at less-than-average salinity of the sites, whereas positive values indicate that species abundance was centered at greater-than-average salinity of the sites. Only species that occurred in at least two collections appear in Figure 1. Faunal-density-weighted salinities may help to screen species for tendencies toward estuarine or marine habitat; however, the confidence limits on most species extend on both sides of the line of neutrality. Furthermore, a few species appear to be miss-assigned according to what else is known about their ecology. More collections may help to reduce the uncertainty and make this approach a useful tool for classifying species according to halo-habitat.

In multiple regression analyses, salinity was an important variable explaining species density in models for both seasons, significant in eight of the nine dry-season species models and six of the 10 wet-season models (Fig. 2). In the dry season, four species (blue crab, caridean shrimp, pink shrimp, and Gulf pipefish) were positively correlated with salinity, and three species (clown goby, rainwater killifish, and goldspotted killifish) were negatively correlated with salinity. In the wet season, four species (blue crab, clown goby, rainwater killifish, and goldspotted killifish) were negatively correlated with salinity, and two species (caridean shrimp and gulf toadfish) were positively correlated with salinity. Salinity was a significant variable, explaining fish species richness in both seasons. Species richness was negatively correlated with salinity in the dry season and positively

correlated with salinity in the wet season. Other variables in the models included water temperature, water depth, seagrass canopy height, other seagrass species, and mangrove predator density.

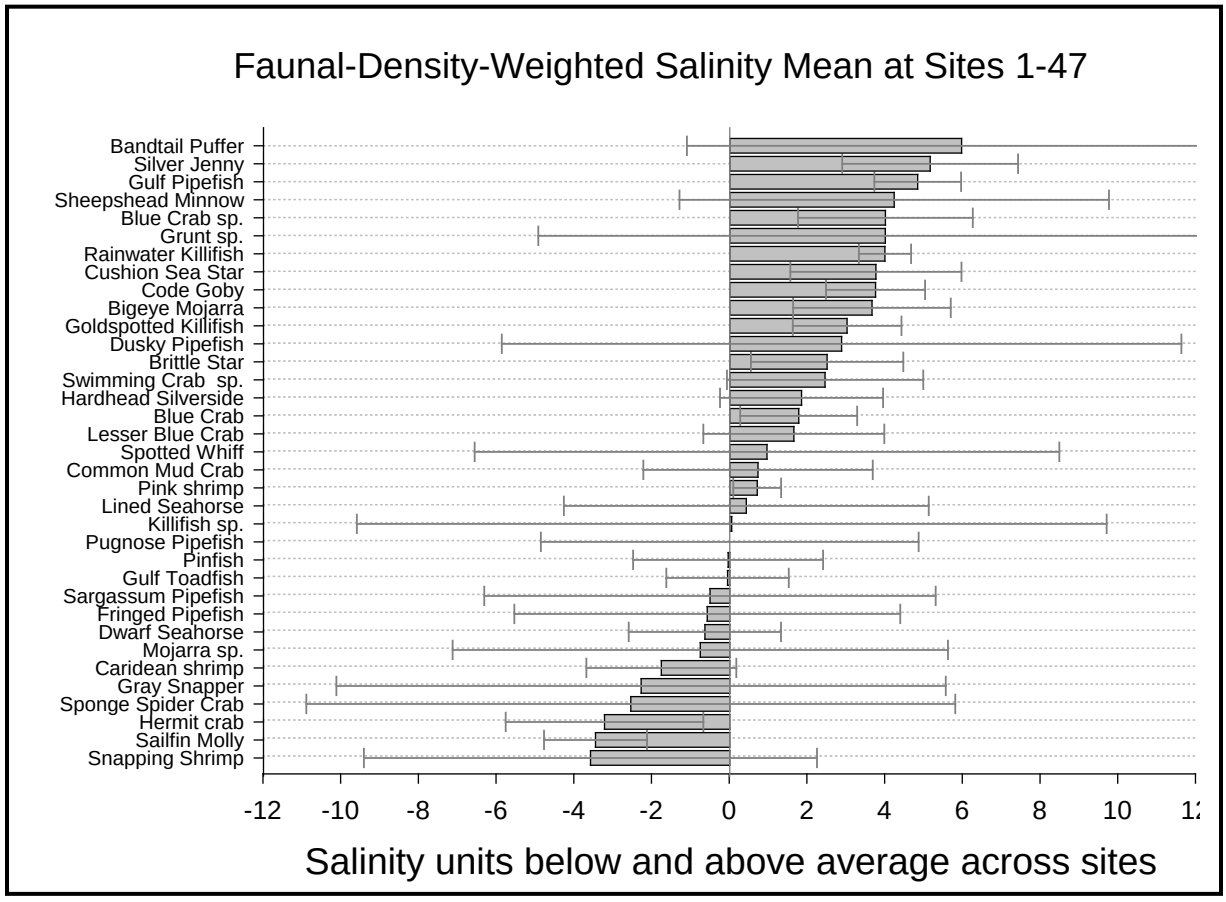


Figure 1: Mean and 95% confidence limits across all collections, wet and dry season, of the standardized faunal density-weighted salinity for each taxa and collection, Sites 1-47, 2005-2008. Standardization was by subtracting, from each density-weighted salinity, the average salinity across sites for that collection. Means and confidence limits are based on two to eight collections.

The degree of similarity of sites that were clustered (Bray-Curtis similarity) on the basis of species composition varied by designated geographic zone, and the sites assigned to each cluster varied by collection. Our working hypothesis was that large discharges of fresh water from canals interrupt salinity patterns along the shoreline, creating disruptions in habitat that affect species composition and cause dissimilar species composition at nearby sites. While we found significant differences ($p<=0.1$) between some collections in our metric, the pair-wise geographic distance between sites clustered by similar species composition (Fig. 3), there was no separation of dry season and wet season, and relationships with salinity and salinity variation, although promising, were not significant ($p>0.1$).

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. The research program is on schedule. Sample collections have been made, and we have made substantive progress in exploring analytical approaches to addressing our objectives.

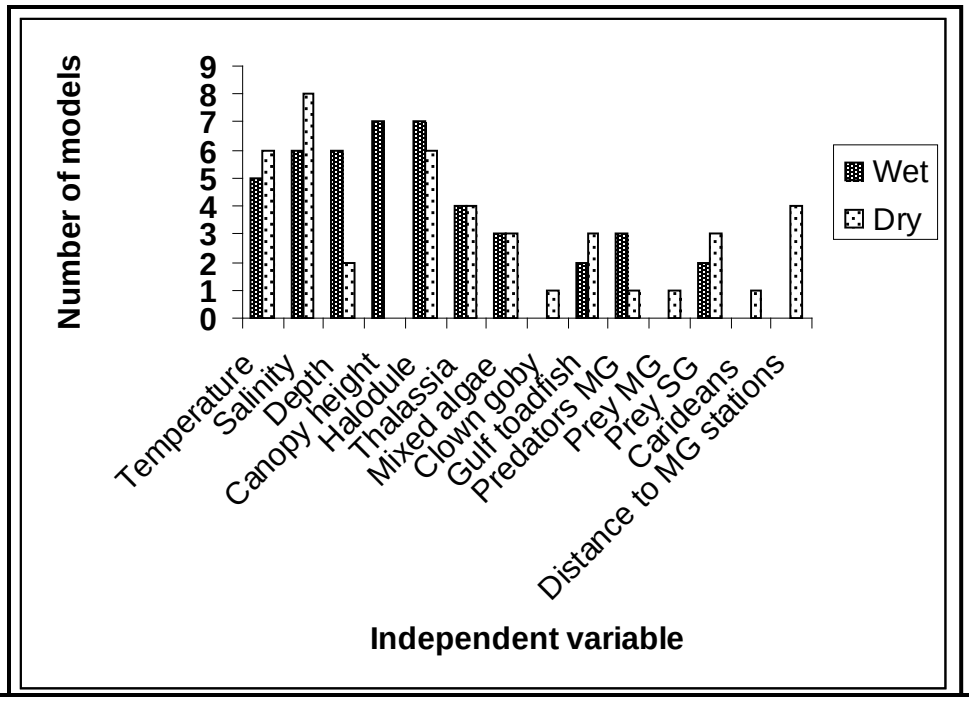


Figure 2: Number of multiple regression models predicting species density in which the indicated independent variable was a significant ($p \leq 0.10$) component, wet season (10 models in total) and dry season (nine models in total). MG=mangrove, SG=seagrass.

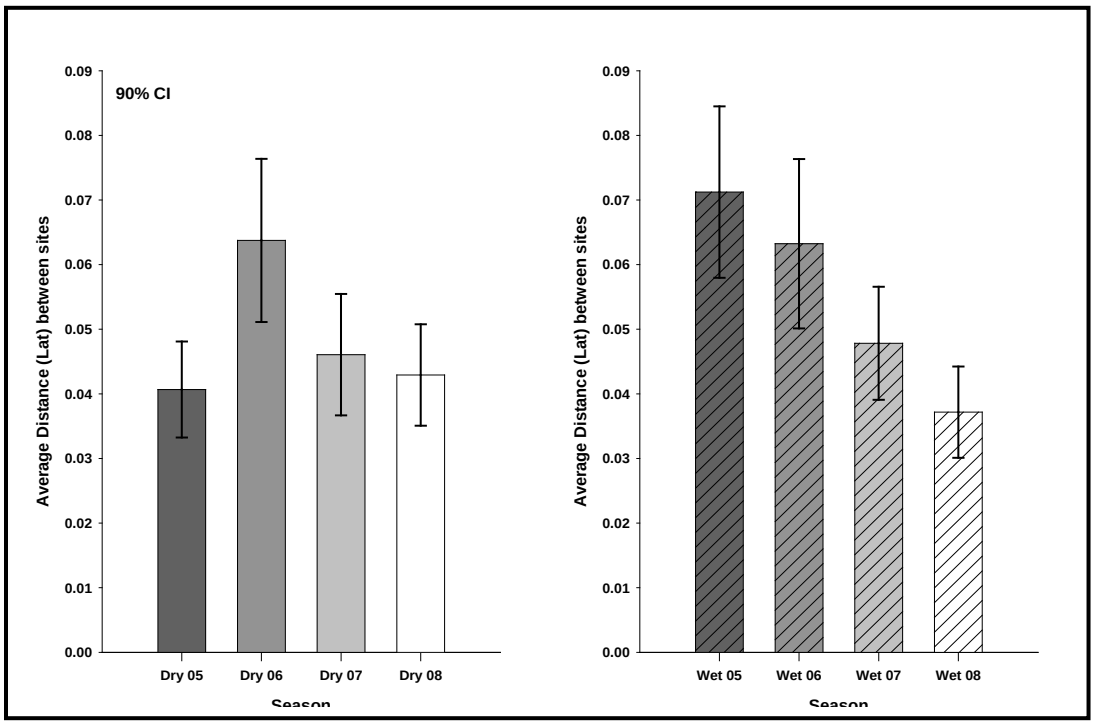


Figure 3: Average within-cluster pair-wise geographic distance between sites and 95% confidence intervals (clusters were based on Bray-Curtis similarity of species composition). Dry-season collections are on the left (plain pattern), and wet season collections are on the right (diagonal striped pattern). Years are coded in shades of gray. Significant differences at $p \leq 0.05$ are indicated by the non - overlap of confidence limits (vertical lines with terminal bars).

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 is focused 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 (Fig. 1). 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.

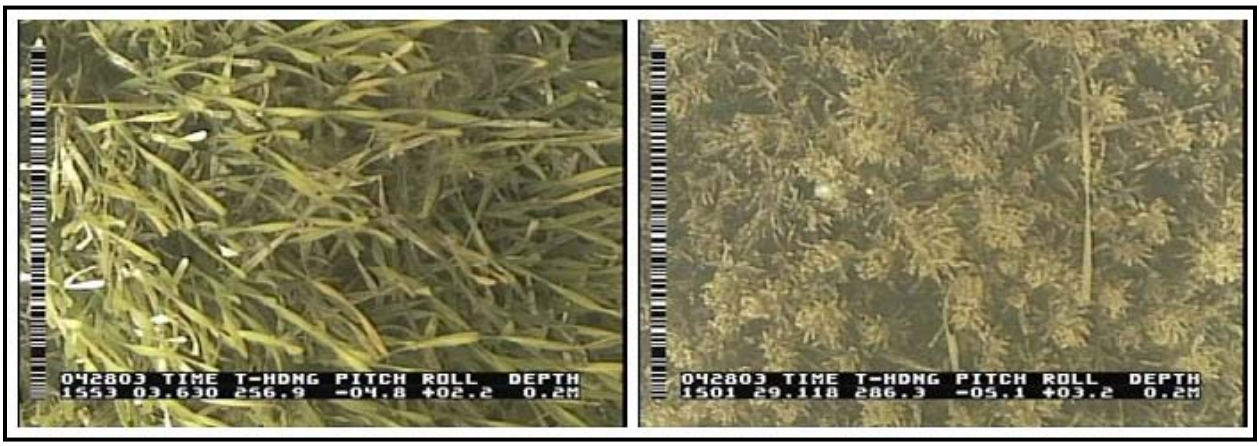


Figure 1: Geo-tagged images of seagrasses and macroalgae from near-shore benthic habitats of western Biscayne Bay.

To date, we have conducted seasonal (wet and dry season) nearshore SAV surveys of > 1500 sites in the region between Matheson Hammock and Manatee Bay. These surveys, initiated in 2003 revealed that two seagrass species, *Halodule wrightii* and *Syringodium filiforme*, showed a stable pattern of benthic cover since 2003, while *Thalassia testudinum* has shown a steady decline, from > 40 % in 2003 to < 20 % in 2008 (Fig. 2). Macroalgal cover remained stable between 2003 and 2008, except for a large increase in the 2005 wet season associated with the bloom of species with a large affinity for freshwater such as *Chara* and *Batophora* (Fig. 2). It is unclear whether the declining trend in *Thalassia* cover is just temporary or a more persistent pattern. But, considering that previous research in Florida Bay suggests that dense *Thalassia* beds may be more susceptible to mortality due to reduced O_2 conditions, it is crucial that monitoring of these habitats be continued over multiple years to tease apart natural variability from CERP impacts.

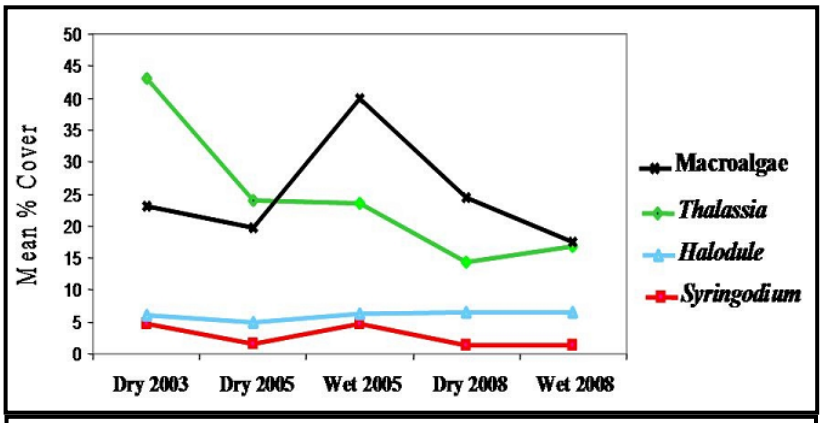


Figure 2: Percent cover of SAV in near-shore habitats of Biscayne Bay from 2003 to 2008.

As expected based on the tolerance of each taxon to salinity, patterns of abundance and spatial distribution are directly influenced by the inflow of freshwater into nearshore Biscayne Bay. All three seagrass species showed significant relationships with mean salinity (logistic regression, $p < 0.05$ for the 3 seagrass species). *Halodule* has a higher probability of occurrence at low mean salinity, while *Thalassia* and *Syringodium* have a higher probability of occurrence at high mean salinity (Fig. 3).

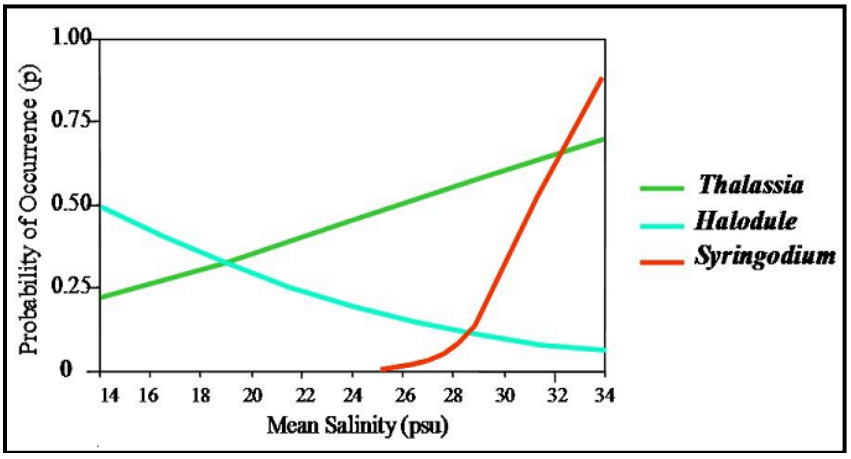


Figure 3: Probability of occurrence of seagrasses in relation to mean salinity during the wet season fitted with logistic regression.

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.

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

A. Morgan and E. Malca (UM/CIMAS);
J. Lamkin and T. Gerard (NOAA/SEFSC); B. Muhling (NOAA/FATE)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** 1) To determine similarities of otolith isotope signatures between four snapper species commonly found in Florida Bay. 2) To determine what percentage of snapper adults utilize Florida Bay as a nursery.

***Strategy*:** 1) 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. 2) 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 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:** John Lamkin

Research Summary:

Species of snapper in Florida Bay are crucial components of the ecosystem and the fishing economy. 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. Carbon isotopes reflect mostly metabolic factors while oxygen isotopes reflect the ambient water conditions including temperature and salinity. Interspecies and temporal analyses were performed on samples taken from seven sites over five years representing 133 km of representative habitat in Florida Bay (see figure 1). Results were inconsistent, with the most promising comparison occurring between schoolmaster and gray snapper found in Northeast Florida Bay. Further research with more comprehensive data is necessary to draw a strong conclusion, but 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 the current 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 (n = 194) *Lutjanus griseus* and *Ocyurus chrysurus* were collected from nine sites along the Florida reef tract in 2004 (see figure 1). 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.

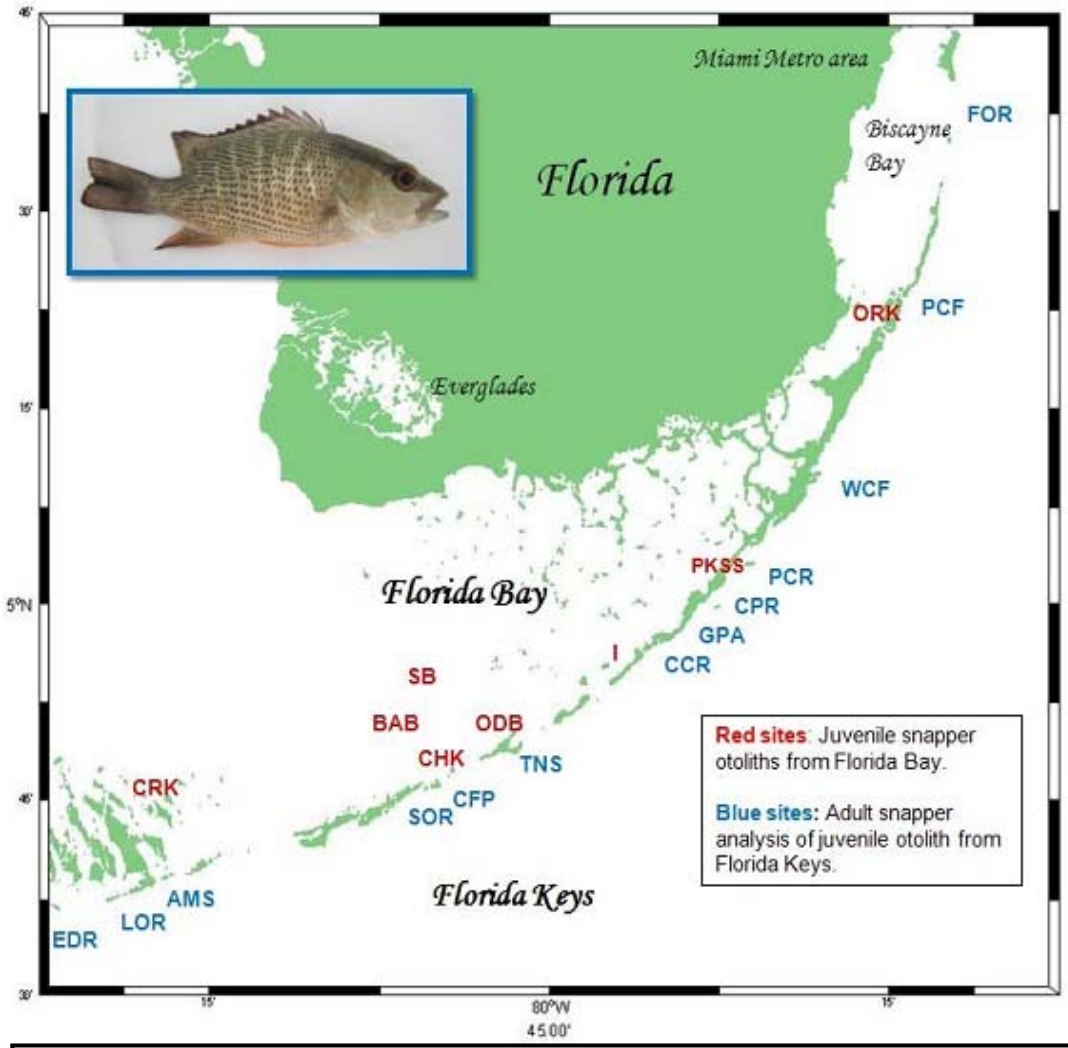


Figure 1: Map shows station locations for juvenile gray snapper study and adult snapper analysis for stable isotope trend comparisons in southern Florida.

Research Performance Measure: The program is meeting its goals on schedule. One of the goals of this study is to determine whether any of these species can be used as a proxy for another in future stable isotope projects in order to alleviate the difficulty of obtaining a substantial sample size. Initial results obtained suggest that stable isotope projects involving snapper in Florida Bay should be species-specific to report any future findings with confidence. Part of this project was submitted and accepted as a Senior Thesis by Anne Morgan to the Biology Department at the University of Miami and was presented orally at the 2008 Florida Bay Science Conference, Naples, FL, December, 2008. Preliminary results of the second component of the study are scheduled to be presented as a talk at the International Otolith Symposium to take place in August 2009.

Acoustic Seabed Classification and Quantification of Reef Fish Habitat

R.P. Reid and A. Gleason (UM/CIMAS); G. T. Kellison (NOAA/SEFSC)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** To assess the utility of a commercial acoustic seabed classification system for mapping coral reef habitats.

***Strategy*:** Test the capability of the Quester Tangent QTCView Series 5 (QTCV) with respect to three questions. First, what physical properties of the seabed dominate the QTCV classification in carbonate reef environments? Second, are the QTCVresults consistent from site to site in deep water, and can they be made to conform to habitat classes defined from optical mapping data in shallow water? Third, are there geomorphological similarities among reef fish spawning aggregation sites in the upper Florida Keys that can be mapped with this system?

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/Coral Reef Conservation Program

NOAA Technical Contact: Todd Kellison

Research Summary:

In 1998 a large (~100 individuals) black grouper (*Mycteroperca bonaci*) aggregation was observed less than 100 m outside the Carysfort Sanctuary Preservation Area within the Florida Keys National Marine Sanctuary. Thus far, efforts to understand why this aggregation occurred in this location have been hampered by the fact that there are no benthic habitat maps of the area, which is too deep to be mapped with conventional optical methods (airphotos/satellite imagery). The main contribution of this project was an assessment of whether the commercial acoustic seabed mapping system Quester Tangent QTCView

Figure 1: Survey vessel and QTCV equipment. Top panel shows the 25-foot research vessel used for data acquisition. Bottom left panel (in purple box) shows the echosounder and data capture screen. Bottom right panel (in yellow box) shows the gunwale-mounted pole used to support the acoustic transducer. Note the system is portable and easily installed, either temporarily, as shown here, or permanently, on virtually any vessel.

Series V (QTCV) could be a useful tool for rapidly mapping areas under consideration for protected status to determine if there are deep habitats that could be protected (Fig. 1).

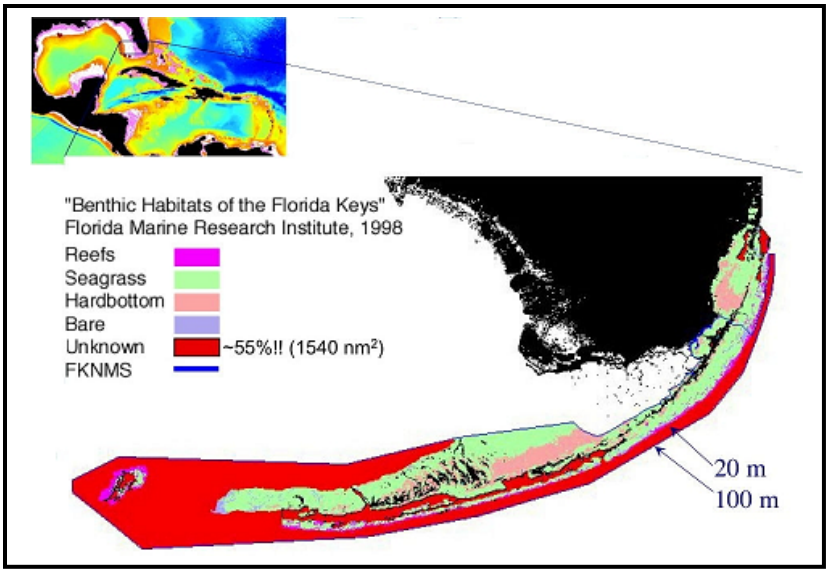


Figure 2: Benthic habitat of the Florida Keys National Marine Sanctuary published by the Florida Marine Research Institute in 1998. Over half of the sanctuary could not be mapped from aerial photographs due to water depth or turbidity constraints thereby highlighting the utility of acoustic mapping technologies for habitat assessment within the Sanctuary.

The benefits to management of a cost-effective acoustic seabed mapping system are clear; over 50% of the FKNMS has not been mapped with sufficient detail to distinguish hard bottom from sediment habitat (Fig. 2). Acoustic technologies must fill this gap, and the QTCV system thus far has proven to be an accurate and cost effective method for doing so (Fig. 3). Accurate and detailed seabed maps benefit other aspects of coral reef ecosystem research/use as well. Understanding how groupers relate to their habitat (this study) is one example, but others include: delineating protected areas, stratifying sampling for coral/fish population surveys, identifying new sites for recreational diving, assisting commercial/recreational fishing, etc.

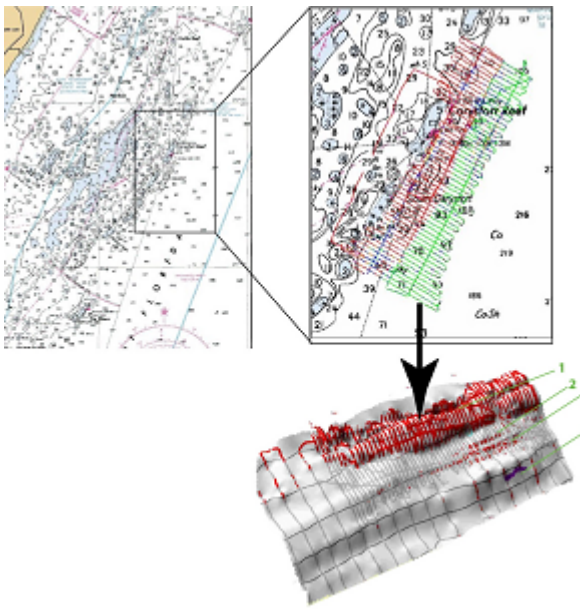


Figure 3: Top left: Portion of NOAA nautical chart 11451 showing the area around Carysfort Reef, FL (soundings in feet). Note lack of bathymetric detail for areas greater than approximately 20 feet deep. Top right: Survey track lines color coded by acoustically-derived substrate: red is hard bottom (reef), 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: The performance metrics for this report period were to complete analysis for the three components of the project (described under research strategy, above) and to begin drafting results for peer-reviewed publication. The details of the entire study are reported in Ph.D. student Art Gleason's dissertation, which was completed in May 2009. One manuscript derived from this dissertation was published in 2006. A second has been reviewed and is being revised for publication. Two additional manuscripts based on Gleason's dissertation are currently being re-formatted for submission.

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

D. Wanless and C. Sinigalliano (UM/CIMAS); K. Goodwin (NOAA/AOML)

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 **NOAA Technical Contact:** Kelly Goodwin

Research Summary:

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

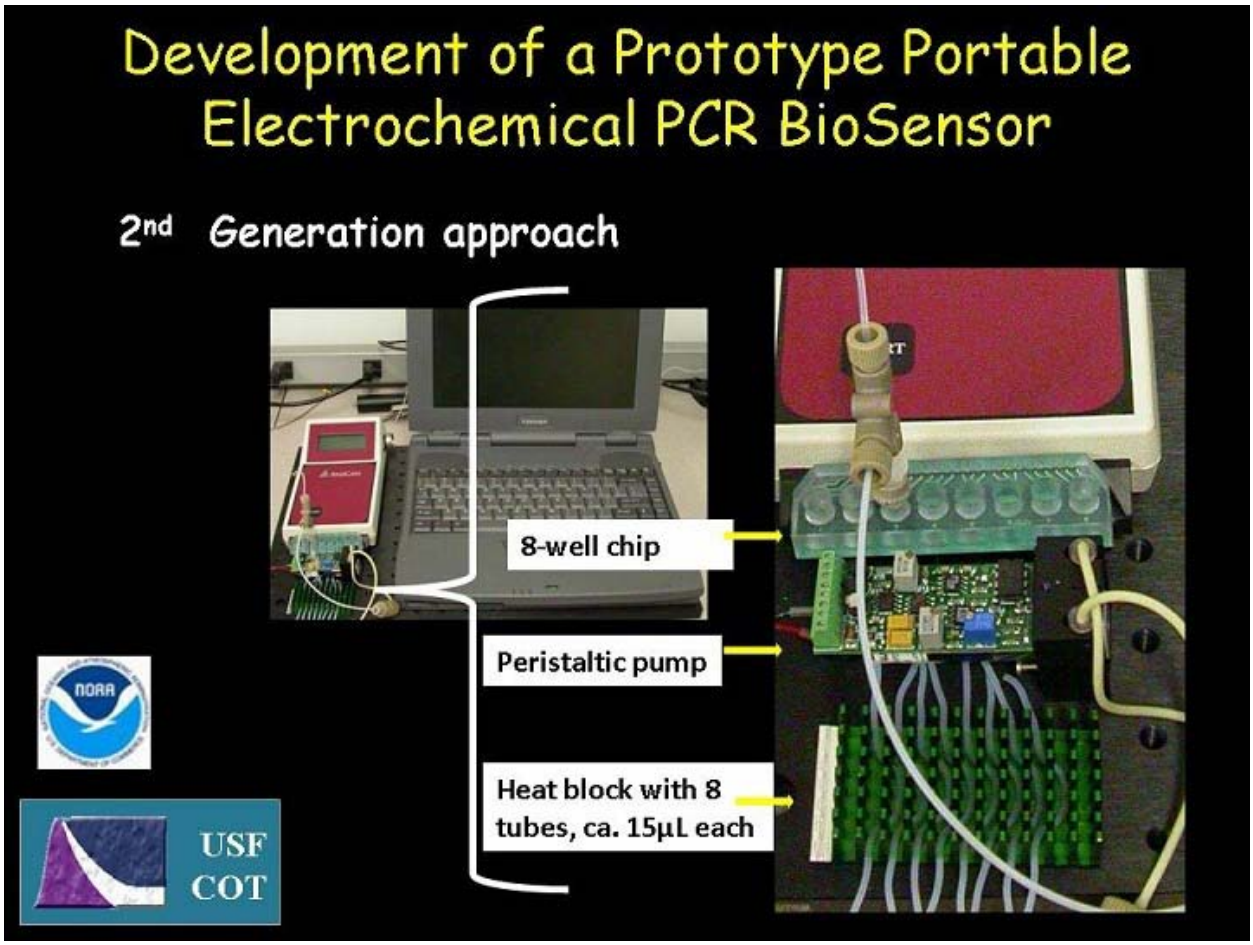


Figure 1: Image of a 2nd generation prototype design for a field-portable electrochemical biosensor utilizing PCR detection of microbial contaminants in environmental samples.

Our research has focused on rapid enumeration of bacterial targets in environmental samples through the use of quantitative PCR (qPCR) and have markedly improved their applicability to field studies (Fig. 1). In collaboration with NOAA/AOML, UM/RSMAS, the UM Oceans and Human Health Center, the Southern California Coastal Water Research Project (SCCWRP), and Florida Atlantic University (FAU), we have successfully employed molecular and traditional microbiological technologies to support epidemiology studies including the CDC BEACHES, Pacific Water Project Avalon, Doheny, and Surfrider studies, and large field programs such as the NOAA Florida Area Coastal Environment Program (FACE), and the EPA STREAMS Virtual Beach Program (Figs. 2 and 3). In addition, we have exchanged protocols and methods with Northern Gulf Institute (NGI) 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).

Figure 2: This project is developing and testing molecular methods to assess the potential impact of canine feces and other domestic animal feces as potential sources of pathogens to recreational waters and beaches.

Figure 3: 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

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.

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/NMFS/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 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 14 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.

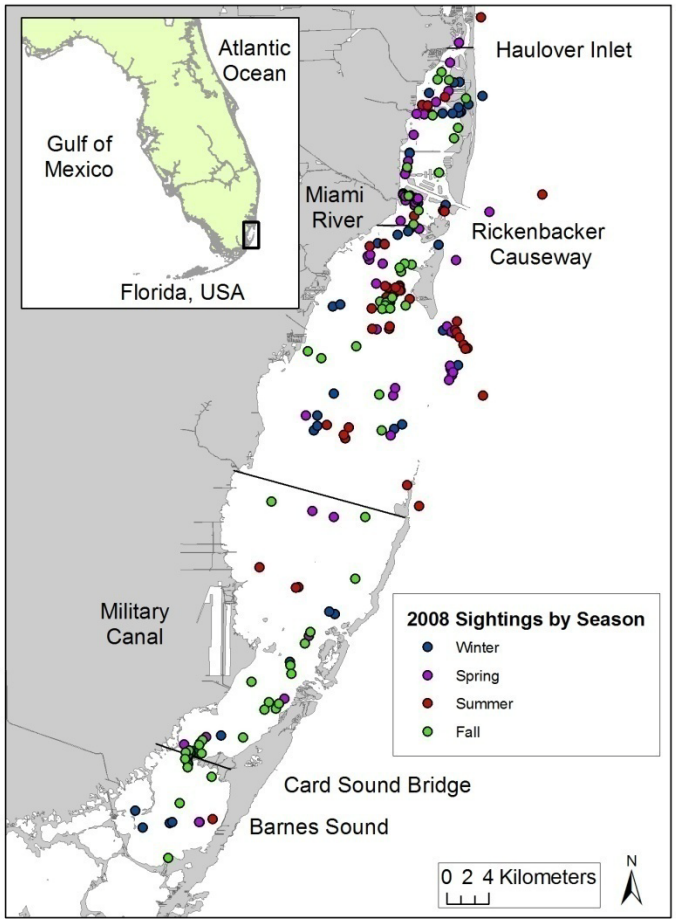


Figure 1: 2008 sightings by season.

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.

Coral Ecological Restoration in the Florida Keys National Marine Sanctuary (F.K.N.M.S)

D.E. Williams, A. Valdivia and L. Johnston (UM/CIMAS); M.W. Miller, (NOAA/SEFSC)

Long Term Research Objectives and Strategy to Achieve Theme:

***Objectives*:** To aid in the restoration and recovery of coral populations in the Florida Keys National Marine Sanctuary (F.K.N.M.S.).

***Strategy*:** (1) 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 attempt to 'seed' larvae/spat onto damaged or depauperate reef areas of the F.K.N.M.S, and (2) undertake experimental evaluation of 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 Ecosystem-based Management.

NOAA Funding Unit: NMFS/SEFSC **NOAA Technical Contact**: Margaret W. Miller

Research Summary:

During the research year (08/09) we continued ongoing research efforts to address recruitment failure by reef-building coral species in the Florida Keys via experiments on how substrate conditioning affects the settlement success of larval reef-building corals. Specifically, experiments were conducted to determine optimal duration and method (lab vs. field) for conditioning artificial substrates to enhance settlement and survivorship of larval corals. Substantially greater settlement-related behavior and settlement success was observed on artificial substrates that were conditioned in the field for ~3 weeks, compared to those conditioned in the field for shorter periods of time or conditioned in the lab (Fig.1)

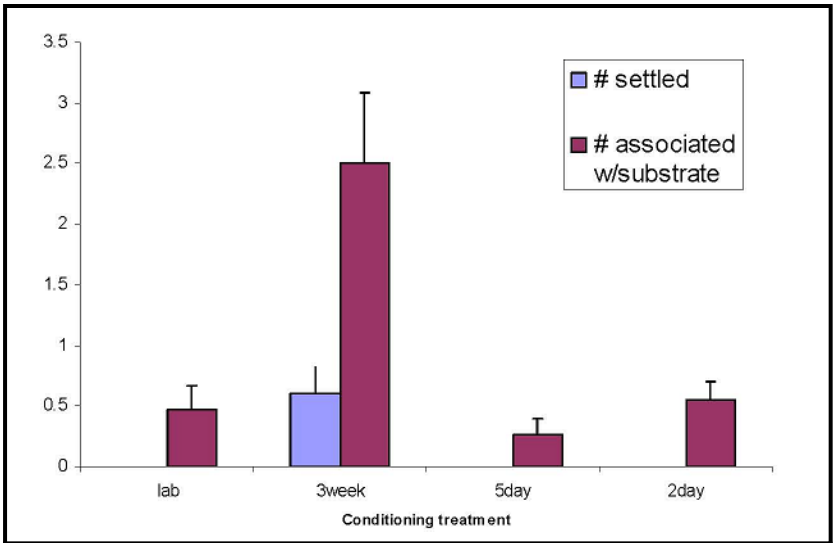


Figure 1: Settlement rates for Acropora palamta larvae on artifical substrates from different conditioning treatments in no-choice assays.

A new, ongoing project component was begun in summer 2008, the Aquarius Coral Restoration/Resilience Experiments (ACRRE), 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. Preliminary results (Fig. 2) indicate substantial variation in survivorship of *A.cervicornis* fragments from different sources.

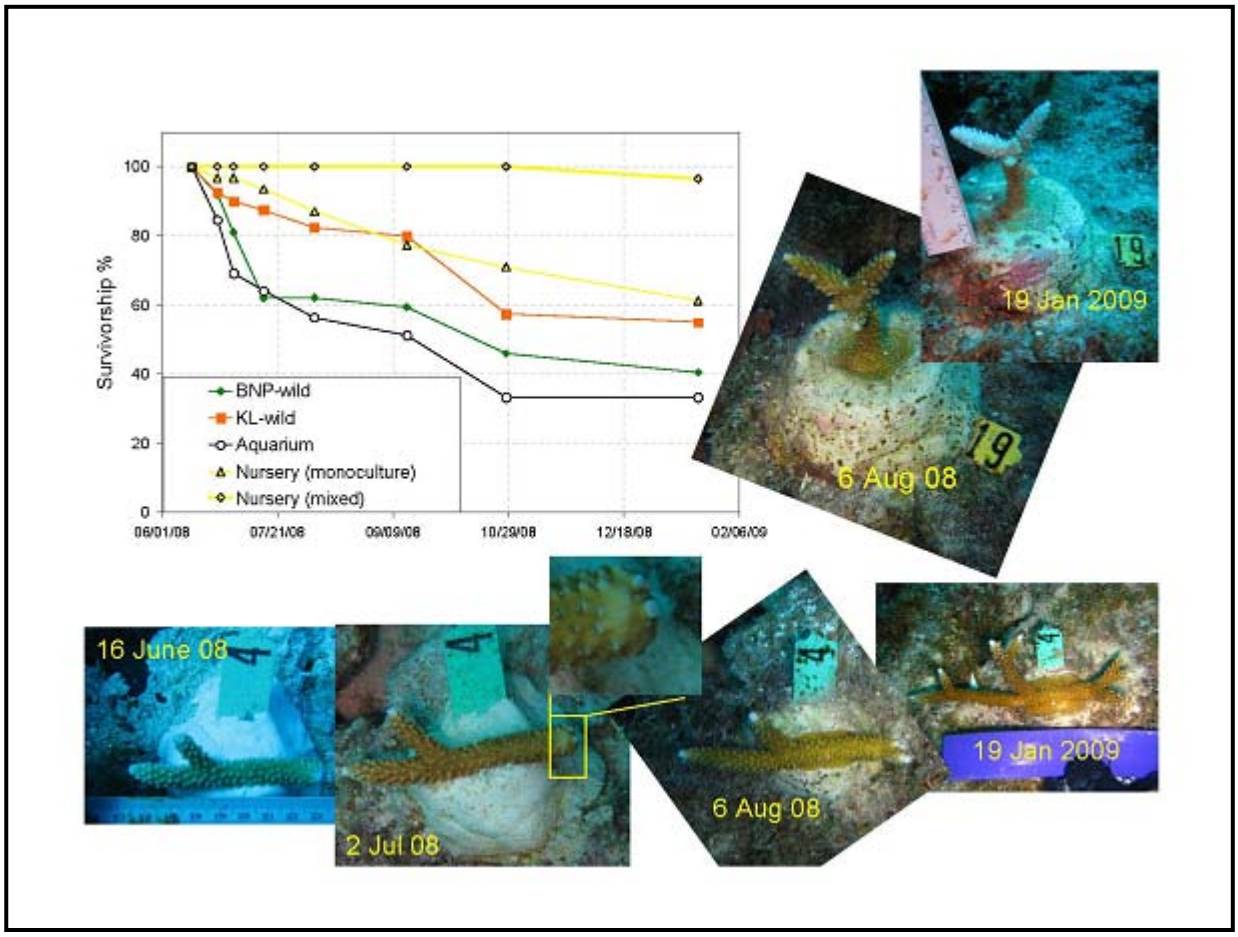


Figure 2: Early survivorship curves for *Acropora cervicornis* transplants from different sources in the ACRRE study. Those cultured from a local field nursery performed somewhat better than those from direct wild collections or from land-based culture. Figure also shows time series photos of representative fragments.

Research Performance Measure: Two manuscripts regarding the research activities in this project reported in review last year are now published or in press. Coral spawning/larval activities were hindered in Aug 2008 by tropical storm activity so few larvae were available for intended experiments. Pilot results for optimizing substrate conditioning were obtained. Morever, a new project component related to evaluating performance of coral transplants in restoration projects has been successfully initiated with ~ 300 coral fragments transplanted and sampled over time.

Assessment of Candidate Corals

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

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** 1) 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'. 2) To document and identify demographic variables (recruitment, mortality etc.) in the Florida Keys *Acropora* spp. population. 3) To compare other populations of Caribbean *Acropora* spp. based on periodic surveys.

***Strategy*:** 1) assess on a quarterly basis the status of individually-tagged colonies of coral at several sites in the upper Florida Keys. 2) Periodically assess other Caribbean *Acropora* spp. Populations for comparison purposes.

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: NMFS/SEFSC **NOAA Technical Contact:** Margaret W. Miller

Research Summary:

Since the 1980s, elkhorn and staghorn corals (*Acropora* spp.*)* have declined by more than 90% on reefs throughout the Caribbean. Because of its fast growth rates and structural complexity, it is ecologically irreplaceable on Caribbean reefs. 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.

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 source of the 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 our other survey areas not affected by the 2005 hurricane season appear to be stable and show evidence of greater inputs from recruitment.

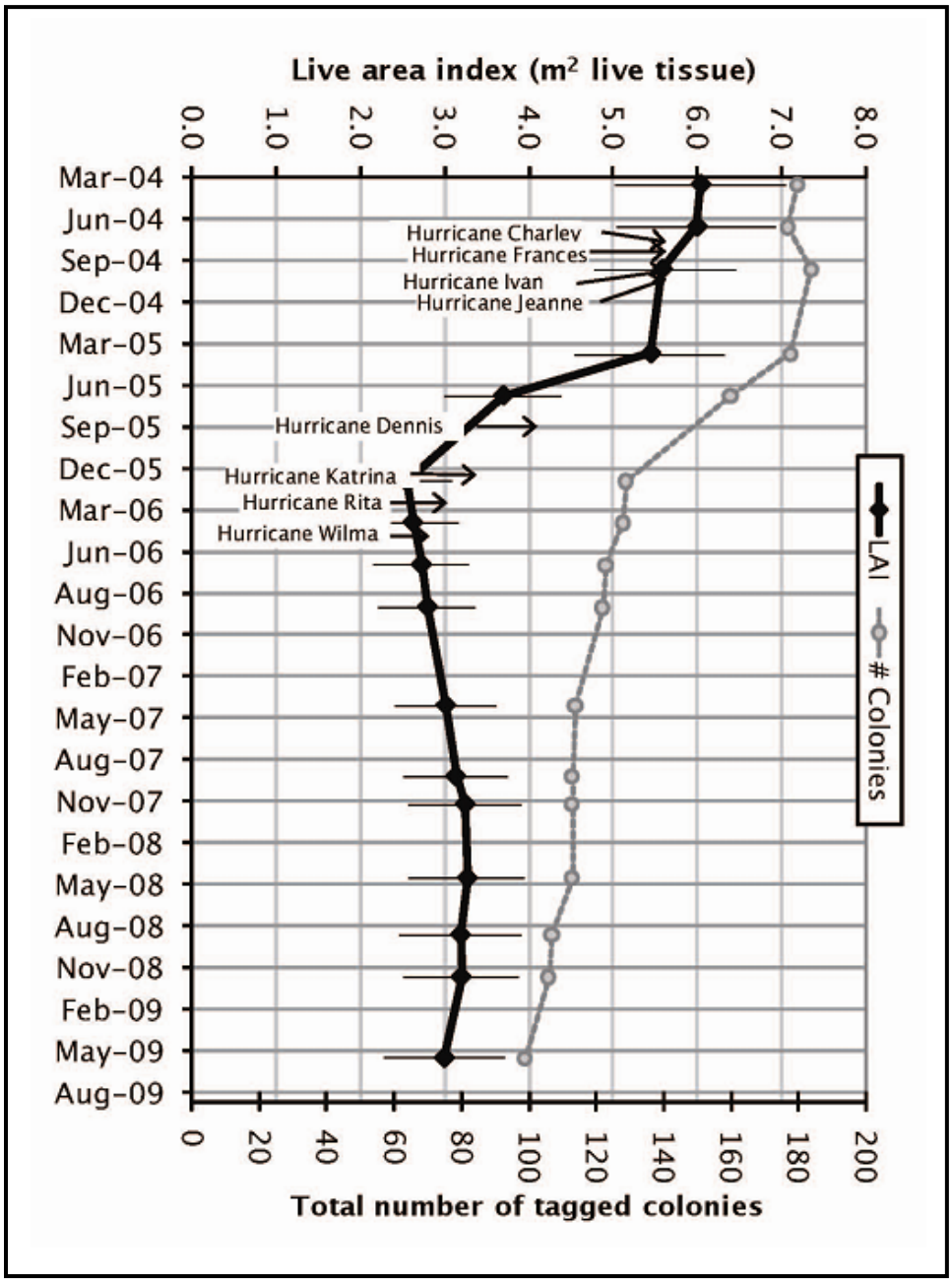


Figure 1: Change in the live *A. palmata* tissue among Florida Keys monitoring plots estimated using a live area index (LAI) for the tagged *A. palmata* colonies summed for each plot, then averaged for all plots (n=15, mean $\pm$ 1 SE). LAI is calculated as the average dimension of a colony squared then multiplied by a visual estimate of the % live tissue cover on the colony. Although the LAI appears to be on a slight increasing trend, the total number of tagged colonies continues to decline due to the effects of disease and predation. The timing of hurricanes are shown by arrows.

Research Performance Measure: All major objectives of this project are ongoing and progress is on schedule. Four surveys of the Florida Keys sites were conducted. New survey sites were established in the Florida Keys in June 2009. Survey sites around Puerto Rico were re-surveyed in October 2008 and April 2009. Annual surveys were conducted at previously established survey sites in Curacao, Navassa, Antigua and St. Vincent.

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); P. Hildebrand (UF/Food & Resource Economics); K.W. Migliaccio (UF/Tropical Research & Education Center); J. O'Brien, D. Zierden, T. LaRow (FSU/COAPS); G. Hoogenboom, D. Stooksbury, J. Paz, C. Roncoli 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, to provide scientifically sound information and decision support tools for agriculture, forestry, and water resources management in the Southeastern USA. As a multi-disciplinary, multi-institutional team, the SECC conducts research and outreach to a broad community of potential users and forms partnerships with extension and education organizations to ensure that SECC products are relevant and reliable. The goal of the Southeastern Climate Consortium is to develop a climate information and decision support system for the Southeastern USA that will contribute to an improved quality of life, increased profitability, decreased economic risks, and more ecologically sustainable management of agriculture, forestry and water resources.

Toward our overarching goal we have established six objectives. As a multi-institutional consortium, different member institutions of the SECC emphasize project objectives that build on the strengths of each institution.

1. To develop downscaled ENSO climate information and forecasts for the Southeastern USA. (Florida State Univ. and Univ. of Florida)
2. To enhance and extend agricultural applications of climate forecasts in the Southeastern USA. (Univ. Miami, Univ. Florida, Univ. Georgia, Univ. Alabama-Huntsville)
3. To develop and refine methods to incorporate climate forecast in water resource management in the Southeastern USA. (Univ. Florida, Florida State Univ., Univ. Georgia, Auburn Univ., and Univ. of Alabama-Huntsville)
4. To develop new and improved methods for integrating models from different disciplines for application of climate forecast information in agricultural and water resource decision making. (Univ. Miami, Univ. Florida)
5. To foster effective use of climate information and predictions in forestry and wildfire management. (Florida State Univ.)
6. To document and assess the utility and impact of climate forecast information provided to stakeholders in agriculture and water resource management. (Univ. Miami, Univ. Georgia)

Objective 1: Develop downscaled ENSO climate information and forecasts for Florida, Georgia, and other Southeast States.

Historically, the Florida State University has been the lead institution in the acquisition and analysis of historical climate data, research on climate variability in the Southeast U.S., dynamic climate modeling, and the production of climate forecast information for incorporation in decision support systems, which target the end user. The climate program works closely with SECC assessment program (Objective 6) to ensure that products, information, and education efforts meet the needs and provide value to the end user. User feedback often provides the impetus for new directions in basic climate research.

Activity 1.1: Dynamical Crop Modeling

To explore the feasibility of using the CFS model output to help determine crop yields in the southeast, a series of experiments were performed using the CFS model data. Because the CFS data is available at 2.5° resolution a statistical downscaling technique was performed in order to obtain the CFS data on the 20km regional grid. For this experiment, only the CFS model precipitation was used.

It was supplemented with the observed surface max/min temperatures and surface solar radiation in order to drive the DSSAT crop model over Tifton, GA. Warm season (March through September) simulations were performed for the 19-year period (1987-2005) to characterized the crop yields.

In addition, we are currently developing a 1-way/2-way crop-atmospheric coupling using the COAPS regional model and the DSSAT crop model over the southeast U.S. with collaboration from the University of Florida. Up to recently, the DSSAT crop models were only applied to specific locations to determine crop yields. The crop model is now being expanded and assigned to each of the 20km downscaled grid points in the southeast U.S. Feedbacks will initially be only one way, that is, the atmosphere forces the crop and the crop doesn't feed back to the atmosphere. In 2009, 2-way full coupling will be available.

Activity 1.2: Statistical Downscaling using the CFS model data

CFS seasonally predicted precipitation at a resolution of 2.5° is statistically downscaled to a fine spatial scale of ~20km over the southeast United States. This study is motivated by the need for regional climate information for crop growing seasons in the southeastern U.S. The downscaling is, therefore, conducted for March through August, when the localized precipitation prediction has been challenging. The present work is part of ongoing downscaling research preceded by Lim et al. (2007), which dealt with surface temperature under the support by NOAA/ARC.

Activity 1.3: Update, expand, and automate climate database operations

Historical weather data is critical to all aspects of this project and provides the basis for all climate information used in the decision support tools, including the wildfire risk forecast. In addition, the historical weather data drives the crop development models whose output is used in peanut, tomato, and potato decision aids. In order to provide the most current information possible, the historical climate data must be updated periodically. The initial data gathering was done in 2003 by manually downloading the data from servers at the National Climatic Data Center (NCDC). We are currently updating the climate data to include all of 2008 and the manual process has proven cumbersome and time consuming, especially when translating the data to the secondary and tertiary levels. The ability to automate and streamline this update process has become apparent and critical to the future of this project. FSU has been working with the Southeast Regional Climate Center personnel to facilitate the daily transmission of NWS automated weather station and cooperative observer observations to FSU for further processing and quality control. An automated update process would not only provide the most current information, but allow us to refine some climate and crop-related products to include near-real time climate events and processes. This is especially important to accumulated climate forecast products where initial conditions are important, such as the chill units, growing degree days, and the Keetch-Byram Drought Index (KBDI) forecast tools available on *AgroClimate.*

Activity 1.4: Modified JMA ENSO index

In previous landmark studies on ENSO variability in the Southeast, COAPS used a sea surface temperature based index developed by the Japanese Meteorological Agency (JMA Index) to classify historic weather observations by ENSO phase. In these studies, the concept of an "ENSO year" was developed where October through the following September would all be designated as one phase, depending on the phase during the northern hemisphere winter season (Sittel, 1994). Until recently, this same approach has been used in most ENSO related climate studies undertaken by the SECC. A

closer examination of individual ENSO events showed some similarities in seasonality (peak SST anomalies in the winter months), but often striking differences in the timing of onset or cessation of warm and cold events. In particular, ENSO phase would often change as early as the spring or summer months. The concept of the "ENSO year" did not fit well with observations and severely limited the ability to identify ENSO related climate impacts at these times of year. In an effort to rectify these problems in the timing of ENSO events and to glean more information on potential climate impacts during the warm or growing season, COAPS modified out approach to ENSO phase classification using the JMA index. In this new approach, called "modified JMA", we keep the criteria that the index must remain above the 0.5 degree threshold for at least 6 consecutive months to classify as an El Niño even (-0.5 for La Niña). However, instead of using the concept of an "ENSO year", phase is classified on a month by month basis with a warm or cold event beginning only when the index reaches the 0.5 degree threshold and ending as soon as the anomalies fall back below 0.5 degrees. (FSU, UGA, UF)

Activity 1.5: Long-term trends and climate change

The first step in preparing for a changing climate is a thorough understanding of the past climate. A careful analysis of historical weather and ocean observations reveals useful information on the average state and variability along with changes on time scales from seasonal, to interannual (1-5 years), decadal, and even long-term trends. As described above, much is known about the year-to-year variations as caused by the ENSO cycle. There are also variations on time scales from 10-50 years, such as the known warm periods around 1950 and 2000 and the cold winters of the 1980s. Warm season precipitation has dropped 10% to 15% in recent decades around central and south Florida, whether caused by land use changes or by circulation changes in the Atlantic Ocean. Many Florida weather stations also exhibit long term trends in temperature and rainfall, whether caused by a changing global climate or by local changes in land use and urbanization.

Further analysis of long-term weather records (80 to over 100 years) from NWS cooperative observers also shows a coherent pattern of multi-decadal cycles in daily maximum and minimum temperatures across the region. This variability is characterized by relatively warm decades in the 1930s and 1950s and cold period from around 1960 through 1990. Superimposed on this region wide signal in the record are influences of land use changes such as the heavy urbanization and draining of wetlands in Southeast Florida and the conversion of the Everglades into agricultural lands south of Lake Okeechobee. Multi-decadal variations are also seen in temperature extremes, with clusters of severe freezes bringing fundamental changes to the citrus industry and other agriculture.

Activity 1.6: Variability of extremes and extreme events

Studies have shown that very limited benefit exists in climate forecasts focused on shifts of temperature or precipitation near the mean or climatological average. The greatest benefit of climate information lies in the forecast of extremes, events near the tails of the historical probability distribution. Further research is needed that addresses the likelihood of such extremes, whether it be torrential rainfall, drought, freezes, or severe weather. The El Nino-Southern Oscillation (ENSO), the North Atlantic Oscillation (NAO), the Pacific Decadal Oscillation (PDO), and the Polar Vortex Oscillation (PVO) produce conditions favorable for monthly extreme temperatures and precipitation. These climate modes produce upper level teleconnection patterns that favor regional droughts,

floods, heat waves, and cold spells, and these extremes impact agriculture, energy, forestry, and transportation. The above sectors prefer the knowledge of the worst (and sometimes the best) case scenarios.

Activity 1.7: Development of numerical tools for the analysis of climatic time series.

Several numerical tools were developed in the last few years to provide a common platform the systematic, reproducible, statistical analysis of hydro-climatic data. These tools consist in a series of libraries of functions (packages) written in Python, a powerful, open-source, platform-independent scripting language. These packages are based on Numpy and Scipy, two libraries for scientific and engineering computing considered the de facto standard for the manipulation of multidimensional arrays in Python. At the core of these tools is a reimplementation of the way series with missing data are handled in Numpy. Our modifications have been officially part of Numpy since version 1.0.5. The current version is 1.2.2 and takes many bugs fixes into account. Another release is planned for early 2009. (1.0.5). A second series of modules has been developed for the manipulation of time-indexed datasets and is also readily available as a specific Scipy package (scikits.timeseries), which can be downloaded at http://pytseries.sourceforge.net/.

Activity 1.8: Lead-time climate and weather data forecasting

Some of our activities focused on using pattern recognition for any possibility of lead time forecasting of realization of daily weather data consisting of precipitation, maximum and minimum temperature and solar radiation. An algorithm for daily weather data series prediction based on the k-NN approach was developed. To test our algorithm of pattern recognition we used 10 different sites across the state of Georgia. This approach was verified across the world for 16 different sites, with at least one site from each continent.

Objective 2: Enhance and extend agricultural applications of climate forecasts in Florida, Georgia, and other SE states.

Activity 2.1: Climate Change

Extension activities related to climate change during 2008 included the development and implementation of a climate change in-service training to Extension faculty during the 2008 IFAS Extension Symposium. The presentations are available online at:
http://pdec.ifas.ufl.edu/symposium/2008/
In addition, a new UF-IFAS focus group area has been created under the Florida Environment main goal area with the objective of coordinating Extension activities related to climate variability and change across the state.

Activity 2.2: AgroClimate enhancement

The main accomplishments related to *Agro*Climate during 2008 were the redesign of the system (Figure 1) and addition/enhancement of several components:

- ENSO phase forecast for the next 3 months is now displayed in the home page
- Inclusion of basic climate change information as related to the Southeast U.S.
- Periodical release of climate and agricultural outlooks

- Addition of monthly climate summaries for the states of Florida, Georgia, and North Carolina
- Translation of most components to Spanish in preparation for the launching of a Spanish version of *Agro*Climate targeting Hispanic growers
- Increased integration with state weather networks in Florida and Georgia to provide in-season updates of cumulative variables such as chill accumulation and growing degree days
- Improved freeze probability maps have been developed and added to *Agro*Climate.

Figure 1: A new AgroClimate layout was developed and implemented in 2008.

Enhanced cooperation with state weather networks resulted into the improvement of the AgroClimate chill accumulation tool to include by-weekly updates of chill accumulation observed at weather stations belonging to the Florida Automated Weather Network (FAWN) and Georgia's Automated Environmental Monitoring Network (AEMN). Observed accumulation is updated by-weekly and seasonal chill accumulation is predicted taking into account current levels of accumulation observed at FAWN or AEMN stations (Figure 2). Chill accumulation is calculated based on the number of hours below 45°F, 32-45°F and also in terms of chill units for several temperate fruits such as peach, blueberry, and strawberry. (C. Fraisse)

Activity 2.3: Transfer of AgroClimate to New Mexico

During 2008 we collaborated with *Climas* in a project that aims to reduce the drought vulnerability of New Mexico's urban agricultural sector through the development of an urban agricultural component for the AgroClimate decision-support tool. The AgroClimate urban landscape drought module provides realistic estimates of urban landscape water budgets and potential water savings under different outdoor water management strategies. A climate needs assessment, administered to New Mexico Extension agents and specialists, revealed a 62% likelihood that urban agriculturists would

use climate information to aid decisions. Furthermore, 76% of the agents believe that information on urban agriculture and home horticulture is highly relevant to their county. In the first part of our project, a pilot study in Las Cruces, New Mexico, we have classified urban landscapes into distinct types, based on quantitative factors such as percentage lawn area and the ratio of softscape (e.g., trees and shrubs) to hardscape (e.g., pavement and patios). We will use climate information to estimate urban landscape water budgets for the different landscape types and estimate landscape performance under changing drought scenarios. These data form the backbone for an AgroClimate map interface that allows users to identify their neighborhood and landscape type. Some custom adjustments can be made for time of year, and other required factors. Drought water budget and landscape performance calculations can be tied to urban drought plans. Our goal is to implement this tool during 2009 in cooperation with *Climas* and the New Mexico Cooperative Extension Service. Key stakeholders include the New Mexico Water Task Force, the New Mexico Drought Task Force, and urban homeowners and horticulturalists. (C. Fraisse, C. Roncoli)

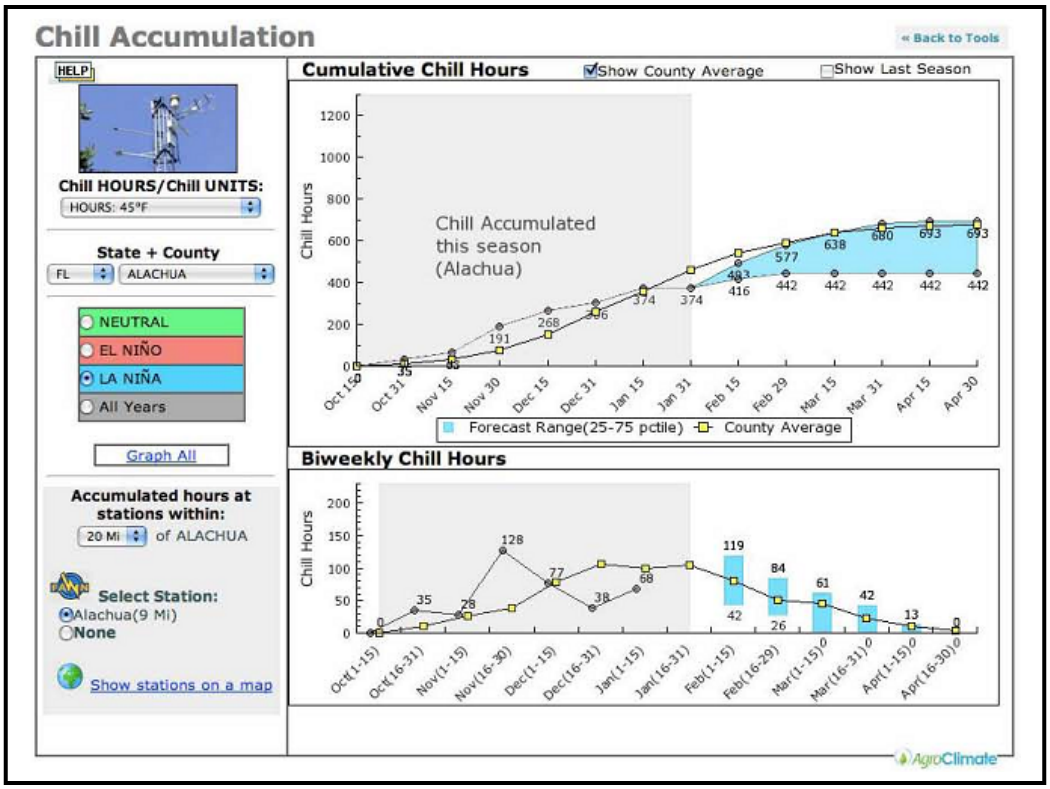


Figure 2: AgroClimate chill accumulation tool showing total and by-weekly accumulation (<45°F) observed at the FAWN Alachua weather station. The graphs also indicate the forecast for the remainder of the season.

Activity 2.4: Economic modeling of climate information use in the context of farm programs (D. Letson and D. Solís)

Can climate information raise farm incomes? To answer this important question, farm risk models must evaluate climate information in a context where farm programs matter. D. Letson and D. Solís have introduced a framework of studying 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. This research is aimed to influence users' decision or government policy making in order to improve economic well being and to reduce risk. A pilot study has been starting in Northwest Florida including selected farm programs. Using this framework to study the value of the climate information, a new framework to strategize crop insurance options has also been developed and is in process of improvement. Most recently we have expanded the research scope to include a wider range of risk management approaches, more farm enterprises, more farm programs, and other locations. Also, the model framework has been adapted to respond new research questions in collaboration with extension agents and other stakeholders.

Activity 2.5: Agricultural Outlooks

Climate and commodity outlooks were developed in close collaboration with different SECC members and University of Georgia (UGA) Research and Extension Faculty. These outlooks were disseminated in various media forms and outlets to stakeholders including county agents and growers. A significant outcome was the increased visibility of the climate extension program as a result of extension specialists and county agents developing their recommendations (e.g. peanut, cotton, turfgrass management) based on the impacts of climate forecasts.

Activity 2.6: Simulated Yield

The CSM-CROPGRO-Maize and CSM-CROPGRO-Cotton models were run for all counties producing both crops in the three states. The counties were selected on those who produced these crops during the period from 1975 to 2006 as reported by USDA-NASS.

Activity 2.7: Pests and Diseases

We examined the effects of El Niño-Southern Oscillation (ENSO) on the prevalence of tomato spotted wilt virus (TSWV) in peanut, and how a weather-based component can be integrated with the current TSWV risk index. The goal was to develop a tool to assist peanut growers in effectively managing spotted wilt disease. Analyses of the five-year TSWV survey dataset (1998, 1999, 2002, 2004 and 2005) showed a varying level of interactions between the ENSO phases and different components of spotted wilt risk index. The results indicate that the severity of spotted wilt in peanut was consistently lower in a La Niña compared to an El Niño or a Neutral year. TSWV severity during a Neutral phase was lower than in an El Niño year, but the differences were not significant. Deviation from the mean severity during different ENSO phases showed a similar trend, with lower than average severity during La Niña years. There were significant interactions between ENSO phases and the individual risk index component. The available data indicate that climate played a significant role in spotted wilt severity of peanut. Climate might indirectly affect spotted wilt severity through varying weather patterns and weather parameters, including temperature and cumulative rainfall. In addition to the risk index component, the average daily air temperature in April, the mean daily minimum air temperature in March and April, the number of rain/wet days in March, total rainfall for April, and the amount of water balance (rainfall minus evapotranspiration) for April, provided significant contributions in predicting the severity of spotted wilt in peanut. A nonlinear regression analysis of the interaction between TSWV risk index point (excluding herbicide and plant population) and wet or rainy days in March showed an additive effect of the two variables on spotted wilt severity.

Objective 3: Develop and refine methods to incorporate climate forecasts in water resource management in Florida, Georgia and surrounding states.

Activity 3.1: Use of seasonal climate forecasts to reduce risk in regional water supply management

The relationship of seasonal sea surface temperatures (SSTs) in the Atlantic and Pacific Oceans with county corn yields in Alabama, Florida, and Georgia was evaluated for the period 1970-2005 using singular value decomposition (SVD) analysis and confirmed using principle component analysis (PCA). Using a Monte Carlo approach, field-significant results were found between SSTs and yields in the July-September (JAS-1) and October-December (OND-1) seasons in the previous year and with the January-March (JFM) season of the current. Based on the results found by SVD analysis and confirmed by PCA, indices of spatially averaged SSTs in regions of the north Pacific and Atlantic Oceans were derived. Using theses indices along with the Niño3.4 index, cross-validated multiple linear regression models were developed to predict the first principal component of corn yield residuals using index values in the JAS-1 and OND-1 seasons. The results of the regression models indicate that the indices of SSTs show significant predictability with corn yield residuals at substantial lead times. Using the cross-validated models 69.6% and 76.0% of county corn yield residuals were statistically significant with seasonal index values in the JAS-1 and OND-1 seasons, respectively. (C. Martinez, J. Jones)

Activity 3.2: Developing and implementing a prototype methodology for incorporating seasonal climate forecasts for use in Tampa Bay Water hydrologic modeling

Tampa Bay Water uses a variety of hydrologic and statistical models as part of their effort at risk-based management of short- and intermediate-term operations and long-term planning. In support of effective water resource management and efficient groundwater/surface water rotation of intermediate-term operations, 1-month to 1-year seasonal forecasts are being developed using historical climate information and regional climate modeling. Using historical climate information, the relationship between hydrologic variables of rainfall, streamflow, and water demand are being investigated by correlation and composite analysis. This exploratory analysis has employed several online climate investigation tools, particularly the interactive plotting and analysis tools of the Earth Systems Research Laboratory, Physical Science Division of NOAA. The goal of these analyses is to identify optimal climate indices for future forecasts of hydrologic variables in the Tampa Bay region. We are carrying out high resolution (3km, 9km and 27km) regional climate modeling experiments using the MM5 model as part of this project. A significant portion of these regional climate simulations are being conducted using the University of Florida High Performance Computing Center. 20-years of daily rainfall and temperature are being simulated for the months of April, September and December. Once complete, the simulations will be statistically downscaled and their forecast skill evaluated in the region. The sensitivity of model results to land use change is also being investigated. (W. Graham, J. Jones, C. Martinez, S. Hwang, S. Risko)

Activity 3.3: Use of intra-seasonal and seasonal forecasts to reduce risk in regional public water supply management

Over the past several months we have begun evaluating 1-14 day “reforecasts” developed by NOAA in short-term hydrologic forecasts of Tampa Bay Water. Currently computer code provided by

NOAA (via the reforecast webpage) is being adapted for use to generate gauge-specific forecasts using both analog and logistic regression techniques. Once adapted, daily and weekly forecasts will be adapted and forecasts showing skill in the region will be blended with climatological forecasts to provide 1-week to 1-month forecasts. (C. Martinez, G. Kiker, W. Graham, J. Jones, D. Boniche)

Activity 3.4: Land use change effects on climate conditions in West-Central Florida

High resolution (3km, 9km and 27km) regional climate modeling experiments are being conducted using the MM5 model. Significant changes in land use coverage in Tampa and the surrounding areas have occurred over the last decade (1995-2006). Our analysis show major transformation from agricultural, rangeland and upland forest categories to urbanization areas which are likely to impact environmental conditions. We are using sensitivity analysis to compare climate conditions from MM5 under default landuse maps and landuse scenarios where agricultural areas are replaced by urban areas and vice versa. The purpose of this work is to study changes in land-air energy exchange and lower atmosphere circulation. (J. Hernandez, G. Baigorria, S. Hwang, J. Jones, W. Graham)

Activity 3.5: Factors Influencing the Incorporation of Climate into Water Resource Management in Florida

Stakeholder driven integrated assessment tools, have been used to link hydro-climate research to water resource management. Though there are a number of case studies where these tools have been tested, the use of integrated assessments in resource management and in policy making is still not understood. This is especially true for hydro-climate research where improvements from large-scale research programs have not translated into changes in water resource management or policy. A contextual understanding of the complex regional factors that influence the integration of climate information into resource management may provide insight into this issue area. This thesis presents an analysis of the complex socio-political factors affecting the incorporation of climate in water resource management in Florida.

Activity 3.6: Identification of Stakeholder Needs

Following the initial survey of water managers undertaken last year, approximately 15 additional stakeholders were identified through contacts with the initial survey respondents. These stakeholders were queried using the previously developed survey to ascertain additional data needs for use by water managers and other stakeholders. Results from these additional surveys did not identify substantial additional data needs from the stakeholder groups. The newly surveyed groups also emphasized the need for training their group members to use available climate data more effectively, particularly in how to interpret longer-term climate predictions.

A follow-up telephone survey was also conducted with a number of last year's stakeholder groups to help refine their stated needs for water data. Several of them, in particular the US Army Corps of Engineers, requested information on longer term climate variability and climate change to allow them to more effectively communicate with their constituent groups on long-term temperature and precipitation variations. They are also studying reallocation of water resources for floods and drought in large reservoirs and need estimates of the effects of climate change on distribution of future water reserves.

Several other groups and individuals who are doing similar surveys of water managers were identified over the course of the year. These include Chris Martinez (University of Florida), Tatiana Borisova (University of Florida) and Nathan Engle (University of Michigan). The survey used last year and this year was circulated to these scientists and discussed. Some alternate wording was evaluated but no final changes were made. It was agreed that we need to continue working together in 2009 to hone the survey further, as well as develop alternate forms specialized for different stakeholder groups.

Activity 3.7: Website development for water managers needs

After the initial content for the web site was determined, a work server was identified at the University of Georgia in the Biological and Agricultural Engineering Department cluster of computers. A template for the home page was developed in cooperation with Brent Ferraro (University of Florida) which parallels the home pages for AgroClimate (agroclimate.org) and the Southeast Climate Consortium (seclimate.org). Additional web pages were developed for the climate outlook and water outlook, including information for precipitation and temperature impacts on water supplies, evaporation potential, and flood and drought outlooks. These pages were prepared in conjunction with AgroClimate.org to make sure that a unified message on El Niño phase was provided to all users. These template web pages were reviewed by Chris Martinez and other members of the Water Resources group and an initial view of the pages was provided for discussion at the annual meeting. The web page is continuing to evolve as additional links and data needs are identified and software problems are resolved.

Activity 3.8: Development of improved Lawn and Garden Moisture Index (LGMI)

Drought can develop on a relatively short time scale in lawn and agricultural systems, so UAH developed a Lawn and Garden Moisture Index based on high-resolution radar derived precipitation data. In order to retain the high spatial resolution and daily updates, we are testing the incorporation of insolation measured NOAA geostationary satellites. We were successfully in tests of scripts to access the GOES data for ingestion into DSSAT crop models and are now ready for a real-time test during the 2009 growing season.

Objective 4: To develop new and improved methods for integrating models from different disciplines for application of climate forecast information in agricultural and water resource decision making.

Activity 4.1: Exploring associations between Water Deficit Index and the yields of different crops

Our hypothesis was that an agricultural drought index can be used to predict yield loss due to drought; so the performance of a drought index can be evaluated based on the accuracy of the index to make yield predictions. The purpose of this study was to test this hypothesis as well as to evaluate a recently developed agricultural drought index, ARID, by comparing actual yields with the index-predicted yields through exploring a relationship between ARID and crop yields.

First, the relationship between crop yields and ARID was derived that accounts for the stage-specific sensitivity of a crop to water stress:

$$\hat{Y} = \overline{Y}_L \left[Y'_P \prod_{i=1}^{n} (1 - ARID)_i^{\lambda_i} \right] \quad [1]$$

Where, $\hat{Y}$ is predicted yield, $\overline{Y}_L$ is location-specific mean yield, Y_P is potential yield, Y'_P is relative potential yield ($Y_P/\overline{Y}_L$), 'i' is a crop stage, 'n' is the number of stages, λ_i is the sensitivity coefficient to water stress during the i'th stage, and $ARID_i$ is the average ARID for the i'th stage. To avoid developing location-specific yield-ARID relationships, Y'_P and $\overline{Y}_L$ terms are used in Eqn. [1].

Then, rainfed maize yields, along with their planting and harvesting dates, and daily weather data for 10 years were collected for three locations in Georgia. The duration of maize season for each year and location was divided equally into 3 stages: initial, middle, and final. Using the weather data, daily values of ARID were computed for each year and location, which later were converted to the stage-level average values. Through regression, values for the coefficients in Eqn. [1] were estimated using the observed yields and average ARID values, thus producing the following relationship for predicting maize yield ($\hat{Y}$) from ARID:

$$\hat{Y} = \overline{Y}_L \left[1.14(1 - ARID)_{initial}^{-0.25} (1 - ARID)_{middle}^{0.31} (1 - ARID)_{final}^{0.18} \right] \quad [2]$$

Finally, using Eqn. [2], maize yields were estimated for the corresponding locations and years and compared with the actual yields. The values of Willmott d-index, RMSE, and percent error were 0.90, 1763, and 19, respectively, which give an impression that not only has ARID the potential to make yield predictions but also an agricultural drought index can be used to predict yield loss due to drought.

Activity 4.2: Support development of regional drought information system for the southeast USA

The US NIDIS program is developing a pilot effort for the southeast US that will help meet the needs for the region. K Ingram and N Breuer served as facilitators during a NIDIS workshop in June 2008. K Ingram also moderated a panel discussion for a NIDIS workshop held in Kansas City, MO. We will continue this support to NIDIS as well as the development of new drought monitoring and drought forecasting tools.

Activity 4.3: Reducing Drought Risks for Small Municipalities in the Southeast USA through Development of Municipal Water Deficit Index

The goal of the project, which is led by Auburn and has cooperators from UF and UGA, is to reduce drought risks for small- to mid-sized communities in the southeast. The specific objectives of the project are:

1. Identify key stakeholders, assess drought-related climate information needs of these communities, identify current and promising new policies for drought mitigation, and elicit data to refine hydrologic and economic modeling;
2. Quantify value of drought information, and evaluate cost-effectiveness of alternative policies for drought risk reduction; and
3. Develop municipal water deficit index (MWDI) and prototype visualization tool for disseminating drought information.

Objective 5: Foster effective use of climate information and predictions in forestry and wildfire management.

Activity 5.1: Enhance the wildfire potential forecast system and extend to other forestry applications. (D. Zierden, G. Watry, FSU)

In response to the wildfire threat forecast assessment, the KBDI forecast tool will be expanded and enhanced for greater utility. A tool will be developed that can display historical, current, or forecasted KBDI values for the Southeast in the same web interface. A KBDI real-time monitoring system will be established that utilizes high-resolution rainfall data such as the NWS stage III radar estimates. The forecast will also be expanded to all 12 months of the year, rather than just the wildfire season.

Objective 6: Document and assess the utility and impact of climate forecast information provided to stakeholders in agriculture and water resource management.

Activity 6.1: Conduct outreach surveys and gather feedback from farmers, extension agents, and other climate information users (N. Breuer, K. Broad)

N. Breuer assesses potential use of seasonal climate forecasts by different groups of potential users. He also undertakes case studies with particular groups of agricultural producers, including resource-limited or marginalized communities. An important step has been to assemble our baseline data on knowledge of climate variability, usefulness of forecasts, and potential adaptations in the states in which we operate. Breuer works with C. Roncoli of the University of Georgia to develop an Internet-based system for eliciting feedback from stakeholders. A survey embedded in the *AgroClimate* website provides real time feedback from end users. Comments and responses are regularly tabulated and analyzed to strengthen the SECC research and development effort. Breuer continues to conduct open-ended, structured, personal interviews with extension agents and farmers with the aim of obtaining useful backwards flow information as a guide to producing more useful products. A learning community is has evolved from these continuous interactions, in which information flows both ways, with a view to constant cross fertilization in a framework of adaptive management, as follow-ups to Sondeos, and in pursuit of new lines of inquiry.

Activity 6.2: Training Workshops

We conducted a session on agricultural applications of climate information during the Annual Extension Winter Conference. We also conducted a workshop on AgroClimate decision support tools for county agents, as part of a program to increase awareness on the use of climate information and climate-based tools available to stakeholders. We were involved in various agent trainings, emphasizing the importance of climate forecasts in farm decisions and risk management. We also released climate and commodity outlooks during the past year.

Activity 6.3: Identification of end-users, understanding decision processes, and the role of climate forecasts

Minority farmers: The southeastern U.S. has experienced severe droughts during the last decade, which have resulted in significant losses in agriculture and restrictions to water use. These droughts have been devastating to farmers, but especially those without irrigation. Many minority farmers

have been unable to invest in irrigation because of a lack of financial resources (including the inability to obtain loans because of racial discrimination). Additionally, they are rarely reached by conventional extension services because of the small-scale, part-time, diversified nature of their operations.

The SECC team has invested time and effort to develop institutional relationships with a Historically Black University (Fort Valley State University) and a civil right organization comprised of farmers' cooperatives (the Federation of Southern Cooperatives). Fort Valley State University has a network of extension agents that work specifically with minority farmers and a range of programs directed to improving the productivity and profitability of their agricultural operations. The Federation is composed of over 100 farmer cooperatives located in the southern US actively engaged in trainings and interventions aimed at preserving the viability of African American rural communities. Several meetings were held with representatives of these groups to discuss minority farmers' needs and capabilities with respect to climate information. In collaboration with these partners, a research design was developed for an assessment of the specific vulnerabilities, risk management strategies and information needs of African American farmers in Georgia.

In addition, the SECC team held exhibits and *Agroclimate* demonstrations at events targeted at minority farmers, including the Federation of Southern Cooperatives' Regional Meeting in Albany, Georgia on February 8-9, 2008 and Annual Meeting in Epes, Alabama on August 14-16, 2008. These interactions offered opportunities to elicit information on potential uses of climate information and tools such as those offered thru *Agroclimate* and users' feedback on what content, format, and language best fits the needs and capabilities of minority farmers.

Organic producers: Although it is comparatively small in acreage, organic production is the fastest growing agricultural sector in Georgia. Organic farmers include highly educated and computer literate individuals, some of whom are new to farming. Therefore, they represent a population who is well-positioned and highly motivated to use climate-based decision support tools, such as *Agroclimate*.

The SECC assessment team participated in several interactions with this community at key events, including an exhibit at the Georgia Organics' Annual Conference in Dalton, Georgia (February 28-March 2, 2008). There were over 600 people in attendance, a 30% increase over the previous year, and up to 1,000 participants are expected for the 2009 Annual Conference, which features prominent author Michael Pollen as keynote speaker. Drs. Roncoli and Furman were asked by Georgia Organics to help them organize a workshop on climate risk management and decision support tools to be included in the 2009 Annual Conference program. The session includes a diverse panel of experts from agriculture, climate, and social sciences, including SECC researchers.

As a parallel activity, Dr. Furman has started reviewing and analyzing organic and sustainable agriculture blogs to better understand how organic farmers perceive and discuss issues related to climate change adaptation and mitigation. The findings will help the SECC team to formulate messages that are consistent with users' cognitive and linguistic framing of climate risk.

Activity 6.4: Evaluating AgroClimate tools for their potential and actual uses and impact

Data analysis and write-up of farmer interviews in South Georgia: Between January to March 2007, Drs. Roncoli and Crane conducted semi-structured interviews with 38 farmers in 20 counties,

representing a broad cross-section of production systems found in Georgia. The objective of these interviews was to examine farmers' decision-making processes, to identify how climate variability factors into them, and to identify which decisions were or may be influenced by forecasts. The research also elicited farmers' views on what climate parameters are most useful and what communication modes are most effective to reach them. Interviews were fully transcribed and entered into qualitative data analysis software (NVIVO). In 2008 the team focused on data analysis and writing up. The outcome is an article submitted to the AMS journal Weather, Climate, and Society, as well as numerous poster and oral presentations.

Activity 6.5: Assessing the accessibility, relevance, utility of AgroClimate tools from end-users' point of view

Media representations of ENSO: In 2008, a study was conducted of newspaper articles on El Niño and/or La Niña impacts in the Southeast U.S. The study aimed to understand how ENSO and ENSO-based forecasts are represented in media available to agricultural producers and natural resource managers. The study is based on analysis of 78 articles, including 14 articles from the Southeast Farm Press (a regional newspaper directed to agricultural producers; 25 articles from urban newspapers (the Atlanta Journal & Constitution and the Augusta Chronicle); and 39 articles from small town newspapers in Georgia published between 2005 and 2008 (period of active SECC outreach). The articles were entered in software for analysis of qualitative data (NVIVO) and quantitative data (EXCEL) by 1 coder and 3 verifiers, and were analyzed for 74 parameters relative to the nature and effects of ENSO, seasonal climate forecasts, sources of authoritative knowledge, public and private responses, references to climate change, etc. The analysis shows that: (1) Newspaper readers in Georgia are routinely exposed to some information about ENSO, but the scientific knowledge is not always represented clearly, correctly, or completely; and (2) the SECC is often cited as an authoritative source, but its ENSO-based climate forecasts are not conveyed in ways that support integration into management decisions. The findings were subject of poster presentation and are being written up in an article to be submitted to a scientific journal.

KBDI assessment: In May 2008, Drs. Roncoli and Breuer carried out 12 phone interviews to follow up the assessment of the KBDI wildfire threat forecast assessment originally conducted in May-June 2006. These interviews identified additional potential barriers to the incorporation of such tool into forest and fire management decisions, including

- Technical factors: The KBDI index tends to "break down" during the dry season, when a light rain can reduce the index by moistening the top layer of duff and soil, inducing fire managers to lower their guard.
- Communication factors: Fire managers are unfamiliar with *Agroclimate* and prefer using "one-stop shop" portals for climate information, such as those of the Georgia Forestry Commission and Florida Division of Forestry (but these portals do not link to the SECC forecast).
- Institutional factors: Regionally specific conditions of fire management in GA and FL have shaped unique institutional cultures (Georgia has a more decentralized system, with greater emphasis on human judgment and field experience; Florida has a more centralized system, which relies mostly on advanced technology): this affects the ability of fire managers to additional tools into their decisions. Private operators may be more inclined than public sector managers to integrate different information sources and long-range planning into management decisions.

Climate Change Fact Sheet: The assessment team contributed to writing and design of "*Climate Change Basics for the Southeast U.S.*", a fact sheet summarizing the state-of-the-art of the science

concerning climate change impacts in the region, for distribution to agricultural extension agents and other stakeholders, in response to their requests.

Activity 6.6: Assessing stakeholders interests and needs for climate change information

While there is much information available about global climate change, there is far less information available on the probably local impacts of climate change. Rational adaptation strategies require local or regional information. Moreover, the stakeholders for climate change information appear to come from many more sectors than the agricultural and water resource managers that the SECC has targeted to date. In this activity, we will focus on the needs for climate information and tools for local governments, business, such as environmental engineering firms, as well as agricultural stakeholders.

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

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

C. Sinigalliano, M. Gidley, D. Wanless, M. Lara, M, Gonzalez, K. Herleman, J. Jans, J. Bartkowiak, F. Tonioli (UM/CIMAS); S. Tomoyuki (UM/MBF)

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.)

***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: Not Applicable (funded by EPA directly through ERD contract)
NOAA Technical Contact: Kelly Goodwin (as AOML Oceans & Human Health Lead)

Research Summary:

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.

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 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.

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 meteorological measurements at recreational 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.

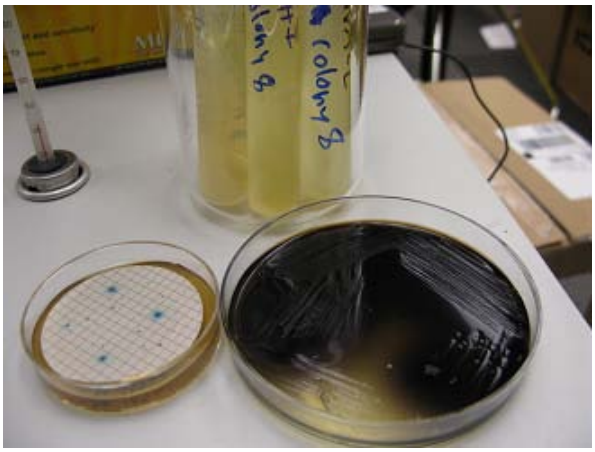


Figure 3: Membrane filtration plate count and confimative culture-based tests indicating the presence of enterococci fecal indicator bacteria.

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.

Research Performance Measure: We have accomplished all of our primary 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

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.

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

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

Long Term Research Objectives and Strategy to Achieve Them:

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

***Strategy*:** Take 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, and thereby better utilize high-resolution observations (dropsonde, radar, flight level, surface wind speed, etc.) collected during the Hurricane Field Program run by NOAA/AOML/HRD

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 is under construction to assimilate high-resolution, vortex-scale observations that are routinely collected during NOAA/AOML/HRD's Hurricane Field Program and transmitted real-time. Various observation types that will be assimilated include dropsonde wind, temperature, and humidity, Doppler radar radial winds and reflectivity, flight-level temperature and humidity, and stepped-frequency microwave radiometer (SFMR) surface wind speed measurements. 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.

Currently, the data assimilation system is being developed within the framework of AOML/HRD's experimental Hurricane Weather Research and Forecast (HWRF-x) model with the ultimate goal of porting it to NOAA's operational HWRF^{TM}. While the forecast model is planned to run on a nested domain with 9/3/1 km resolutions, data assimilation is planned to be performed on the 3-km nest. Initial ensemble perturbations are obtained from NCEP's Global Forecast System (GFS) ensemble.

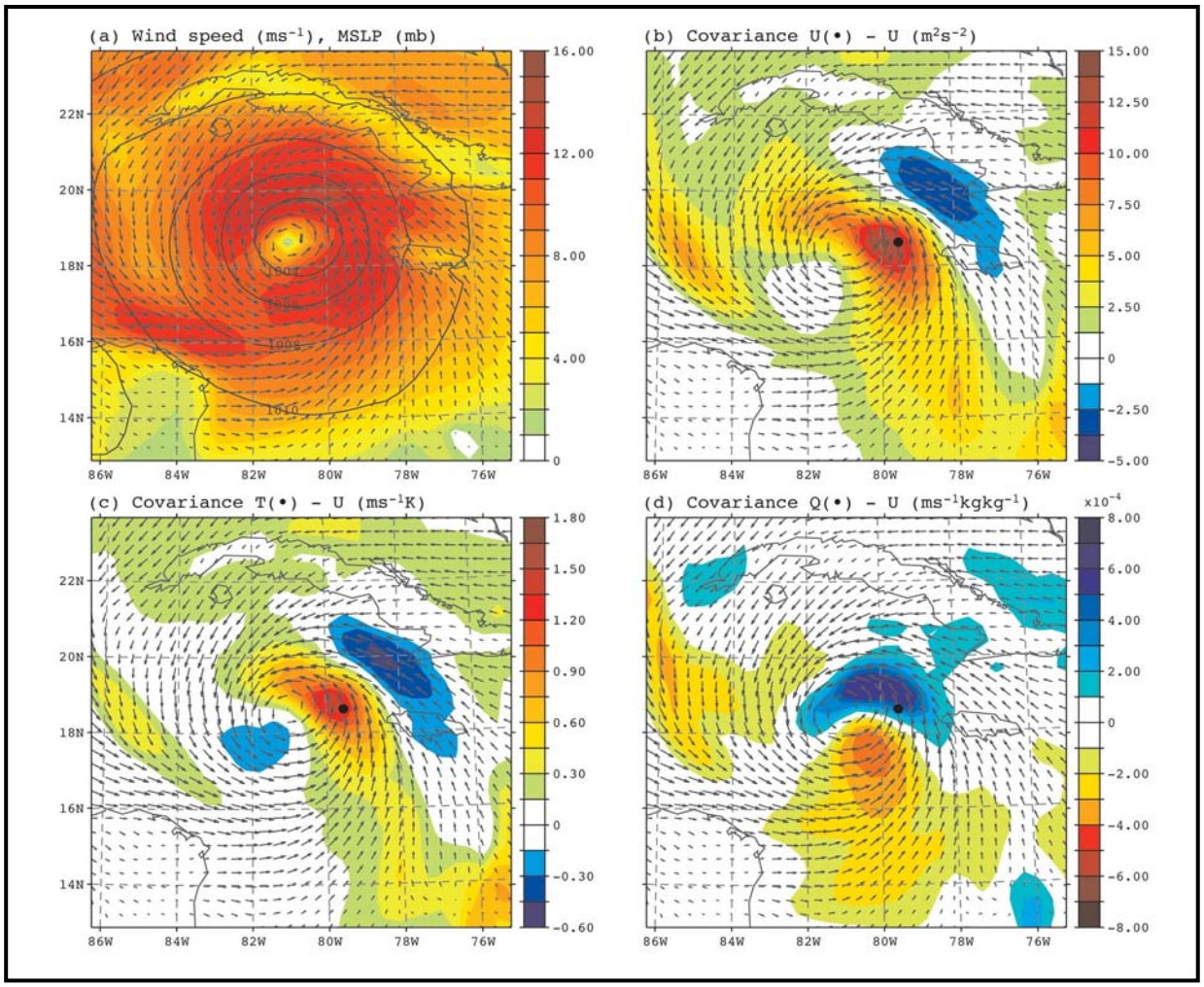


Figure 1: 12-hour forecast for Hurricane Paloma, valid at 12Z 8 November 2008. (a) Ensemble mean 10-m wind speed (ms^{-1}, shaded), mean sea-level pressure (MSLP, mb, contoured), and 10-m horizontal winds (vectors). Covariances at the lowest model level between (b) zonal wind (U) at location shown with "●" and U in the rest of the domain (m^{-2}s^{-2}), (c) temperature (T) at location shown with "●" and U in the rest of the domain (m^{-1}s^{-1}K), and (d) water vapor mixing ratio (Q) at location shown with "●" and U in the rest of the domain (m^{-1}s^{-1}kgkg^{-1}).

The potential impacts of ensemble-based data assimilation are briefly illustrated in Figure 1 through the distribution of covariances among various model variables. The case of interest is Hurricane Paloma of 2008 and shown fields are computed from 12-hour, 30-member ensemble forecasts initialized at 00Z of 8 November 2008 from GFS ensemble analysis perturbations. All runs are generated on a domain with 27-km horizontal resolution. The observed storm, as of 12Z 8 August 2008, had a minimum pressure of 943 mb. As can be seen in Figure 1a, the representation of the storm in the ensemble mean is very weak (minimum central pressure is ~1001 mb and maximum 10-m wind is ~15 ms^{-1}). This is mainly due to a combination of the low-resolution initial vortex in the GFS ensemble analysis and the low-resolution nature of the ensemble forecast itself. Nevertheless, Figs 1b-d show that, even at this low resolution, the covariances between zonal wind (u), temperature (T), and specific humidity (Q) at the specific location (east of the eye near radius of maximum winds, shown with black circles) at the lowest model level and zonal wind within the rest of the domain at the lowest model level contain flow-dependent structure, mostly localized within and around the mean vortex. Such flow-dependent structure will be key to the successful implementation of the EnKF to initialize a vortex using information contained in high-resolution observations collected within the vortex, just like the hypothetical observation location shown in Figures 1b-d.

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

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 round 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 was compared with the surface fluxes and meteorology (Fig. 1). The derived cloud fraction compares poorly with the ISCCP derived low cloud cover but compares well and shows high correlation (0.86) with ISCCP low plus middle cloud cover. The monthly averaged diurnal variations in cloud cover show a marked variability in the amplitude and the temporal structure of the day-to-night cycle (Fig. 2) from different seasons. These diurnal variations in cloudiness differ from those obtained from coarser temporal resolution satellite retrievals and show much sharper day-night transitions than have been observed previously. Annual and diurnal cycles of surface longwave and shortwave cloud radiative forcing were estimated. A manuscript describing these results is in press (*J. Climate)*.

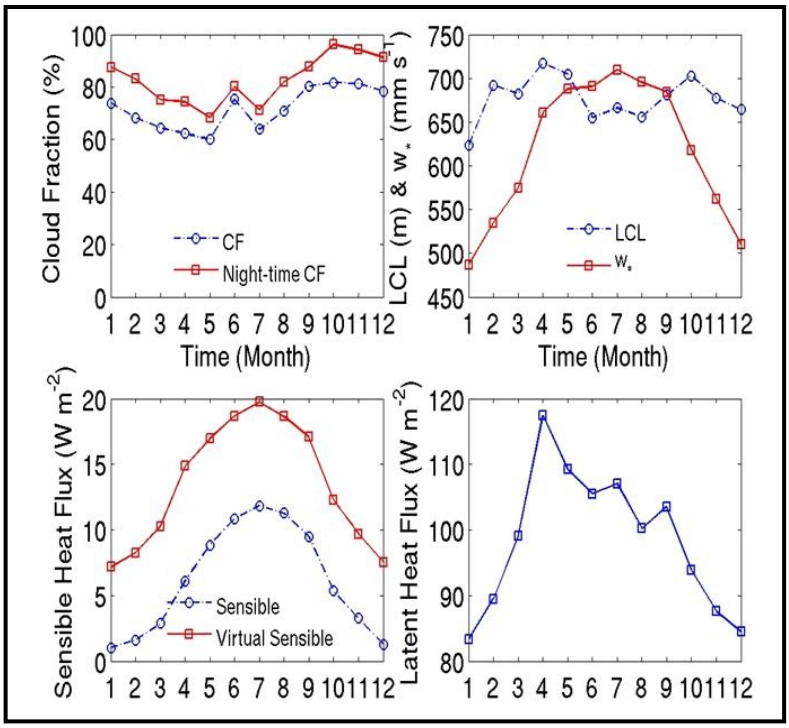


Figure 1: Average seasonal variation of the cloud, surface flux, and derived parameters observed at WORS (2001-2005); a) fractional cloudiness derived from surface radiation measurements for all day and night-time values, b) LCL calculated from buoy T and q and surface-forced convective velocity w* from surface fluxes and LCL; c) sensible and virtual sensible heat fluxes; and d) latent heat fluxes.

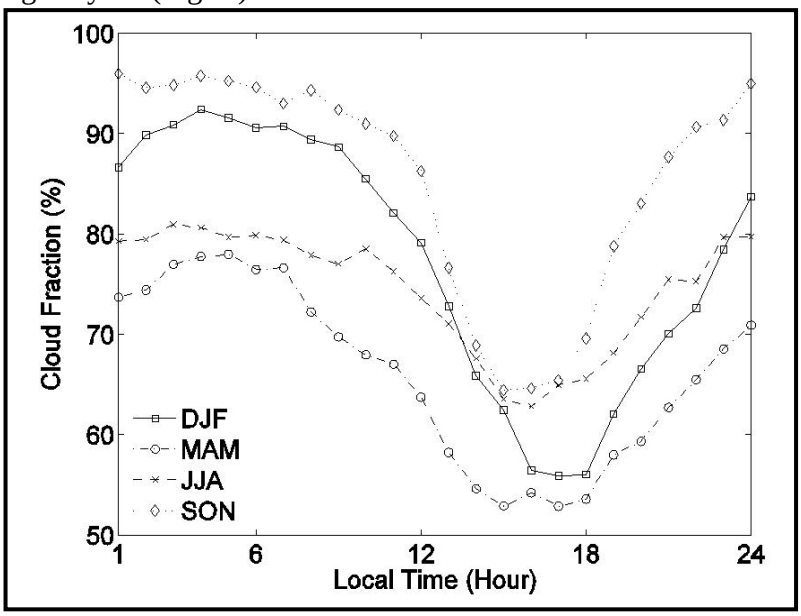


Figure 2: Diurnal cycle of cloud fraction at the Stratus ORS for different seasons averaged for the 2001-2005 period.

In support of NOAA's component of VOCALS-REx, the University of Miami W-Band and X-Band radars were prepared, deployed, and operated on the R/V Ron Brown on the Oct-Nov. 2008 cruise. UM graduate student Xue

Zheng was on leg 2 of the cruise who assisted with the operation of the radars and other data collection activities on the cruise. A graduate student from North Carolina State University, Matthew Miller, was supported under this grant for participation in Leg 1 of the cruise. The graduate student participation on the cruise during VOCALS contributed to the broader impact goal of this grant to support student involvement in making the ship borne observations and operating state-of-the-art remote sensing systems.

Following the cruise we have been working in collaboration with Chris Fairall and other VOCALS collaborators to synthesize the initial data sets obtained on the cruise and perform initial analyses. This initial work focus has been on putting the remote sensing and *in situ* observations observation from the ship into perspective with observations made from the previous cruises in this region and the climatology obtained from WORS. Additional efforts were made in developing techniques for characterizing turbulence and drizzle characteristics from the NOAA Doppler cloud radar observations made on the VOCALS cruise.

Research Performance Measure: The research completed during this first year of the grant was consistent with the expectations outlined in the proposal. The next year will focus on the observations that were obtained during VOCALS.

Public Hurricane Loss Projection Model

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

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** To make probabilistic assessments of the risk to insured residential and commercial properties associated of wind damage from hurricanes and tropical storms.

***Strategy*:** Develop a wind field model that will provide wind risk information to engineering and actuarial concerns.

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: Through an FIU subcontract **NOAA Technical Contact:** M. Powell

Research Summary:

We collaborated upon the development of 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.

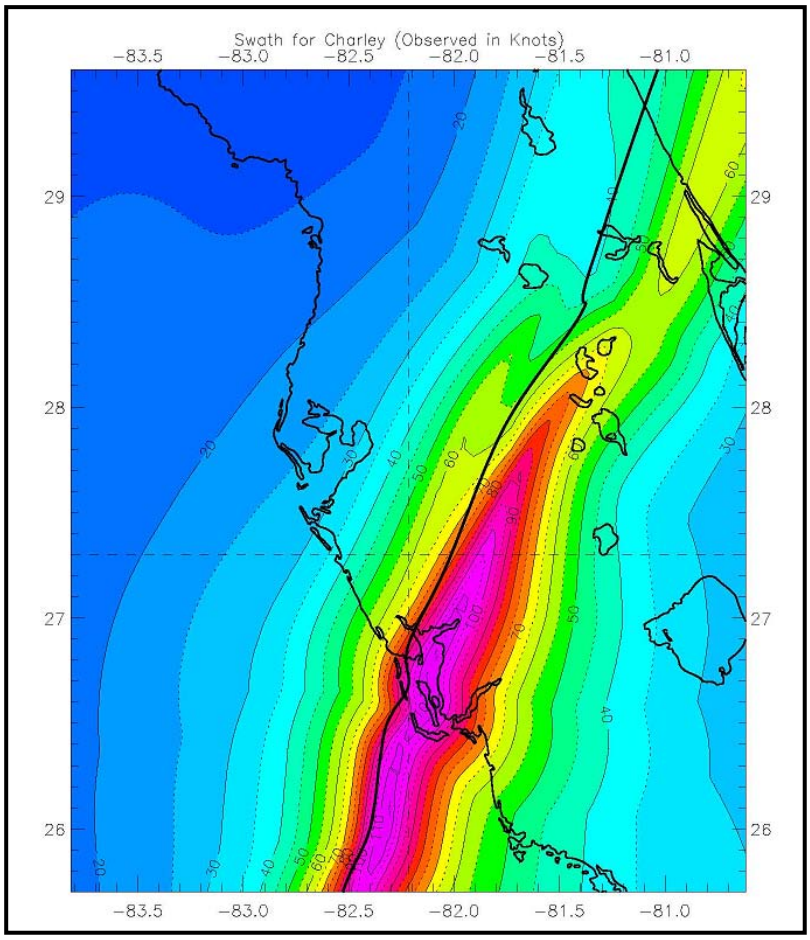


Figure 1: Swath for Hurricane Charley, based on observations.

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 storms.

The activities of the past year have focused on updating the residential model to make use of the latest climatic data. Also our focus was to meet the standards of the 2008 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 now available for insurance rate making purposes in Florida.

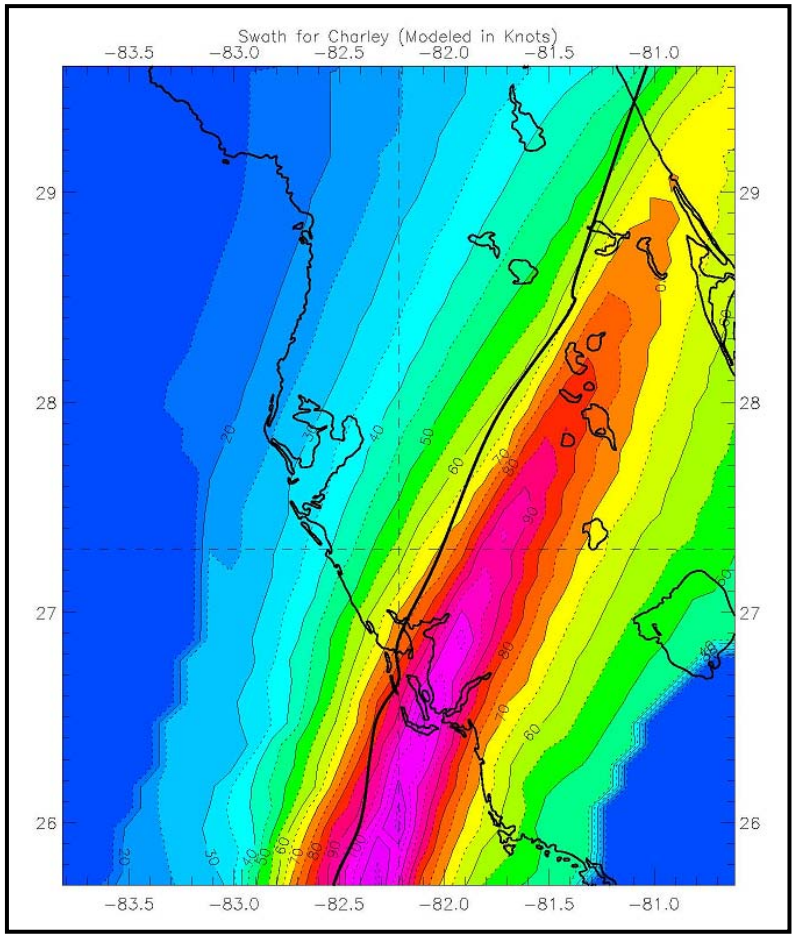


Figure 2: Swath for Hurricane Charley, a product of the commercial model

A commercial model variant was also developed and a linear wind field model 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 ones constructed from all available observations 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).

Research Performance Measure: All objectives were met on schedule.

Real-Time Hurricane Wind Analysis

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

Long Term Research Objectives and Strategy to Achieve Them:
***Objectives*:** To improve our understanding of the wind distribution in tropical cyclones.
***Strategy*:** 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:** M. 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 product of this analysis is a colored and annotated wind contour plot.

Our recent research emphasis is concentrated upon 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, we develop a more

relevant metric of the physical forces that actual create damage, as opposed to relying upon the guidance of a single value representing the maximum surface wind speed (the well know Safir-Simpson scale). A new web page (www.aoml.noaa.gov/hrd/ike) reflects these efforts, with a calculator tool (Fig. 1) that lets the interested community roughly estimate IKE and surge destructive potential by providing the radii of 34, 50, 64kt winds at each quadrant. For the last 2 years, IKE has been computed for each gridded H*Wind surface wind analysis.

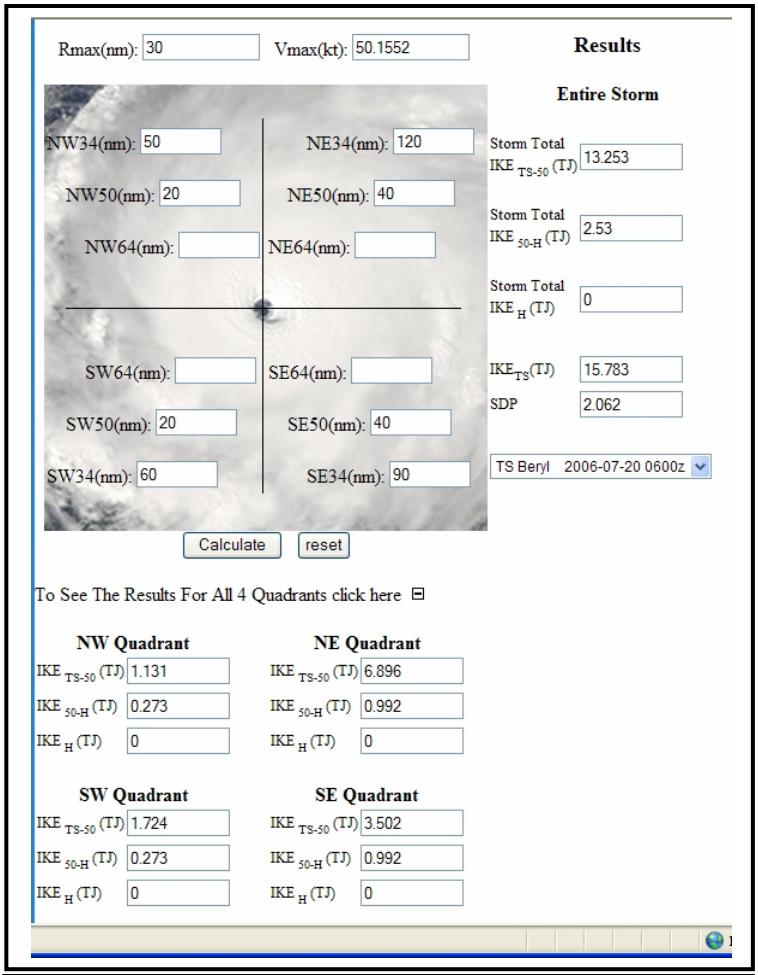


Figure 1: Integrated Kinetic Energy web calculator, showing a sample radii input and results for Tropical Storm Beryl (2006).

In parallel, AOML/HRD's database of processed dropsondes underwent a major overhaul in terms of the quality of storm tracks used to calculate storm-related derived fields. Chronological coverage shortcomings of initial flight track splines were remedied with a combination of wind-center and official BestTrack storm positions, that allowed a more comprehensive set of sondes to be associated accurately to their operational environments.

Finally, this project team closely collaborates with another 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.

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 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 can be developed to provide an improved product which can in the future be implemented 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:** Eric Uhlhorn

Research Summary:

Hurricane forecasters rely on accurate surface wind speed data to provide estimates of storm intensity. For over a decade, CIMAS and NOAA/HRD scientists have been involved in a collaborative effort to increase accuracy of surface wind measurements from NOAA's research Stepped Frequency Microwave Radiometer (SFMR). Instrument and algorithm improvements over the years have greatly enhanced this capability, and led to a transitioning of this unique research tool to an operational hurricane surface wind measuring device by NOAA aircraft.

Recently, SFMRs were installed on Air Force Reserve Command WC-130J hurricane reconnaissance aircraft beginning in 2007, and the entire fleet was outfitted for the 2008 hurricane season. 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 to be 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, since little real-time QC was performed. In this study we found errors were due to:

- Contamination by land-based microwave emission;
- Interference from non-natural radar sources;
- Incorrect sea-surface temperature specification; and
- Instrument failure.

Of these issues, only instrument failure cannot be corrected in a post-processing mode, and was found to occur in 3 of 91 total cases. To correct the other anomalies, 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. An example of this is shown in Figure 1, as anomalous surface wind retrievals resulted from RFI contamination prior to quality control. Finally, accurate sea surface temperature values are used when re-processing surface wind data.

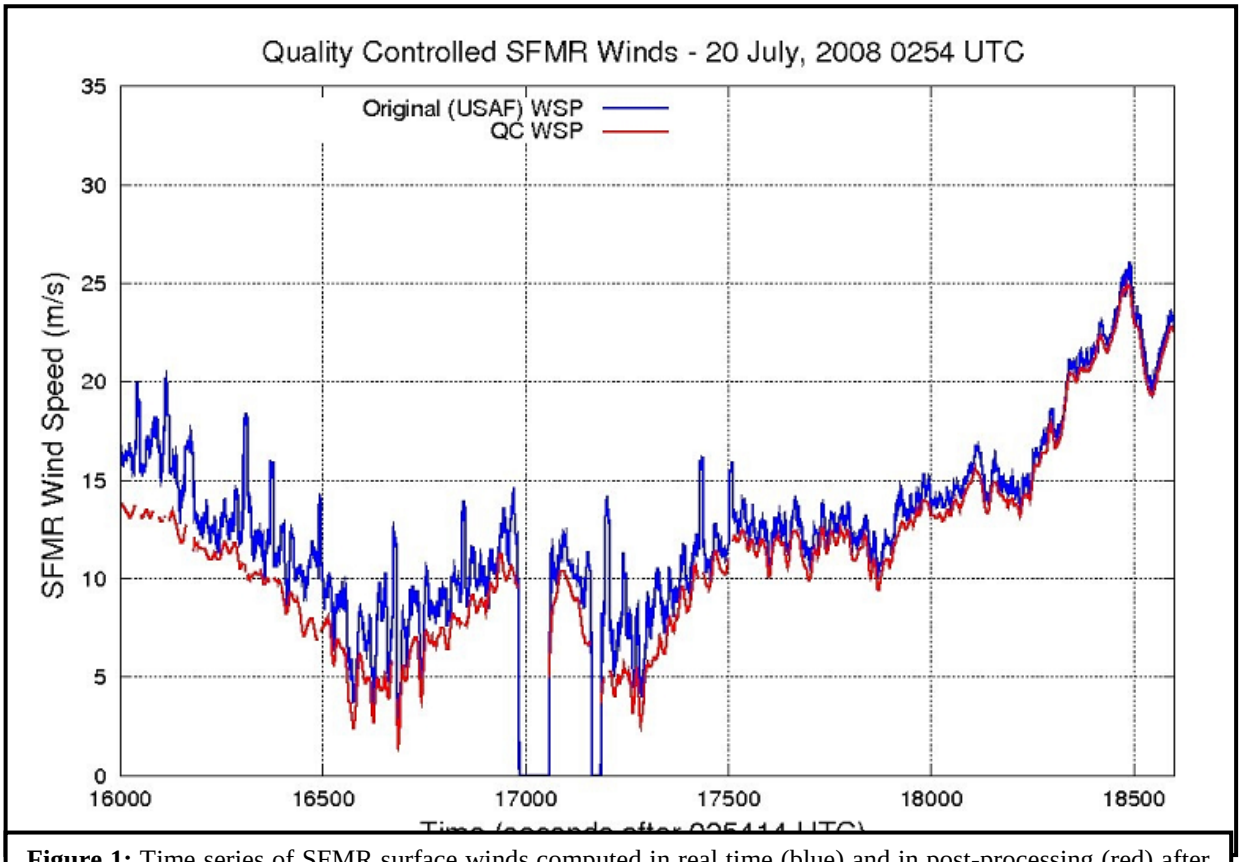


Figure 1: Time series of SFMR surface winds computed in real time (blue) and in post-processing (red) after implementing QC procedures. High wind-speed spikes result from external interference of the SFMR brightness temperature measurements.

Research Performance Measure: All major research objectives have been met. The quality-controlled re-processed SFMR data are now available to the research community via the NOAA/AOML web server.

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 energy for a better boundary layer parameterization in numerical weather prediction models

***Strategy*:** To analyze Doppler radar and *in-situ* measurements from various instruments and to develop a method to estimate low-level turbulent energy 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:

In order to better understand the processes influencing hurricane intensity change, and ultimately to improve intensity forecasts, it is crucial to have a better understanding of the structure of tropical cyclones. In particular a better knowledge of the turbulent processes in the hurricane boundary layer (HBL) through observational data is essential to evaluating and improving the boundary layer (BL) parameterization in numerical weather prediction (NWP) models.

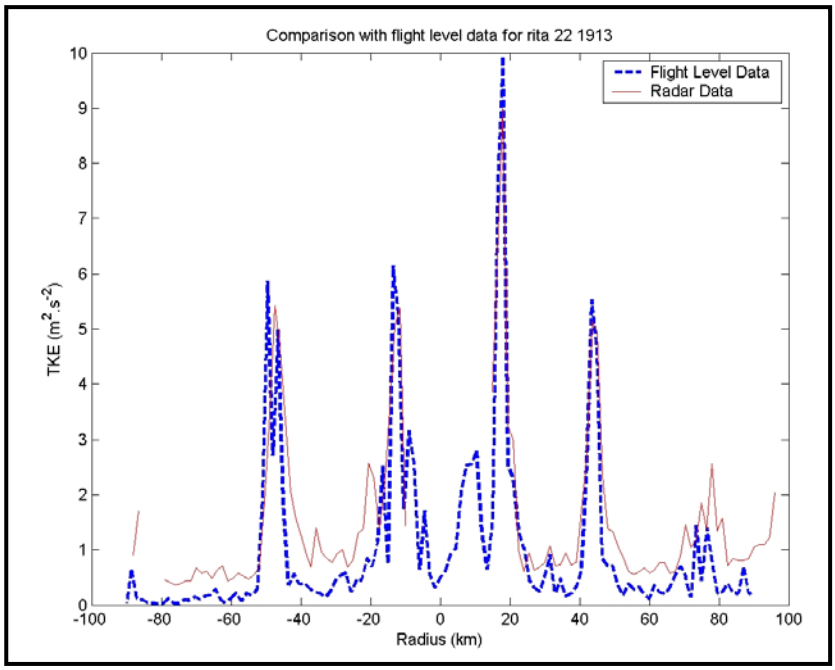


Figure 1: A comparison of radar-retrieved TKE estimates (m^2s^{-2}) with flight-level values in Hurricane Rita.

The goal of this research project is to estimate turbulent parameters of the HBL using airborne Doppler 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 this type of instrument are crucial to identify turbulent processes impacting hurricane intensity and to evaluate models.

The activities of the past year have focused on developing and evaluating a method of estimation of turbulent kinetic energy of hurricanes using the tail Doppler radar data. First we improved the method designed the previous year, and then reprocessed the data. We increased the data set with additional storms for a statistically relevant analysis.

The data were analyzed for a general interpretation of the results. The method was then quantitatively evaluated. The first step of the valuation process was to make sure than the TKE estimates were not biased by hypotheses on which the method was based on. The next step was to evaluate the magnitude of TKE retrievals. The radar-retrieved TKE estimates were compared with flight-level data and direct measurements of turbulence from the Coupled Boundary Layers Air Sea Transfer (CBLAST) experiment and very good agreement was found. The scales of motion documented by the method were then identified using a Fourier analysis.

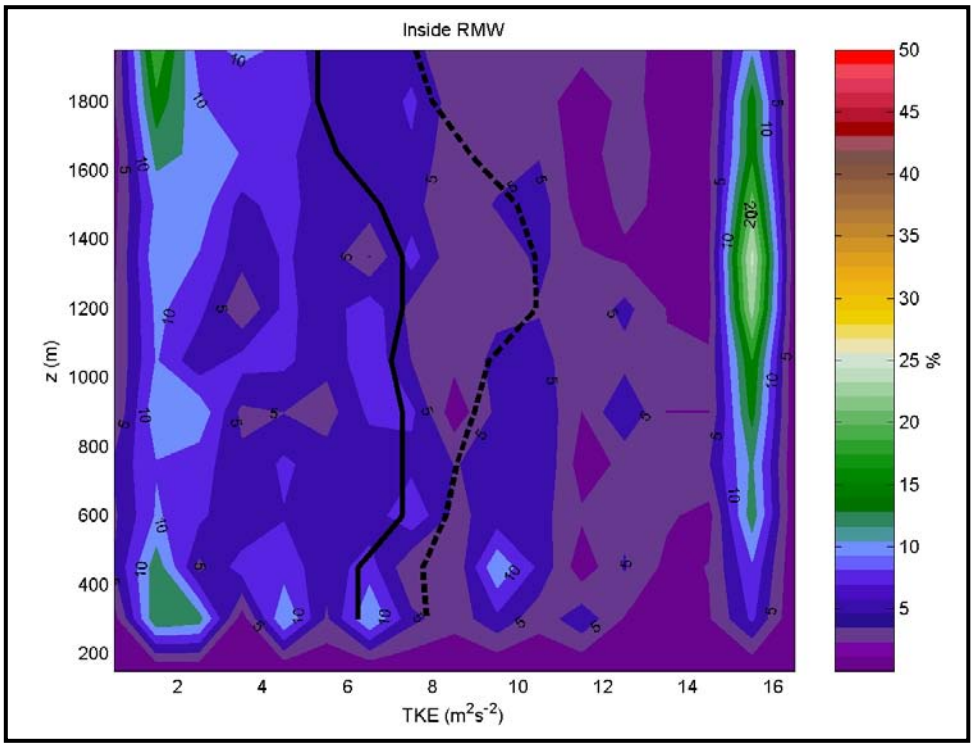


Figure 2: The distribution with height of TKE inside the radius of maximum wind. The solid black line and the dash black line represent the median and the mean at each height, respectively.

Research Performance Measure: The objectives regarding the design of a method able to estimate TKE of hurricanes using airborne Doppler measurements were met. A draft of a paper regarding the method and promising results has been submitted for NOAA internal review. However, the analysis of IWRAP data has been put on hold as the current specifications on which the instrument operate do not allow the estimation of turbulent parameters we seek to retrieve.

Ensemble Kalman Filters and OSSEs in Hurricane Models

S.J. Majumdar (UM/RSMAS); A. Aksoy (UM/CIMAS); R. Atlas (NOAA/AOML);
S.D. Aberson, J.J. Cione, F.D. Marks and E.W. Uhlhorn (NOAA/AOML/HRD)

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 to support of NOAA's Hurricane Forecast Improvement Project (HFIP).

***Strategy*:** Collaborate in the development of an Ensemble Kalman Filter to exploit existing ensemble-based forecast information in 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:

***Aerosonde unmanned aerial system (UAS) missions into tropical cyclones*:** Part of this grant was to complete a prior collaboration with Dr Joe Cione and Dr Eric Uhlhorn of NOAA/AOML/HRD on analyzing two Aerosonde flights into tropical cyclones. Guy Cascella, a Master's student at RSMAS funded on this grant until December 2008, produced time series and vertical profiles of dynamic and thermodynamic fields, and demonstrations of the influence of the new Aerosonde data on analyses of the near-surface wind field.

Ensemble-based data assimilation at HRD: As part of NOAA's Hurricane Forecast Improvement Project (HFIP), the PI has begun collaborating with Dr Altug Aksoy (CIMAS). The Ensemble Kalman Filter (EnKF) for tropical cyclones is being prepared by Dr Aksoy on NOAA's computer system, and preliminary tests will be performed using NOAA's experimental version of the hurricane WRF model after bugs in the model machinery have been corrected.

Observing System Experiments (OSE) and Observing System Simulation Experiments (OSSEs) for hurricanes: The PI has been involved in multiple meetings with Dr Bob Atlas (AOML Director) and HRD personnel, and Dr Steven Koch (ESRL Global Systems Division Director) and his staff with respect to enabling both OSEs and OSSEs. The PI has drafted and circulated a white paper giving working hypotheses and prospective implementations of both global and regional OSSEs pertaining to hurricanes. Efforts are now under way with both AOML and ESRL to build components of the OSSE. Preliminary OSE work using the NCEP system involving the assimilation of wind and temperature near hurricanes is also under way.

Weather In-Situ Deployment Optimization Method (WISDOM): The PI was also an active participant in the new WISDOM project (http://wisdom.noaa.gov), headed by Sandy MacDonald (NOAA/ESRL Director). Through the summer and fall of 2008, he prepared hypothetical concepts of operations for deployments of constant-pressure balloons based on targeted observing methods. These concepts were shared with the WISDOM team and will contribute to the planning of balloon deployments in 2009. The PI also organized University of Miami student teams to launch WISDOM balloons, culminating in the demonstration ahead of Hurricane Paloma in November 2008.

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

Application of Satellite Surface Wind Data to Ocean Surface Analysis and Numerical Weather Prediction

S. J. Majumdar (UM/RSMAS); R. Atlas (NOAA/AOML)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** To understand the influence of assimilating scatterometer-based winds in global models of hurricanes in order to determine the optimal assimilation of future scatterometer data.

***Strategy*:** Assimilate winds derived from the QuikSCAT satellite into the NCEP Global Forecast system (GFS) and diagnose the influence of these data in modifying hurricane forecasts.

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:** Robert Atlas

Research Summary:

The operational NCEP GFS uses the Gridpoint Statistical Interpolation (GSI) data assimilation scheme. As documented in the 2008 Annual Report, the corrections to surface wind analyses by assimilating QuikSCAT wind data into the GSI were found to be minimal. Subsequently, the QuikSCAT data had negligible influence on track forecasts of tropical cyclones.

In the past year, analyses have been performed to understand how the QuikSCAT wind vectors are being assimilated into the NCEP system. The preparation of the observational data involves the following steps: Quality control (Swath edge; rain flag); Pre-processing; Wind Retrieval; Ambiguity Removal; Super-Obbing: average over 1^o x 1^o boxes; output at 0.5^o resolution. The resulting output vectors are then added to NCEP's suite of observational data, and blended with the NCEP first guess field in the 3d-variational GSI system to produce the NCEP analysis every 6 hours. Observational errors for QuikSCAT are 3.5 m/s in the current NCEP system.

In order to understand the strengths and limitations of the NCEP GSI in assimilating surface wind data, a synthetic observation experiment was performed. For a test case (Hurricane Florence 2006), four synthetic wind vectors were added to the suite of operational observations. These wind vector 'observations' were placed in each quadrant near the radius of maximum winds in the (incorrect) global model representation of the tropical cyclone, with speeds that were 10 m/s higher than the first guess. The observation errors were chosen to be an artificially low value of 0.1 m/s. The horizontal structure of the increment is localized and symmetric around the observation location (Fig 1a). A deepening of about 4 mb is observed in the mean sea-level pressure (Fig. 1b). While this deepening near the surface is encouraging, the influence of assimilating the surface wind vectors on the vertical structure of the tropical cyclone leaves considerable room for improvement. The modification to the dynamic and thermodynamic fields appears useful up to about 800 mb, with a strengthening of the lower-tropospheric winds (Fig. 1c) and associated warming in the inner-core (Fig. 1d). However, the influence in the middle troposphere is negligible, even though it is well-known that the tropical cyclone is a coherent vortex in which surface and mid-tropospheric winds are likely to be correlated. These experiments were repeated with NCEP's new "anisotropic" error covariance formulation. Analysis increments were found to be nearly identical to those illustrated in Figure 1.

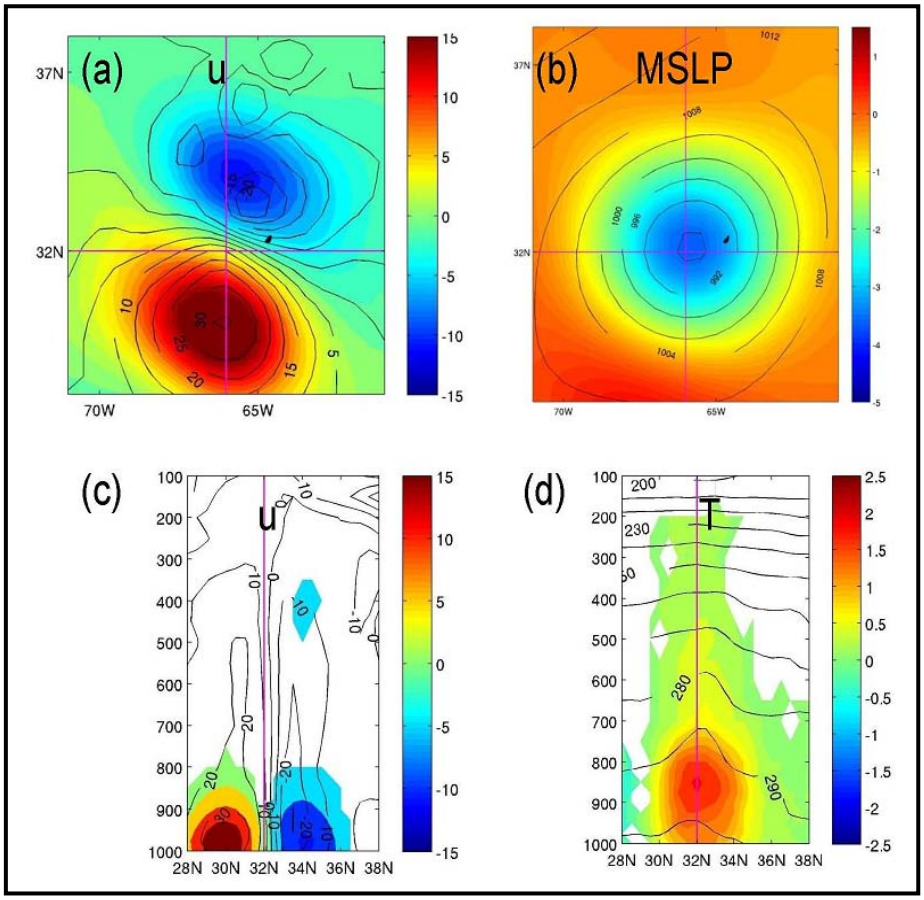


Figure 1: NCEP GFS analysis increments due to the assimilation of the four artificial wind vectors around Hurricane Florence. Increments are of (a) near-surface zonal wind in m/s; (b) mean sea level pressure (in hPa); (c) vertical cross-sections through 66W of tropospheric zonal wind (m/s), (d) temperature (K).

The primary conclusion of the synthetic observation experiments to date is that the NCEP GSI system is only able to produce limited modifications to the dynamic and thermodynamic fields above the lower troposphere. Further investigation of the error covariance structure in the horizontal and vertical is necessary, in addition to parallel runs without 'super-obbing'.

In additional to the collaborations with NOAA/AOML and NASA Goddard, Majumdar has been working with Prof. Chun-Chieh Wu and colleagues at National Taiwan University on validation studies of QuikSCAT data in the environment of typhoons in the north-west Pacific basin. These collaborations will continue and will likely extend to institutions in Japan in the future.

Advanced data assimilation schemes such as the Ensemble Kalman Filter (EnKF) are becoming more widely used by the community, and are being considered by operational centers as the next generation of data assimilation. The EnKF has been extended for use with the NCEP GFS, and is nearly ready for use with NOAA's next-generation Finite Icosahedral Model (FIM). Our team plans to collaborate with colleagues at NOAA/Earth System Research Laboratory on advanced assimilation of QuikSCAT data in global models.

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

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/HRD)

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*:** Directly compare in-situ measurements of wind, temperature, and humidity near the surface in observed hurricanes to the same variables generated by computer simulations of the same hurricanes for 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 has 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. Isabel (2003) was well suited for this purpose because of the abundance of in-situ data obtained during the CBLAST field project and the fact that simulations with the Weather Research and Forecasting Model (WRF) reproduced the track and intensity of the storm remarkably well, making such close comparisons meaningful.

As stated in the goals of our proposal, 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.

Some of these differences can be seen in Figure 1, which shows the mean structure of the tangential (shaded) and radial (contoured, negative values dashed) wind speeds for the inner core of Hurricane Isabel around 18Z (2PM EDT) on Sept. 13th, 2003. Results are shown for the YSU and the MYJ boundary layer schemes, and for each of these schemes with the improved formula for surface roughness of the ocean as a function of wind speed. Also shown is an analysis of the wind field based on numerous flight-level and dropsonde (falling instrument) observations that were taken around that time in Isabel, and synthesized into a single coherent analysis by Bell and Montgomery (2008, *Mon. Wea. Rev.;* they provided their data for this comparison). While the results with the modified YSU scheme are a remarkably good match to the observations in the eyewall region (around r = 40 to 50 km), the two simulations with the MYJ scheme show lower wind speeds at the surface, excessive wind speeds above the surface, and excessive radially inward flow at low levels.

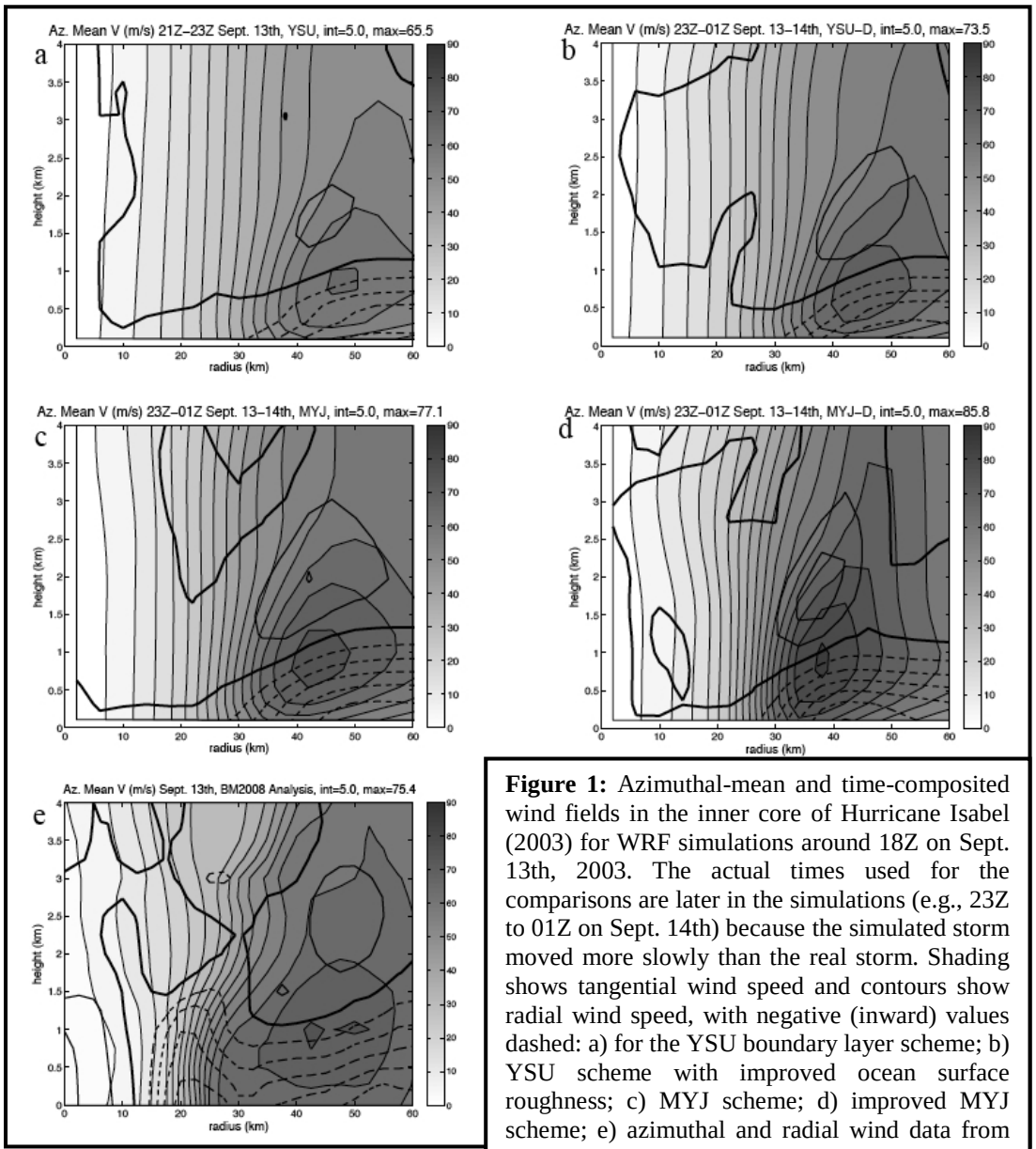


Figure 1: Azimuthal-mean and time-composited wind fields in the inner core of Hurricane Isabel (2003) for WRF simulations around 18Z on Sept. 13th, 2003. The actual times used for the comparisons are later in the simulations (e.g., 23Z to 01Z on Sept. 14th) because the simulated storm moved more slowly than the real storm. Shading shows tangential wind speed and contours show radial wind speed, with negative (inward) values dashed: a) for the YSU boundary layer scheme; b) YSU scheme with improved ocean surface roughness; c) MYJ scheme; d) improved MYJ scheme; e) azimuthal and radial wind data from an observational analysis of the inner core of Isabel reported by Bell and Montgomery (2008, *Mon. Wea. Rev.).* Wind speeds are in m/s.

This work is presently being 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. We are also re-applying our comparisons of observations in Isabel (2003) to simulations using the NOAA operational hurricane forecasting model, HWRF, so that improvements can hopefully be made to that model as well.

Research Performance Measure: The first objective of this project was 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 acceptance for publication of two papers to appear in *Monthly Weather Review*. The second objective was a study and comparison to observations of the boundary layer in a landfalling hurricane. Hurricane Wilma (2005) has been selected for this purpose, and preliminary simulations and data acquisition have already begun.

A Twelve-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.

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

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.

Figure 2: AVAPS operator Jeff Smith, aboard a NOAA P3 aircraft, preparing a GPS dropwindsonde for launching from the aircraft.

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

Evaluation and Improvement of Ocean Model Parameterizations for NCEP Operations

L.K. Shay (UM/RSMAS); G. Halliwell (NOAA/AOML); C. Lozano (NOAA/NCEP/EMC)

Long Term Research Objectives and 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*:** 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 Testbed
NOAA Technical Contact: Jiann-Gwo Jiing

Research Summary:

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).

The model evaluations completed to date have 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. The impact of ocean dynamics is illustrated in Fig. 1 within a Gulf of Mexico cold-core cyclone where a large difference in the cooling forced by Ivan resulted between a simulation by the full three-dimensional HYCOM and another simulation by a one-dimensional model. The model accurately reproduces the upper-ocean near-inertial velocity 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. 2). The near-inertial response over the shelf break in Gulf Common Water differs considerably from the near-inertial response in warm and cold core cyclones that interacted with Ivan. A paper summarizing these results has been submitted for publication (Halliwell *et al.*, MWR, 2009).

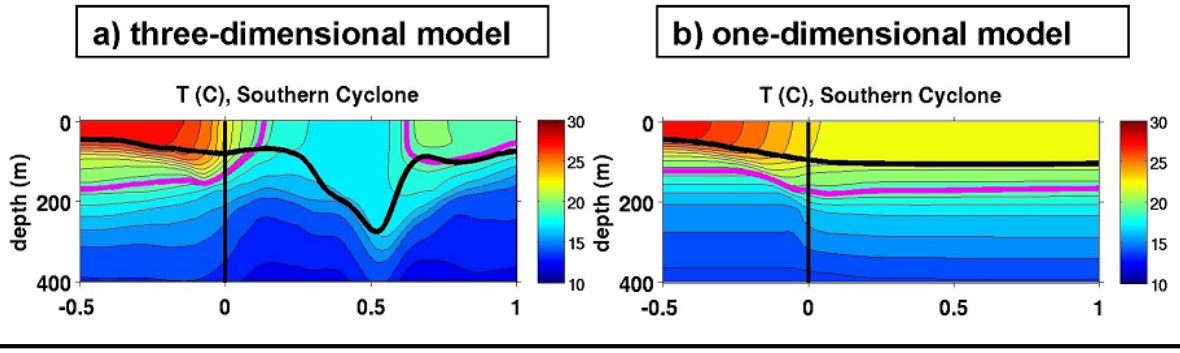


Figure 1: Time depth plots of the temperature response to hurricane Ivan from the full three-dimensional HYCOM control run (left) and a one-dimensional ocean model (right), the latter obtained by running HYCOM as for the control experiment but with all three-dimensional dynamical and thermodynamical processes switched off. This response was located within a cold-core cyclone in the eastern Gulf of Mexico.

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). Analysis of these storms along with the major storms Gustav and Ike from last year will be high priorities. During the past year, G. Halliwell has moved from RSMAS to NOAA/AOML. Part of his duties are to interact 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.

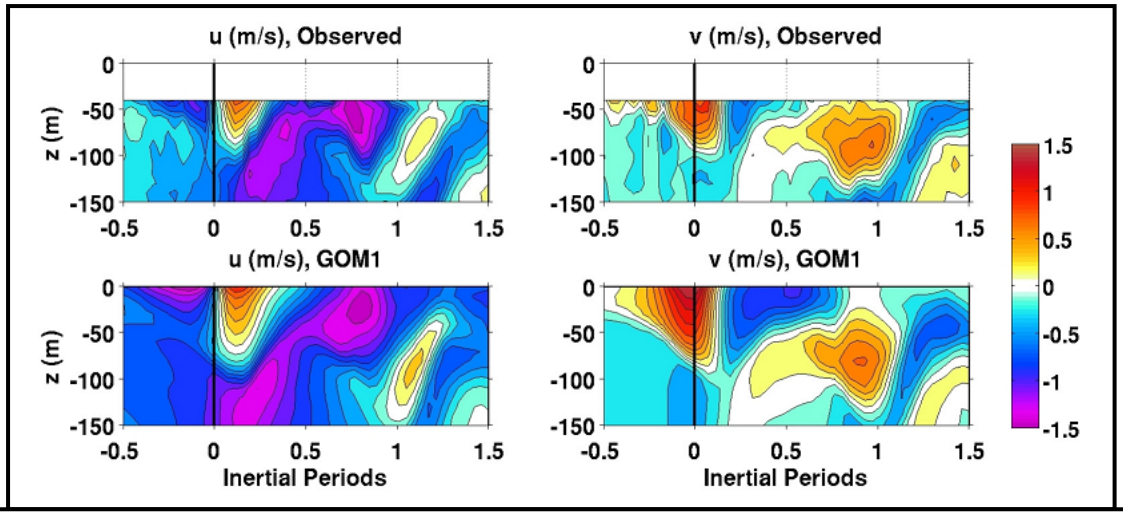


Figure 2: Zonal (left panels) and meridional (right panels) velocity response to Ivan from ADCP observations (top panels) and a three-dimensional HYCOM control experiment (bottom panels). The ADCP instrument could not resolve velocity profiles within 40m of the surface.

Research Performance Measure: The objectives of this program are being met on schedule.

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 a system that combines data from several sources (meteorological and not-meteorological) and uses them together to improve the public's awareness of the dangers that may be imposed by Tropical Cyclones.

***Strategy*:** 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.

CIMAS Research Theme:

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

Link to NOAA Strategic Goals:

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

NOAA Funding Unit: AOML **NOAA Technical Contact:** Frank Marks and Mark Powell

Research Summary:

Videos are collected from YouTube based on the location and date information of a storm extracted from the H*Wind system. The YouTube videos are then ranked based on the relevancy to the weather event using a concept detection algorithm, which classifies the different videos to different categories based on low-level features extracted from the audio track. 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. Several other sources such as radar images and satellite images are also available for the user to view.

The public's ability to evaluate the potential dangers that can be inflicted by a Tropical Cyclone can have a significant effect on the damage outcome, both in life and property. Many warning systems are currently in place but the overall damage caused by major tropical storms is still high. We use data from YouTube and H*Wind to attempt to improve the ability to warn the public from damage caused by approaching severe weather events. Figure 1 shows a visualization example of data taken from H*Wind and YouTube. Once a video is available, a YouTube icon is displayed to the user in the relevant geographic location. Once the user clicks on the YouTube icon, a popup balloon opens with the video for the user to view. Figure 2 shows the developed web-based prototype displaying current satellite imagery.

Research Performance Measure: All objectives were reached.

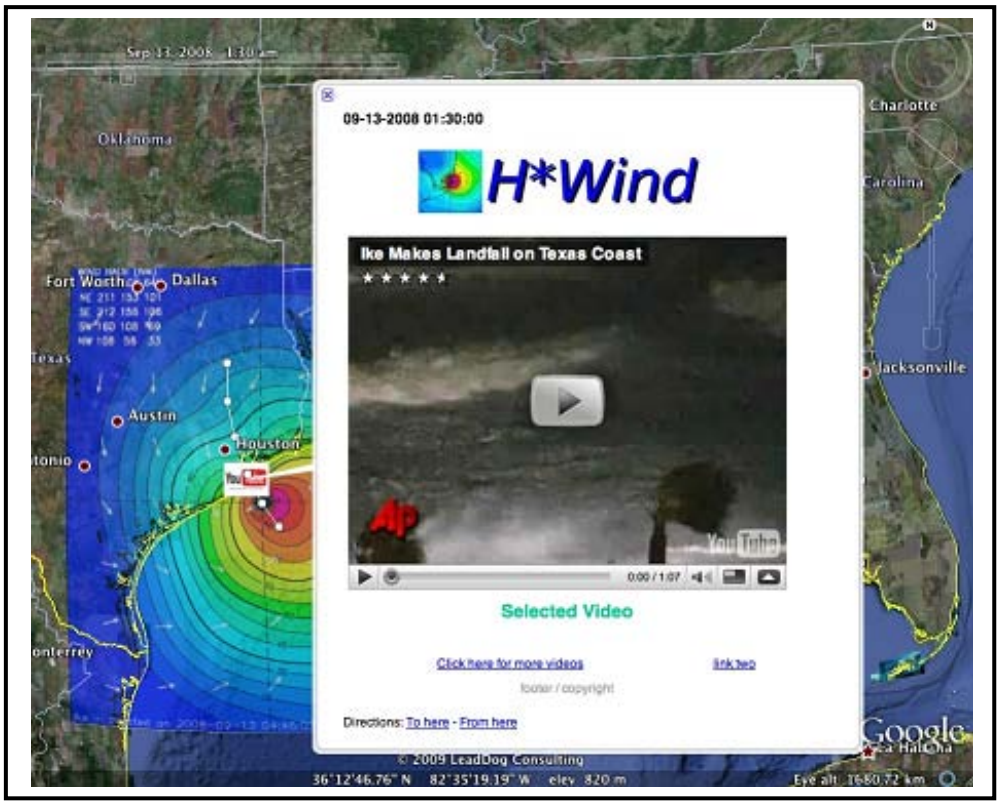


Figure 1: A Snapshot of H*Wind and YouTube Data Visualization in Google Earth.

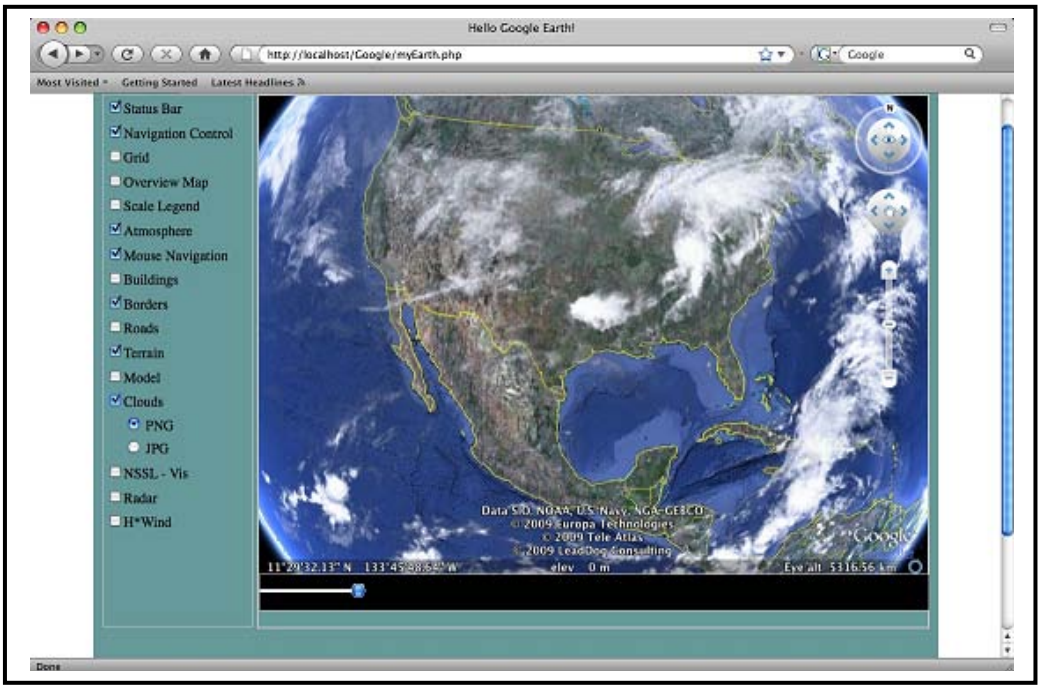


Figure 2: A Snapshot of the Web-Based Prototype Displaying Satellite Information

System Support for the Development and Simulation of Tropical Cyclone Numerical Models in a 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.

***Strategy*:** Use the Experimental Hurricane Weather and Research Forecast (HWRF-X) System at AOML/HRD for the study of the structure and dynamics of tropical cyclones (TCs) and analyze specific hurricane cases using model and observational data sets.

CIMAS Research Theme:

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

Link to NOAA Strategic Goals:

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

NOAA Funding Unit: OAR/AOML
NOAA Technical Contact: 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 of the environmental wind, upper oceanic temperature structure, and low- and mid-level environmental relative humidity. All these parameters were analyzed in data sets collected from the model runs on 60 hurricane cases.

We developed a system that is capable of generating graphical simulations from the WRF-HFS output data and displaying them directly on a 3D environment - World-wind (NASA). The development and simulation of TC models involve the use and generation of large amounts of data that originate in many different sources and different formats. Our approach will enable scientists to analyze all the models on a single platform, as well as help them understand the nature of various past and future hurricanes.

An architecture was designed and implemented that helps manage such large amounts of data and make it simple for different systems to access and use the data. This helps achieve the standardization and generalization of both existing and new data. Figures 1 to 3 show the three parts of *TS.Wilma* case study analytics.

Research Performance Measure: All objectives were reached.

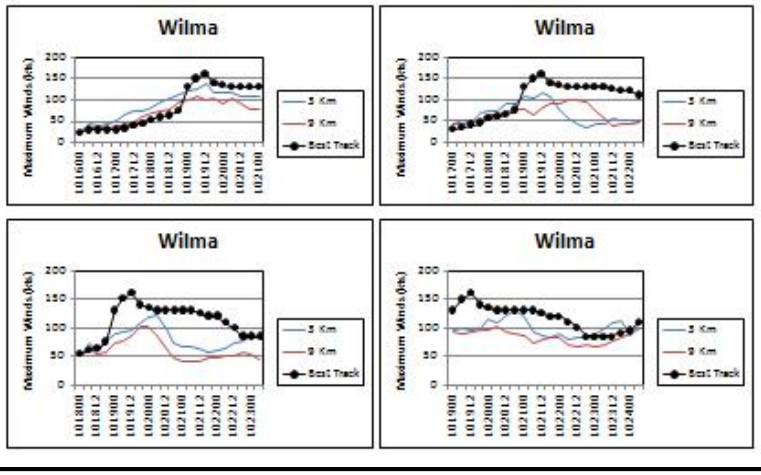


Figure 1: Part 1 of Wilma analytics

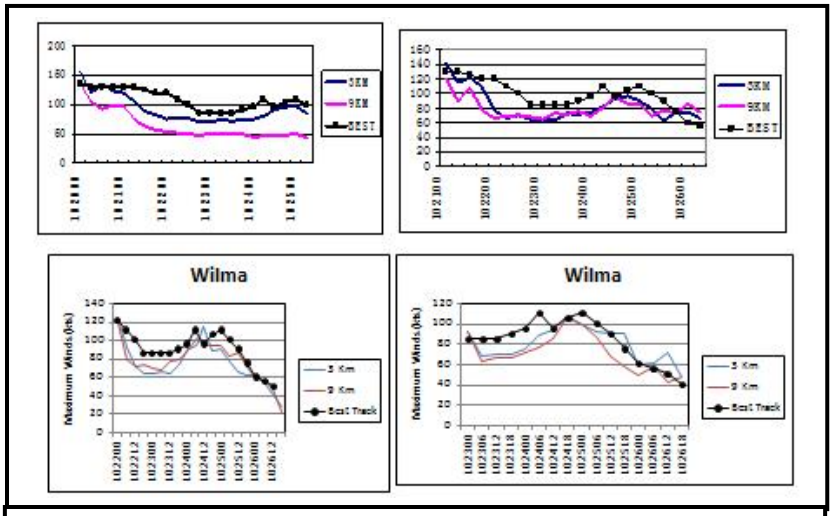


Figure 2: Part 2 of Wilma analytics

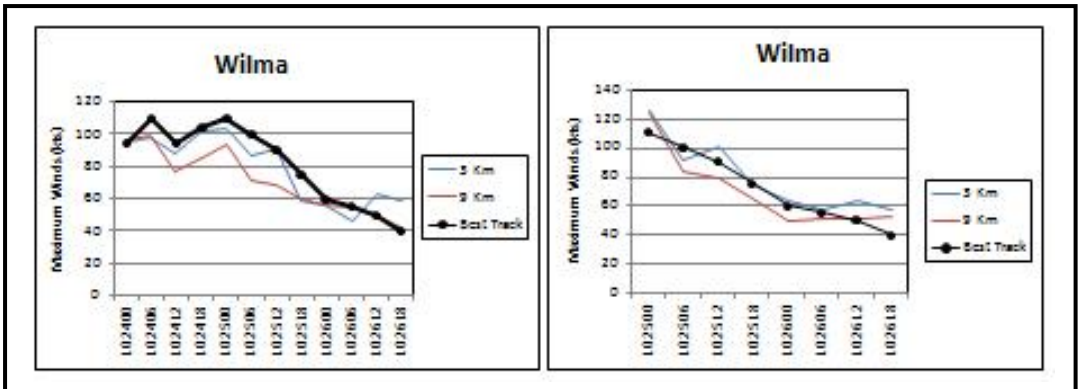


Figure 3: Part 3 of Wilma analytics

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

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

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** To improve the understanding and prediction of tropical cyclone genesis, intensity change and rainfall, as well as, the microphysical parameterization schemes in tropical cyclone simulations at all stages of their lifecycle.

***Strategy*:** Evaluate and compare microphysical fields from high-resolution numerical model simulations, *in situ* and remotely-sensed data retrieved by the NOAA-WP-3D's and NASA ER-2 aircraft, and data from the TRMM Precipitation Radar and Microwave Imager.

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:** Robert Rogers

Research Summary:

The goal of this work is to evaluate convective-scale and microscale fields in tropical cyclones at all stages of their lifecycle to better understand how these fields relate to TC structure and intensity change. To answer these questions, we are conducting comparisons of statistics of the distributions and concentrations of TC microphysical fields, in this case vertical velocity and radar reflectivity, from airborne (Doppler Radar) and space-borne (TRMM satellite) observations and from high-resolution numerical model simulations (MM5).

The first task focuses on a high-resolution MM5 simulation of the rapid intensification of Hurricane Dennis (2005). Figure 1 shows a time-height series of mean inner-core vertical velocity and model-derived reflectivity in the convective and stratiform regions prior to and during RI in the simulation. Upward motion in the convective regions is maximized in the 2-4 km layer prior to RI and extends over a much deeper layer after RI. No clear trend in mean convective updraft intensity is evident. Mean inner-core vertical velocity in the stratiform regions shows the typical pattern of upper-level updraft and lower-level downdraft couplet. Stratiform updraft intensity varies prior to RI and steadily increases after RI; stratiform downdrafts do not show a clear trend over time. The reflectivity profiles do not show a clear trend prior to or during RI. A comparison of contoured frequency by altitude diagrams (CFADs) for times with and without a burst prior to RI, and times with a burst after RI (Fig. 2), shows that clear differences exist between vertical velocity and reflectivity distributions for times with and without a burst, but little difference is seen between burst times prior to and after RI.

The second task involves evaluating reflectivity statistics from TRMM PR swaths from 1998-2007. We have compiled a database of these swaths that are within 0.5 degrees of a tropical cyclone during this 10-year time period. The database includes the Atlantic (125 swaths), Eastern Pacific (80

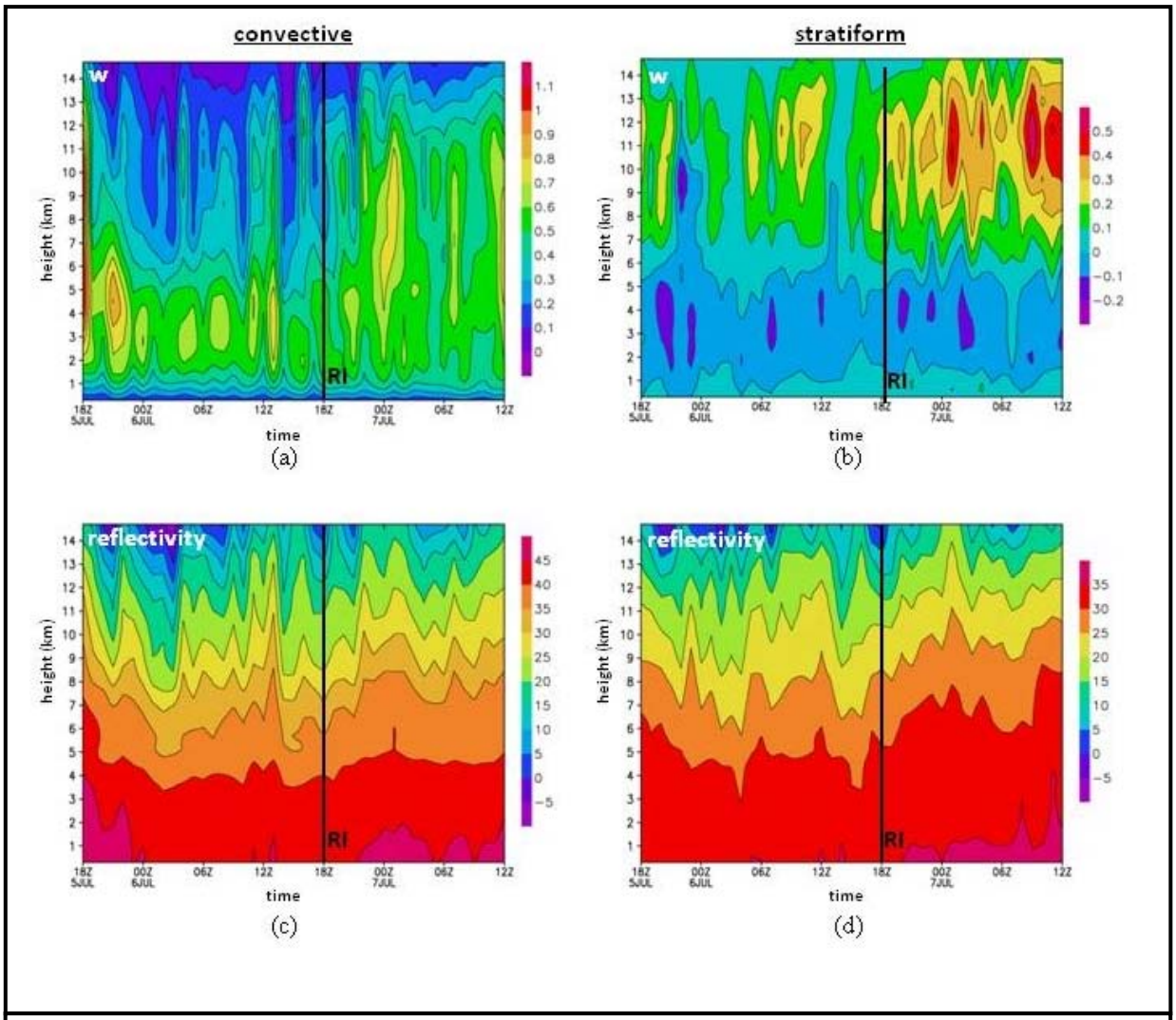


Figure 1: (a) Time-height series from 18 UTC 5 July to 12 UTC 7 July 2005 of mean vertical velocity (shaded, m s^{-1}) in convective regions within inner 75 km for MM5 Hurricane Dennis simulation; (b) Time-height series of mean vertical velocity in stratiform regions within inner 75 km; (c) As in (a), but for mean reflectivity (shaded, dBZ); (d) As in (b), but for mean reflectivity. Black line denotes onset of RI.

swaths), and Western Pacific (241 swaths) basins. We have stratified the datasets by basin, storm intensity, and storm intensity change in the 24 h after the swath time. Figure 3 shows an example of this analysis, showing mean reflectivity profiles partitioned into eyewall, rainband, and stratiform regions as a function of ocean basin. Little difference is seen in the reflectivity profiles for all regions and basins. The only notable difference is in the eyewall reflectivity at high altitude (i.e., above 11-12 km). The eyewall reflectivity in the Western Pacific is about 3-4 dBZ lower than the Atlantic and Eastern Pacific reflectivity at these altitudes. This relationship is also seen in CFAD plots of eyewall reflectivity for the various basins (Fig. 4). Whereas the bulk of the distributions is virtually identical for all three basins, the top 0.1% of the reflectivity, representing the most intense eyewall convection, does extend to higher altitudes in the Atlantic and Eastern Pacific basins. These results suggest that most of the properties of convection in tropical cyclones is remarkably similar from basin to basin.

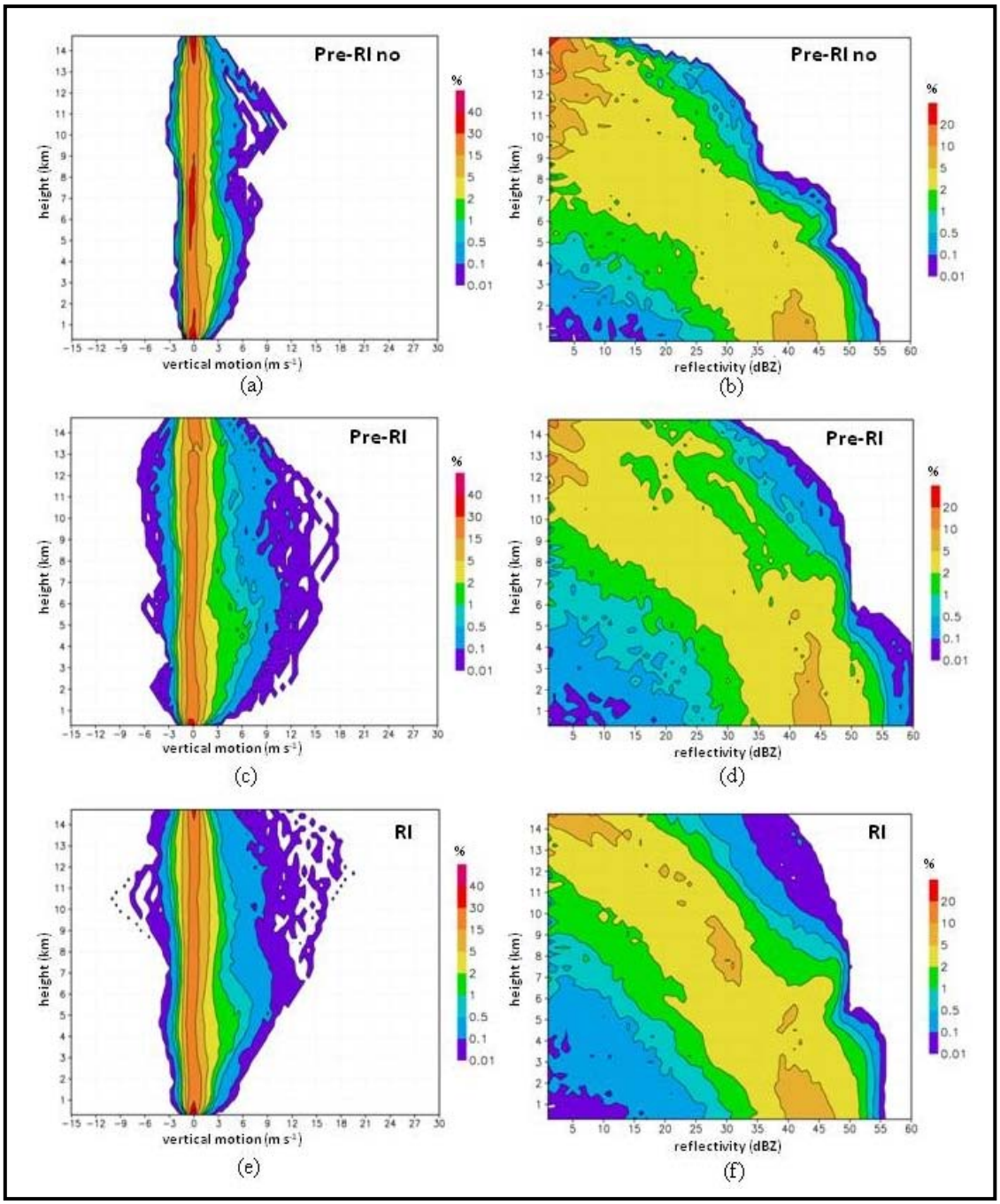


Figure 2: (a) Composite contoured frequency by altitude diagram (CFAD; shading, %) of vertical velocity for times prior to rapid intensification (RI) during which no bursts occurred; (b) As in (a), but for model-derived reflectivity; (c) As in (a), but for times when bursts occurred prior to RI; (d) As in (c), but for reflectivity; (e) As in (a), but for times when bursts occurred during RI; (f) As in (e), but for reflectivity.

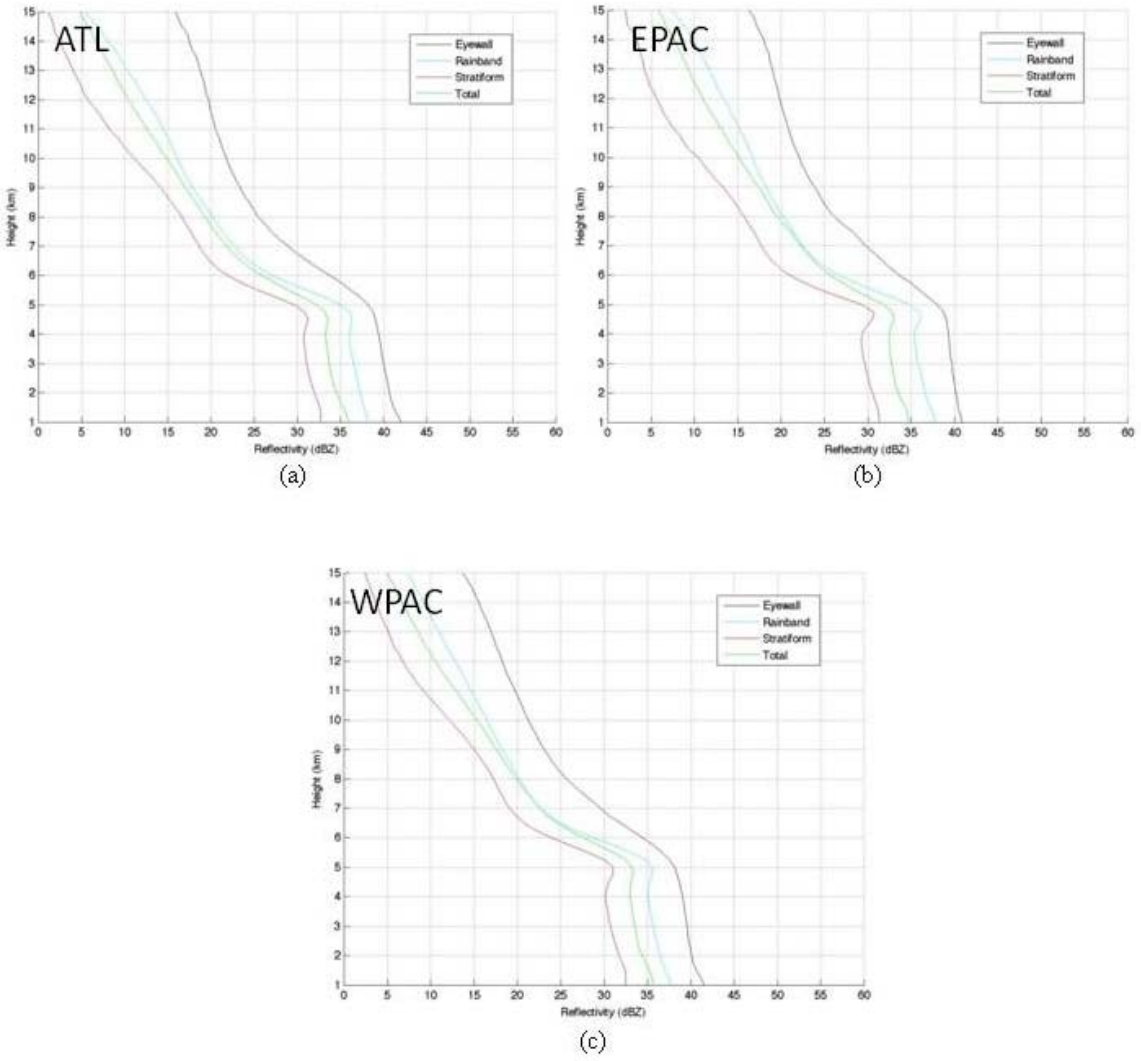
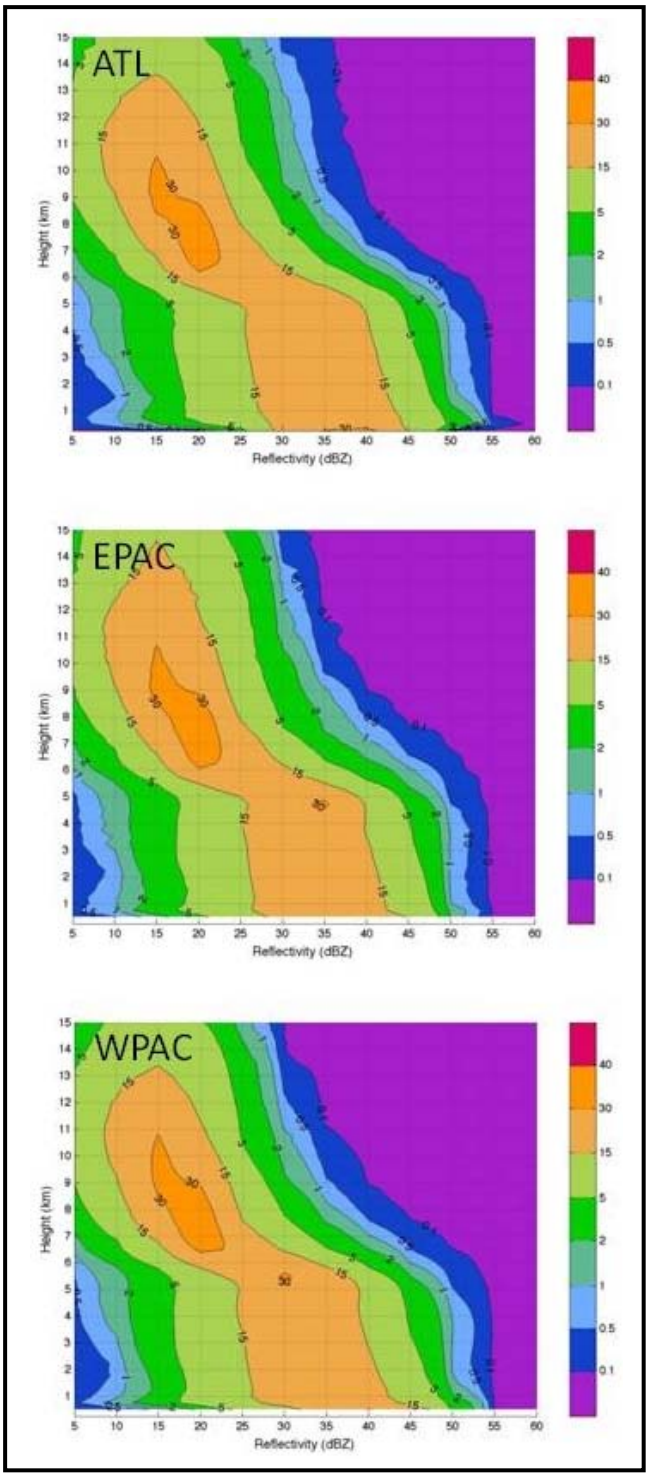


Figure 3: (a) Mean profile of reflectivity (dBZ) for eyewall, rainband, and stratiform regions for all TRMM PR swaths over tropical cyclones from 1998-2007 for the Atlantic basin; (b) As in (a), but for Eastern Pacific basin; (c) As in (a), but for Western Pacific basin.



Research Performance Measure: Progress is proceeding on the analysis of this data. A manuscript has been submitted to *Journal of Atmospheric Sciences* describing the work shown in Figs. 1-2. Work is ongoing to analyze the TRMM data shown in Figs. 3-4. The next step will be to compare TRMM reflectivity statistics for systems undergoing rapid intensification vs. those that are steady-state vs. those that are weakening. Future work will also involve evaluating reflectivity and vertical velocity fields from airborne Doppler radar and comparing them with model output. These results will be written up for submission to a refereed journal.

Figure 4: (a) CFADs of reflectivity for eyewall regions for all TRMM PR swaths over tropical cyclones from 1998-2007 for the Atlantic basin; (b) As in (a), but for Eastern Pacific basin; (c) As in (a), but for Western Pacific basin.

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

J. Zhang (UM/CIMAS); F. Marks (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:

As considerable efforts are being made toward 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 has become 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 characteristic height scales such as the height of the maximum wind speed, the mixed layer depth and height of the inflow layer are examined. The drag coefficients are calculated using the profile method. The level-off of drag coefficients above a certain surface wind speed found in previous studies is tested using a much larger datasets.

The second part of this project investigates the turbulence structure of the hurricane boundary layer by partitioning the data into mean and perturbation components. The turbulence properties such as the turbulent kinetic energy and fluxes can be estimated and will be compared to the results from the Coupled Boundary Layer Air-Sea Transfer (CBLAST) experiment during which direct measurements of turbulence were carried out.

Research Performance Measure: Half of the annual goals of the project were achieved; the program is on schedule.

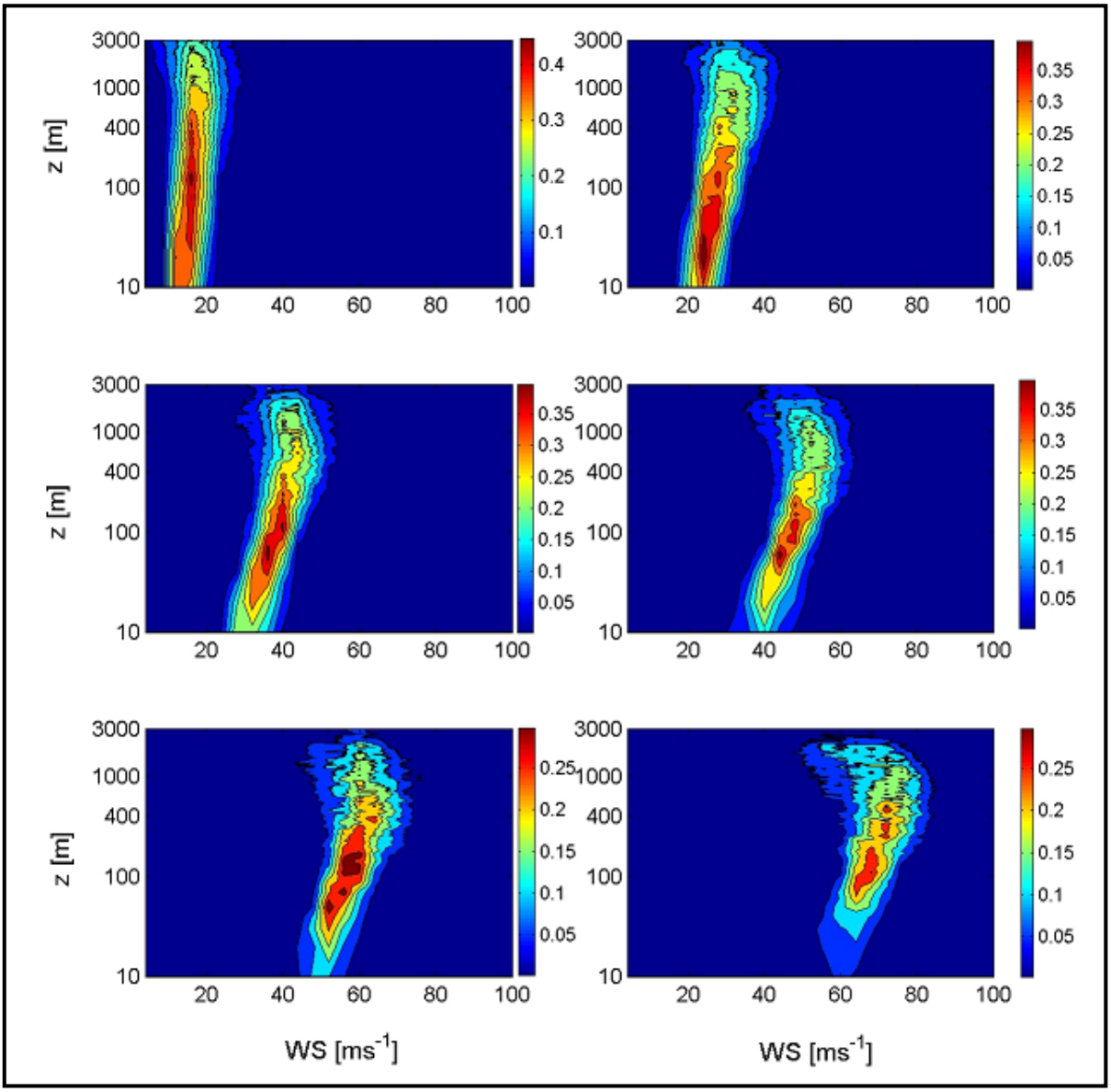


Figure 1: Contoured Frequency by Altitude Diagram (CFAD) plots of the wind speed in six groups according to the W_{L150} which is defined as the mean wind speed of the lowest 150 m data. The vertical scale is in log space.

Advanced Modeling and Prediction of Tropical Cyclones

X. Zhang and K.-S. Yeh (UM/VCIMAS); S.G. Gopalakrishnan, R. Rogers,
S. Aberson and F. Marks (NOAA/AOML/HRD); Jian-Wen Bao (ESRL/PSD)

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/HRD
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 in 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 are proposed to quantify the impact of increased model resolution on hurricane intensity forecasts. To enhance the confidence in model performance, we are 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 2008 to June 2009:
(a) We have established the experimental Hurricane Weather Research and Forecast (HWRFx) system (Fig. 1) and performed real-time forecasts during the 2008 hurricane season (Yeh et al, 2009). The results indicate that the performance of the HWRFx is generally comparable to those of the NOAA operational models (Figs. 2 and 3);
(b). The HRH test has been performed at two different resolution configurations based on the NOAA operation for hurricane forecast. Preliminary results indicate that the increased model resolution has significantly improved five-day forecasts of both track and intensity (Fig. 4); and.
(c). The requirement of model evaluation and verification have fostered the creation of an infrastructure for hurricane model developments, including the development of the Diagnostic Post-Processor (Diapost) and the HWRFx Graphic User Interface (GUI) software.

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

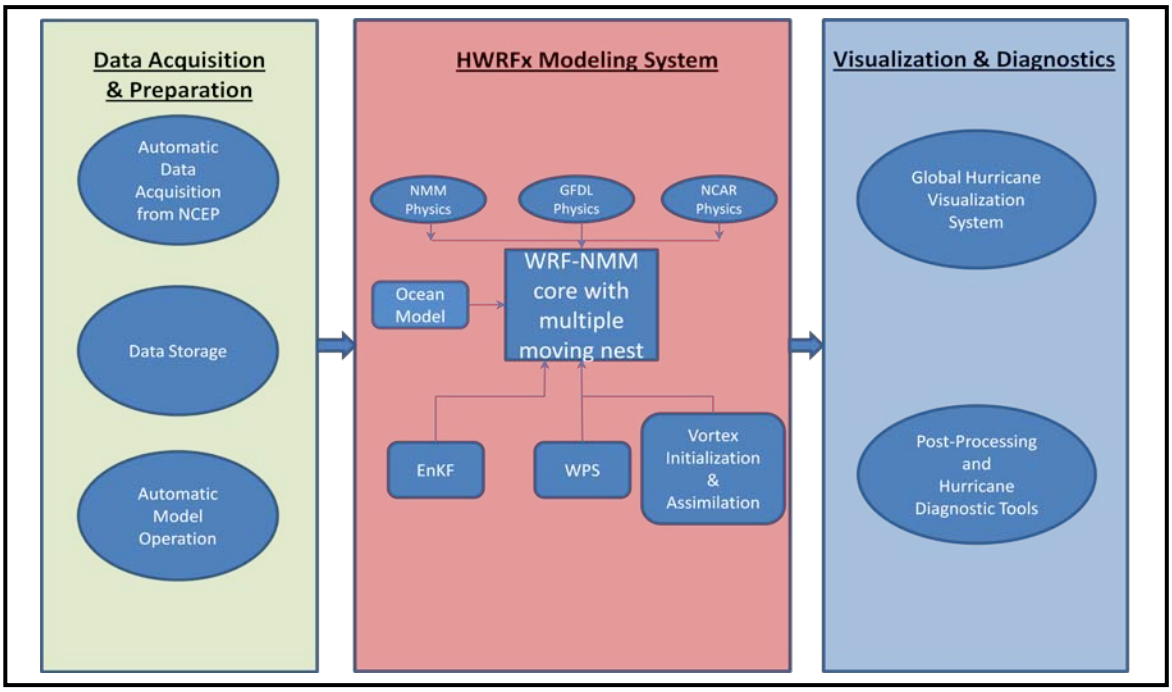
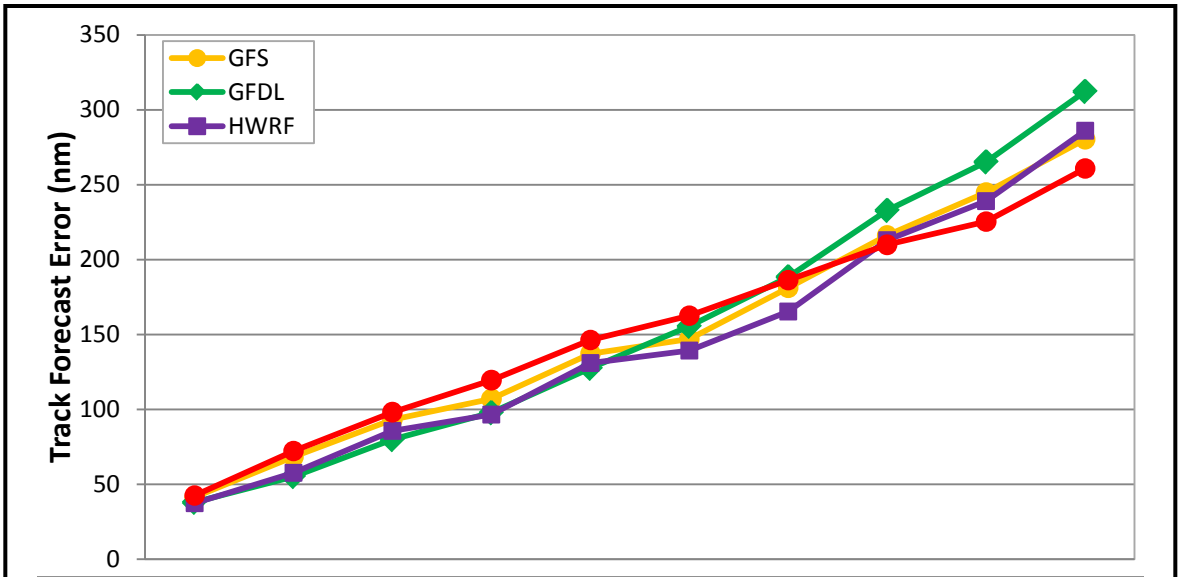
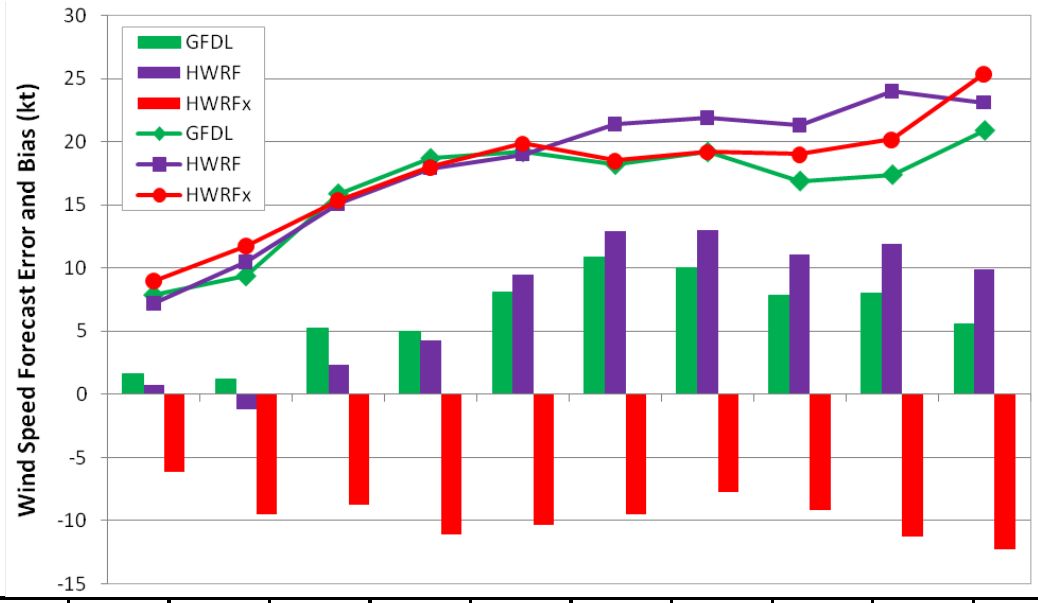


Figure 1: Framework of the HWRFx modeling system.



Time	12 h	24 h	36 h	48 h	60 h	72 h	84 h	96 h	108 h	120 h
GFS	41.6	68.4	93.2	107.1	137.3	147.1	181.3	216.2	244.9	280.4
GFDL	38.1	55.3	80.0	97.9	127.5	155.6	188.6	232.9	265.3	312.3
HWRF	37.5	57.8	85.8	96.6	131.0	139.3	165.5	213.0	239.1	286.2
HWRFx	42.6	72.4	98.2	119.6	146.3	162.6	186.3	210.0	225.5	260.9
Cases	57	51	46	40	38	32	29	25	21	20

Figure 2: 2008 hurricane track forecast errors (nm) of GFS, GFDL, HWRF and HWRFx, which are averages of the numbers of cases shown in the last row.



Time	12 h	24 h	36 h	48 h	60 h	72 h	84 h	96 h	108 h	120 h
GFDL	7.9/1.6	9.4/1.2	15.9/5.2	18.7/5.0	19.2/8.1	18.2/10.9	19.2/10.0	16.9/7.8	17.4/8.0	20.9/5.6
HWRF	7.2/0.7	10.5/-1.2	15.1/2.3	17.9/4.3	19.0/9.5	21.4/12.9	21.9/13.0	21.3/11.1	24.0/11.9	23.1/9.9
HWRFx	9.0/-6.2	11.8/-9.5	15.4/-8.8	18.0/-11.1	19.9/-10.4	18.5/-9.5	19.2/-7.8	19.0/-9.2	20.2/-11.3	25.4/-12.3
Cases	62	57	52	46	43	37	33	30	27	24

Figure 3: 2008 hurricane 10-m wind speed forecast errors (curves) and biases (bars) of GFDL, HWRF and HWRFx, which are averages of the numbers of cases shown in the last row. The statistics are also shown in the table with the first number in each box of rows 2-4 referring to the absolute error (kt) and the second referring to the bias (kt).

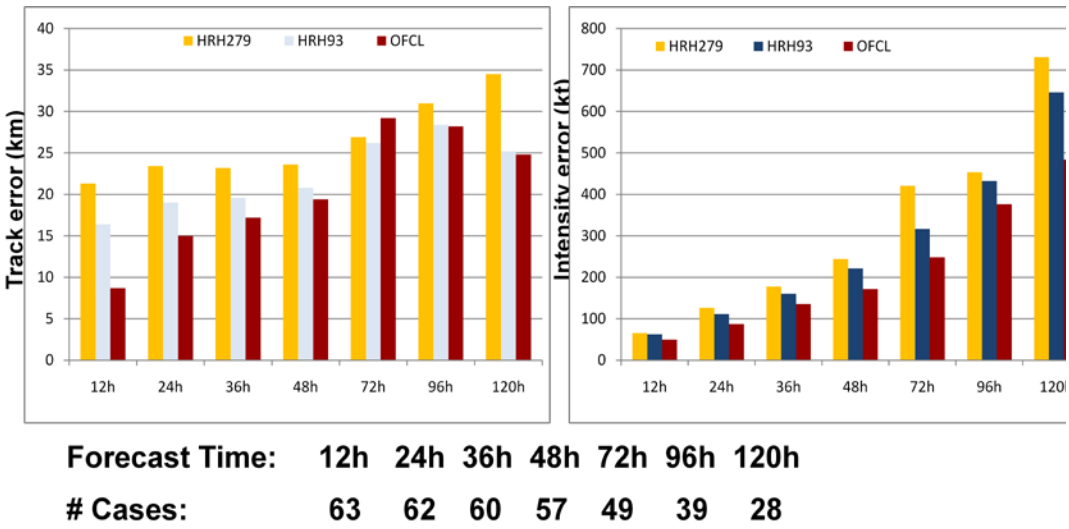
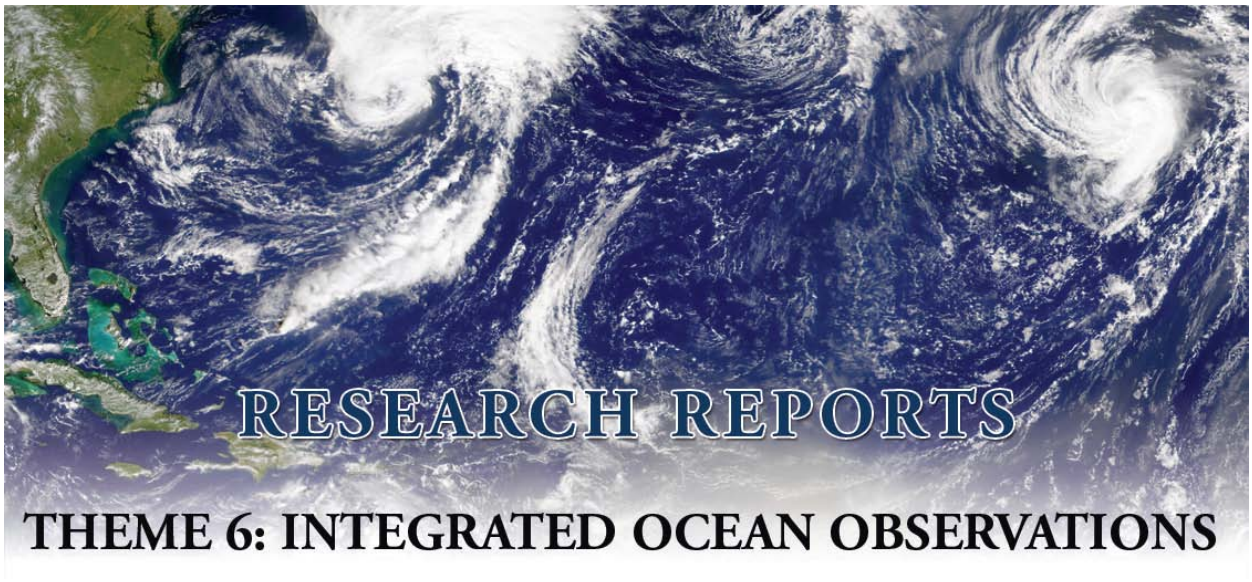


Figure 4: The HRH Test track and intensity errors. HRH279 refers to a domain of 27-km resolution with a moving nest of 9-km resolution. HRH93 refers to a 9-km resolution domain with a 3-km resolution moving nest. OFCL stands for the official forecasts by NOAA NHC.



Global Drifter Program

S. Dolk, E. Valdes and S. Elipot (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*:** *P*roduce 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/CPO **NOAA Technical Contact:** Rick Lumpkin

Research Summary:

The Global Drifter Program (GDP) is a principal component 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 project.

- *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 the 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.

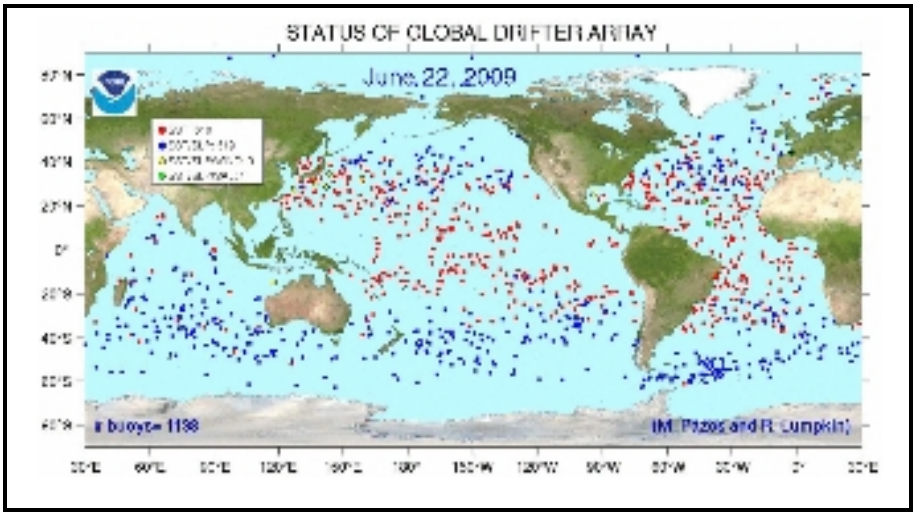


Figure 1: Status of the Global Drifter Array (updated weekly)

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 Tele-communications 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.

A major activity as an added task under this project is titled "Evaluating the Ocean Observing System: Surface Currents, an Add-on task in 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. The first global analysis of hourly-resolution drifter data was published in Elipot and Lumpkin, *Geophys. Res. Letts., 35,* 2008. This study documented the tidal, inertial and superinertial motion measured by drifters in the Atlantic, Pacific and Indian Ocean basins.

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

S. Dong, E. Forteza, R. Sabina, and L. Lin (UM/CIMAS);
V. Halliwell (UM/RSMAS); Y.-H. Chong Daneshzadeh, C. Schmid, S.L. Garzoli (NOAA/AOML)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** To improve our understanding of interannual to multidecadal ocean variability and its role in climate.

***Strategy*:** Monitor ocean parameters over large areas of the ocean through the maintenance and 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 profilers provide measurements of temperature and salinity to depths of 1000-2000 meters, and currents at the drift depth of the floats. Researchers in many scientific disciplines, 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 and implemented through CIMAS is responsible for deploying floats, and for acquiring and processing the data. The US DAC has developed and maintained an automatic system for decoding, quality control, and distribution of data obtained from the US Argo floats in real-time. The system runs in a 24/7 mode. The data are open to the public, and are used by scientists working on climate models and oceanographic data analysis. Some of the accomplishments in this year are:

- 383 floats were deployed by the USA
- 65 of these floats were deployed by AOML and CIMAS investigators
- 2198 US floats are actively reporting.
- 73063 profiles have been sent to Global Data Assembly Centers
- 55874 profiles were sent to GTS by the US DAC
- US DAC is processing 126 Argo-equivalent floats (i.e. not funded by Argo) from different institutions and organizations (Florida State University, NAVOCEANO, University of Hawaii); 17 floats were donated to Brazil and Argentina.

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.

As part of the South Atlantic Regional Argo Data Assembly Center the final quality control steps are being developed. They involve comparing Argo profiles after scientific quality control by float providers with each other and with other independently obtained profiles (for example those collected during research cruises) to determine if additional corrections are needed. Software has been developed to derive time series of the differences between the profiles of each float and climatology as well as nearby profiles from other instruments (e.g. XBT, CTD) at multiple levels. Summary statistics for each float are derived to allow the detection of floats with problems. A web-based system for navigation of the results from the statistics are being developed. This system will facilitate the detection of floats with potentially erroneous calibrations by the float provider.

Data from Argo floats and other instruments are used in conjunction with sea surface height anomalies from satellite altimetry to derive heat storage of the upper part of the water column in the world ocean. We also continue to derive the properties of the mixed layer (temperature, salinity and pressure) from the combined hydrographic data sets on a monthly basis and generate products showing the quarterly heat storage of the mixed layer.

The monthly fields of the mixed layer heat storage are used to generate maps of the annual mean for 2007 and 2008 (Fig. 1). At first glance these maps look quite similar. However, there are significant

differences (Fig. 2) in some areas: (1) there is a tongue of relatively low heat storage in the western Indian Ocean, just south of the equator (Fig. 1); (2) there are a positive anomalies in the eastern Indian Ocean (Fig. 2); (3) there are positive and negative anomalies in the tropical to subtropical Pacific Ocean that have a shaped like a v with the opening to the east, this is due to the anomalies arising from the negative phase of the 2007 ENSO event (La Nina, Fig. 2); (4) in the Atlantic Ocean positive anomalies predominate on the northern hemisphere, whereas negative anomalies are more prevalent in the southern hemisphere (Fig. 2).

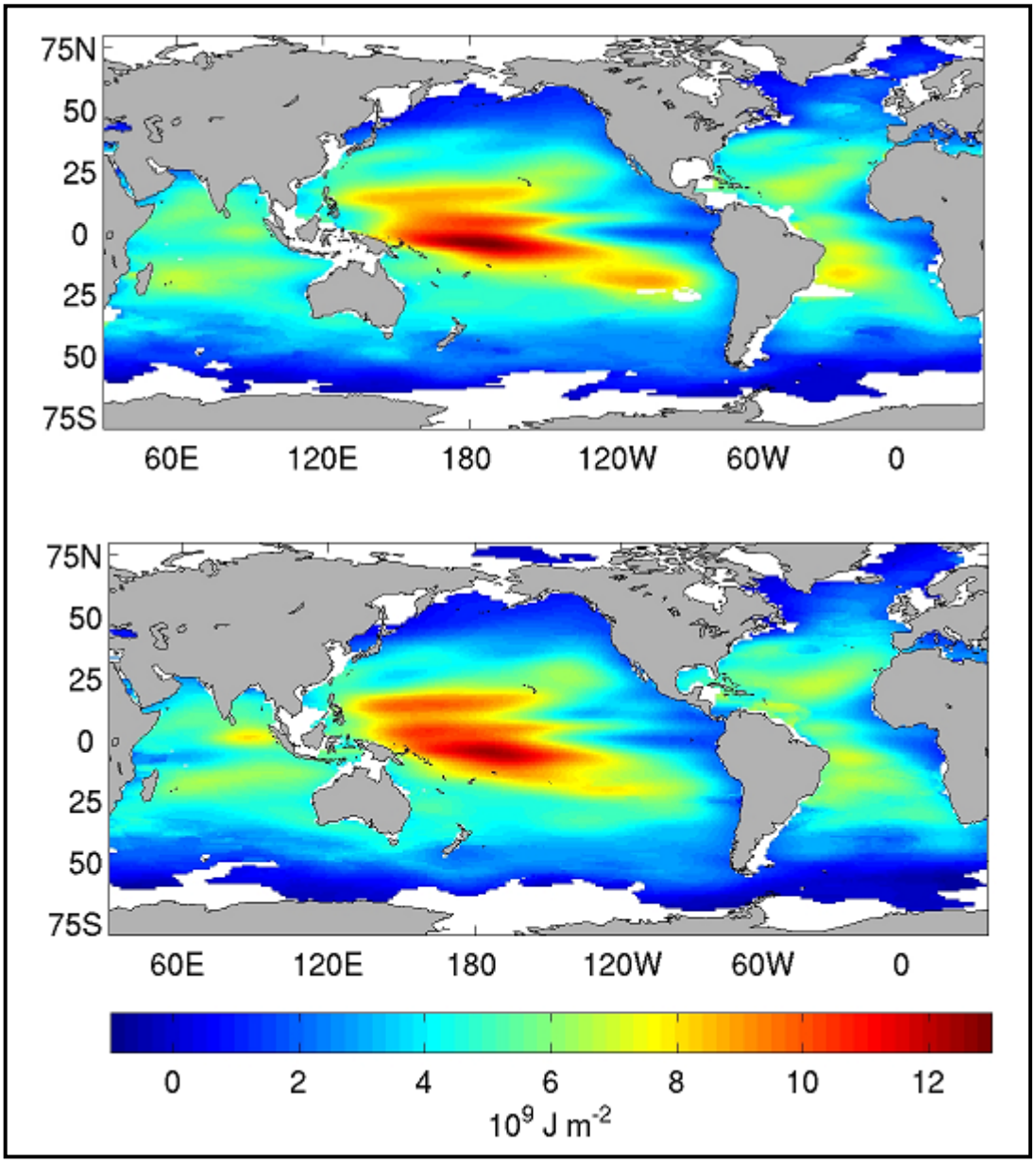


Figure 1: Ocean mixed layer heat content estimated following Schmid (2005) for calendar years 2007 (top) and 2008 (bottom).

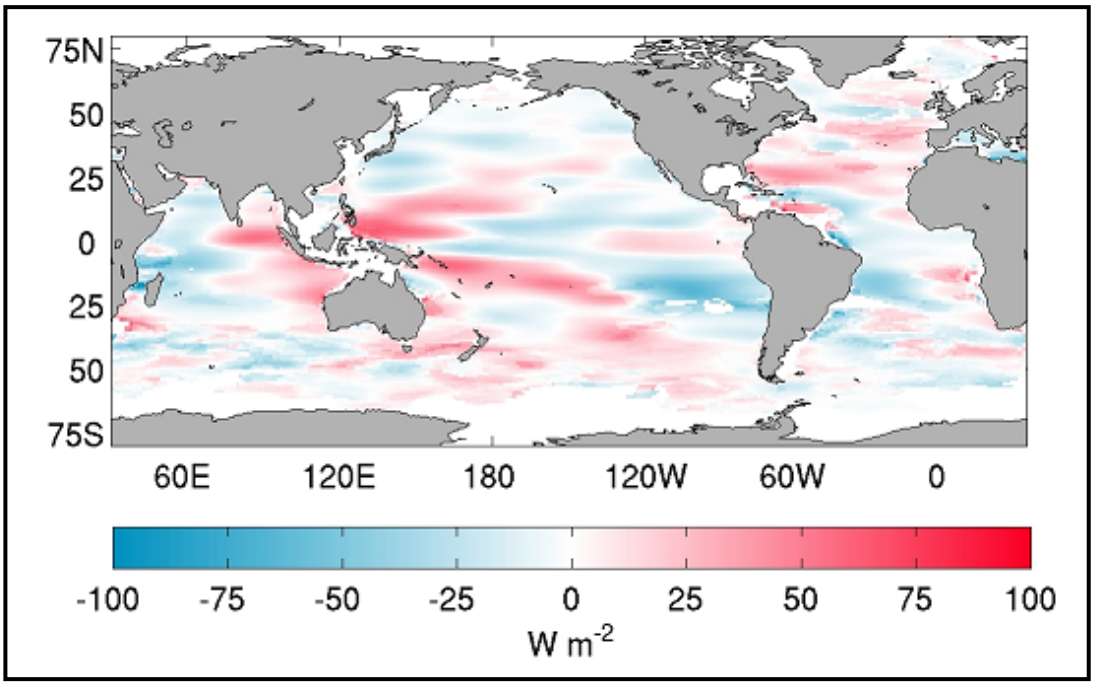


Figure 2: Change of ocean mixed layer heat content estimated following Schmid (2005) expressed as a surface heat flux equivalent (W m-2). The map is based on subtraction of a yearly mean of ocean mixed layer content for calendar year 2007 from that for calendar year 2008.

The same hydrographic data set is used in conjunction with trajectories from subsurface floats (including Argo floats) to analyze the spreading of the Antarctic Intermediate Water (AAIW) in the Atlantic Ocean. Figure 3 shows the annual mean of the zonal transports in the 800-1100 dbar layer for the South Atlantic Current and the Benguela Current Extension. These two currents are part of the subtropical gyre in the South Atlantic. The Figure reveals a clear tendency that the transports decrease from west to east. A linear fit has been applied to further analyze this longitude dependence.

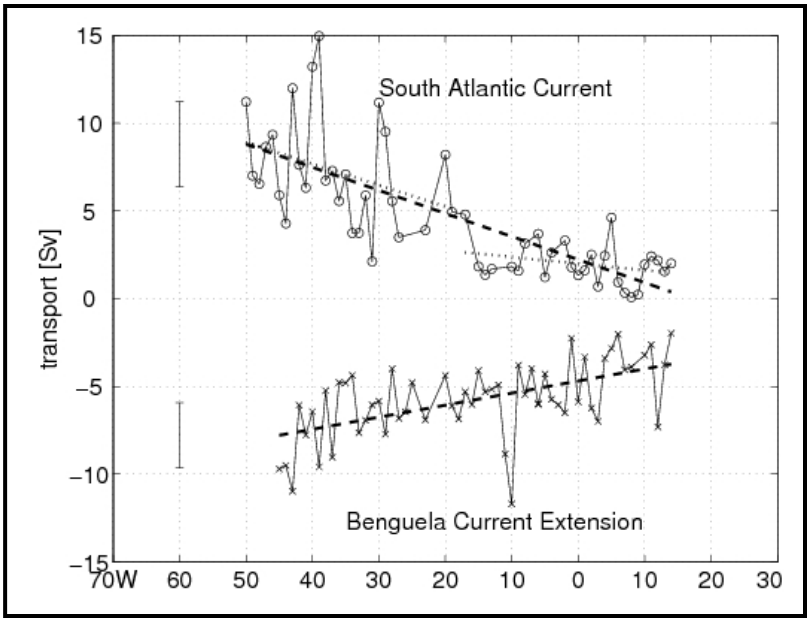


Figure 3: Annual mean zonal transports of the eastward and westward currents between 800 and 1100 dbar, that form the subtropical gyre in the South Atlantic. The mean was derived from quarterly fields of the velocity that were derived from float trajectories. The error bars to the left of the curves reflect the error of the linear fits indicated by dashed lines. A piece-wise linear fit for the transport of the South Atlantic Current is indicated by dotted lines.

The slopes of the fits are: -0.133 for the SAC based on all longitudes, -0.128 for the SAC west of 17.5°W, -0.038 for the SAC east of 17.5°W, and 0.067 for the Benguela Current Extension. Transports in the zonal currents of the subtropical gyre in the South Atlantic in the 800 to 1100 dbar layer.

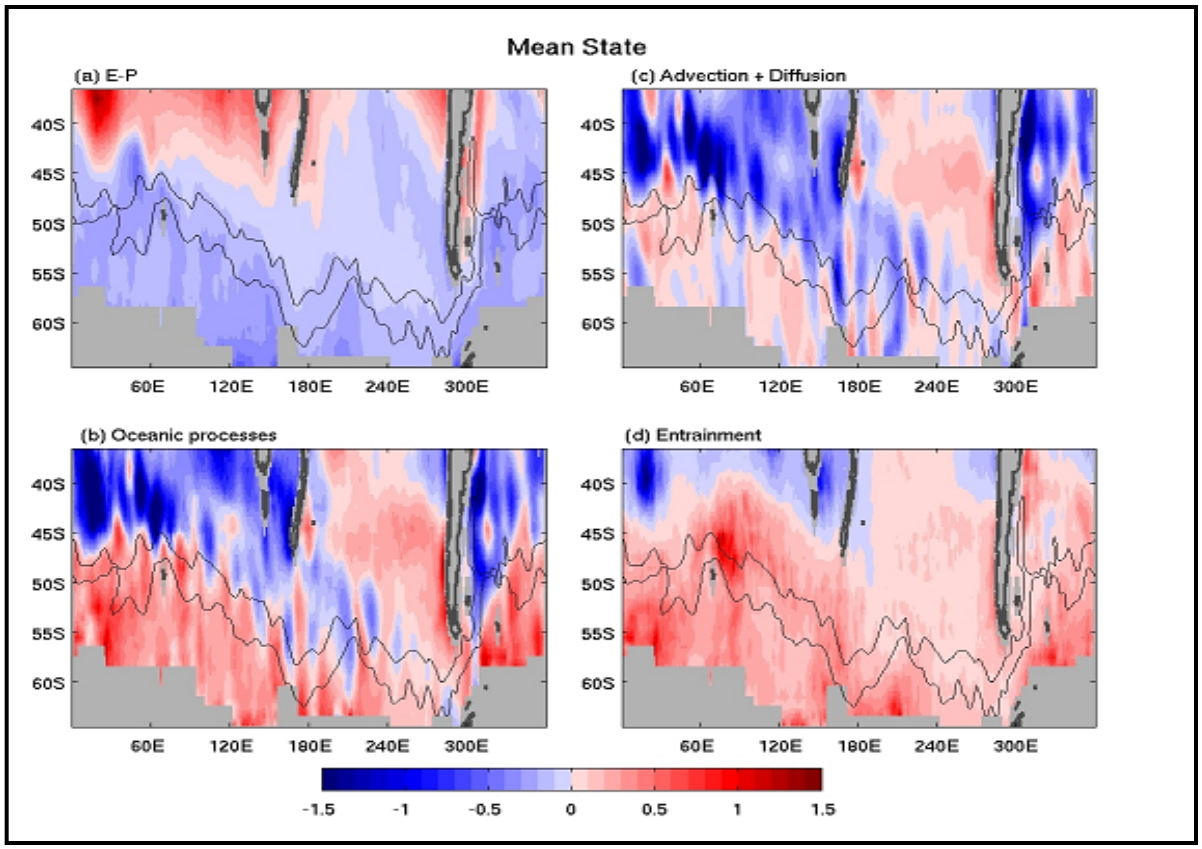


Figure 4: Spatial distribution of the time-mean (a) air-sea freshwater flux defined as positive out the ocean (Sm(E-P)/hm), (b) oceanic processes (advection + diffusion + entrainment), (c) advection-diffustion term, and (d) entrainment. The black lines denote the SAF and PF, respectively. Units are psu/year.

Profiles from Argo float are also used to assess the seasonal mixed-layer salinity Budget in the Southern Ocean, in combination with remotely sensed measurements. The domain-averaged terms of air-sea freshwater flux (evaporation minus precipitation, Fig. 4a), oceanic advection and diffusion (Fig. 4c), and entrainment (Fig. 4d) are largely consistent with the seasonal evolution of mixed-layer salinity. This seasonal cycle is largely attributed to the oceanic advection and entrainment (Fig. 4b), while the air-sea freshwater flux (Fig. 4a) plays a minimal role. The advection-diffusion term itself is dominated by the Ekman advection (Fig. 5). The spatial structure of salinity tendency in each month is also well captured by the sum of contributions from air-sea freshwater flux, advection-diffusion, and entrainment (not shown). However, substantial imbalances in salinity budget exist locally, particularly in regions with strong eddy kinetic energy and sparse in situ measurements. Sensitivity tests suggest that a better freshwater flux product, and an improved surface salinity field itself are important to close the budget.

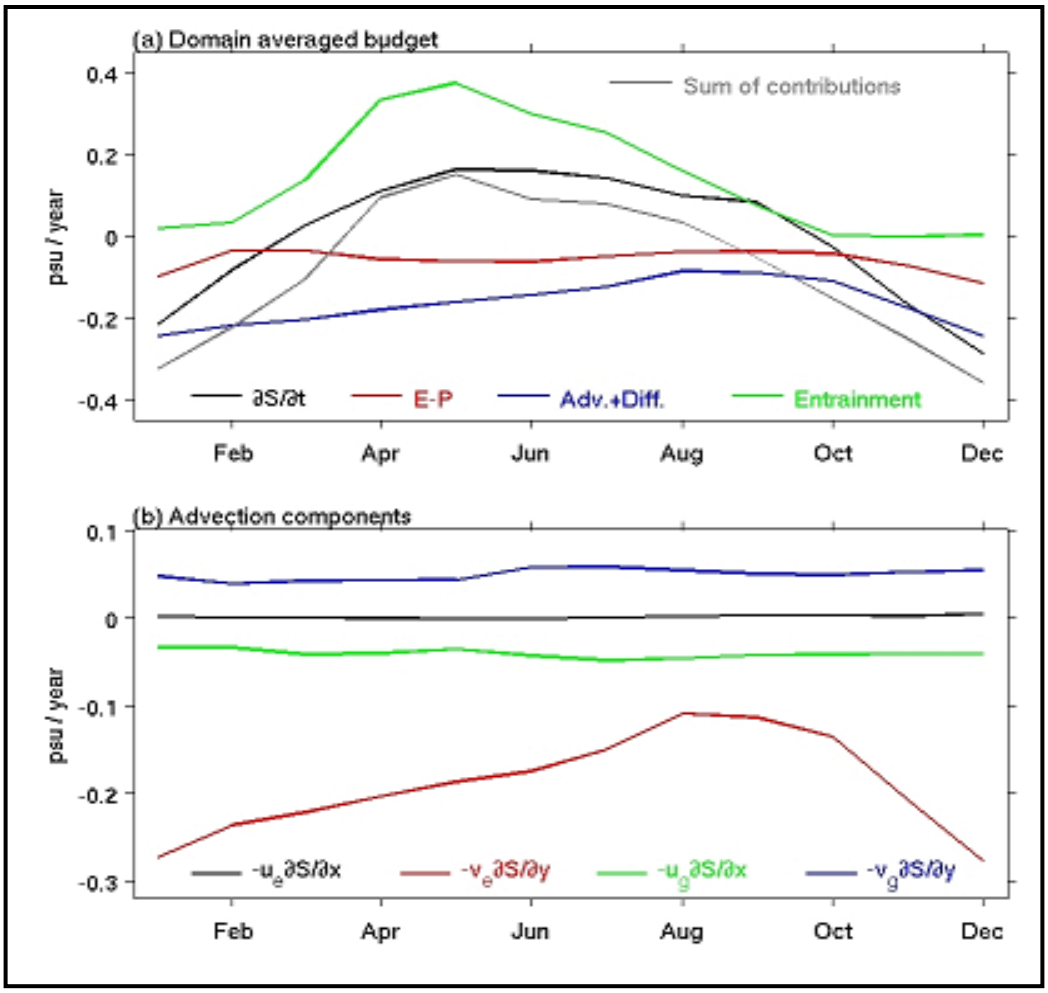


Figure 5: (a) Domain-averaged salinity budget in the Southern Ocean (35°S-65°S). The gray curve is the sum of contributions from air-sea freshwater flux (red, positive out of the ocean), oceanic advection-diffusion (blue), and vertical entrainment (green) to the salinity tendency (black). (b) Contributions of the zonal and meridional geostrophic advection and Ekman advection to the total advection.

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

Extending the Pathfinder SST V5 Fields to Include NOAA-7 1981-1984

R. Evans and K. Kilpatrick (UM/RSMAS)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** To ensure the long term availability of the NOAA/NASA AVHRR Pathfinder SST timeseries by transferring the algorithms, code and expertise to NODC.

***Strategy*:** Extend the climate quality AVHRR Pathfinder SST time series to include the NOAA-7 period of 1981-1984.

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:** Chet Ropelewski

Research Summary:

The NOAA-7 time period from Fall, 1981 to early 1984 has been processed through the NOAA/NASA Pathfinder SST analysis procedure and has been added to the Pathfinder time series. This effort has required extensive interaction with Dick Reynolds, NCDC, to initially acquire sufficient in situ ship observations to augment the sparse in situ buoy SST observations in order to obtain sufficient data from which NOAA-7 satellite retrieval equations could be developed. Subsequently, an iterative process was initiated where our group processed daily, 4km Pathfinder SST fields and provided these to Dick for incorporation into his daily OI scheme. The resulting Reynolds fields then provided a reference SST field that was incorporated into the Pathfinder processing. After several iterations, a final Pathfinder NOAA-7 data set was prepared and transferred to Ken Casey, NODC, for distribution to the CPO/OAR/NOAA and general Pathfinder user community.

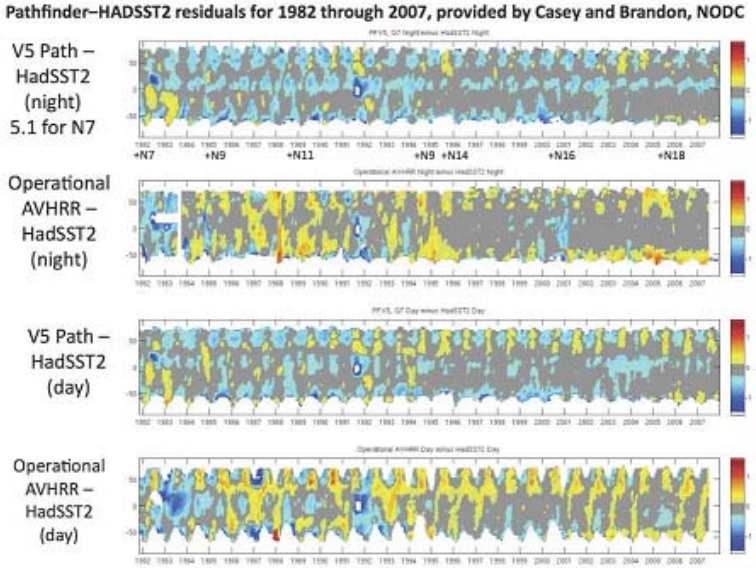


Figure 1: Day and Night differences between the NOAA/NASA Pathfinder SST time series and the comparison NOAA Operational AVHRR product referenced to the Hadley Center HadSST2 data set. The time periods for the various NOAA satellites are shown at the bottom of the first figure section. The Pathfinder SST shows improved consistency of the residuals compared to the operational NOAA SST product. Time period is from the start of the NOAA 5 channel AVHRR series in Fall 1981 through the end of 2007. The complete Pathfinder SST time series is available through NODC.

Research Performance Measure: Delivery of the NOAA-7 daily, 4km Pathfinder SST data set has met schedule and is archived at NODC.

Western Boundary Time Series Project

C. Fonseca, R. Garcia, G. Berberian, Q. Yao, G. Rawson, N. Melo, K. Seaton,
P. DiNezio, L. Gramer, F. Bringas and A. Stefanick (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*:** 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. The requisite charter ship-time is provided CIMAS by NOAA/NMAO.

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 and NOAA/NMAO
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 has been maintaining 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, the monitoring and data distribution systems for the Florida Current cable program have continued to see improvement, providing Florida Current transports in near real time via the web page www.aoml.noaa.gov/floridacurrent/ (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.

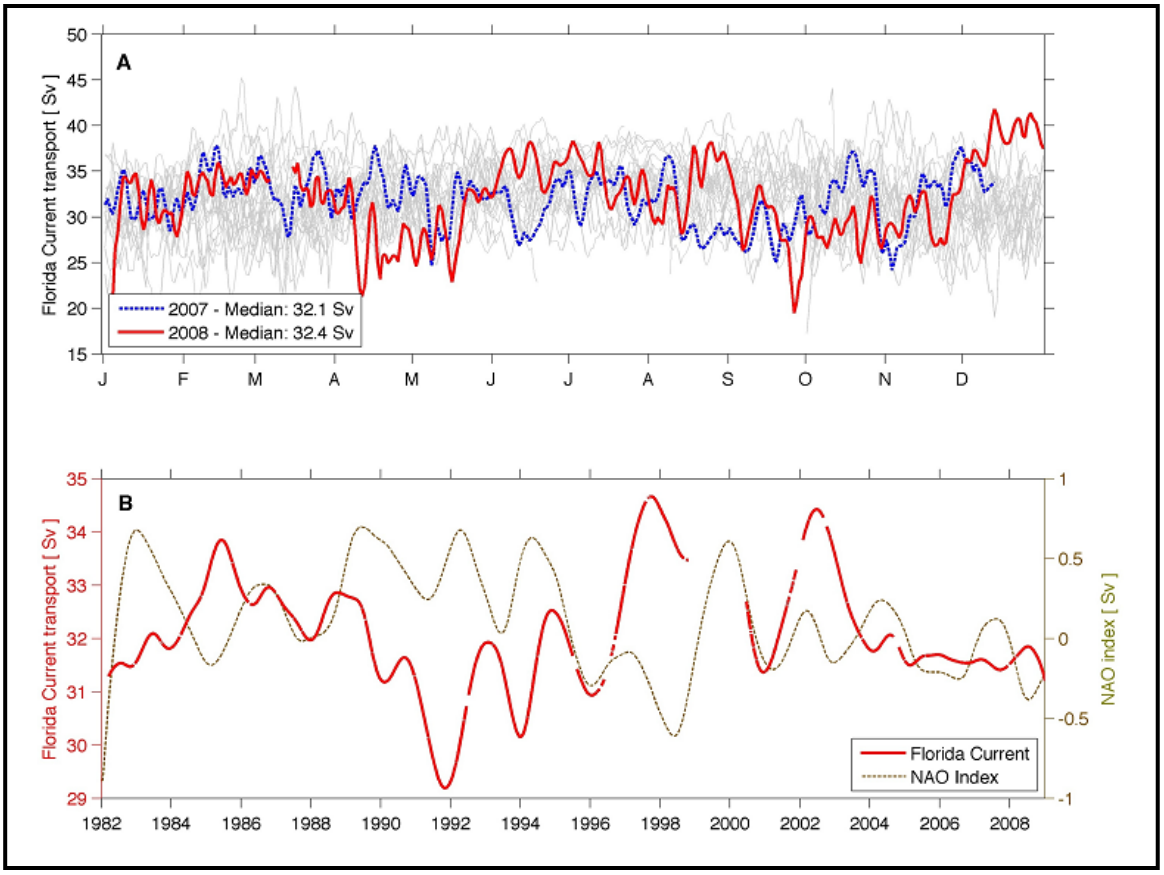


Figure 1: (A, top) Daily estimates of the transport of the Florida Current for 2008 (red solid line) compared to 2007 (dashed blue line). The daily values of the Florida Current transport for other years since 1982 are shown in light grey. The median transport in 2008 increased slightly relative to 2007 and 2006, and is slightly above the long-term median for the Florida Current (32.2 Sv). (B, bottom) Two-year smoothed Florida Current transport (red) and NAO index (dashed orange). The daily Florida Current transport values are accurate to 1.1-1.7 Sv (Meinen *et al.*, 2009) 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.

Synoptic Estimates of Sea Surface Ocean Acidification

D. Gledhill (UM/CIMAS); R. Wanninkhof (NOAA/AOML);
C.M. Eakin (NOAA/CRW); J.W. Morse (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 chemistal 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 satellite-based algorithms that drive this experimental model are regionally specific to the GCR and derived from underway and discrete geochemical survey data.

The details of the model are presented in Gledhill et al. [2008, *J. Geophys. Res.*, *113*, C10031, doi:10.1029/2007 JC004629] but are briefly described here. The general approach is to fully describe the carbonic acid system and solve for aragonites saturation state (Ω_{arg}) by deriving estimates of at least two of the carbonate parameters ($pCO_{2,sw}$, A_T, DIC, pH). To achieve this, daily fields of total alkalinity (A_T) and carbon dioxide partial pressure ($pCO_{2,sw}$) are computed through the application of a variety of modeled and remotely sensed environmental parameters. Sea surface $pCO_{2,sw}$ is computed as a function of CO_2 gas solubility using an regionally specific empirical relationship according to [Gledhill et al., 2008]:

$$pCO_{2,sw} = y_0 + A \times EXP(-K_0 / B) + pCO_{2,air}$$

The temperature and salinity dependent gas solubility coefficient (K_0, moles kg^{-1} atm^{-1}) is calculated according to Weiss [1974, *Marine Chem.*, *2*, 203-215] in Near-Real-Time using the 1/4-degree gridded fields of daily OI AVHRR + AMSR-E SST OI.2 (henceforth referred to as SST_{OI}) and Real-Time Ocean Forecast System (Atlantic) SSS. Atmospheric CO_2 partial pressure ($pCO_{2,air}$) is computed according to:

$$pCO_{2,atm} = XCO_2(SLP - pH_2O)$$

where sea-level pressure (SLP) is obtained from NCEP, water vapor pressure (pH_2O) is calculated as a function of SST_{OI} according to the empirical formula offered by Cooper *et al.*, [1998, *Marine Chem.*, *60*, 147], and the dry atmospheric CO_2 mole fraction data (XCO_2) are obtained from the GMD Carbon Cycle Cooperative Global Air Sampling Network [Thoning *et al.*, 1995, *J. Atmos. Oceanic Tech.*, *12*, 1349 – 1356]. Estimates of sea surface A_T are derived according to the (sub)tropical relations offered by Lee *et al.* [2006, *Geophys. Res. Lett.*, *33*, L1905, doi:10.1029/2006GL027207] for using a simple empirical equation of the form:

$$A_T = a + b(SSS - 35) + c(SSS - 35)^2 + d(SST - 20) + e(SST - 20)^2$$

Monthly composites of daily A_T and $pCO_{2,sw}$ fields are then coupled to solve the carbonic acid system using the CO_2SYS program [Lewis and Wallace, 1998, ORNL/CDIAC-105, Carbon Dioxide Information Analysis Center, Oak Ridge National Laboratory, U.S. Department of Energy, Oak Ridge, Tennessee].

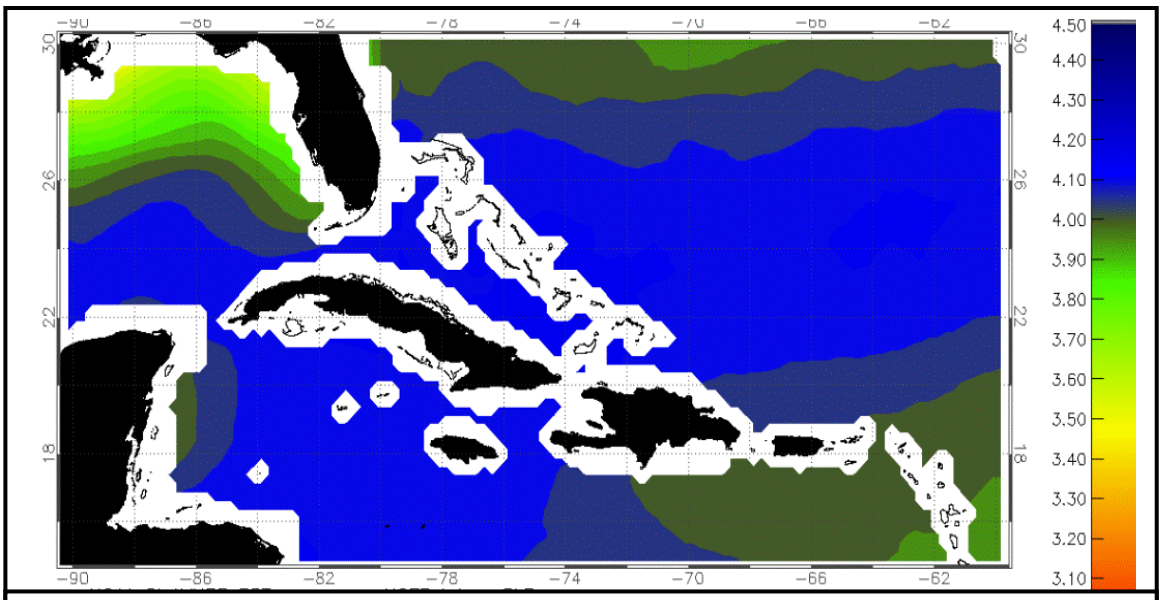


Figure 1: Example output from the Experimental Ocean Acidification Product Suite v0.1 showing the annual composite aragonite saturation state across the Greater Caribbean Region for 1996.

Research Performance Measure: The program is progressing according to plan. We have further constrained and verified the Greater Caribbean models and are working to advance it to other regions. The current model exhibits a mean residual $\Omega_{arg} = -0.2 \pm 0.08$ with the GCR.

Integrated Coral Observing Network (ICON) Project

L. J. Gramer, M. Jankulak and D. Gledhill (UM/CIMAS); C. Langdon (UM/RSMAS);
J.C. Hendee, D.P. Manzello, M. Shoemaker, J. Craynock, J. Stamates (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 processes that affect the health and life cycles of organisms in the reef system, 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 assessment of the physical and biogeochemical environment at these reefs.

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

NOAA Funding Unit: Coral Reef Conservation Program
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 2008-2009 year, the ICON project continues to focus its efforts in two primary areas: (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. ICON stations continue to operate at Salt River, St. Croix in the U. S. Virgin Islands ("SRVI2") and at La Parguera, Puerto Rico ("LPPR1"). Until November of 2008, an ICON station also operated at Discovery Bay, Jamaica ("DBJM1"). A new ICON station and suite of monitoring instruments have been shipped to Little Cayman Research Centre in the Cayman Islands, awaiting final deployment at a site on the north shore of Little Cayman in the summer of 2009. Finally, a cooperative effort between the ICON and SEAKEYS projects is currently underway to reinstall instrumentation and begin near real-time transmission of monitoring data from the Lee Stocking Island station ("LSIB4"), pending funding in 2009. Plans call for additional deployments of ICON stations during the coming fiscal year, in both the Caribbean Sea and at several locations in the Indo-Pacific region. During the past year, data acquisition and collection procedures at all ICON stations have been normalized, allowing near real-time quality assurance and archiving of ICON data by the NOAA National Data Buoy Center, for use by the National Weather Service and other entities in modeling and forecasts.

Biological monitoring of coral reefs at each ICON and SEAKEYS site continues to form an integral part of the ICON mission, with visual and photographic surveys by field biologists and ecologists in collaboration with the ICON team throughout the past year (e.g., see Fig. 1 below).

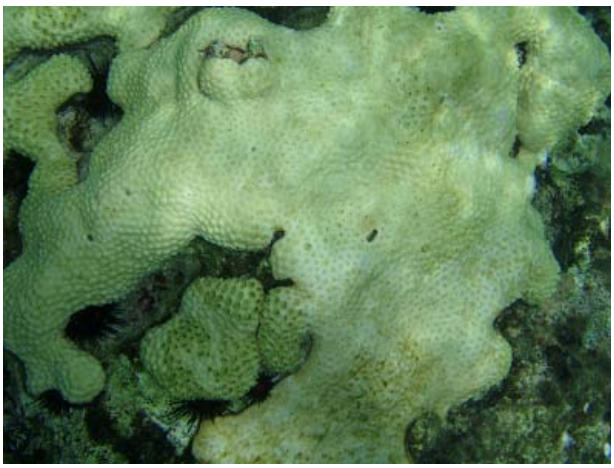


Figure 1: Colony of *Palythoa caribaeorum* displaying visually discernible bleaching. Photo taken by Dr. Derek Manzello as part of a qualitative biological survey at Enrique and Media Luna Reefs from 29-31 July 2008 near La Parguera, Puerto Rico.

s part of a cooperative effort with the NOAA Pacific Marine Environmental Laboratory (PMEL), a Moored Autonomous Profiler for Carbon Dioxide (MAPCO2; see Fig. 2 below) buoy was deployed at the La Parguera embayment in January 2009; combined with physical sensors deployed at the LPPR1 ICON station nearby, this novel system is designed to provide near real-time feedback for studies of ocean acidification and its impact on coral reef ecosystems. As of May 2009, instruments have also been deployed at Tennessee Reef lighthouse ("TNRF1") in the Florida Keys National Marine Sanctuary, as part of a cooperative endeavor with the Florida Institute of Oceanography (SEAKEYS program) and the NOAA Great Lakes Environmental Research Laboratory (GLERL). This monitoring station will combine two innovative instruments – a BioSonics DT-X Digital Scientific Echosounder System for near real-time measurement of reef fish and zooplankton abundances, and a Pulse Amplitude Modulated (PAM) fluorometer for near real-time monitoring of coral symbiont photosynthetic efficiency. This collaborative deployment will characterize multiple indices of reef ecosystem health at this trial site, relating these indices to a set of physical variables (meteorology, ocean currents, hydrography) being simultaneously measured there. In March of 2009 in Port Everglades channel, a suite of instruments was deployed to monitor the salinity, temperature and current structure of inflow and outflow through the channel, and to attempt to characterize the impact of those flows on coral reefs just offshore. This station ("PVGF1") is part of an ongoing collaboration between ICON and the NOAA Florida Area Coastal Environment (FACE) project.

Development has also continued on the ICON/G2 data integration and ecological forecasting system, a research platform that combines station observations from instruments such as pCO_2 sensors, multi-spectral light instruments, meteorological, ocean-current and hydrographic instruments and others, together with data from satellite sensors including NOAA GOES, MODIS, AVHRR, AMSR-E, TRMM and QuikSCAT. The resulting high-resolution, near real-time integrated data streams are used to predict conditions conducive to coral bleaching, to upwelling or 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 protected-resource managers, and to the public via the ICON/G2 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. Research results published using ICON/G2 in 2009 include anautomated system to ground-truth, and in turn implement ecoforecasts based on, very high-

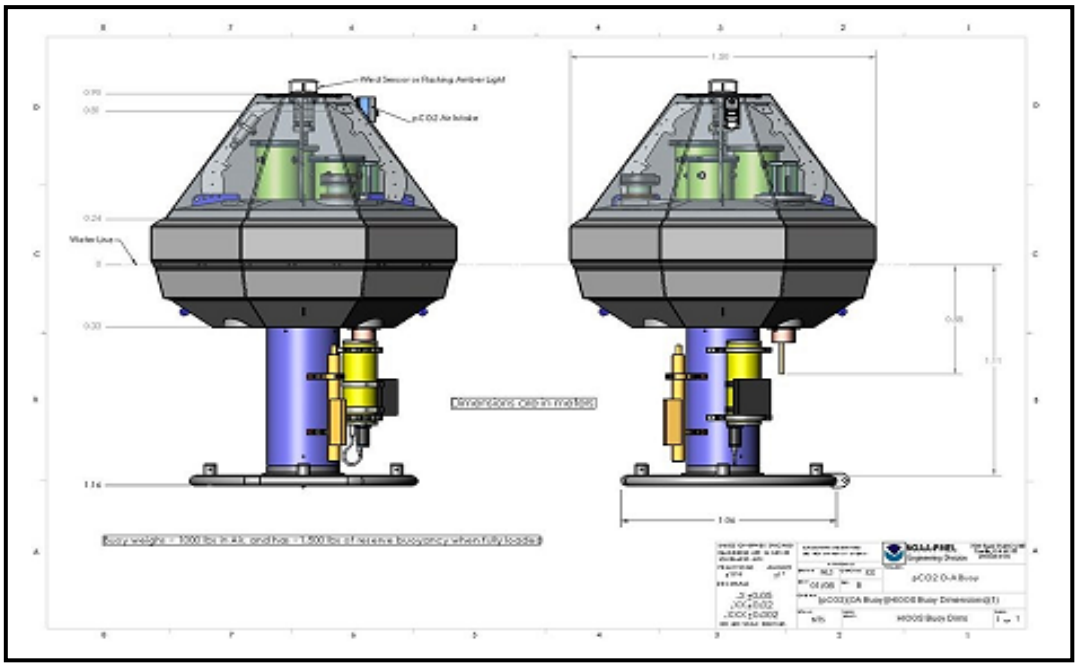


Figure 2: Schematic of the MAPCO2 buoy installed in January of 2009 near ICON station "LPPR1", within the La Parguera embayment, Puerto Rico. (Buoy design diagram courtesy of NOAA PMEL.)

resolution (1km), near real-time datasets for Sea Surface Temperature (SST) and chlorophyll *a* concentration in Florida coastal waters (University of South Florida, see Fig. 3 below); and a system to subset a high-resolution (9km) global gridded SST dataset (MISST) for ecological forecasts on coral reefs in the Pacific Islands and other remote reef locations. Finally, in May of 2009 a collaborative project funded by NASA (grant # NNX09AI88G) has begun between researchers at NOAA ICON, the University of Miami, and Remote Sensing Systems Inc. of California, to develop a very high-resolution daily gridded SST data set with corrections for diurnal warming, to be specifically applied to ecoforecasting on shallow coral reef sites around the world.

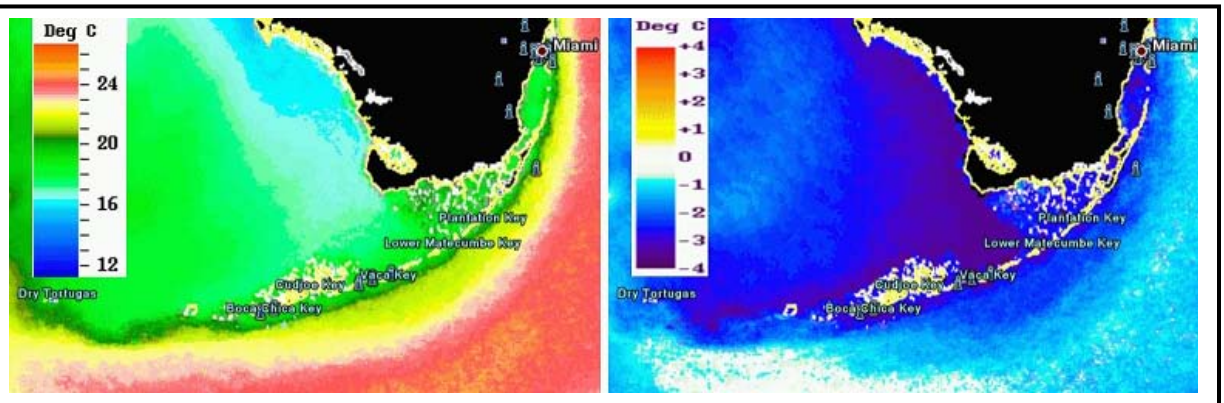


Figure 3: High-resolution (1-km) satellite composite images showing mean sea surface temperature (SST) and SST anomaly (SSTA) in ºC for the week of 5-11 February 2009. Large gradients around the Florida Reef Tract are clearly visible, where water is 2-4ºC colder than normal. These SST / SSTA fields are updated weekly, and are used for forecasts of coral bleaching and other ecological events by the ICON/G2 system. (Data courtesy of University of South Florida.)

Research Performance Measure: All objectives were reached.

Enabling and Initiating Observing System Simulation Experiments of the Coastal High Resolution Oceanographic Model in the Northern Gulf of Mexico

V. Kourafalou (UM/RSMAS); P. Ortner and M. Le Henaff (UM/CIMAS);
R. Atlas and G. Halliwell (NOAA/AOML)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** To quantify the contribution of new ocean observing systems to the quality of coastal nowcasts; to assess the influence of downscaled information from basin scale ocean models on the capability of nested regional/coastal models to reproduce mean conditions and seasonal variability, and to both hindcast and forecast synoptic and mesoscale/submesoscale variability.

***Strategy*:** Develop a nested system of (a) a high resolution coastal model in an area of strong coastal to offshore interactions and strong land-sea interactions (Northern Gulf of Mexico) and (b) a regional (Gulf of Mexico) model and perform numerical simulations that represent the coastal dynamics with enough accuracy (as validated through observations) to enable Ocean System Simulation Experiments (OSSEs).

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 represents a unique collaboration between two cooperative institutes (CIMAS and the NGI), and two federal agencies (NOAA and DOD/NRL). In addition, it 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 Northern Gulf of Mexico is a unique coastal region where circulation and its regulation of biogeochemical processes are especially influenced by intense watershed interactions due to the Mississippi River and by strong offshore influences due to the episodic proximity of the Loop Current. This study aims to elucidate and predict the transport and fate of river-borne waters on the Northern Gulf of Mexico and enable the performance of prototype Observing System Simulation Experiments and, thereby, guide the design of the Gulf Coastal Oceanographic Observing System (GCOOS).

To accurately downscale offshore variability into the coastal domain, models must be nested within fields that accurately represent the state of the ocean and its variability at the nested model boundaries. We have developed a high resolution coastal model for the entire Northern Gulf of Mexico (NGoM model, resolution ~1.8 km), based on the publicly available HYCOM (Hybrid Coordinate Ocean Model) code. The NGoM-HYCOM is nested in a regional, data assimilative model of the entire Gulf of Mexico (GoM-HYCOM, resolution ~4 km), which is itself nested within the

U.S. GODAE model for the entire North Atlantic. We thus connect a coastal effort (collaboration with the NGI) with regional (collaboration with NRL) and international/global (collaboration with GODAE) efforts.

The study findings suggest that the downscaling, nested approach was crucial for the simulation of the complex circulation in the Northern Gulf of Mexico and its influence on the pathways of Mississippi River (MR) waters. In addition to the buoyancy-driven (due to river runoff), westward coastal current (along the Texas-Louisiana shelf), transport processes due to topography and interaction with the shelf break and offshore circulation (namely the Loop Current, LC) were revealed. In particular, NGoM-HYCOM simulations with realistic forcing showed a tendency of riverine waters to reach the DeSoto canyon during periods of light winds and in the absence of direct interaction with the LC (Figure 1), in agreement with ocean color imagery where chlorophyll-a serves as a proxy for the variability of the brackish MR waters. This finding has implications for "upstream" (toward the Mississipppi-Alabama and Florida panhandle) MR influence. During periods of direct LC influence, simulations elucidated offshore removal of the MR waters, through eddy action near the shelf break. Associated with the LC, warm core eddies (LCEs) and frontal eddies (LCFEs) were found to have a pronounced impact on the formation of jet-like offshore streaks of MR waters, supplying an extended pathway along the LC (Figure 1) that can reach the Straits of Florida, potentially impacting the fragile Florida Keys ecosystem.

Initial simulations toward Ocean System Simulation Experiments (OSSEs) have been performed in the Gulf of Mexico. To perform efficient data assimilation, it is necessary to have a realistic long term "free-running" simulation of the Gulf of Mexico, appropriately evaluated with observations to serve as the so-called "nature run" by ensuring the representation of the governing processes and dynamics. The first step of the validation has been to compare sea surface height from the model to sea level anomalies (SLA) from altimetry (along-track Jason 1 and Envisat data). Daily averaged model outputs have been interpolated on the same locations as the altimetric tracks, using only outputs from the closest date to the observations. The time average has been removed from each location along the tracks (in both model and data), to compare the time variability of the signal. The agreement between the two time series is very satisfying in terms of amplitude, scales and timing of the SLA signal. Ongoing OSSE related simulations involve improvements in model resolution, forcing and boundary conditions, toward a "nature run" for the Gulf of Mexico that will enable improved data assimilative simulations and the design of optimal ocean observing systems.

The study has highlighted that to successfully address (a) coastal circulation in a topographically complex area dominated by a large river plume, (b) coastal to offshore interactions and (c) connectivity of remote ecosystems, the following elements are essential: a comprehensive, high resolution coastal model; proper representation of river plume dynamics; suitable atmospheric forcing functions; and realistic boundary conditions from a data-assimilative regional model. The study of MR pathways has important implications on the Northern Gulf ecosystem dynamics, especially as related to the understanding and prediction of hypoxia events, and on sea level changes associated with extreme events and climate change, with implications on coastal resilience efforts.

Research Performance Measure: The two models developed in this study have been data validated, through satellite observations provided by AOML and the NGI and through in-situ data provided by NRL. The coastal NGoM-HYCOM model can provide hydrodynamic parameters for use by ecosystem models and by nearshore and wetland models concerned with coastal resilience. The regional GoM-HYCOM model has already demonstrated evaluation of data assimilation, resolution

and forcing toward Observing System Simulation Experiments (OSSEs) that will help guide the design for the Gulf Coastal Oceanographic Observing System (GCOOS). The study has fulfilled all planned research activities.

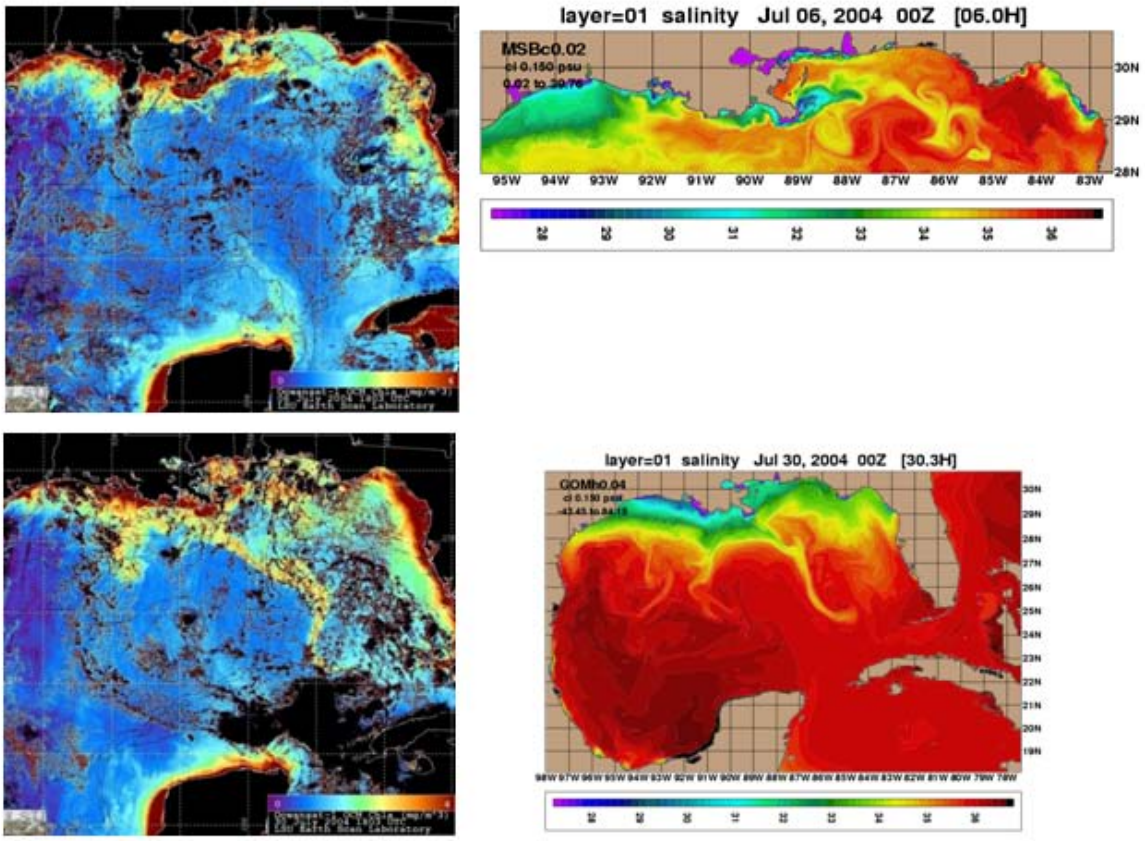


Figure 1: Comparison of satellite Ocean Color imagery (left panels, provided by LSU, an NGI academic affiliate) and model derived Sea Surface Salinity from the high resolution Northern Gulf model (NGoM-HYCOM, upper right) and the regional Gulf of Mexico model (GoM-HYCOM, lower right, provided by NRL-SSC; data assimilation scheme provided by NRL-MRY). The upper panels are for July 6, 2004, during a "young" Loop Current (away from the Northern Gulf); the lower panels are for July 30, 2004, during an "extended" Loop Current (approaching the Northern Gulf, near the Mississippi River delta). The eastward advection of MR waters (guided by the DeSoto canyon topography during light wind conditions) enhances the potential for offshore removal along the Loop Current front and toward teh Straits of Florida.

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) 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 processes that affect the health and life cycles of organisms in the reef system, 3) compile ecological forecasts for coral reef ecosystems to help to understand them, and to aid in decision support for Marine Protected Area management. 3) Determine the baseline rate of coral reef calcification at the test bed site in La Parguera, Puerto Rico using a combination of old and new geochemical techniques.

***Strategy*:** 1) Reoccupy transects on a decadal timescale to quantify the uptake of anthropogenic CO_2 by the ocean. 2) Construct meteorological and oceanographic monitoring platforms near key coral reef areas; to 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 assessment of the physical and biogeochemical environment at these reefs. 3) Apply the flowing waters method of measuring total alkalinity and dissolved inorganic carbon at upstream and downstream locations on a forereef, apply the alkalinity anomaly-water residence time method and apply a new method based on measuring the gradient in total alkalinity in the benthic boundary layer.

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

NOAA Funding Unit: OAR/CPO **NOAA Technical Contact:** Mike Johnson

Research Summary:

This project encompasses the participation of Dr. Langdon in two separately detailed CIMAS projects: The *CLIVAR CO_2 Repeat Hydrography Program* and the *Integrated Coral Observing Network (ICON)*. The background on both of those projects and the highlights from 2008 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). This project also supports Dr. Langdon to make biogeochemical measurements in support of the Integrated Coral Observing Network (ICON). Specifically this involves making measurements of coral reef calcification at the test bed site in La Parguera, Puerto Rico. The objective to establish baseline rates of system wide calcification against which it will be possible to judge the impacts of climate change in ensuing years. The test bed concept was developed at a Think Tank meeting organized by Jim Hendee that was held in Little Cayman in 2007. The idea is to apply a variety of different methods of measuring coral reef calcification in the same geographic area so that the results are intercomparable. Intercomparison experiments have not been performed in the past and more needs to be known about the relative strengths and disadvantages of the methods. Presentations describing the progress of this effort were made at national and international meetings in 2008.

Research Performance Measure: This program is attaining all its goals on schedule.

Climate Data Records of Sea-surface Temperature

P.J. Minnett and M. Szczodrak (UM/RSMAS)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** To determine the uncertainty characteristics of sea-surface temperature 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*:** 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 first year of the project effort has been directed at identifying the appropriate satellite data sets for analysis and quality control of the in situ measurements. An international workshop was hosted by the PIs at RSMAS in May 2009 to compare radiometric performance of several ship-based

radiometers and to provide NIST traceability to the radiometric measurements by characterizing the RSMAS laboratory black body cavity with the NIST TXR (Transfer Radiometer).

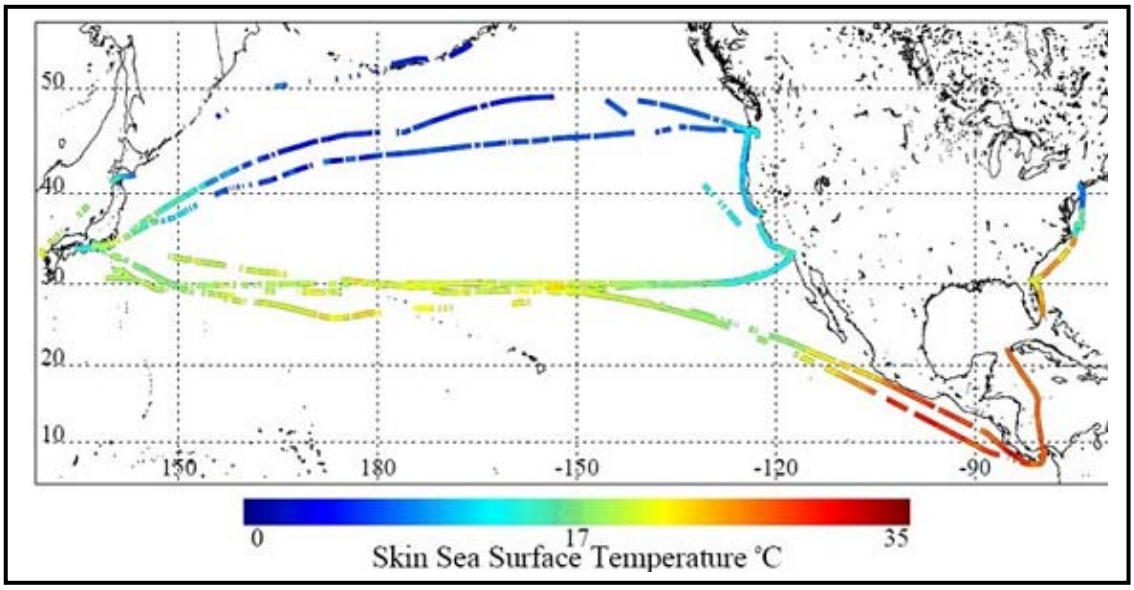


Figure 1: The tracks of the M/V *Jingu Maru* for January to June, 2008, with the colors indicating skin SST measured by an ISAR.

A long time series of measurements taken by one of the RSMAS ISARs (Infrared SST Autonomous Radiometer) mounted on the ship *Jingu Maru* as it plied across the Pacific Ocean in 2008 (Fig. 1), has been processed and analysis has begun. A second ISAR was mounted on the *Andromeda Leader* and thus far has produced many weeks of data, also in the Pacific Ocean. The radiometric characterization of the RSMAS infrared laboratory facilities has been done (Fig. 2), and the measurements are being conducted in a "double-blind" fashion at NIST and at the National Physical Laboratory in the UK. Orbital brightness temperatures from the microwave radiometer AMSR-E (Advanced Microwave Scanning Radiometer for the Earth Observing System) on the NASA *Aqua* satellite have been delivered by Remote Sensing Systems Inc to RSMAS for this analysis. Dr Ken Casey of NOAA NODC has agreed to assist in the provision of AVHRR AVHRR (Advanced Very High Resolution Radiometer) Pathfinder SSTs for this analysis, and Dr Pierre LeBorgne of Metéo-France has offered to provide SEVIRI (Spinning Enhanced Visible and IR Imager) data from the Eumetsat Meteosat Second Generation satellite over the Atlantic Ocean.

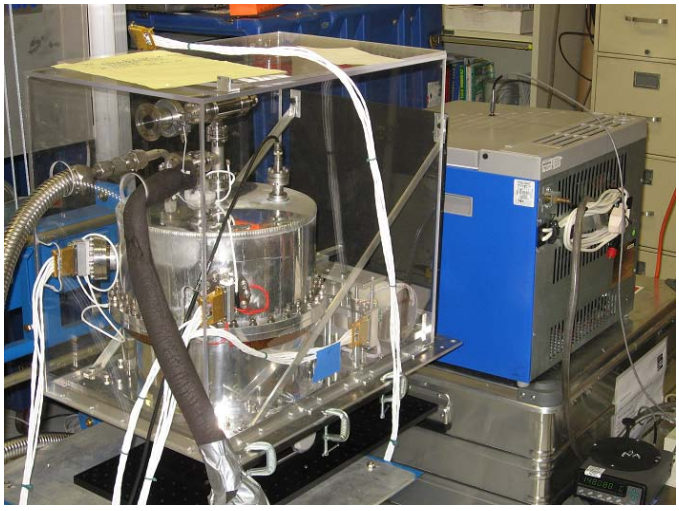


Figure 2: The NIST Transfer Radiometer (TXR) in the infrared laboratory at RSMAS during the International Infrared Radiometry Workshop, in May 2009.

Research Performance Measure: The project is largely on schedule.

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 develop new techniques for more efficient ocean observing systems. To evaluate time dependent uncertainties in depth estimates from XBT data.

Strategy: 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. Collaborate with modelers and surface drifter observationalists to develop methods to determine regions requiring future deployments. Compare XBT data with more accurate data to establish corrections to fall rate equations.

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/CPO **NOAA Technical Contact:** Joel Levy

Research Summary:

A time-dependent correction, including uncertainty estimates, to the depth values of XBT data developed by Australian scientists has been applied to the historical data. An attempt to verify these corrections using oceanographic data from weather ships was attempted. Several months of effort indicated that a larger activity is required to compensate for sampling differences in time and space between the XBT and weather ship observations.

Recognizing that temperature data can be used to study a wide range of ocean features and processes, the first stage of the project has been directed at using low-density XBT lines to study decadal variability of the subtropical and subpolar gyres of the North Atlantic. In the subpolar Atlantic, although lines do not extend over long periods they do show the presence of strong decadal signals in the position of near surface currents, which result in variable propagation of the mean temperature field. 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 the recently hypothesized slowing of the thermohaline circulation derived from only a few data points is not unique. The continuous XBT time series show that events used to define this event also occurred in the past.

A model has been developed using surface current fields derived from satellite-tracked drifters to determine areas that will require additional deployments in the near future. Results from the XBT study have been included in a report to the OceanOBS09 meeting on XBT sampling and will be used to establish future sampling approaches.

Research Performance Measure: Research objectives are being met, with some delay because of time directed at trying to verify fall rate equations for XBT probes. To perform this verification will require additional funding and at least a year of effort.

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–RCCL Ocean Fund
NOAA Technical Contact: Shailer Cummings

Research Summary:

In 2009 with funding provided through the Ocean Fund, we were were able to complete conversion of the Explorer of the Seas to full automation and begin autonomous data collection and dissemination.

Figure 1 below depicts the fully automated system that will be completed in the Fall of 2009 prior to the start of this operational phase. 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 ports
- 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 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.

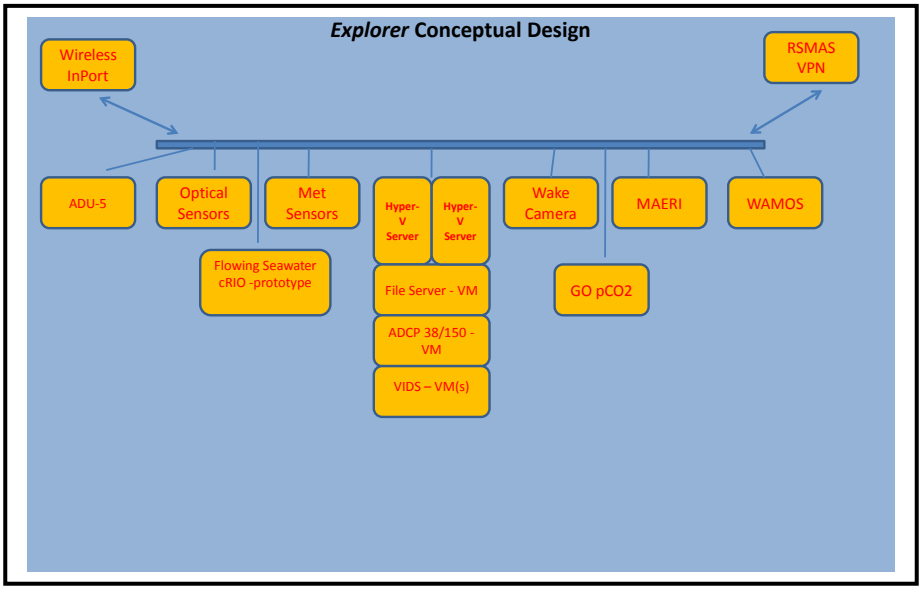


Figure 1 – The Concept Design of the Fully Automated Highly Flexible Oceanographic and Meteorological Sampling System to be operated aboard the EXPLORER.

Implementing the above has required close coordination with RCCL Information Technology Personnel during the course of the project with regard to maintaining the highest level of computer security for systems aboard the EXPLORER. We are grateful for their continuing cooperation. Depicted below is the current near final configuration.

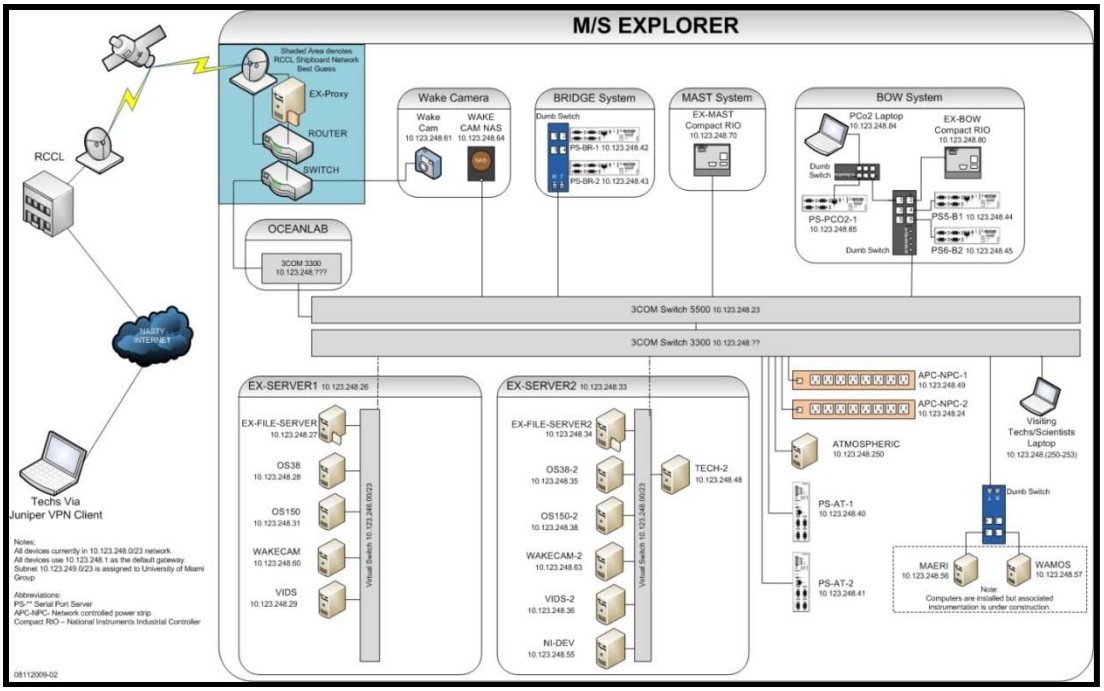


Figure 2: Computer connections (and IP addresses) of scientific systems aboard the EXPLORER (August 2009).

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 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 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 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). 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.
Results of the first meeting will be reported by Dr. Ortner to the international scientific community at OceanObs09 in Venice, Italy in September 2009. The next Working Group meeting will be hosted by the International Chamber of Shipping and will take place in London in April 2010.

Research Performance Measure: Timely completion of conversion of all core shipboard systems to full automation.

PIRATA Northeast Extension (PNE)

R. Perez and C. Alex (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*:**

1. improve the description of the intra-seasonal to interannual variability in the atmospheric and oceanic boundary layers of the tropical Atlantic Ocean;
2. 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;
3. provide a set of data useful for developing and improving the predictive models of the ocean-atmosphere coupled system;
4. document interactions between tropical Atlantic climate and variability outside the region, such as ENSO and the North Atlantic Oscillation;
5. design, deploy, and maintain an array of moored oceanic buoys and collect and transmit a set of oeanic and atmospheric data, via satellite in near-real time, to monitor and study the upper ocean and atmosphere of the tropical Atlantic Ocean.

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.

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

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.

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.

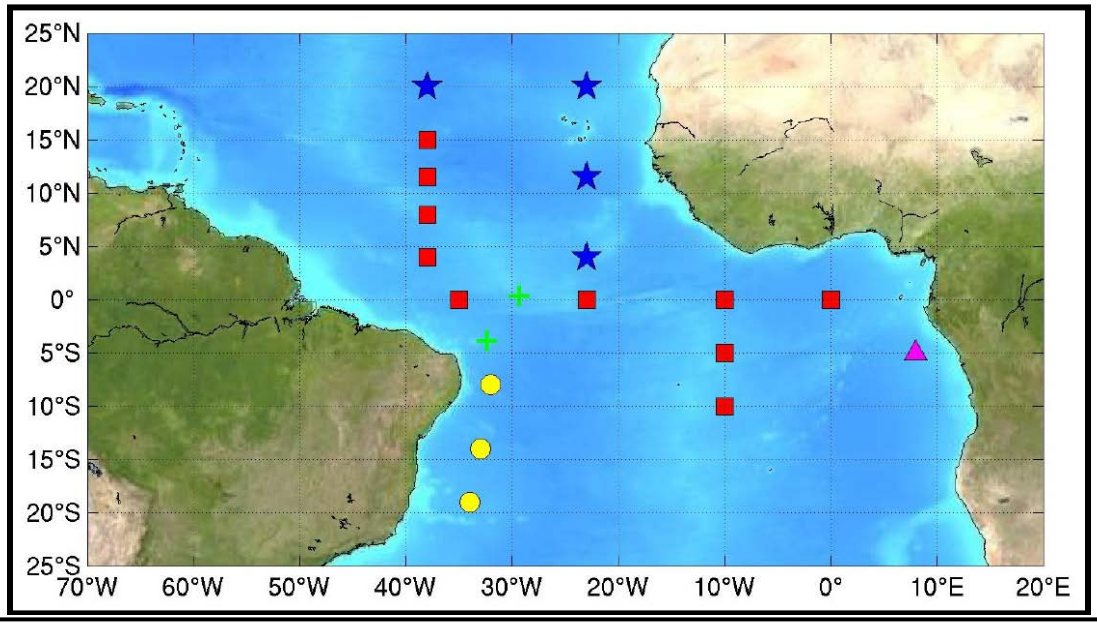


Figure 1: The Tropical Atlantic, showing the PIRATA backbone (red squares), automatic meteorological stations (green +), southwest extension (yellow circles), southeast extension pilot site (magenta triangle), and NOAA's northeast extension (blue stars).

Research Performance Measure: In April 2008, the PNE servicing cruise was planned aboard the NOAA ship Ronald H. Brown, scheduled for Montevideo to Barbados. The cruise was canceled due to safety concerns with the ship, and as a consequence all moorings of the northeast extension failed and created damaging gaps in the climate record. NOAA chartered a French research vessel, the R/V Antea, to replace the failed moorings in October—November 2008.

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) and 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*:** 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: AOML **NOAA Technical Contact:** Claudia Schmid

Research Summary:

The focus of this project is to support an international program that calls for the deployment of more than 3,000 drifting profiling floats, distributed over the global oceans. This will allow continuous monitoring of real-time ocean temperature and salinity.

Float processing software and programs of decoders are developed and implemented. The integration of all the decoders of all APEX floats makes the goal of developing one decoder that works for all APEX float types reachable. It will save a lot of time when new floats coming out. The decoders for eight float types have been integrated this year. Moreover, the revision of the functions that were called by the decoders has been done for the correctness of HEX, PHY and CNT files and fitness of more real-time cases.

Existing data sets are understood and analyzed to help on data integration and updating, such as the salinity adjustment from new metadata and pressure adjustment from data, to track the pressure at surface and various depths. Figure 1 shows the active floats around the oceans, and Figure 2 shows the real-time salinity adjustment program procedure.

Research Performance Measure: All objectives were reached.

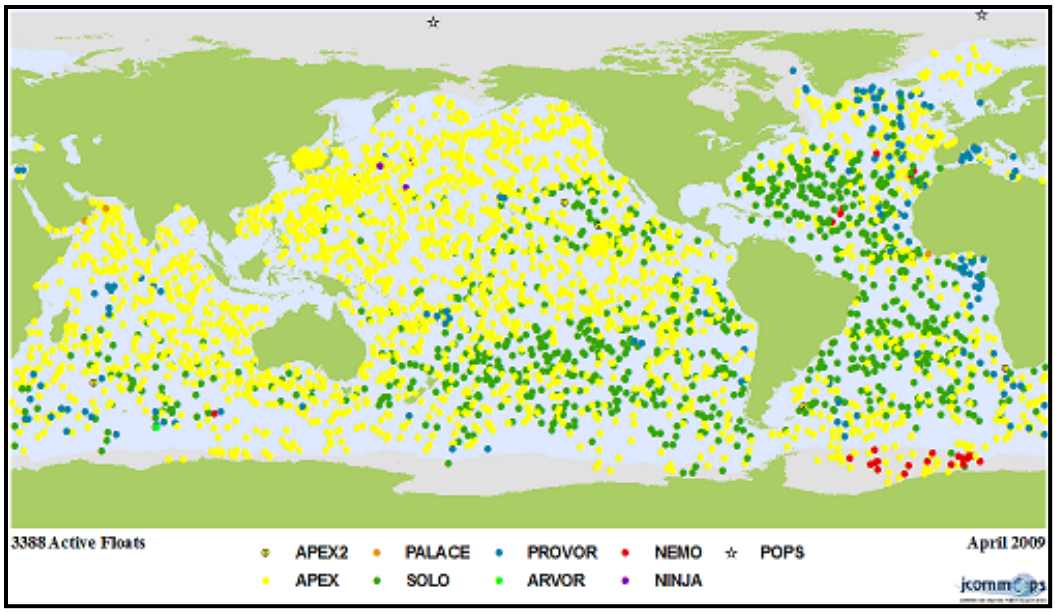


Figure 1: Active Floats.

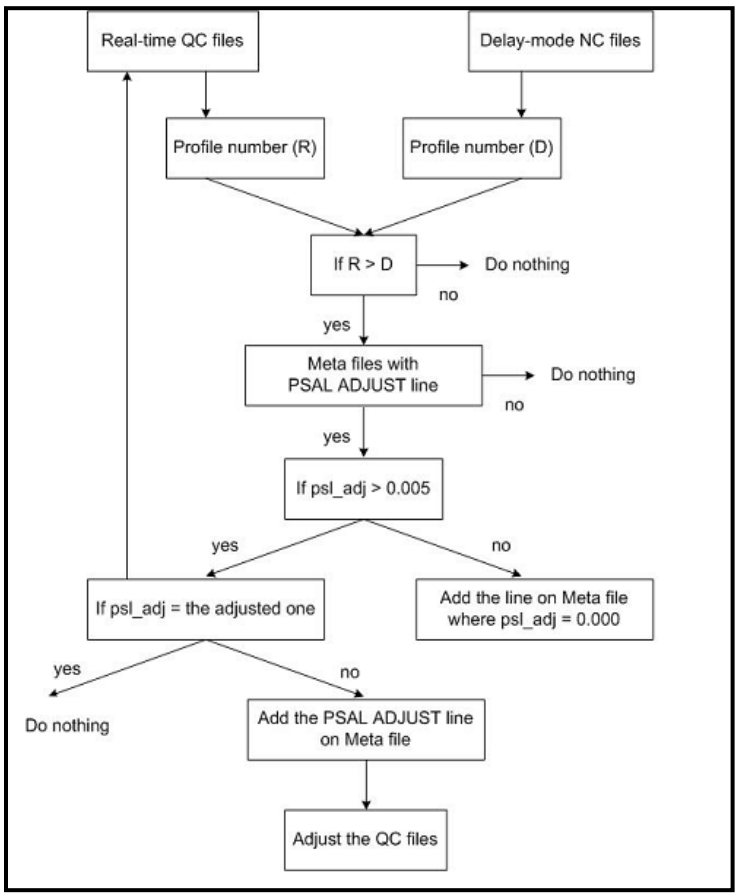


Figure 2: Salinity Adjustment Algorithm.

Research and Implementation of a Hydrographic Database in Support of the Operational and Research Community

M.-L. Shyu (UM/ENG); C. Schmid and R. Sabina (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*:** 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

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

NOAA Funding Unit: AOML

NOAA Technical Contact: Claudia Schmid and Reyna Sabina

Research Summary:

During this project, the following components were designed and developed: (1) a web-based database retrieval system, which can be utilized to retrieve netcdf data according to user search criteria; (2) a GUI that can query and retrieve CTD/XBT dataset and be applied into real use; and (3) a Data Access System that processes data requests, delivers the required data, and notifies the requesting investigator. The resulting system largely facilitates data retrieval for scientific analyses of world ocean data.

Specifically our approach has been to develop and implement a Web-based system called HYDROWEB to retrieve Global Hydrographic Data. This system returns the zipped data files according to the user's query, by observation dates, Geographical Coordinates, or both. Due to the fact that the source dataset, such as WOD (World Ocean Data), contains a lot of records with different levels, shell script program needs to be developed in order to refine the retrieval results to exclude those records that do not hold the maximal levels.

The "Envids" request processing system, it processes the requests sent from different users and uploads the zipped result data to the FTP server before emailing the user with the instructions of downloading the request data. To accelerate the retrieval speed, CAPI is used to access the database instead of JDBC since based on the experiment, JDBC takes longer time than CAPI. CAPI is compiled on different platforms since C code is not as flexible as Java.

Research Performance Measure: The project is proceeding in a timely manner.

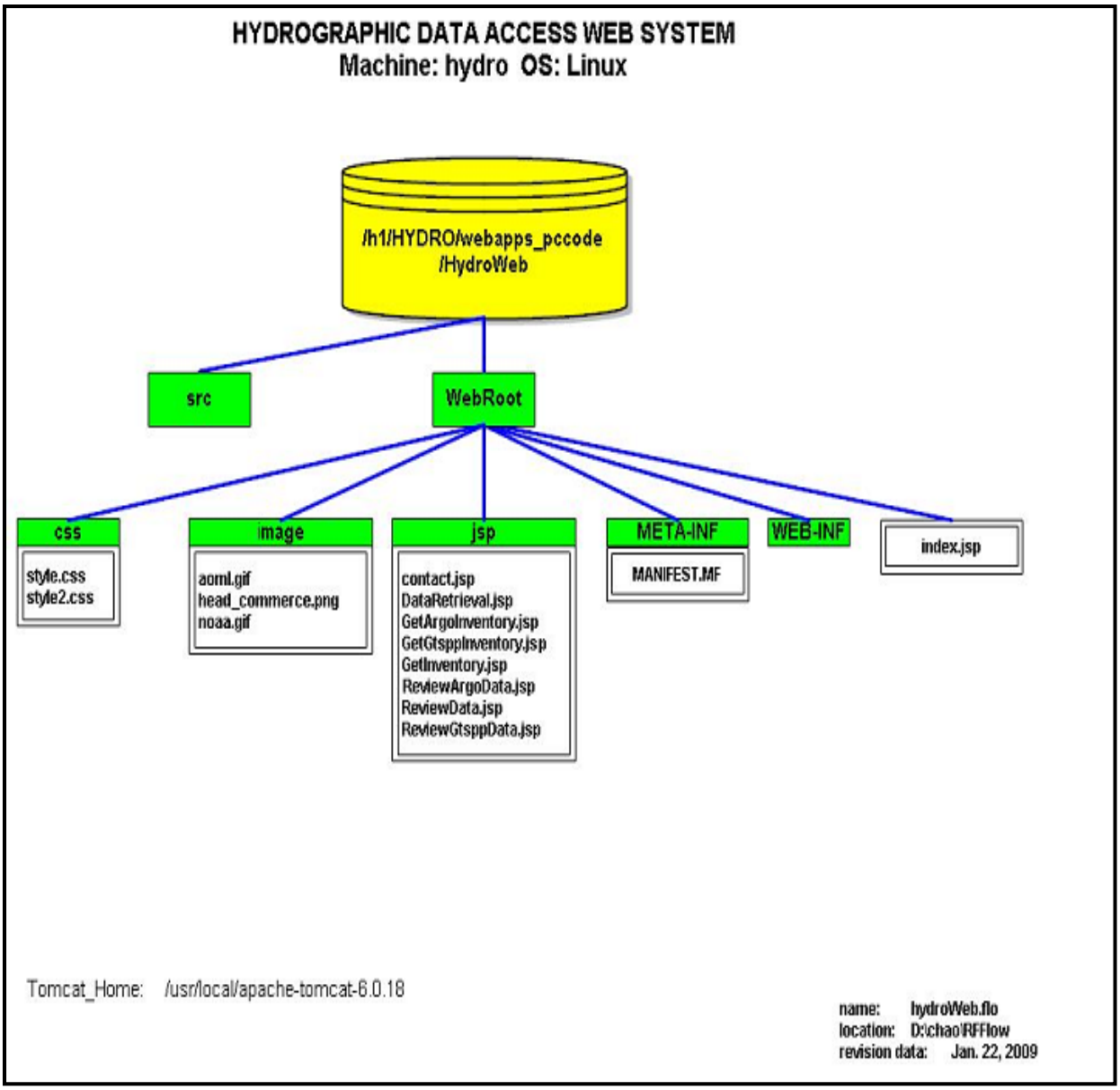


Figure 1: Global Hydrographic Data Access System

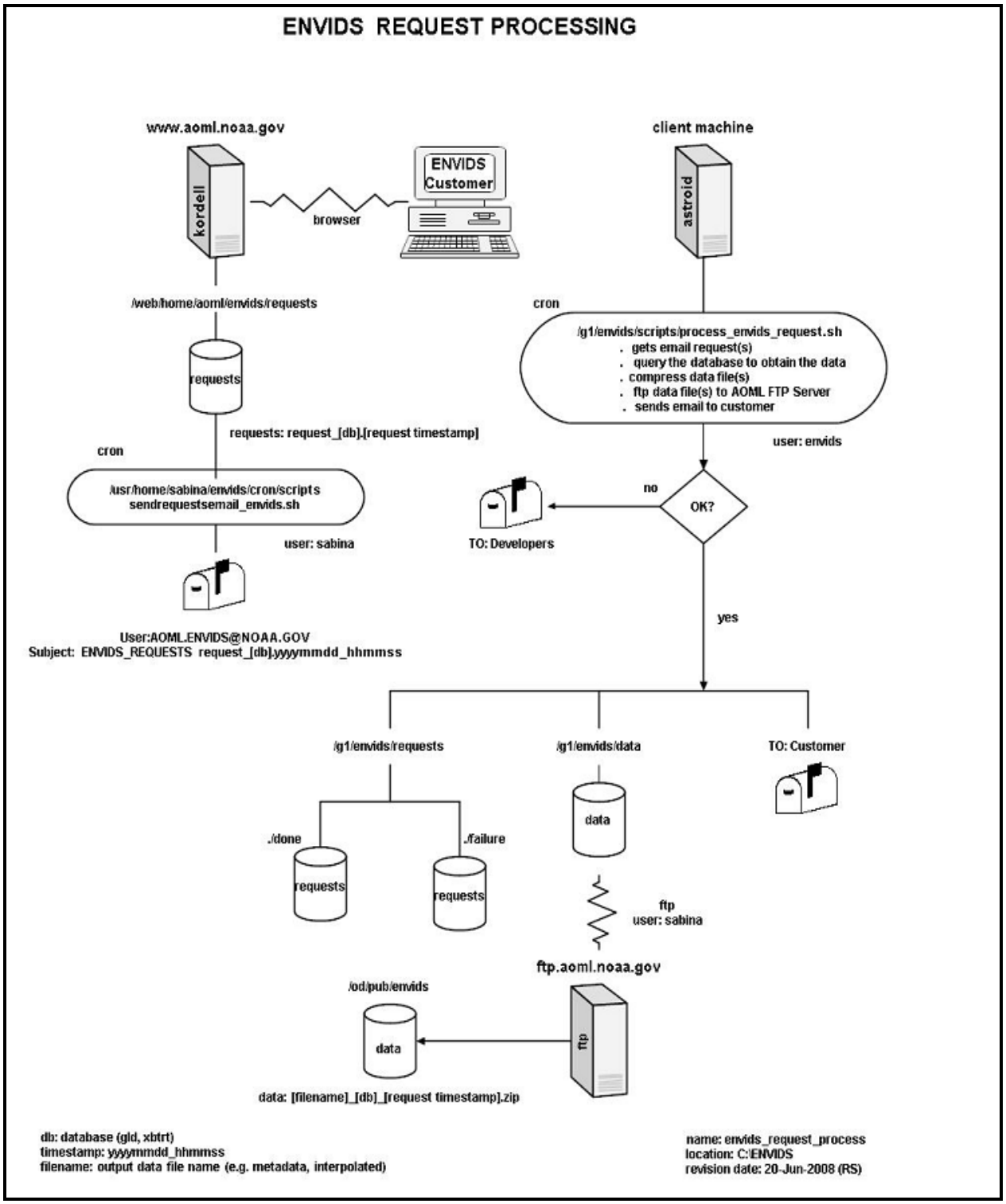


Figure 2: EVIDS Request Processing.

Surface Water pCO_2 Measurements from Ships

K. Sullivan, D. Pierrot, J. Trinanes, F. Bringas, S. Pochan and G.-H. Park (UM/CIMAS);
F. J. Millero (UM/RSMAS); G. Goni and R. Wanninkhof (NOAA/AOML)

Long Term Research Objectives and Strategy to Achieve Them:
***Objectives*:** To 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: OAR/CPO
NOAA Technical Contact: Mike Johnson and 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 an assessment of the carbon dioxide sources and sinks over the coterminous United States through the North American Carbon Program (NACP). In FY-09 the NOAA funded participants maintained instrumentation and reduced data from eleven ships and

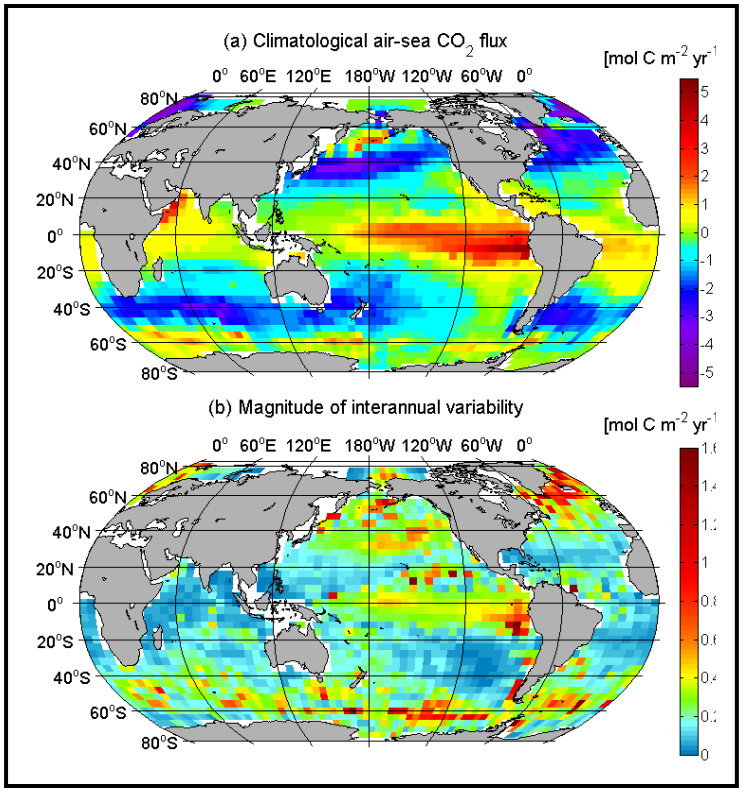


Figure 1: Maps of (a) Climatological air-sea CO_2 flux map from *Takahashi et al*. [2009] and (b) magnitude of interannual air-sea CO_2 flux variability in each pixel for 26 years. Negative fluxes in (a) represent uptake of CO_2 by the ocean. The global mean uptake is -1.44 Pg C yr^{-1} and interannual variability is ± 0.14 Pg C.

posted the data. Flux maps, based on extrapolation routines using remotely sensed wind and sea surface temperature (SST) have been created for the Equatorial Pacific, and Caribbean Sea. Estimates of global seasonal air-sea fluxes have been produced as part of this effort (Figure 1).

An increasing emphasis is put on coastal observations as the fluxes in the region are very poorly constrained. To address this, a new generation pCO_2 system was installed on the Miami research vessel *F. G. Walton Smith* and NOAA ship *Gordon Gunter*. They are currently making measurements on coastal waters in the Atlantic Ocean, Caribbean Sea, and Gulf of Mexico and are of direct relevance to NOAA's efforts in Coastal IOOS and coastal ocean acidification programs.

Recent measurements made on the *F. G. Walton Smith* off the Southern Coast of Florida are shown in Figure 2. These measurements were made along with studies on local coral reefs examining the affect of ocean acidification on coral growth rates. Samples for total alkalinity (TA) are also collected to examine the changes in the CO_2 in regional waters. The study is scheduled to be repeated a total of four times in the calendar year of 2009. The *F. G. Walton Smith* is also scheduled for two additional repeating cruises in 2009: one in the Florida Straits and another off the West Coast of Florida. Using the pCO_2 data collected from these cruises, it will be possible to estimate the seasonal air-sea fluxes in South Florida coastal waters.

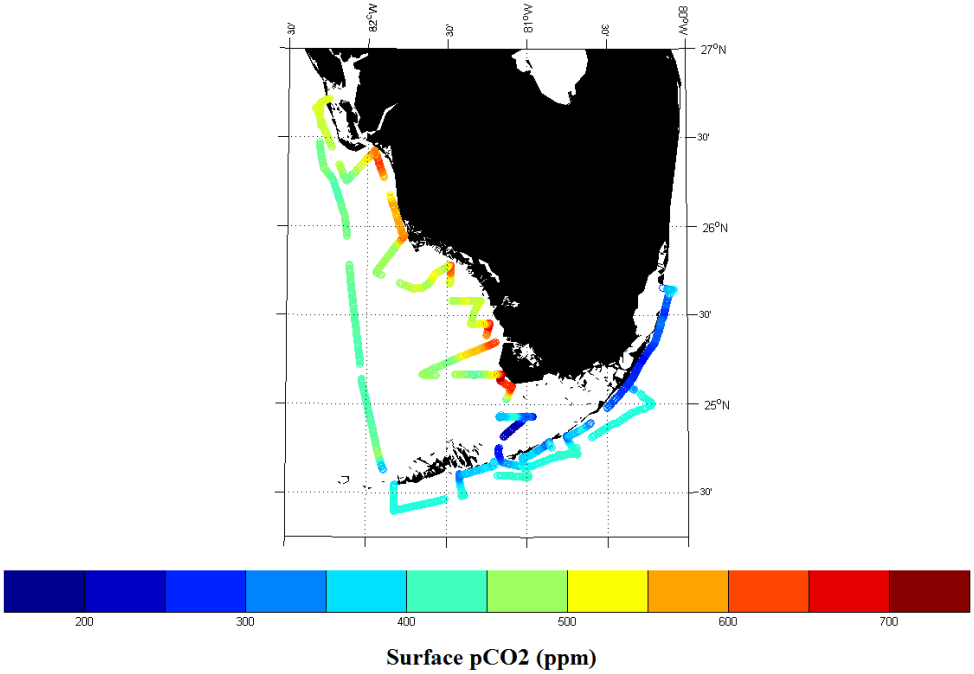


Figure 2: Surface pCO_2 from the Florida Bay measured on the F. G. Walton Smith during April 2009.

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 (SOOP). Through a successful technology transfer and continued guidance, General Oceanics Inc. based 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 (Pierrot et al. 2009). 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 2009.

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 M/V Oleander and NOAA ship Gunter are transmitting TSG data.

Research Performance Measure: Timely delivery of Flux Maps for Global Ocean and assessments of seasonal variability of air-sea CO_2 fluxes.

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*:** 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: Climate Observation Division
NOAA Technical Contact: Mike Johnson and 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 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-2009 we completed quality control of a meridional line in the Pacific was occupied from 20° N to 65° S (P-18) with full

physical and chemical characterization of 160 water column profiles. CIMAS personnel assisted with preparation and planning of cruise I5 from Capetown to Fremantle in the Indian Ocean in February-May, 2009.

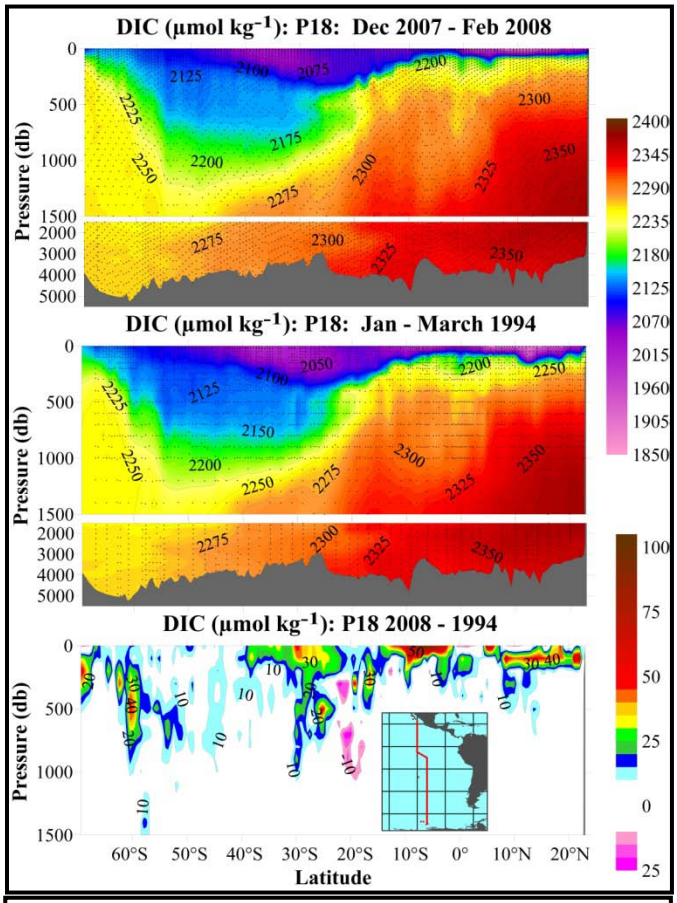


Figure 1: Sections of dissolved inorganic carbon (µmol kg^{-1}) nominally along 105°W in 2008 (top) and 1994 (middle). The bottom section shows the DIC change between the two cruises (2008-1994). Black dots show sample locations. Inset map shows cruise track in red

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 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 updated estimated changes in anthropogenic carbon inventory are shown in Table 1. 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. The high rates in the Indian Ocean are speculated to be caused be enhanced intermediate water formation in the Southern Indian Ocean.

Table 1: Estimates of ocean column inventory changes in anthropogenic carbon (mol C m^{-2} yr^{-1}) over the last decade.

	Atlantic (25°W) 1993-2005	Pacific (152°W) 1991-2006	Indian (90°E) 1995-2007
Northern Hemisphere	0.63	0.25	0.63
Southern Hemisphere	0.75	0.41	0.83

From Sabine et al. (2009).

Research Performance Measure: The program is progressing according to plan. Our performance measure has been augmented in that we are actively interacting with modelers at Princeton and WHOI to compare our observed decadal changes with model trends.

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*:** 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; perform "virtual OSSEs" to conduct preliminary assessments of AMOC observing strategies.

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:** James F. Todd

Research Summary:

Although our eventual goal is to design and execute viable OSSEs to evaluate and recommend AMOC monitoring strategies, development of that capability will take at least 1-2 years. The work performed during year one has emphasized two components: (1) explore the use of "virtual OSSEs" to provide an initial assessment of the utility of different proposed observational strategies and (2) set up the basic software systems at AOML required to perform OSSEs and OSEs, and then perform a "demonstration" OSSE using low-resolution ocean models that are sub-optimal but enable efficient testing of the system to be performed. The planned work during year two will continue these efforts and also begin the process of running and evaluating high-resolution ocean model runs to identify suitable choices for the nature run model and the operational model that will be required to execute viable OSSEs for the AMOC.

The initial effort has focused on virtual OSSEs because they do not require data assimilative model runs to be performed. The postdoctoral researcher recruited for this project (Haoping Yang) started in November 2008 and has been working to estimate the ensemble model uncertainties (error covariances) required to execute virtual OSSEs. Both classical OSSE and virtual OSSE have the same goal: quantitatively evaluating the usefulness of a proposed observing system. While the classical OSSE requires that the proposed observations be simulated and then be assimilated in order to gauge their impact, the actual simulation and assimilation of the observations is not required for the virtual OSSE. Consequently, our initial strategy is to use a multi-model ensemble of simulations to estimate the error covariances without the benefit of the proposed observing system. Effort is underway to exploit simulations from a variety of models that are publically available on the web. Fields from 14 models have been assembled to estimate the ensemble error covariance matrix. These have been supplemented by three additional multi-decadal model runs at AOML (for a total of 17) using the HYbrid Coordinate Ocean Model (HYCOM). We are presenting results of this analysis in

the AMOC session at the MOCA09 conference in Montreal during July 2009. Figure 1 illustrates the large differences in the strength of the AMOC and the associated meridional heat flux produced by these models.

The demonstration OSSE effort will use the "fraternal twin" approach, which uses one model type as both the nature run and operational ocean models, but with the model run in a substantially different configuration that reproduces the same level of uncertainty in the representation of the AMOC that is achieved by other model types. The three HYCOM runs included in Figure 1 were run in substantially different configurations to mimic different model types, and the differences in AMOC representation among these three runs is consistent with the differences observed in the AMOC produced by other model types. We are therefore proceeding with the fraternal-twin demonstration OSSE.

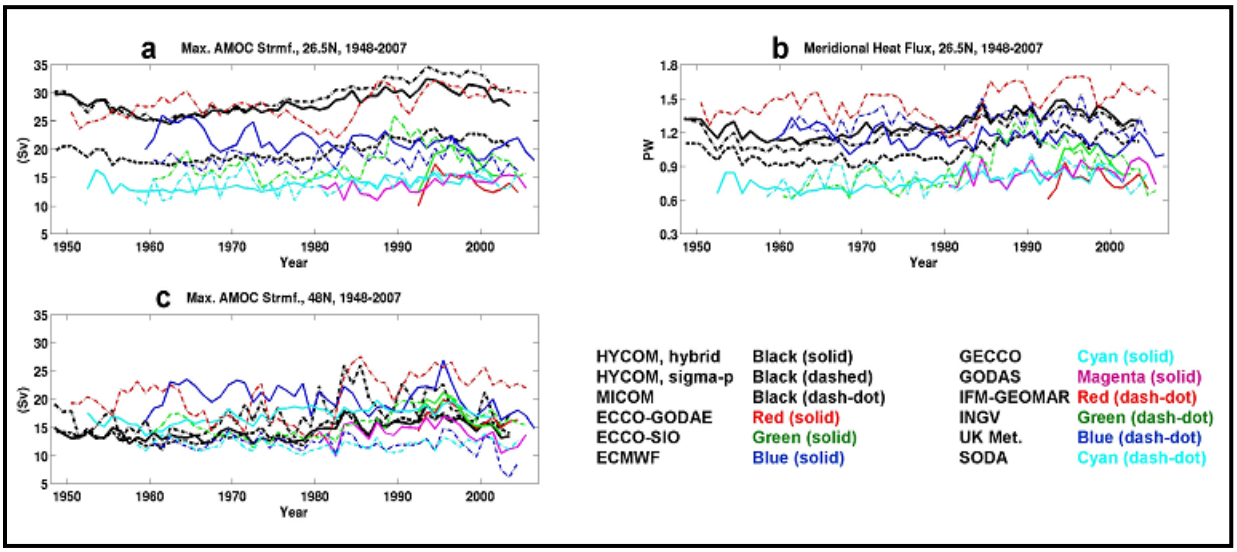


Figure 1: AMOC transport (maximum AMOC streamfunction) at 26.5°N (a) and at 48°N (c) along with meridional heat flux at 26.5°N (b) from all 12 models listed in the legend. The first three models listed were performed using the HYCOM modeling system at AOML, and they substantially reproduced the large differences in AMOC transport and heat flux that are observed in the other models. The demonstration fraternal-twin OSSE will therefore be performed using two of these three model configurations as the nature run and operational models.

Research Performance Measure: We had a slow start due to hiring a postdoctoral researcher with extensive modeling experience but no oceanography experience, and also because of the necessity to assemble large datasets from decadal to multi-decadal ocean model simulations. However, we are now on track to perform both virtual OSSEs and the demonstration fraternal twin OSSE this calendar year.

Ship of Opportunity Program

Q. Yao, F. Bringas, P. DiNezio, S. Pochan, G. Rawson, N. Melo,
T. Casal, E. Munoz, S. Dong, A. Stefanick and J. Delgado (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, PX26, 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 (AX7, AX0, AX08, 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.

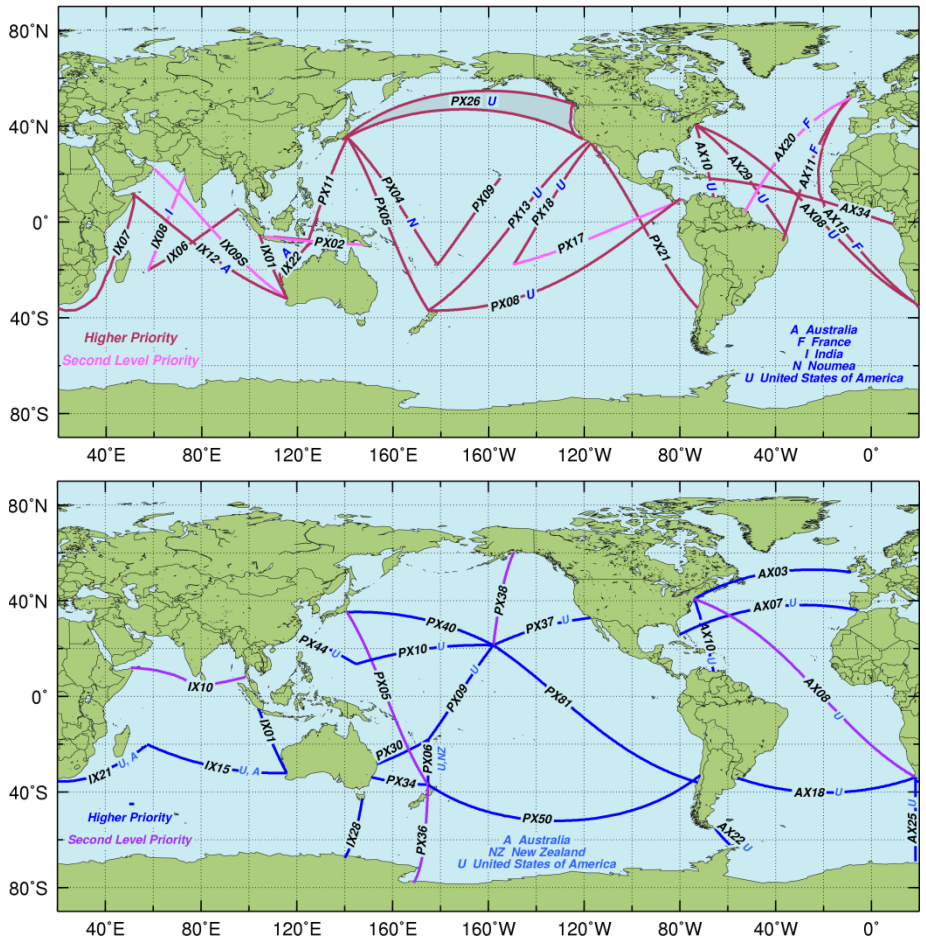


Figure 1: (top) Location of Frequently Repeated and Low Density XBT network and (bottom) the High Density network recommended by the 1999 Upper Ocean Thermal Review Panel. The blue letters indicate the country that leads the effort of each transect.

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 (for additional details see http://www.aoml.noaa.gov/phod/hdenxbt/). 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 (TC) occur in seven regions in all ocean basins: tropical Atlantic, northeast Pacific, northwest Pacific, southwest Indian, north Indian, southeast Indian, and south Pacific. While sea surface temperature (SST) plays a role in the genesis of TCs, the ocean heat content contained between the sea surface and the depth of the 26°C isotherm, also referred as Tropical Cyclone Heat Potential (TCHP), has been shown to play a more important role in TC intensity changes, provided that atmospheric conditions are also favorable. The TCHP shows high spatial and temporal variability associated with oceanic mesoscale features (Figure 2). The west Pacific basin exhibits the anomalies from the signature of the negative phase of the 2007 ENSO event (La Nina). The South Pacific basin showed mostly positive anomalies. The North Indian basin exhibited positive values in the Bay of Bengal and in the eastern Arabian Sea and negative values in the western Arabian Sea. The Gulf of Mexico (insert) showed an alternation of regions with positive and negative values. The tropical Atlantic exhibited positive values to the north of 30°N and south of 15°N. The most evident changes that happened between 2008 and 2007 are the increase of values in the southern region of the western Pacific basin.

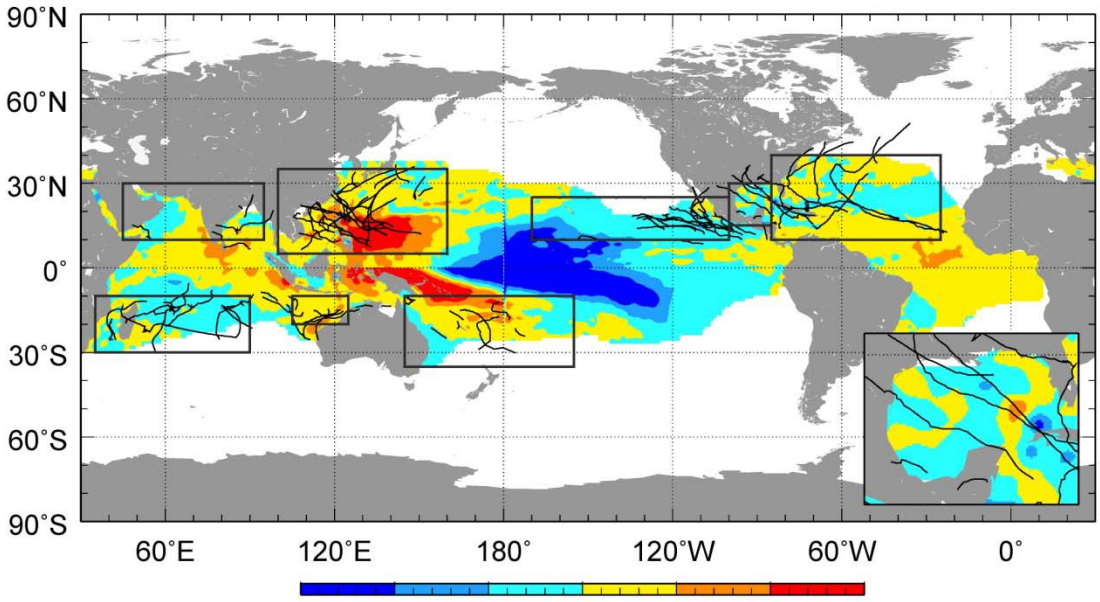


Figure 2: Global anomalies of Tropical Cyclone Heat Potential corresponding to 2008 computed as described in the text. The boxes indicate the seven regions where Tropical Cyclones occur: from left to right, Southwest Indian, North Indian, West Pacific, Southeast Indian, South Pacific, East Pacific, and North Atlantic (shown as Gulf of Mexico and tropical Atlantic separately). The black lines indicate the trajectories of all tropical cyclones category 1 and above during November 2007-December 2008 in the Southern Hemisphere and January-December 2008 in the Northern Hemisphere. The Gulf of Mexico conditions during June-November 2008 are shown in detail in the insert shown in the lower right corner.

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.

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. 2008 basin-scale upper ocean heat content patterns are consistent with current phasing of familiar climate indices such as ENSO. The year-to-year changes in mixed layer ocean heat content anomaly has fallen over a year on either coast of S. America around 20ºS (Figure 3). Changes in mixed layer depth can have large impacts on the heat content in the mixed layer even if there is no change in the mixed layer temperature.

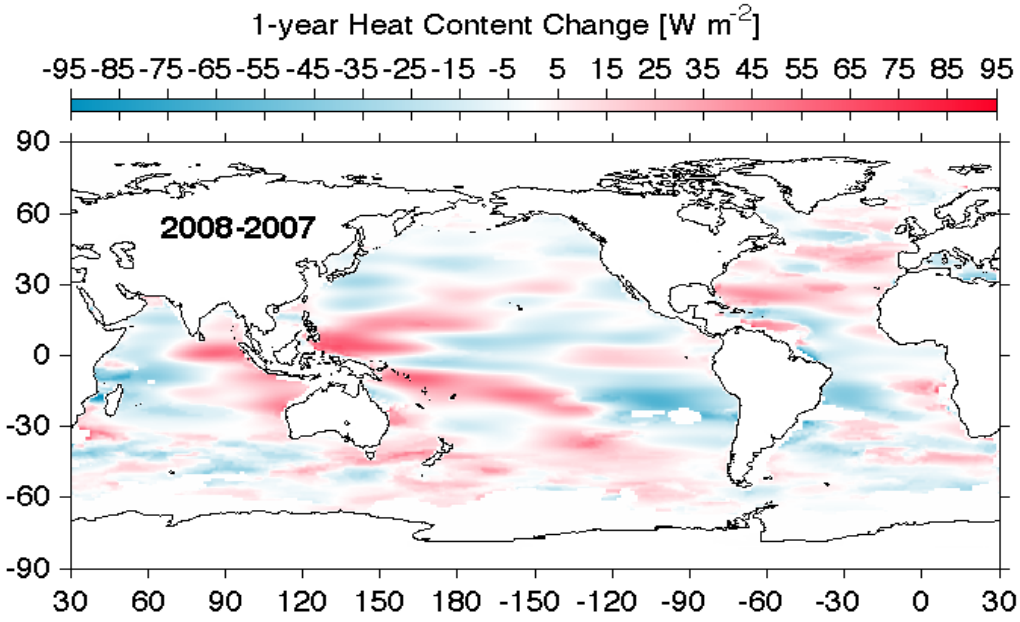


Figure 3: Change of ocean mixed layer heat content estimated following Schmid (2005) expressed as a surface heat flux equivalent (W m^{-2}). The map is based on subtraction of a yearly mean of ocean mixed layer content for calendar year 2008 from that for calendar year 2007. Available online at at: www.aoml.noaa.gov/phod/soto/ghs/reports.

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.

VII. OUTREACH

The Rosenstiel School and CIMAS are active in education and outreach at the undergraduate and high school level. We are also involved with outreach to the general public. Many of these activities take place in cooperation with the local NOAA laboratories. Here we present a brief overview of outreach activities at the School in which CIMAS 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.

The MAST Academy and High School Student Outreach

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

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

Undergraduate Student Education

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

- During the past year, students actively participated in the SEFSC-CIMAS program: *Monitoring Coral Reef Fish Populations in the Florida Key* in a program led by Dr. J. Ault, RSMAS, and funded through CIMAS (see below). The program drew students from UM, from Florida International University (FIU) and from Miami-Dade College. Students have used this work for their senior research topics. Past students have gone on to graduate school in the sciences.
- UM undergraduate students from the Marine Science Program participate in the bi-monthly cruises that take place as a part of the program: ***Interdisciplinary Surveys of Western Florida Bay and Connecting Waters Including Gulf Stream Transects,*** a project involving P. Ortner, C. Kelble (UM/CIMAS), G. Hitchcock (UM/RSMAS) and L. Johns, M. Barringer, and R. Smith (NOAA/AOML)

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.

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

Public outreach and informal educational activities associated with specific CIMAS projects include:

Monitoring Coral Reef Fish Populations in the Florida Keys

Jerald S. Ault, Steven G. Smith (UM/RSMAS); James A. Bohnsack (NOAA/NMFS)

The research was documented in a number of media pieces including NBC Nightly News with Brian Williams, ABC Good Morning America, Washington Times, New York Times, Los Angeles Times, BBC (British Broadcasting Company), France 24, Discovery Channel, Chicago Tribune, Honolulu Advertiser, Miami Herald (front page feature), Associated Press, Reuters International, etc. In addition, Dr. Ault provided a number of public lectures on this research: Dolan Lecture Series; Key Biscayne Historical Society; Naples *Sea Secrets*; Florida Keys Sanctuary Advisory Board; Flower Garden Banks National Marine Sanctuary; South Atlantic Fishery Management Council; Western Pacific Regional Fishery Management Council; and, also offered expert testimony before the Florida Governor and Cabinet at the Capital Building in Tallahassee, Florida.

Shallow-Water Grouper Distribution, Habitat Characteristics and Spawning Behavior

D.J. Die and V. Koch (UM/RSMAS)

Veronique Koch was awarded an NSF fellowship to help middle school educators in their teaching of science and to help her develop outreach and education skills. During the academic year 2009-10 she will be using results from her black grouper study in the grade 8 classroom of a local middle school.

US Virgin Islands Larval Distribution and Supply Research

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

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 most recently to the British Virgin Islands Conservation and Fisheries Department during the cruise port stop in Tortola, BVI. Scientific personnel and general public were invited to tour the ship and observe operations. In addition, several articles appeared in the local news media (Virgin Islands Daily News, May 9, 2009; St. Thomas Source, May 5, and also April 21, 2009) mentioning the research and one radio interview was given on Puerto Rican Univision radio on May 6, 2009.

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

David Wanless, Chris Sinigalliano (UM/CIMAS); Kelly Goodwin (NOAA/AOML)

The education/outreach components of this project have been integrated into the larger outreach programs of the UM Oceans and Human Health Center, and NOAA AOML. 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. 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, as well as local academic partners such as the UM OHH Center and the Applied Research Center of Florida International University.

Coral Ecological Restoration in the Florida Keys National Marine Sanctuary (F.K.N.M.S.)

D.E. Williams, A. Valdivia and L. Johnston (UM/CIMAS); M.W. Miller, (NOAA/SEFSC)

- Press coverage during ACRRE mission including live interview on NBC6.
- Featured in 'Earth Science Picture of the Day' website, 28 Oct 2008. http://epod.usra.edu/archive/epodviewer.php3?oid=449568
- Presentation to the FKNM Sanctuary Advisory Council, Ocean Reef Club, 21 Oct 2008.

Assessment of Candidate Corals

Dana E. Williams and Abel Valdivia (UM/CIMAS), Margaret W. Miller (NOAA/SEFSC)

- Partnership with Seamester (semester at sea) to incorporate our survey protocol into their undergraduate curriculum.
- Interview for television show to air on Voice of America, a federally funded broadcast network.

Reef Assessment Cruise to Navassa Island

Margaret Miller (NOAA/SEFC)

Navassa is a small uninhabited island ~40 miles west of Haiti under jurisdiction of the USFWS Refuge system. Though uninhabited, transient fishers from Haiti are active at Navassa, and overfishing is the primary threat to reef condition. This project has undertaken biennial assessment cruises (2002, 2004, 2006) to document reef status, habitat characterization and mapping, and a description of the Haitian fishery.

This was the fourth Coral Reef Conservation Program (CRCP) funded assessment cruise to Navassa, an effort that represents the only in-water monitoring record for US coral reef resources (including fisheries) in this remote location. Monitoring, assessment, and mapping products from this project have been used by managers at the National Wildlife Refuge (USFWS) and the Caribbean Fishery Management Council.

During the NOAA Reef/Fishery Assessment cruise to Navassa Island National Wildlife Refuge in April 2009, NOAA and CIMAS personnel compiled a realtime blog as a public outreach tool (http://noaanavassa09.blogspot.com/). We were able to provide daily updates and photos on discoveries (such as invasive Pacific lionfish, new recruits of the ESA-listed elkhorn coral, and mass spawning by barrel sponges), basic operations of a scientific cruise, and management issues facing the Refuge (such as trap fishing or feral cats). This proved an effective outreach tool, garnering over 700 unique visitors during the course of the cruise.

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

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

Agricultural Outlooks. Climate and commodity outlooks were developed in close collaboration with different SECC members and University of Georgia (UGA) Research and Extension Faculty. These outlooks were disseminated in various media forms and outlets to stakeholders including county agents and growers. A significant outcome was the increased visibility of the climate extension program as a result of extension specialists and county agents developing their recommendations (e.g. peanut, cotton, turfgrass management) based on the impacts of climate forecasts.

Training Workshops. Extension activities related to climate change during 2008 included the development and implementation of a climate change In-service training to Extension faculty during the 2008 IFAS Extension Symposium. The presentations are available online at: http://pdec.ifas.ufl.edu/symposium/2008/. We also conducted a session on agricultural applications of climate information during the Annual Extension Winter Conference. We were involved in various agent trainings, emphasizing the importance of climate forecasts in farm decisions and risk management. In addition, a new UF-IFAS focus group area has been created under the Florida Environment main goal area with the objective of coordinating Extension activities related to climate variability and change across the state.

Integrated Coral Observing Network (ICON) Project

Lewis Gramer, Mike Jankulak and Dwight Gledhill (UM/CIMAS); Chris Langdon (UM/RSMAS); James Hendee, Derek Manzello, Michael Shoemaker, Jules Craynock and J. Stamates (NOAA/AOML)

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.

Global Drifter Program

S. Dolk, E. Valdes and S. Elipot (UM/CIMAS); R. Lumpkin and M. Pazos (NOAA/AOML)

World Oceans Day '09: 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. In conjunction with Blue Ocean Film and the United States Coast Guard, NOAA deployed two drifting buoys into the Gulf Stream, to celebrate World Oceans Day and emphasize the importance of oceanographic research. Aboard the USCG TARPON, approximately 70 Thunderbolt Elementary School students, 5 teachers, 2 school administrators, and various media personnel departed from Savanna, Georgia and steamed 10 hours to reach the edge of the Gulf Stream. During the journey, the students were taught about the importance of ocean sciences, environmental awareness, and boat safety. Along with their classmates, family, and friends, these students can track the movement of their drifters throughout the Atlantic.

Determining Information Content in Repeat Low-density XBT transects

Robert L. Molinari

Through a component of Argo, AOML and CIMAS investigators have been working with the U.S. Navy to build capacity in collecting and using oceanographic data in West African countries. The third capacity building session was held in Lagos, Nigeria and I contributed lessons on the collection and use of XBT data for the participants. In addition, at the request of the author, an article to appear in Earth Magazine, formerly GEOTIMES, on observations of the Meridional Overturning Circulation was reviewed and comments provided.

VIII. 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 typically scheduled to meet on a nominal quarterly basis although scheduling is usually difficult because of the extensive travel schedules. During Year 8 there were two formal meetings: 6 November 2008 and 29 April 2009. In addition there are frequent meetings of focus groups. In particular during the past year there were many meetings between CIMAS Fellows, RSMAS Faculty and scientists from AOML, and the National Hurricane Center to discuss the development of an NSF Science and Technology Center proposal: "Center for Hurricane Impacts and Prediction Research (CHIPR)". The Center would closely link research activities in RSMAS, including NOAA-supported hurricane research, with that carried out in NOAA and provide much of the basic science research required to sustain the NOAA HFIP program. CHIPR was not funded however a number of HFIP supporting activities were initiated through CIMAS.

Many Fellows-related matters are 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.

FELLOWS	AFFILIATION
Dr. Bruce Albrecht	UM/RSMAS Meteorology and Physical Oceanography
Dr. Molly Baringer	NOAA/Physical Oceanography
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
Dr. Rod G. Zika	UM/RSMAS Marine and Atmospheric Chemistry

Ex Officio

Dr. Robert M. Atlas	NOAA/AOML, Office of the Director
Dr. Otis B. Brown	UM/RSMAS Dean
Dr. Bonnie.Ponwith	NOAA/Southeast Fisheries Science Center

IX. AWARDS AND HONORS

Global Warming and United States Landfalling Hurricanes
C. Wang (NOAA/AOML) and S.-K. Lee (UM/CIMAS)

- This paper appeared in 23 January 2008 issue of Geophysical Research Letters. According to NOAA Public Affairs Office, the paper was covered by more than 300 newspapers worldwide plus many TV and radio programs after its publication. In the OAR updated news by Richard Spinrad on December 2008, this paper was listed as one of the OAR 2008 outstanding research achievements. This paper was also selected as one of the three outstanding papers of 2008 by NOAA/AOML.

Why do some El Niños have no impact on tropical North Atlantic SST?
S.-K. Lee (UM/CIMAS), D. B. Enfield (UM/CIMAS) and C. Wang (NOAA/AOML)

- This paper appeared in 23 August 2008 issue of the Geophysical Research Letters, was selected as a "hot item" for researches in cooperative institutes of NOAA.

Distinguished Career Award for seminal research in climate
David. B. Enfield (UM/CIMAS)

- In late 2008, Dr. Enfield was presented with NOAA's prestigious Distinguished Career Award for seminal research in climate. Since 1987 he has been a Research Oceanographer at the NOAA Atlantic Oceanographic and Meteorological Laboratory in Miami, Florida, and has more than 60 refereed publications to his credit.

Shallow-Water Grouper Distribution, Habitat Characteristics and Spawning Behavior
D.J. Die and V. Koch (UM/RSMAS)

- Science Made Sensible NSF Fellowship.

Simulation of Management Strategies
David J. Die and Elizabeth Babcock (UM/RSMAS); John Hoenig (VIMS)

- A participating student, Bill Harford was awarded a NSERC research fellowship for 3 years from the Canadian Government.

Enabling and Initiating Observing System Simulation Experiments of the Coastal High Resolution Oceanographic Model in the Northern Gulf of Mexico
V. Kourafalou (UM/RSMAS); P. Ortner and M. Le Henaff (UM/CIMAS); R. Atlas and G. Halliwell (NOAA/AOML)

- Best poster award in the international "Final Symposium of the Global Ocean Data Assimilation Experiment: the revolution in global ocean forecasting, 10 years of achievement". The paper entitled "*On the use of GODAE and satellite products to improve coastal simulations on the northern Gulf of Mexico*," was presented by Ph.D. student R. Schiller with co-authors V. Kourafalou (RSMAS), G. Halliwell and G. Goni (NOAA-AOML), P. Hogan and O.M. Smedstad (NRL-SSC).

X. POSTDOCTORAL FELLOWS AND GRADUATE STUDENTS

CIMAS-Supported Postdoctoral Fellows and Graduate Students

Postdoctoral Fellows

Aksoy, Altug
Amornthammarong, Natchanon
Casal, Tania
Elipot, Shane
Jones, David L.
Kleisner, Kristin
Le Henaff, Matthew
Lorsolo, Sylvie
Muñoz, Ernesto
Park, Geun-Ha
Yang, Haoping
Zhang, Jun

Graduate Students

Task I
Buck, Eric
Chen, Chao
Dominique, Lazarre
Drew, Katherine
Ebanks, Dwight
Forretal, Francesca
Gleason, Arthur
Glodek, Todd
Helms, Joshua
Johnston, Lyza
Karras, Constantina
Koeneke, Robert
Lin, Lin
Martin, Elizabeth
McNeal, Jena
Pina, Diana
Quinino, Thiago
Ravitz, Guy
Sainani, Varsha
Saul, Steven
St. Hilaire, Sandra
Stone, Megan

Other Participants in CIMAS Projects

Postdoctoral Fellows

Baigorria, G.
Bannayan, M.
Chatzis, Sotirios
Chung, Eui-Seok
Garcia y Garcia, A.
Gerard-Marchant, B.P.
Min, Dughong
Muhling, Barbara

Graduate Students

Bolson, Jessica
Casella, Guy
Chanson, Mareva
Chen, Chao
Davis, Jonathan
DiTrolio, Benjamin
Farmer, Nick
Ghate, Virendra
Greer, Adam
Gruskin, Zach
Hagen, Andrew
Harford, Bill
Herlan, James
Huntington, Brittany
Jaimes, Benjamin
Judd, Zack
Keener, V.
Koch, Veronique
Larkin, Mike
Machemer, Ethan
McCrea, Ashley
Miller, Matthew
Meyers, Patrick
Odell, Chris
Pathak, T.
Porter, Megan

CIMAS Graduate Students Cont'd

Employees

Di Nezio, Pedro
Gramer, Lew
Jankulak, Michael
Kelble, Christopher
Malca, Estrella
Wanless, David
Whitcraft, Samantha

Other Graduate Students Cont'd

Santos, Rolando
Rafael Schiller
Smith, Matt
Smith, Ryan
Stern, Daniel
Swanson, Dione
Trapp, J. Michael
Vaughan, Nathan
Waters, Jason
Watterhouse, Lynn
Woli, P.
Woosley, Ryan
Zhang, Xue

XI. RESEARCH STAFF

Aksoy, Altug	Postdoctoral Associate
Alex, Carmen	Research Associate II
Amornthammarong, Natchanon	Postdoctoral Associate
Annane, Bachir	Senior Research Associate III
Berberian, George	Research Associate II (PT)
Bringas Gutierrez, Francis	Research Associate II
Brown, Cheryl	Research Associate II
Cardenas, Hernando	Research Associate I
Carrasco, Hector N.	Senior Research Associate I
Casal, Tania	Postdoctoral Associate
Delgado, Juan	Research Associate I
Di Nezio, Pedro N.	Research Associate III
Diaz, Jose E.	Research Associate II
Dolk, Shaun	Research Associate II
Dong, Shenfu	Assistant Scientist
Elipot, Shane	Post Doctoral Associate
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
Gledhill, Dwight	Associate Scientist
Gramer, Lewis J.	Research Associate III
Huang, Xiaolan	Assistant Scientist
Jankulak, Michael L.	Research Associate III
Johnson, Darlene R.	Scientist
Jones, David L.	Postdoctoral Associate
Kelble, Christopher R.	Senior Research Associate II

Kleisner, Kristin	Postdoctoral Associate
Klotz, Bradley	Research Associate III
Le Henaff, Matthieu	Postdoctoral Associate
Lee, Sang-Ki	Associate Scientist
Lorsolo, Sylvie	Postdoctoral Associate
Malca, Estrella	Research Associate II
Melo, Nelson	Senior Research Associate II
Molinari, Robert	Scientist (PT)
Munoz, 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
Stefanick, Andrew J	Research Associate II
Sullivan, Kevin F.	Senior Research Associate III
Teare, Brian	Research Associate I
Thacker, Carlisle	Scientist (PT)
Valde, Krystal M.	Research Associate I
Valdes, Erik	Research Associate I
Valdivia, Abel	Senior Research Associate I
Wanless, David R.	Research Associate II
Whitcraft, Samantha R.	Senior Research Associate I
Wicker, Jesse A.	Research Associate II
Wilborn, Rachel	Research Associate II
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

XII. VISITING SCIENTISTS PROGRAM

Prof. Daniel Rosenfeld
Program of Atmospheric Sciences
Institute of Earth Sciences
The Hebrew University of Jerusalem
Jerusalem, Israel
14 November, 2008

14 November, 2008: *"Floods or Droughts: How do Aerosols Affect Precipitation?"*

Dr. Fred Jopp
Associate Professor and Senior Researcher
Institute of Zoology
Free University of Berlin
Berlin, Germany
(Visiting Professor, Department of Biology, University of Miami, Coral Gables, FL)
24 November, 2008

24 November, 2008: *"Modeling the Aquatic Food Web Structure of the Everglades"*

Dr. Nathan Taylor
University of British Columbia
Vancouver, Canada
1 – 5 December, 2008

4 December, 2008: *"A Multistock Age-Structured Assessment Model of Atlantic Bluefin Tuna: Integrating Stock Composition, Conventional and Electronic"*

Dr. Peter Lamb
Cooperative Institute for Mesoscale Meteorological Studies
School of Meteorology
The University of Oklahoma
Norman, Oklahoma
9 January, 2009

9 January 2009: *"Sahel Drought: How Did Mesoscale Weather System Variations Produce the Largest Regional Climate Change in the 20th Century?"*

Dr. Martin Visbeck
Deputy Director (IFM-GEOMAR)
Head of Research Unit "Physical Oceanography"
Leibniz-Institut fuer Meereswissenchaften (IFM-GEOMAR)
Duesternbrooker Weg 20
D-24105 Kiel, Germany
15 December, 2008 – 30 January, 2009

14 January, 2009: *"Observed Changes in the Southern Ocean Winds and Associated Impacts On the Oceans Stratification and Circulation: Are there Lessons for the role of the Southern Ocean in CO_2 Uptake and Paleo Climatic Events?"*

21 January, 2009: *"First Results from the Guinea Dome Tracer Release Experiment (GUTRE) in the Tropical North Atlantic Oxygen Minimum Zone"*

Dr. Frank Raes
Director, Atmospheric Processes Division
Institute for Environment and Sustainability
Joint Research Centre of the European Commission (JRC/EU)
Ispra, Italy
30 April – 4 May, 2009

1 May, 2009: *"Linkages Between Air Pollution and Climate Change: Science and Policy"*

4 May, 2009: *"Air Pollution Monitoring from a Mediterranean Cruise Ship from 2006 to Present: Operational Considerations and Some Data and Analysis"*

XIII. PUBLICATIONS

We list all publications for the years 2008-2009, presented in categories. The category "Conference Proceedings" lists only publications that derive from presentations at meetings, it does not include oral presentations.

In Table 1 we summarize the record of publications over the period 2001 – 2009, listed as "peer reviewed" and "non-peer reviewed". The table also shows the distribution of lead author affiliation (CIMAS, NOAA scientist, or other institutions).

Table 1: Publication Record 2001-2009

	Institute Lead Author				**NOAA Lead Author**				**Other Lead Author**			
	2001 2002	2002 2003	2003 2004	2004 2005	2001 2002	2002 2003	2003 2004	2004 2005	2001 2002	2002 2003	2003 2004	2004 2005
Peer Reviewed	54	60	36	33	0	7	14	14	--	--	30	28
Non Peer Reviewed	7	8	34	10	0	3	17	11	--	--	28	6

	Institute Lead Author				**NOAA Lead Author**				**Other Lead Author**			
	2005 2006	2006 2007	2007 2008	2008 2009	2005 2006	2006 2007	2007 2008	2008 2009	2005 2006	2006 2007	2007 2008	2008 2009
Peer Reviewed	37	37	39	27	17	32	38	26	37	47	29	18
Non Peer Reviewed	9	18	21	22	7	3	5	9	15	13	3	3

Refereed Journal Articles

Allan, R.P. and B.J. Soden (2008), Atmospheric warming and the amplification of precipitation extremes, *Science, 321*, 1481-1483.

Amornthammarong, N. and J.-Z. Zhang (2009), Liquid-waveguide spectrophotometric measure-ment of low silicate in natural waters, *Talanta*., *79*, 621-626.

Arguez, A, J.J. O'Brien and S.R. Smith (2009), Air temperature impacts over Eastern North America and Europe associated with North Atlantic SST variability, *Int. J. Climatol.*, doi:10.1002/joc.1700.

Ault, J.S., S.G. Smith, J. Luo, M.E. Monaco and R.S. Appeldoorn (2008), Length-based assessment of sustainability benchmarks for coral reef fishes in Puerto Rico, *Environmental Conservation, 35*(3): 221-231.

Babcock, E.A. and E. Cortes (2009), Updated bayesian surplus production model applied to blue and mako shark catch, cpue and effort data, *ICCAT Collect. Sci. Papers*, in press.

Boyer, J.N., C.R. Kelble, P.B. Ortner, and D.T. Rudnick (2009), Phytoplankton Bloom Status: An Indicator of Water Quality Condition in the Southern Estuaries of Florida, USA, *Ecological Indicators, 9*, s56-s67.

Cabrera, V.E, D. Solís and D., Letson (2009), Optimal crop insurance under climate variability: contrasting insurer and farmer interests. *Trans. Am. Soc. Agri. Bio. Eng.*, 52(2): 623-631.

Chou, K.-H., C.-C. Wu, P.-H. Lin and S. J. Majumdar (2009), Validation of QuikSCAT wind vectors by dropwindsonde data from DOTSTAR, *J. Geophys. Res.*, accepted.

DiNezio, P.N., L.J. Gramer, W.E. Johns, C.S. Meinen and M.O. Baringer (2009), Observed omterammia; variability of the Florida current: Wind forcing and the North Atlantic Oscillation, *J. Phys. Oceanogr., 39*, 721-736, doi: 10.1175/2008JPO4001.1.

Enfield, D.B., and L. Cid-Serrano (2009), Secular and multidecadal warmings in the North Atlantic and their relationships with major hurricane activity, *Int. J. Clim.*, in press.

Elipot, S., and S.T. Gille (2009), Estimates of wind energy input to the Ekman layer in the Southern Ocean from surface drifter data, *J. Geophys. Res.*, 114, C06003, doi:10.1029/2008JC005170.

Elipot, S., and S.T. Gille (2009,) Ekman layers in the Southern Ocean: spectral models and observations, vertical viscosity and boundary layer depth, *Ocean Sci*., *5*, 115-139.

Fraisse, C.W. N.E. Breuer, D. Zierden and K.T. Ingram (2009), From Climate Variability to Climate Change: Challenges and Opportunities to Extension, *J. Extension.*, 47(2). http://www.joe.org/joe/2009april/a9.php.

Gentemann, C.L., P.J. Minnett, J. Sienkiewicz, M. DeMaria, J. Cummings, Y. Jin, J.D. Doyle, L. Gramer, C.N. Barron, K.S. Casey, and C.J. Donlon (2009), MISST The Multi-Sensor Improved Sea Surface Temperature Project, *Oceanography, 22*(2), 76-87.

Ghate, V., B. Albrecht, C. Fairall, and R. Weller (2009), Climatology of surface meteorology, surface fluxes, cloud fraction and radiative forcing over South-East Pacific from Buoy Observations, *J. Climate*, in press.

Gledhill, D.K., R. Wanninkhof, F.J. Millero, and M. Eakin (2008), Ocean acidification of the Greater Caribbean Region 1996–2006, *J. Geophys. Res., 113*, C10031, doi:10.1029/2007 JC004629.

Goodwin, K.D., and M. Pobuda (2009), Performance of CHROMagar™ Staph aureus and CHROMagar™ MRSA for detection of *Staphylococcus aureus* in beach water and sand – comparison of culture, agglutination, and molecular analyses, *Water Res*., doi:10.1016/ j.watres.2009.06.025.

Goodwin, K.D., L. Matragano, D. Wanless, C. Sinigalliano, and M. J. LaGier (2009), A preliminary investigation of fecal indicator bacteria, human pathogens, and source tracking markers in beach water and sand, *Env. Res. J.*, *2*(4):395-417.

Hoolihan, J.P., N.F. Perez, R.M. Faugue, A.M. Bernard, R.L. Horn, D. Snodgrass and D.R. Schultz (2009), Surface mucous as a source of genomic DNA from Atlantic billfishes (Istiophoridae) and swordfish (Xiphiidae), *Fishery Bulletin, 107*, 339-342.

Hoolihan, J.P., J. Luo, D.E. Richardson, D. Snodgrass, E.S. Orbesen and E.D. Prince (2009), Vertical behavior of Atlantic billfishes inferred from pop-up satellite archival tags, *Bull. Mar. Sci., 83*, 257-264.

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Huang Xiao-Lan, Jia-Zhong Zhang (2009), Neutral persulfate digestion at sub-boiling temperature in an oven for total dissolved phosphorus determination in natural waters, *Talanta, 78*, 1129-1135 doi:10.1016/j.talanta.2009.01.029.

John, V., R.P. Allan, and B.J. Soden (2009), How robust are observed and simulated precipitation responses to tropical ocean warming?, *Geophys. Res. Lett., 36*, L14702, doi:10.1029/2009GL038276.

Jury, M. and D.B. Enfield (2009), Environmental patterns associated with active and inactive Caribbean hurricane seasons, *J. Climate*, in press.

Kerstetter, D.W., P.H. Rice, D. Snodgrass and E.D. Prince (2008), Behavior of an escolar (*Lepidocybium flavobrunneum*) in the Windward Passage as determined by pop-up satellite archival tagging, *Gulf and Caribbean Research, 20*, 97-102.

Kirtman, B.P., and D. Min (2009): Multimodel Ensemble ENSO prediction with CCSM and CFS, *Mon. Wea. Rev.*, doi: 10.1175/2009MWR2672.1.

Kirtman, B.P., D.M. Straus, D. Min, E.K. Schneider and L. Siqueira (2009), Toward linking weather and climate in the interactive ensemble NCAR climate model, *Geophys. Res. Lett*., doi:10.1029/2009GL038389.

Lee, S.-K., D.B. Enfield and C. Wang (2008), Why do some El Ninos have no impact on tropical North Atlantic SST?, *Geophys.l Res. Lett.*, doi: 10.1029/2008GL034734.

Lee, S.-K., C. Wang and B. E. Mapes (2009), A Simple Atmospheric Model of the Local and Teleconnection Responses to Tropical Heating Anomalies, *J. Climate, 22*, 272-284.

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Marshall, J., et al. (2009), Observing the cycle of convection and restratification over the Gulf Stream and the subtropical gyre of the North Atlantic Ocean: preliminary results from the CLIMODE field campaign, *Bull. Amer. Meteor. Soc.*, in press.

Meinen, C.S., D.S. Luther and M.O. Baringer (2009), Structure and transport of the Gulf Stream at 68ºW: Revisiting older data sets with new techniques, *Deep Sea Res. I, 56*(1), 41-60, doi:10.1016/j.dsr.2008.07.010.

Miller, M.W., K. L. Kramer, S. Williams, L. Johnston and A.M. Szmant (2009), Assessment of current rates of *Diadema antillarum* larval settlement, *Coral Reefs, 28*, 511-515.

Miller, M.W., A. Valdivia, K.L. Kramer, B. Mason, D.E. Williams, and L. Johnston L (2009), Alternate benthic assemblages on reef restoration structures and cascading effects on coral settlement, *Marine Ecology Progress Series*, accepted.

Molinari R.L., Z. Garraffo, and D. Snowden (2008), Differences between observed and a coupled simulation of North Atlantic sea surface current and temperature, *J. Geophys. Res.,* 113,doi:10.1029/2008JC004848.

Muñoz, E., C. Wang, and D. Enfield (2009), The Intra-Americas Sea surface temperature anomaly dipole as fingerprint of remote influences, *J. Climate*, accepted.

Nolan, S.D., J.A. Zhang and D.P. Stern (2009), Validation and comparisons of planetary boundary layer parameterizations in Tropical Cyclones by Comparison of in-situ observations and high-resolution simulations of hurricane Isabel (2003). Part I: Initialization, track and intensity, and the outer core boundary layer, *Mon. Wea. Rev.*, in press. See: http:// ams.allenpress.com/archive/1520-0493/preprint/2009/pdf/10.1175_2009MWR2795.1. pdf.

Nolan, S.D., D.P. Stern**,** and J.A. Zhang (2009), Validation and comparisons of planetary boundary layer parameterizations in Tropical Cyclones by Comparison of in-situ observations and high-resolution simulations of hurricane Isabel (2003). Part II: Inner core boundary layer and eyewall structure, *Mon. Wea. Rev.*, in press. See: http://ams. allenpress.com/archive/1520-0493/preprint/2009/pdf/10.1175_2009MWR2786.1.pdf.

Park G.-H., K. Lee, P. Tishchenko (2008), Sudden, considerable reduction in recent uptake of anthropogenic CO_2 by the East/Japan Sea, *Geophys. Res. Lett., 35*, L23611, doi:10.1029/2008GL036118.

Perez, R.C., and W. S. Kessler (2009), The three-dimensional structure of tropical cells in the central equatorial Pacific ocean. *J. Phys. Oceanogr.* 39(1), 27-49.

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Roemmich, D., G.C. Johnson, S. Riser, R. Davis, J. Gilson, W. B. Owens, S. Garzoli, C. Schmid, M. Ignaszewski (2009), The Argo Program: Observing the Global Oceans with Profiling Floats, *NOPP Special Issue of Oceanography*, in press.

Romero, C.C., M.D. Dukes, G.A. Baigorria and R. Cohen (2009), Comparing theoretical irrigation requirements and actual irrigation for citrus in Florida, *Agricultural Water Management*, in press.

Schoof, J.T., D.W. Shin, S. Cocke, T.E. LaRow, Y.K. Lim and J.J. O'Brien (2009), Dynamically and statistically downscaled seasonal temperature and precipitation hindcast ensembles for the southeastern USA, *Int. J. Climatol., 29*, 243-257, DOI:10.1002joc.1717.

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Sellwood, K.J., S. J. Majumdar, B.E. Mapes and I. Szunyogh (2008) Predicting the influence of observations on medium-range forecasts of atmospheric flow, *Q. J. R. Meteorol. Soc., 134***,** 2011-2027.

Simpfendorfer C., E. Cortes, M. Heupel, E. Brooks, E.A. Babcock, J. Baum., R. McAuley, S. Dudley, J. Stevens, S. Fordham and A. Soldo, (2009), An integrated approach to determining the risk of over exploitation for data poor pelagic Atlantic sharks, *ICCAT Collect. Sci. Papers*, in press.

Sinigalliano, C.D., J. Winshell, M.A .Guerrero, G. Scorzetti, J.W. Fell, R.W. Eaton, L. Brand, and K.S. Rein (2009), Viable cell sorting of dinoflagellates by multi-parametric flow cytometry, *Phycologia*, in press.

Stewart, J.R., R.J. Gast, R.S. Fujioka, H.M. Solo-Gabriele, J.S. Meschke, L.A. Amaral-Zettler, E. Del Castillo, M.F. Polz, T.K. Collier, M.S. Strom, C.D. Sinigalliano, P.D.R. Moeller and A.F. Holland (2008), The coastal environment and human health: Microbial indicators, pathogens, sentinels and reservoirs, *Environ. Health, 7*(2), S3.

Takahashi, T., S.C. Sutherland, R. Wanninkhof, C. Sweeney, R.A. Feely, D.W. Chipman, B. Hales, G. Friederich, F. Chavez, C. Sabine, A. Watson, D.C.E. Bakker, U. Schuster, N. Metzl, H.Y. Inoue, M. Ishii, T. Midorikawa, Y. Nojiri, A. Koertzinger, T. Steinhoff, M. Hoppema, J. Olafsson, T.S. Arnarson, B. Tilbrook, T. Johannessen, A. Olsen, R. Bellerby, C.S. Wong, B. Delille, N.R. Bates, H.J.W. de Baar (2009), Climatological Mean and Decadal Change in Surface Ocean pCO_2, and Net Sea-air CO_2 Flux over the Global Oceans, *Deep -Sea Res II*, 56.

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Vasquez-Yeomans, L., et al. (2009), Patterns of distribution and abundance of bonefish larvae *Albula spp*. (Albulidae) in the western Caribbean and adjacent areas, *Ichthyological Res., 56*(3).

Vecchi, G.A., A.C. Clement and B.J. Soden, (2008), Examining the tropical Pacific's response to global warming, *EOS Transactions, 89*, 81-83.

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