Cooperative Institute for Marine and Atmospheric Studies

"First Year" Annual Report

NOAA Cooperative Agreement NA10OAR4320143

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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 hosted at the University of Miami (UM) in the Rosenstiel School of Marine and Atmospheric Science (RSMAS) and includes at present eight additional Florida and Caribbean University Partners (FAU, FIU, FSU, NSU, UF, UPR USF, UVI). CIMAS is jointly sponsored by the University of Miami and the National Oceanic and Atmospheric Administration (NOAA). CIMAS works particularly closely with three NOAA facilities located in Miami: the Atlantic Oceanographic and Meteorological Laboratory (AOML), the Southeast Fisheries Science Center (SEFSC) and the National Hurricane Center (NHC). Reflecting the diversity of research conducted throughout NOAA, CIMAS research, education and outreach encompass seven inter-related Themes which are linked to NOAA's Strategic Goals. These Research Themes were defined by NOAA in the request for proposals (RFP) to which we responded in the recompetition process.

Theme 1: Climate Research and Impact
Theme 2: Tropical Weather
Theme 3: Sustained Ocean and Coastal Observations
Theme 4: Ocean Modeling
Theme 5: Ecosystem Modeling and Forecasting
Theme 6: Ecosystem Management
Theme 7: Protection and Restoration of Resources

Total expenditures (Tasks 1, II, III and IV) on this Cooperative Agreement (CA) during this reporting period were $12.1M. Task I which includes not only Administration but also Research Infrastructure, Education and Outreach was ca. $1.9M of which $.23M was provided by NOAA. Task II, which supports CIMAS employees whose primary work site is off campus was ca. $ 8M.

Additional research funding (Tasks III and IV) totaled ca. $2.4M. The largest portions of research in Tasks III and IV were in Themes (3, 6) Sustained Ocean & Coastal Observations and Ecosystem Management which together account for 46%. The smallest portions were in Themes (2, 5) Tropical Weather and Ecosystem Modeling & Forecasting which together account for only 15%. These percentages are somewhat misleading in that the Theme assignments reflect only the "primary" not secondary or tertiary "theme" designations. Moreover in some cases which Theme is primary is arbitrary. Moreover the above expenditures refer only to those under the new CA initiated October 2010. They do not include continuing expenditures under the prior agreements which may bias in some cases the allocation amongst themes.

During this reporting period a total of 113 individuals at UM were directly provided salary support through CIMAS. Of these, 97 received over 50% of their support from NOAA through CIMAS. Of the 97 research employees who received over 50% NOAA support, 58 worked with AOML, 38 with SEFSC and one with the NHC.

The employees in the Research Associate and Research Scientist ranks have a diverse demographic profile. The population is 41% female. Foreign-born individuals make up 53% of the personnel. Of these, Hispanics make up 23% of the ranks; Asian and Pacific Islander, 18%. The population of CIMAS is relatively young in comparison with NOAA and has an average age of only 39.

The research program in the re-invented CIMAS continues to be productive. During 2010/2011 there were 107 peer-reviewed publications and another 37 non-peer reviewed technical reports or other publications resulting from CIMAS related research. The results from some of the individual projects are highlighted below. They were selected from each of the themes to be representative of the wide diversity of activities carried out within CIMAS and are sorted with respect to the three major NOAA scientific goals. A more detailed description of these results can be found in the body of the Report within the full sets of individual project summaries provided for each of the seven new CA Themes.

Research and educational and outreach activities conducted by CIMAS during the nine months summarized herein but not under the new CA will be reported in subsequent reports as directed by the NOAA CI Program Office.

SOME RESEARCH HIGHLIGHTS

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

Upper Ocean Sampling of Currents and Salinity in the Loop Current to Monitor the Deepwater Horizon Oil Spill: This project provided near-real time (within 12 to 24 hours) subsurface (and deep) temperature profiles to initialize the data assimilative ocean circulation models used to predict the surface and subsurface oil movement by NAVOCEANO and others over the 100 plus days of DWH oil spill. Tests indicate that synoptic measurements from the aircraft over a 9-hour flight improved the fidelity of the model in simulating more realistic ocean fields reducing temperature bias as much as 50% and reduced RMS error to 25-30%.

Evaluation of ESA listed Acropora spp. Status and Actions for Management and Recover:
In the Florida Keys the most common source of tissue loss on *Acropora palmata* is white disease, followed by breakage and feeding by the corallivorous snail *Coralliophila abbreviata*. This project has begun to assess the effectiveness of removal of the predatory snails as a management tool.

Oceanographic and Spectroscopic Analysis Relating to the Deepwater Horizon Oil Spill:
This project furnished responders a satellite derived "Oil Oceanographic Analysis" (Oil OA) for the areas affected by the Deepwater Horizon Oil along with new satellite data products that fused the Oil OA with satellite data derived from NOAA/AOML's altimetry product, with data derived from surface drifting buoys, and with acoustic doppler current profilers (ADCP) from both ships and fixed platforms.

Biscayne Bay's Nearshore Submerged Aquatic Vegetation (SAV: Since 2008, this research group has been collecting data on the seasonal abundance and distribution of SAV communities in central and southern Biscayne Bay which have revealed that the abundance and distribution of seagrasses are tightly linked to water quality and, more specifically, to salinity patterns. During this last year the project was expanded to evaluate the potential role of macroalgal community abundance and diversity as early-warning indicators of changes in littoral salinity and nutrient regimes.

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

Predicting the Effects of Climate Change on Bluefin Tuna (Thunnus thynnus) Spawning in the Gulf of Mexico Using Downscaled Climate Models: Low-resolution models, such as the IPCC-AR4 models, underestimate the reduction of the LC and its cooling effect, thus fail to simulate the reduced warming feature in the northern GoM. A reduced warming feature implies that the negative effect upon Bluefin Tuna recruitment may be less severe than previously estimated.

Assessing the Sensitivity of Northward Heat Transport/Atlantic Meridional Overturning Circulation to Forcing in Existing Numerical Model Simulations: The linear increase in the Meridional Heat Transport from 1980-1993 is due to the increase in advective heat transport into the South Atlantic from the Pacific and Indian Oceans. Of the observed increase about two thirds is contributed through the Agulhas Current system, suggesting that the warm water route from the Indian Ocean was the dominant component of northward flowing water in the upper branch of the AMOC at 34°S from 1980-1993.

The CLIVAR CO_2 Repeat Hydrography Program: *C*hanges in the deep ocean are being analyzed based on observations and models using the NCAR SCEM-1 model in collaboration with WHOI and PMEL scientists using the GLODAP dataset. Preliminary analyses of anthropogenic carbon inventories at depths greater than 2000 m show appreciably greater changes in the deep ocean than previously recognized.

What Causes the Tropical Atlantic SST Bias in CCSM3?: State-of-the-art atmosphere-ocean coupled climate models cannot accurately reproduce the annual cycle of tropical Atlantic SST. Due to this shortcoming in the climate models, we do not currently have the skill to simulate much less forecast tropical Atlantic climate variability. Primary ensemble experiments indicate when atmosphere model and ocean model are coupled, atmosphere model errors and ocean model errors work together to amplify the SST bias.

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

Ensemble-Based High-Resolution, Vortex-Scale Data Assimilation for Hurricane Model Initialization: While little impact on track forecasts was seen from assimilating radar observations, there were significant improvements in intensity forecasts for the first 72 h presumably because assimilating aircraft Doppler radar wind observations improves the characterization of initial hurricane structure.

New Infrared Satellite Imagery for Detecting Changes in Tropical Cyclone Structure: Although results are preliminary, there appear to be remarkable consistencies between different TCs in both the timing of outward propagating cool rings and the correlation between cool rings and arc clouds/transverse cloud bands. Cool rings may very well be forced by features (e.g. gravity waves) that have significant vertical extent (several kilometers).

Advanced Modeling and Prediction of Tropical Cyclones: Advanced formulations for storm-size correction in HWRF vortex initialization have been successfully implemented in NOAA operational models and an experimental genesis model derived from the operational HWRF for basin-scale modeling is showing very promising preliminary results in regard to significantly improving track prediction.

Improving Predictability of the Atlantic Warm Pool in Ocean Model for Assistance to Operational Hurricane Forecasting: The 5-day forecast error of the NCEP/EMC's Real Time Ocean Forecasting System for Atlantic (RTOFS-Atlantic) is as large as 2degC and usually negative. In particular, the cold SST error is largest in the deep tropics between equator and 10N, and in the southern Caribbean Sea. It is demonstrated here that the application of a simple bias correction scheme could substantially reduce the 5-day forecast error of the RTOFS in the deep tropics and Southern Caribbean Sea.

II. CIMAS MISSION AND ORGANIZATION

CIMAS, the University Partners, and NOAA

The Cooperative Institute for Marine and Atmospheric Studies (CIMAS) is hosted at the University of Miami (UM) in the Rosenstiel School of Marine and Atmospheric Science (RSMAS) and including at present eight additional Florida and Caribbean University Partners (Florida Atlantic University (FAU), Florida International University (FIU), Florida State University (FSU), NOVA Southeastern University (NSU), University of Florida (UF), University of Puerto Rico (UPR) University of South Florida (USF) and University of the Virgin Islands (UVI). CIMAS works particularly closely with the three NOAA facilities located in Miami: the Atlantic Oceanographic and Meteorological Laboratory (AOML), the Southeast Fisheries Science Center (SEFSC) and the National Hurricane Center (NHC) - see www.ci-mas.org for additional details and geographic distribution.

Goals

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

Vision:

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

Mission:

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

- *To create and implement formal education and training programs creating the intellectual capital required by the present and future NOAA*

To achieve this Vision and carry out this ambitious Mission, CIMAS re-invented and restructured itself:

- By enhancing interconnections with the regional NOAA community beyond Virginia Key (including inter alia NWS/NHC, Florida SG, SECART, GOMART);
- By broadening the participation of the regional academic community beyond UM by incorporating; complementary capabilities from other Florida and U.S. Caribbean universities (specifically FAU, FIU, FSU, UF, USF, NSU, UPR and UVI);
- By offering NOAA access to state-of-the-art research infrastructure both at UM and its partner universities (including high performance computing facilities, ships, ocean engineering technology, hurricane simulation facilities etc);
- By developing new graduate and undergraduate educational programs to train the NOAA workforce of the future.
- By establishing collaborative relationships with other regional CI's (specifically NGI, CIOERT and CICS);
- By specifically addressing NOAA priorities most relevant to our thematic focus including the Future NOAA Workforce, the NOAA Hurricane Forecasting Improvement Program, Community Resilience to Extreme Weather Events, Climate Services, Ecosystem Approaches to Management and Marine Spatial Planning as reflected in NOAA's Annual Guidance Memorandum, Research Plan and Next Generation Strategic Plan.

How CIMAS Carries Out Its Mission

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

- *By fostering, facilitating and implementing joint projects between regional university scientists and those employed by NOAA;*
- *By providing a mechanism for engaging undergraduate students, graduate students and post-doctoral fellows in this research;*
- *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 facilities as a scientific working environment. It also serves to increase the breadth of university activity in research areas that are complementary to NOAA's mission.

The Link between CIMAS Research and NOAA Goals

CIMAS research and its scientific objectives have been guided by the general objectives of

NOAA's scientific mission goals:

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

These NOAA's scientific mission goals are consistent with the broader scientific mission of CIMAS and each research project in CIMAS is associated with at least one of these NOAA goals.

The Administration and Governance of CIMAS

The organization of CIMAS is designed to reflect the joint interests of the universities and NOAA in carrying out the CIMAS Mission. The Director of CIMAS is a senior faculty member of the host institution, the University of Miami. Many aspects of the governance of CIMAS are dealt with in consultation with the CIMAS Council of Fellows and the CIMAS Executive Advisory Board. Fellows are scientists of established national or international standing who hold regular teaching or research faculty appointments in one of the nine universities or who are senior staff members at one of the three local NOAA facilities. The Fellows play an important role by providing guidance to the Director of CIMAS in matters regarding the implementation 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 universities. The Council of Fellows is chaired by the CIMAS Director. The Executive Advisory Board consists of a senior administrator from each of the universities, the Directors of the three local NOAA facilities and the Director of the NOAA CI Office. The CIMAS Director participates as an *ex officio* member of the Board and was appointed by the Board.

CIMAS activities fall into four Task categories. The administrative functions of CIMAS are carried out under Task I with funding provided by both the University and NOAA. Task I also includes both Research Infrastructure and Education & Outreach. Under Task II CIMAS supports highly specialized UM research scientists who work on research projects carried out off campus primarily at NOAA's Miami facilities. The expertise of these CIMAS employees complements that already present within NOAA. CIMAS employees provide support that is essential to the success of specific activities or projects under the collaborative research themes of the Institute. Senior CIMAS employees frequently initiate new projects through Task III and IV (see below).

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 project-based research consistent with CIMAS research themes. Task III primarily encompasses research collaborations with NOAA scientists (typically but not necessarily located in Miami) and NOAA program directed efforts. Support for individual Task III projects is based on proposals submitted to specific NOAA units or funding programs often but not necessarily in response to a general Announcement of Opportunity or Request for Proposals. Task IV encompasses projects that support or complement the NOAA mission but are funded by other federal (non-NOAA), state or private funding sources.

III. PERSONNEL

Distribution of Personnel

CIMAS personnel participate in a wide range of NOAA-related activities. During the past nine months a total of 113 persons were associated with CIMAS in various capacities. Of these, 97 received over 50% of their support from NOAA sources. Table 1 shows the distribution of these individuals by category and by their association with the local NOAA facilities. Of the 97 who received over 50% NOAA support, 58 are associated with AOML, 38 with SEFSC and one with NHC. Two of these work out of state.

Table 1: CIMAS Research Personnel 2010 – 2011

Category	Number	BS	MS	Ph.D
Research Associate/Scientist	65	18	22	24
Part Time Research Associate/Scientist	7	2	2	3
Postdoctoral Fellow	8			6
Research Support Staff	17	2	2	
Total (> 50% NOAA support)	**97**	**22**	**26**	**33**
Administration	5			2
Task I Undergraduate Students	5			
Task I Graduate Students	4			
Visiting Scientists	3			
NOAA Association	58-OML 38-EFSC 1-NHC			
Obtained NOAA employment within the last year	1			

Research Associates, Research Scientists and Postdoctoral Associates are Task II employees who work off campus primarily at the local NOAA facilities. There are also two CIMAS non-research staff who work at the same facilities. A total of 97 persons in these categories were employed under Task II over the past nine months.

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). Over the last nine months, there were in addition a total of 8 Postdoctoral Fellows. Postdoctoral Fellows have become an increasingly important part of the CIMAS employee pool during the current Cooperative Agreement. A new category of CIMAS employment is non-research support employee (e.g. computer program or engineer).

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 UM's Rosenstiel School it has no faculty. School faculty participate in CIMAS activities in many ways, but they hold their primary appointment in one of the School academic divisions. Such faculty are not counted in the listing of the 113, not even those who serve as CIMAS Fellows or conduct Task III research projects. All the graduate students who work on CIMAS programs and are included in the 113 total have their primary affiliation with an Academic Division which has the ultimate responsibility for overseeing the students' academic performance and the granting of degrees.

See *Section X* for the list of students and post-docs associated with CIMAS.

Over the past nine months, CIMAS has continued its efforts to improve the working environment of its many off-campus employees. Specific efforts included:

1. Initiating an Awards Policy modeled upon the awards available to NOAA employees (http://cimas.rsmas.miami.edu/pdfs/CIMAS_Award_Program_Policy.pdf) and awarding 13 awards under this policy;
2. Expanding the breadth and increasing the upper limit of the Pay Bands applicable to CIMAS employees (http://cimas.rsmas.miami.edu/pdfs/pay-bands.pdf) and not only hiring new employees within these limits but raising the salary of legacy employees so they now fall within the appropriate pay bands;
3. Assisting personnel with respect to the increasing difficulty of negotiating the escalating requirements of the Department of Homeland Security (many CIMAS Task II employees are not U.S. citizens); and,
4. Preparing and providing briefing documents and workshops for relevant NOAA personnel (advisors and administrators) regarding UM Human Resources policies, practices and regulations.
5. Providing support for a part-time a liaison position at each of the two primary off-campus work sites (AOML and SEFSC).

CIMAS Fellows

CIMAS Fellows play a critical role in the governance of the Institute. At present there are 30 CIMAS Fellows. 6 CIMAS Fellows are from RSMAS, 9 from the local NOAA facilities and 15 from the Partner Universities. A list of the present CIMAS Fellows is given in the *Fellows* section of this report along with their affiliation. The CIMAS Director serves *ex officio* as the Chair of the Fellows. Given the geographic dispersion of the membership, meetings are conducted as GOTOMEETING teleconferences. Although it was cancelled this year due to the overall uncertainty in the NOAA budget process (and the inability therefore to obtain appropriate NOAA representation) an annual meeting in Miami was planned will be held in subsequent years.

CIMAS Executive Advisory Board

The Board includes the Directors of the local NOAA facilities (R. Atlas, OAR/AOML; B. Ponwith, NMFS/SEFSC and Bill Reid, NWS/NHC), the Director of the NOAA CI Office (P. Hoffman) and senior administrators from each of the Partner Universities including the Dean of UM/RSMAS (R. Avissar), the host institution. (A list of members is given in the *Executive Advisory Board* section of this report along with their affiliation. Given the geographic dispersion of the membership, these meetings as well are conducted as GOTOMEETING teleconferences.

CIMAS Administration

CIMAS administrative staff consists of a Director: Dr. Peter B. Ortner, an Associate Director: Dr. David Die, and three full-time administrative personnel. Part-time or work-study students are employed on an as needed basis.

Transition to Federal Positions

More than thirty five former UM undergraduate/graduate students and/or research CIMAS employees currently hold Federal positions in the three local NOAA facilities. This total represents only a small fraction of the hundreds contributed to the national NOAA workforce. During the past year, 1 more CIMAS employee joined his predecessors in this regard.

Demographics of CIMAS Employees

The CIMAS population is 41% female. Foreign-born individuals make up 53% of the personnel; of these Hispanics make up 23% of the ranks; Asian and Pacific Islanders, 18%. Only 3% are African-Americans despite our efforts to expand this group's participation. The population of CIMAS is relatively young with an average age of 39. The largest age decade is that between 30 and 40, for a total of 55. Comparison with local laboratory populations and the overall NOAA federal workforce analyses, indicate this is a much younger and more diverse group than the overall NOAA population.

CIMAS Student Employees

There are currently 4 UM/RSMAS graduate students supported through CIMAS Task I. Many others are supported on Task III projects and in other capacities (see *Section X* for a full list). In addition 5 undergraduates are currently supported. A number of high school students are also being employed as temporary hires (under 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 adjacent to AOML and across the street from the UM marine campus

IV. FUNDING

General Funding:

In the first nine months, funding from all sources totaled ca. $12.1M under the new Cooperative Agreement. A summary of funding under the four Tasks is shown in Table 1.

Table 1: Summary of Funding

Task I	Task II	Task III	Task IV	TOTAL
1,742,457	7,924,090	1,583,572	824,640	12,074,459

The sources of that funding are shown in Table 2. The major source of funding continued to be OAR which provided 56% of the total. NMFS and Department of Defense (the USACE in support of the South Florida Restoration program) were second at 14% and 9% respectively. Of the total OAR funding most originated from the Climate Program Office (CPO). Another major source of OAR funding was associated with the implementation of the NOAA Hurricane Forecast Improvement Program (HFIP) program. "Other" sources of funding include awards from NSF, ONR, National Parks and private industry as well as subawards from FIU and USF.

Table 2: Funding by Source

1 October 2010 - 30 June 2011		
Source	**Funding $M**	**% Total**
OAR	6.78	56%
NMFS	1.73	14%
NESDIS	0.27	2%
NOS	0.70	6%
Dept. of Defense	1.10	9%
Homeland Security	0.34	3%
NWS	0.36	3%
Other	0.74	7%
GRAND TOTAL	**12.07**	**100%**

Funding by Task

CIMAS activities continue to be administratively grouped under four distinct Tasks that reflect complementary aspects of the CIMAS mission.

- **Task I** provides support for the administrative structure of CIMAS (including website outreach, meetings, GOTOMEETING etc.), NOAA access to research infrastructure as well as support for students and limited-term visiting scientists. UM directly contributes to the administration of CIMAS as a Division within the School moreover UM charges no Indirect Costs (IDC) whatsoever on Task I expenditures.
- **Task II** provides support for highly specialized research scientists who are employed by CIMAS to conduct collaborative research primarily at NOAA facilities. Their expertise complements that already existing at NOAA or present at UM. Support for postdoctoral research associates is also included under Task II. UM charges 26% IDC on Task II.
- **Task III and Task IV** encompass project-specific research funding at CIMAS. These Tasks provide support for research by university faculty, scientists and students. Task III encompasses activities that are funded by NOAA and may be carried out in cooperation with NOAA personnel in the local NOAA laboratories and elsewhere in the United States. Task III proposals may be submitted by UM or Partner University faculty and scientists or CIMAS employees. Task IV includes projects supported by other (non-NOAA) funding sources. With the approval of the Director, CIMAS employees (Assistant, Associate and Full Scientist rank only) may submit Task IV proposals. Their subject must be consistent with CIMAS research themes and contribute to NOAA strategic goals. The indirect cost rate for Task III is 40% and for Task IV is either the federally negotiated UM rate (currently 53%) or whatever rate is specified in the relevant RFP. The lower rate for Task III is in recognition of the substantial funding CIMAS receives from the local NOAA laboratories under Task 1 for the administrative services toward which that IDC would have contributed.

The total of Task I Funding (including the UM contribution) was $ 1.93M, of which $0.65M was for the Administration component and the remainder for Research Infrastructure, Education and Outreach. The distribution of NOAA Task 1 expenditures is shown in Figure 1.

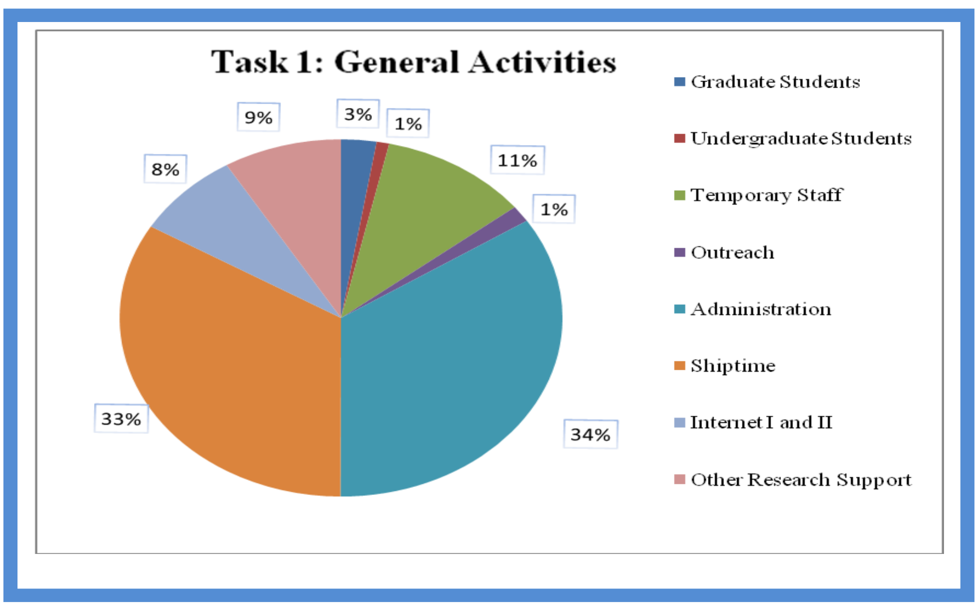

Figure 1: Distribution of Task 1Funding

The total NOAA-supported Task 1 budget was $ 1.7M. The category "Administration" 34% covers only a portion of the salary of CIMAS staff including its Director and Associate Director. In addition, the University of Miami provided a direct contribution to Task I Administration of another $.231M.

The category "Other" 9% includes: travel for students, visiting scientists and temporary staff in support of research activities; new hire expenses (drug tests, background searches), consulting agreements, other supplies (computer equipment, peripherals, etc.), research ship-time and access to high performance computing or other university owned research facilities. Temporary Staff (11%) covers persons hired on a temporary basis to support research.

The funding provided for Task II employees totaled $7.9M over the past nine months. The distribution of these funds by employee category is depicted in Figure 2.

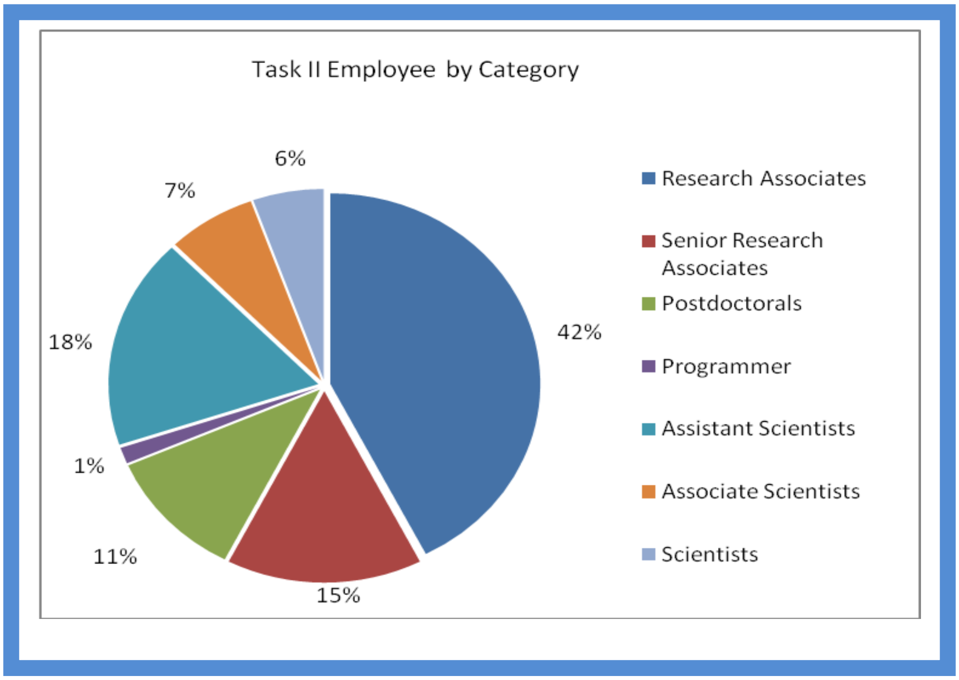

Figure 2: Distribution of Task 2: Funds by Employee Category

Funding By Theme

Additional research funding (Tasks III and IV) under the new CA totaled ca. $2.4M as shown above in Table 1. Figure 3 shows the percentage of Task III and Task IV funding expended upon each CIMAS Themes during the first nine months. Of total CIMAS research funds, Theme 3: Sustained Ocean and Coastal Observations accounts for the largest portion of the funding - 28%. The smallest portion of funding was in Theme 5: Ecosystem Modeling and Forecasting – 7%.

The distribution of research funding by Theme as shown in Figure 3 is based upon somewhat arbitrary assessments of the major focus of specific projects. In truth nearly all CIMAS projects are highly interdisciplinary and could reasonably be assigned to more than one Theme. To better reflect this complexity projects are given not only primary but also secondary (and sometimes tertiary) theme assignments. This figure only shows the distribution of funding under Tasks III and IV; it does not show the funding that supports Task II research personnel working on projects all of which necessarily fall within these same Themes. While the salary of those personnel is paid through CIMAS all the other costs for those research projects are budgeted directly within NOAA and no specific project proposal was submitted through CIMAS to obtain the requisite funding.

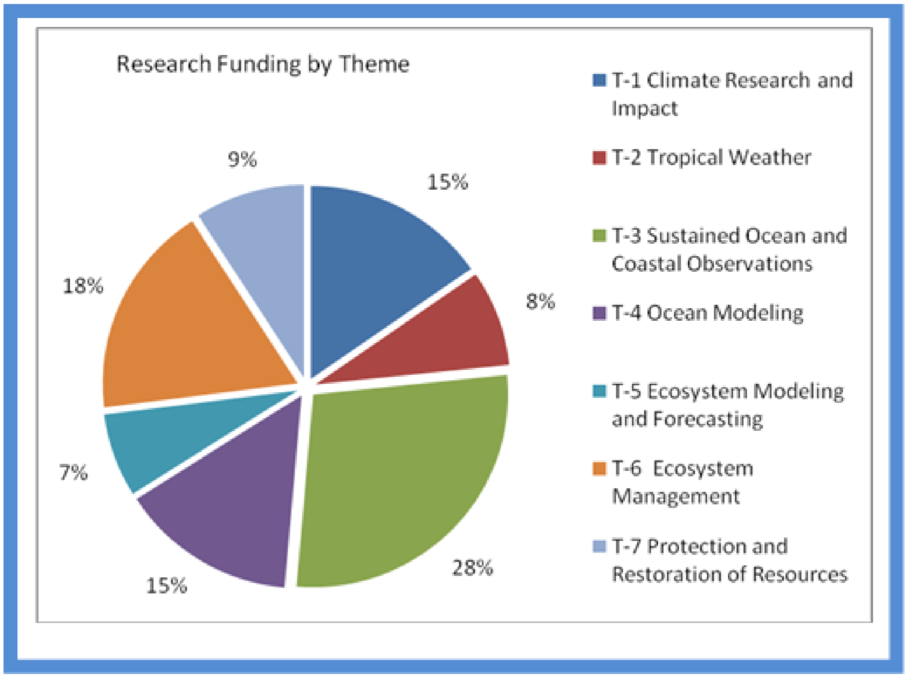

Figure 3: Percentage of Task 3 and Task 4 (Research) funding in the CIMAS Themes

Table 3 below tabulates NOAA funding received by CIMAS under the present Cooperative Agreement as well as its predecessors over the past decade. Note that the Continuation and Shadow continue to be operative and in effect during the present reporting period but those expenditures are not reported herein. As per the guidance issued by the NOAA CI Program Office, they will be the subject of subsequent reports.

Table 3: NOAA Funding

Award Number	Award Period	Total Funds
NA17RJ1226 Original	07/01/01 - 09/30/11	$ 69,935,728
NA08OAR4320892 Continuation	07/01/08 - 06/30/12	$ 6,809,019
NA08OAR4320889 Shadow	07/01/08 - 06/30/13	$ 3,068,262
NA10OAR4320143	10/01/10 - 09/30/15	$ 11,250,119

Due to in part to the uncertainty within the federal budget process, funding distributed through CIMAS to the Partner Universities under Task III was a comparatively minor $.021M or 1% of the Task III total and primarily in support of Deepwater Horizon response. Actions taken when the budget was finally resolved (after the end of this reporting period) suggest that Task III overall and the Partner University component will be substantially greater in the next Annual Report. For example we received notification that a major new five year proposal (ca. $1.0M per annum) in which six of the CIMAS partners are participating has been accepted and funds will soon be received so that it will commence October 1. A number of other Task III project awards (and Deepwater Horizon supplemental funding) were also processed through CIMAS under the new CA in June and early July just after the close of this foreshortened nine month progress report period. All of those project awards will be included in the first truly annual report which will cover June 1, 2011 to May 31, 2012.

Conclusion

In our funding summary we report only expenditures during the nine month initial project period under the new Cooperative Agreement. As noted above there were considerable additional CIMAS expenditures that either just missed the deadline (or represented continuations of pre-existing awards) which were not included herein. Moreover there are a substantial number of research and educational activities that are carried out by university faculty that complement and contribute to the NOAA-supported CIMAS-linked programs but are supported directly outside CIMAS. Consequently there is considerable leveraging of NOAA funds which does not appear in the present accounting. One example of such an activity at UM/RSMAS 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 prior CIMAS CA. For legal reasons the CIE was removed from that CA and since 2002 the CIE has been funded by a separate contract with NOAA. Since 2002, the CIE has received nearly $3.4M in funding from NMFS none of which was reported by CIMAS. The CIMAS Associate Director serves as the lead for the CIE at UM/RSMAS.

V. RESEARCH THEMES OVERVIEW

Organization of CIMAS Themes

CIMAS conducts research, support research and education and provides outreach services with respect to the following scientific topics. These Research Themes were defined by NOAA in the request for proposals (RFP) to which we responded in the recompetition process.

- Climate Research and Impact
- Tropical Weather
- Sustained Ocean and Coastal Observations
- Ocean Modeling
- Ecosystem Modeling and Forecasting
- Ecosystem Management
- Protection and Restoration of Resources

Research Themes

1. Climate Research and Impacts - *Research focused upon understanding oceanic and atmospheric processes associated with global and regional climate change on various temporal scales as well as the impacts of climate variability and change. Activity under this theme also includes both research to determine effective regional adaptation strategies, and the development of new climate information products and tools appropriate for evolving user needs, particularly in the Southeast United States and the Caribbean.*

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

2. Tropical Weather – *Research conducted under this theme encompass the collection and analysis of hurricanes and other tropical weather system observations. Research activities include identifying and validating observational needs, developing instrumentation, obtaining observations, studying the optimum configurations for observation networks, modeling and data assimilation, expediting and facilitating the transition of research to operations, and developing analysis and forecast applications for operations.*

Theme 2 activities contribute to NOAA Mission Goal 3: Serve Society's Needs for Weather and Water Information

3. Sustained Ocean and Coastal Observations - *Research focused on the collection and analysis of observations of the ocean and coastal environment important for understanding and monitoring on a range of timescales, particularly in the Gulf of Mexico, Caribbean and Atlantic.*

This includes the development and improvement of ocean and coastal observation platforms and instruments that measure biological, physical, and chemical parameters; studying the optimum configurations for observation networks; modeling, data assimilation, and diagnostic analysis of local, regional, and global marine data sets; and information product development.

Theme 3 activities contribute to NOAA Mission Goal 1: Protect, Restore, and Manage the Use of Coastal and Ocean Resources through Ecosystem-based Management
Theme 3 activities contribute to NOAA Mission Goal 2: Understand climate variability and change to enhance society's ability to plan and respond.
Theme 3 activities contribute to NOAA Mission Goal 3: Serve Society's Needs for Weather and Water Information

4. Ocean Modeling – *Research focused upon improved model representation of ocean processes particularly those processes governing sea surface temperature, upper ocean heat content, and salinity variability including air-sea exchanges, heat-flux, lateral ocean advection, and entrainment at the base of the ocean mixed layer that play a significant role in controlling short-term variability in ocean and coastal circulations as well as long-term variations. It also includes modeling of the ocean from the surface to the ocean floor to improve understanding and, eventually, forecasting of climate variability and climate change.*

Theme 4 activities contribute to NOAA Mission Goal 1: Protect, Restore, and Manage the Use of Coastal and Ocean Resources through Ecosystem-based Management
Theme 4 activities contribute to NOAA Mission Goal 2: Understand climate variability and change to enhance society's ability to plan and respond.
Theme 4 activities contribute to NOAA Mission Goal 3: Serve Society's Needs for Weather and Water Information

5. Ecosystem Modeling and Forecasting – *Research focused upon improved forecasting of the structure and function of marine ecosystems including the provision of ecosystem services, particularly in the Southeast U.S. coastal ocean, the Caribbean Sea, and Gulf of Mexico Large Marine Ecosystems. These regions are the primary geographic focus of this and the following two research theme areas. Modeling and forecasting topics include: human health (e.g., beach closings, fish contaminants, and harmful algal blooms), fish recruitment and productivity, and protected species sustainability and recovery, all of which are deemed relevant to NOAA's responsibilities with respect to the assessment and management of living marine resources and their habitats.*

Theme 5 activities contribute to NOAA Mission Goal 1: Protect, Restore, and Manage the Use of Coastal and Ocean Resources through Ecosystem-based Management

6. Ecosystem Management – *Research focused upon promoting sustainable coastal development, facilitating community resiliency, and enabling NOAA's ecosystem approach to management in the Southeast U.S. coastal ocean, the Caribbean Sea, and Gulf of Mexico marine* *ecosystems by enhancing scientific understanding of the interconnections between the marine ecosystem and the adjacent watershed including their human health and resource stewardship implications. This research theme (as well as the one following) specifically includes human dimensions science in addition to the natural sciences.*

Theme 6 activities contribute to NOAA Mission Goal 1: Protect, Restore, and Manage the Use of Coastal and Ocean Resources through Ecosystem-based Management

7. Protection and Restoration of Resources – *Research focused upon the prototype development of technology, tools, and effective approaches to restoration, as well as bio-geographical characterizations, intended to enable improvements in defining and protecting components of marine protected areas and restoring habitats and populations. A wide range of problems are addressed from removing contaminants to providing new materials and techniques to protect underwater cultural resources.*

Theme 7 activities contribute to NOAA Mission Goal 1: Protect, Restore, and Manage the Use of Coastal and Ocean Resources through Ecosystem-based Management

In Section VI following, Task II, III and IV CIMAS research activities are briefly described and the participating university and NOAA personnel enumerated. More detailed information on specific research activities can be obtained by contacting the participants. As discussed above, the activities are sorted by *primary* theme but in some cases this is an essentially arbitrary decision and the same project could as well have been assigned to another thematic category. For that reason we asked those preparing reports to choose not only the primary theme but also if they so desired a *secondary* and *tertiary* theme.

RESEARCH REPORTS

THEME 1: Climate Research and Impact

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

Project Personnel: S. Dong (UM/CIMAS)
NOAA Collaborators: M. Baringer, G. Goni and G. Halliwell (NOAA/AOML)

Long Term Research Objectives and Strategy to Achieve Them:
Objectives**:** To investigate the mechanisms underlying observed differences in the role of Ekman and geostrophic transports in the Atlantic Meridional Overturning Circulation (AMOC) and net northward heat transports in both the North and South Atlantic on seasonal to longer time scales and to diagnose the causes for inconsistencies between observed variability and that demonstrated in numerical model simulations.
Strategy**:** Integrate and compare data analyses and numerical model outputs.

CIMAS Research Theme:
Theme 1**:** Climate Research and Impact

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

Funding Unit: NOAA/OAR/CPO **NOAA Technical Contact:** Jim Todd

Research Summary:

In the Atlantic, one of the most prominent ocean circulation systems is the Atlantic Meridional Overturning Circulation (AMOC), which consists of a northward flow of warm water in the upper layers from the tropics and South Atlantic into the North Atlantic, and a southward cold water return flow at depth. Many factors are involved in meridional heat transport (MHT) in the South Atlantic, including the inter-ocean exchanges with the Pacific and Indian Oceans, ocean heat gained from the atmosphere and heat stored in the ocean. Thus, to understand the changes of the heat transported to the north from the South Atlantic, it is important to determine variability in the inter-ocean exchanges and its underlying mechanism, as well as the variations in heat storage and air-sea heat fluxes. A better understanding of inter-ocean exchanges and thermal balance in the South Atlantic will improve our ability to predict long-term climate change to the degree that it is linked to the AMOC.

The inter-ocean exchange of water from the South Atlantic with the Pacific and Indian Oceans was examined using the output from the Ocean Circulation Model for the Earth Simulator (OFES) during the period 1980-2006. The MHT from the OFES model shows similar response to AMOC variations to that derived from observations: one sverdrup increase in the AMOC strength would cause a 0.054 ± 0.003 PW increase in MHT at approximately 34°S. See **Figure 1**. The main feature in the AMOC and MHT across 34°S is their increasing trends during the period 1980-1993. See **Figure 2**. Separating the transports into boundary currents and ocean interior regions indicates that the increase in transport comes from the ocean interior region, suggesting that it is important to monitor the ocean interior region to capture changes in the AMOC and MHT on decadal-to-longer time scales. The linear increase in the MHT from 1980-1993 is due to the increase in advective heat converged into the South Atlantic from the Pacific and Indian Oceans. Of the total increase in the heat convergence about two thirds is contributed by the Indian Ocean through the Agulhas Current system, suggesting that the warm water route from the Indian Ocean was the dominant component of the northward flowing water in the upper branch of the AMOC at 34°S during our study period. See **Figure 3**.

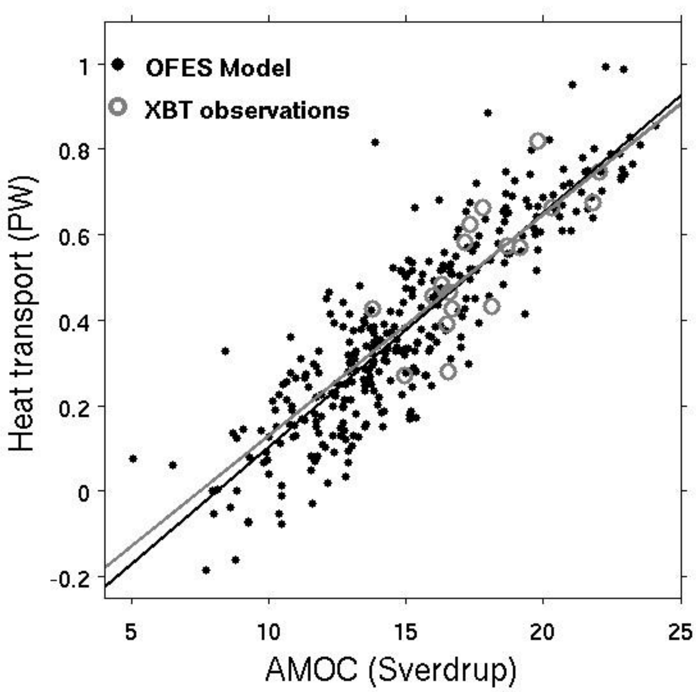

Figure 1: Scatter plot of the strength of the AMOC versus total MHT across 34°S. Dots and circles correspond to the OFES model and XBT observations, respectively. The black line indicates the regression of the heat transport to the AMOC from OFES model, and the gray line for the XBT observations.

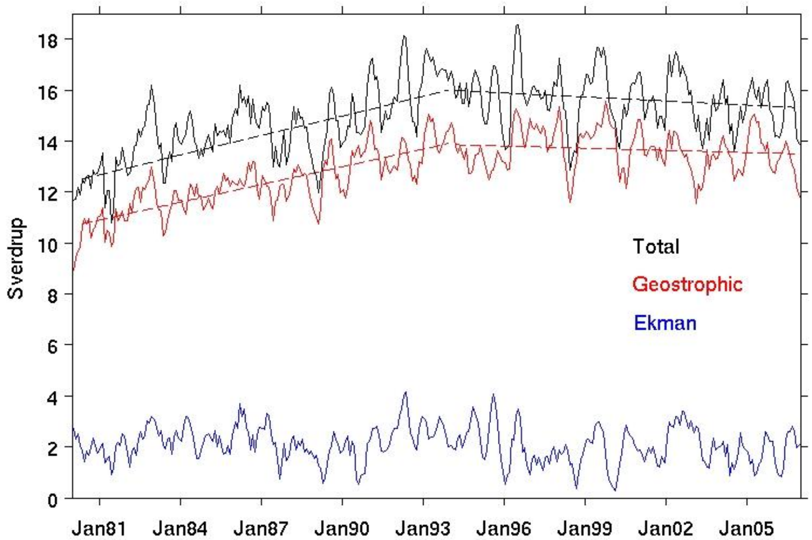

Figure 2: Time series of the strength of the AMOC (black) at 34°S and contributions from the geostrophic (red) and Ekman (blue) components. Dashed lines denote the linear trends from least-square analysis.

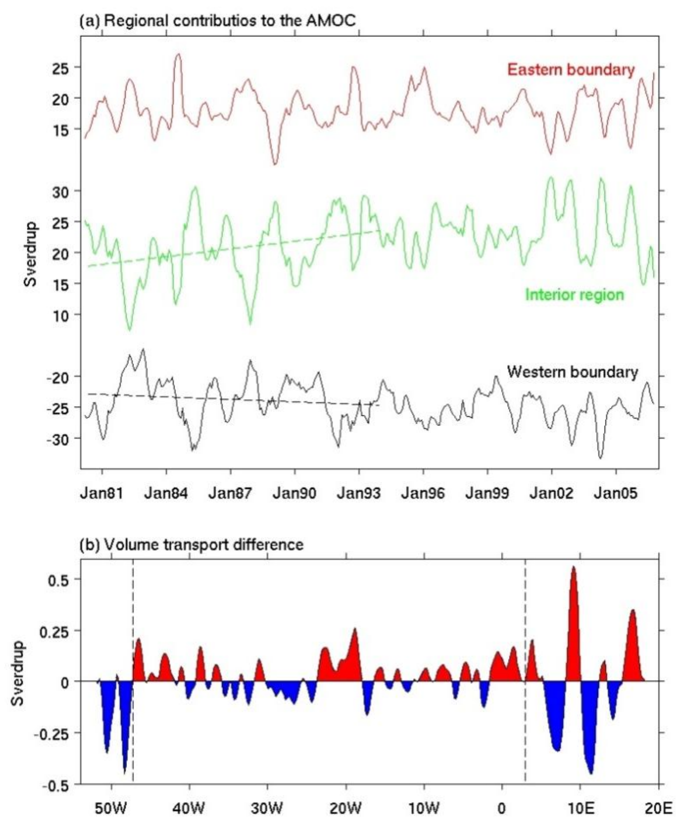

Figure 3: (a) Regional contributions to the AMOC across 34°S: the eastern (red) and western (black) boundaries and ocean interior region (green). Dashed lines show the linear trend during 1980-1993. (b) Zonal distribution of the differences in vertically integrated volume transport between two 10-year periods: (1994-2003) minus (1980-1999). Dashed lines approximate the longitudes where the boundary currents and ocean interior are separated.

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

Collaborative Research: Dynamics of Eighteen Degree Water from CLIMODE Observations and its Climate Implications

Project Personnel: S. Dong (UM/CIMAS)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** (1) to examine interannual variability in Eighteen Degree Water (EDW) volume, (2) to characterize its dependence on ocean processes and atmospheric forcing (with guidance from other CLIMODE analyses), (3) to parameterize these processes using variables that can be observed over longer time periods, and (4) to use that parameterization to examine the ability of IPCC-class models to simulate the role of EDW in climate variability.

***Strategy*:** Integrate and compare data analyses and numerical model outputs

CIMAS Research Theme:

***Theme 1*:** Climate Research and Impact

Link to NOAA Strategic Goals:

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

Funding Unit: NSF **NOAA Technical Contact:** Alan Leonardi

Research Summary:

Subtropical Mode Water (STMW), an isothermal layer that forms on the equatorward side of western boundary current (WBC) in response to wintertime cooling, is central to understanding climate variability in mid-latitude regions because it integrates anomalies in both the ocean and atmosphere to contribute to climate system memory. The STMW region has a large capacity to store heat, and its heat storage rate has been shown to depend both on air-sea fluxes and on ocean circulation. The volume of STMW is so large that several years of air-sea interaction alone cannot dissipate it; after formation, it is partially re-entrained in subsequent winters to again interact with the atmosphere.

Many processes have been identified that could affect STMW formation or its subsequent destruction. The processes responsible for the formation and dissipation of STMW in the North Atlantic (referred as Eighteen Degree Water, EDW) were the subject of the CLIvarMOde Water Dynamics Experiment (CLIMODE). To complement the 2-year field program with a perspective of interannual variability, we combined the altimetric time series with historical hydrographic data to examine the contribution of several processes to EDW volume anomalies. A simple box model was used to hindcast observed EDW volume anomalies in two regions: one in which EDW is formed and an adjacent region of subducted EDW. Formation by air-sea fluxes is estimated from OAFlux sea surface temperature and heat flux fields for 1985–2007. See **Figure 1**. Proxy variables derived from the satellite altimeter record were used to examine dissipation. As in the North Pacific mixing associated with the meandering current appears to play an important role in dissipation. See **Figure 2**. Unlike in the North Pacific, much of the interannual variability can be attributed to heat flux forcing anomalies and to advection in the subducted region.

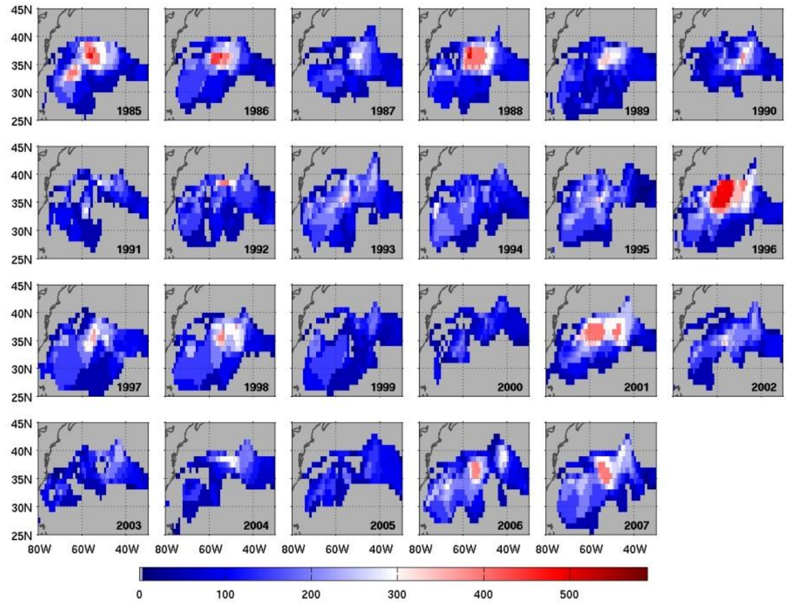

Figure 1: EDW thickness. Maps of wintertime (JFM) EDW thickness for 1985–2007. Thickness units are meters.

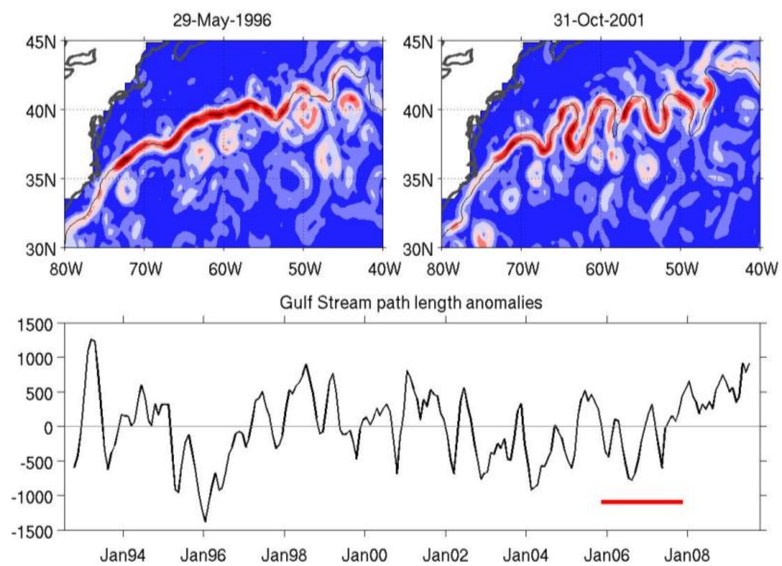

Figure 2: Examples of the Gulf Stream path from satellite altimeter sea surface height measurements (top panels), and time series of the Gulf Stream path length (bottom panel). Red line in the bottom panel indicates the period of CLIMODE field program.

Research Performance Measure: Progress was made upon both principal objectives: to characterize the dependence of EDW volume interannual variability on ocean processes and atmospheric forcing (with guidance from other CLIMODE analyses), and to examine the ability of IPCC-class models to simulate the role of EDW in climate variability.

Characterization of Ocean Acidification in Coral Reef Waters

Project Personnel: D. Gledhill and D. Manzello (UM/CIMAS); C. Langdon (UM/RSMAS)
NOAA Collaborators: J. Hendee and R. Wanninkhof (NOAA/AOML); J. Corredor (NOAA/UPRM); G. Piniak (NOAA/CCFHR); C.Sabine (NOAA/PMEL)
Other Collaborators: W. McGillis (CICAR); B. Loose (WHOI); R. Moyer (USGS)

Long Term Research Objectives and Strategy to Achieve Them:

***Objective*:** Changes in ocean chemistry in response to increasing atmospheric CO_2 (e.g. ocean acidification; OA) pose unique, albeit poorly constrained, challenges to coral reef ecosystems (e.g. accretion/growth, community structure, resiliency). The FY11 Atlantic Ocean Acidification Test-bed (AOAT) project has maintained and enhanced for a third year the ocean acidification question-based monitoring capabilities at a coral reef in La Parguera, PR. The long-term objective is to parameterize and verify models which can explicitly account for the effects of OA on coral reefs and to discern possible local feedback processes.

***Strategy*:** To use an interdisciplinary research team to conduct the collaborative targeted investigations necessary to achieve a more process understanding of the primary controls on near-reef carbonate dynamics. This understanding is a prerequisite towards enhancing NOAA's understanding of the impacts of ocean acidification to coral reef ecosystems.

CIMAS Research Theme:

***Theme 1*:** Climate Research and Impact (*Primary*)
***Theme 3*:** Sustained Ocean and Coastal Observations (*Secondary*)

Link to NOAA Strategic Goals:

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

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

Funding Unit: NOAA/AOML **NOAA Technical Contact:** Alan Leonardi

Research Summary:

Atmospheric carbon dioxide (CO_2) concentrations are currently at levels greater than, and increasing at a rate faster than, earth has 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).

CIMAS investigator Dr. Dwight Gledhill leads an interdisciplinary team of investigators from NOAA, University of Puerto Rico, University of Miami, Columbia University, Woods Hole

Oceanographic Institute and the USGS in the on-going AOAT project to: a) establish methodologies for monitoring, assessing, and modeling the impacts of OA on coral reef ecosystems, b) identify critical thresholds, impacts, and trends necessary for developing geochemical forecasts, c) characterize the variability in carbonate chemistry in coral reef environments, and d) provide data and information needed to inform ecological impact modeling. See **Figure 1.**

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.

Since 2009 the AOAT has established a high-resolution time-series of Ω within the La Parguera embayment of Puerto Rico. See **Figure 2**. FY11 has included repeated observations across a seasonal cycle in carbonate mineral saturation state (Ω, a key parameter of interest for OA) of net community productivity (P), respiration (R), and calcification (G) in tandem with coral growth rates, bioerosion, and targeted community characterizations. Throughout FY11 the AOAT team as advanced the development of techniques designed to measure, at low cost and with limited logistical complexity, net community P,R,G together with contemporaneous observations of carbonate chemistry, coral growth rates and bioerosion. The data collected throughout FY11 are to be applied in the development of models that describe the dynamics near-reef OA and can forecast the effects changes in net community trophic status might confer to the rate and magnitude of future OA. Such models can be used to identify critical thresholds (e.g. OA levels at which key coral reef mineral achieve dissolution), inform ecological response models, and support local management actions in response to such changes.

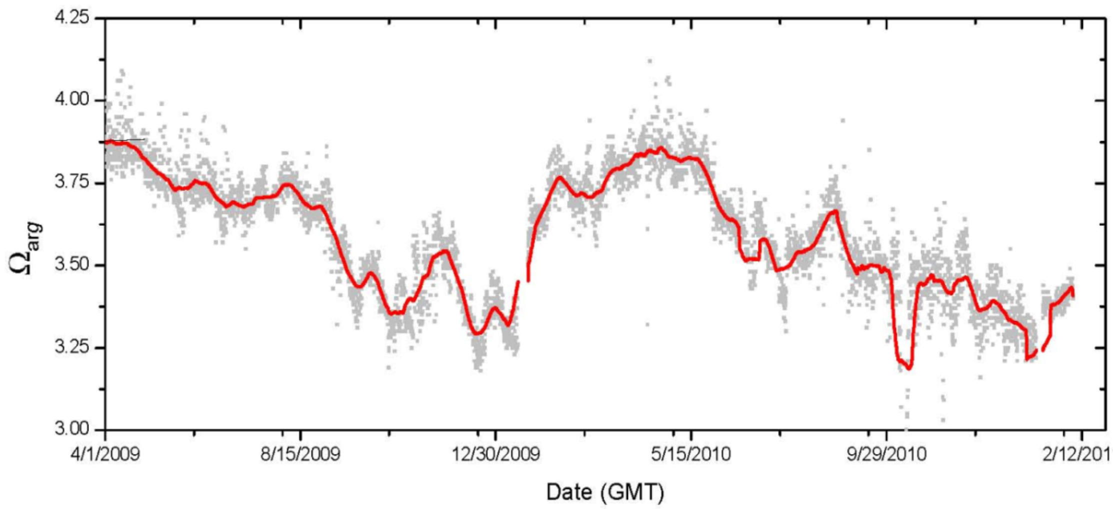

Figure 2: The Atlantic Ocean Acidification Test-bed unites both autonomous and discrete measurements to provide a means to track carbonate mineral saturation state (Ω_{arg}) which is a key parameter of concern with regards to OA effects on coral reef.

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

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Synoptic Estimates of Sea Surface Ocean Acidification

Project Personnel: D. Gledhill and D. Pierrot (UM/CIMAS)
NOAA Collaborators: R. Wanninkhof (NOAA/AOML)
Other Collaborators: S. Yvon-Lewis (TAMU)

Long Term Research Objectives and Strategy to Achieve Them:
***Objective*:** To provide monthly synoptic (near-real-time & retrospective) estimates of changing sea surface carbonate chemistry in response to ocean acidification.
***Strategy*:** Utilize regionally specific algorithms applied to satellite data and synoptic geochemical models to estimate sea surface carbonate chemistry parameters.

CIMAS Research Theme:
Theme 1: Climate Research and Impact *(Primary)*
Theme 3: Sustained Ocean and Coastal Observations (*Secondary*)

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

Funding Unit: NOAA/AOML **NOAA Technical Contact:** Alan Leonardi

Research Summary:

AOML/OCD and CIMAS provide for the quasi-operational processing and development of regionally synoptic maps of surface carbonate chemistry. The Ocean Acidification Product Suite (OAPS) is distributed by NOAA [Coral Reef Watch (CRW)] following regular updates. See **Figures 1 and 2**. The product suite includes a monthly x 0.25 degree synthesis of satellite and modeled environmental datasets to provide a synoptic estimate of the distribution sea surface carbonate chemistry throughout Greater Caribbean Region (GCR). The general approach is to fully describe the carbonic acid system and solve for aragonites saturation state (Ω_{arg}) through the application of regionally specific satellite-based algorithms. The satellite-based algorithms that drive this experimental model are derived from underway and discrete geochemical survey data. The details of the original model are presented in Gledhill et al. [2008, *J. Geophys. Res.*, *113*, C10031, doi:10.1029/2007 JC004629]. Ongoing efforts seek to improve the constraint and performance of these algorithms In part by increasing their regional specificity. To achieve this, surface carbonate chemistry (A_T, total inorganic carbon, $pCO_{2,sw}$) are routinely measured aboard a series of VOS and research cruises throughout the GCR to evaluate the OAPS model performance in estimating surface Ω_{arg}. See **Figures 3 and 4**.

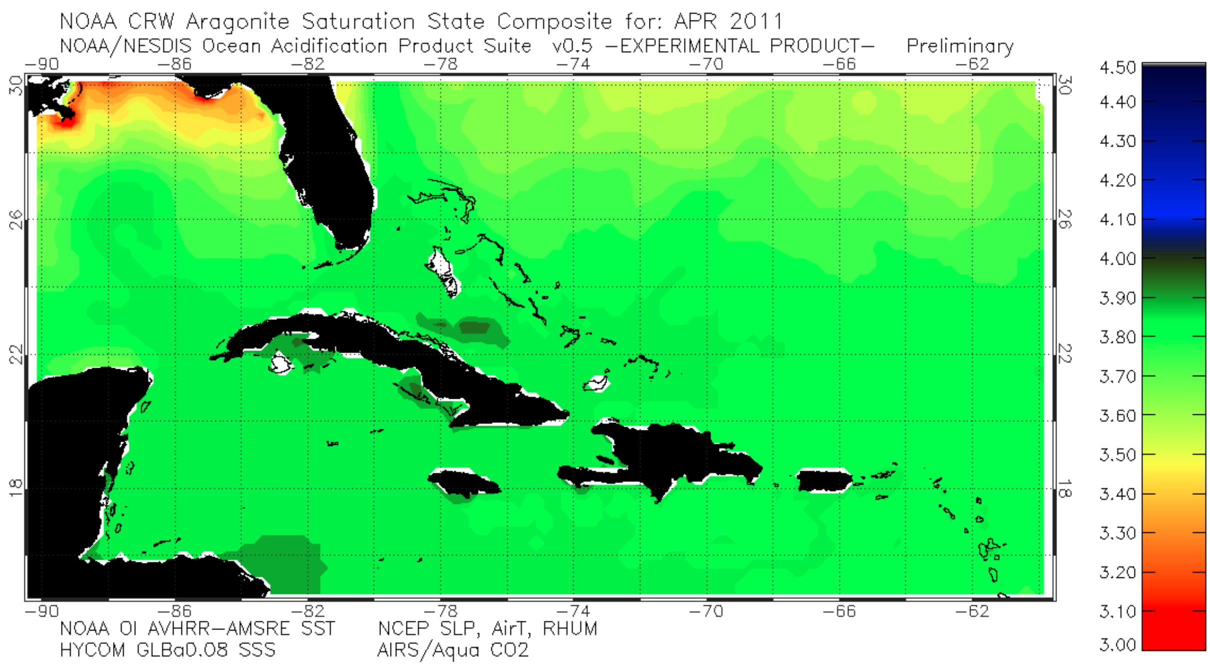

Figure 1: Example output from the Experimental Ocean Acidification Product Suite v0.4 showing the distribution of aragonite saturation state (Ω_{arg}) across the Greater Caribbean Region for April, 2011.

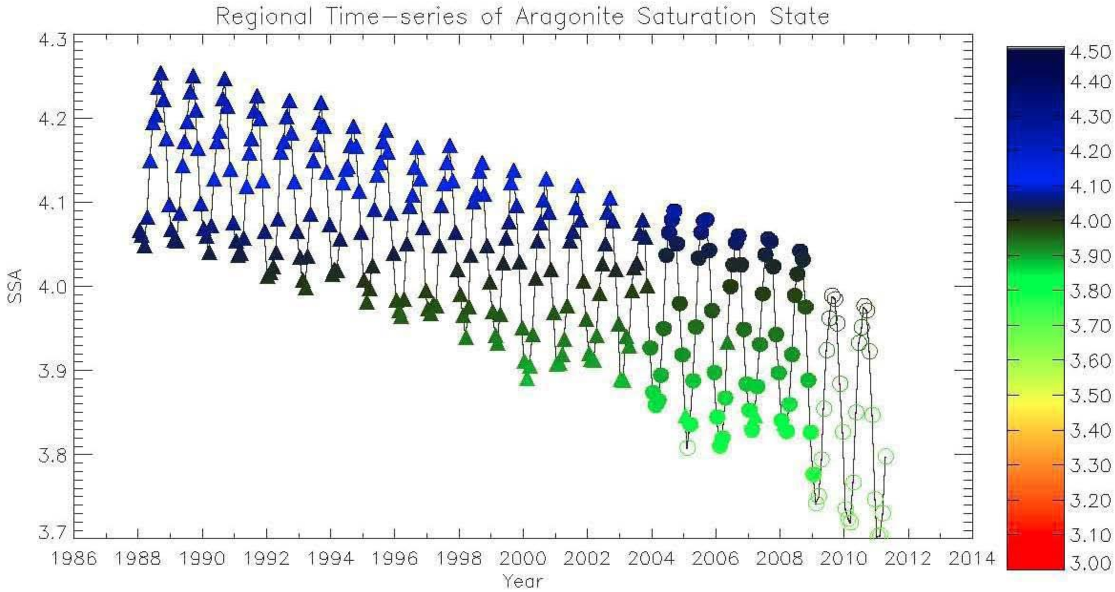

Figure 2: Time-series of the regional mean Ω_{arg} for the Greater Caribbean Region derived from the Experimental Ocean Acidification Product Suite v0.5.

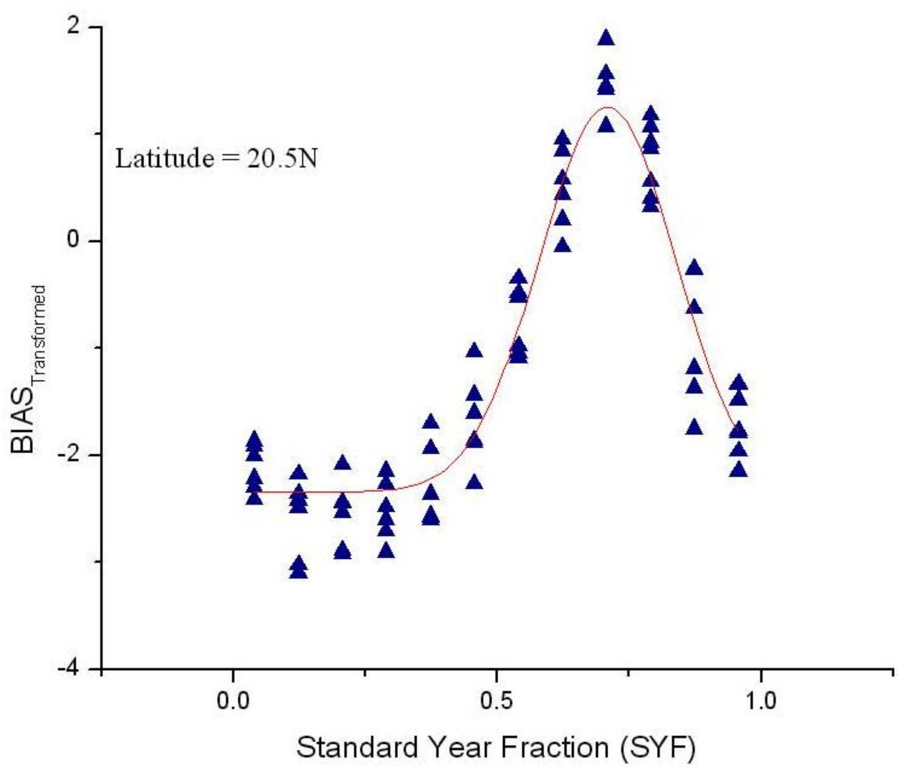

Figure 3: Shown here is the bias between the GVMBL and AIRS/Aqua CO_2 (2003-2009) modeled as a function of year fraction at 20.5N.

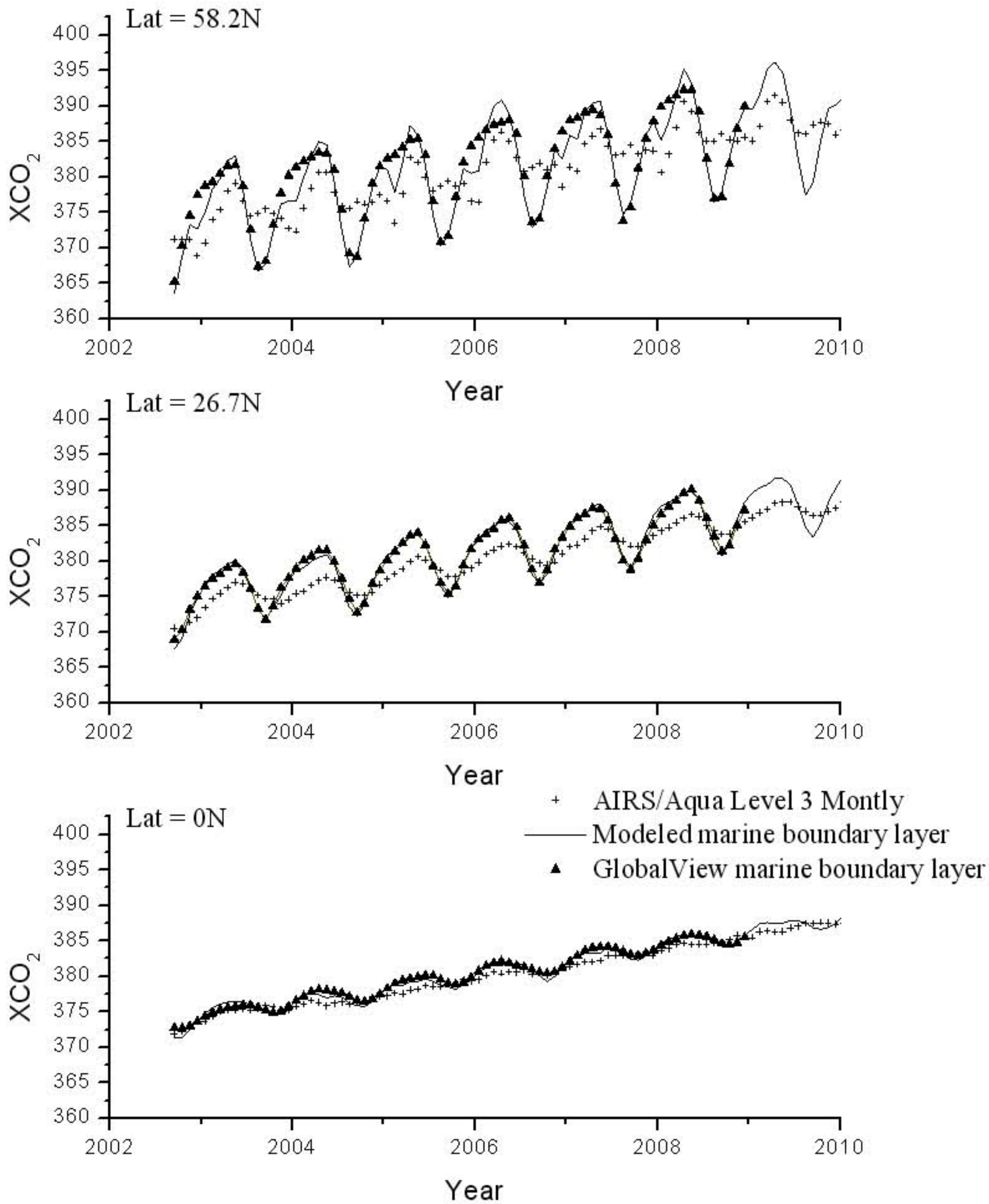

Figure 4: Shown here is the time-series of the GVMBL (black triangles), the AIRS/Aqua CO_2 values longitudinally averaged (grey crosses), and the marine boundary layer as modeled from AIRS/Aqua (black line).

Research Performance Measure: Provide monthly estimates of changes in surface ocean chemistry throughout the Greater Caribbean Region in response to ocean acidification. Fully achieved.

Climate Effects on Coral Reef Fishes

Project Personnel: P. Glynn, V. Brandtneris and J. Afflerbach (UM/RSMAS); I. Enochs (UM/CIMAS)
NOAA Collaborators: J. Serafy (NOAA/SESFC)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** Concurrent monitoring of live coral cover and fish assemblages at Uva reef over a 30-yr time span provided a rare opportunity to examine for sequence of changes fish community composition and structure, ostensibly in response to the steady increase in live coral cover that occurred since the 1982 El Niño disturbance. We examined the temporal trajectories of several aspects of the Uva reef fish community including: (1) taxonomic richness (i.e., number of different taxa per transect); and (2) total fish density (i.e., species combined); and (3) densities of each of five trophic groups (i.e., piscivores, herbivores, facultative corallivores, benthic invertivores, and mixed diet feeders. Next, we investigated the nature of correlation, if any, between coral cover and each of the above fish community metrics by fitting linear, parabolic and asymptotic regression models. Given that coral cover increased from < 2 to ~70 % over the study period, we were in a position to examine the fish data for consistency with several hypotheses that have been suggested in the literature.

***Strategy*:** Examine the strength of linear, parabolic or asymptotic relationships between coral cover and fish community metrics including mean taxonomic richness, total fish density and trophic guild densities over a multi-decadal period.

CIMAS Research Theme:

***Theme 1*:** Climate Research and Impacts (*Primary*)
***Theme 2*:** Ecosystem Management (*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 2*:** Understand Climate Variability and Change to Enhance Society's Ability to Plan and Respond (*Secondary*)

Funding Unit: NOAA/NMFS/SEFSC **NOAA Technical Contact:** Theo Brainerd

Research Summary:

1. Coral cover

Coral cover assessed in 1984, one year after the ENSO bleaching event, was 0%. By 1994 and 1995, *Pocillopora* spp. corals recruited to the study plot, and increased to ~20% cover by 1997. In 2010, 27 years after the bleaching/mortality event, pocilloporid cover was ~70%, similar to pre-disturbance abundance. Nearly all of the coral belonged to *Pocillopora* spp. with <1% contributed by *Porites* and *Pavona*. From 2002 on, *Pocillopora* cover was continuous with vertical growth and reef framework development in certain areas.

2. Fish community

A total of 224 transects were sampled over the 30-year monitoring period (1980-2010). Of the 63 recorded taxa, 58 were identified to species, three to genus and two to the family level. It is likely that the *Lutjanus* sp. and Carangidae sp. taxonomic groups were each represented by more than one species. All 22 of the numerically-dominant (n ≥ 40 individuals) taxa were identified to species. The two predominant trophic groups were mixed diet feeders (MDF) and benthic invertivores (BIN), which consisted of 21 and 20 member species, respectively. Some species ranking high in abundance, e.g. *Lutjanusviridis* and *Paranthiascolonus*, typically occurred in large schools that were often absent during sampling periods. However, several abundant species, such as *Sufflamenverres*, *Arothronmeleagris*, *Holacanthus passer* and *Scarusrubroviolaceus*, were consistently present during all sampling dates over the course of the study.

Reef fish community abundance (all taxa pooled) was relatively stable over the study period with mean density ranging from 20 to 50 individuals per transect (800 m2). Mean taxonomic richness ranged between 6 and 9 taxa from 1980 to 2010. The temporal trend for taxonomic richness, was one of gentle increase until about 2001, followed by gentle decline over the next nine years. While reef fish community densities were relatively stable regardless of coral abundance, taxonomic richness demonstrated a significant (p = 0.0037) parabolic relationship with coral cover. Relatively low mean values of 6 to 8 taxa per transect were observed at low and high coral cover and maximum richness values of 8-10 between 20-40% coral cover.

3. Trophic groups

Mean trophic group densities varied widely over time, with trends of increase, decrease or no change depending on the group under scrutiny. Densities of piscivores (Figure 1A) and planktivores (Figure 1B) appeared uncorrelated with live coral cover; however, this was not the case for densities of the four remaining trophic groups (Figure 1C-F). Herbivores (Scaridae and Acanthuridae) showed a significant (p = 0.0364) parabolic relationship with maximum densities at 20-30% live coral cover (Figure 1C). Two significant, but opposite, linear relationships were observed in faculativecorallivore (Figure 1D, p = 0.0001) and mixed diet feeding (Figure 1E, p = 0.0227) trophic groups. Corallivores (predominantly *Arothronmeleagris*) increased in density with increasing coral cover, while mixed diet feeders (predominantly *Lutjanus* spp. and *Holacanthus passer*) demonstrated declines in density at high coral abundance. Members of the benthic invertivore group (predominantly the balistid*Sufflamenverres*) demonstrated a highly significant (Figure 1F, p = 0.0004) asymptotic increase in density with increasing coral cover. Mean density increased from about 7 indiv. at 0% cover and ranged between 12 to 15 indiv. from 10 to 70% coral cover.

Research Performance Measure: Our primary objective was to investigate correlations between fish population dynamics and recovering coral populations at Uva Island, Panamá. The objective was accomplished. Thirty years of visual census data exhibited a number of significant relationships with coral cover.

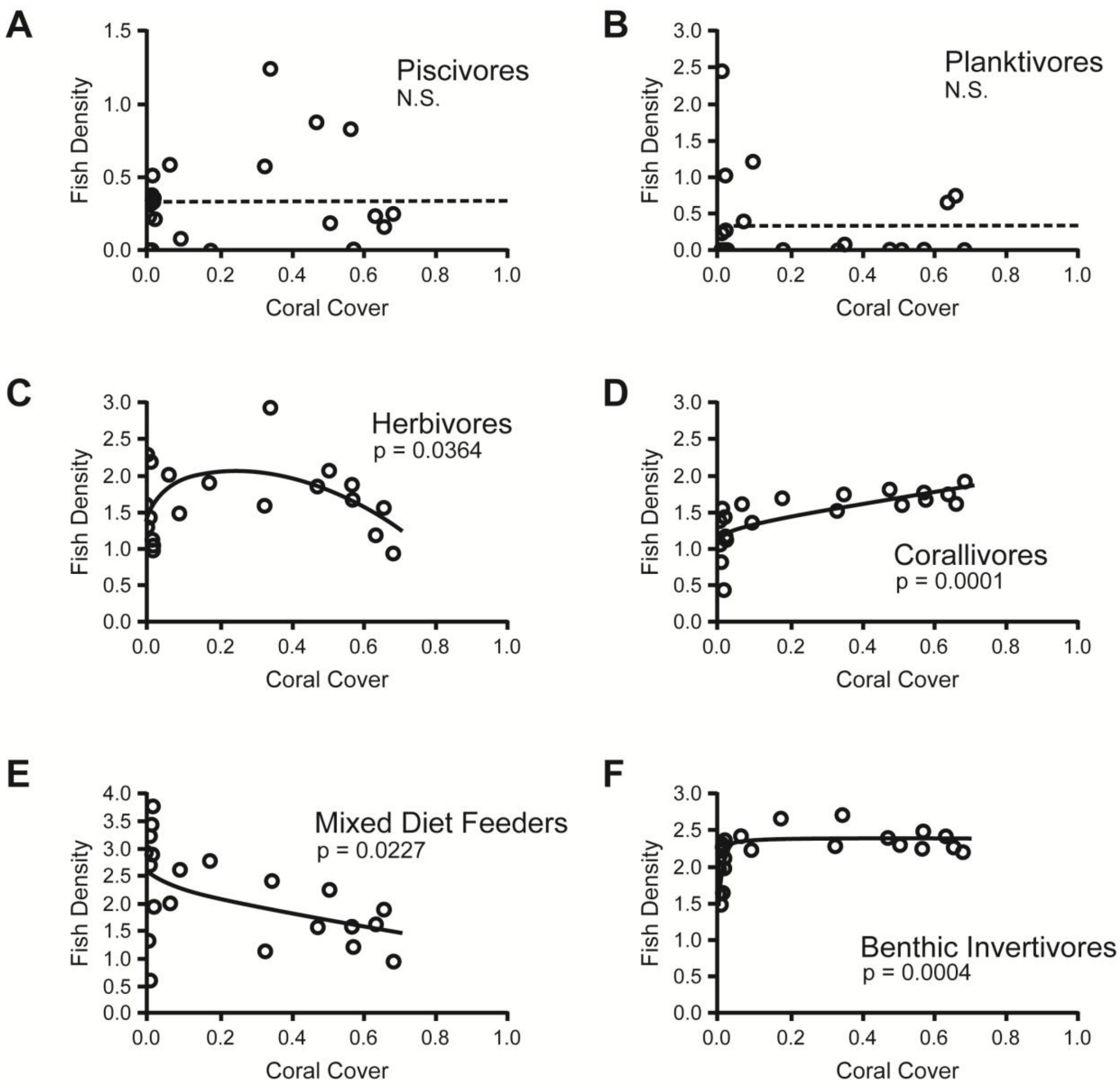

Figure 1: Correlation between fish trophic group density and percent coral cover. Fish densities are loge transformed and percent coral cover is arcsine transformed. A, B are not significant. C shows significant parabolic correlation, D, E are linear correlation and F is asymptotic.

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

Project Personnel: S.K. Lee, H. Liu, D. Enfield (UM/CIMAS)
NOAA Collaborators: C. Wang (NOAA/AOML)

Long Term Research Objectives and Strategy to Achieve Theme:
***Objectives*:** To understand and improve coupled model simulation of AWP variability and its influence on climate and extreme weather events.
***Strategy*:** To diagnose the IPCC-AR4 simulations for the 20th century and perform coupled model experiments using NCAR Community Climate System Model (CCSM3).

CIMAS Research Theme:
***Theme 1*:** Climate Research and Impact

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

Funding Unit: NOAA/AOML **NOAA Technical Contact:** Alan Leonardi

Research Summary:
The Atlantic hurricane season officially starts on June 1 and ends on November 30. An average hurricane season, based on the hurricane data from 1950 to 2000 without considering short-lived storms, has 9.6 named storms and an accumulated cyclone energy (ACE) index of 96.1 (a measure of overall tropical cyclone activity with the unit of 10^4 kt^2). Of these 9.6 storms, 5.9 are hurricanes (categories 1-5) and 2.5 are major hurricanes (categories 3-5). The average ratio between U. S. landfalling hurricanes and total hurricanes is about 25%. The 2010 Atlantic hurricane season had 19 named storms, 12 hurricanes, 5 major hurricanes and an ACE index of 160.0, all of which indicate that the 2010 season was extremely active. However, for the 2010 hurricane season, not a single hurricane made landfall in the United States. There were 6 tropical storms and hurricanes that made landfall in Central America, and one tropical storm that made landfall in Florida. But, these were largely short-lived tropical storms that formed in the Caribbean Sea. Excluding those that formed in the Caribbean Sea, tropical storms and hurricanes formed in the main development region (MDR; 60°W-20°W, 10°N-20°N) moved northwestward and then recurved northeastward to the North Atlantic Ocean, with the exception of two storms that dissipated near the MDR.

Observational data from 1970-2010 (also extending back to 1950) and numerical model experiments are used to show that the Atlantic warm pool (AWP) – a large body of warm water comprised of the Gulf of Mexico, the Caribbean Sea and the western tropical North Atlantic – plays a role in the hurricane track (Figure 1). An eastward expansion of the AWP shifts the hurricane genesis location eastward, decreasing the possibility for a hurricane to make landfall. A large AWP also induces barotropic stationary wave patterns that weaken the North Atlantic subtropical high and produce the northward and northeastward steering flow anomalies. Due to these two mechanisms, hurricanes are steered toward the northeast without making landfall in the United States. Although the La Niña event in the Pacific may be associated with the increased number of Atlantic hurricanes, its relationship with landfalling activity has been offset in 2010 by the effect of the extremely large AWP.

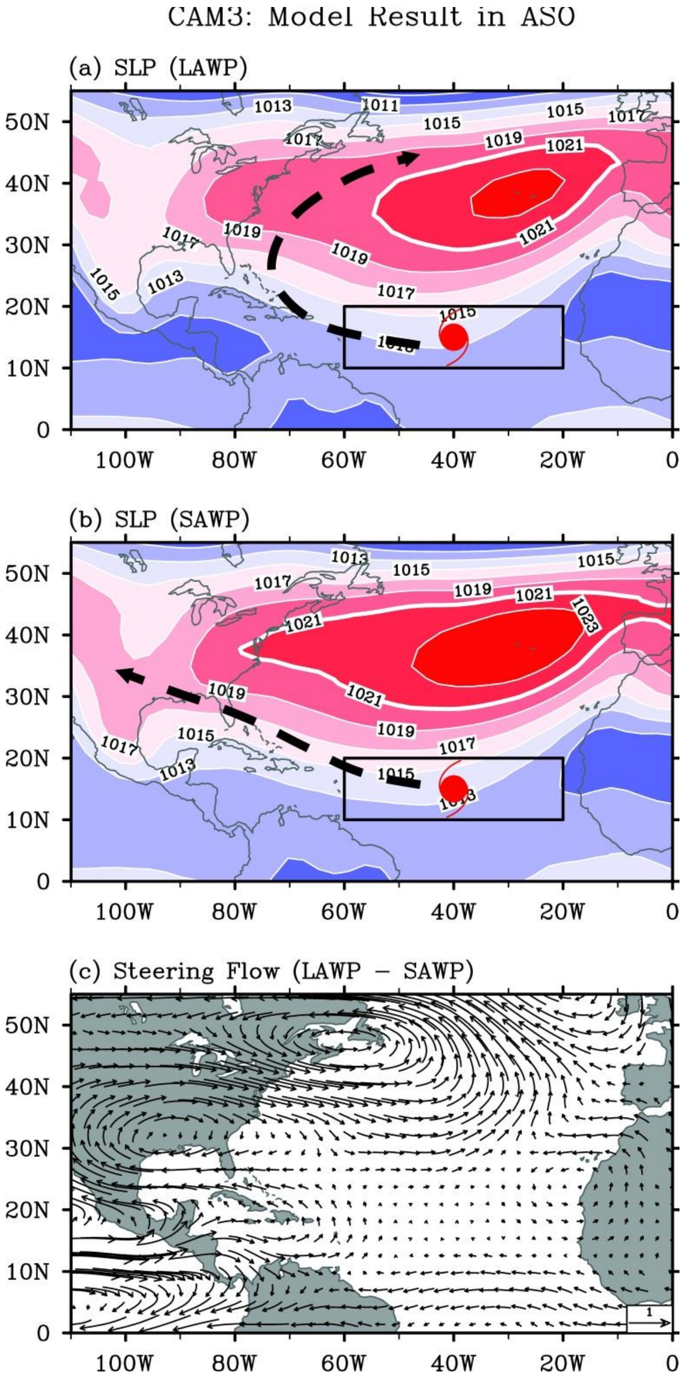

Figure 1: The simulated effect of the AWP on the NASH and steering flow from the CAM3 runs during ASO. Shown are the simulated SLPs for the (a) large AWP (LAWP) run, (b) small AWP (SAWP) run and (c) steering flow difference between LAWP and SAWP runs. The steering flow ($\times 10^3$ hPa m/s) is calculated as the vertically-averaged wind from 850 hPa to 200 hPa. The dashed arrows are schematically drawn, illustrating the hurricane tack if a hurricane forms in the MDR.

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.

Measuring the Value of Climate Variability on the Agricultural Sector

Project Personnel: D. Solís and D. Letson (UM/RSMAS)

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 1*:** Climate Research and Impact

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*)

Funding Unit: National Weather Service/Climate Prediction Center/Climate Test Bed

NOAA Technical Contact: Fiona Horsfall

Research Summary:

Climate variability influences agricultural yields and incomes. Climate information offers a potential to tailor agricultural management to mitigate impacts of adverse conditions and to take advantage of favorable conditions. Drought has negative effects on crop and dairy production, and increases the likelihood for wildfire affecting forestry sector. Variability in extreme temperatures (i.e., freezes and heat waves) also affects agricultural and livestock production. In addition, the impact of El Niño Southern Oscillation (**ENSO**) on crop production has been well documented around the world.

Although there is strong evidence that climate variability impacts the agricultural sector, the economic literature has, in general, neglected climate in empirical production analysis. Indeed, a recent review of the agricultural productivity and efficiency literature, reports very few studies including climate related variables in their empirical models. In general, authors have justified such an omission by arguing that weather and climate can be considered as stochastic shocks, since they are beyond control of the farmers.

However, in recent years, some authors have questioned this approach, claiming that the omission of environmental variables could bias the results of empirical production models. Advances in climate forecasting and the consequent ability to predict climate fluctuations provide opportunities to improve the management of climate related issues in agriculture.

Procedures

Our main goal is to evaluate the impact of climate variability and prediction on agricultural production. In this study we propose the implementation of a regional Stochastic Production Frontier (**SPF**) analysis for the Southeast U.S. The SPF method is proposed because of its potential ability to measure the marginal effect of climate variability on aggregate production levels as well as on technical efficiency. To evaluate this impact in economic terms, agricultural production will be measured as the total value-added. That is, we will be able to measure the monetary change in the contribution of this sector to the whole economy due to the use of climate information. Then, a sensitivity analysis will allow us to measure the impact for alternative climatic scenarios. The difference between the current estimates and the estimates obtained from the sensitivity analysis will give an estimate of the potential economic value of climate prediction.

The Southeast U.S. (i.e., Alabama, Florida, Georgia, North Carolina and South Carolina) is an appropriate region of study because of its ENSO signal, making it ideal for studying the interaction of climate variability and agricultural production.

The specific goals of this study are the following:

1) Measure the current marginal effect of climate variability on aggregate agricultural production as well as on its three major subsectors: Crop, Forestry and Livestock;
2) Perform a sensitivity analysis to evaluate the economic impact of alternative climatic scenarios;
3) Measure the impact of climate variability on the technical efficiency of aggregate agricultural sector as well as on its three subsectors; and,
4) Evaluate regional and temporal disparities on the impact of climate variability on agricultural production.

Proposed Emperical Model

We are using the SPF method in this study (Figure 1). A tentative empirical model specification is:

$$\ln VA_{it} = \alpha + \sum_j \beta_j \ln x_{jit} + \frac{1}{2}\sum_j \sum_k \beta_{jk} \ln x_{jit} \ln x_{kit} + \delta_t T + \frac{1}{2}\delta_t T^2 + v_{it} - u_{it} \qquad (1)$$

where VA_{it} is the agricultural value-added for the State i in year t; x are the inputs including cultivated land (A), labor (L), capital (K) and climate index (C); and T is a time trend. The error term is composed of two terms, v and u. $v$is a random variable reflecting noise and other stochastic shocks entering into the definition of the frontier, and $u$captures the technical inefficiency (TI) relative to the stochastic frontier.

To control for regional differences in land quality and labor we will use the well-known approach originally proposed by Eldon Ball. A set of climate indexes will be also tested in the implementation of the empirical model (e.g., ENSO index, Drought index, Freeze index, etc.). In addition, to measure the impact of climate variability on the agricultural subsectors, we will disaggregate the output variable into it three components crop, forestry and livestock production.

Following common practices, all variables in the empirical model will be normalized by their geometric mean (**GM**). Thus, the first-order coefficients could be interpreted as partial production elasticities (marginal effects) at the GM. The maximum likelihood estimation of equations (1) will produce consistent parameter estimates for the SPF. A sensitivity analysis on the estimated marginal effects will be used to estimate the potential economic value of climate prediction

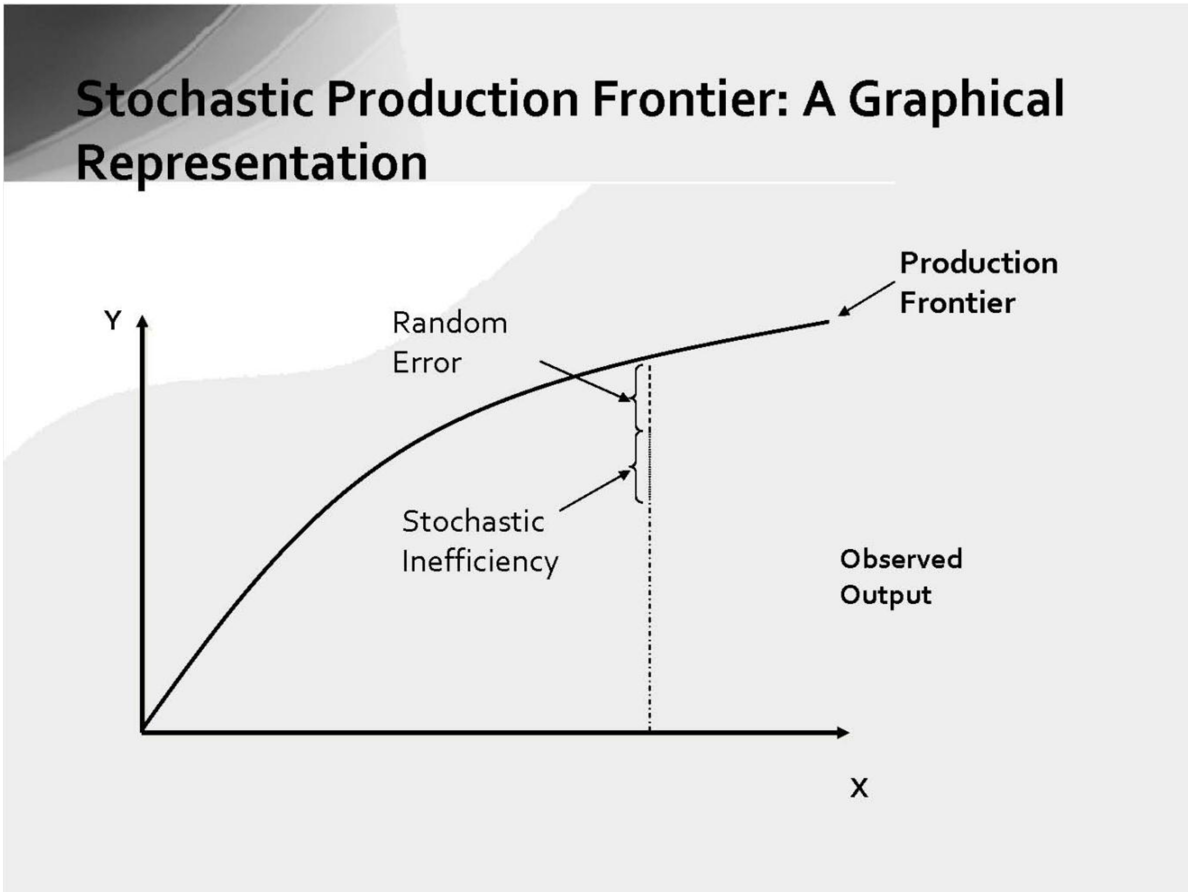

Figure 1: Stochastic Production Frontier.

After estimating the SPF an index for technical efficiency (**TE**) can be defined as the ratio of the observed output (*y*) and maximum feasible output (*y**):

$$\mathrm{TE}_i = \frac{y_i}{y_i\,*} = \frac{f(x_{ij};\beta)\cdot \exp(v_i - u_i)}{f(x_{ij};\beta)\cdot \exp(v_i)} = \exp(-u_i);\ \mathrm{TI}_i = 1 - \mathrm{TE}_i \quad (2)$$

A statistical analysis will be performed, in using the TE estimates, to evaluate the impact of climate variability on agricultural efficiency. We will also test for regional, subsector and temporal disparities on this impact.

To implement this model we will use a balance panel data, including the economic, production and climate information over approximately a 50-year period from 1960 to 2007. The economic and production data will be collected from the USDA Economic Research Service and the USDA National Statistical Service. The climate information will be collected from the South East Regional Climate Service.

Research Performance Measure: The initial project goals of this long term study include development of models and forecast-information systems and have been met on schedule.

Predicting the Effects of Climate Change on Bluefin Tuna (<u>Thunnus thynnus</u>) Spawning in the Gulf of Mexico Using Downscaled Climate Models

Project Personnel: Y. Liu, S.-K. Lee, B. Muhling and D. Enfield (UM/CIMAS)
NOAA Collaborators: J. Lamkin, W. Ingram and M. Schirripa (NOAA/SEFSC)

Long Term Research Objectives and Strategy to Achieve Them:

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

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

CIMAS Research Theme:

***Theme 1*:** Climate Research and Impacts (*Primary*)
***Theme 5*:** Ecosystem Modeling and Forecasting (*Secondary*)

Link to NOAA Strategic Goals:

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

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

Funding Unit: NOAA/SEFSC **NOAA Technical Contact:** Theo Brainerd

Research Summary:

Although the Atlantic bluefin tuna (BFT) is widely distributed, its spawning in the western Atlantic has been recorded predominantly in the Gulf of Mexico (GoM) from April to June with the optimal spawning temperature of 24 - 27^{o}C. Adult BFTs are adversely affected by warm water (>28°C) and thus avoid warm features in the GoM such as the Loop Current (LC). A recent study, which used the IPCC-AR4 climate model simulations, showed that cooler areas in the northern GoM with high probabilities of larval occurrence could be substantially reduced by the end of the 21st century (Muhling et al. 2011).

BFTs are therefore likely to be vulnerable to climate change, suggesting that there is potential for significant changes in their spawning and migration behaviors. However, since the IPCC-AR4 models have a very coarse resolution, the simulated changes in the strength, position and eddy-shedding characteristics of the LC, which are important factors for the upper ocean temperature response to the changing climate, are far from realistic. Therefore, in this study, we examine the potential impact of future Anthropogenic global warming (AGW) on the GoM by using a downscaled high-resolution ocean model constrained with the surface forcing fields, initial and boundary conditions obtained from the IPCC-AR4 models. The high-resolution model results indicate that the GoM is warmed everywhere, but the spatial pattern of the warming is quite different from that of the IPCC-AR4 models (Figure 1a).

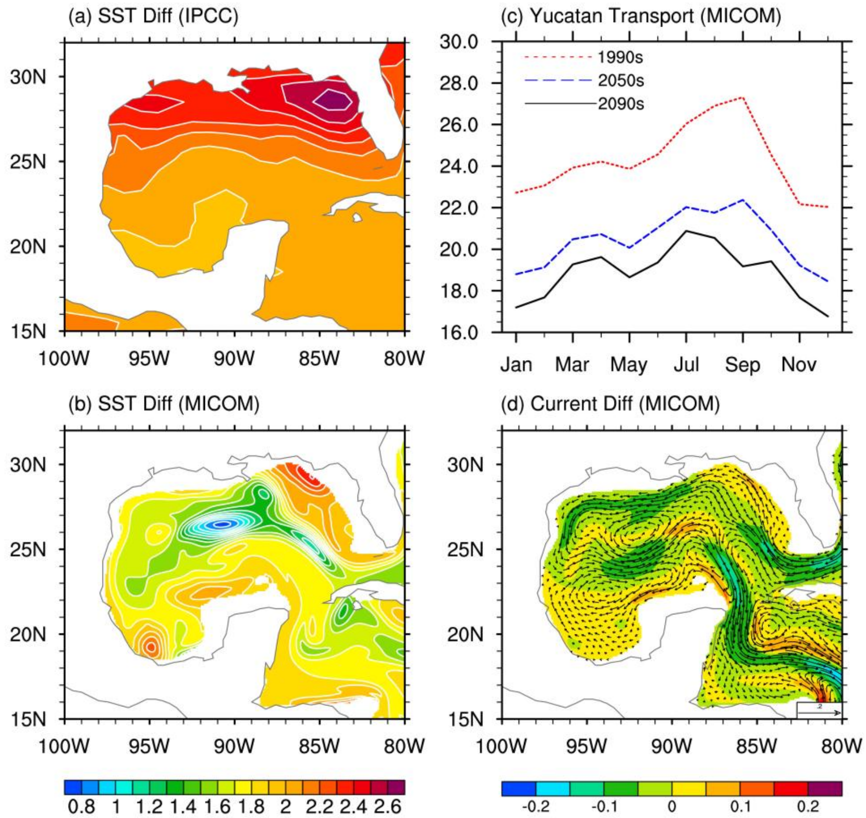

Figure 1: SST difference between the late 21st century and late 20th century for the AMJ spawning season obtained from (a) IPCC-AR4 models (low resolution) and (b) high-resolution MICOM. (c) Seasonal transport through the Yucatan Channel for the three different periods (late-20th century, mid-21st century and late 21st century) from the high-resolution MICOM. (d) Surface current (vectors) and current speed difference (colors) between the late 21st century and late 20th century for AMJ season from the high-resolution MICOM.

In particular, the SST increase in the high-resolution model (Figure 1b) is much less especially in the northern GoM away from the Florida west coast. A potential cause for this difference may be the weakening of the LC and the associated reduction in the warm water transport through the Yucatan Channel, which are not well simulated in the IPCC-AR4 models. The MICOM-simulated volume transport across the Yucatan Channel is reduced by 20 - 25% during the 21st century (see Figure 1c), consistent with a similar rate of reduction in the Atlantic meridional overturning circulation (AMOC). Figure 1d shows clearly the weakening of the main branch of LC, an anomalous cyclonic ring formed in the central and northern GoM. Further surface mixed layer heat budget analysis indicates that the reduced LC and the associated weakening of the warm LC eddy have a cooling impact in the GoM, particularly in the northern GoM (not shown). Therefore, the northern GoM is characterized as the region of minimal warming. Low-resolution models, such as the IPCC-AR4 models, underestimate the reduction of the LC and its cooling effect, thus fail to simulate the reduced warming feature in the northern GoM.

Research Performance Measure: We have met our primary objective: to quantify potential impacts of climate change on bluefin tuna spawning habitat in the Gulf of Mexico.

Natural Variability and Anthropogenic CO_2 Increase in the Synthesis and Data Management Project, NOAA Ocean Climate Observation Program (OCO)

Project Personnel: T.-H. Peng, UM/CIMAS

Long Term Research Objectives & Strategy to Achieve Them:
***Objectives*:** To understand the temporal variations of anthropogenic CO_2 increase
***Strategy*:** To compare properties along the isopycnal surfaces in order to minimize the effects of mixing processes on variations in dissolved inorganic carbon

CIMAS Research Theme:
***Theme 1*:** Climate Research and Impact

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

Funding Unit: OAR/AOML **NOAA Technical Contact:** Alan Leonardi

Research Summary:
The atmospheric CO_2 concentration continues to rise due to the emission of CO_2 through the burning of fossil fuel and changes in land use. The increasing CO_2 concentration in the atmosphere is an important factor forcing climate change. The ocean is a vast carbon reservoir, which exchanges CO_2 with the atmosphere through air-sea interface, and is recognized as an important carbon sink which takes up a substantial fraction of anthropogenic-released CO_2 from the atmosphere. The amount taken up by the ocean and the temporal and spatial distribution of anthropogenic CO_2 in the ocean provides important information for a better understanding of the variability of the carbon cycle in the ocean and the ocean's role in sequestering fossil fuel CO_2. Extensive ocean surveys have been carried out to quantify the uptake and distribution of anthropogenic carbon in the ocean. In the 1990s, the global observational campaigns have included World Ocean Circulation Experiment/World Hydrographic Program (WOCE). In recent years, high quality datasets become available from the CLIVAR/CO_2 Repeat Hydrography surveys along selected cruise tracks that were occupied during WOCE program. In this research, a cruise line P06 along 30^{o}S in the Pacific is the focus of analysis. As shown in **Figure 1**, the total dissolved CO_2 as a function of longitude along the isopycnal surface 26.60 ± 0.05 increases from 1992 WOCE measurements to 2003, and then to 2010 CLIVAR/CO_2 Repeat hydrography surveys. The average increase is estimated to be 0.77 umol/kg/yr from 1992 to 2003, and 0.74 from 2003 to 2010. The ongoing research plans to estimate from isopycnal surfaces in the upper thermocline including sigma0 of 26.0 to 27.4. The whole water column increase in total CO_2 can then be estimated in next few months. The variations of AOU along the same isopycnal surface 26.6 are shown in **Figure 2**. The temporal variations of AOU from 1992 to 2010 are not apparent in this isopycnal horizon. Reanalysis is planed due to the upcoming release of final P06 data set in next few weeks. A progress report to NOAA/OCO will be done by the end of August, 2011.

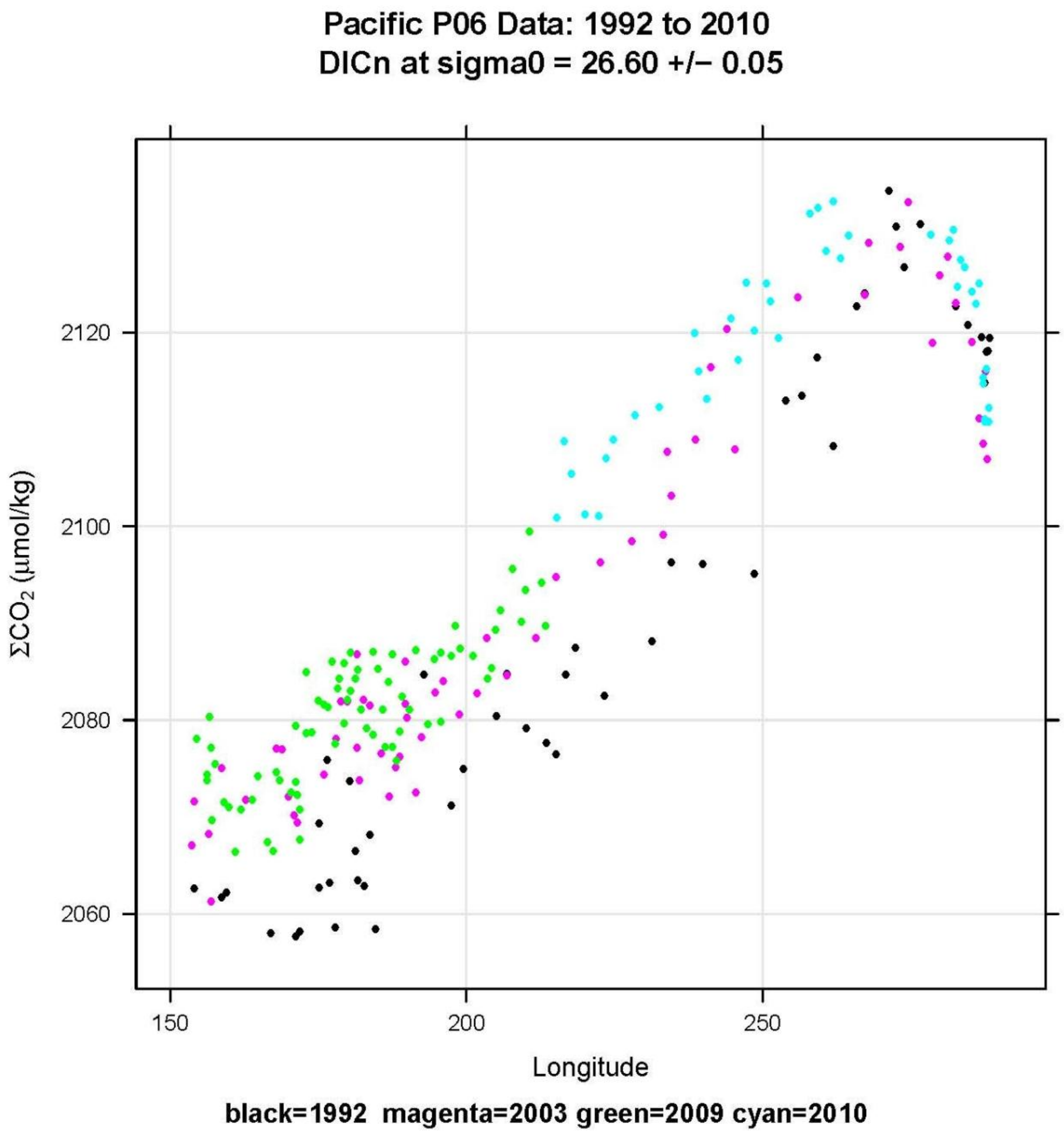

Figure 1: Total CO_2 as a function of longitude on Pacific cruise P06 along latitude of 30°S. The total CO_2 is corrected for AOU and normalized to salinity of 35 on the isopycnal surface of 26.6 ± 0.05 from 1992 (black) to 2003 (magenta), to 2009 (green), and to 2010(cyan).

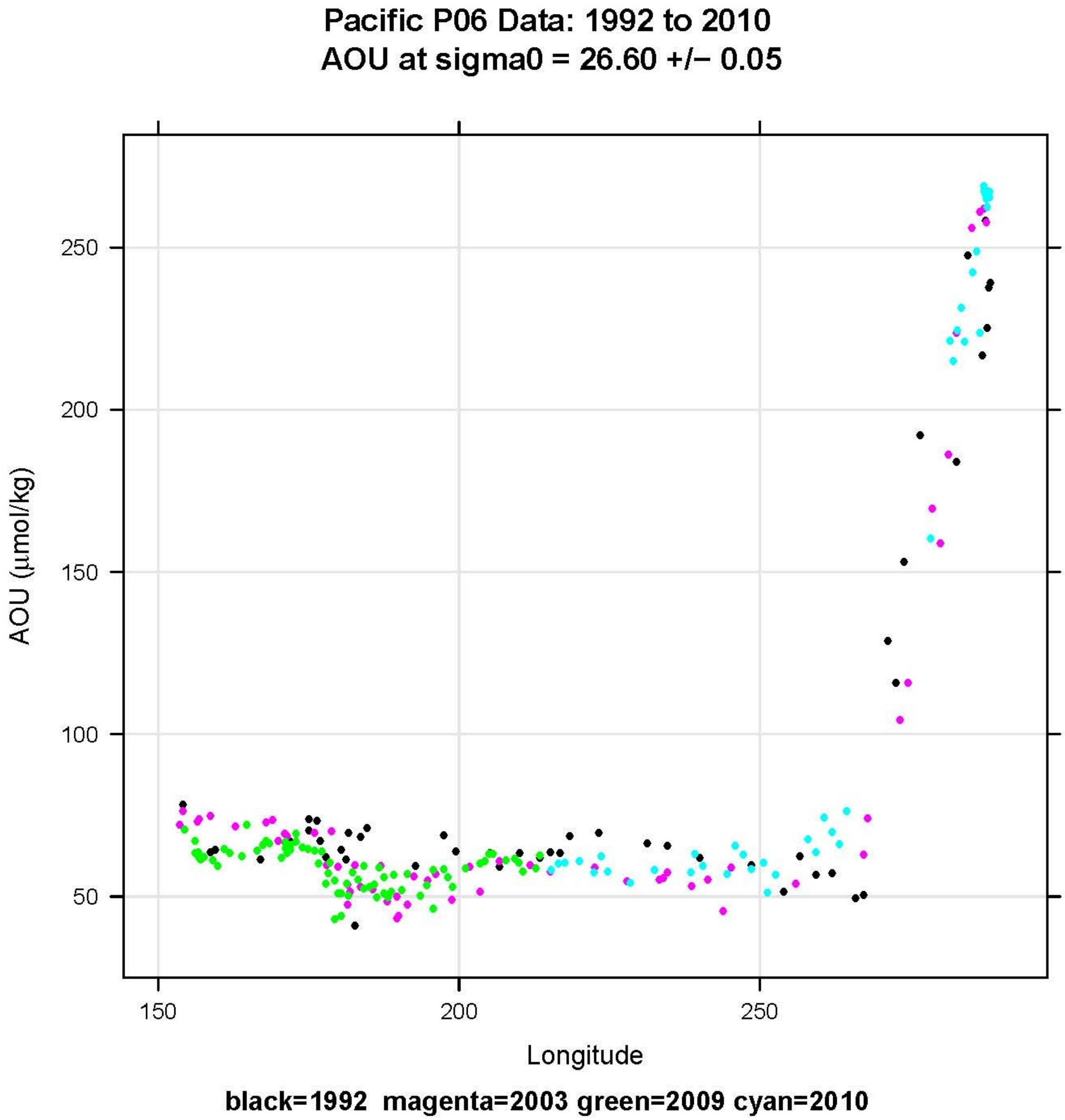

Figure 2: Distribution of AOU on isopycnal surface 26.6 as a function of longitude on Pacific cruise P06 along latitude of 30°S. The color represents year of survey: 1992 (black), 2003 (magenta), 2009 (green), and 2010(cyan).

Over the coming year we had planned an exhaustive carbon data analysis for the Indian Ocean to better understand alkalinity variations in surface and deep oceans. We have no decided extend that analysis to the Atlantic and Pacific Oceans. The surface carbon data above 50m depth in the Indian, Atlantic and Pacific Oceans taken during the WOCE program have been extracted for analysis. One of initial results of analysis in the Atlantic Ocean for the region north of 30°N is shown in **Figure 3**. A tight linear relationship between Alkalinity and Salinity gives a best fit line as Alk = 540.82 + 50.6073*Sal.

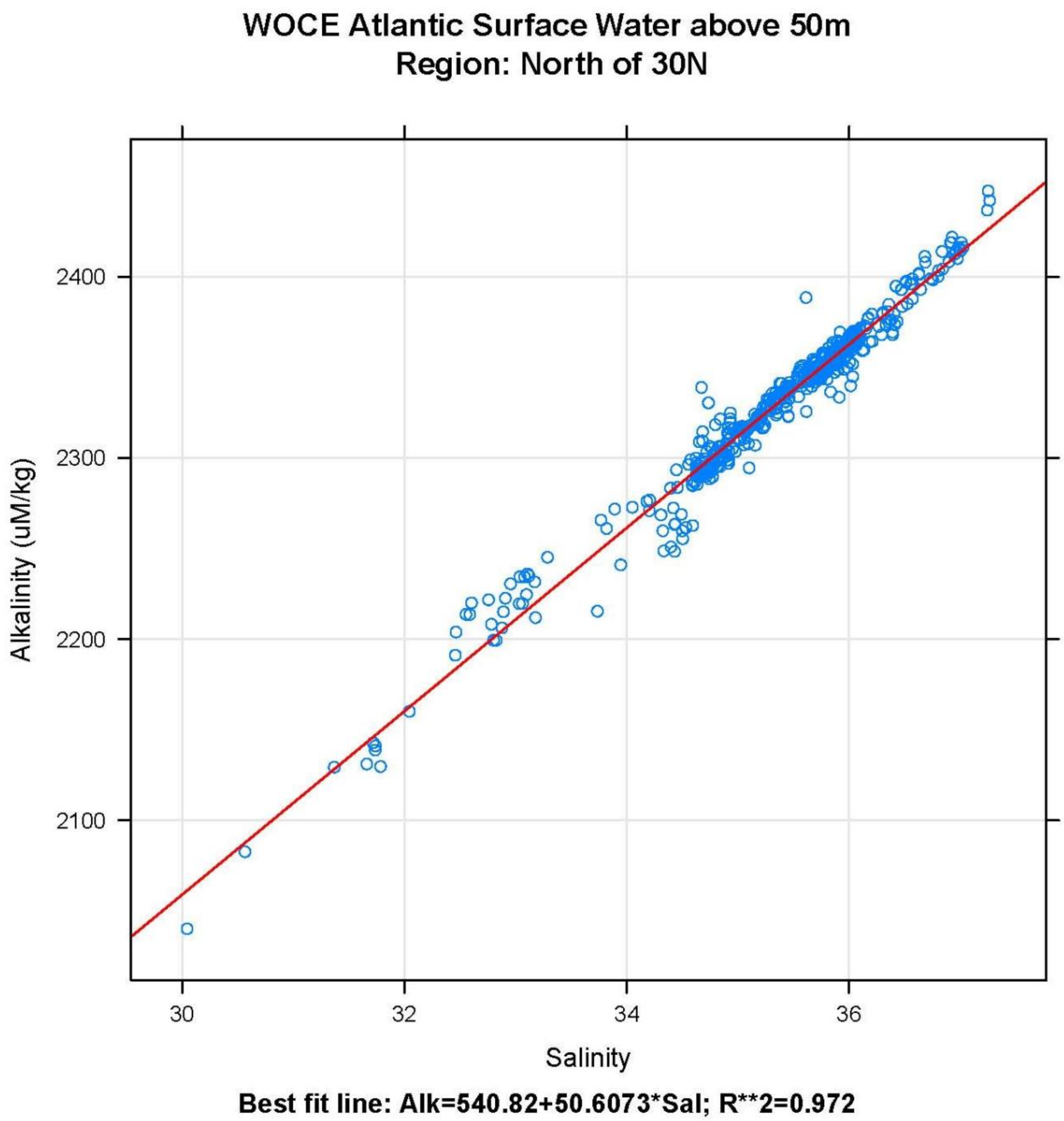

Figure 3: Linear relationship between surface Alkalinity and Salinity for region north of 30^{o}N in the Atlantic Ocean.

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

Estimating the Rate of Increase of Anthropogenic CO_2 in the Ocean

Project Personnel: W.C. Thacker (UM/CIMAS)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** To review current regression-based methods for estimating the rates of increase of anthropogenic CO_2 in the ocean and to suggest improvements.

***Strategy*:** To analyze from a mathematical perspective the pros and cons of the methods and to identify correctable weaknesses.

CIMAS Research Theme:

***Theme 1*:** Climate Research and Impact

Link to NOAA Strategic Goals:

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

Funding Unit: OAR/AOML **NOAA Technical Contact:** Alan Leonardi

Research Summary:

The two regression-based methods (MLR and eMLR) for estimating rates of increase of oceanic CO_2 were analyzed and found to have deficiencies. MLR compares regress estimates from an earlier survey with data from a second survey in such a way that, when the interval between the surveys is reduced to zero, residuals of the regression model are treated as substantial instantaneous change in oceanic carbon. While eMLR avoids this problem by comparing separate regression estimates for the individual cruises, the use of two different regression models contradicts the basic assumption that the relationship between oceanic carbon and other measured parameters is unchanged between the repeated surveys. Both methods have problems in their localization of the rates of change, as the models assume homogeneity over a large fitting region while spatial variations of rates of change are attempted within the fitting region.

A method for overcoming these deficiencies has been suggested. A single regression model can be fitted to data from the repeated surveys to account the empirical relationships between carbon and other oceanic variables, leaving the anthropogenic signal in the residuals. Then, as is illustrated in **Figure 1**, a second regression model accounting for the temporal changers in the residuals can provide an estimate of the rate at which carbon has been changing. If the relationships of carbon to environmental variables changes slowly, a large fitting region may be used for the first model, and if the residuals show variations of the effects of uptake of anthropogenic CO_2 on a smaller spatial scale, smaller fitting regions may be used for the second model. The proposed method has the advantage of easy application to several intersection survey tracks and, if they become available, to data from properly instrumented autonomous floats. In addition, by focusing on the sampling requirements, the analysis leading to this method provides an improved basis for inferring the adequacy of the data for determining anthropogenic changes.

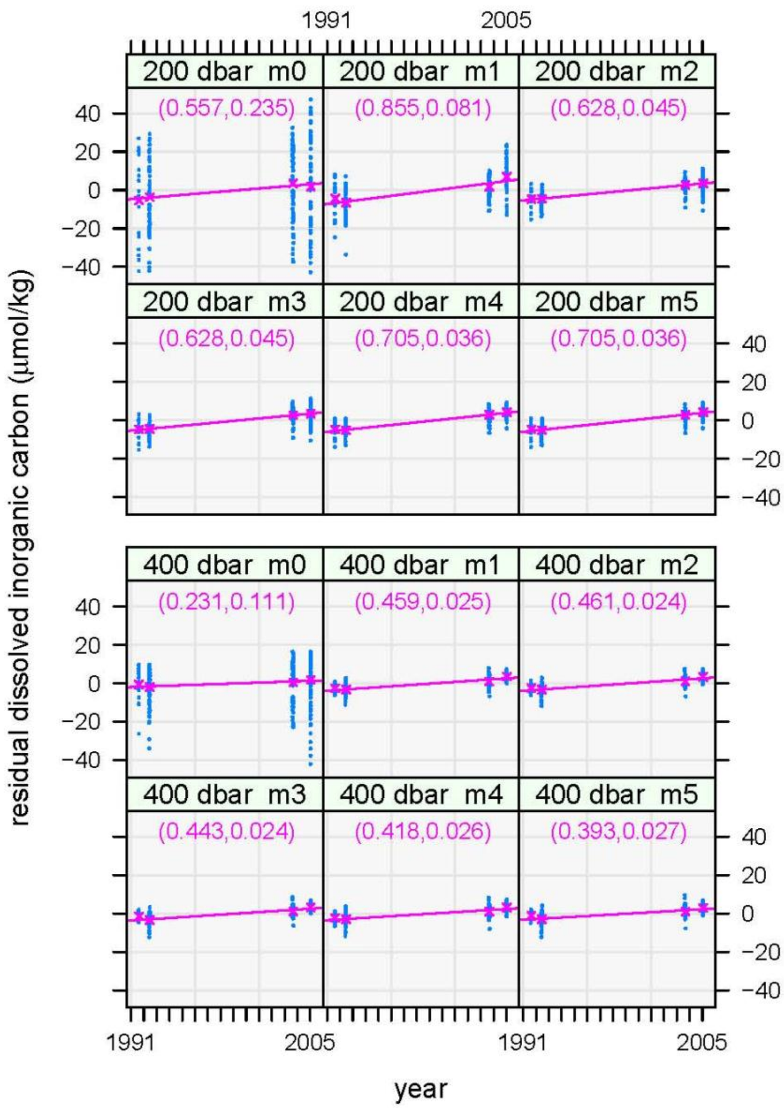

Figure 1: Several regression models, differing in which variables are used to account for non-anthropogenic environmental variability, have been fitted to data from repeated P06 and P16 surveys in the neighborhood of their intersection for two different depth ranges, one centered on 200 mb and the other centering on 400 mb. Model m0 neglects environmental variability; m1 uses potential density as a proxy for it; m2 uses potential density and nitrate; m3 adds silicate; m4 replaces silicate with apparent oxygen utilization; and m5 uses all four variables The residuals,from these models, which carry the anthropogenic signal, are plotted in cyan. The magenta lines represent regressions of the residuals against time, and the magenta annotations indicate (rate of increase, error of rate of increase) associated with the slopes of the regression lines. Given sampling limitations, m2 estimates might be preferred.

Research Performance Measure: Submit for publication a paper describing results. Done.

RESEARCH REPORTS

THEME 2: Tropical Weather

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

Project Personnel: A. Aksoy, K. Sellwood and S. Lorsolo (UM/CIMAS)
NOAA Collaborators: S.D. Aberson and T. Vukicevic (NOAA/AOML/HRD)
Other Collaborators: F. Zhang (Pennsylvania State University)

Long Term Research Objectives and Strategy to Achieve Them:
***Objectives*:** Improve hurricane intensity and track forecasts through improved representation of hurricane vortex structures in the initial conditions of hurricane forecast models.
***Strategy*:** To better utilize high-resolution observations (dropwindsonde, radar, flight level, surface wind speed, etc.) collected during the Hurricane Field Program run by NOAA/AOML/HRD by taking advantage of flow-dependent covariance structures that can be obtained from an ensemble of model forecasts that form the basis of an ensemble Kalman filter data assimilation system.

CIMAS Research Theme:
***Theme 2*:** Tropical Weather

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

Funding Unit: OAR/AOML **NOAA Technical Contact:** Alan Leonardi

Research Summary:
An ensemble Kalman filter (EnKF) data assimilation system, the Hurricane Ensemble Data Assimilation System (HEDAS), has been built to assimilate high-resolution, vortex-scale observations that are routinely collected and transmitted in real time, during NOAA's annual

Hurricane Field Program and regular reconnaissance flights. Various observation types that are assimilated include Doppler radar radial wind speed, dropwindsonde wind velocity, pressure, temperature, and humidity, flight-level wind velocity, pressure, temperature, and humidity, and stepped-frequency microwave radiometer (SFMR) surface wind speed. The EnKF is a state-of-the-art data assimilation system first proposed for geophysical applications by Evensen (*JGR*, 1994). In this specific application, the "ensemble square root" filter of Whitaker and Hamill (*MWR*, 2002) is implemented.

HEDAS has been developed within the framework of NOAA's Hurricane Weather Research and Forecast (HWRF) model. Data assimilation is performed on a domain with 3-km horizontal resolution, while HWRF runs in a nested 9/3-km configuration during cycling. At this scale, the numerical model is capable of resolving the details of the hurricane vortex. By incorporating high-resolution airborne observations into the model through data assimilation, a realistic vortex structure is obtained for the initialization of a subsequent 5-day model forecast.

Currently, there are several major research directions with HEDAS:

(1) A detailed diagnosis of HEDAS performance has been carried out in an OSSE environment. For this purpose, a higher-resolution version of HWRF-x, at 4.5/1.5-km horizontal resolution with explicit convection in all domains is used to obtain a nature run, which was the basis for simulating airborne Doppler radar wind observations. The availability of a nature run enables detailed diagnostics of a data assimilation system when observations simulated from that nature run are assimilated. The fact that such observations are obtained from a model run also eliminates non-meteorological noise from them so that the performance of a data assimilation system entirely depends on the underlying modeling and data assimilation characteristics. This work is now complete with a manuscript that is in internal review to be submitted to Monthly Weather Review.

In **Figure 1**, storm-relative horizontal cross-sections of 10-m wind speed and 1-km total cloud water mass are compared between the nature run (left), HEDAS analysis (middle), and control (no data assimilation, right). The general wavenumber-1 asymmetry as well as radius of maximum wind are captured well in the final mean analysis, although the wind analysis near the core appears noisier than the truth. Cloud water mass analysis reveals that the primary rainband structure is generally captured well, especially when compared to the broad distribution in the control.

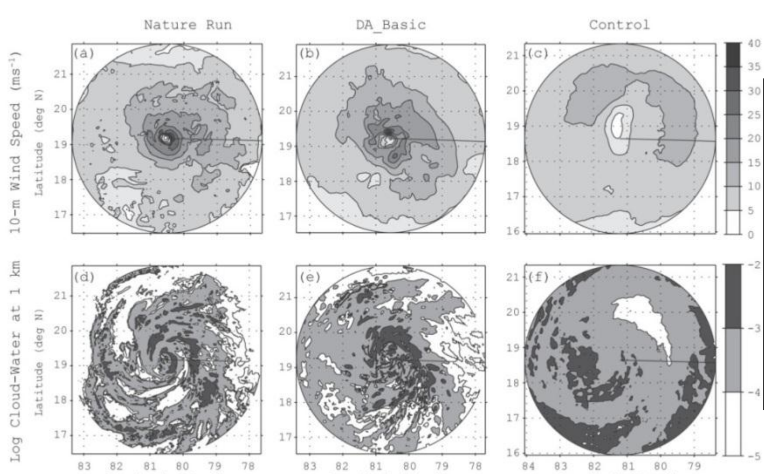

Figure 1: Storm-relative horizontal cross-sections of 10-m wind speed (m s^{-1}, top row) and logarithm of 1-km total cloud water mass (bottom row) in the nature run (left column), the final mean analysis in the data assimilation experiment (DA_BASIC, middle column), and the control (right column).

Figure 2 compares azimuthally-averaged vertical cross-sections of tangential and radial wind speeds, as well as equivalent potential temperature. In general, the structure of tangential wind speed is captured well in the final analysis. The structure of the radial flow, too, is generally captured very well in the analysis, although the vertical structure of the inflow in the boundary layer is somewhat exaggerated in the final analysis. Finally, the thermal structure is also well represented in the analysis in an azimuthally-averaged sense. However, the generally over-estimated equivalent potential temperature in the boundary layer suggests that this bias may be the result of a high bias in the initial vortex. The magnitude of the mid-level warm core is also over-analyzed, but this feature is non-existent in the control.

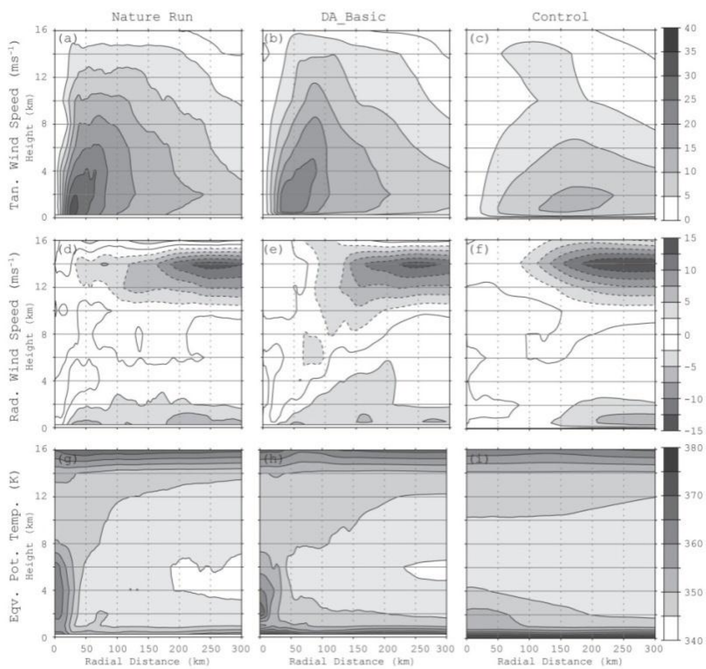

Figure 2: Vertical cross-sections of azimuthally-averaged tangential wind speed (m s^{-1}, top row), radial wind speed (m s^{-1}, inflow with solid contours, outflow with dashed contours, middle row), and equivalent potential temperature (K, bottom row) in the nature run (left column), the final mean analysis in the data assimilation experiment (DA_BASIC, middle column), and the control (right column).

(2) The performance of HEDAS is being evaluated with real observations (Doppler radar, dropwindsonde, SFMR, and flight-level data) that were collected by NOAA and the Air Force during 2008-2010. A total of 66 such cases have been identified, and HEDAS analyses for all cases have been completed. Using the high-resolution HEDAS vortex analyses obtained for these cases, separately for all aircraft data and all aircraft data without Doppler radar observations, 126-h forecast runs have also been carried out.

In **Figure 3**, the average track and intensity forecast errors in forecasts initialized with HEDAS vortex analyses are compared for when all aircraft observations versus when no radar data were assimilated. While little impact on track forecasts is seen from assimilating radar observations, noticeable improvements in intensity forecasts for the first 72 h suggest that assimilating aircraft Doppler radar wind observations has positive impact on initial hurricane structure.

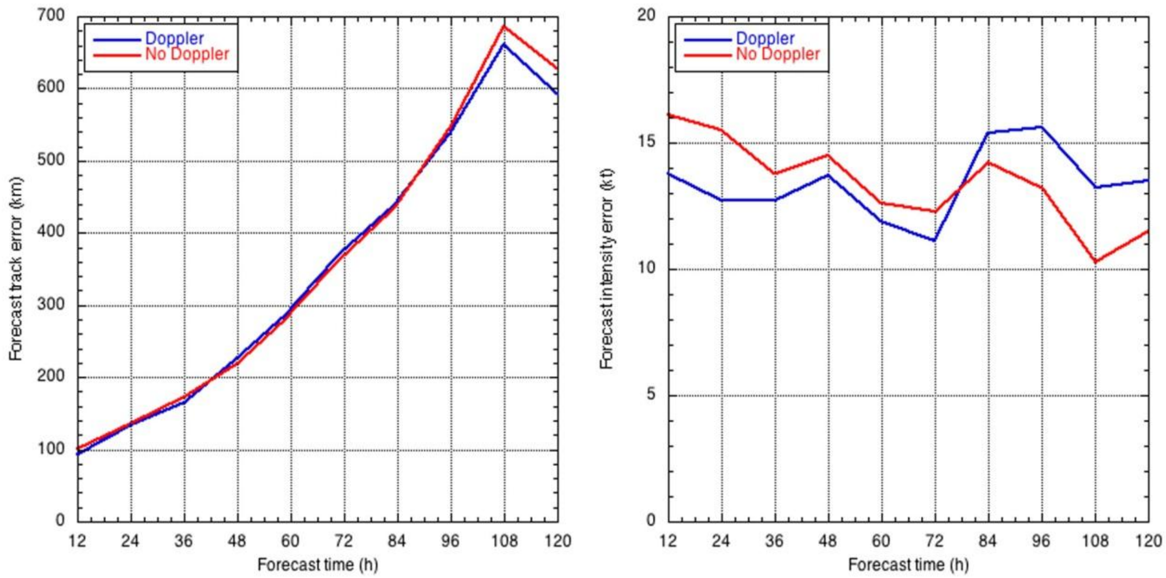

Figure 3: Left: Average track error (km) for HWRF forecasts initialized with HEDAS vortex analyses when all aircraft data were assimilated (Doppler, blue) versus when all aircraft data except radar were assimilated (No Doppler, red) for all available cases during 2008-2010. Right: As in left, but for average intensity error (kt).

(3) Using the OSSE infrastructure of research topic (1), the current Doppler radar wind superobservation methodology is being evaluated so that it can be optimized for the problem of high-resolution vortex-scale data assimilation. Specifically, vertical resolution of data and impacts of the quality control criteria are being investigated.

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

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Public Hurricane Loss Projection Model

Project Personnel: B. Annane (UM/CIMAS)
NOAA Collaborators: M. Powell (NOAA/AOML/HRD)

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

CIMAS Research Theme:
***Theme 2*:** Tropical Weather

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

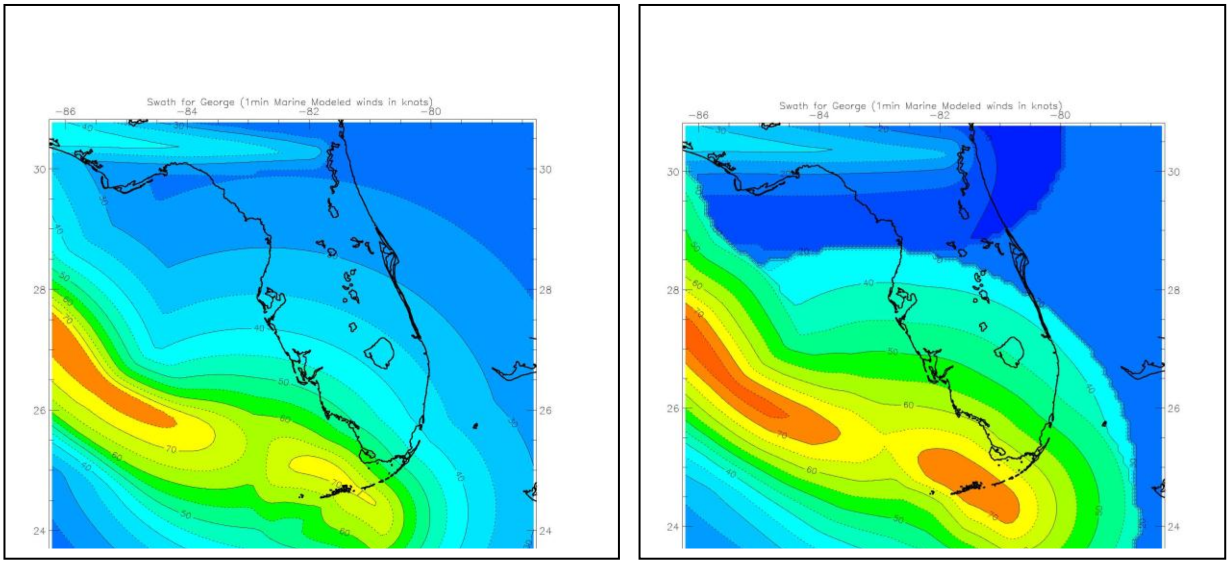
Funding Unit: FIU **NOAA Technical Contact:** Alan Leonardi

Research Summary:
A team of scientists (Annane and Powell both members of that team) developed the new Florida Public Hurricane Loss Model (FPHLM). It is an open, transparent computer model used by the State Office of Insurance Regulation to provide a baseline for evaluating rate change requests for windstorm insurance. The FPHLM is the first model that enables all of the results and details from the modeling approach to be open to scrutiny. To date, all other models used for rate making in Florida have been proprietary.

FPHLM comprises atmospheric science, engineering, and actuarial components. The atmospheric component includes modeling the track and intensity life cycle of each simulated hurricane within the Florida threat area. When a model storm approaches within a damage threshold distance of a Florida zip code location, the wind field is computed by a slab model of the hurricane boundary layer, coupled with a surface layer model based on the results of recent GPS sonde research. A maximum open terrain surface wind is then recorded for each zip code in the threatened area. Depending on wind direction, an effective roughness length is assigned to each zip code based on the upstream fetch roughness as determined from remotely sensed land cover/land use products. Based on historical hurricane statistics, thousands of storms are simulated allowing determination of the wind risk for all residential zip code locations in Florida. The wind risk information is then passed to an engineering model that estimates the damage to residential structures within the zip code, followed by an actuarial model that estimates the insured loss. The average annual loss is then estimated statewide for every zip code in Florida.

The Florida Public Hurricane Loss Model provides estimates of future insured losses that can be used by insurance companies as input in determining homeowner's windstorm rates. Insurance rates in Florida have been rapidly rising in recent years because of eight hurricanes striking the State in a 14-month period of 2004-2005. The FPHLM can also provide immediate estimates of losses from specific hurricane events like Dennis, Katrina, Wilma, and Charley. This is the "commercial" model.

The activities of the past year have focused on updating the residential model to make use of the latest climatic data and to provide wind risk information at 1 km resolution. See **Figure 1**. We also attempted to meet the standards of the 2009 Report of Activities of the Commission on Hurricane Loss Projection Methodology. We were successful in both regards. 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 meteorology part of the FPHLM passed the "pro team" review in June and received a unanimous acceptance vote from the Commission on Thursday, June 16, 2011.



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

Research Performance Measure: All objectives were met on schedule.

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New Infrared Satellite Imagery for Detecting Changes in Tropical Cyclone Structure

Project Personnel: J.P. Dunion (UM/CIMAS)
Other Collaborators: C.S. Velden (University of Wisconsin-CIMSS) and J.D. Hawkins (Naval Research Laboratory-Monterey)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** To develop new GOES infrared satellite imagery to monitor changes in the middle to upper level structure of tropical cyclones.

***Strategy*:** To continue algorithm development and refinement of the new GOES infrared brightness temperature difference satellite imagery; design real-time scripts to run this imagery in real-time for North Atlantic tropical cyclone cases during the hurricane season; apply for proposal-driven funding through the NOAA/NESDIS/GOES Improved Measurements and Products Assurance Plan (GIMPAP) project to support these research activities

CIMAS Research Theme:

***Theme 2*:** Tropical Weather

Link to NOAA Strategic Goals:

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

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

Funding Unit: OAR/AOML **NOAA Technical Contact:** Alan Leonardi

Research Summary:

The analysis and prediction of tropical cyclone (TC) intensity change and structure remains a difficult challenge for forecasters and researchers alike. Microwave imagery from polar orbiting satellites provides vital information of TC structure by penetrating the cirrus canopy that obscures the tops of most well developed storms. However, these satellites are limited in spatial and temporal coverage. Geostationary IR imagery is also an important tool for examining storm structure (e.g. Dvorak intensity estimates) though it is limited in that it cannot see below the TC cirrus canopy. However, there is important information within the cirrus canopy and convective cloud tops of TCs that is not being fully realized. A new, yet conceptually simple technique has been developed to monitor changes in the middle to upper levels of the TC environment. This new imagery is created using GOES 10.7 μm infrared imagery in a storm relative coordinate system to examine 6-hourly brightness temperature changes in the imagery. At the basic level, this GOES IR BT-Difference imagery can be used to quantify how deep convection and cirrus structures are changing over the storm. A more surprising finding (though preliminary) is that mature TCs appear to have a diurnally linked cool ring of brightness temperatures that propagate away from the inner core after sunset and reach outer radii (~400-500 km) by the early afternoon the following day (**Figures 1 and 2**). Given the diurnal nature and marked symmetry of these phenomena, a working hypothesis is that they are gravity waves that become trapped below the stratosphere and begin propagating radially outward when the inner core cloud tops begin cooling at sunset. The new GOES IR BT-Difference imagery may provide important insights into a previously unknown process that routinely impacts mature TCs. Regardless of the exact mechanism that is driving this phenomenon, the cool ring features are most certainly diurnal in nature and appear to be significant features of the environment of mature TCs.

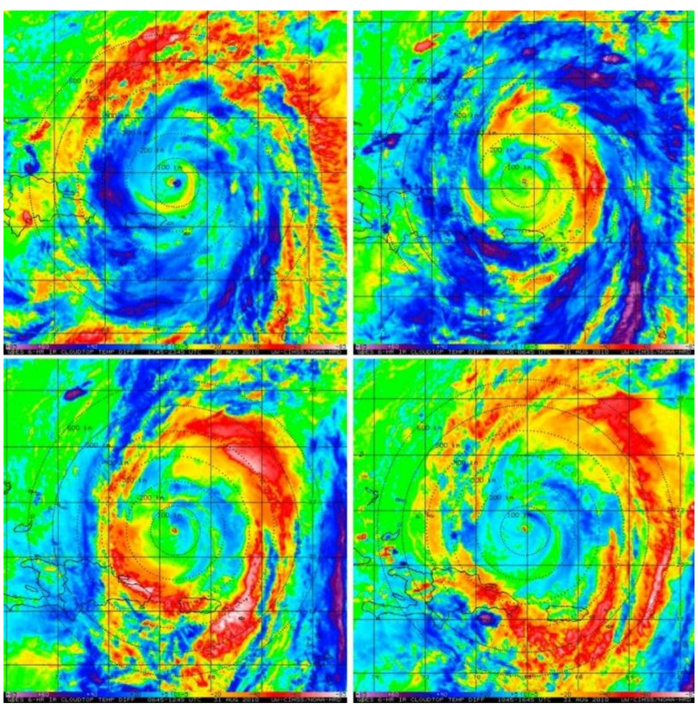

Figure 1: GOES 6-hourly IR brightness temperature difference satellite imagery for 2010 Hurricane Earl. Images are valid for (upper left) 30 Aug 2345 UTC and 31 Aug at (upper right) 0645 UTC, (lower left) 1245 UTC, and (Lower right) 1645 UTC. The warm colors (green to red shading) indicate that the deep convection and/or cirrus canopy have cooled in the past 6 hours. The cool colors (blues to purples) show areas of warming over the past 6 hours. The cool ring begins to form at approximately sunset local time on 30 Aug in the inner 100-150 km of the storm (upper left image). After ~7 hours, the ring has propagated to a radius of 200-300 km (upper left), reaches 300-450 after 13 hours (lower right), and is positioned 450-600 km from the center after ~17 hours (lower right).

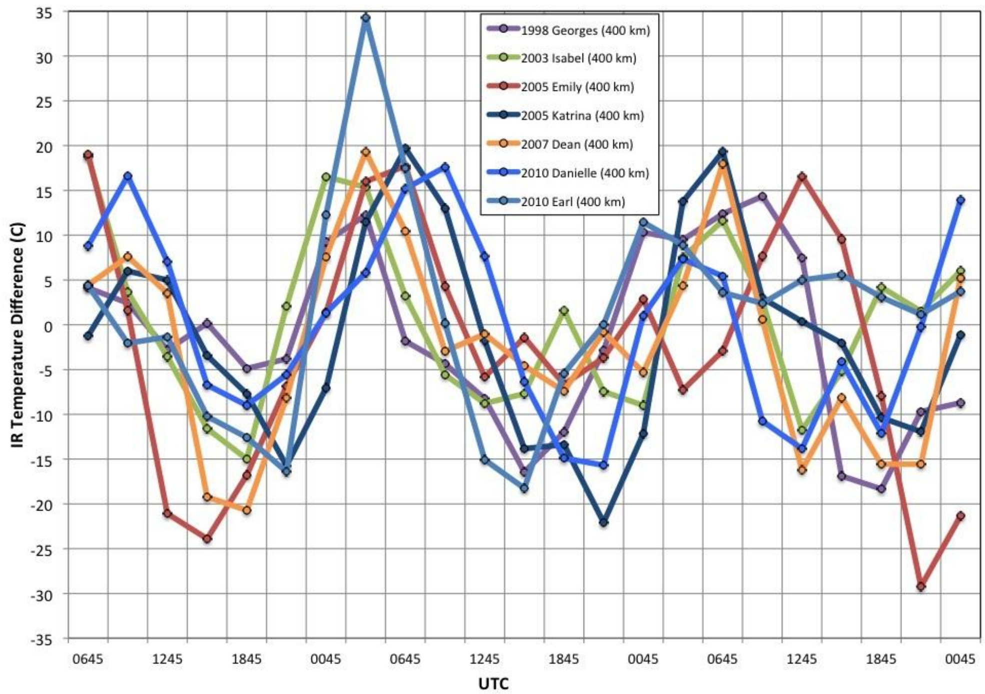

Figure 2: Time series for several mature North Atlantic tropical cyclones showing GOES 6-hourly IR brightness temperature differences azimuthally averaged at the 400 km radius from the storm center. The x-axis displays time over a ~3 day period for each storm. Negative y-axis values indicated times when the brightness temperatures have cooled (i.e. cool rings) at the 400 km radius. The pattern suggests a significant episodic diurnal trend in the cool rings with a preferred 400 km radius passing time in the early afternoon local time. Significant warming is also noted during the hours prior to and after the cool ring passages.

The GOES IR BT-Difference imagery also suggests that arc clouds, indicators of low to mid-level dry air entrainment in the periphery of the TC environment, tend to form along the leading edges of the expanding cool rings (**Figure 3**). This suggests that the cool rings are associated with enhanced mid-level entrainment as they propagate away from the storm. This in turn suggests that they could provide a mechanism for making the TC more vulnerable to negative environmental influences (e.g. lower to middle level dry air). Another atmospheric feature that appears to be correlated with the expanding cool rings are transverse cloud bands in the upper levels of the TC central dense overcast that occur hundreds of kilometers from the center (**Figure 3**). These transverse bands suggest that the propagating cool ring is lifting local air parcels vertically through a layer of strong vertical wind shear (e.g. between the storm's strong outflow layer below the tropopause and the relatively quiescent lower stratosphere above). Although these results represent preliminary findings, there appear to be remarkable consistencies between different TCs in both the timing of the outward propagating cool rings and the correlation between the cool rings and arc clouds/transverse cloud bands. It is interesting to note that arc clouds are lower to middle level atmospheric features while the transverse cloud bands are upper-level features. The fact that both phenomena are apparently linked to cool ring passages suggests that the cool rings may very well be forced by a feature that has significant (several kilometers) vertical extent (e.g. gravity waves). The development of the GOES IR BT-Difference imagery is intended to address many of these unanswered questions.

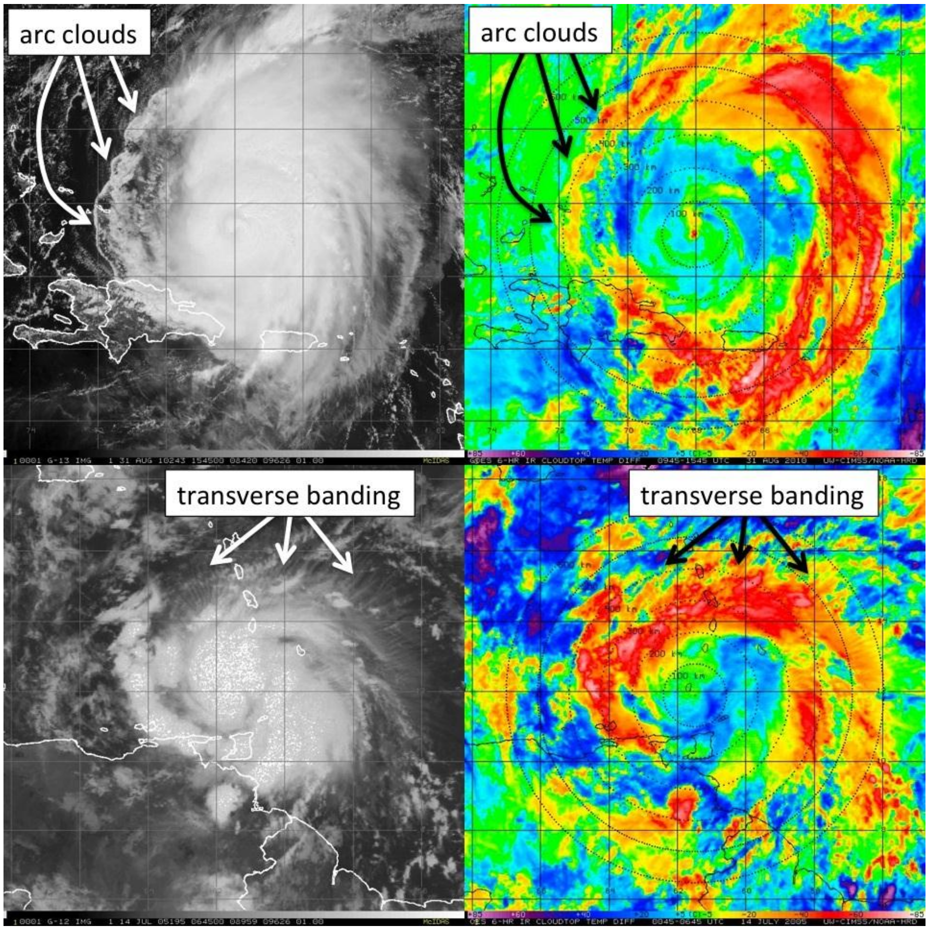

Figure 3: (Top) Arc clouds in the western semicircle (~400-450 km radius) of 2010 Hurricane Earl as detected from (left) GOES visible satellite imagery and (right) GOES 6-hourly IR brightness temperature difference satellite imagery. The arc cloud feature appears to have formed along the leading edge of the expanding cool ring. (Bottom) Transverse banding in the western semicircle (~350-500 km) of 2005 Hurricane Emily as detected from (left) GOES visible satellite imagery and (right) GOES 6-hourly IR brightness temperature difference satellite imagery. The transverse banding clouds features also appear to be collocated with the expanding cool ring.

Research Performance Measure: Although this project is in its early stages, the following tasks have been completed and progress is ahead of schedule: 1) The PI presented preliminary findings and results of the new GOES infrared brightness temperature satellite imagery at the 65th Interdepartmental Hurricane Conference in Miami, FL (March 2011); 2) The PI secured funding through the NOAA/NESDIS/GIMPAP visiting scientist program to collaborate with scientists at the University of Wisconsin-CIMSS to continue algorithm development of the new GOES infrared brightness temperature satellite imagery and develop the capability to generate this imagery in real-time; 3) The PI submitted a letter of intent to the NOAA/NESDIS/GIMPAP project titled: *Development of GOES IR Brightness Temperature Differencing Imagery To Monitor Changes in Tropical Cyclone Structure*

A Fifteen-Year Tropical Cyclone Global Positioning System Dropwindsonde Dataset

Project Personnel: K. Sellwood (UM/CIMAS)
NOAA Collaborator: 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 2*:** Tropical Weather

Link to NOAA Strategic Goals:

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

Funding Unit: OAR/AOML **NOAA Technical Contact:** Alan Leonardi

Research Summary:

Since 1996, NOAA, the United States Air Force, and other international agencies have been releasing dropwindsondes 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.

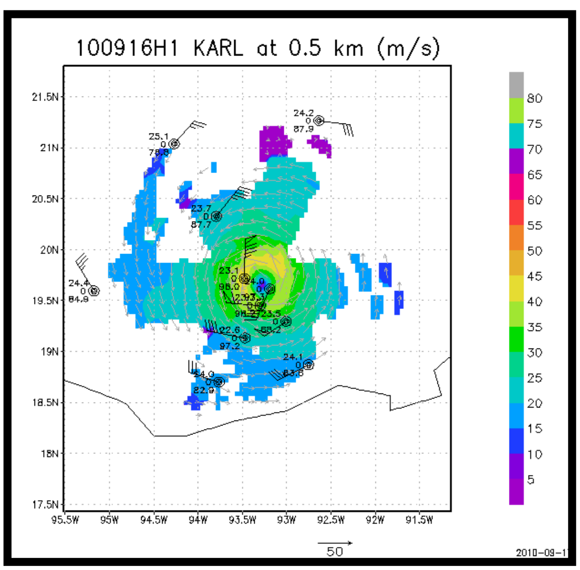

Figure 1: Graphic representations of the dropwindsonde data are also available in the archive. Shown is a composite of dropwindsonde and radar data for a NOAA P-3 flight into hurricane Karl.

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 dropwindsonde 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. Both numerical and graphic versions of the data are provided in order to meet the various needs of the research community. **See Figure 1.** Additionally we have developed computer programs to extract the environmental data that are transmitted, in real time, from the various aircraft. One such program produces estimates of the missing fields and formats the information in a manner that provides a quick look at the data and can be easily ingested into numerical models. These programs were successfully implemented for real-time data assimilation into HRD's experimental version of the Hurricane Weather Research and Forecasting model (HWRFx) during the 2010 Atlantic hurricane season. The codes, although still undergoing some refinement have been made publicly available upon request in an effort to meet the growing needs of the scientific community that is focused on computer modeling of tropical cyclones and the assimilation of observational data.

Figure 2: Shirley Murillo and Kathryn Sellwood process dropwindsonde data onboard the NOAA P-3 aircraft before transmitting to operational forecast centers.

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

Advanced Modeling and Prediction of Tropical Cyclones

Project Personnel: X. Zhang, K.-S. Yeh (UM/CIMAS)
NOAA Collaborators: S. Gopalakrishnan, T. Quirino, S. Goldenberg and F. Marks (NOAA/AOML); V. Tallapragada, and S. Trahan (NOAA/NCEP)

Long Term Research Objectives and Strategy to Achieve Them:
***Objectives*:** To guide and accelerate improvements in hurricane track and intensity forecasts with emphasis on rapid intensity (RI) change and the reduction of false alarms.
***Strategy*:** To 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 2*:** Tropical Weather

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

Funding Unit: OAR/AOML **NOAA Technical Contact:** Alan Leonardi

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 enhance the confidence in model performance, we developed a high-resolution modeling system (27-9-3km triple nest) in collaboration with the Hurricane Research Division (HRD) at the Atlantic Oceanographic and Meteorological Laboratory (AOML) and Environmental Modeling Center at National Centers for Environmental Prediction (NCEP). We have merged the system into operational system and completed retrospective forecasts for past three seasons (2008-2010) under the guidance of HFIP stream 1.5. The system is undergoing real-time parallel forecast in this season. We have also participated in the development of the operational HWRF model directly with vortex initialization that has resulted in substantial improvement on the intensity forecast. A new effort in basin-scale modeling has been started recently to further improve both the track and the intensity forecasts by cycling the environment flows to emphasize the model consistency. The HRD diagnostic post-processor (Diapost) is also upgraded to support the model development.

We have achieved several of our research objectives during the period of October 2010 to June 2011:
(a) We have successfully transferred the latest model development in CIMAS and HRD to operational model and merged into its latest code in EMC;
(b) We have implemented the new nesting algorithm and moving algorithm in latest HWRF repository;
(c) We have completed more than one thousand retrospective forecast in both North Atlantic Basin and East Pacific Basin.
(d) The high-resolution HWRF (27-9-3 km) is undergoing real-time forecast parallel to operational HWRF (resolution 27-9 km).
(e) Evaluation of the retrospective forecasts for HFIP stream 1.5 is underway.

(f) Advanced formulation for the storm-size correction in HWRF vortex initialization is successfully implemented in the operational model.
(g) An experimental genesis model is derived from the operational HWRF for basin-scale modeling with very promising preliminary results showing significant improvement in track forecasts.
(h) Diapost is upgraded to calculate more storm structures associated with characteristic radii, and to improve the storm tracker with the addition of smooth mean-sea-level pressure.

Current high-resolution (27-9-3 km) model configurations are listed in Table 1 along with HWRF and GFDL operational hurricane forecast models and 2010 HWRF experimental model (HWRFx).

Table 1: Model Configuration

	Stream 1.5 HWRF	Operational HWRF	HWRFx	GFDL
Domain	27 KM: 77.76° X 77.76° 9 KM: 10.56° X 10.2° 3 KM: 7.6° X 6.4°	27 KM: 77.76° X 77.76° 9 KM: 7.2° X 6.0°	27 KM: 57.12° X 55.56° 9 KM: 5.84° X 5.8°	54 KM: ~75° X ~75° 18 KM: ~11° X ~11° 9KM: ~5° X ~5°
Vortex Initialization	27-9 KM: Yes 3 KM: No (Downscaling)	27-9 KM: Yes	9KM: Yes 3KM: No (Downscaling)	54-18-9KM: Yes
Cycling	Yes	Yes	No	No
Ocean Coupling (Ocean model: POM)	27-9 KM: Yes 3 KM: No (Downscaling)	27-9 KM: Yes	No	Yes
GSI	Yes	Yes	No	No
Platform	JET-Linux	IBM	JET-Linux	IBM
Physics schemes				
Microphysics	Ferrier	Ferrier	Ferrier	Ferrier
Radiation (SW)	GFDL	GFDL	NCAR SW	GFDL
Radiation (LW)	GFDL	GFDL	RRTM	GFDL
Surface Scheme	GFDL (2010 implementation)	GFDL (2011 implementation)	GFDL (2009 implementation)	GFDL
PBL Scheme	GFS (Modified for HR implementation)	GFS	GFS	GFS
Cumulus Parameterization	New SAS (27-9 KM); no CP (3 KM)	New SAS	SAS	SAS
Land Surface	GFDL Slab	GFDL Slab	GFDL Slab	GFDL Slab

The preliminary results from 2008-2010 retrospective forecasts show the new high-resolution HWRF modeling system offers potential improvements with regard to both track and intensity forecasts in North Atlantic Basin. Further evaluations are underway.

Research Performance Measure: All research objectives are being met on schedule as determined with the HFIP leadership

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

Project Personnel: D. Willey (UM/CIMAS)
NOAA Collaborators: G. Halliwell and Robert Atlas (NOAA/AOML)

Long Term Research Objectives and Strategy to Achieve Them:
***Objectives*:** To design optimal ocean observing system strategies to improve initialization of ocean models in coupled hurricane forecast models.
***Strategy*:** To develop the capability of performing Observing System Simulation Experiments (OSSEs) and Observing System Experiments (OSEs) at NOAA/AOML and use these systems for designing observing system enhancements, both operational and targeted, that will improve ocean model initialization and potentially more-accurate hurricane intensity forecasts.

CIMAS Research Theme:
***Theme 2*:** Tropical Weather (*Primary*)
***Theme 3*:** Sustained Ocean and Coastal Observations (*Secondary*)
***Theme 4*:** Ocean Modeling (*Tertiary*)

Link to NOAA Strategic Goals:
***Goal 2*:** Serve Society's Needs for Weather and Water Information

Funding Unit: OAR/AOML **NOAA Technical Contact:** Alan Leonardi

Research Summary:
For a coupled tropical cyclone (TC) prediction model to correctly forecast intensity evolution, it must accurately predict the magnitude and pattern of sea surface temperature (SST) cooling over the region directly forced by the storm, particularly beneath the storm's inner core. The ocean model component must therefore accurately predict the magnitude and pattern of temperature cooling within the ocean mixed layer (OML) under intense TC forcing. SST evolution is sensitive to the initial temperature-salinity and associated density profiles provided to the ocean model because between 70 and 90% of OML cooling typically results from the entrainment of colder water into the OML. Initial errors in the thickness of the surface warm layer can produce large errors in the predicted SST cooling rate. This places a high premium on accurate initialization of ocean model fields.

The goal of this project is to improve the accuracy of data-assimilative ocean analysis products used to initialize the ocean component of coupled hurricane forecast models and potentially improve the accuracy of intensity forecasts. The strategy of the CIMAS and AOML collaborators is to use Observing System Experiments (OSEs) and Observing System Simulation Experiments (OSSEs) to evaluate existing ocean observing systems (OSE) and new ocean observing strategies (OSSE). Our initial OSSE system employs the "fraternal twin" approach; i.e., using one model type (HYCOM) as the nature run and also as the ocean model component of the operational data assimilation system. The key to this approach is to employ two substantially different configurations of HYCOM that reproduce the same level of uncertainty between them in the representation of synoptic ocean variability in the ocean that is achieved by present-day state-of-the-art ocean models with respect to synoptic variability in the actual ocean.

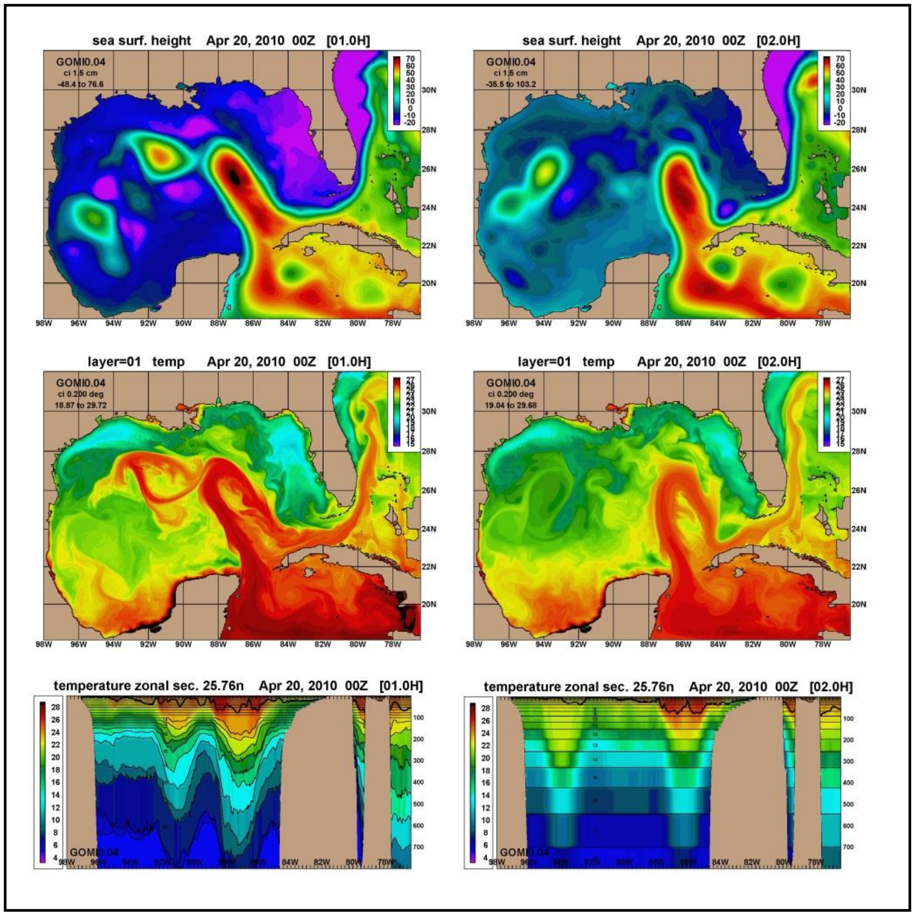

Figure 1: Maps of SSH (top panels) and SST (middle panels) along with temperature cross-sections (bottom panels) for the hybrid coordinate model run (left panels) and the sigma-z model run (right panels) on 20 April 2010.

To evaluate potential nature runs, HYCOM was run in two substantially different configurations in the Gulf of Mexico for the years 2004 through 2010. One configuration uses the standard hybrid vertical coordinate while the other uses the sigma-z vertical coordinate configuration (see Figure 1, bottom panels). These two runs generate substantially different representations of synoptic ocean fields in the GOM (**Figure 1**) demonstrating that these two HYCOM configurations can be used as the nature run and operational models, respectively. Model errors measured by airborne profilers deployed by NOAA WP-3D hurricane research aircraft during the Deepwater Horizon oil spill. Bias and RMS error graphs for the nine flight days during 2010 demonstrate that biases and errors between the two models are similar in magnitude to biases between each model run and the ocean observations (**Figure 2**). The growth rate in separation errors between actual surface drifters released in the ocean (data provided by R. Lumpkin, AOML/PhOD) and synthetic drifters released in the two models at the same locations as actual drifters is also similar in magnitude between the two models as between each model and the actual drifters (**Figure 3**). The “fraternal twin” approach to OSSEs is reasonable given these results.

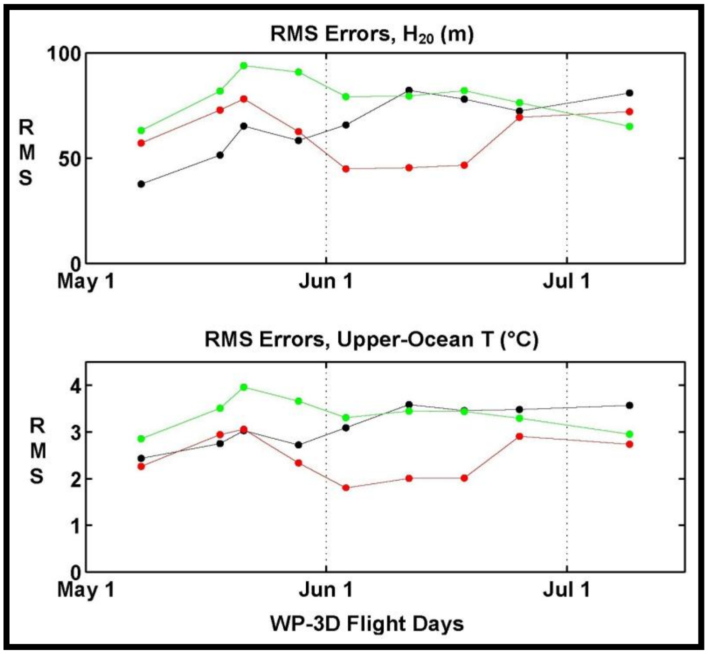

Figure 2: RMS errors in H_{20} (top) and upper-ocean temperature between 30 and 360 m (bottom) on the nine P-3 flight days.

Development of our new state-of-the-art ocean forecast system that will be used as the operational data assimilation system for the OSEs and OSSEs is nearing completion. Ashwanth Srinivasan is developing the data assimilation software along with the communication software required for ocean forecasting. He is expected to deliver this code within two weeks of this writing. This new code contains four data assimilation methods (Multi-Variate Optimum Interpolation, Sequential Extended Evolutive Kalman Filter, Ensemble Kalman Filter, and Reduced Order Information Matrix).

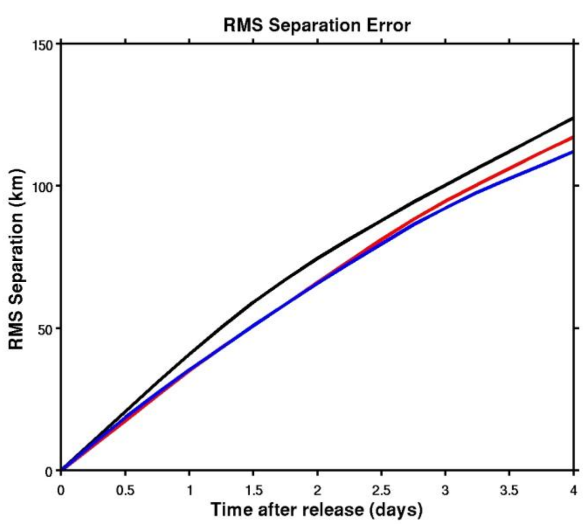

Figure 3: Growth of RMS separation error between surface floats as a function of time after release. Error growth is shown between synthetic drifters released in the nature run model and actual drifters (black), between synthetic drifters released in the operational model and actual drifters (red), and between synthetic drifters released in the two models (blue).

Research Performance Measure: The development of the OSSE toolbox and the new ocean forecast system is nearly complete. We are now preparing a paper that thoroughly demonstrates how a rigorous ocean OSSE must set up, evaluated, and calibrated to provide valid assessments of ocean observing systems. Our first OSSE experiments will be performed to assess the impact of targeted observations (aircraft, ship, drifter, glider, etc) on improving initial ocean fields for hurricane forecasting.

Observational Investigation of the Hurricane Boundary Layer Structure

Project Personnel: J.A. Zhang, S. Lorsolo (UM/CIMAS); D.S. Nolan (UM/RSMAS)
NOAA Collaborators: R.F. Rogers, F.D. Marks, M. T. Montgomery (NOAA/AOML)
Other Collaborators: P. Zhu (FIU); F. J. Masters (UF)

Long Term Research Objectives and Strategy to Achieve Them:

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

***Strategy*:** To study the mean hurricane boundary layer structure, a composite analysis of hundreds of Global Positioning System (GPS) dropsonde dataset is conducted. To investigate the turbulence structure of the hurricane boundary layer, in-situ aircraft and portable tower data are analyzed.

CIMAS Research Theme:
***Theme 2*:** Tropical Weather

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

Funding Unit: OAR/AOML **NOAA Technical Contact:** Alan Leonardi

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.

The first part of this project focuses on the investigation of the mean boundary layer structure. We analyze hundreds of dropsonde data that were collected in multiple storms in the last two decades. The data are grouped and analyzed according to the distance from the storm center that is normalized by the radius of maximum wind speed. 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 data analyses show that there is a clear separation of the thermodynamical and dynamical boundary layer heights (**Figure 1**). The dynamical boundary layer height is found to decrease with decreasing radius to the storm center. The thermodynamic boundary layer height is also found to decrease with decreasing radius to the storm center. The results also suggest that using the traditional critical Richardson number method to determine the boundary layer height may not accurately reproduce the height scale of the hurricane boundary layer.

The second part of this project is to investigate the turbulence structure in the hurricane boundary layer. We analyzed the flight-level data collected by research aircraft that penetrated the eyewalls of Category 5 Hurricane Hugo (1989) and Category 4 Hurricane Allen (1980) between 1 km and the sea surface. Estimates of turbulent momentum flux, turbulent kinetic energy (TKE) and vertical eddy diffusivity are obtained before and during the eyewall penetrations. Spatial scales of turbulent eddies are determined through a spectral analysis. The turbulence parameters estimated for the eyewall penetration leg are found to be nearly an order of magnitude larger than those for the leg outside the eyewall at similar altitudes (**Figure 2**). In the low-level intense eyewall region, the horizontal length scale of the dominant turbulent eddies is found to be between 500 – 3000 m, and the corresponding vertical length scale is approximately 100 m. For turbulence

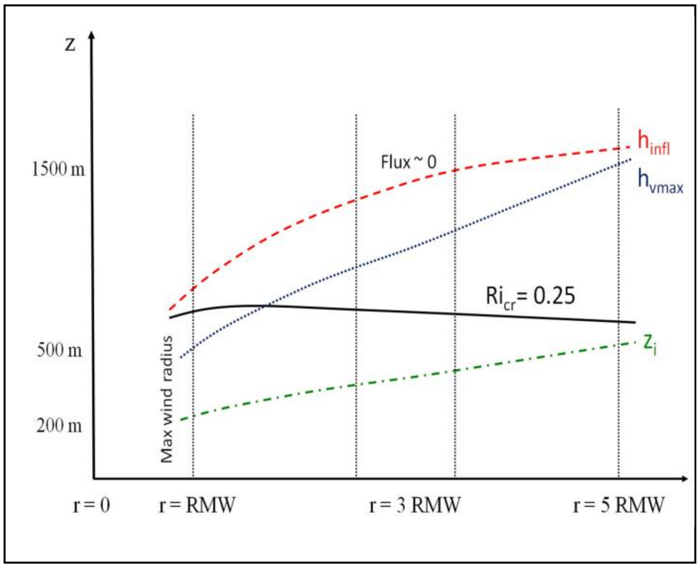

Figure 1: Schematic diagram of the characteristic height scales of the hurricane boundary layer. The height scales are based on the composite analysis of the dropsonde data. h_{inflow} is the inflow layer depth (red dashed line); z_i is the mixed layer depth (green dash-dotted line); and h_{vmax} is the height of the maximum wind speed (blue dotted line). The solid black line represents the height where the bulk Richardson number is equal to 0.25.

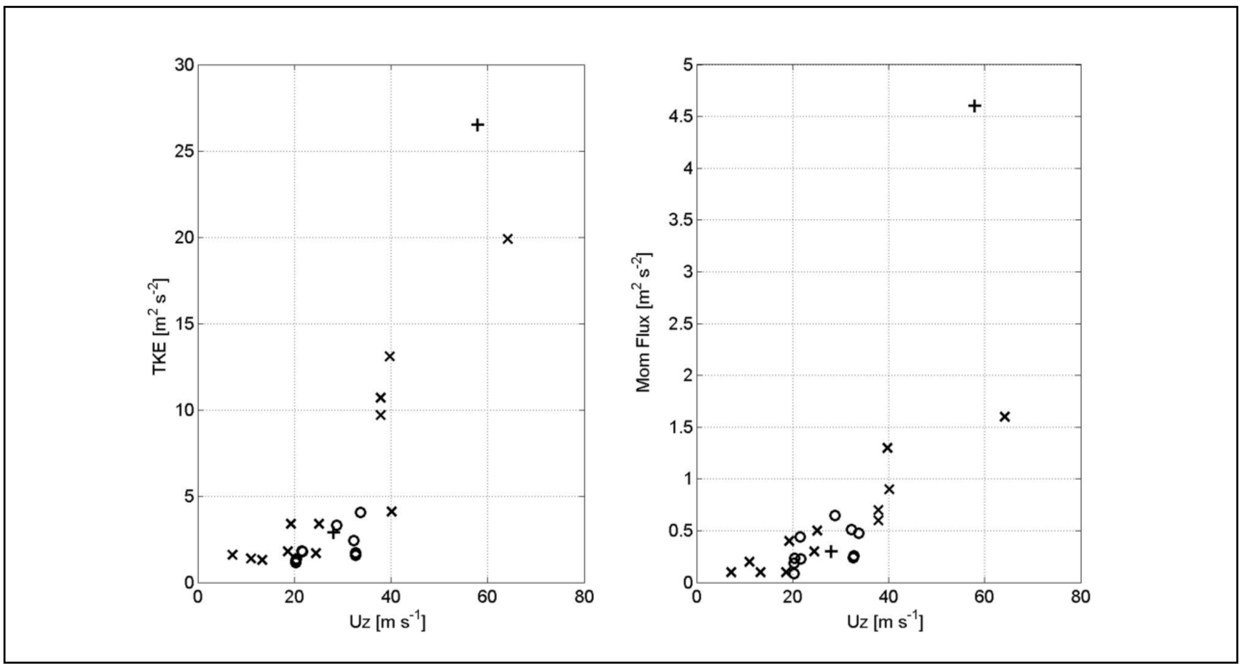

Figure 2: Plots of turbulent kinetic energy (TKE) and momentum flux as a function of the mean wind speed at the flight level for all the good runs in Hurricanes Allen (x), Hugo (+) and Frances (o).

study, we analyzed also the high-resolution (10 Hz) wind data collected by Florida Coastal Monitoring Program portable weather stations in the surface layer of three landfalling hurricanes. We estimated dissipative heating using two different methods: 1) integrating the rate of dissipation in the surface layer; 2) multiplyingthe drag coefficient by the cubic of the surface wind speed. It is found that the second method, which has been widely used in previous theoretical and numerical studies, significantly overestimates the magnitude of dissipative heating (**Figure 3**). This finding is consistent with a recent study on estimation of the dissipative heating over the ocean using in-situ aircraft observations. This part of the work also involves further analyzing the turbulence data collected using the 2002-2004 hurricane seasons, focus on investigating the dissipative heating and spectral characteristics of turbulence.

Future work includes evaluating the surface layer and boundary layer schemes used in the high-resolution Hurricane Weather and Research Forecast System (HWRF) using the observational data.

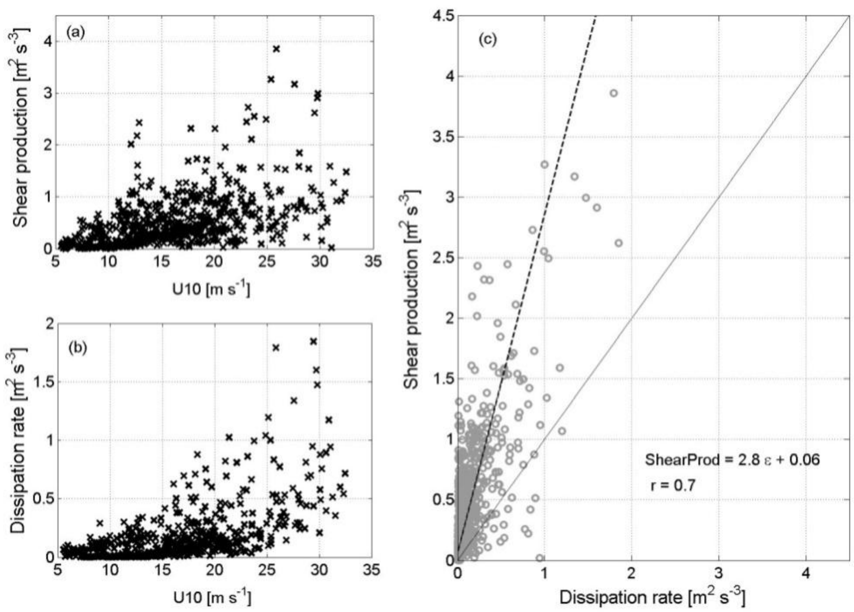

Figure 3: Plots of shear production as a function of 10m wind speed (a); dissipation rate as a function of 10 m wind speed (b); and comparison between the shear production and dissipation rate (c). The light solid line shows the 1:1 ratio. The black dashed line denotes the least-square best fit of the data. The linear regression equation and the correlation between the two estimates are also shown in (c).

Research Performance Measure: The program is on schedule. Six peer-reviewed articles have been published, in *Journal of Atmospheric Sciences*, *Monthly Weather Review*, and *Quarterly Journal of Royal Meteorological Society*. Another paper has been accepted for publication in *Monthly Weather Review.*

Characterization of the Kinematic and Turbulent Structure of the Hurricane Boundary Layer Using Doppler Measurements

Project Personnel: S. Lorsolo, A. Aksoy and J. Zhang (UM/CIMAS)
NOAA Collaborators: J. Gamache, R. Rogers, P. Reasor and F. Marks (NOAA/AOML)

Long Term Research Objectives and Strategy to Achieve Them:

Objectives**:** To characterize the Hurricane Boundary Layer (HBL) kinematic and turbulent processes to better understand HBL physical processes impacting hurricane intensity change and to enable a more accurate parameterization of the HBL in numerical weather prediction models thereby improving intensity forecasting.

Strategy**:** To process and analyze extensive airborne Doppler radar database and other remote sensing and *in-situ* measurements from the NOAA WP-3D research aircraft to provide a comprehensive evaluation of the kinematic and turbulent structure of hurricanes and more specifically the HBL. To design new analysis methods to study HBL physical processes using Doppler measurements and to develop better data processing method and new metrics for data assimilation and model evaluation.

CIMAS Research Theme:

Theme 2: Tropical Weather

Link to NOAA Strategic Goals

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

Funding Unit: OAR/AOML **NOAA Technical Contact:** Alan Leonardi

Research Summary:

One of the main challenges of hurricane research is to better understand the processes that influence hurricane intensity change, which could ultimately lead to improved intensity forecasts. The HBL is believed to play a crucial role in hurricane intensity change and improved forecast greatly depends on a better understanding of the HBL dynamics.

The goal of this research project is to characterize kinematic and turbulent structure of hurricanes, and more specifically the HBL, using airborne remote sensing instruments such as NOAA WP-3D tail Doppler radar.

The activities of the past year have primarily focused on analyzing the NOAA Airborne Doppler radar data to provide an overall representation of hurricane kinematic structure from high resolution two-dimensional Doppler profiles. This work was conducted to provide a baseline of the capability of such data type to represent specific regions of a tropical cyclone (i.e. HBL) and parameters (i.e. vertical and radial wind). Over 150 aircraft penetrations have been processed and Doppler analyses from 8 hurricanes were produced and analyzed, and provided a well-documented characterization of the hurricane kinematic and turbulent (**Figure 1**) structure. Once it was established that the two-dimensional Doppler profiles were a prime tool to characterize the HBL structure, the research has been essentially concentrated on the HBL to identify processes influencing intensity change.

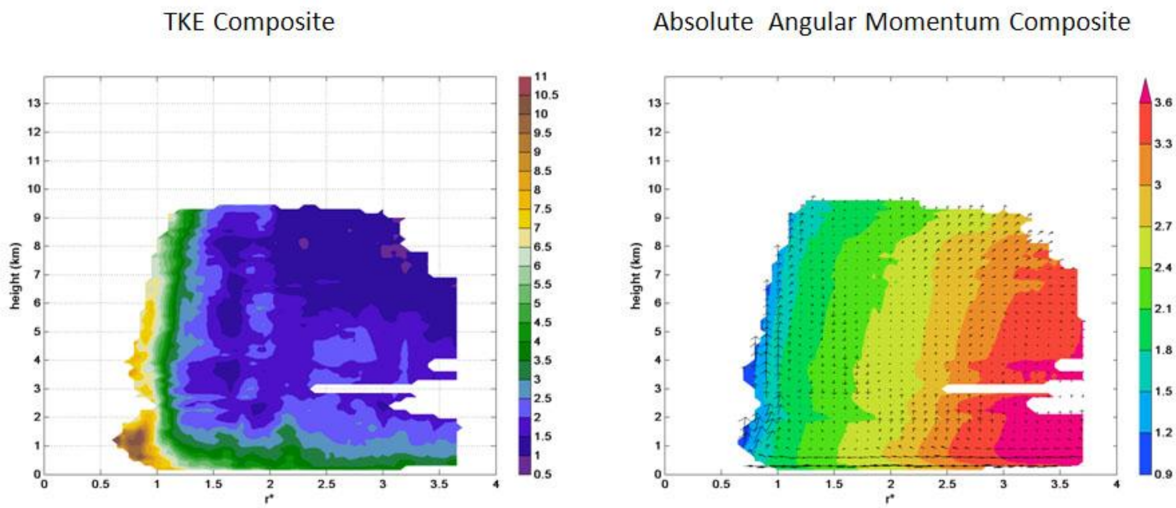

Figure 1: TKE and absolute angular momentum composites.

Preliminary results have provided statistics on critical parameters such inflow layer depth and inflow magnitude and their evolution in the inner-core and outer regions. A composite analysis of some parameters of the HBL has revealed some key differences in the HBL kinematic structure for various phases of a hurricane lifetime (**Figure 2**).

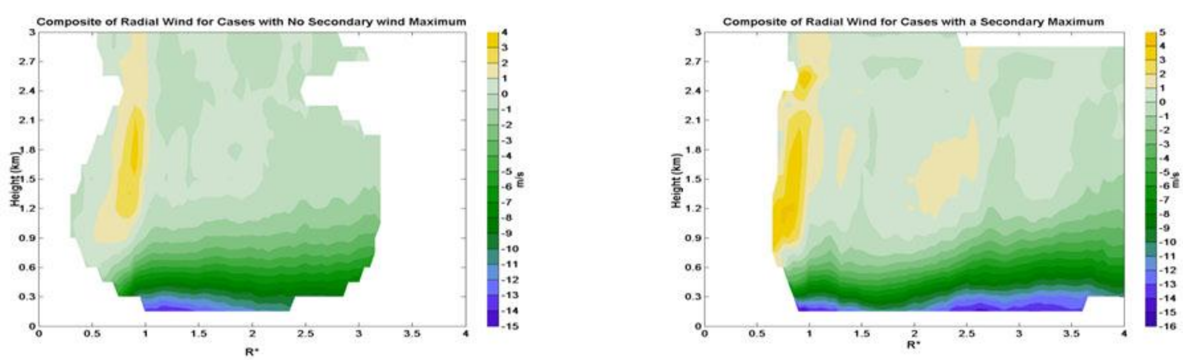

Figure 2: Radial wind composites for cases with no 2nd wind max (left) and for cases with 2nd wind max (right).

To fully investigate the hurricane structure, wavenumber analysis is generally necessary. However, Doppler analyses often exhibit data gaps hindering wavenumber decomposition, and assessing the maximum gap size beyond which not to perform Fourier decomposition has always been challenging. The help overcome this challenge a study was carried on to provide an objective and systematic method to choose the maximum gap size allowed to perform a Fourier analysis on observational data. A Monte-Carlo experiment called “gap experiment” was conducted and results indicate that, when 2 or more gaps are present in the data, the maximum gap size allowed is greater than originally suggested in the literature. The study was presented in such a way (**Figure 3**) that can be used as valuable guidance to scientists facing the issue of performing Fourier analysis on “gappy” data.

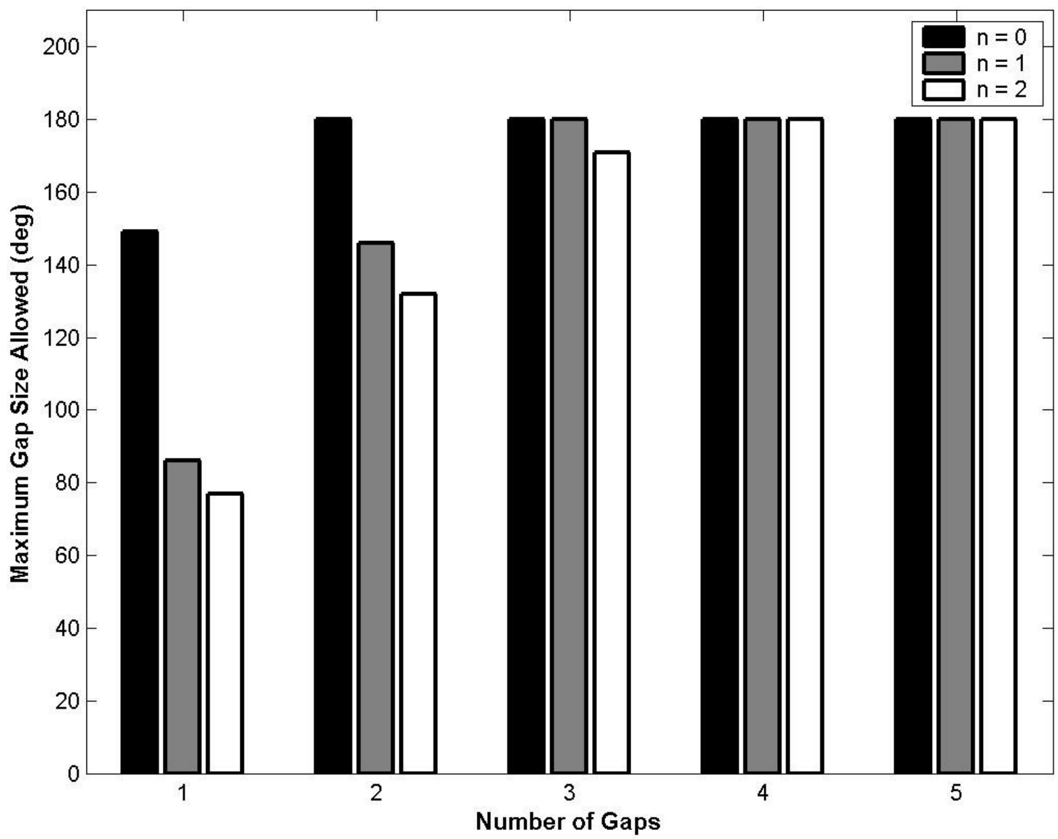

Figure 3: Maximum gap allowed for wavenumber, 0,1 and 2 as a function of gaps in data.

Research Performance Measure: NOAA strategic goal to serve society’s need was met as high-resolution Doppler analyses and superobs were produced and are now available to the hurricane and data assimilation and model community. The work providing high-resolution representation of the hurricane structure and the HBL using the two-dimensional Doppler profiles is still on-going but the first phase was successfully completed and is published in the journal Monthly Weather Review. Some collaborative work that pertains to a better characterization of the HBL and led by Dr. Jun Zhang was conducted and a peer-reviewed paper was published. Finally, the gap experiment was completed and a manuscript that can ultimately be used as a reference document has been submitted to NOAA’s Hurricane Research Division internal review process.

Development of Observing System Simulation Experiments for Unmanned Aircraft Systems in Hurricanes

Project Personnel: D.S. Nolan and S.J. Majumdar (UM/RSMAS)
NOAA Collaborators: R. Atlas (NOAA/AOML)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** To contribute to the development of a complete observing system simulations experiment (OSSE) to evaluate the impact on hurricane forecasts of observations obtained from current and future unmanned aircraft.

***Strategy*:** To develop and perform one or more high quality, high-resolution numerical simulations of an Atlantic hurricane which will be used as the ground truth, the so-called "nature run," which is used to derive observations from hypothetical instruments and to evaluate the track and intensity prediction of forecast models that assimilate those observations.

CIMAS Research Theme:

***Theme 2*:** Tropical Weather

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*)

Funding Unit: OAR/AOML **NOAA Technical Contact:** Alan Leonardi

Research Summary:

The goal of the CIMAS - AOML team is to produce one or more highly realistic simulations of a hurricane in the Atlantic basin. The numerical prediction model used for this purpose is the Weather Research and Forecasting Model (WRF) version 3.2.1 (Skamarock et al. 2008). The nature run simulation is performed with 1 km horizontal grid spacing on the innermost nested grid, which is sufficient for the reproduction of relevant inner-core processes such as rapid intensification, polygonal eyewalls, and secondary eyewall formation. The T511 ECMWF nature run that is being used by NOAA in their global model OSSE studies has been chosen to provide the initial and boundary conditions for the regional, nested simulation.

The first task accomplished during this first project year was the selection of a hurricane case that occurred during the simulated Atlantic hurricane season of the ECMWF nature run. Then, extensive testing was performed to assess the best possible configurations for the size of the WRF model domain used to reproduce a (vastly) more realistic version of this same storm. (See **Figure 1**). We evaluated the sizes and resolutions for the moving, nested grids that follow the hurricane vortex, the number and distribution of the vertical levels, and the choices of physics parameterizations such as those for radiation, microphysics, the boundary layer, and ocean surface cooling.

To summarize the results, the WRF nature run uses a 27 km grid that covers the much of the tropical Atlantic, with nested grids of 9km, 3km, and 1 km resolution. The inner-most grid uses 480x480 grid points. 60 vertical levels are used. The selected physics parameterizations include the WRF 6-class double-moment microphysics scheme, the recently updated RRTM longwave and shortwave radiation schemes, the YSU boundary layer scheme with surface exchange coefficients improved for hurricane conditions, and a one-dimensional mixed-layer ocean model to reproduce ocean cooling under the eye of the storm. The simulation covers 13 days, including genesis of the storm from an easterly wave, rapid intensification, a mature stage with an expanding wind field, and then recurvature into the North Atlantic.

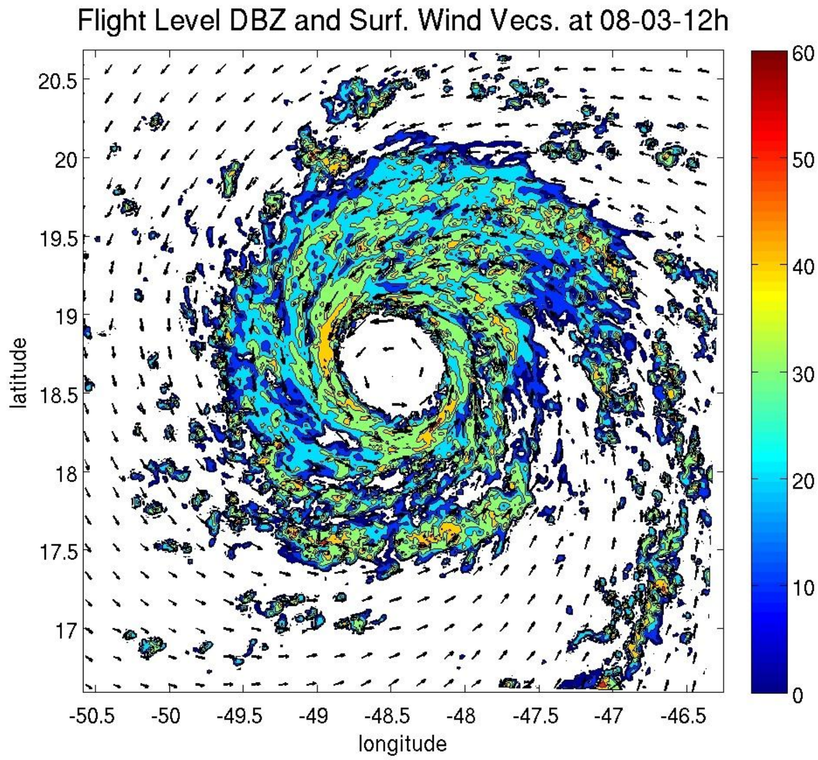

Figure 1: This figure shows a snapshot of surface wind vectors and simulated flight-level radar reflectivity for the hurricane nature run at the beginning of the period of rapid intensification. Note that the highest reflectivities are confined to strong convective cells that are only a few km in scale, embedded in broader areas of moderate reflectivity (and moderate precipitation). There are also large areas of light precipitation. These aspects are much more realistic than most hurricane simulations.

Research Performance Measure: While most of the objectives have been met, it remains to be determined whether the nature run simulation is sufficiently realistic as compared to observations of real storms. This will be the main focus of the project for the remaining months of the current funding period. The wind fields of the simulated hurricane will be compared to composites of hurricane wind fields derived from dropsonde and airborne radar observations. The distributions of precipitation and radar reflectivity will also be evaluated.

*Real-Time Hurricane Wind Analysis (H*Wind)*

Project Personnel: B. Annane, S. Otero and R. St. Fleur (UM/CIMAS)
NOAA Collaborators: M. Powell and S. Murillo (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*:** To apply advanced computing methodologies to integrate cyclone data and to make the data more readily available to scientists in real-time.

CIMAS Research Theme:
***Theme 2*:** Tropical Weather

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

Funding Unit: OAR/AOML **NOAA Technical Contact:** Alan Leonardi

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

Data collection is accomplished through a suite of Unix scripts and C programs. Current platforms being ingested include Air Force and NOAA reconnaissance, Dropwindsondes, GOES, SSM/I, TM/I, QSCAT, ASCAT, WINDSAT satellites and the AMSU satellite product, METAR, C_MAN, Buoys, Ships, mobile Towers, MESONET data from FSL MADIS Group and WeatherFlow. Currently based on research performed, the packages developed to bring data into the H*Wind database are being ported to Python, a platform independent language similar to Java. The effort will lead to a wider use with in other systems and tools and further promotes the software paradigm of code reuse endorsed by the H*Wind project.

The H*Wind Quality Control (QC) Client is the focal point of the H*Wind system. The QC Client allows scientist to interact with the data stored in the database. QC graphically displays the data and allows close inspection, editing or removal of data from the analysis, and customization of analysis parameters.

The analysis algorithm consists of a process of estimating the continuous spatial field of a physical variable from a set of discrete observational data. For our purposes, the physical variables of concern are wind, pressure, temperature and relative humidity. The basic product of this analysis is a colored and annotated wind contour plot. Other products offer vorticity, divergence and google plots. Each analysis is published with a self-explanatory metadata file compliant with FGDC (Federal Geographic Data Committee).

Dropwindsondes are considered one of the most valuable data platforms for the continuous information transmitted during their fall at heights that are impossible to reach for most other in-situ platforms. Their characteristics make them a sought-after research asset. HRD maintains an FTP archive of NOAA and AFRES dropwindsonde files, both operationally-processed and post-processed. In an effort to help scientists better assess the content of this dataset, a combination of a proper database (PostgreSQL) and a web graphical interface (Google Web Toolkit) was developed, with the aim of becoming HRD's Dropsonde Portal. Users have the ability to query sondes over a range of years, storms, flights or based on azimuthal and radial criteria. The splash locations of the query result are visualized on a Google map, and the user can choose to download either the lines of data corresponding to splash locations or all the detail lines transmitted per sonde (**Figure 1**). The skills acquired during the implementation of the dropsonde portal prototype seek to transform H*Wind's Quality Control Client in a similar direction.

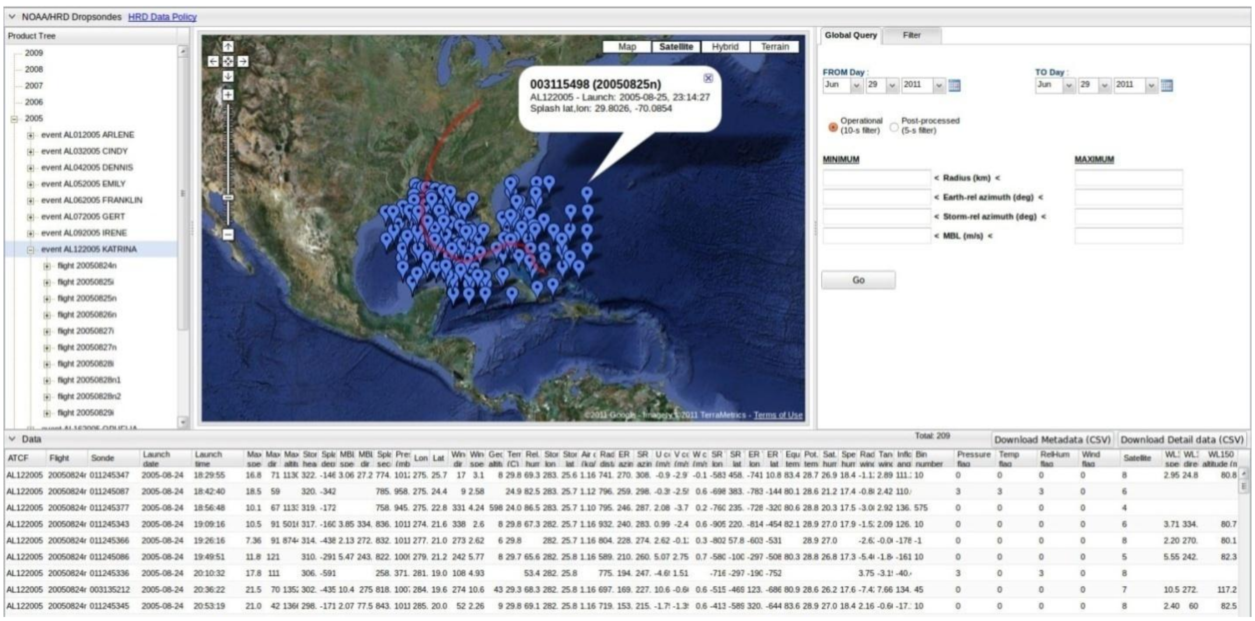

Figure 1: Web interface of the dropsonde portal featuring all operationally-processed dropsondes for storm Katrina 2005.

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

Data Integration and Data Mining Support for Tropical Cyclone Integrated Observing Systems

Project Personnel: M.-L. Shyu (UM/ENG)
NOAA Collaborators: F. Marks, M. Powell and T. Quirino (NOAA/AOML)

Long Term Research Objectives & Strategy to Achieve Them:

***Objectives*:** To design, develop, and implement a "HRD Web Portal" that combines data from several sources (geographical and non-geographical), enables researchers and scientists to connect to the database via the web portal platform to integrate, mine, and analyze raw and post-processed Tropical Cyclones data, and displays the results to the user in order to improve the public's awareness of the dangers that may be imposed by Tropical Cyclones.

***Strategy*:** To utilize Java, Smart GWT/GWT (Google Web Toolkit), and Google Maps APIs for the development of a "lightweight" web-based interface dubbed the "HRD Web Portal".

CIMAS Research Theme:

***Theme 2*:** Tropical Weather *(Primary)*
***Theme 1*:** Climate Research and Impact *(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)*

Funding Unit: OAR/AOML **NOAA Technical Contact:** Alan Leonardi

Research Summary:

Raw point-observational data (land, atmosphere, and ocean) and graphical products derived from observational and model data are stored in the centralized database. "HRD Web Portal" was designed, developed, and implemented as a bridge to render wind data from diverse sources and in different formats with geographical information in multiple visualization maps, as well as synchronized animations of various products, all geared toward comprehensive forecast and model evaluation. **Figure 1** shows the proposed HRD Forge framework for improving the utility of NOAA's hurricane data, the "HRD Web Portal" is on the left-hand side of the figure. The visualization interface, shown in **Figure 2**, specifically tailored toward tropical cyclone (e.g., hurricanes) forecast and model diagnostics by real natural events or idealized studies. On the basis of the designated event or study, available graphical products of model or observation in the centralized database are presented for visualization. The design and implementation included the following features that are key to comprehensive data inter-comparison: 1) a lightweight architecture (i.e., runs on a web-browser), and 2) a multi-map interface capable of side-by-side animations of diverse model and observational data products (geo-referenced and non-geo-referenced). The portal serves as an example of potential visualization applications that is built to take advantage of the Web Services Layer as the data source. It allows the users to overlay different types of tropical cyclone data, including their own KML documents with proprietary data. **Figure 3** shows a series of snapshots of the Web-Based portal interfaces which help the users search products of real natural events or idealized studies in the database for visualization.

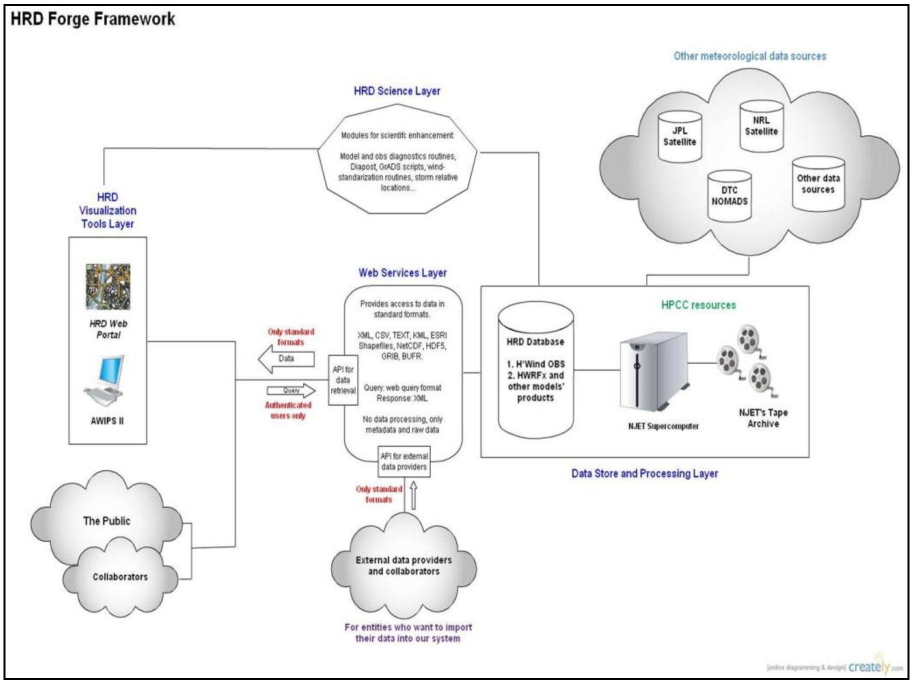

Figure 1: The proposed HRD Forge framework for improving the utility of NOAA's hurricane data.

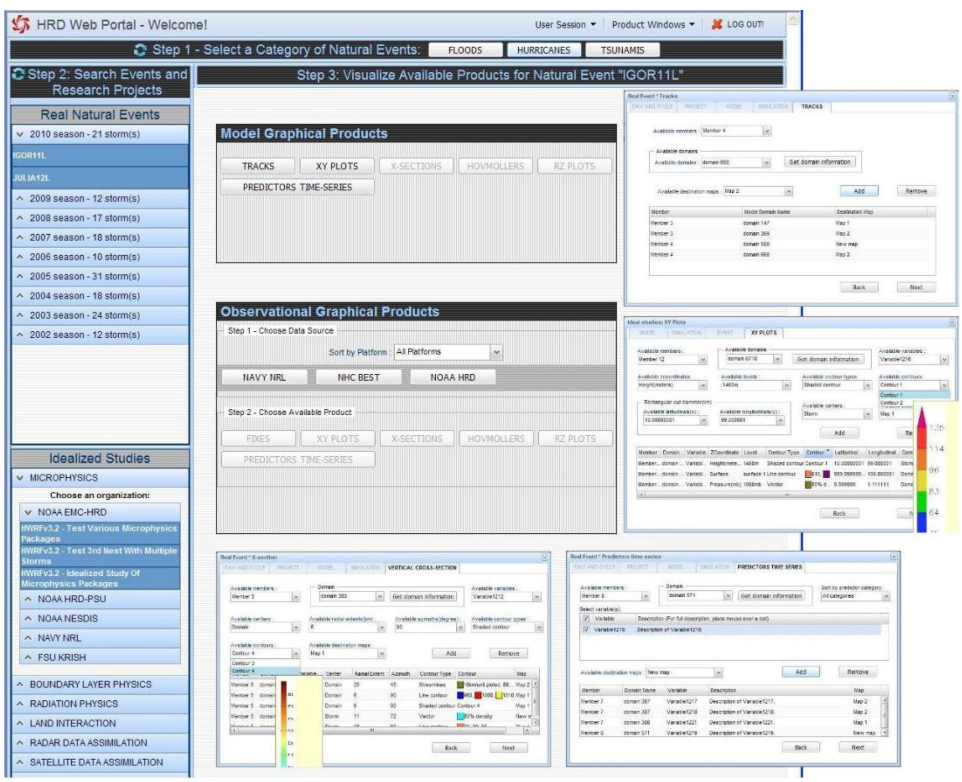

Figure 2: Snapshots of Web-Based main interface of HRD Web Portal with selection windows of graphical products (Tracks, XY plots, X-sections, and Predictors time-series).

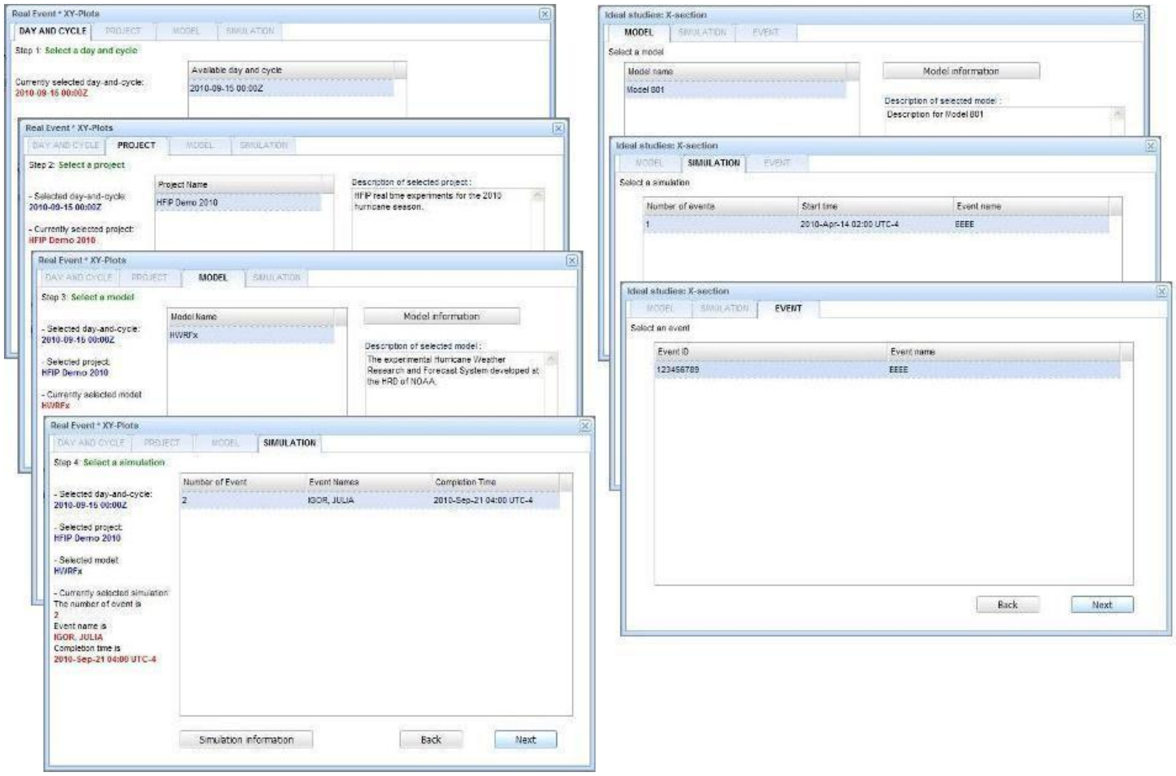

Figure 3: Snapshots of a series of selection windows help user search products of real natural events or idealized studies in the database.

Research Performance Measure: All objectives were reached.

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

Project Personnel: M.-L. Shyu (UM/ENG)
NOAA Collaborators: F. Marks, S. Gopalakrishnan, T. Quirino 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 researching on rapid intensity changes in tropical cyclones (TCs) , to build a centralized database to integrate both the historical and modeling data from different sources, and to develop a lightweighted web portal to present the data geared towards scientists' needs.

Strategy**:** To study structure and dynamics of tropical cyclones (TCs) and analyze specific hurricane cases using model and observational data sets, the Experimental Hurricane Weather and Research Forecast (HWRF-X) System at AOML/HRD has been developed and maintained. To build the centralized database, data from the H*WIND relational database, HRD's operational flights (radar, dropsondes, AXBT, UAS), satellite, and operational and research models were integrated. To develop the lightweight web portal for data presentation, industry standard developmental tools such as Smart Google Web Toolkit (SmartGWT) and Google Maps APIs were utilized.

CIMAS Research Theme:
Theme 2**:** Topical Weather (*Primary*)
Theme 1**:** Climate Research and Impact (*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*)

Funding Unit: OAR/AOML **NOAA Technical Contact:** Alan Leonardi

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. Currently, hurricane researchers have no ability to synthesize *model* and *observation* data in a centralized and comprehensive approach. The worlds of modelers and observers have not united in an efficient way to access and share data for the sake of inter-comparison, verification or other potential research tools. Nevertheless, advances in hurricane modeling are tightly correlated with the ability to quickly evaluate model output against a diverse set of observations. This activity leads to the determination of deficiencies in model forecast.

In this project, a centralized database which stores hurricane data from different data sources such as the H*WIND relational database and satellites were designed and implemented. A user-friendly HRD Web Portal was implemented so that the scientists could access different real-time and historical hurricane data easily. **Figure 1** shows the overall design of the whole system. **Figure 2** shows the synchronized animation control for data products from different sources. **Figure 3** shows the implementation of creating and managing multiple animation groups.

Research Performance Measure: All objectives were reached.

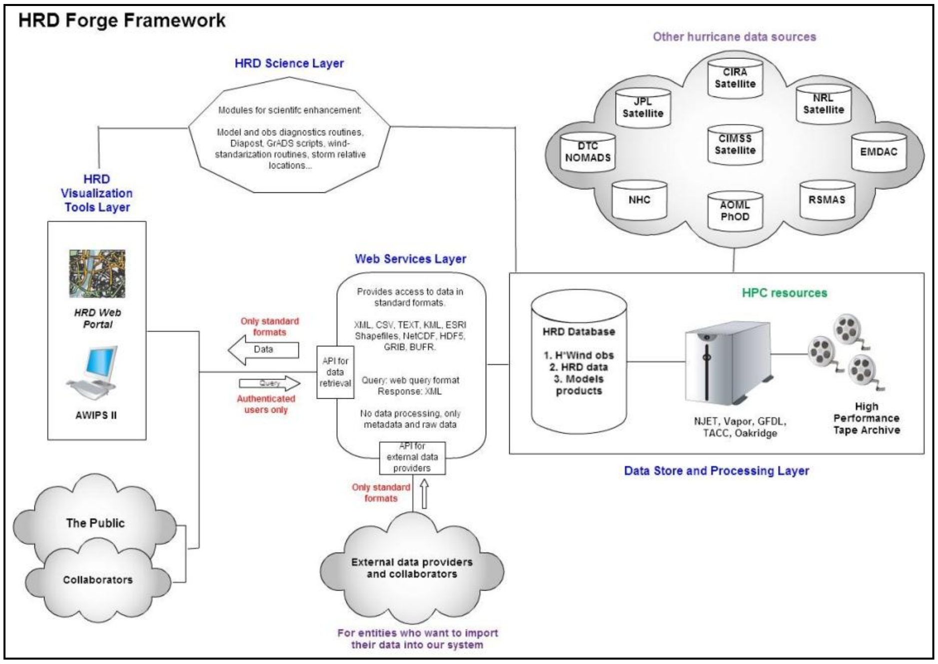

Figure 1: Overall design of the framework.

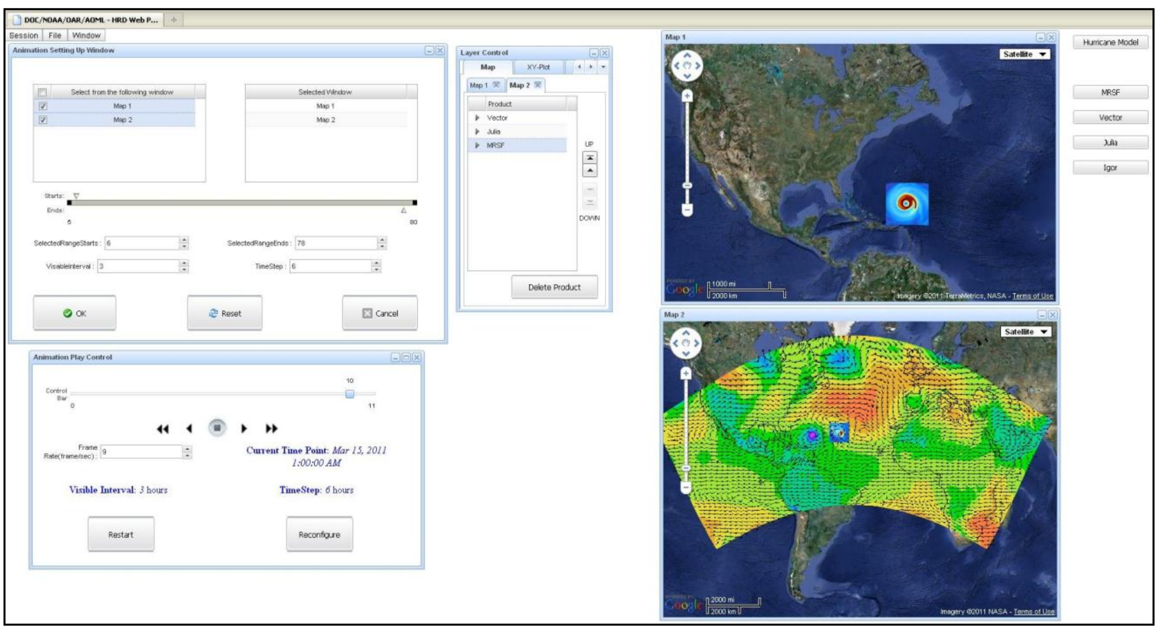

Figure 2: Synchronized animation control.

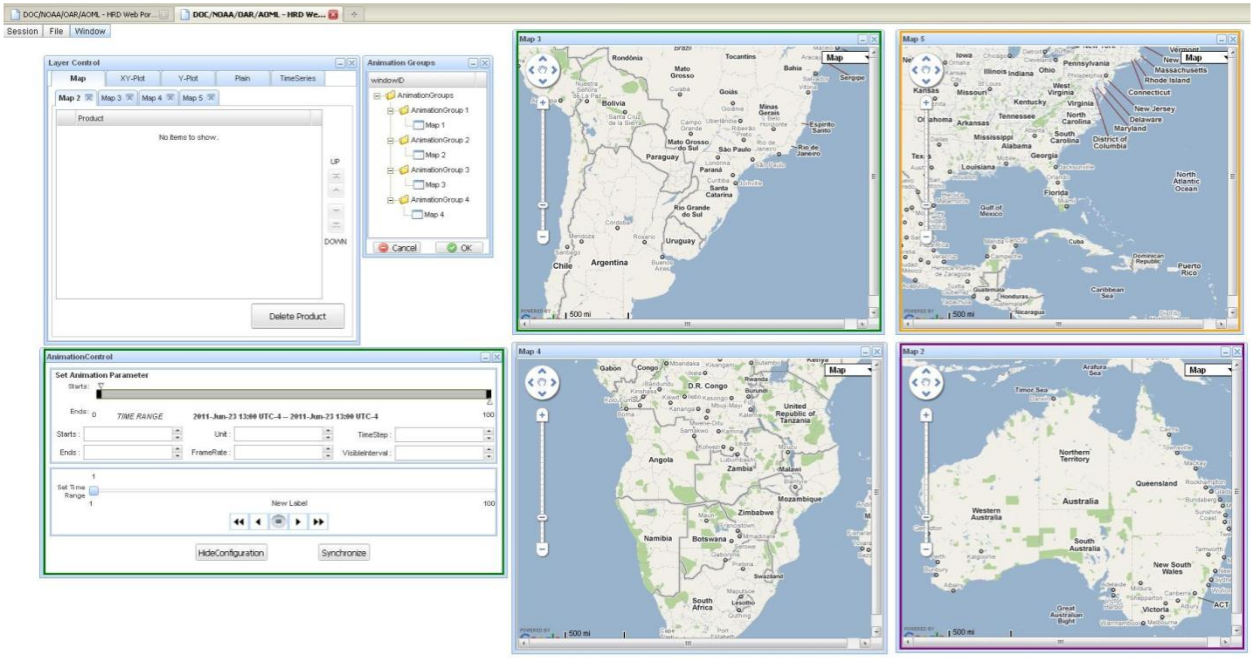

Figure 3: Animation group management

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SFMR Archive Expansion and Evaluation of the 2010 Air Force Reserve Command SFMR Data

Project Personnel: B. Klotz (UM/CIMAS)
NOAA Collaborators: E. Uhlhorn (NOAA/AOML)

Long Term Research Objectives & Strategy to Achieve Them:
Objectives: To collect and process the raw SFMR files from NOAA and Air Force Reserve Command (AFRC) missions and evaluate shortcomings as well as future needs.
Strategy: To take collected SFMR data from 2010 and compare to previous seasons. Based on these comparisons, a larger archive can be developed to improve its statistical relevance. From this larger archive of data, specific problems related to the SFMR can be addressed.

CIMAS Research Theme:
Theme 2**:** Tropical Weather

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

Funding Unit: OAR/AOML **NOAA Technical Contact:** Alan Leonardi

Research Summary:
The Stepped Frequency Microwave Radiometer (SFMR) is an aircraft based instrument that measures a set of ocean surface brightness temperatures, which are used to calculate surface wind speeds and rain rates. A form of the SFMR has been on the NOAA WP-3D aircraft since the 1980s, and several changes to this instrument have occurred over the years. In 2008, the AFRC added an SFMR to all of their WC-130J reconnaissance aircraft, allowing for increased coverage of surface winds within tropical cyclones. The current SFMR is very useful for measuring hurricane force winds, where the effects of rain contamination and noise are negligible. Much of the SFMR archive contains data in mature hurricanes, but with increased community-wide emphasis on tropical cyclone genesis and intensification, the instrument could become more useful by improving its ability to measure tropical depression and weak tropical storm winds, especially in the presence of moderate to heavy rain.

In order to improve on the statistical relevance of the SFMR archive, data from NOAA and AFRC flights were collected throughout the 2010 hurricane season, including data from the ITOP field program based in Guam. In order to evaluate the performance of the AFRC data, they were compared to the 2006-2010 NOAA dataset, which contains SFMR surface wind speeds paired with surface adjusted wind speeds from the GPS dropwindsondes. As an independent comparison, the 2005 NOAA pairs were also evaluated alongside the 2006-2010 NOAA pairs.

During the 2006-2010 period, the SFMR wind speeds compared to the dropwindsonde surface-adjusted wind speeds produce a root mean square error (RMSE) of ~2.5 m s^{-1}. Compared to the 2010 AFRC data, this RMSE is slightly lower, but the AFRC data performs better than the 2005 data. **Figures 1 and 2** provide a general idea of how the AFRC data compares with the NOAA 2006-2010 data.

- Figure 1a indicates through the two regression lines (green and red lines) that the NOAA and AFRC data have similar fits in relationship to the dropwindsondes, but the AFRC data is slightly higher in comparison.
- Figure 1b amplifies the idea that higher rain rates have adverse effects on the accuracy of SFMR wind speed measurements, which is apparent in both NOAA and AFRC data.
- Figure 1b and Figure 2 exemplify the fact that there are very few measurements of weak wind speeds in moderate to heavy rain while hurricane force winds have a wider range of measurements as a function of rain rate.

It is indicative of these two figures that the AFRC SFMR has improved since it became operational in 2008 because the 2010 data compare relatively closely to the NOAA data. They also help show that by actively trying to increase the number of measurements at the higher rain rates within the depression and tropical storm wind speed regimes, the SFMR archive can be expanded to contain weaker wind speeds in all rain conditions. This improvement increases the instrument reliability during operational missions.

Research Performance Measure: All major research objectives have been met and provide evidence for future improvements. Research towards improving the SFMR algorithm is ongoing.

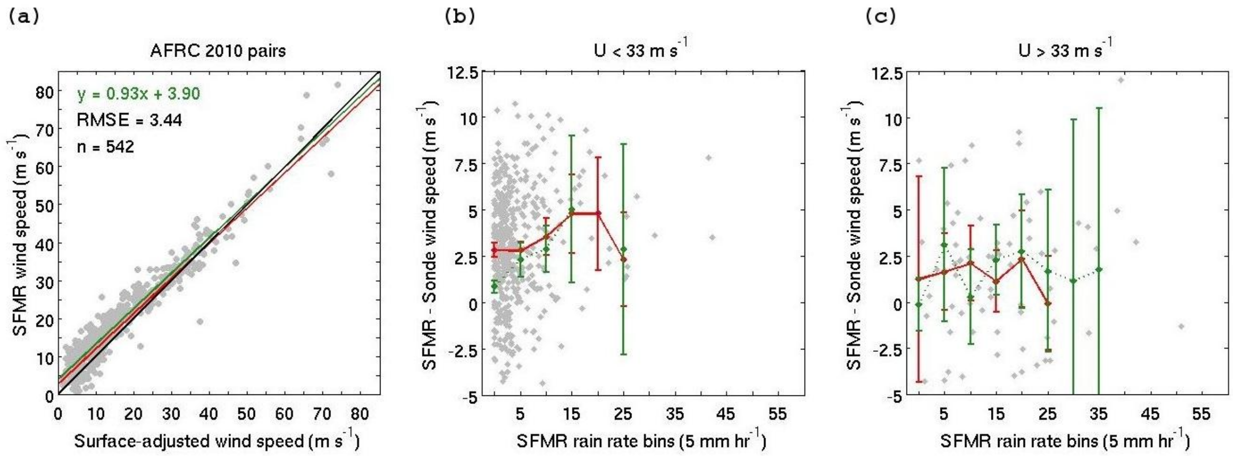

Figure 1: In (a), 2010 AFRC SFMR-dropwindsonde pairs (gray circles), AFRC 2010 linear best-fit (green line), 2006-2010 NOAA linear best-fit (red line), and the 1:1 relationship (black line) are shown with dropwindsonde surface-adjusted wind speeds indicated on the horizontal axis. In (b) and (c) dropwindsonde pairs are binned every 5 mm hr^{-1} of rain rate within the less than hurricane and hurricane force wind speeds. The red line represents the AFRC bin-averaged data with error-bars indicating the 95% confidence. The green lines in (b) and (c) represent the 2006-2010 NOAA data in a similar fashion to the AFRC data.

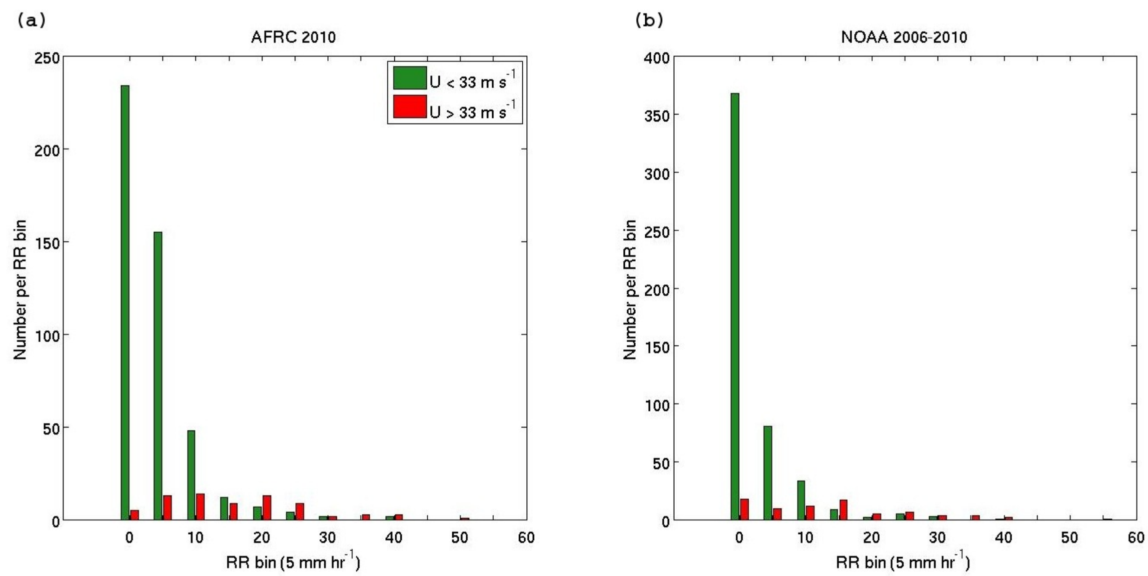

Figure 2: Histograms are shown for the 2010 AFRC data (a) and for the 2006-2010 NOAA data (b). These histograms are shown with respect to the 5 mm hr^{-1} rain rate bins and are divided into less than hurricane force winds (green) and hurricane force winds (red).

Verification of SFMR Observed Extreme Surface Winds in Super-Typhoon Megi

Project Personnel: B. Klotz (UM/CIMAS)
NOAA Collaborators: E. Uhlhorn (NOAA/AOML)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** To determine if the observed SFMR surface wind speeds are dynamically realistic based on the equations of motion.

***Strategy*:** To create radial profiles of various parameters including surface wind speed and surface pressure. From these radial profiles, the inflow equation can be solved as a function of radius from the storm center. Calculations using the available components produce the dynamically expected surface wind speed, which are compared to the observed wind speed from the SFMR.

CIMAS Research Theme:

***Theme 2*:** Tropical Weather

Link to NOAA Strategic Goals:

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

Funding Unit: OAR/AOML **NOAA Technical Contact:** Alan Leonardi

Research Summary:

Tropical cyclones (TCs) are known to impact locations across the world, sometimes causing massive damage. The West Pacific basin experiences many tropical cyclones every year and these cyclones occasionally reach intensities rarely seen in other TC producing basins. However, unlike the NOAA and Air Force Reserve Command (AFRC) operational missions over the Atlantic basin, there are no aircraft equipped to fly missions into West Pacific TCs on a regular basis.

During the 2010 season, the Impact of Typhoons on the Ocean in the Pacific (ITOP) field campaign was able to collect observations within West Pacific TCs using the AFRC WC-130J aircraft. While much of this field program focused on ocean impacts, SFMR measurements were obtained within several tropical cyclones, including super-typhoon Megi. The flights into Megi were able to capture its intensification from a weak typhoon to super-typhoon status over a period of 4-5 days.

Radial profiles of the surface wind speed from Megi's strongest period, which are shown in **Figure 1**, indicate that wind speeds as high as 90 m s^{-1} were observed with a mean maximum surface wind speed of near 85 m s^{-1} at a radius of 16 km from the center. These radial profiles also indicate that Megi was a relatively symmetrical cyclone. For comparison, only a handful of SFMR flights over the Atlantic basin have recorded wind speeds in excess of 75 m s^{-1}. SFMR measurements during hurricane Rita from 2005 reached maximum wind speeds of near 75 m s^{-1} while hurricane Felix from the 2007 season had SFMR winds near 80 m s^{-1} during one pass through the storm. While these two storms were very intense, the extreme wind speeds were only measured once or twice within each respective flight. Megi, however, was observed to have wind speeds in excess of 80 m s^{-1} through three full passes, equaling six separate instances of the extreme wind speeds.

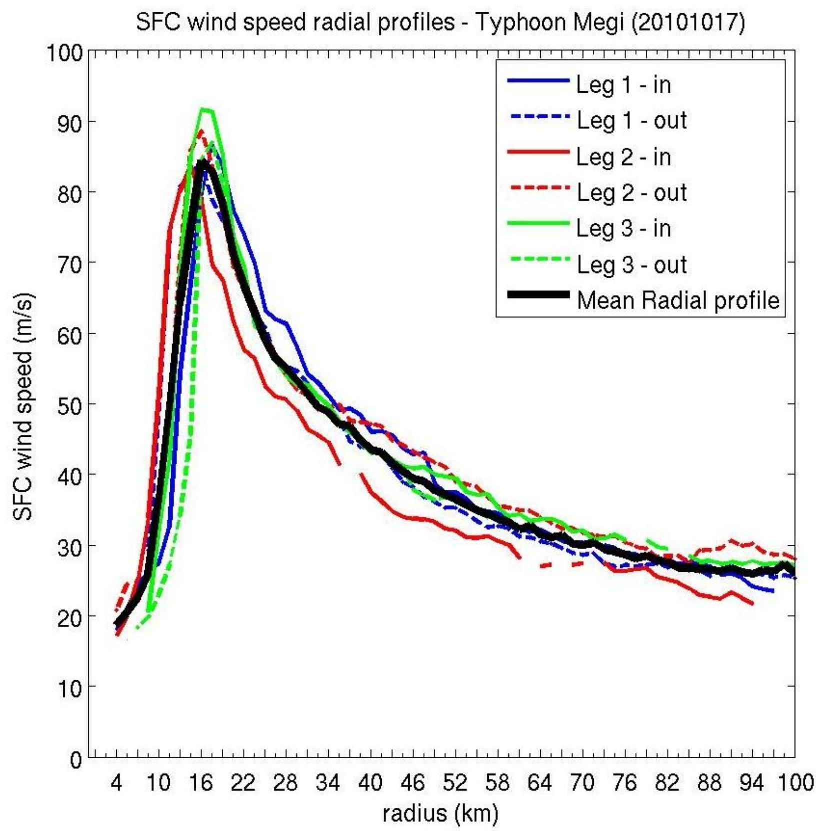

Figure 1: Radial profiles of SFMR surface wind speed from typhoon Megi are shown with inbound portions of each flight leg represented by a solid line and outbound portions of each leg represented as dashed lines. There were three legs studied for this storm and the mean radial wind speed profile is provided with the emboldened black line.

In order to verify these extreme SFMR wind speeds from Megi, the inflow trajectory equation in cylindrical coordinates is solved for velocity as a function of radius. This equation incorporates several important forces, including the Coriolis, friction, centrifugal, and pressure gradient forces. Most of the variables used to calculate these forces are included in the radial profiles. However, several variables, such as the inflow height, are not included but are necessary for solving the equation. The inflow height is determined by taking a set of strong tropical cyclones and finding the height at which the minimum residual in the radial wind is produced. Once inflow height is calculated, the friction term can be accounted for in the inflow trajectory equation. Although the velocities have not been calculated yet, it is expected that by comparing the calculated velocities to those measured with the SFMR, a better understanding of how the SFMR performs at extreme wind speeds will be obtained.

Research Performance Measure: All major research objectives are currently being met and remain on schedule.

Improving Predictability of the Atlantic Warm Pool in Ocean Model for Assistance to Operational Hurricane Forecasting

Project Personnel: S.-K. Lee, (UM/CIMAS)
NOAA Collaborator: C. Wang (NOAA/AOML)
Other Collaborator: C. Lozano (NCEP/EMC)

Long Term Research Objectives and Strategy to Achieve Theme:

***Objectives*:** To improve the forecast of the formation and intensification of Atlantic hurricanes in NCEP/EMC operational model by improving the simulations of the Atlantic warm pool (AWP) in that model during the Atlantic hurricane season of June to November.

***Strategy*:** To evaluate and improve HYCOM's predictability of the AWP and associated mesoscale ocean features for NCEP/EMC transition to operational hurricane forecast.

CIMAS Research Theme:

***Theme 2*:** Tropical Weather (*Primary*)
***Theme 4*:** Ocean Modeling (*Secondary*)

Link to NOAA Strategic Goals:

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

Funding Unit: OAR/AOML **NOAA Technical Contact:** Alan Leonardi

Research Summary:

The rationale for the current project is the recent scientific finding that including the Atlantic warm pool (AWP) — a large body of warm water comprised of the Gulf of Mexico, the Caribbean Sea, and the western tropical North Atlantic — may improve the simulation of Atlantic tropical cyclone (TC) in operational hurricane forecast models. In particular, recent studies using both observations and models have shown that a large AWP reduces the vertical wind shear and increases the convective available potential energy over the main development region for Atlantic hurricanes, and thus facilitates the formation and development of Atlantic TCs. Therefore, our ultimate goal is to improve the forecast of the formation and intensification of Atlantic hurricanes in NCEP/EMC operational model, by improving the simulations of the AWP in that model during the Atlantic hurricane season of June to November.

We have shown through our research during the JHT year-1 that HYCOM has a tendency to produce a large cold bias of up to 2degC in the AWP region. Such tendency is mostly hidden in the forced simulations because the model SST is damped toward the observations in the forced simulations. The cold AWP bias is revealed only when HYCOM is thermally coupled to the atmospheric mixed layer model (AML). This is because nonphysical thermal interaction, which may be caused by the ocean model bias in the forced HYCOM simulations, is not allowed in the thermally coupled HYCOM simulations. However, further model simulations suggest that such bias emerges very slowly. Over the AWP region, it takes about 4 ~ 5 months to develop a –1degC SST bias. Therefore, the cold AWP SST bias should not cause a serious problem in the 5-day forecast of the NCEP/EMC operational models.

Nevertheless, we find that the 5-day forecast error of the NCEP/EMC's Real Time Ocean Forecasting System for Atlantic (RTOFS-Atlantic) is as large as 2degC and usually negative. In particular, the cold SST error is largest in the deep tropics between equator and 10N, and in the southern Caribbean Sea. We suspect that the 5-day forecast error of RTOFS originates from a combination of many different sources, including the Cooper and Haines scheme, GFS weather forecast error, initialization, and 2DVAR data assimilation. It is demonstrated here that the application of a simple bias correction scheme could substantially reduce the 5-day forecast error of the RTOFS in the deep tropics and Southern Caribbean Sea (**Figure 1)**.

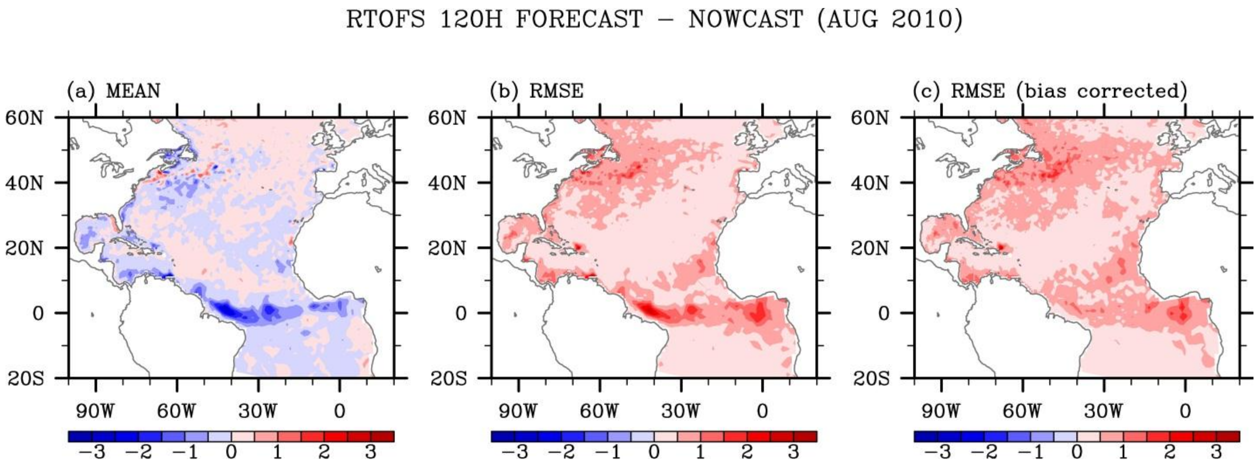

Figure 1: (a) Mean and (b) RMSE of the 5-day forecast of RTOFS along with (c) RMSE of the bias-corrected 5-day forecast during August 2010.

Research Performance Measure: We achieved our main objective: To evaluate and improve HYCOM's predictability of the AWP and associated mesoscale ocean features for NCEP/EMC transition to operational hurricane forecast.

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Microphysics of Deep Convection

Project Personnel: P. Willis (UM/CIMAS)
NOAA Collaborators: F. Marks (NOAA/AOML)
Other Collaborators: A. Heymsfield (NCAR)

Long Term Research Objectives & Strategy to Achieve Them:

Objectives**:** To improve the understanding and prediction of tropical cyclone genesis, intensity change, rainfall, water content, as well as the microphysical schemes in tropical cyclone simulations.

Strategy**:** Evaluate and compare microphysical fields from in situ data and from NOAA-WP3D's and NASA DC-8 aircraft and high resolution numerical models.

CIMAS Research Theme:
Theme 2**:** Tropical Weather

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

Funding Unit: OAR/AOML **NOAA Technical Contact:** Alan Leonardi

Research Summary:
Work continues on the study of the NAMMA cloud system (MCS) convective cloud microphysics as outlined in the 2010 report.

The work on the microphysics of deep convection has been expanded to include deep convection in hurricanes and pre-depression tropical cloud systems. As part of this planned expansion I participated in the NSF PREDICT and NASA GRIP field programs in the fall of 2010.

In PREDICT the NCAR G-5 aircraft flew a new state of the art microphysical instrument and collected microphysical data in the upper very cold temperature regions of tropical convective clouds. Presently, these data have not been reduced and made available to researchers. We will explore these data as soon as they become available. In the NASA GRIP project the DC-8 aircraft sampled the microphysics of high cold levels in hurricanes EARL and CARL. These microphysical and dynamical data which just recently became available are being analyzed in detail. In addition, the JPL APR-2 dual wavelength radar data, which were used in the NAMMA study, are also available for the GRIP DC-8 flights. We are starting to examine this radar data in conjunction with the microphysical measurements on selected DC-8 flights.

An example of a preliminary analysis of the DC-8 hurricane Earl data is presented in the following figures. Data are shown from a transect through the eye of Earl when it was a major hurricane at about 31.5N on 2 Sep 10. **Figure 1** displays a temperature trace across the eye-wall and eye at 10 km altitude. This temperature trace shows a temperature difference of 12 deg. C between the warmest temperature measured in the eye and that outside the eye. **Figure 2** shows the 5 s ice water content summed from the CIP and PIP image data (D> 50 um) on the same section of the transect as Figure 1. Peak 5s ice water contents are in the range of 1-1.5 g/m3.

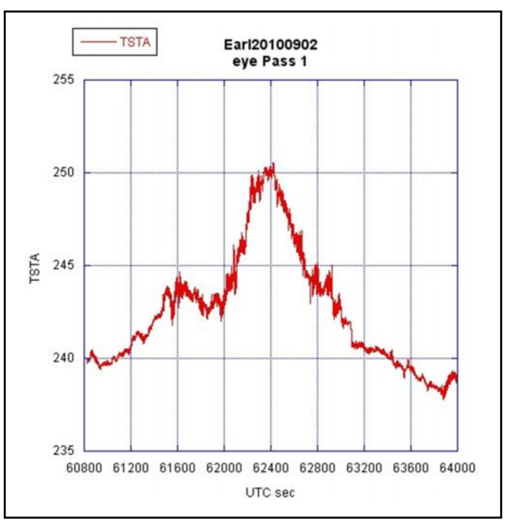


Figure 1: Temperature Profile for hurricane EARL – 02 Sep 2010 at 10.5 km.

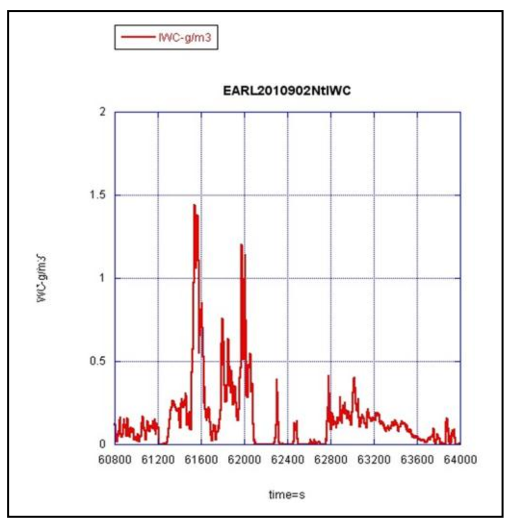


Figure 2: Ice Water content for time of Fig. 1 – calculated using CIP & PIP.

In the following figures data from a 150 s (~36 km) section of this transect are presented in some detail. **Figure 3** is the vertical air velocity in the west eye-wall on this pass from west to east. The peak updrafts are a rather modest 6-7 m/s, and the 5s hydrometeor ice water contents in the matching section are 1.4 g/m3 (**Figure 4**), but >0.5 g/m3 over a distance of ~25 km. Assuming the orthogonal dimension is similar, this is a significant volume of water mass at 10 km in this portion of the eye-wall.

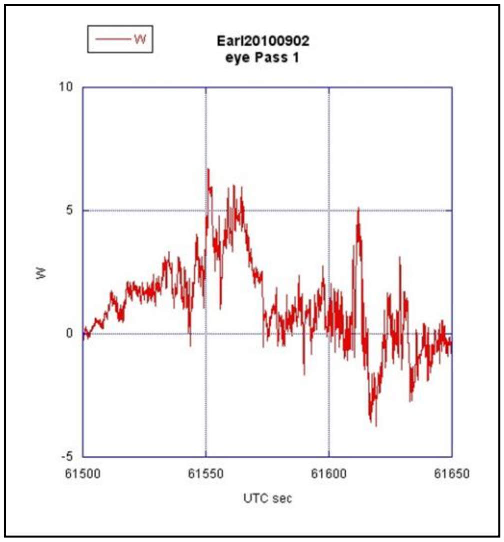


Figure 3: 150 s (36 km) section of west eye-wall -Vertical Air Velocity m/s.

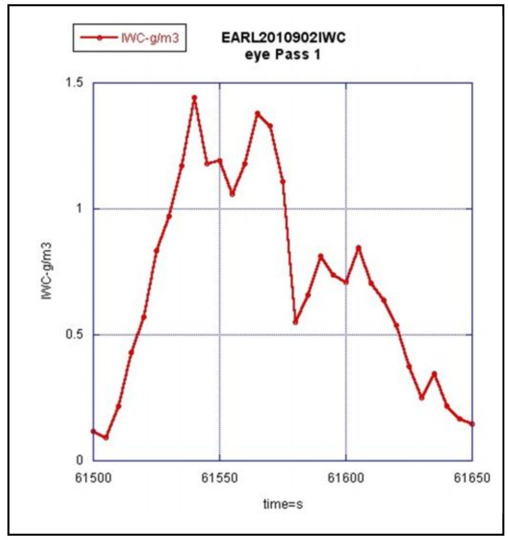


Figure 4: Ice Water Content as Fig. 2 for same time as Fig. 3.

In **Figure 5** three hydrometeor size distributions measured in the two ice water content peaks of Figure 4 are shown. These three distributions are roughly exponential from D=1 mm to an inflection point at about D=5 mm, then the slope flattens somewhat out to a dimension of about 1 cm.

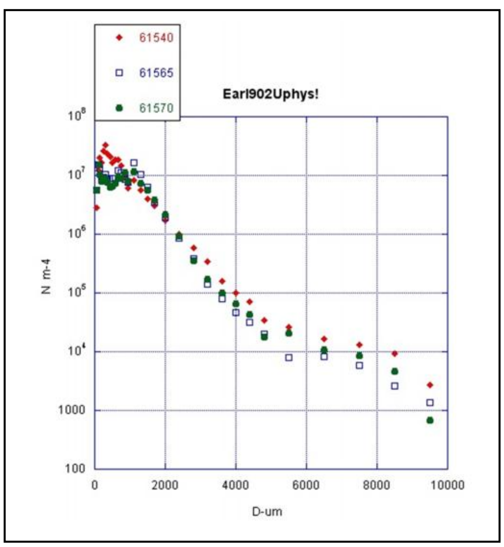


Figure 5: Hydrometeor Size Distributions in two IWC peaks in Fig. 4.

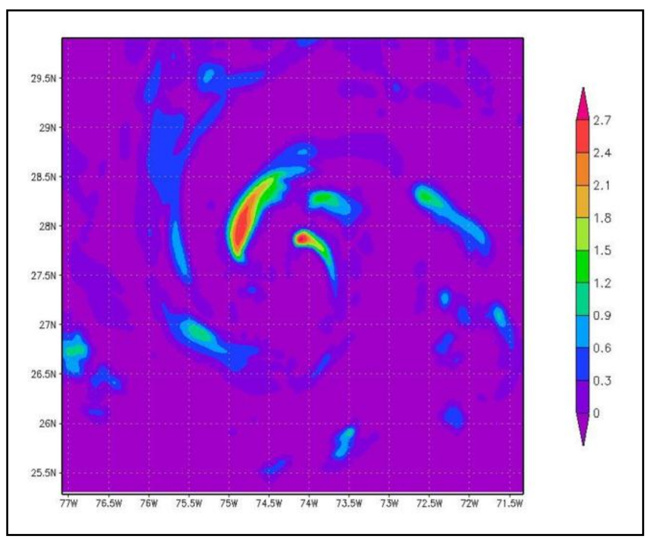
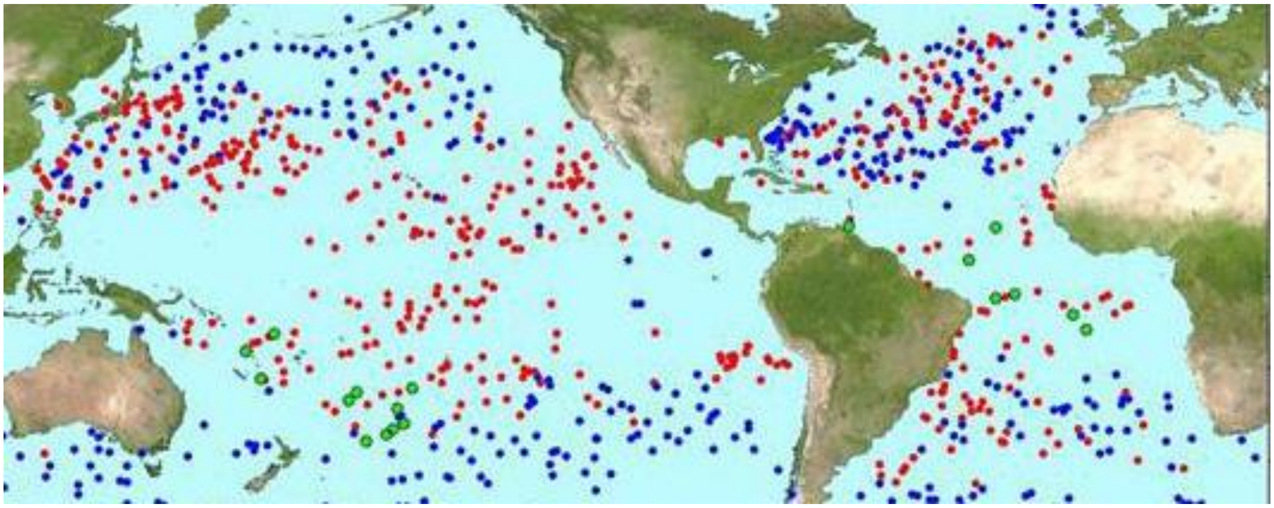


Figure 6: Snow (large ice) water content at 10.5 km - HWRFx simulation of hurricane EARL.

These figures are presented as illustrative of typical characteristics of numerous transects through the eye at these high cold cloud altitudes.

A large part of the strategy of this project is to compare observed microphysics to numerical model microphysics. Work is just starting on comparing observed microphysics (difficult measurements and sampling) to the evolution of parameterized microphysics in numerical simulations of hurricanes. **Figure 6** illustrates a field of snow ice (large ice) water content at 10.5 km from an HWRFx 3 km resolution simulation of hurricane Earl. It is planned to increase the scope of these comparisons using the context provided by the JPL APR-2 radar data from the GIP DC-8 flights in a collaborative effort with JPL and NCAR.

Research Performance Measure: All research objectives are being met.



RESEARCH REPORTS

THEME 3: Sustained Ocean and Coastal Observations

Western Boundary Time Series Project

Project Personnel: R. Garcia, G. Berberian, Q. Yao, G. Rawson, N. Melo, K. Seaton, R. Roddy, and E. Valdes (UM/CIMAS)
NOAA Collaborators: M. Baringer, C. Meinen and S. Garzoli (NOAA/AOML)

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

CIMAS Research Theme:
***Theme 3*:** Sustained Ocean and Coastal Observations (*Primary*)
***Theme 1*:** Climate Research and Impacts (*Secondary*)
***Theme 4*:** Ocean Modeling (*Tertiary*)

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

Funding Unit: OAR/AOML **NOAA Technical Contact:** Alan Leonardi

Research Summary:
Variations in the transport of the Meridional Overturning Cell (MOC) in the Atlantic Ocean have been shown in numerical climate models to have significant impacts on the climate at both the

international and local levels. Near 27˚N in the Atlantic the warm upper-limb of the MOC is principally carried by the Florida Current between the eastern Florida coast and the Bahamas, although the Antilles Current east of the Bahamas also carries some of the warm northward flow. The southward deep flow of the MOC is contained primarily within the Deep Western Boundary Current east of Abaco Island in the Bahamas, although some fraction is also thought to transit near the Mid Atlantic Ridge. Long-term observations of the Florida Current, Antilles Current and Deep Western Boundary Current are required in order to quantify the natural time scales of variability for these currents.

This project maintains NOAA's well-established and climatically significant Florida Current volume transport time series. Over 25 years of daily mean voltage-derived transports have been obtained for the Florida Current using out-of-use and in-use telephone cables spanning the Straits of Florida. The cable voltages are converted to physically meaningful volume transport estimates, i.e. intensity of the flow, using electromagnetic induction theory and data from calibration sections on research vessels. This project also maintains repeated hydrographic sampling east of Abaco Island that has established a high-temporal-resolution record of water mass properties in the Deep Western Boundary Current near 27ºN. Events such as the intense convection period in the Labrador Sea and the renewal of classical Labrador Sea Water in the 1980s are clearly reflected in the cooling and freshening of the Deep Western Boundary Current waters off Abaco, and the arrival of a strong pulse of Labrador Sea Water approximately 10 years later.

During the past year, 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.

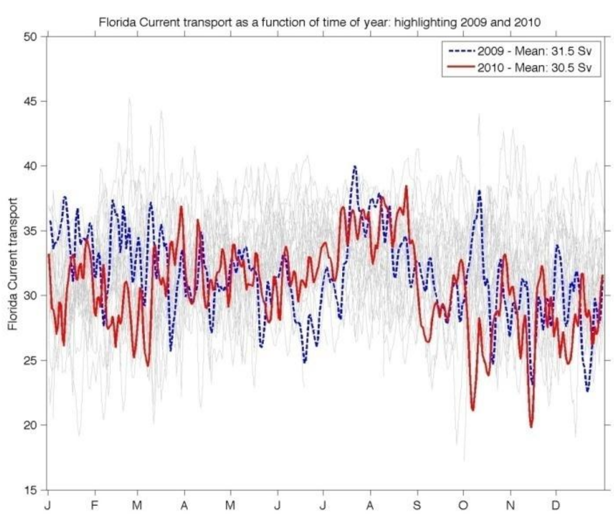


Figure 1: Florida Current transport as a function of time of year: highlighting 2009 and 2010.

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.

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South Atlantic Meridional Overturning Circulation ("SAM") Project

Project Personnel: R. Garcia, R. Perez (UM/CIMAS)
NOAA Collaborators: C. Meinen, S. Garzoli, M. Baringer and G. Goni (NOAA/AOML)

Long Term Research Objectives and Strategy to Achieve Theme:
Objectives**:** To initiate a sustained time series measurement system for the western boundary components of the meridional overturning circulation at 34.5°S.
Strategy**:** To use moored instruments and hydrographic observations collected in partnership with international collaborators to study the Brazil Current and the Deep Western Boundary Current systems.

CIMAS Research Theme:
Theme 3**:** Sustained Ocean and Coastal Observations (*Primary*)
Theme 1**:** Climate Research and Impacts (*Secondary*)
Theme 4**:** Ocean Modeling (*Tertiary)*

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

Funding Unit: OAR/AOML **NOAA Technical Contact:** Alan Leonardi

Research Summary:
Studies using numerical climate models have suggested that variations in the transport of the Meridional Overturning Cell (MOC) are correlated with significant changes in surface air temperatures and precipitation both regionally and globally. NOAA has maintained a crucial long-term array measuring the western boundary components of the MOC in the Atlantic near 27˚N since 1982; the SAM project represents an effort to start a similar program in the South Atlantic near 34.5°S. Observations and modeling studies have indicated that water mass transformations occurring in the South Atlantic alter the waters circulating in the global MOC resulting in changes to the global circulation system. The SAM project represents a collaborative effort with partners in France, Argentina, Brazil, and South Africa to begin to monitor the MOC-related flows in the South Atlantic to improve our understanding of the key processes occurring in the South Atlantic Ocean. Specifically the NOAA component of this international effort is focused on the western boundary currents, specifically the Brazil Current in the upper layer and the Deep Western Boundary Current (DWBC) at depth. The DWBC is of particular importance because it is difficult to observe, it is poorly known at this location, and yet it is believed to carry a significant percentage of the lower limb of the MOC. Long-term observations of these key flows will be required to understand the mechanisms leading to changes in the MOC system in the South Atlantic.

This project began in March 2009 with the deployment of four moored instruments near the western boundary at 34.5°S. Collaborators from France have a pair of moored instruments deployed along the same line of latitude off the western coast of South Africa, providing an initial effort at observing the western and eastern boundary flows. Ultimately the goal of the NOAA SAM program and the international collaborating programs is to expand to develop a truly trans-basin measuring array from South America to Africa along 34.5°S.

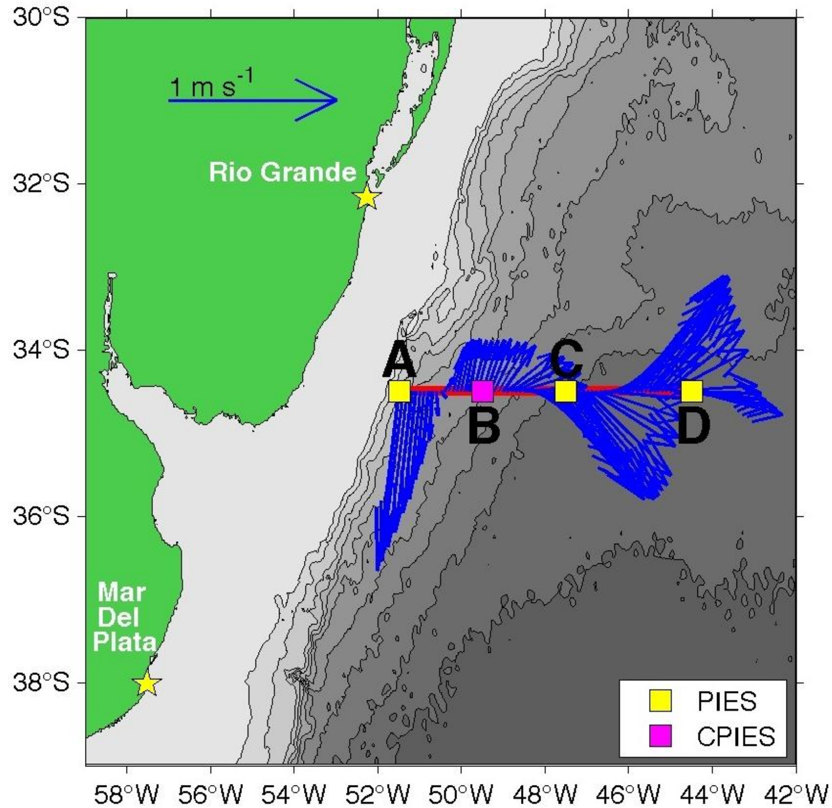

Figure 1: Map indicating the location of the four PIES/CPIES making up the SAM array. Blue vectors indicate the water velocity at 21 meters measured via shipboard acoustic Doppler current profiler on the Brazilian naval research vessel Cruzeiro do Sul in March 2009 during the array deployment cruise. Black letters indicate site names – instrument types are noted in legend.

The SAM project is in its initial stages, with the moored instruments (three pressure-equipped inverted echo sounders, PIES, and one current-and-pressure-equipped inverted echo sounder, CPIES) being deployed in March 2009 on a collaborative cruise with the Brazilian Naval Hydrographic Service. Research cruises to acoustically download data from the PIES & CPIES have been completed in August 2009, July 2010, and December 2010 during cruises jointly sponsored by NOAA and the Argentine Naval Hydrographic Service. The next cruise is scheduled for July 2011. Data collection from three of the instruments has been quite successful, however one instrument has been communicating poorly and this has hindered the detailed analysis of the data somewhat. The problematic instrument is scheduled to be replaced during the July 2011 cruise.

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

Surface Water pCO_2 Measurements from Ships

Project Personnel: K. Sullivan, D. Pierrot, F. Bringas, G.-H. Park and L. Barbero (UM/CIMAS); F.J. Millero (UM/RSMAS)
NOAA Collaborators: G. Goni and R. Wanninkhof (NOAA/AOML)
Other Collaborators: J. Trinanes (Universidad de Santiago de Compostela)

Long Term Research Objectives and Strategy to Achieve Them:
***Objectives*:** Constrain regional air-sea CO_2 fluxes to 0.2 Pg C/yr.
***Strategy*:** Sustained observations using automated pCO_2 systems on ships of opportunity.

CIMAS Research Theme:
***Theme 3*:** Sustained Ocean and Coastal Observations

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

Funding Unit: OAR/AOML **NOAA Technical Contact:** Alan Leonardi

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. It is the largest program in the world (See **Figure 1**). 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-1a the NOAA funded participants maintained instrumentation and reduced data from twelve ships and posted the data. Flux maps, based on extrapolation routines using remotely sensed wind and sea surface temperature (SST) have been created to estimate global seasonal air-sea (Park et al. 2010 a, b).

An increasing emphasis is put on observations in marginal seas as the fluxes in these regions are very poorly constrained. To address this, new generation pCO_2 systems were installed on the methanol carrier LAS CUEVAS and container ship BARCELONA EXPRESS, the cargo ship REYKJAFOSS and NOAA fisheries ship BIGELOW. They are currently making measurements in the Atlantic Ocean, Caribbean Sea, and Gulf of Mexico.

An appreciable focus continues to be global coordination of similar efforts. We have taken the lead in providing uniform autonomous instrumentation for installation on ships of opportunity (SOOP). Through a successful technology transfer and continued guidance, General Oceanics 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 summer of 2011. Our NOAA funded effort is the single largest contributor of data to SOCAT

As part of the effort, improvements in auxiliary data such as sea surface temperature (SST) and sea surface salinity (SSS) from thermosalinographs (TSG) have been made. Currently as part of this project, the NOAA ships BROWN and GUNTER, and the container SHIP BARCELONA EXPRESS are transmitting TSG data. The NOAA ship BROWN, BIGELOW and EXPLORER of the SEAS also sends complete daily files of pCO_2 to shore via internet.

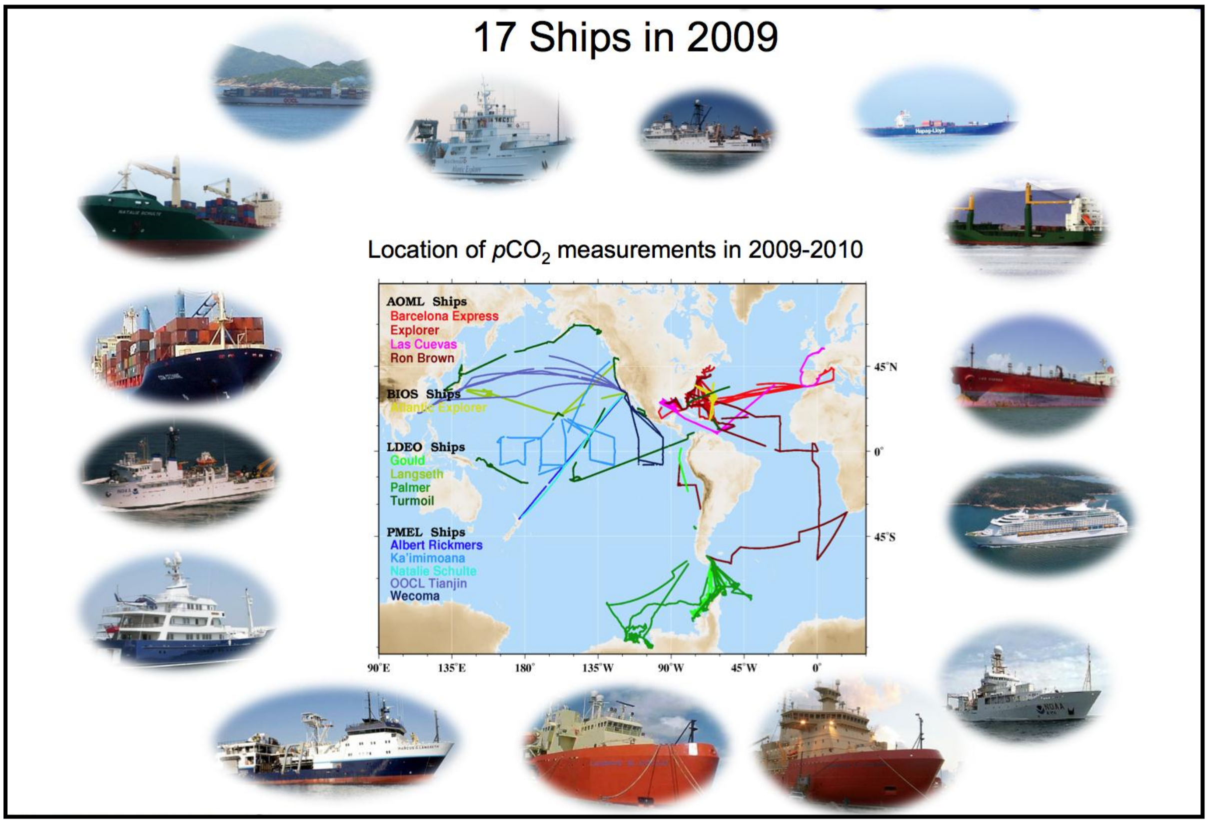

Figure 1: The cruise lines for surface pCO_2 measurements and pictures of the ships of opportunity used in the effort.

Research Performance Measure: Create flux maps of the Global oceans. Assess seasonal variability of air-sea CO_2 fluxes.

The CLIVAR CO_2 Repeat Hydrography Program

Project Personnel: K. Sullivan, G. Berberian, G.-H. Park and L. Barbero (UM/CIMAS); C. Langdon (UM/RSMAS)
NOAA Collaborators: R. Wanninkhof (NOAA/AOML)

Long Term Research Objectives and Strategy to Achieve Them:
***Objective*:** To determine decadal changes in ocean interior and to constrain ocean CO_2 inventories to 2 Pg C/ decade.
***Strategy*:** To reoccupy transects on a decadal timescale to quantify the uptake of anthropogenic CO_2 by the ocean.

CIMAS Research Theme:
***Theme 3*:** Sustained Ocean and Coastal Observations

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

Funding Unit: OAR/AOML **NOAA Technical Contact** Alan Leonardi

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-2011 we completed occupation of a zonal line in the Southern Ocean between McMurdo Station, Antarctica and Punta Arenas, Chile (S-4P) with full physical and chemical characterization of 140 water column profiles. Kevin Sullivan and Nancy Williams (JISAO) were responsible for the Total Inorganic measurements on the 60-day cruise, quality control and data reduction.

A recent focus has been on the changes in carbon in the deepocean and attribution of changes. Geun-Ha Park is a co-investigator in looking at changes in the deep ocean based on observations and from models using the NCAR SCEM-1 model in collaboration with WHOI scientists Lima and Doney and PMEL scientist Bullister. **Figure 1** shows an estimate of anthropogenic carbon inventory at depths greater than 2000 m based on the GLODAP dataset (figure courtesy of N. Gruber ETH Zurich). Our novel preliminary analysis shows appreciably greater changes in the deep ocean.

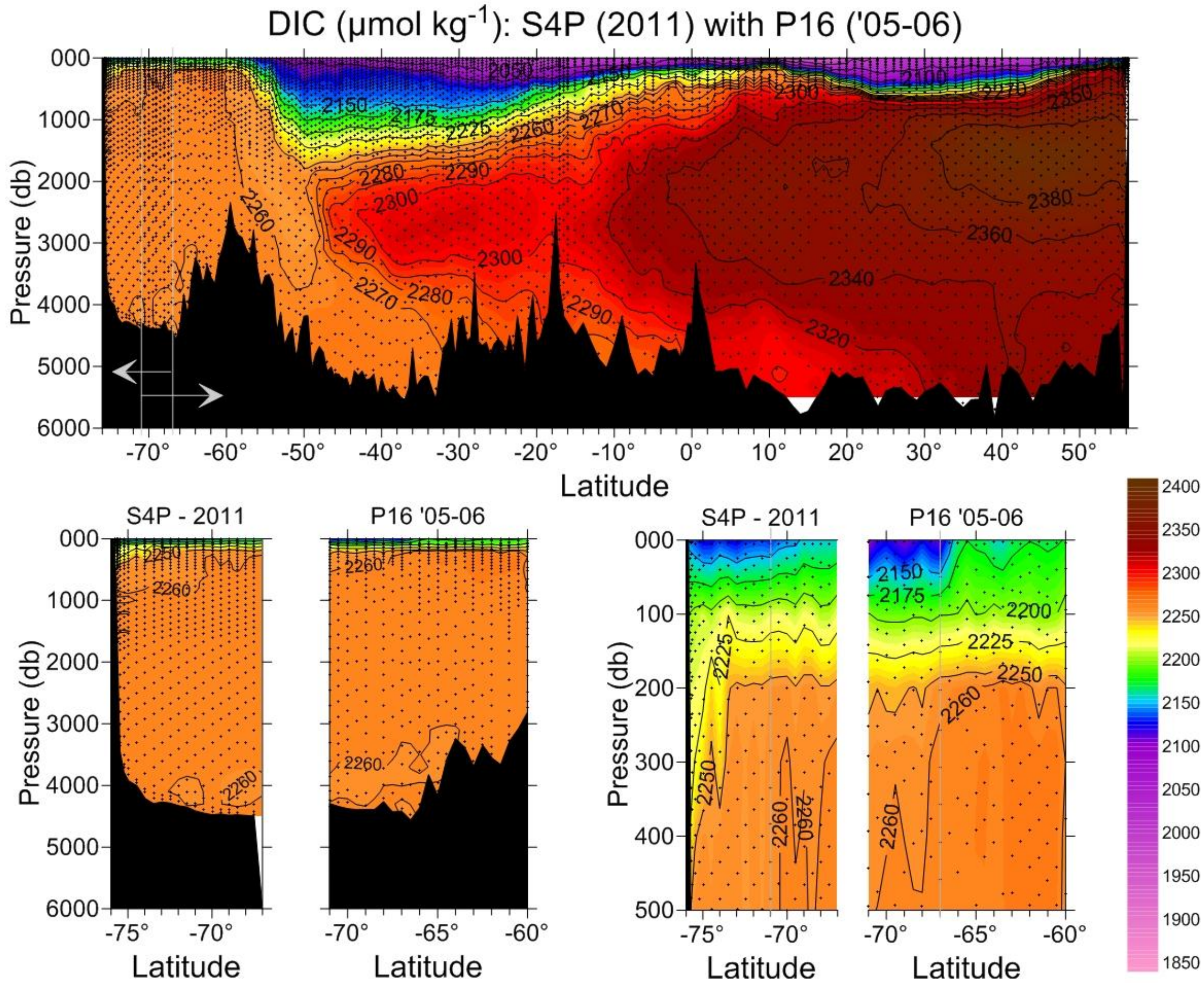

Figure 1: Cross section of dissolved inorganic carbon from cruise S4P in 2011 and P16 in 2006. The 2011 data was obtained by Kevin Sullivan (CIMAS) and Nancy Williams (JISAO).

Research Performance Measure: The Repeat Hydrography Sections is progressing according to timeline of the CLIVAR CO_2 Repeat Hydrography Committee (http://ushydro.ucsd.edu/cruises). Our performance measure has been augmented in that we are actively interacting with modelers at Princeton, GFDL and WHOI to compare our observed decadal changes with model trends.

Global Drifter Program

Project Personnel: S. Dolk and E. Valdes (UM/CIMAS)
NOAA Collaborators: R. Lumpkin and M. Pazos (NOAA/AOML)

Long Term Research Objectives and Strategy to Achieve Them:

Objectives**:** To maintain a global 5x5 degree array of 1250 satellite-tracked surface drifting buoys to meet the need for an accurate and globally dense set of in-situ observations of mixed layer currents, sea surface temperature (SST), atmospheric pressure, winds and salinity; to provide, archive, and disseminate a uniform quality-controlled data set of SST and surface velocity.

Strategy**:** To produce an annual plan for the global distribution and deployment of 1000-1050 drifters through interaction with international partners; to coordinate drifter objectives with NOAA field personnel, contractors, shipping companies and various ship personnel; to verify deployment status and update the Drifter Database and to monitor on a daily basis systems status.

CIMAS Research Theme:

Theme 3**:** Sustained Ocean and Coastal Observations

Link to NOAA Strategic Goals:

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

Funding Unit: OAR/AOML **NOAA Technical Contact:** Alan Leonardi

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 program.

- *Drifter Operations Center (DOC)* whose task is 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.

- *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 salinity drifters to validate and calibrate satellite-based observations - while its qualitative characteristics and water-following properties have remained relatively stable since the earliest deployments. 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.

The major challenge facing AOML's DOC, which coordinates drifter deployments, is to arrange deployments in regions of surface divergence and areas infrequently visited by research or voluntary observation vessels. This logistical challenge is being addressed by increased international cooperation, and the development of tools to predict global drifter array coverage based on its present distribution and historical advection/dispersion. As the array grows, it provides invaluable observations of ocean dynamics, meteorological conditions and climate variations, and offers a platform to test experimental sensors measuring parameters such as rain rates, biochemical concentrations, and air-sea fluxes throughout the world's oceans.

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

A major activity as an added task under this program is titled "Evaluating the Ocean Observing System: Surface Currents, an Add-task to the Surface Drifter Program" (Pedro DiNezio, CIMAS; Rick Lumpkin and Gustavo Goni, NOAA/AOML). In this study, the status of the observing system for surface currents obtained from quality-controlled, drogued Lagrangian drifter observations is derived. Sea height anomaly data are used to match with those from the drifters to evaluate the correlation between along-track sea height anomaly gradients and across-track drifter-derived geostrophic velocity anomalies. Global fields of correlations and eddy kinetic energy are computed and differences between estimates from both observations are evaluated. High correlations indicate where altimetry observations can be calibrated by the in-situ measurements to provide a good proxy for surface currents. On the other hand, low correlations may indicate where errors in the winds or Ekman model are problematic, where ageostrophic ocean dynamics are contributing significantly to the surface momentum budget, where the signal-to-noise ratio is low, or where there are depth-compensating effects in the upper layer causing the sea height to have low variability.

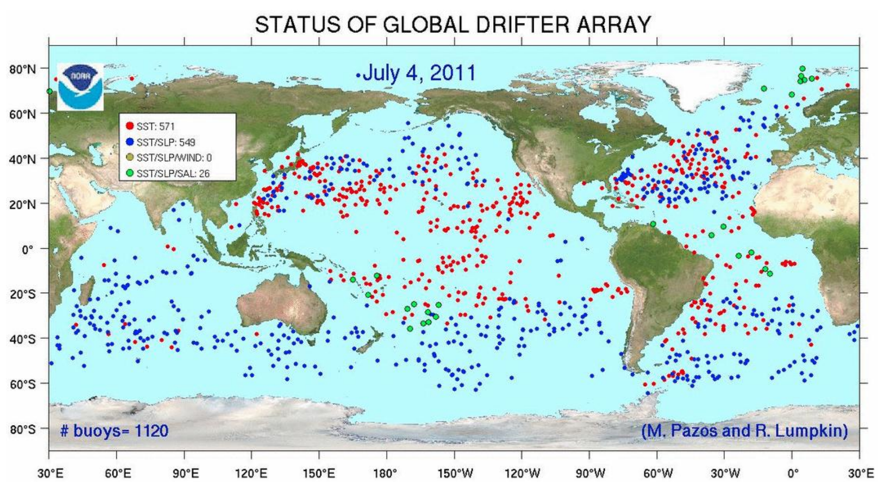

Figure 1: Status of the Global Drifter Array (updated weekly).

Research Performance Measure: All goals were met in that the array was maintained and timely quality-controlled data made available to the research and operational communities.

Development of the Next Generation Ships-of-Opportunity

Project Personnel: P.B. Ortner (UM/CIMAS); E. Williams, P. Minnet and L. Beal (UM/RSMAS/MPO), R. Findley (UM/RSMAS/MarOps)
NOAA Collaborators: R. Wanninkof and S. Cummings (NOAA/AOML)
Other Collaborators: A. Solokiev (NSU)

Long Term Research Objectives and Strategy to Achieve Theme:
***Objectives*:** To develop a full autonomous oceanographic and meteorological sampling system that can be installed on commercial vessels, deliver data stream automatically and be serviced no more frequently than every three months.
***Strategy*:** To modify the system aboard the Explorer of the Seas for fully autonomous operation and to use that system as the basis for a simpler replicable modular design to be first tested aboard additional cruise ships then used in the pilot phase of the global OceanScope sampling fleet.

CIMAS Research Theme:
***Theme 3*:** Sustained Ocean and Coastal Observations (*Primary*)
***Theme 1*:** Climate Research and Impact (*Secondary*)

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

Funding Unit: RCCL Ocean Fund **Technical Contact:** Alan Leonardi

Research Summary:
This project is the continuation of a decade long multi-institutional public-private partnership lead by UM and AOML and sponsored by the Royal Caribbean Cruise Lines. Current status is as follows:

The Explorer of the Seas automation is complete:
Most data are delivered hourly through the established always on connection from the *Explorer of the Seas* to RSMAS. Larger data sets are delivered via a wireless radio modem linked to a broadband connection while the ship is docked at Cape Liberty Cruise Port. These data include: 1) the *Explorer* legacy core surface seawater measurements; 2) the meteorological measurements from the bridge, and UM instruments on the mast; 3) the Acoustic Doppler Current Profiler (ADCP) data from the transducers mounted amidships; 4) data collected for three ancillary projects funded separately. This last group includes marine carbon dioxide (pCO2 - NOAA/AOML), ocean surface temperature skin (M-AERI - UM/RSMAS) and the vessel wake modeling project (NSU).

All data are made freely available and have been widely requested and used by investigators and students at Scripps Insitution of Oceanography, Woods Hole Oceanographic Institution, State University of New York, and University of Rhode Island Graduate School of Oceanography, to name a few. We also have had requests for the real-time data and access to the archived database (2000-2007), from commercial users such as Roffer's Ocean Fishing Forecast Service and Shell Oil Company. The first quarterly servicing and maintenance visit is scheduled for July. The data transfer mechanisms developed with cooperation and help from the RCI IT department can and will be used for all future installations.

A significant achievement of this program is that the broadband satellite link access provided by RCI allows scientists to communicate directly with their instrumentation and computers. This allows a level of automation and control never before possible for unmanned instruments installed on a vessel.

With respect to subsequent ships:
We have selected *Allure of the Seas* (**see Figure 1**) for the second vessel and have made three visits to her to meet with engineering personnel. It will be easiest to go with new technology aboard a vessel docking nearby during the installation period and this will permit us to continue to sample regions comparable to the historical *Explorer* data set A draft design was reviewed by the engineers onboard, and a space identified which met our requirements. The marine superintendant for the Oasis Class was also included in the discussions. The only concern is access to a clean external air supply required for the oceanic carbon dioxide project. Tests will be conducted this summer to determine how clean is the readily available air supply and if that is insufficient is there a reasonable alternative. The draft design is in the process of being converted to construction drawings. As soon as 2011 funds are received components will be ordered and construction will begin upon a modular core system to be completely assembled and tested ashore. New systems will be compact, entirely modular and installable (or removable) in a matter of days. The basic requirements from the ship will include seawater access, potable fresh water access, power and a ship's network connection. We anticipate installing aboard *Allure* in early fall 2011, followed by field testing and then fully automated operations by the end of 2011.

Figure 1: The next cruise ship to be instrumented, Allure-of-the-Seas, the largest cruise ship afloat.

The modular core system, composed of sensors for surface seawater measurements and meteorological measurements, will be "open", and will allow the integration of any scientific instrumentation which can deliver and accept data via a computer network. Based on current plans for *Explorer* route change next summer, we anticipate that that the M-AERI and pCO2 teams will likely wish to continue their measurements in the Caribbean and will transfer their instruments from the *Explorer* to the *Allure.*

The third system will be ready for installation before the summer of 2012 as originally scheduled, however we have not selected the vessel. We were just informed that we can consider not only Royal Caribbean but also Celebrity ships and have not had an opportunity to evaluate the routes and home ports for their scientific value and logistical ease. From an OceanScope perspective (see below) some transatlantic passages would be highly desirable (also to the M-AERI group) and other relevant factors include ease of installation and the ship layout with respect to ease of expansion beyond the core system. Specifically including a current profiler (ADCP) and automated probe launchers would be a significant scientific achievement from the OceanScope perspective. We have been contacted by FerryBox operators at NOC/Southampton who are interested in adding to our core instrumentation in exchange for providing field service technicians if that is logistically sensible.

We are also testing a cost effective method of maintaining and repairing the automated instruments in between scheduled at sea maintenance visits will be piloted tested this year. Travel costs for technician visits for simple repairs or maintenance that require a presence on board for a day or less could become prohibitively expensive with installations on multiple vessels in more remote home ports. This year we have used a portion of the Ocean Funds to train and hire a part-time marine technician from UVI (a CIMAS Partner University).

OceanScope Update:
The draft report has been delivered to SCOR and IAPSO and has been thoroughly reviewed. Presentations were made at a series of scientific meetings concerning OceanScope and the final report is being completed over the summer of 2011. For updates and progress see the project website: http://www.scor-int.org/Working_Groups/wg133.htm.

Research Performance Measure: We are on schedule in all respects in accordance with the three-year timetable in the proposal accepted last year and are now nearly four months into Year Two.

Florida Area Coastal Environment (FACE) Program

Project Personnel: N. Amornthammarong, C. Brown, M. Gidley, L. Visser and D. Wanless (UM/CIMAS)

NOAA Collaborators: J. Bishop, T. Carsey, J. Craynock, C. Featherstone, C. Sinigalliano and J. Stamates (NOAA/SEFSC); H. Casanova, R. Kotkowski (NOAA Corps)

Long Term Research Objectives and Strategy to Achieve Them:

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

***Strategy*:** To perform extensive water quality monitoring and deliberate tracer experiments in the area of interest.

CIMAS Research Theme:

***Theme 3*:** Sustained Ocean and Coastal Observations

Link to NOAA Strategic Goals:

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

Funding Unit: OAR/AOML **NOAA Technical Contact:** Alan Leonardi

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, acoustic remote sensing of plumes, and microbiological measurements. This year, monthly water quality measurement cruises were operational off of Broward County, including the vicinities of Hollywood and Broward outfalls, and the Port Everglades and Hillsboro Inlets. Some typical results are shown in **Figure 1**, which shows contour plots of some significant analytes measured from surface and bottom samples. When completed, these data will indicate the distribution of a number of analytes across depth and across time (when a sequence of monthly data are compared).

In addition, we are proceeding with flux measurements from the Port Everglades inlet. A side-looking ADCP has provided more than two years of calibrated flow data from the inlet. A complicated two-layer flow pattern was detected (**Figure 2**). Flow data will be employed along with water sample chemical analysis results to determine the flux of significant nutrients from the inlet. The station is a part of NOAA's Integrated Coral Observing Network (ICON) and is a NOAA buoy (Station PVGF1).

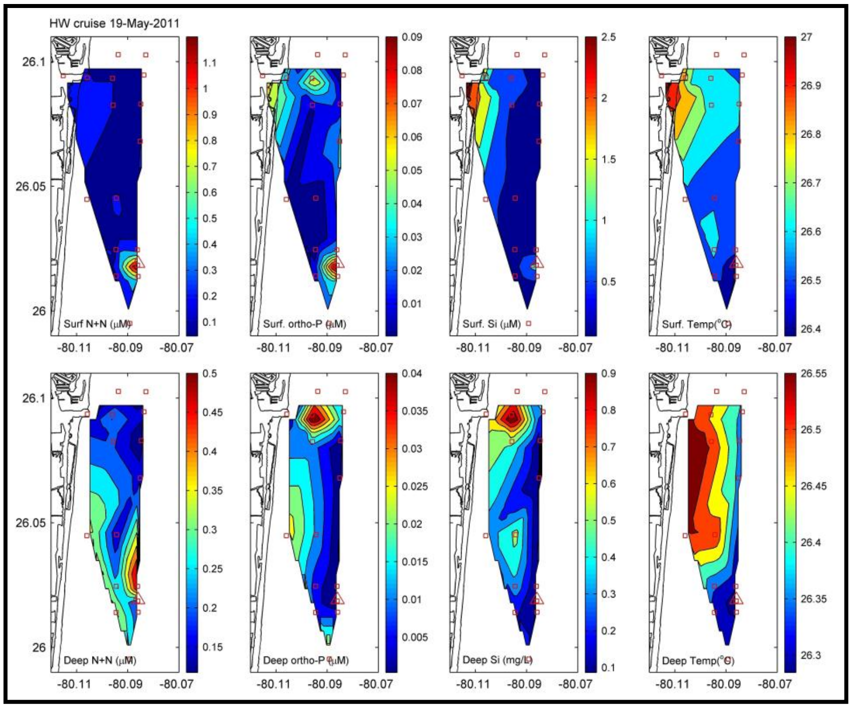

Figure 1: Contour plots of various chemical and physical water quality parameters from locations near the Hollywood outfall and Port Everglades inlet, from the May 2011 cruise. Top row profiles are from the surface samples, bottom row profiles are from the deep water samples. Locations are denoted by red squares; outfall locations are denoted by a red triangle. Note increased concentrations near inlets and outfalls.

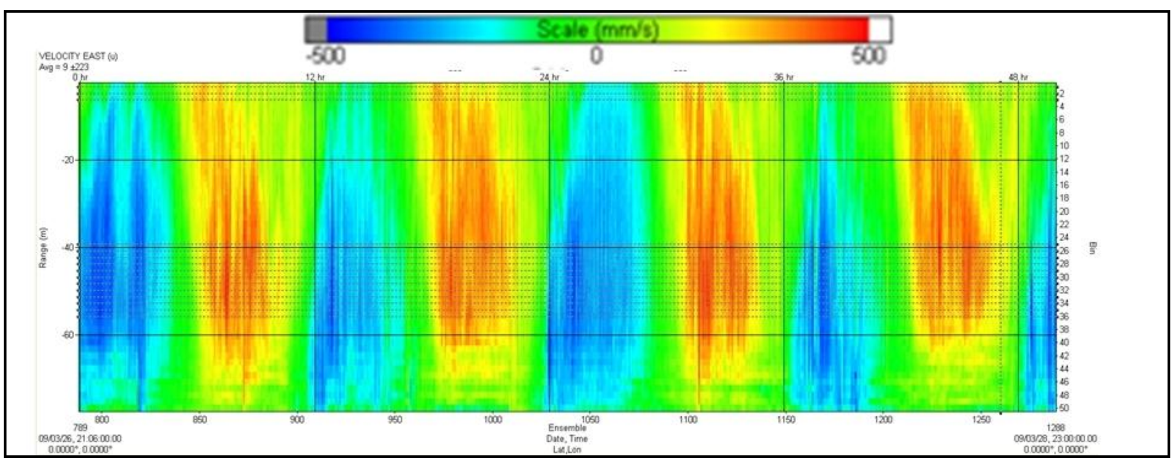

Figure 2: Flow through the Port Everglades inlet during spring tide. Inbound (flood) tide flow is negative (blue), outbound (ebb) tide is positive (red). It is possible to have surface flowing outward at the same time that the deeper flow is flowing inland.

Research Performance Measure: Instrumentation at Port Everglades completes a second year of operation. The R/V Hildebrand has been employed in a one-year sequence of monthly water sampling cruises off of Broward County. More details can be found at (http://www.aoml.noaa.gov/themes/CoastalRegional/projects/FACE/WQ-Survey.htm).

Developing the Operational Calibration/Validation Components for VIIRS SST Retrievals

Project Personnel: R. Evans and P. Minnett (UM/RSMAS)

Long Term Research Objectives & Strategy to Achieve Them:
***Objectives*:** To provide consistent, accurate SST fields derived from VIIRS infrared observations.
***Strategy*:** To incorporate VIIRS data and SST retrievals algorithms in the SEADAS processing framework currently supporting AVHRR and MODIS, acquire radiometric in situ observation to validate VIIRS SST retrievals.

CIMAS Research Theme:
***Theme 3*:** Sustained Ocean and Coastal Observations

Link to NOAA Strategic Goals:
***Goal 1*:** Understand Climate Variability and Change to Enhance Society's Ability to Plan and Respond – Goal 5: Mission Support

Funding Unit: NESDIS/DNIP **NOAA Technical Contact:** Heather Kilcoyne

Research Summary:
The VIIRS sensor will be first launched on the NPP satellite in Fall, 2011. Our activities are focused on providing at launch SST retrieval algorithms and associated coefficients based on radiative transfer (RT) code simulations and MODIS-in situ matchups transformed to VIIRS band-pass specifications. Following launch, radiometric measurements of in situ SST will be used to validate VIIRS retrievals. Initial implementation of the VIIRS retrieval codes has been tested using MODIS observations and RT simulations. Initial post launch SST retrieval coefficients will be estimated using the NOAA Optimal Interpolation global SST fields derived from in situ, AVHRR infrared and AMSR microwave retrievals. Validation will be based on the in situ radiometric skin temperature measured by the M-AERI infrared interferometer.

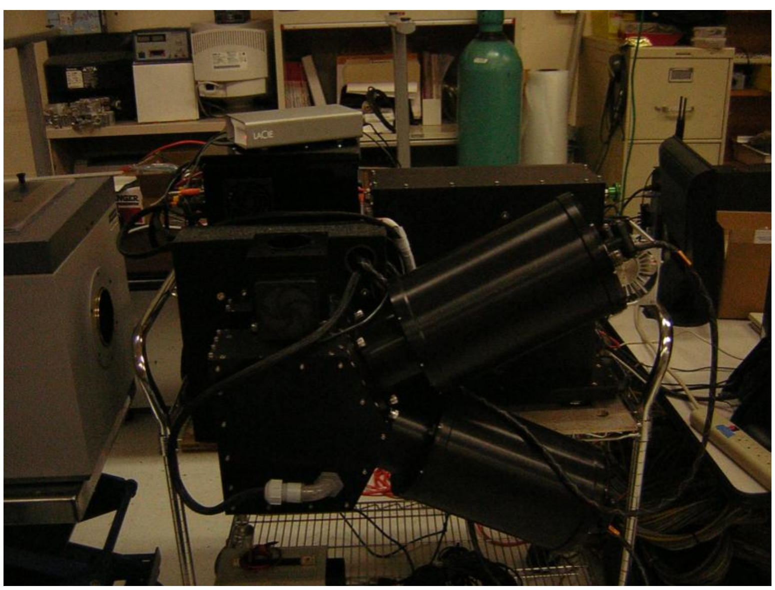

Figure 1: M-AERI infrared interferometer, black instrument in center of picture, being calibrated against a NIST traceable temperature source, grey box to the left. The M-AERI is the primary at-sea instruments to measure the skin temperature of the ocean and measures both the up-welling ocean and down-welling atmospheric radiance spectrum. Several on these instruments will be deployed as part of the VIIRS validation program.

Research Performance Measure: Delivery of the initial VIIRS algorithms has been completed. The VIIRS SST calibration and validation processing will be undertaken using the SeaDAS code base that has been evolved to include VIIRS SST and to extract satellite-in situ matchups of contemporaneous and co-located in situ, satellite observation pairs.

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Pelagic Fisheries Logbook Program

Project Personnel: K. Erickson (UM/CIMAS)
NOAA Collaborators: D. Gloeckner 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. Answer requests from fishermen and dealers, providing information on the completion of logbook forms, retrieving vessel permit information and updating delinquent vessels' data and permit renewal information. Educate myself on Statistical Analysis Software (SAS) and when time permits to facilitate data requests, assist colleagues in other divisions, and begin working toward stock assessment analysis. Provide Access database management support for Dr. Miller's team. Participate in coral reef field work when time permits.

CIMAS Research Theme:

***Theme 3*:** Sustained Ocean and Coastal Observations (*Primary*)
***Theme* 6**: Ecosystem Management (*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

Funding Unit: NMFS/SEFSC **NOAA Technical Contact:** Theo Brainerd

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.

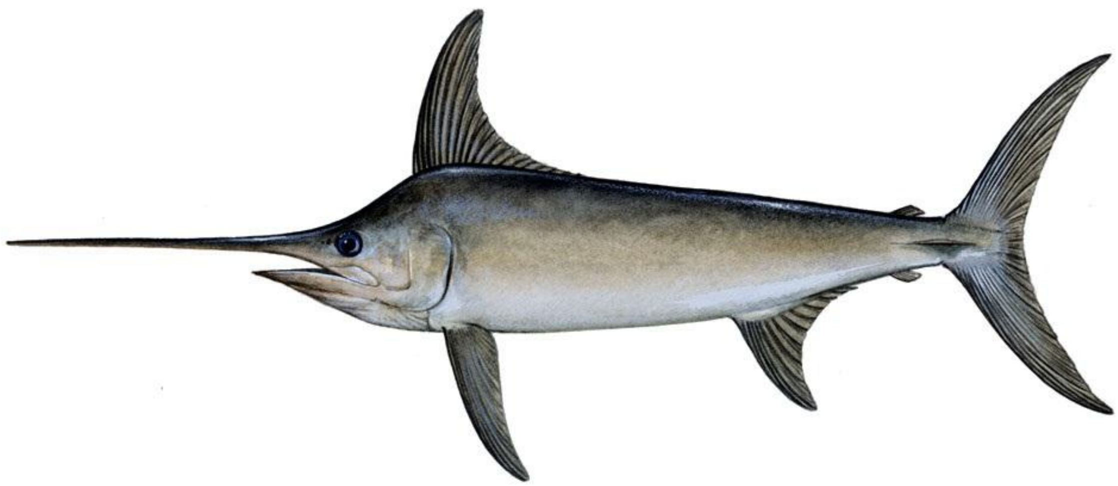


Figure 1: Photo of Xiphias gladius the swordfish (www.safmc.net, 2009).

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.

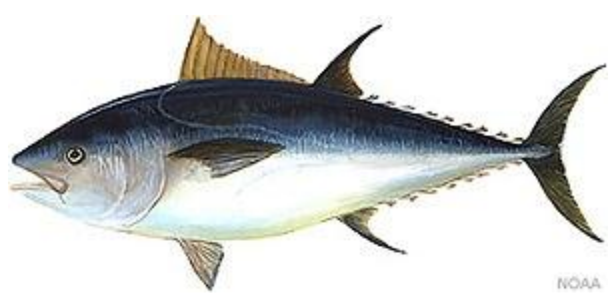


Figure 2: Photo of Thunnus thynnus the Atlantic Bluefin Tuna (www.MarineBio.org, 2009).

Research Performance Measure: All major objectives have been met.

Ship of Opportunity Program

Project Personnel: Q. Yao, F. Bringas, P. DiNezio, G. Rawson, N. Melo, S. Dong, J. Molina, M. Goes, D. Aranda and C. Gonzalez (UM/CIMAS)
NOAA Collaborators: 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 transmit that information 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 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 transport and upper ocean heat content.

CIMAS Research Theme:
***Theme 3*:** Sustained Ocean and Coastal Observations (*Primary*)
***Theme 1*:** Climate Research and Impact (*Secondary*)

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

Funding Unit: OAR/AOML **NOAA Technical Contact:** Alan Leonardi

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 and Pacific Oceans with high resolution (Figure 1). Approximately 8000 XBTs are deployed annually in both modes (frequently repeated and high density; Figure 2). 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, exclusively or as part of international and/or multi-institutional collaborations, the following transects in frequently repeated mode: AX01, AX07, AX08, AX10, AX20 and AX32 in the Atlantic Ocean, and PX08, PX09 and PX13 in the Pacific Ocean. Nine high-density XBT transects have been chosen in the Atlantic Ocean (AX02, AX07, AX08, AX10, AX18, AX22, AX25, AX32 and AX97) and six in the Pacific Ocean (PX06, PX09, PX10, PX31, PX37 and PX44) to monitor properties in the upper layers. High-density XBT transects provide real time high resolution temperature profiles spaced approximately 30-50 km apart. 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 transects are used to investigate the inter-basin mass exchange between the Indian and Atlantic Ocean (AX25), the meridional heat transport at 30^{o}S (AX18) and 30^{o}N (AX07), the variability of the Gulf Stream (AX10) and the zonal current system in the tropical Atlantic (AX08). Moreover, in the South Atlantic, transect 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.

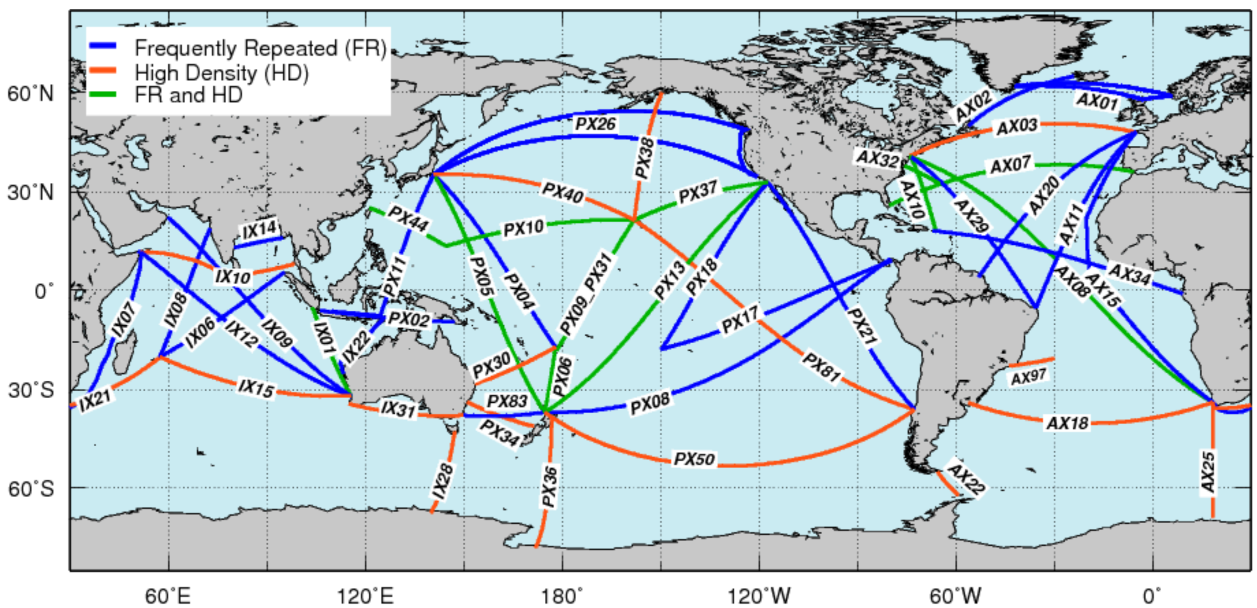


Figure 1: OceanObs09 XBT transects recommended by the scientific community to be occupied in frequently repeated mode (FR, in blue), high density mode (HD, in orange) or both (in green).

This project includes extensive operations that collect, organize and distribute the data which are gathered from as many as eighteen cruises conducted by AOML each year, including in excess of 225 days at sea and more than 8000 XBTs deployed in both modes. Data obtained from these transects are provided to the scientific community to investigate the thermal structure of the subtropical gyres, equatorial system and the Antarctic Circumpolar Current and to study and understand the role that the ocean plays in climate fluctuations, and to improve the ability to predict important climatic signals such as the North Atlantic Oscillation (see *www.aoml.noaa.gov/phod/hdenxbt/* for more details). In addition, satellite altimetry data are being used to complement the observations provided by the XBT transects and together provide estimates of Tropical Cyclone Heat Potential.

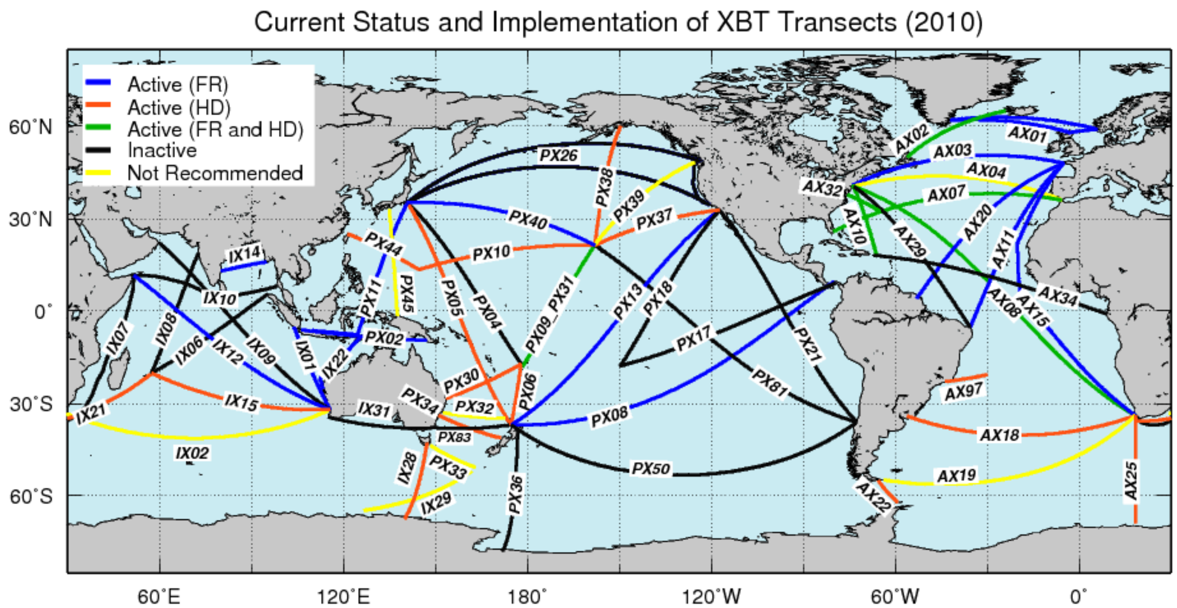


Figure 2: Current status and implementation of XBT transects recommended by the international community. Transects in black were not sampled during 2010. Other colors indicate transects sampled in frequently repeated mode (FR, in blue), high density mode (HD, in orange) or both (in green). During 2010 XBTs were also deployed along several transects that are not part of the scientific community recommendations (in yellow).

Tropical cyclones occur in seven ocean basins: tropical Atlantic, northeast Pacific, northwest Pacific, southwest Indian, north Indian, southeast Indian, and south Pacific. The intensification of TCs includes very complex mechanisms, such as TC dynamics, upper ocean interaction, and atmosphere circulation. In general, the accuracy of TC intensity forecast has lagged behind the TC track because of the complexity of the problem and because many of the errors introduced in the track forecast are translated into the intensity forecast. While sea surface temperature (SST) plays a role in the genesis of TCs, the ocean heat content (OHC) contained between the sea surface and the depth of the 26°C isotherm (D26), also referred as Tropical Cyclone Heat Potential (TCHP), has been shown to play a more important role in TC intensity changes. The TCHP shows high spatial and temporal variability associated with oceanic mesoscale features (Figure 3). TC intensification has been linked with high values of TCHP contained in these mesoscale features, particularly warm ocean eddies, provided that atmospheric conditions are also favorable. Since sustained *in situ* ocean observations alone cannot resolve global mesoscale features and their vertical thermal structure, different indirect approaches and techniques are used to estimate the TCHP. Most of these techniques use sea surface height observations derived from satellite altimetry, a parameter that provides information on the upper ocean dynamics and vertical thermal structure.

Storage and transport of heat in the ocean are central to other aspects of climate such as El Niño, the North Atlantic Oscillation, sea level rise, and global warming. Global integrals of upper ocean heat content for the last several years have reached values consistently higher than for all prior times in the record, demonstrating the dominant role of the oceans in the Earth's heat budget. Changes in mixed layer depth can have large impacts on the heat content in the mixed layer (Figure 4) even if there is no change in the mixed layer temperature.

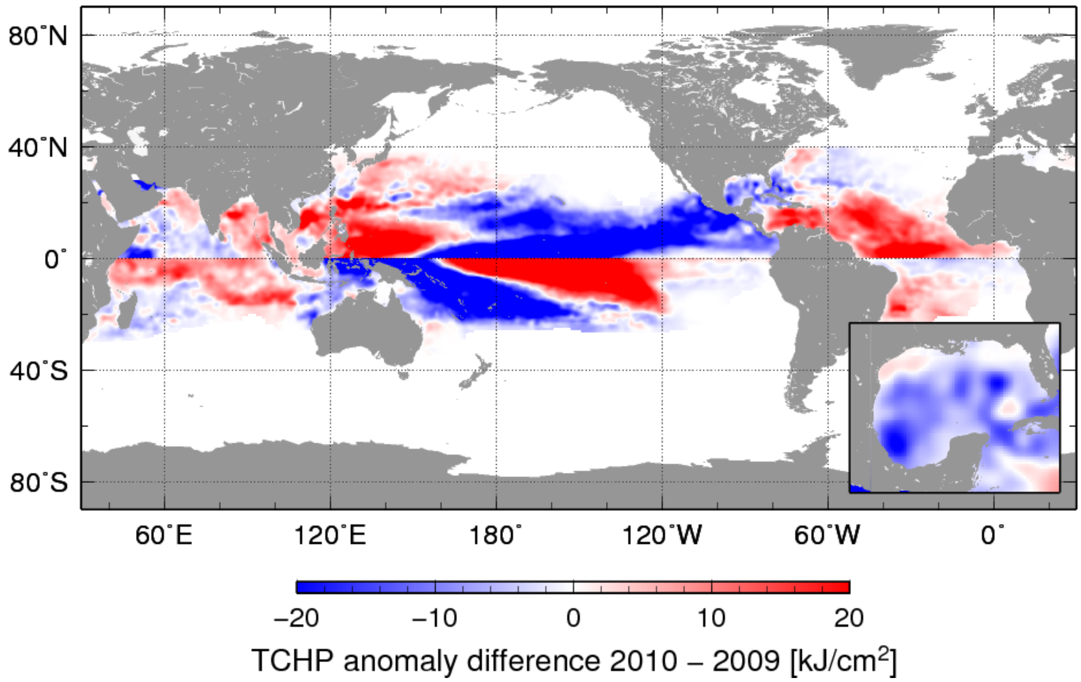
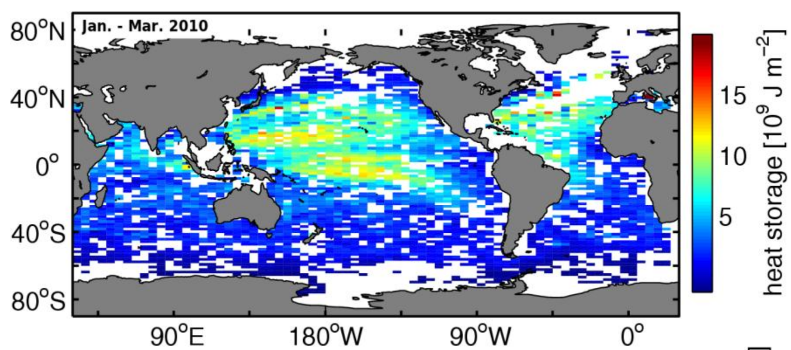


Figure 3: Global Tropical Cyclone Heat Potential (TCHP) anomaly differences between 2010 and 2009. The insert show the detail of these values in the Gulf of Mexico.



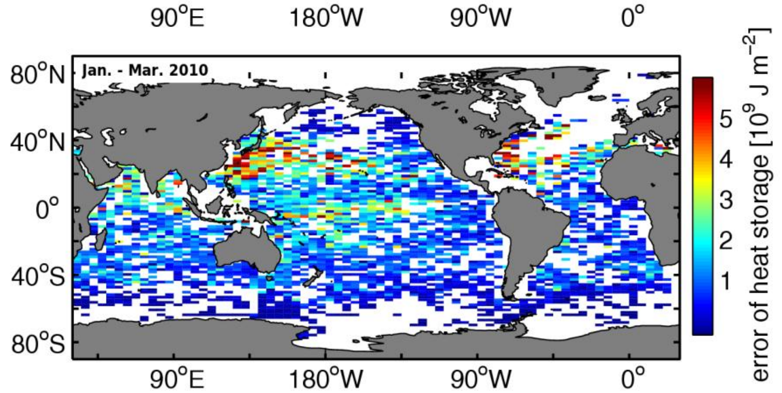


Figure 4: (top) Global map of in situ estimates of heat storage of the mixed layer and (bottom) error of these estimates for the period January – March, 2010. Available online at *www.aoml.noaa.gov/phod/soto/ghs/reports.*

The Meridional Overturning Circulation (MOC) is the main mechanism for global redistribution of heat in the ocean. The Atlantic Ocean is the major ocean basin involved in large-scale northward transports of heat typically associated with the MOC, where warm upper layer water flows northwards, and is compensated for by southward flowing North Atlantic Deep Water. This large-scale circulation is responsible for the northward heat flux through the entire Atlantic Ocean. Historical estimates of the net northward heat flux in the vicinity of its maximum, which occurs in the North Atlantic roughly at the latitude of the center of the subtropical gyre, range from 0.9 PW to 1.6 PW, while estimate in the 30°S to 35°S band are even more uncertain, ranging from negative to more than 1 PW. While much of this variability may be a consequence of the different methods used to estimate the heat transport, natural variability cannot be ruled out. Quarterly reports of heat storage (Figure 4; *www.aoml.noaa.gov/phod/soto/ghs/reports.php*) and heat transport (Figure 5; *www.aoml.noaa.gov/phod/soto/mht/index.php*) are created to provide an overview of the current state of knowledge about ocean climate, including anomalies, placed in historical context. Climate applications are presented along with an explanation of how the observing system needs to be enhanced to improve ocean analysis and reduce present uncertainties.

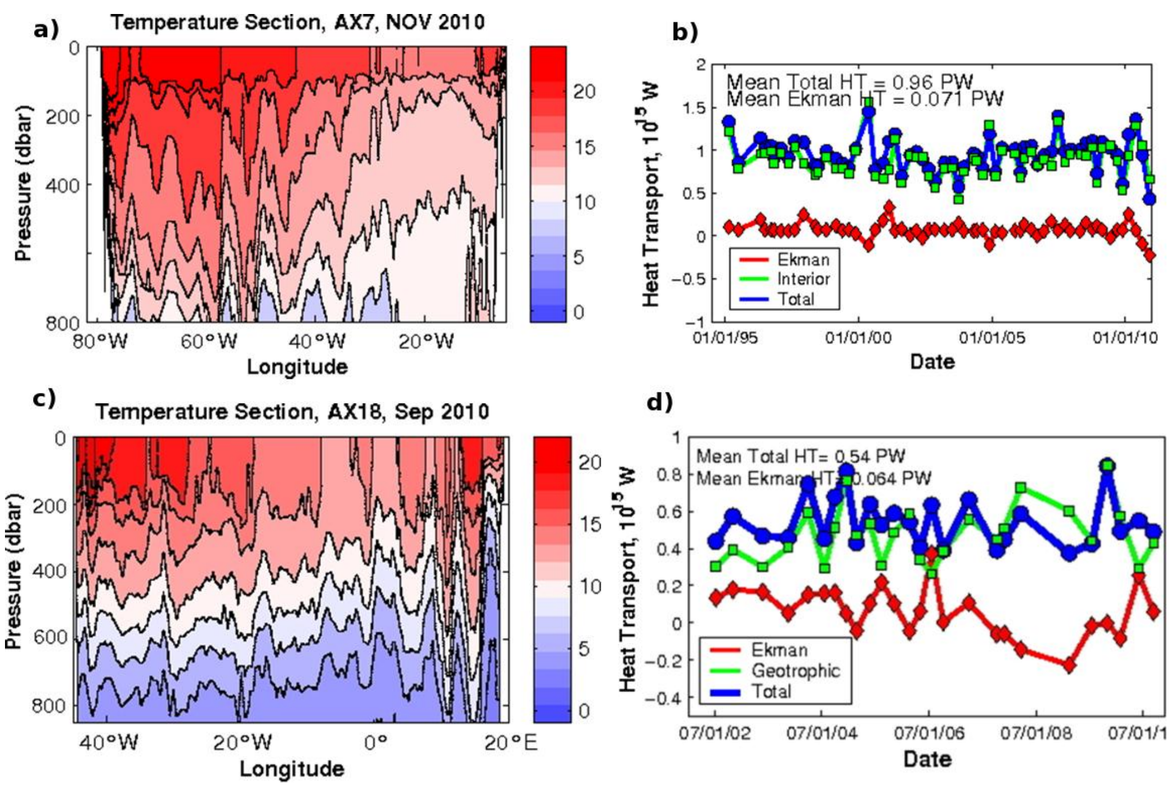


Figure 5: a) Temperature section and b) Ekman, Interior and Total heat transport in the North Atlantic obtained with the XBT data from the high density AX07 cruise on Nov, 2010. c) Temperature section and d) Ekman, Interior and Total heat transport in the South Atlantic obtained with the XBT data from the high density AX18 cruise on Sep. 2010. Available online at: *www.aoml.noaa.gov/phod/soto/mht/ax7/report.php.*

The XBT data obtained within this program is also used to study the variability of the upper tropical Atlantic circulation between 10°S-15°N along the nominal meridian of 26°W on seasonal to interannual timescales, in particular the investigation if the seasonal variability of the equatorial currents. Results obtained using a methodology based on the XBT data combined with satellite altimetry confirm that the North Equatorial Counter Current (NECC) follows an annual cycle, is weaker during March-April, is closely related to the meridional displacement of the Intertropical Convergence Zone (ITCZ), and its highest values of transport are approximately 12 Sv (Figure 6, left). The North Equatorial Undercurrent (NEUC) presents variability in both annual and semi-annual scales, and a transport of 5.2 ± 3 Sv (Figure 6, right). These results emphasize the need for sustained altimetry and XBT observations for a long-term monitoring system of the region.

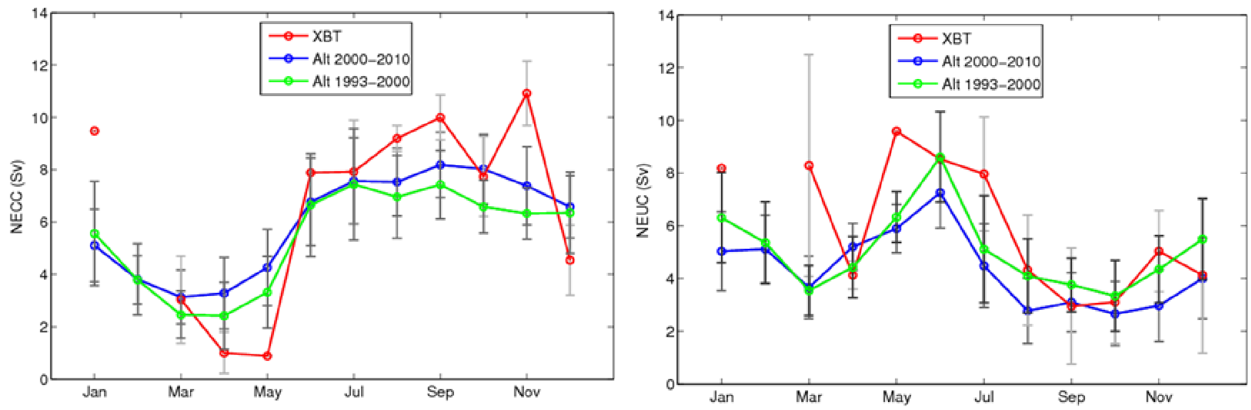


Figure 6: Seasonal cycle of the transport of the NECC (left) and the NEUC (right) derived from: XBT + Levitus salinity data (red); Synthetic method using SSHA data from altimetry for 1993-2000 (green) and 2000-2010 (blue).

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.

AOML's South Florida Program (SFP): Long-Term Measurement of Physical, Chemical, and Biological Water Column Properties in the South Florida Coastal Ecosystem

Project Personnel: N. Melo, G. Rawson, D. Lindo, S. Dolk, K. Seaton, L. Visser and P. Ortner (UM/CIMAS)

NOAA Collaborators: A.M. Wood, C. Kelble, E. Johns, R. Smith, D. Manzello, J.-Z. Zhang, C. Fischer and S. Cummings (NOAA/AOML)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** Determine the circulation and water property patterns within Florida Bay, Biscayne Bay, and surrounding south Florida coastal waters on "event" to interannual time scales, and 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 bimonthly and supplemental event-focused monitoring cruises in conjunction with a moored instrument array and satellite-tracked surface drifter deployments, and incorporate these results into system models supporting resource management decisions.

CIMAS Research Theme:

***Theme 3*:** Sustained Ocean and Coastal Observations

Link to NOAA Strategic Goals:

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

Funding Unit: NOAA/AOML and NOAA/NMAO **NOAA Technical Contact:** Alan Leonardi

Research Summary:

The Comprehensive Everglades Restoration Program (CERP) is the largest and most expensive ecosystem restoration ever attempted. Its 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 large portion of south Florida's economy, including the Florida Keys National Marine Sanctuary and 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 CERP project will be undertaken individually and management decisions will be altered if it is found they are likely to cause detrimental ecological effects.

Understanding the circulation and water property patterns of Florida Bay and surrounding waters is of vital importance to incorporate the health of the coastal ecosystem into the iterative adaptive restoration component of the Comprehensive Everglades Restoration Plan (CERP). The South Florida coastal ecosystem is economically and environmentally important and a large portion of the ecosystem is contained within the Florida Keys National Marine Sanctuary. The aim of this project is to quantify and comprehensively understand the variability of inter-related physical, chemical, and biological water column properties. This is achieved through a sustained research and monitoring program that incorporates analysis from a moored instrument array, regular cruises (See representative hydrocast in **Figure 1**), and numerical modeling. The primary outcomes of this project have been rigorous quantification of the pre-CERP baseline condition, testable hypotheses, predictive models and alternative management options. Together these products provide a science-based methodology to assess CERP's effect on the coastal ecosystem and provide the feedback and predictive skill required by CERP's ambitious adaptive management plan.

A number of new sampling techniques have recently been added to the typical SFP suite of observations. For example, Turner crude oil fluorometers were purchased in 2010 and incorporated into the flow-through monitoring system for the SFP cruises. Since the time of the Deepwater Horizon oil spill in spring 2010 glass sampling containers are now kept on board during SFP cruises to permit sampling of suspicious water masses. Regular neuston net tows along the cruise track have also been added to the standard SFP sampling protocol, allowing evaluation of the health and degree of oiling of *Sargassum* found in the Straits of Florida or other regions. All net tows are examined for the presence of tar balls; to date, no tar balls have been recovered by net tows in the SFP program. Other new measurements which have been added to the SFP during this report period include bio-optical profiles to assess water clarity over the water column, and to provide valuable light transmissivity data which is used by satellite ocean color experts from USF to improve their algorithms for interpreting ocean color in the shallow turbid coastal waters of south Florida. Carbonate chemistry sampling to provide baseline values and variability of ocean acidification over the Keys coral reef tract has also become a regular part of the bimonthly sampling effort.

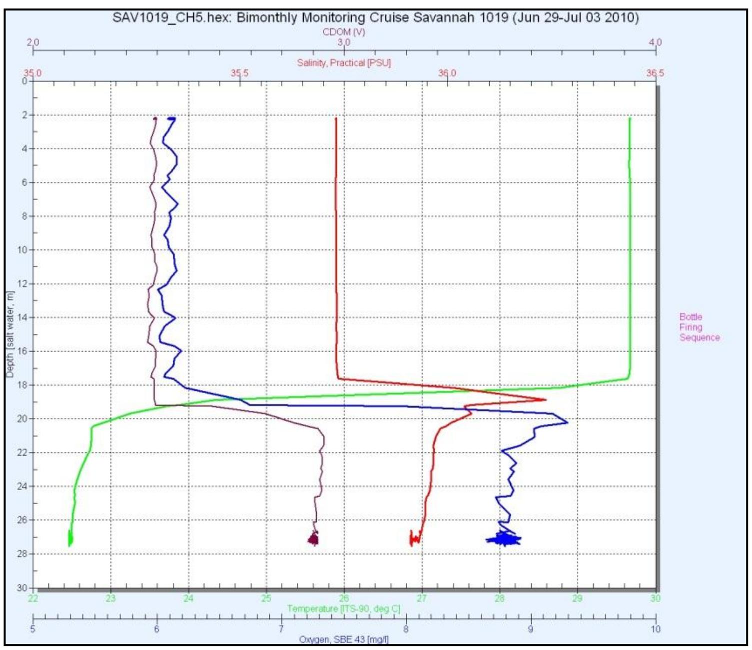


Figure 1: CTD profiles of temperature, salinity, dissolved oxygen, and fluorescence voltage collected offshore of Charlotte Harbor, FL, during June-July 2010.

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 Investigators) provided critical contributions to the relevant components of the congressionally mandated 2010 System Status Report.

Global Impact of Eddies on Inertial Oscillations of the Mixed Layer

Project Personnel: R.C. Perez (UM/CIMAS)
NOAA Collaborators: R. Lumpkin (NOAA/AOML)
Other Collaborators: J.M. Lilly (NWRA); M.-P. Lelong (NWRA); K. Dohan (ESR); S. Elipot (NOC)

Long Term Research Objectives and Strategy to Achieve Them:
***Objectives*:** To understand near-inertial energy pathways from the mixed layer to the ocean interior.
***Strategy*:** To investigate near-inertial pathways through combined analysis of the Global Drifter Program near-surface measurements and numerical models.

CIMAS Research Theme:
***Theme 3*:** Sustained Ocean and Coastal Observations (*\Primary*)
***Theme 1*:** Climate Research and Impact (*Secondary*)

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

Funding Unit: NSF **NOAA Technical Contact:** Alan Leonardi

Research Summary:
Wind stress fluctuations acting at the surface of the ocean cause the mixed layer to "ring" with strong inertial oscillations. Some fraction of the energy is locally dissipated, either within the mixed layer or in the strongly stratified zone at its base. A large portion, however, makes its way into the ocean interior in the form of propagating near-inertial waves, which eventually break and drive small-scale mixing. (see **Figure 1**). The near-inertial energy pathways, far from being controlled by linear processes, appear to be shaped at first order by interactions with the mesoscale eddy field. The nature of these interactions may be more complex than previously thought, involving several distinct mechanisms of energy transfer.

As part of this project, we investigate fundamental aspects of the near-inertial pathways through a combination of data analysis and numerical modeling. Our strategy is built around accessing and interpreting data from the Global Drifter Program network of surface buoys, now available with approximately hourly resolution since 2005. Analysis of the surface drifter dataset will quantify previously unobservable details of the near-inertial variability in the surface mixed layer. At the same time, outstanding dynamical questions of wave/eddy interactions will be explored with high-resolution numerical experiments and dynamical models. The net result will be an improved and quantitative understanding of the near-inertial energy flux from the mixed layer to the ocean interior, an important element of the ocean's energy budget.

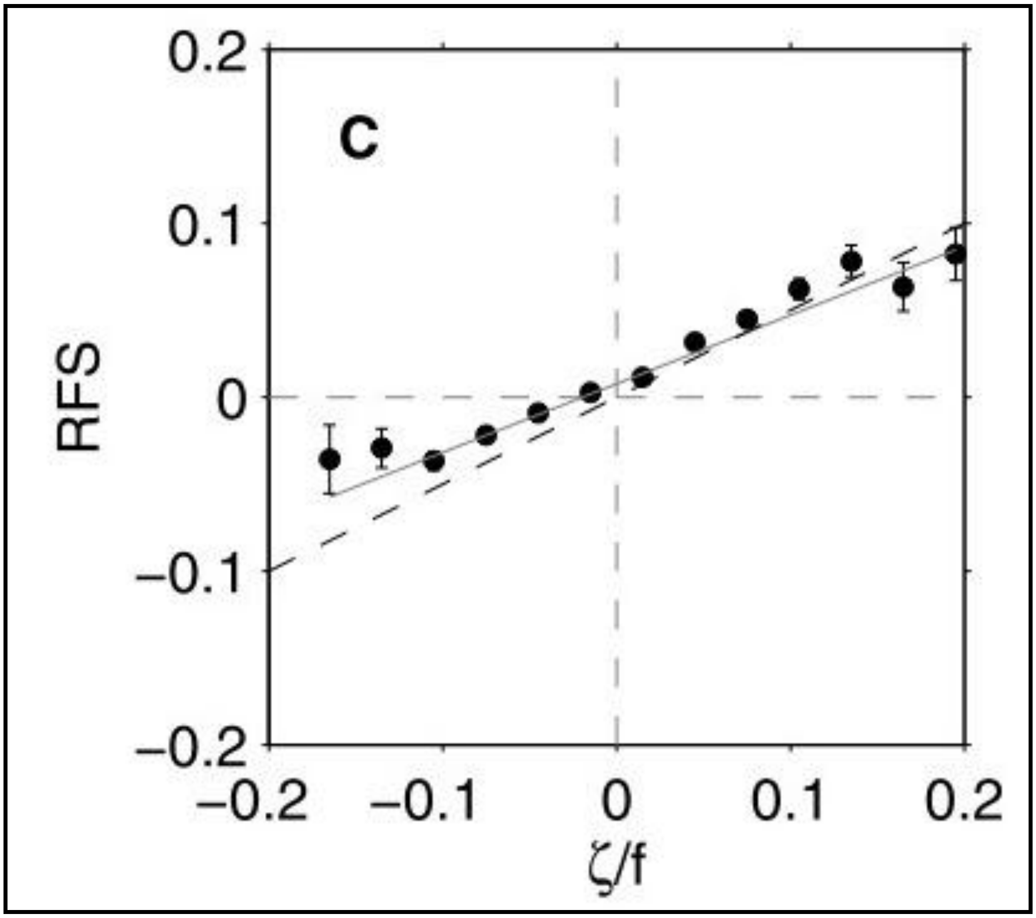


Figure 1: Mean relative frequency shift of near-inertial oscillations seen by drifters (vertical) vs. mesoscale background vorticity (□/f) determined from altimetry (horizontal). Error bars correspond to the standard error of the mean in each bin. Figure reproduced from Elipot et al. (2011).

Research Performance Measure: A planning meeting was held in Seattle, WA February 22-24, 2011. The drifter data assembly center at NOAA/AOML generated a high-resolution drifter dataset. In collaboration with PIs on the project and Luca Centurioni, we have assessed the quality of data after the switch from ARGOS least-squares to Kalman-filtering positioning algorithm. One paper was published in the Journal of Geophysical Research.

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

Project Personnel: S. Dong, E. Forteza, V. Halliwell, V. Hormann and R. Sabina (UM/CIMAS)
NOAA Collaborators: S. L. Garzoli, E. Ramos and C. Schmid (NOAA/AOML)

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

CIMAS Research Theme:
Theme 3**:** Sustained Ocean and Coastal Observations
Theme 1**:** Climate Research and Impact

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:** Alan Leonardi

Research Summary:
The Argo array is part of the Global Climate Observing System/Global Ocean Observing System (GCOS/GOOS). Argo profiling floats provide measurements of temperature and salinity to depths of 1000-2000 meters, and currents at the drift depth of the floats. Researchers in many scientific disciplines, including meteorology, climatology and oceanography, use data collected from the floats. The Argo array achieved its goal of a total of 3000 floats in November 2007 and is maintaining the number of floats.

The US Argo Data Assembly Center (US DAC) at AOML is responsible for deploying floats, and for acquiring and processing the data. The US DAC has developed and maintained an automatic system for decoding, performing 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 during this year (10/1/10 – 6/20/11):

- 253 floats were deployed by the USA
- 48 of these floats were deployed by AOML
- 2,014 US floats are actively reporting.
- 47,679 profiles have been sent to Global Data Centers
- 38,711 profiles were sent to GTS by the US DAC
- US DAC is processing 133 Argo-equivalent floats (i.e. not funded by Argo) from different institutions and organizations (Florida State University, NAVOCEANO, University of Hawaii).

On November 2010, the US Argo Data Assembly Center at AOML started to disseminate real-time data in BUFR format via the Global Telecommunication System. Use of this format allows the distribution of profiles of any length, as well as the inclusion of meta data and quality flags.

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.

All Argo profiles undergo the standard scientific Delayed-mode Quality Control (DMQC) process, which is performed at the institution that provided the float. As part of the South Atlantic Regional Argo Data Assembly Center, the development of the Post-DMQC analysis was completed, and is in the process of being implemented. This last stage of the quality control is based on various consistency checks applied to the delayed mode profiles for floats in the SAARC region, and is intended to identify profiles or even entire floats that may need further attention. This Post-DMQC analysis involves comparing each delayed-mode Argo profile to four separate data sets: 1) the monthly Levitus World Ocean Atlas 2005 climatology, 2) the Navy GDEM3 ocean climatology, 3) a monthly climatology composed from the global monthly means of Argo-derived temperature and salinity (from 1992 forward), and 4) a data set consisting of all available temperature and salinity profiles from all sources (CTD, XBT, Argo profiles, etc.), where each Argo profile is compared to any other profile in close proximity (~100km in space and 10 days in time). These comparisons are made at multiple levels from 400m to 2000m, and are used to derive difference statistics for each float. A set of web pages is used to display time series of the difference statistics, profiles and their location for each float, and individual profiles together with the profiles used in the comparisons. Summary plots (**Figure 1**) show overall statistics from all floats, highlighting floats that may have larger deviations from the comparison data sets with or without a time dependence. The latter could be caused, for example, by inadequate correction of sensor drift. This system will facilitate the detection of floats with potentially erroneous corrections performed during the DMQC.

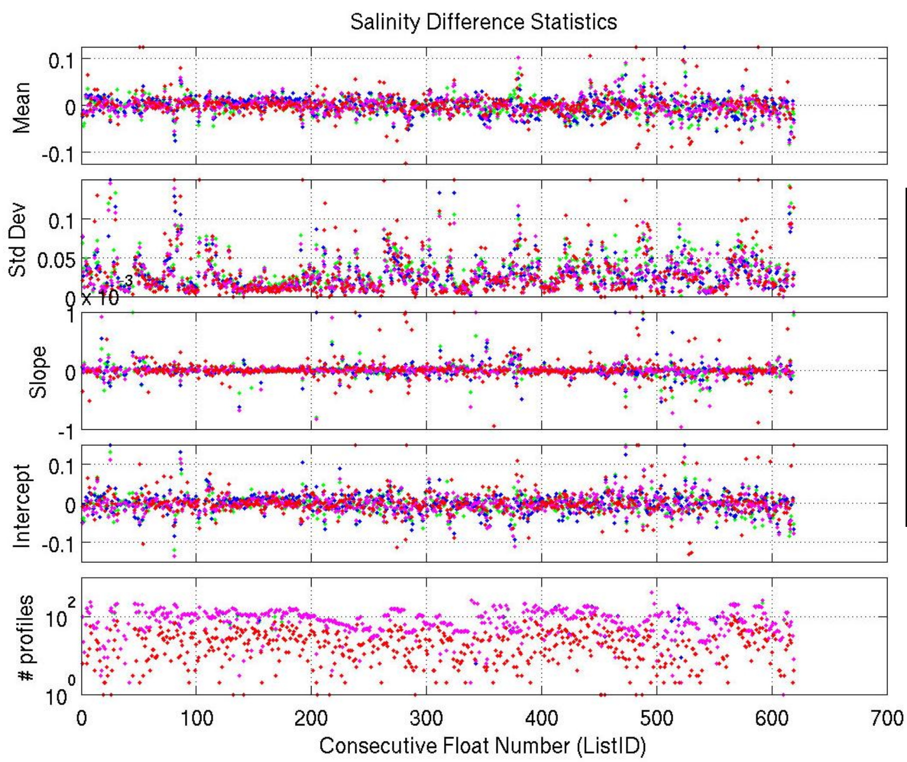


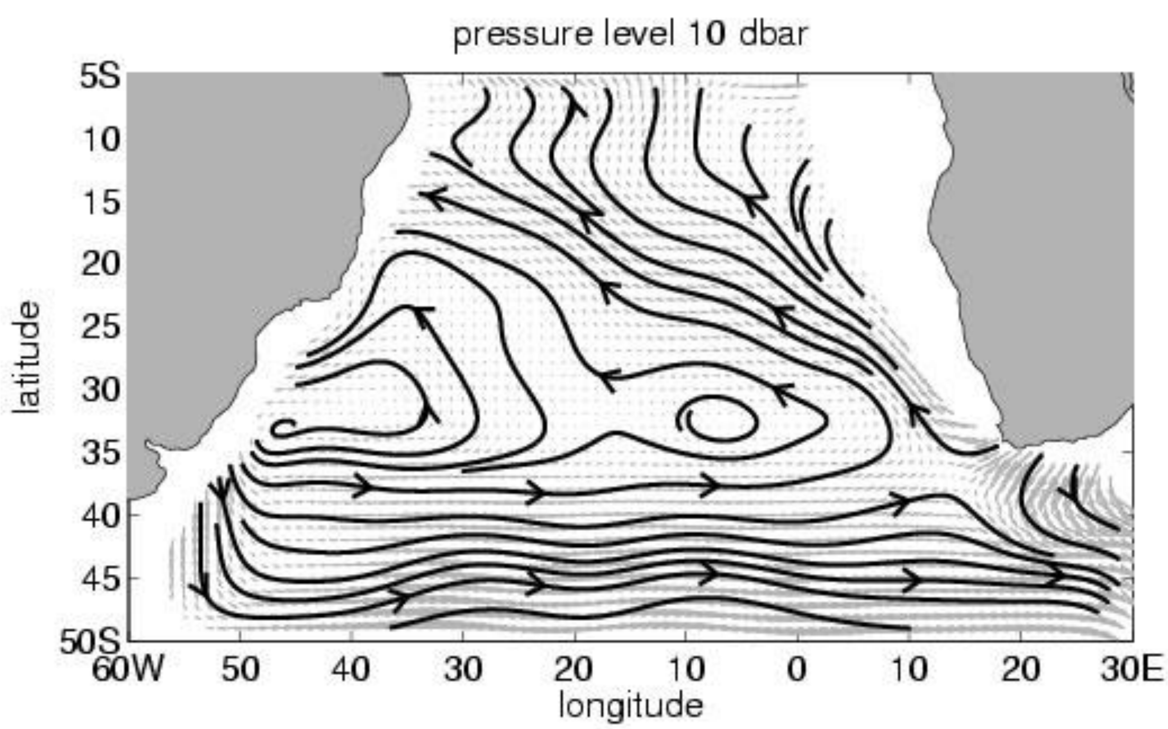
Figure 1: Summary plots of the statistic analysis performed on the salinity of the delayed-mode profiles of Argo floats in the region covered by the South Atlantic Argo Regional Center.

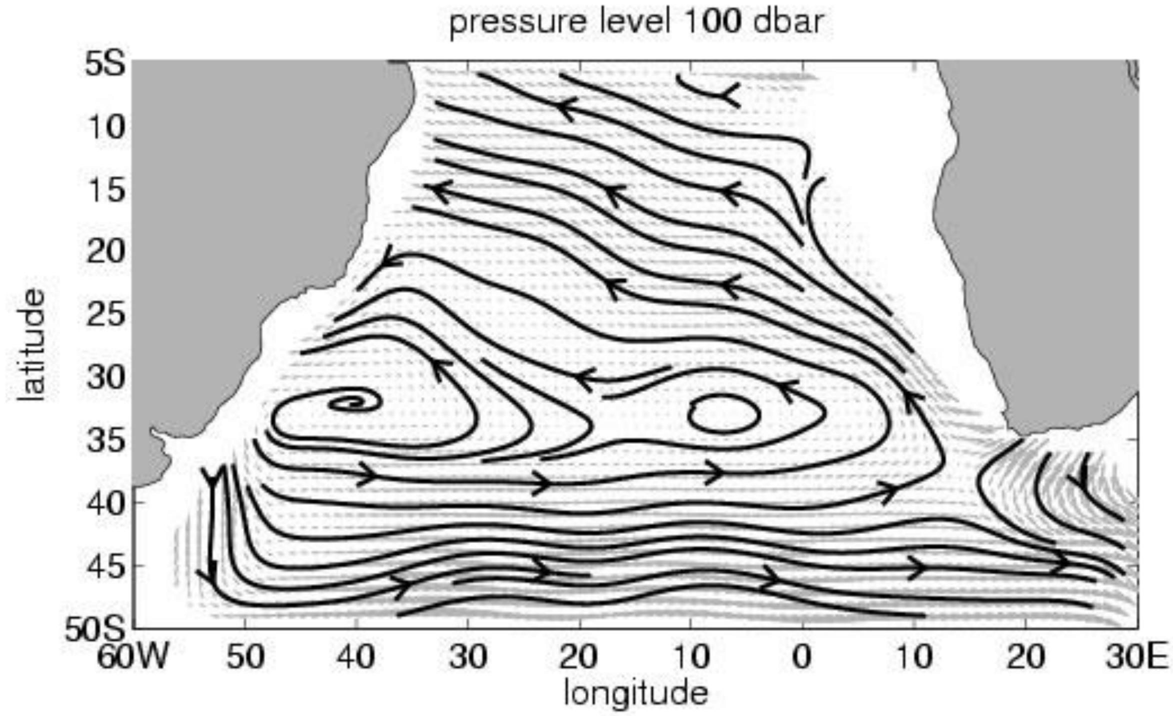
In addition to the statistical analysis, various consistency checks are also used to identify floats or profiles that need correction. Examples are: 1) identify cases where the pressure is not monotonically while being flagged as good, 2) cases where a parameter has good flags, but fill values, 3) errors in the fill values themselves. The first analysis (performed in the first quarter of 2011) identified a number of cases that required attention by their PIs. The analysis of 619 floats with 69412 delayed mode profiles, performed in the first quarter of 2011, identified a number of cases that required attention by their delayed-mode operator. Of these, 17 floats have errors detected during the consistence checks, and 8 floats required attention because of the results of the statistical analysis.

Further checks have been identified that will be useful, and will be added in the next analysis period (expected to be performed quarterly). Also, use of SST and SSH maps may be added to the individual profiles pages, to better differentiate floats that enter a different water mass from those that will require further attention from their delayed-mode operator.

Quality controlled Argo profiling data are also used to calibrate thermosalinograph (TSG) data. Float data have to be measured within one week and 150km distance from the TSG measurement for this purpose.

Three-dimensional adjusted geostrophic velocity fields (annual means for 2008 to 2010, and monthly climatology) in the South Atlantic are derived from hydrographic profiles (mainly from Argo) and the subsurface velocity from the Argo floats. The changes of the shape of the subtropical gyre with depth can be clearly seen in **Figure 2**. The velocity fields are used, among others, to analyze changes in the gyre structure, and the contribution of the interior transports to the Meridional Overturning Circulation.

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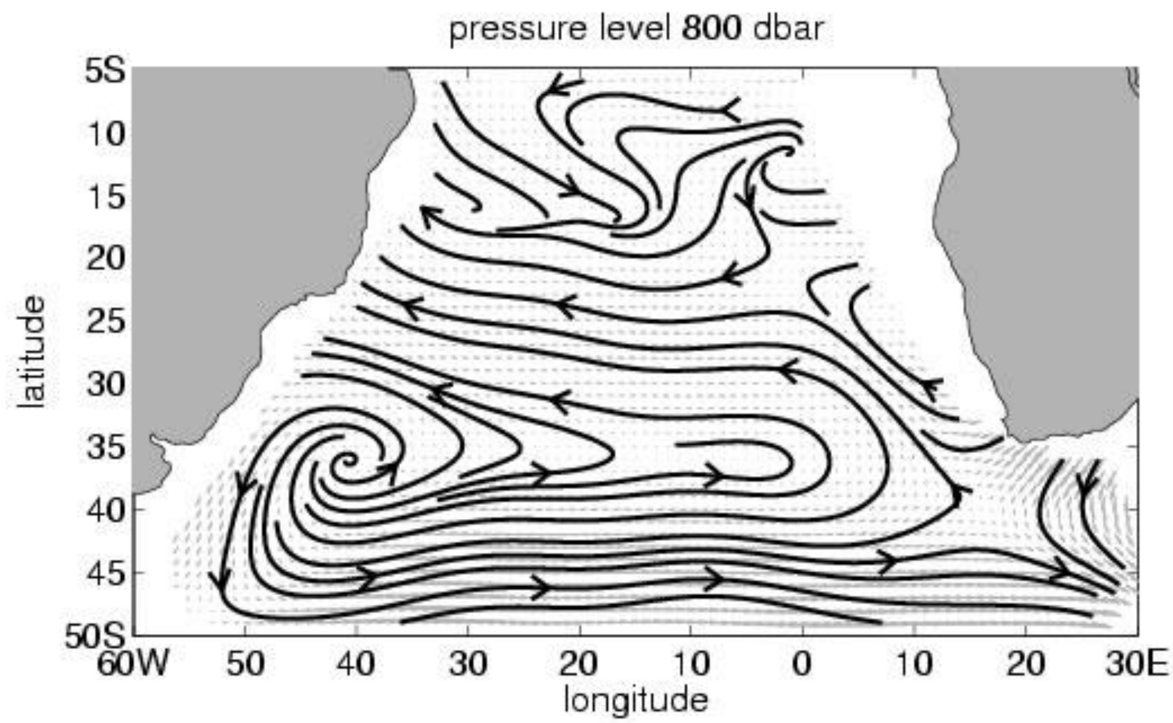
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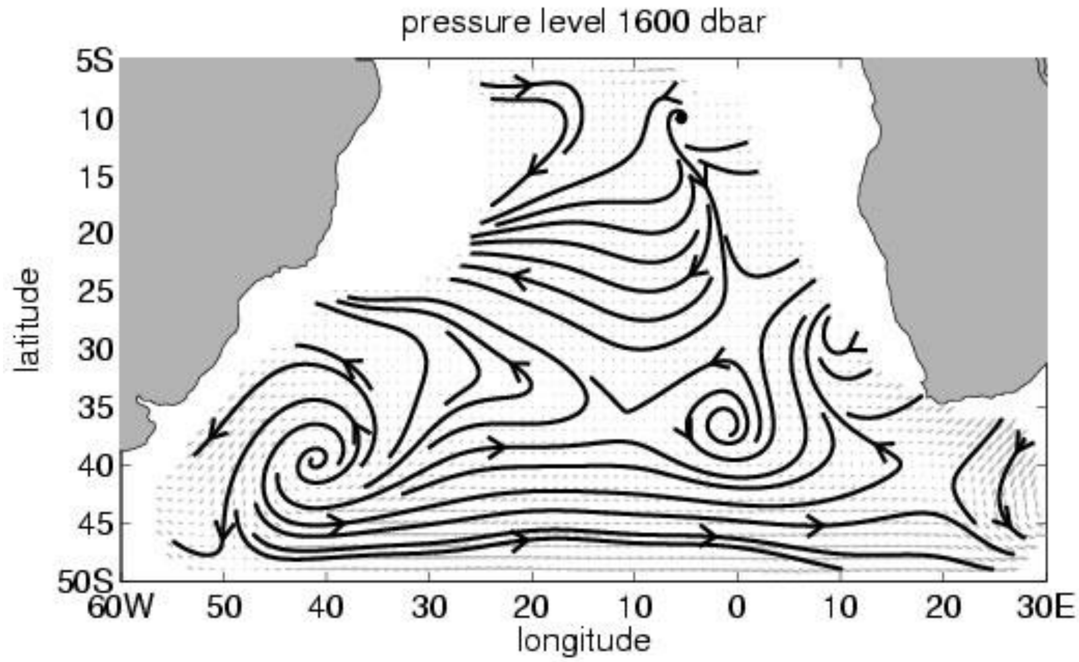


Figure 2: Annual mean of the adjusted geostrophic flow field at 10, 100, 800 and 1600 dbar for 2010. Objective mapping with correlation length scales of 20^o in latitude and longitude was applied to the observations.

Data from Argo floats and other instruments are used to study the mixed layer salinity in the eastern tropical Atlantic. **Figure 3** shows the mean distribution of the mixed layer salinity as well as the standard deviation, as derived from data collected in 2006 to 2010. Relatively low salinity predominates around 5^{o}N, with the lowest values near Africa (at about 10W). In the former area which is strongly influenced by the annual migration of the Intertropical Convergence Zone (ITCZ) the standard deviation of the salinity is very high, as expected. In the latter area the standard deviation is quite low, thus indicating that the annual migration of the ITCZ has little impact in this region.

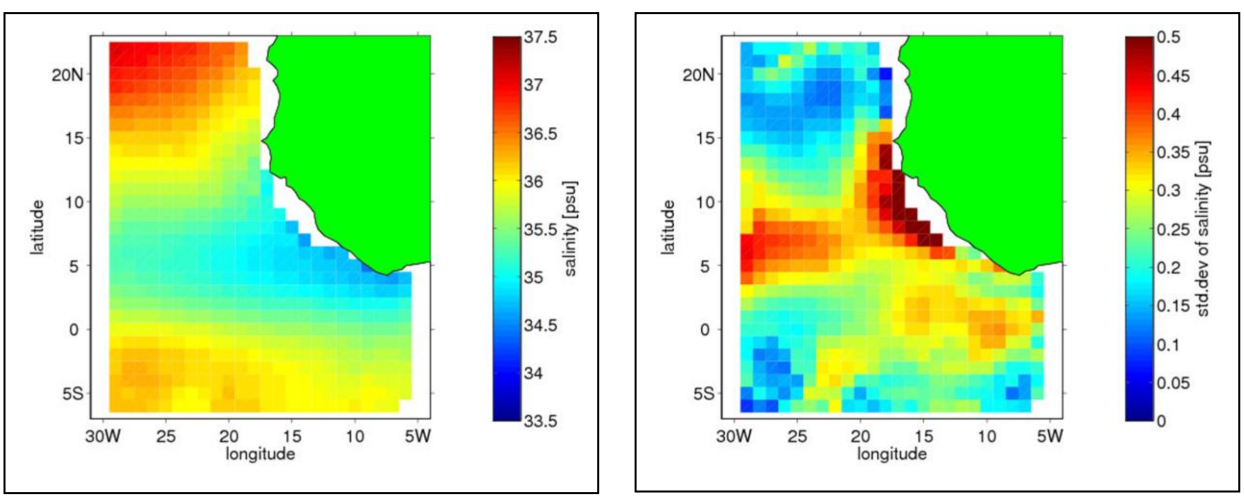


Figure 3: Mean mixed layer salinity (top) and standard deviation (bottom) based on Argo and other profiles collected in 2006 to 2010.

The time series derived from these data shows clearly that the salinity has a minimum in about 3-8^{o}N that is strongest in the fall (**Figure 4**). A secondary minimum exists in the summer of 2007. The minimum in fall is significantly stronger in 2006 and 2008, when compared with 2009 and 2010, and somewhat stronger than in 2007.

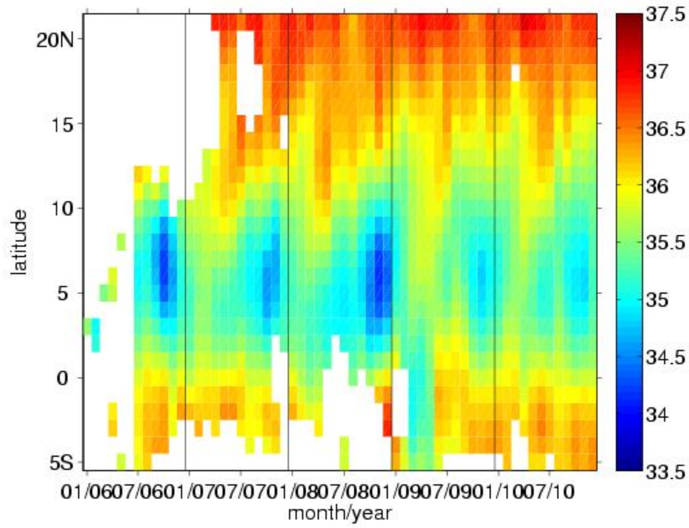


Figure 4: Latitude-time diagram of the mixed layer salinity at 23W based on Argo and other profiles. The correlation length scale for the objective mapping was 15^o.

The meridional overturning circulation (MOC) and meridional heat transport (MHT) obtained from two GFDL coupled models, with and without data assimilation, are examined and compared with observations collected at nominally 34^{o}S in the South Atlantic (**Figure 5**). The results demonstrate that the performance of the Geophysical Fluid Dynamic Laboratory (GFDL) coupled data assimilation (CDA) model is quite different between the two periods, 1979-2002 and 2003-2007, due to the assimilation of Argo data in later period. The MOC components from the GFDL CDA during 1979-2002 are similar to those from GFDL CM2.1 IPCC simulation, both give weak boundary currents and strong interior overturning transport compared to observations. However, after assimilating temperature and salinity profiles from the Argo floats, the performance of the GFDL CDA is greatly improved in terms of representing the observed MOC and MHT structure: the transports of boundary currents are twice as strong as those during pre-Argo period, and the overturning flow in the interior region is reduced. Possible causes for the changes in model performance are discussed.

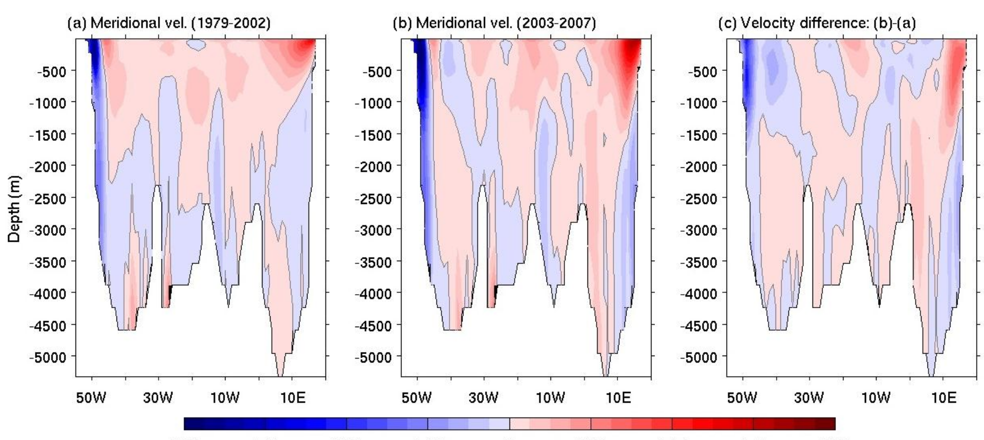


Figure 5: Meridional velocity from GFDL CDA averaged (a) during 1979-2002, (b) during 2003-2007, and differences in averaged meridional velocity for the two periods, 2003-2007 and 1979-2002. Unit is m/s.

Data from Argo floats were used to study the equatorial deep jets (**Figure 6**). In the equatorial Atlantic, evidence has been found that vertically alternating deep zonal jets of short vertical wavelength can affect sea surface temperature, wind and rainfall in the tropical Atlantic region and constitute a 4.5-yr climate cycle. Although deep jets are also observed in the Pacific and Indian oceans, only the Atlantic deep jets seem to oscillate on interannual timescales. In the Pacific, the dominant signal is associated with low-baroclinic-mode variability and despite geometric similarities between the Indian and Atlantic oceans, the Argo float velocities of the former are characterized by rather incoherent signals.

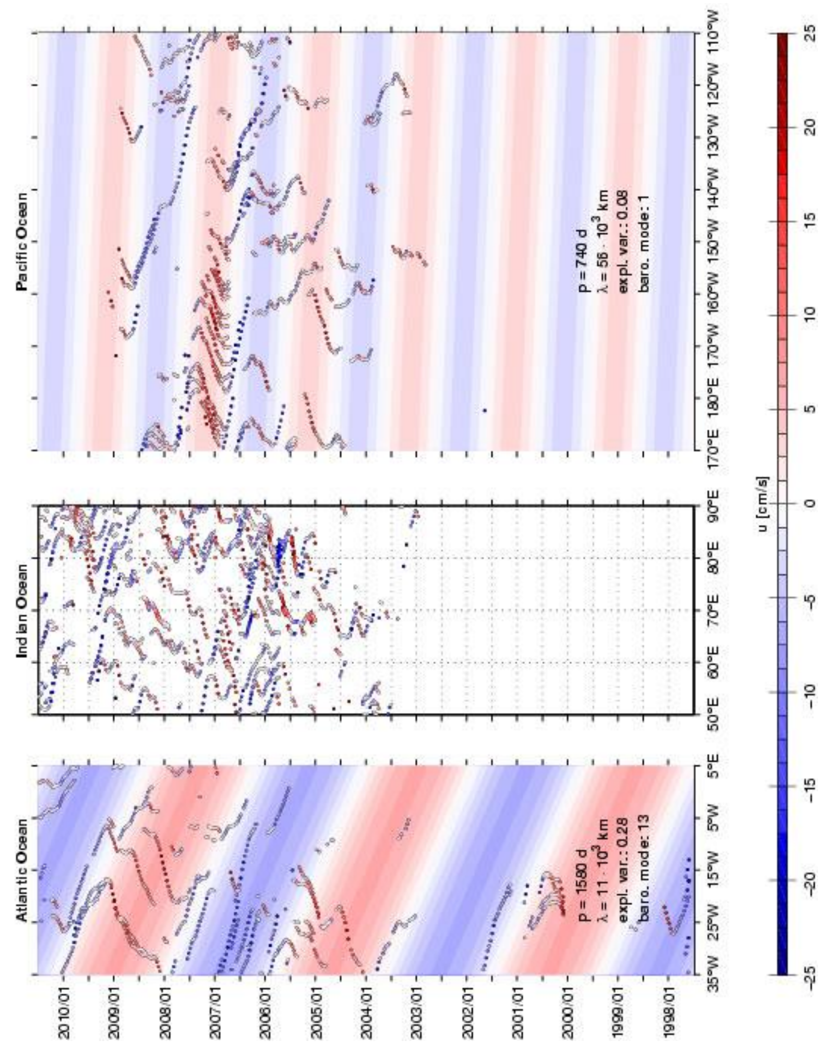


Figure 6: Equatorial zonal velocities from 1,000-m Argo float drift data. Argo float drift data (colored dots, color scale) were acquired between latitudes 1°S and 1°N. The dominant interannual variability in the Atlantic and Pacific oceans obtained by maximizing explained variance using a plane wave fit is visualized by color shadings. Associated harmonic parameters for the Atlantic and Pacific oceans are also given.

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

Upper Ocean Sampling of Currents and Salinity in the Loop Current to Monitor the Deepwater Horizon Oil Spill

Project Personnel: L. K. (Nick) Shay (UM/RSMAS)
NOAA Collaborators: F.D. Marks, E.W. Uhlhorn and G.R. Halliwell, Jr. (NOAA/AOML)

Long Term Research Objectives and Strategy to Achieve Them:

***Objective*:** To provide ocean temperature profiles in near real time to the National Centers via global telecommunication systems (GTS) for assimilation of data into operational ocean models for improved trajectory analyses of potential pathways of oil movement in and along the periphery of the Loop Current (LC). A key aspect of the research was to provide deep measurements of salinity and currents.

***Strategy*:** To utilize the NOAA WP-3D aircraft to deploy airborne expendable conductivity temperature and depth profiles (AXCTD), airborne expendable current profilers (AXCP) and airborne expendable bathythermographs (AXBT) on repeated transects at seven to ten-day intervals in and along the periphery of the LC. The AXCTDs and AXCPs were provided through a contract from Bureau of Ocean Energy Management Regulation and Enforcement (BOEMRE) as part of their Loop Current Dynamics Study (LCDS).

CIMAS Research Theme:
***Theme 3*:** Sustained Ocean and Coastal Observations
***Theme 4*:** Ocean Modeling

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

Funding Unit: OAR/AOML **NOAA Technical Contact:** Alan Leonardi

Research Summary:
In collaboration with scientists from NOAA's Atlantic Oceanographic and Meteorological Laboratory, the research grant involved the measurement of oceanographic and atmospheric data acquired from the NOAA WP-3D research aircraft (Hurricane Hunter) that made flights from seven to ten day intervals from 8 May to 9 July 2010 over the eastern Gulf of Mexico. Throughout the Deep Water Horizon (DWH) event, NOAA hurricane hunter aircraft conducted nine complete grids from 24 to 28^{o}N encompassing the Loop Current and its energetic eddy field over the deep eastern Gulf of Mexico deploying sonobuoys for a 3D assessment of physical oceanographic conditions for use in predictive operational models. These aircraft deployments totaled 588 profilers including AXBT, AXCP and AXCTD to provide deep-water (AXBTs to 350 m, AXCPs to 1500m, and AXCTDs to 1000 m) profiles of temperature, currents and salinity in the vicinity of the oil spill and the LC/Warm Core Eddy (WCE) complex. This project provided near-real time (within 12 to 24 hours) subsurface (and deep) temperature profiles to initialize data assimilative ocean circulation models used to predict the surface and subsurface oil movement at the National Centers (e.g., NAVOCEANO) over the 100 plus days of DWH oil spill.

The impact of the aircraft observations was tested using the regional Gulf of Mexico HYbrid Coordinate Ocean Model (HYCOM; http://www.hycom.org) (*Chassignet et al*., 2003; *Halliwell*, 2004) run with 0.04° (~4 km) horizontal resolution and 20 hybrid vertical layers. Data assimilation was performed using the Navy Coupled Ocean Data Assimilation (NCODA) system that in this region relies primarily on satellite altimetry and SST measurements. To correct subsurface upper-ocean structure in the model analyses, surface anomaly signals in SST and SSH are projected vertically downward as anomalous temperature and salinity profiles using a statistical technique based on regression analysis between the surface measurements and historical subsurface temperature and salinity profiles. Synthetic profiles are calculated only along the altimeter tracks, and are used to incrementally adjust the model temperature and salinity profiles based on the previous day's forecast.

To assess the impact of aircraft measurements on the HYCOM analyses, two reanalyses were performed in hindcast mode. The first reanalysis (P3_GoM_HYCOM) assimilated all observations including the aircraft surveys. The second (GoM_HYCOM) is identical except for denying the P-3 observations. The reduction in bias and RMS error on each of the flight days resulting from assimilation of the aircraft observations is illustrated by comparing temperature between 30 and 360 m for experiments P3-GoM-HYCOM and GoM-HYCOM (**Figure 1, left panels**). The reduction in temperature bias is about 50% on average while the reduction of RMS error is 25 to 30% on average, demonstrating a significant and positive impact of aircraft data assimilation. Note that error reduction is not uniform across the detaching Eddy Franklin (**Figure 1, right panels**). The reduction in temperature error reaches 50% in the central region of the eddy and also along Franklin's eastern boundary. This correction reduces errors in the subsurface density distribution along with errors in the upper-ocean currents associated with this density distribution. Similarly, assimilation of the data improved the representation of depth of the 20°C isotherm in P3-GoM-HYCOM between 28% and 34%, compared to GoM-HYCOM. These promising results with thermal structure and isotherm depth variations are considered an initial assessment because important factors such as the ocean model, data assimilation method, and details of the assimilation update cycle such as observation time windows are crucial in the process. *However, synoptic measurements from the aircraft over a 9-hour flight improved the fidelity of the model in simulating more realistic ocean fields.*

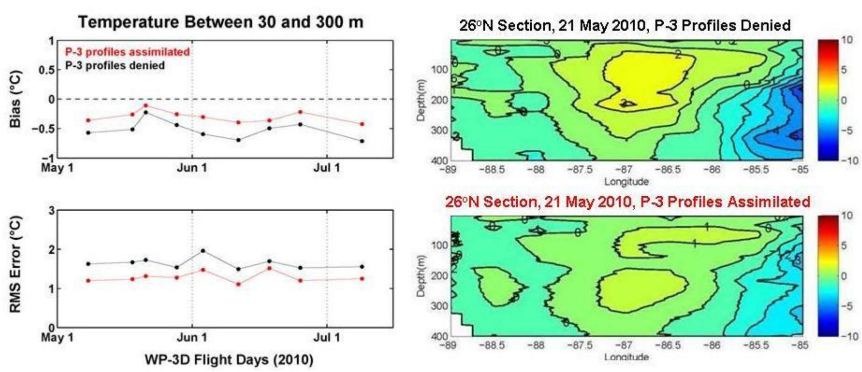


Figure 1: Mean bias (°C: top left panel) and RMS error (°C: bottom panel) for temperature between 30 m and 360 m on each of the nine flight dates. The black (red) curves represent model experiments GoM-HYCOM (P3_GoM_HYCOM) where P-3 observations were denied (included). Zonal sections at 26°N across the detaching Eddy Franklin on 21 May 2010 for experiments GoM HYCOM (top right panel) and

Research Performance Measure: Objectives are being met on schedule.

Remote Sensing in Support of Climate Research

Project Personnel: R.C. Perez (UM/CIMAS)
NOAA Collaborators: G.J. Goni (NOAA/AOML)
Other Collaborators: J.A. Trinanes (Universidad de Santiago de Compostela, USC)

Long Term Research Objectives and Strategy to Achieve Them:

Objectives: To develop a monitoring system for operational field missions and to implement new techniques for visualizing oceanographic & meteorological data over the Web.

Strategy: Provide operational satellite monitoring capabilities in the Gulf of Mexico and Caribbean. Improve access to satellite Level0-4 products. Develop procedures and implement solutions for improving the rapid processing, visualization and distribution of remote sensing data and products. Provide solutions based on recognized standards for data and services. Promote integration of remote geospatial data sources by embracing and implementing service-oriented-architecture (SOA) solutions.

CIMAS Research Theme:

***Theme 3*:** Sustained Ocean and Coastal Observations (*Primary*)
***Theme 1*:** Climate Research and Impact (*Secondary*)

Link to NOAA Strategic Goals:

***Goal 5*:** Mission Support (*Primary*)
Goal 2: Understand Climate Variability and Change to Enhance Society's Ability to Plan and Respond (*Secondary*)
Goal 3: Serve Society's Needs for Weather and Water Information (*Tertiary*)

Funding Unit: OAR/AOML and NOAA/NESDIS **NOAA Technical Contact:** Alan Leonardi

Research Summary:

The first phase of this project is designed to provide raw and processed quality satellite products to scientists, decision-makers and the general public, ensuring reliable data availability and accessibility. The range of primary satellite products include sea surface height, sea surface temperature fields, ocean color and surface winds. Work associated with this project involves management and operation of the High Resolution Picture Transmission (HRPT) satellite receiving station at NOAA/AOML. During this last year, we have continually received direct broadcast HRPT data from NOAA/POES satellites and have completed and validated the operational processing of Eumetsat's MetOp-A satellite data. Within this project, we provide NOAA/NESDIS Office of Satellite Data Processing and Distribution, and CLS/ARGOS with rapid access to the received HRPT telemetry and DCS/TIP data, respectively.

Following NOAA/NESDIS/CoastWatch and NOAA/AOML requirements and goals towards promoting interoperability and information sharing, data distribution combines the traditional approach that provide direct access to data files through a URL, with other state-of-the-art technologies such as OPeNDAP, THREDDS, ERDDAP and OGC Web services (**Figure 1**). Through the implemented interfaces, users can download satellite products in a variety of data and image formats such as MAT-files, NetCDF and KML.

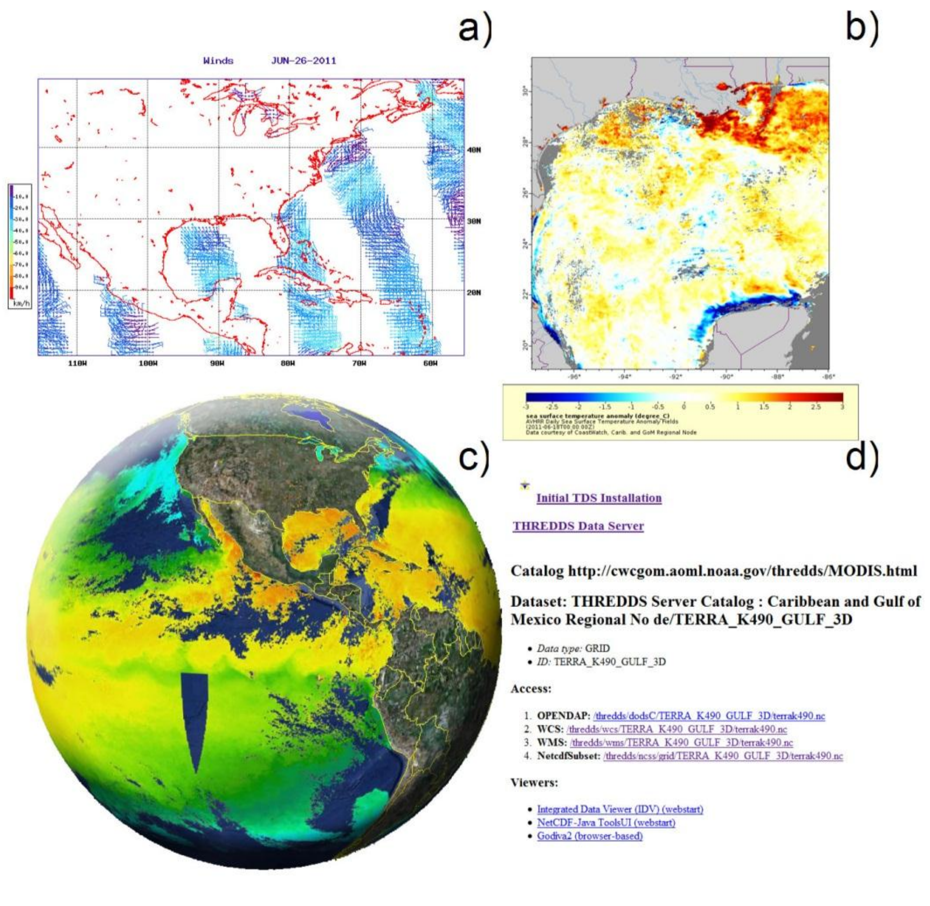


Figure 1: Some of the satellite products being distributed using the techniques described in this report: a) ocean surface winds from ASCAT ascending passes on Jun 26th 2011; b) 1-km sea surface temperature (SST) anomalies for Jun 18th 2011 obtained from HRPT data received at NOAA/AOML; c) GOES SST fields for Jun 26th 2011 exported to KML and displayed in Google Earth; d) THREDDS catalog for the 3-Day Diffuse Attenuation Coefficient at 490 nm from MODIS/Terra. This page specifies the data services that provide access to the dataset.

The data visualization schema comprises web tools that users can use to dynamically select the region of interest, modify the color palette, and combine local and remote layers, among other features (**Figure 2**). This approach makes extensive use of open Web Services such as Web Map Services (WMS), Web Feature Services (WFS) and Web Coverage Services (WCS). These standards provide a XML-based well-defined interface, and are independent of programming languages, operating systems and hardware. They can be put together to create composite services, are highly scalable, and both humans and applications can interact with them. As a result, remote users can integrate our products within their computing environment (**Figure 3**).

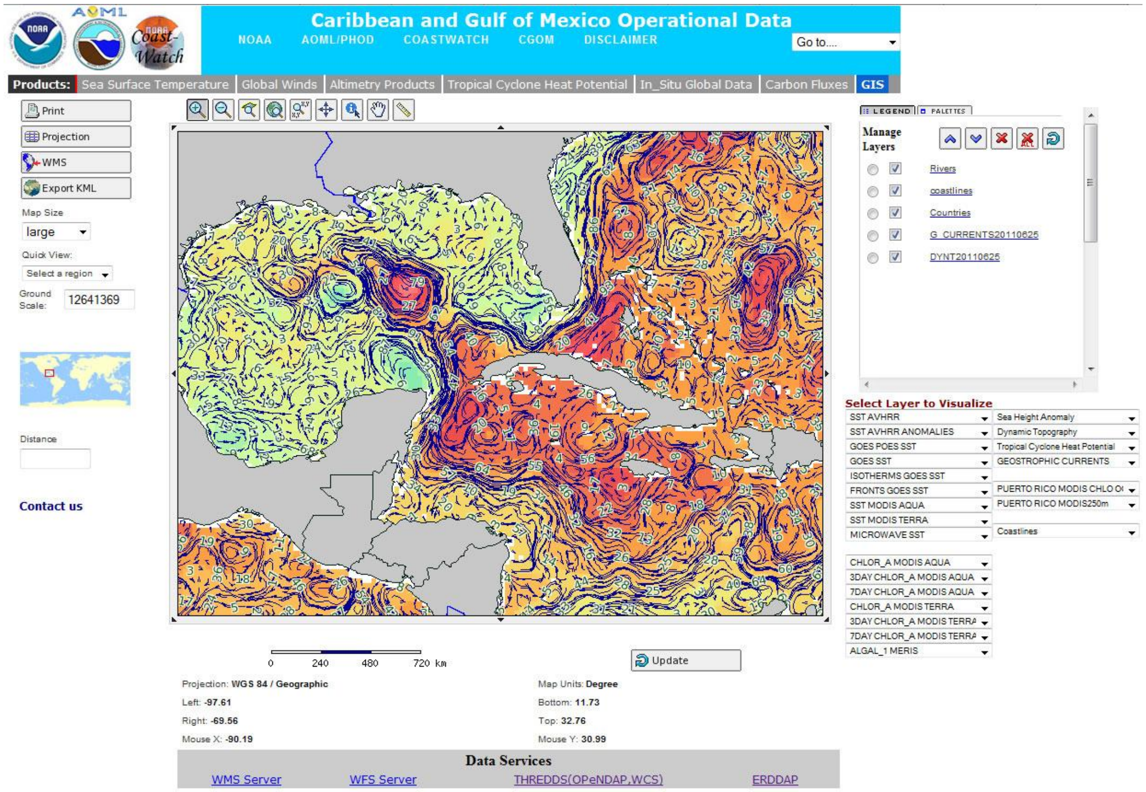


Figure 2: WebGIS interface showing a combination of raster and vector layers: dynamic topography on Jun 25th 2011 (raster) and corresponding geostrophic currents (vector). We included additional vector layers (rivers, coastlines and countries) from external WMS and WFS servers.

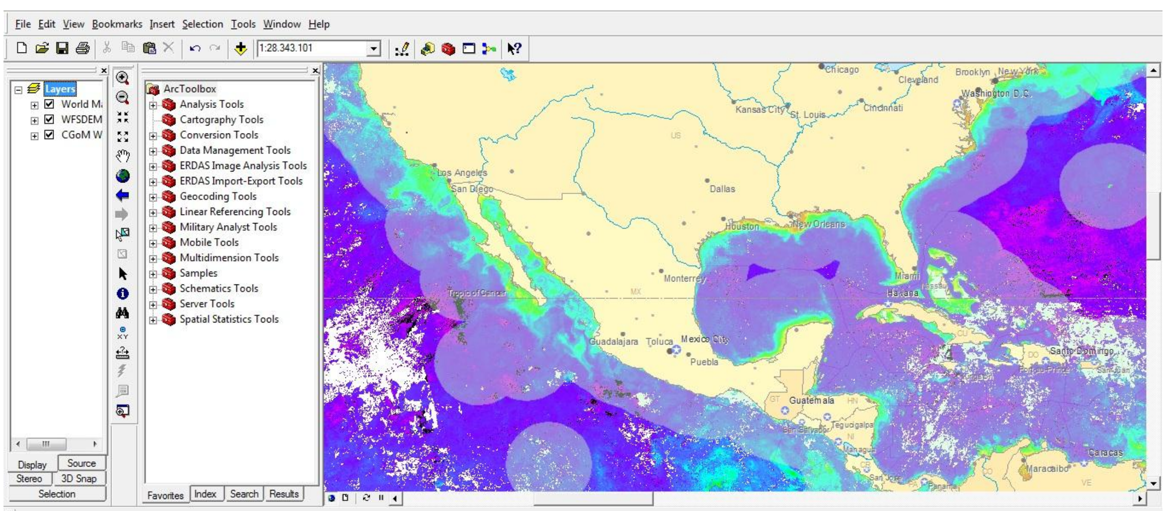


Figure 3: OGC services allow to integrate layers from remote servers within the user's working environment. This example shows the typical ArcGIS desktop interface that includes layers obtained from our servers through Web Services (the 1-km weekly MODIS/Aqua chlorophyll field and the EEZ areas).

Raw and Level1 satellite data serve as basis to generate higher level products. Within the full suite of products provided by the CoastWatch Caribbean and Gulf of Mexico Node and NOAA/AOML, we will focus on the Maximum Chlorophyll Index (MCI), a measure of the radiance peak at 709 nm obtained from MERIS. The main objective of this work is to track sargassum in the Gulf of Mexico and Caribbean regions. MCI can be an indicator of phytoplankton abundance and aquatic vegetation, such as sargassum, that plays a vital role in providing habitat to a wide range of species, including turtles, fish and birds. This satellite product can provide location and extent of floating sargassum and consequently, can provide a way to remove false positives when using SAR imagery for oil spill detection. It has been integrated within a Google Maps and ncWMS web interfaces (**Figure 4**).The final product is served at 2 different spatial resolutions: 300 m from the Full Resolution data stream downloaded at Gatineau (Canada) and 1.1 km from the Reduced Resolution data obtained from the European Space Agency through a Cat-1 proposal. The ncWMS interface also provides the capability to modify the color palette, extract the parameter value at a location and create animations between two dates.

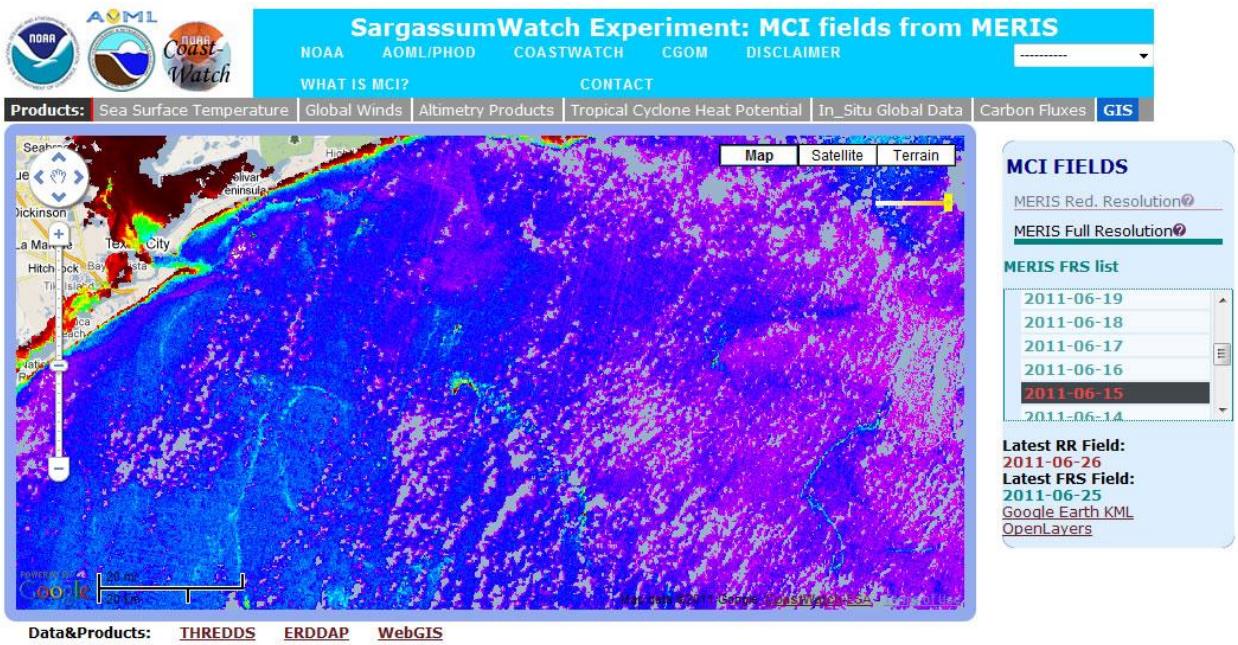
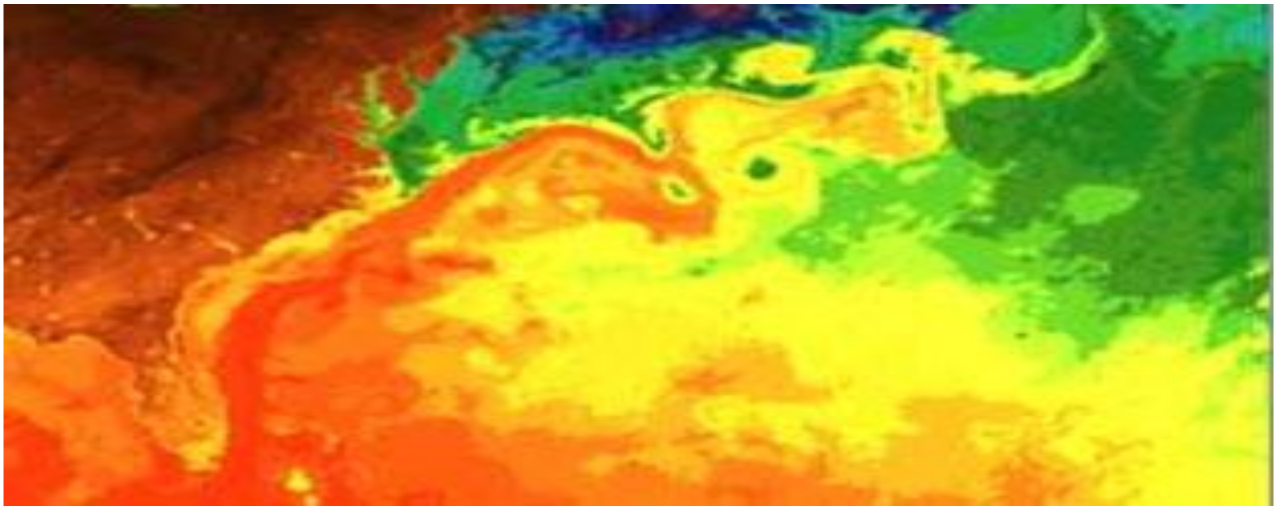


Figure 4: MCI fields on Jun 15th 2011 obtained from Full Resolution MERIS data in the Western Gulf of Mexico. The linear features in the image denote possible floating sargassum regions.

Research Performance Measure: The research goals were met during this last year. New products have been developed and included for online distribution using open standards and protocols. Solutions have been integrated within a service-oriented architecture (SOA).



RESEARCH REPORTS

THEME 4: Ocean Modeling

Hydrodynamic Modeling in Support of the Oil Spill Response in the Gulf of Mexico

Project Personnel: M. Le Hénaff (UM/CIMAS); V. Kourafalou and A. Srinivasan (UM/RSMAS)
NOAA Collaborators: George Halliwell (NOAA/AOML)

Long Term Research Objectives and Strategy to Achieve Them:
***Objectives*:** To develop a high resolution numerical model for the Gulf of Mexico and perform simulations over the Deepwater Horizon oil spill accident period (April-September 2010), in support of oil spill modeling.
***Strategy*:** To perform free-running simulations to study important aspects of the Gulf of Mexico circulation (with a focus on the Loop Current variability) and data assimilative simulations that can provide improved hindcasts of the year 2010, with a focus on the Deepwater Horizon oil spill event; and to use the experience gained toward an advanced predictive tool for the future monitoring of the Gulf of Mexico.

CIMAS Research Theme:
***Theme 4*:** Ocean Modeling (*Primary*)
***Theme 5*:** Ecosystem Modeling and Forecasting (*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*)

Funding Unit: OAR/AOML **NOAA Technical Contact:** Alan Leonardi

Research Summary:
Shortly after the Deep Water Horizon oil spill occurred, modelers based at NOAA/AOML/PhOD, University of Miami (RSMAS), and the Cooperative Institute for Marine and Atmospheric Studies (CIMAS) commenced an emergency collaborative effort to develop improved ocean nowcast and forecast products to monitor and predict the spill. This effort has involved ocean modelers and data assimilation experts that use the HYbrid Coordinate Ocean Model (HYCOM; Chassignet *et al*., 2007) who are part of the recently-established AOML/CIMAS Ocean Modeling and OSSE* Center (OMOC), (co-directors G. Halliwell, AOML; V. Kourafalou, RSMAS), and also has involved collaboration with regional Gulf of Mexico (GoM) modelers (P. Hogan, NRL-SSC) and ocean trajectory modelers (A. Mariano and C. Paris, UM/RSMAS). [*Observing System Simulation Experiments]

Building on this development work, this project has undertaken a comprehensive ocean modeling effort in support of oil spill studies. The modeling tasks have been designed to produce and disseminate optimized ocean nowcast and forecast products through model improvements and the use of advanced data assimilation methods. The modeling system will support the long-term goal of observing system design studies in the Gulf of Mexico.

We have built on experience gained for oil particle modeling using the regional GoM-HYCOM (Gulf of Mexico Hybrid Coordinate Ocean Model, ~3.6 km horizontal resolution) which covered the Deepwater Horizon (DH) oil spill period (April-September 2010) in real time (collaboration with NRL-SSC). Using surface trajectory modeling, we showed that development and shedding of the Loop Current (LC) Eddy Franklin (anticyclonic LC ring) played an important role in disrupting the connectivity of South Florida to the DH spill site (Mariano et al., 2011). We also took part in the development of a full 3-D Lagrangian oil spill model, based on the Connectivity Modeling System (CMS, collaboration with C. Paris through an ancillary NSF project). We showed the crucial role played by the wind during the DH event. The related wind induced drift favored the containment of the main spill in the Northern GoM (**Figure 1**).

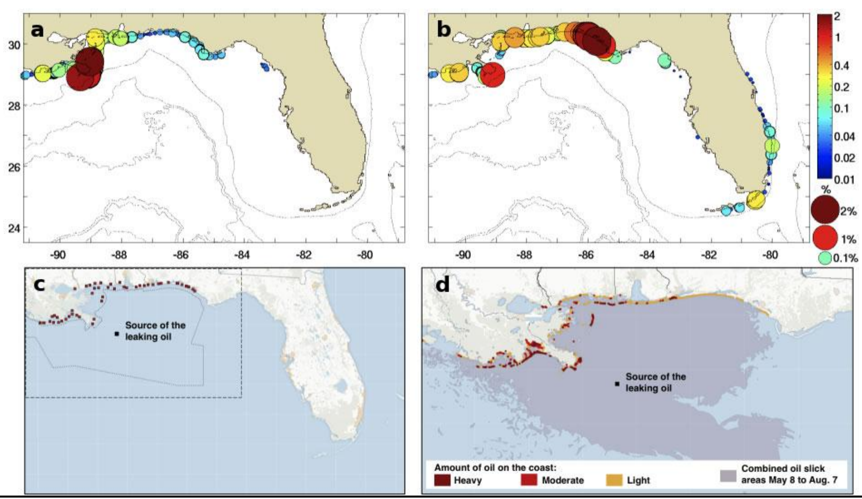


Figure 1: Observed and simulated oil landfall: (a) Total quantities of oil affecting the Gulf coasts (% of total oil particles making landfall along a 1 km segment) in the simulation including wind-induced drift. (b) Same as (a), but for the simulation ignoring the wind-induced drift . (c) Coastal locations affected by oil landfall (red spots). (d) Zoom over the northern Gulf of Mexico area, defined by the border dashed line on (c), with the level of oil presence on August 7, 2010; the grey zone is the Gulf of Mexico area affected by oil presence during the whole oil spill event. (c) and (d) are adapted from observational composites at the New York Times website (www.nytimes.com/interactive/2010/05/01/us/20100501-oil-spill-tracker.html). Thin black lines in (a, b) are the 200, 2000 and 3000 m isobaths.

To better understand the role of Eddy Franklin in the DH period, we have also performed a free-running, multi-year simulation of the above predictive model to investigate the dynamics of frontal eddies, which play a major role in the detachment of the LC anticyclonic rings. The frontal cyclones appear to have a structure extending to the deep layers of the GoM. They are intensified when the extended LC flows over the northern GoM shelf slope, through a "promontory effect" involving the aggregation of potential vorticity anomalies in the deep part of the cyclone. This leads to the intensification of the relative vorticity, hence the vertical circulation, of the whole structure, including in the upper layers. We have demonstrated that LC frontal eddies tend to split, between upper and deep parts, and merge with each other, horizontally or vertically. Such merging is crucial for sustaining or strengthening the cyclone intensity, promoting its ability to influence the LC variability (such as the ring shedding events).

A new GoM-HYCOM model was developed for this project, recognizing that certain attributes were missing from existing models. First, the new regional GoM model has a horizontal resolution of ~1.8 km (and thus called the GoM-HYCOM $1/50^0$ model), which is between 1.6 and 4 times finer than the resolutions of existing operational products. It can, therefore, resolve smaller scales along with the narrow convergence zones of ocean fronts associated with the Loop Current and eddies where oil and other debris tends to accumulate. Second, it contains an improved representation of river plume dynamics (Schiller and Kourafalou, *Ocean Modeling*, 2010), which is critically important to oil spill dispersion in the Northern Gulf due to the Mississippi River plume. In contrast, all existing global and regional ocean models relax salinity to climatology, thus degrading the river impact. Finally, an updated data assimilation scheme has been successfully adopted (SEEK: Singular Evolutive Extended Kalman filter).

We have performed several simulations with the GoM-HYCOM $1/50^0$ model. A free running simulation for the years 2007-2009 has been completed to test the realism of the configuration and derive the statistics necessary for the data assimilation step. Two data assimilative simulations, based on the SEEK filter, have been performed for the period of Spring 2010, during the DH oil spill. The first assimilates the Sea Surface Height (SSH) derived from altimetry; the second assimilates the same SSH as well as remotely sensed Sea Surface Temperature (SST). The simulation with assimilation of both SSH and SST gives the best results. The assimilation of the along-track sea level anomaly, together with the SST, allows for the correction of the model surface dynamics in a couple of weeks and provides a description of the GoM close to what is observed (**Figure 2**).

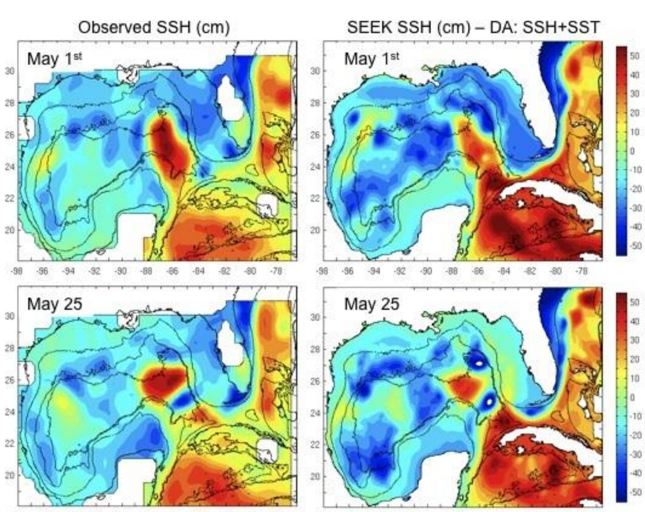


Figure 2: Observed (left) and modeled (right) Sea Surface Height (SSH, cm). The observations are from AVISO altimetry maps, the model simulation is the predictive GoM-HYCOM 1/50° model with the Singular Evolutive Extended Kalman (SEEK) data assimilation filter, incorporating along-track altimetry and satellite Sea Surface Temperature (SST) measurements.

Research Performance Measure: The free running simulations have been successfully evaluated with several observational data sets. Mean Absolute Dynamical Topography (MADT) maps from Aviso, Reynolds analyzed SST maps from AVHRR and AMSR satellites and NODC/MMS hydrographic data. Similar evaluation is now taking place for the predictive GoM-HYCOM $1/50^0$ model. In addition, a wealth of observations became recently available, as part of academia and government response to the Deepwater Horizon oil spill accident in spring-summer 2010; preliminary evaluation using these data has also commenced.

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Quantifying Prediction Fidelity in Ocean Circulation Models

Project Personnel: W. C. Thacker (UM/CIMAS); M. Iskandarani and A. Srinivasan (UM/RSMAS)
Other Collaborators: O. Knio (Johns Hopkins University)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** To develop, to validate and to demonstration new methods for uncertainty quantification in ocean circulation models.

***Strategy*:** To explore the use of the method of polynomial chaos expansions for quantifying uncertainties in model outputs stemming from uncertainties in their inputs.

CIMAS Research Theme:

***Theme 4*:** Ocean Modeling

Link to NOAA Strategic Goals:

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

Funding Unit: ONR **NOAA Technical Contact:** Alan Leonardi

Research Summary:

When a model provides quantitative estimates of the ocean's behavior, the estimates are more valuable when information about their uncertainty is also provided. A class of uncertainties that might be quantified are those resulting from the choice of the model's input parameters. The straightforward Monte Carlo approach of sampling the possible values of the inputs according to their likelihood is impractical due to the immense number of model simulations required to explore the many inputs. Focusing on a few important inputs can make the problem more manageable, but even then the number of combinations of input values to explore remains huge. The method of polynomial chaos expansions can reduce the number of simulations to something more affordable.

The dependence of the model's estimate on the input parameters is expressed by a truncated polynomial expansion, and the problem becomes that of evaluating the expansion coefficients. The coefficients, which can be expressed as integrals over possible input values, can be evaluated by quadrature, with the locations of the quadrature points determining the simulations that are needed. While the information about the output uncertainties is approximate, as computational resources dictate the number of terms retained in the expansions and the number of quadrature simulations, it can be highly useful and better information from other methods at the same computational cost is unlikely.

As a demonstration of the method we have explored how uncertainties in the flow from the Caribbean Sea into the Gulf of Mexico manifests in the Gulf's surface elevation field. Uncertainties in the multivariate spatially and temporally varying inflow were described by two modes, the amplitudes of which were assumed to be independent random variables. Surface elevations were then assumed to be polynomial series in these two variables truncated at total degree of six, and 49 simulations were used to compute the coefficients by quadrature. Variances and covariances of the surface elevation field were computed, as were kernel estimates of probability densities (See **Figure 1**).

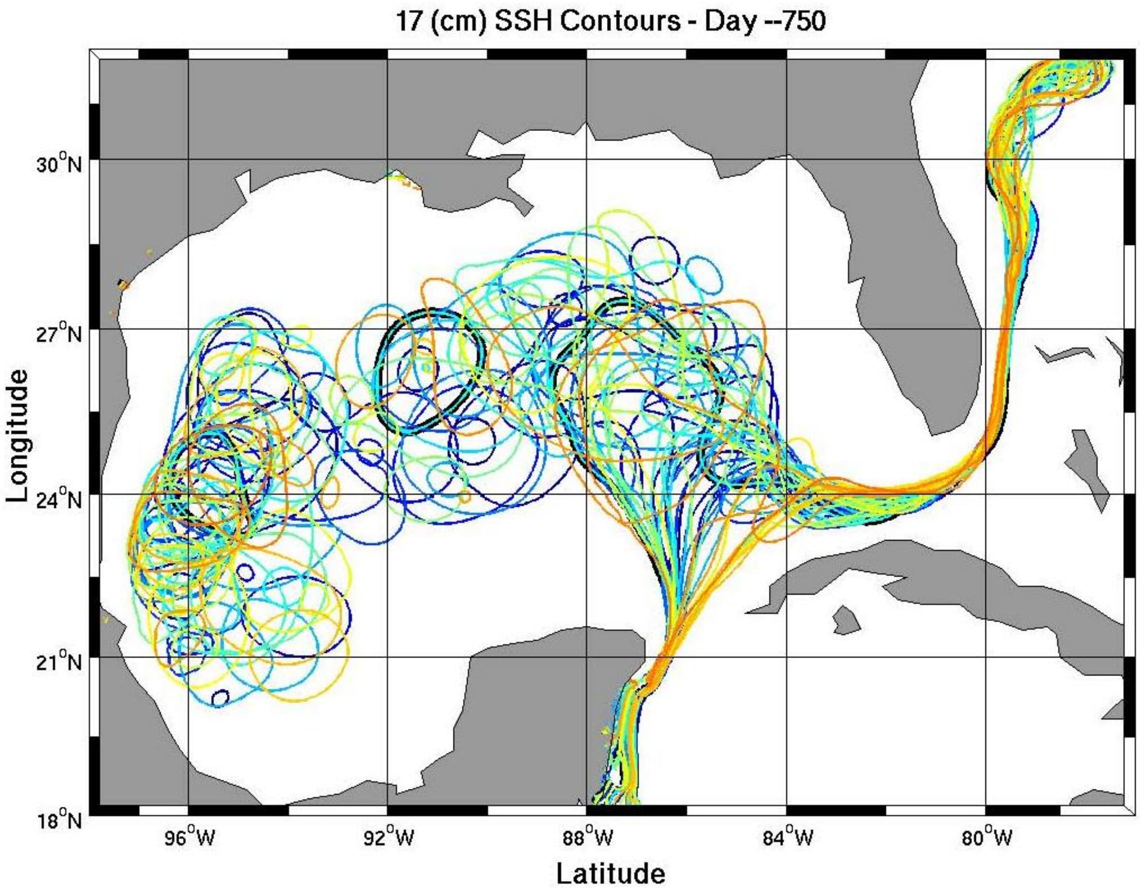

Figure 1: Curves indicate 17 cm contours of surface elevation for the 49 quadrature simulations. Clearly these simulations capture a wide variety of configurations of the Gulf Streams and its rings resulting from uncertainties in the specification of the inflow from the Caribbean Sea.

Research Performance Measure: Objectives are being met.

What Causes the Tropical Atlantic SST Bias in CCSM3?

Project Personnel: S.-K. Lee, H. Liu and D. Enfield (UM/CIMAS); B. Kirtman (UM/RSMAS)
NOAA Collaborators: C. Wang (NOAA/AOML)

Long Term Research Objectives and Strategy to Achieve Theme:
***Objectives*:** To identify processes and/or parameterizations in the coupled models that are responsible for generating the tropical Atlantic SST bias in the NCAR community climate system model version 3 (CCSM3).
***Strategy*:** To perform coupled model experiments using CCSM3 and to diagnose the mixed layer heat budget.

CIMAS Research Theme:
***Theme 4*:** Ocean Modeling

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

Funding Unit: NSF **NOAA Technical Contact:** Alan Leonardi

Research Summary:
Despite our growing recognition for the important role of tropical Atlantic atmosphere-ocean processes on climate variability, almost all of the state-of-the-art atmosphere-ocean coupled climate models cannot reproduce the annual cycle of tropical Atlantic SSTs. Due to this shortcoming in the climate models, currently we do not have a skill to simulate or to forecast the tropical Atlantic climate variability. In order to identify the processes (or terms) that contribute significantly to the tropical Atlantic SST bias in CCSM3, we have performed three primary ensemble experiments using CCSM3. These experiments are a forced atmosphere-land model experiment (EXP_ATM), a forced ocean-ice model experiment (EXP_OCN) and a fully coupled model experiment with its atmosphere-land model initialized using EXP_ATM and the ocean-ice model using EXP_OCN. By analyzing the mixed heat budget biases in the three models experiments, we find that the ocean model is responsible for large biases in oceanic heat flux terms in three key regions, namely the southeastern tropical Atlantic (SE_TA), the central and eastern equatorial Atlantic (CE_EA), and the northwestern tropical Atlantic (NW_TA). The ocean model SST bias patterns in these regions associated with the oceanic heat flux bias are consistent with those of the coupled model. The atmosphere-land model contains a large bias in terms of surface wind and associated latent heat flux (**Figure 1**). In particular, the atmosphere-land model experiment clearly shows a large reduction of latent cooling in SE_TA and CE_EA due to a weaker-than-observed surface wind. In the NW_TA and SW_TA, on the other hand, the atmosphere-land model experiment clearly shows a large increase of latent cooling due to a stronger-than-observed surface wind. When the atmosphere model and ocean model are coupled, these atmosphere model errors work in collaboration with the ocean model errors to amply the ocean model SST bias.

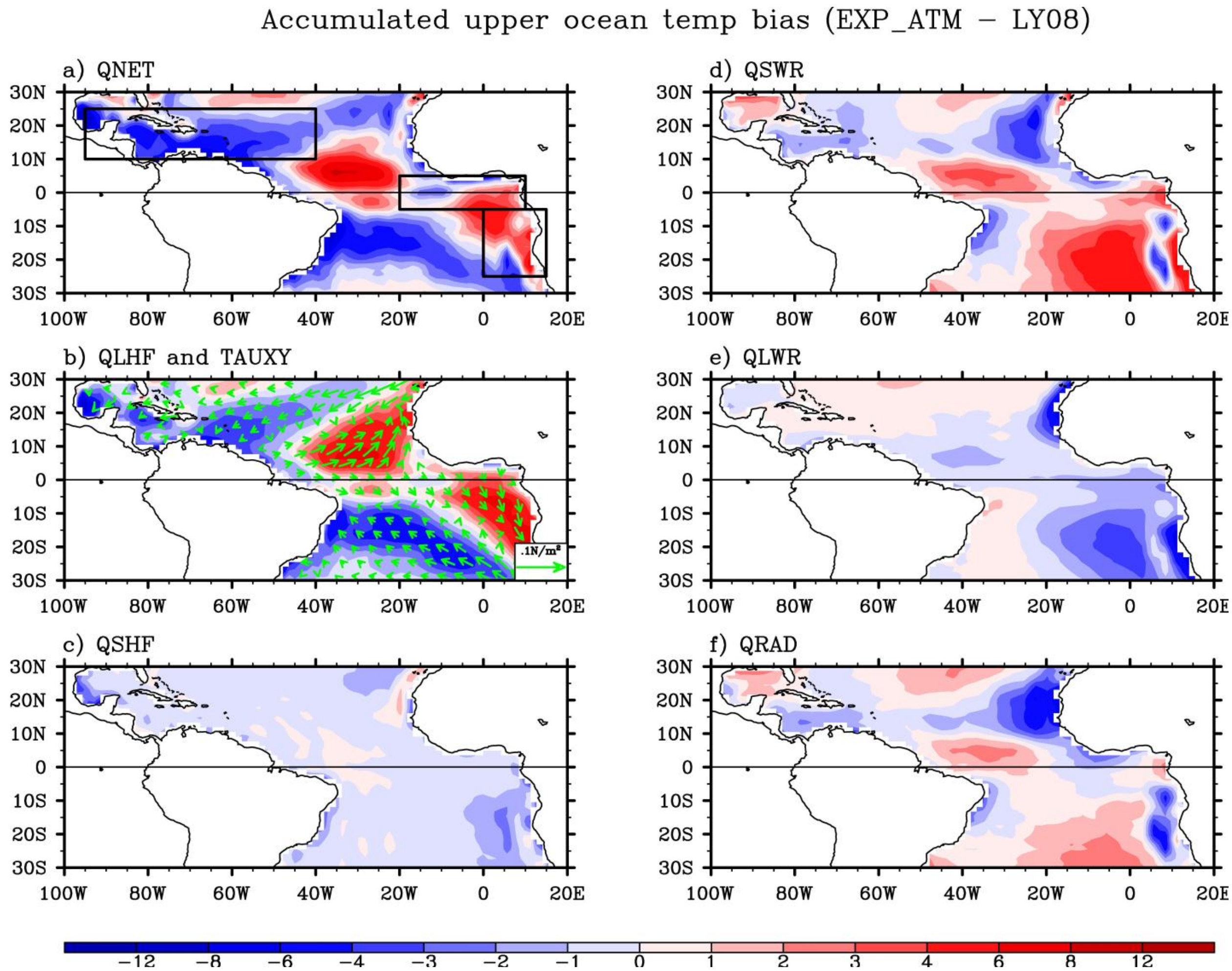

Figure 1: The accumulated mixed layer temperature bias after one year due to (a) net surface heat flux bias, (b) latent heat flux bias, (c) sensible heat flux bias, (d) shortwave radiative heat flux bias, (e) long wave radiative heat flux bias, and (f) net (shortwave + longwave) radiative flux bias in the forced atmosphere-land model experiment (EXP_ATM). The vectors in (b) show the annual mean surface wind stress bias.

Research Performance Measure: We achieved our main objective for the first year: To perform the three primary CCSM3 runs and to carry out a comprehensive mixed layer heat budget analysis.

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

Project Personnel: R.C. Perez (UM/CIMAS)
NOAA Collaborators: S.L. Garzoli and C.S. Meinen (NOAA/AOML)
Other Collaborators: R.P. Matano (OSU/COAS)

Long Term Research Objectives and Strategy to Achieve Them:
***Objectives*:** To determine suitable latitudes for the deployment of a trans-basin meridional overturning circulation (MOC) and meridional heat transport (MHT) array in the South Atlantic.
***Strategy*:** To conduct observing system experiments within high-resolution ocean general circulation models to design a trans-basin array.

CIMAS Research Theme:
***Theme 4*:** Ocean Modeling (*Primary)*
***Theme 3*:** Sustained Ocean and Coastal Observations (*Secondary*)
***Theme 1*:** Climate Research and Impact (*Tertiary*)

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

Funding Unit: OAR/AOML **NOAA Technical Contact:** Alan Leonardi

Research Summary:
Variations in the ocean's MOC are strongly correlated to important climatic changes in precipitation and surface air temperatures. The Atlantic component of the MOC includes the sinking of surface waters at high latitudes in the North Atlantic, meridional translation of these deep waters around the world, gradual upwelling, and a return to the deep-water formation regions through the South Atlantic. However, model studies show that the South Atlantic is not just a passive conduit for water masses formed in other regions of the world ocean, but instead actively participates in their transformation. The South Atlantic also plays a significant role in the establishment of oceanic teleconnections: the Agulhas leakage reaches the northern hemisphere, and models suggest that changes occurring in the South Atlantic alter the global MOC. These results highlight the need for sustained observations in the South Atlantic that in conjunction with modeling efforts would improve our understanding of the processes necessary to formulate long-term climate predictions.

Model sampling experiments have been used to test the ability of *in situ* geostrophic velocity measurement systems to measure the MOC and MHT in the extra-tropical South Atlantic. Two methods of estimating geopotential height anomalies and geostrophic velocities were tested, simulating dynamic height moorings and current and pressure recording inverted echo sounders (CPIES) deployed within the models. It was shown that MOC and MHT reconstructions from arrays of dynamic height moorings and CPIES have comparable skill at higher latitudes, and that an realistically-sized array of approximately 20 instruments can be effectively used to reproduce the temporal evolution and vertical structure of the MOC and MHT along 34.5°S. Based on the sampling experiments, the South Atlantic MOC community intends to deploy a balanced array (including both dynamic height moorings and CPIES) of approximately 20 instruments along the nominal latitude of 34.5°S (see **Figure 1**).

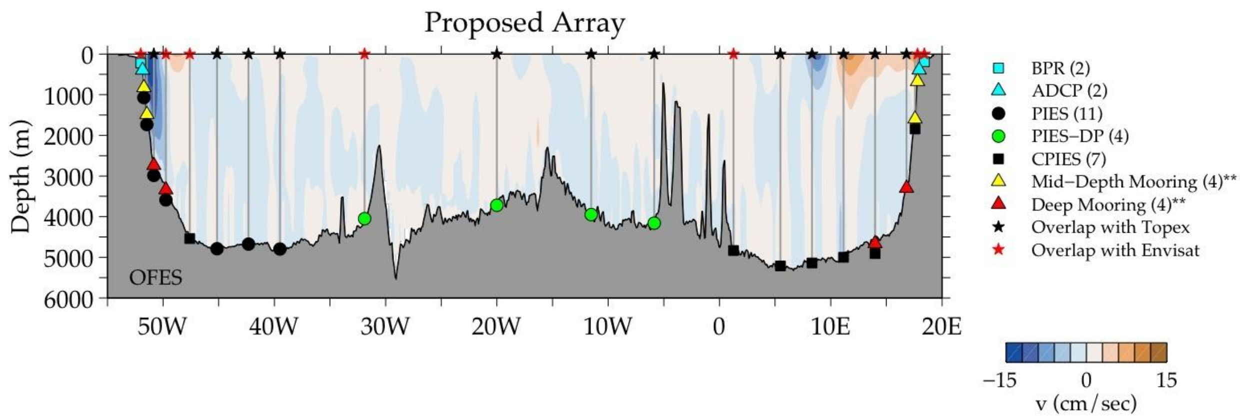

Figure 1: Schematic of the proposed trans-basin array along 34.5°S. The array consists of bottom pressure gauges, ADCPs, mid-depth and deep dynamic height moorings, PIES, PIES-with datapods, and CPIES. Black and red asterisks denote sites that overlap with JASON and Envisat altimetry groundtracks, respectively. Color contours show mean meridional velocity from a numerical simulation.

Research Performance Measure: Based on our findings, several proposals have been submitted to request support for a trans-basin array along 34.5°S (Figure 1). One paper is under revision for Journal of Atmospheric and Oceanic Technology - Oceans.

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Observing System Simulation Experiments for the Atlantic Meridional Overturning Circulation

Project Personnel: C. Thacker and H. Yang (UM/CIMAS)
NOAA Collaborators: G. Halliwell (NOAA/AOML)

Long Term Research Objectives & Strategy to Achieve Them:

***Objectives*:** To design optimal observing system strategies to monitor changes in the Atlantic Meridional Overturning Circulation (AMOC), particularly changes that are potentially related to rapid climate change.

***Strategy*:** To develop the capability of performing Observing System Simulation Experiments (OSSEs) and Observing System Experiments (OSEs) at NOAA/AOML and use these systems for observing system design; to perform "virtual OSSEs" to conduct preliminary assessments of AMOC observing strategies.

CIMAS Research Theme:

***Theme 4*:** Ocean Modeling (*Primary*)
***Theme 3*:** Sustained Ocean and Coastal Observations (*Secondary*)
***Theme 1*:** Climate Research and Impact (*Tertiary*)

Link to NOAA Strategic Goals:

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

Funding Unit: OAR/CPO **NOAA Technical Contact:** James F. Todd

Research Summary:

The primary goal of this project is to develop and test an OSSE system that can be used to design ocean observing strategies for monitoring the Atlantic Meridional Overturning Circulation (AMOC). Substantial progress was made during the first 2.5 years in terms of developing the required software toolboxes and testing early versions of these toolboxes by performing a "demonstration" OSSE that used a low-resolution Atlantic Ocean model. These results were promising but not publishable due to the use of sub-optimal model configurations to efficiently test the code. The next steps were designed to set up and perform a more realistic and rigorous OSSE and publish the results. This initial OSSE uses the "fraternal twin" approach; i.e., using one model type (HYCOM) as the nature run and also as the ocean model component of the operational data assimilation system. The key to this approach is to employ two substantially different configurations of HYCOM that reproduce the same level of uncertainty between them in the representation of the AMOC that is achieved by present-day state-of-the-art ocean models with respect to the actual ocean.

For the nature run, HYCOM was run in a sigma-z vertical coordinate configuration in a fully global domain for 1948-2010. This run was recently completed and is now undergoing analysis. The operational data assimilation system uses HYCOM within an Atlantic Ocean domain that is nested within the global HYCOM model, where the standard hybrid vertical coordinate configuration is employed for both the Atlantic domain and the global outer model. The two model domains are illustrated in **Figure 1**. The AMOC streamfunction maps presented in **Figure 2** demonstrate that the nature run (sigma-z global model) and the operational model (here run without data assimilation) generate substantially different representations of the strength of the AMOC and are suitable choices for the two OSSE models.

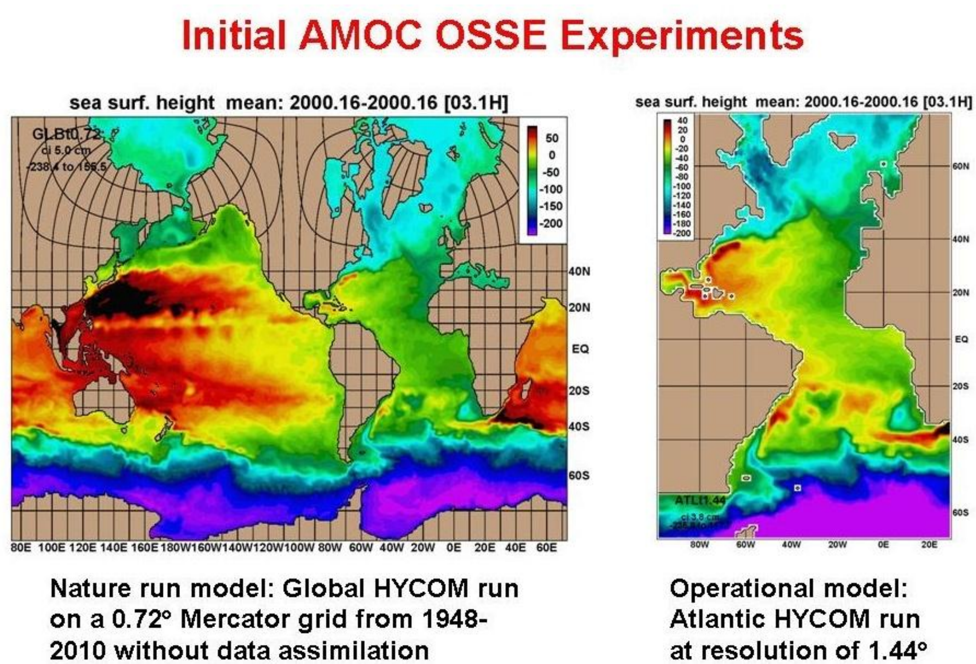
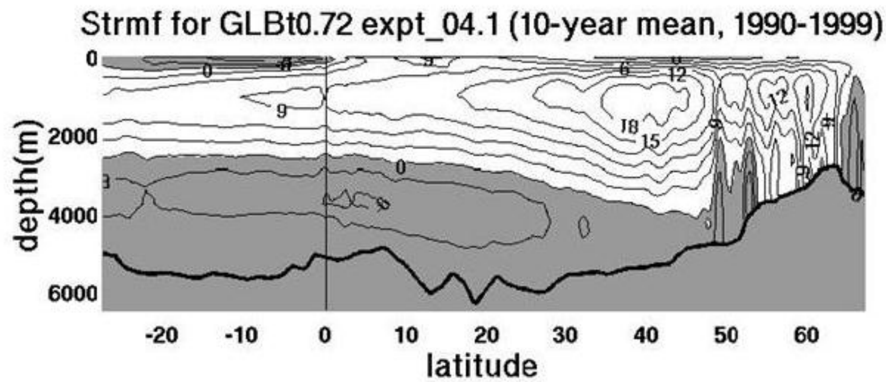
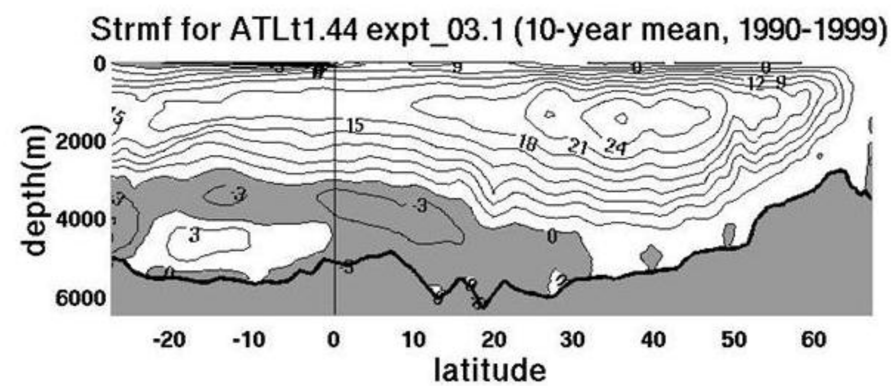


Figure 1: The global and Atlantic Ocean domains used for the OSSE nature run and operational models, respectively. Both panels show sea surface height for February 29, 2000.

data assimilation system for the OSSEs is nearing completion. Ashwanth Srinivasan is developing the data assimilation software along with the communication software required for ocean forecasting. He is expected to deliver this code within two weeks of this writing. At that time, we will set up this new code for performing the Atlantic AMOC OSSEs. This new code contains four data assimilation methods (Multi-Variate Optimum Interpolation, Sequential Extended Evolutive Kalman Filter, Ensemble Kalman Filter, and Reduced Order Information Matrix). The initial OSSEs will sample satellite altimetry and SST along with Argo floats and XBT transects sampled from the nature run. The planned initial experiment will be designed to determine the impact of extending Argo profiles below 2000 m on monitoring changes in the AMOC.



Overturning Streamfunction in GLBt0.72, 10-year mean (1990-1999)

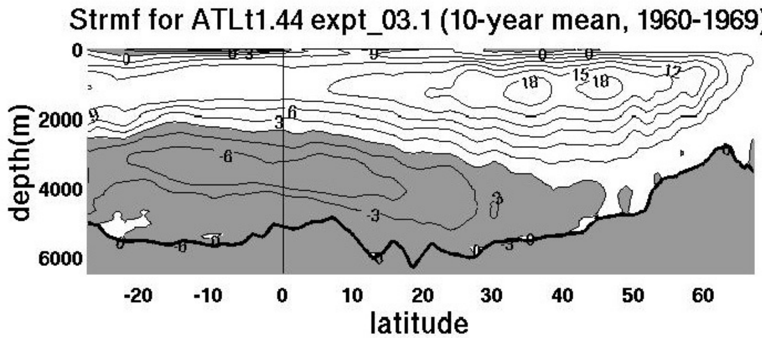


Overturning Streamfunction in ATLt1.44, 10-year mean (1990-1999)

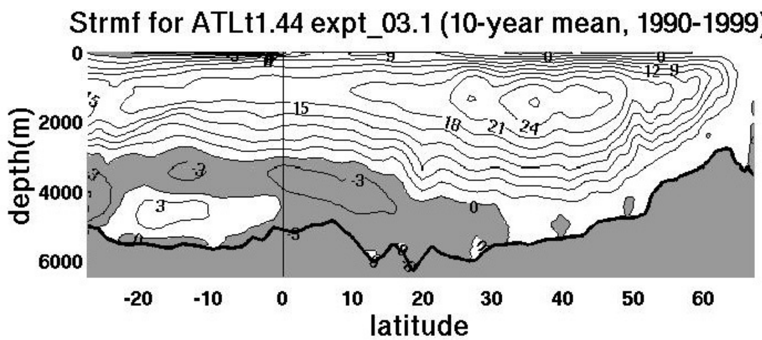
Figure 2: AMOC zonally-integrated streamfunction averaged over 1990-1999 from the global HYCOM simulation using the sigma-z vertical coordinate configuration (nature run, top) and from an Atlantic Ocean simulation nested within a global HYCOM run (bottom), both of which used the hybrid vertical coordinate configuration. The hybrid Atlantic model is the ocean model for the data assimilation system that will be used to perform the rigorous OSSEs. Significant differences in the magnitude and structure of the streamfunction maps is evident.

Finally, we have commenced scientific analysis of the new 1948-2000 global HYCOM simulation along with Atlantic Ocean simulations nested within this global model. In particular, we are focusing on two time intervals (1960s vs. 1990s) when the AMOC was relatively weak and strong respectively. Differences in the strength of the AMOC between these two intervals are illustrated in **Figure 3**.

Hybrid (Atlantic)



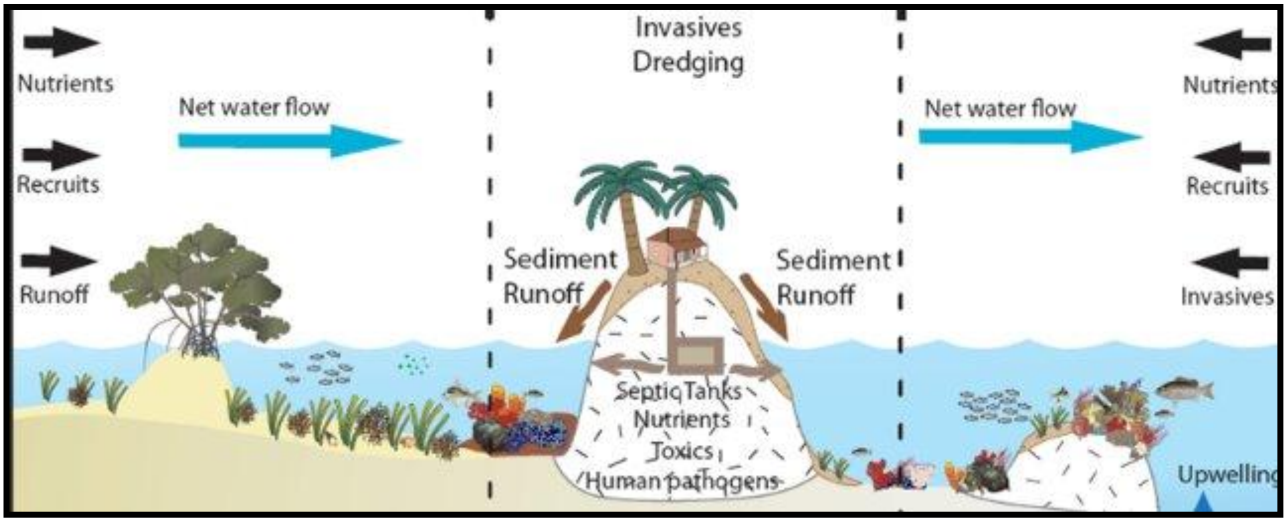
Overturning Streamfunction in ATLt1.44, 10-year mean (1960-1969)



Overturning Streamfunction in ATLt1.44, 10-year mean (1990-1999)

Figure 3: AMOC zonally-integrated streamfunction from the hybrid-coordinate nested Atlantic Ocean simulation averaged over the 1960s (top) and the 1990s (bottom). The stronger AMOC during the latter interval is associated with a large multi-decadal signal in the simulated AMOC. Differences between these two intervals are being explored to understand model adjustments associated with this long-period signal.

Research Performance Measure: Preparation for the rigorous AMOC OSSEs required running two global HYCOM runs with the two vertical coordinate configurations over several decades, a task that took several months. The nested Atlantic model was then set up and tested. During the next few months, our goal will be to set up and run rigorous OSSEs using the new ocean forecasting system. We intend to prepare three publications, one focusing on the AMOC OSSEs, another focusing on multi-decadal changes in the AMOC and associated global overturning using the global model runs, and the other presenting results from a “virtual OSSE” analysis developed by Carlisle Thacker.



RESEARCH REPORTS

THEME 5: Ecosystem Modeling and Forecasting

Development of a Fishery Ecosystem Model for the Gulf of Mexico

Project Personnel: D.J. Die and E. Babcock (UM/RSMAS); J. Zabalo (UM/CIMAS)
NOAA Collaborators: M. Shirripa (NOAA SEFSC)
Other Collaborators: C. Ainsworth (USF)

Long Term Research Objectives and Strategy to Achieve Them:
***Objectives*:** To develop an ecosystem model for the Gulf of Mexico to evaluate fishery management strategies
***Strategy*:** To use the ATLANTIS framework (Fulton et al. 2004,) to develop a spatially explicit model of the Gulf of Mexico. By incorporating enough detail on federally managed species we will evaluate whether current management strategies developed for each stock are sufficient and appropriate for the management of the Gulf ecosystem according to the principles of ecosystem-based management.

CIMAS Research Theme:
***Theme 5*:** Ecosystem Modeling and Forecasting (*Primary*)
***Theme 6*:** Ecosystem Management (*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

Funding Unit: NMFS/SEFSC **NOAA Technical Contact:** Theo Brainerd

Research Summary:
The team has started building the team of collaborators that will work on the Gulf of Mexico Ecosystem model. This project will need to obtain funds beyond those currently available at CIMAS

for it, thus we have participated in the preparation of five different proposals for external funding that would provide funds to support major components of this effort:

- D. Die, co-P.I. in the NOAA proposal "Understanding Coral Ecosystem Connectivity in the Gulf of Mexico-Pulley Ridge to the Florida Keys", awarded.
- D. Die collaborator in NOAA CAMEO "Comparative Analyses and Synthesis of the Impacts of Hypoxia on the Connectivity, Stability and Resilience of Coastal Ecosystems" (P.I. J. Pierson, Univ. Maryland), funding for CAMEO cancelled for 2011.
- E. Babcock advisor in NOAA-SEAGRANT – An ATLANTIS model to inform ecosystem-based management for the Gulf of Mexico – (P.I. H. Perryman RSMAS/CIMAS), pending.
- C. Ainsworth P.I., D. Die, collaborator in FL SEAGRANT proposal "Spatial ecological modeling of the Gulf of Mexico supporting an integrated Ecosystem Assessment", pending.
- D. Die lead P.I. and E. Babcock and C. Ainsworth co-P.I. in GRI-I "SC-MEROS Scientific consortium for Marine Ecosystem Restoration after Oil Spills", pending.

Data collection to support the model's parameterization in its southeastern limit will start in earnest with the start of the Pulley Ridge project in Jan 2012. Model development for the Pulley Ridge sub-model will not start until 2013.

We have also started developing the information required to design an ecosystem model of the Gulf of Mexico based on the ATLANTIS software platform (**Figure 1**). With that aim the following activities were undertaken:

- Holly Perryman attended a one week ATLANTIS training session in the summer 2010
- Holly Perryman and Joaquin Zabalo got trained in the use of EWE and its implementation for the Gulf of Mexico – Parameters for such model are to be the starting point of parameters for the ATLANTIS Gulf of Mexico model
- Joaquin Zabalo, joined CIMAS in February 2011. He audited three fisheries classes (Fisheries population Biology MBF 546, Marine population dynamics MBF 613, fishery ecosystems management and conservation MBF 571), during the spring semester 2011 to improve his understanding of fisheries and therefore facilitate the application of his mathematical and modeling knowledge into the research program.
- Co-organized and hosted the ICCAT meeting of the Ecosystems working group in March 2011.

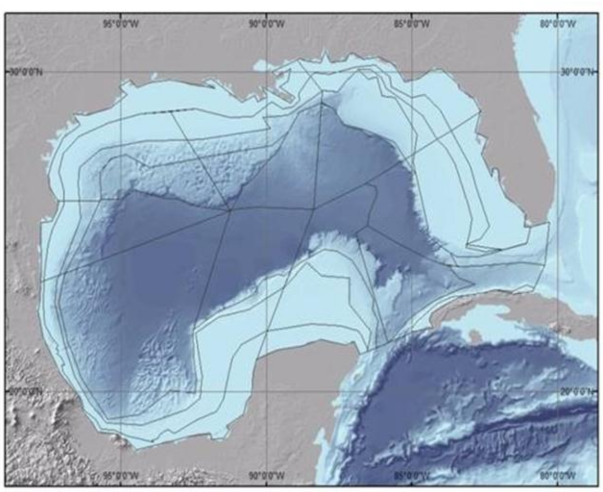


Figure 1: Draft polygon design for GOM Atlantis model (C. Ainsworth pers. Comm.)

Research Performance Measure: We have started gathering data to design the structure of the ATLANTIS Gulf of Mexico model. However, this project has been delayed considerably by the difficulties encountered in recruiting an appropriate candidate for the Post-Doc position. The search took more than one year and this, combined with the fact that the first year of the graduate student was exclusively dedicated to courses and the comprehensive exam, has limited the amount of research conducted.

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

Project Personnel: M.M. Criales and I. Zink (UM/CIMAS)
NOAA Collaborators: J.A. Browder and T. L. Jackson (NOAA/SEFSC)
Other Collaborators: M.B. Robblee (USGS/SESC)

Long Term Research Objectives and Strategy to Achieve Theme:

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

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

CIMAS Research Theme:

***Theme 5**:* Ecosystem Modeling and Forecasting

Link to NOAA Strategic Goals:

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

Funding Unit: NMFS/SEFSC **NOAA Technical Contact:** Theo Brainerd

Research Summary:

We continued the development of an understanding of the ecology and behavior of this important species in Florida Bay and the SW Florida shelf of the Gulf of Mexico. Activities during the past year consisted of complementary laboratory experiments on survival, growth and behavior of pink shrimp postlarvae and juveniles.

Pink shrimp juveniles are found in different salinity regimes ranging from brackish to hypersaline. In FloridaBay, the main nursery grounds, juveniles reside in 25-50 salinity; 20 km to the northwest in Whitewater Bay, juveniles inhabit more estuarine salinities between 5 and 15. We tested the hypothesis that the disparate salinity regimes juveniles tolerate may result from a non-genetic adaptation. These adaptations are the result of acclimation to salinities experienced during postlarval development within respective nursery habitats. Laboratory experiments were conducted to determine *i)*postlarval abrupt salinity change tolerance ranges and effects of differing acclimation salinities on those ranges during postlarval ontogenetic development, and *ii)* the effects of salinity and temperature on postlarval growth and survival.

In the Fall of 2010, salinity tolerance trials were conducted with four postlarval ages (PL15, PL25, PL35 and PL55, PL= days as postlarvae) previously acclimated in two salinities (15 and 35) and then exposed to an abrupt salinity change for 96 h. Results indicated that postlarvae acclimated at 15 tolerated salinities 20 units lower than those acclimated at 35 irrespective of postlarval age (Fig 1). Supporting our initial hypothesis, this demonstrates the species exhibits an ability to shift salinity tolerance ranges relative to acclimation salinity. In addition, we found that the range of salinity tolerance changed during postlarval development (**Figure 1**). Postlarvae of age PL 35 and PL 55 exhibited significantly broader salinity tolerance ranges than those of PL15 and PL25 age. This result suggests that development of more complete osmoregulatory capabilities to cope with abrupt changes in salinity is achieved between 25 and 35 d as postlarvae. This concurs with the age at which planktonic postlarvae settle on sea-grass banks within Florida Bay; it also concurs with studies of the ontogeny of osmoregulatory structure development in other penaeid species. Another interesting result was a reduction in the low salinity tolerance range at the oldest age tested (PL55) (**Figure1**); similar observations have been reported for other penaeid species. However, this observation may be an artifact of laboratory testing conditions and interactions of ammonia toxicity with low salinity tolerance. Building upon the abrupt salinity tolerance range experiment conducted in Fall 2010, similar trials were conducted in the Spring of 2011 to further investigate this potential interaction. Preliminary results suggest utilization of an ammonia-neutralizing agent can improve low salinity tolerance at PL65, suggesting that contraction of salinity tolerance range does not occur until later during ontogenetic development, i.e. during later juvenile stages.

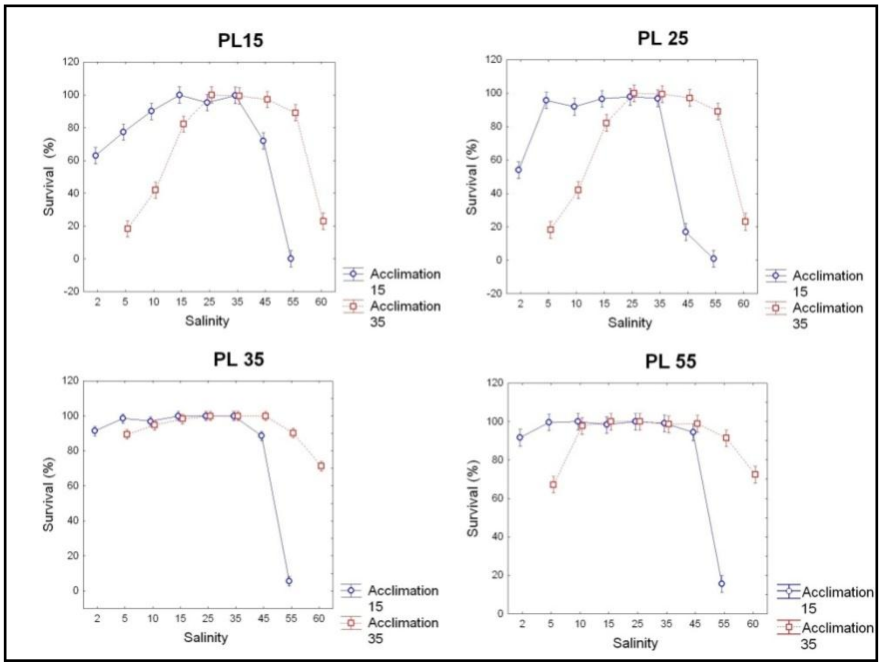


Figure 1: Observed salinity tolerance ranges of pink shrimp postlarvae separated by age (PL= days as postlarvae) after acclimation to salinities of 15 and 35 for 30 days and subsequently exposed to eight salinity treatments for 96 h. Results indicate a shift in salinity tolerance range by acclimation salinity irrespective of postlarval age and an increase in salinity tolerance range with age.

During the Fall of 2010, a growth experiment was conducted to determine the combined effect of salinity and temperature on growth and survival of postlarvae and juveniles. The experiment was designed as a factorial design which included three salinity treatments (15, 35, 55) and three temperatures (22, 27, 32 ^{0}C) with two replicates per each salinity-temperature treatment combination. The experiment duration was 60 d; however, it was divided into two 4-week phases (months). On a weekly schedule (sample events 1 through 8), fifteen shrimps were randomly sampled from each experimental treatment and replicate tank to conduct measurements on carapace length (CL) and total wet weight (TW). Data analysis is in progress and results will be incorporated into the growth and recruitment model developed for the species. Thus far, analysis has clearly demonstrated that temperature is the main factor affecting growth rates as demonstrated by sampling events shrimp weights (**Figure 2**). However, during the second month, temperature and salinity interact to yield a significant effect on growth (**Figure 3**). In conjunction, these results suggest that the effect of salinity on shrimp growth may be not as immediate as the temperature, and growth trials of 2 months or longer are necessary to detect significant influences of salinity on growth. Another interesting result is that the high salinity (55) treatment produced a clear detrimental effect on growth and survival; however, both growth and survival at 15 and 35 salinities are comparable. These findings coincide with previous studies which report the hemolymphosmality is isosmotic when external salinities are ~26, which is intermediate of the 15 and 35 test salinities. Furthermore, these results indicate pink shrimp postlarval growth and survival would be affected by hypersaline events occurring in Florida Bay, most likely resulting in a reduction of habitat availability and concentration within more favorable habitat conditions.

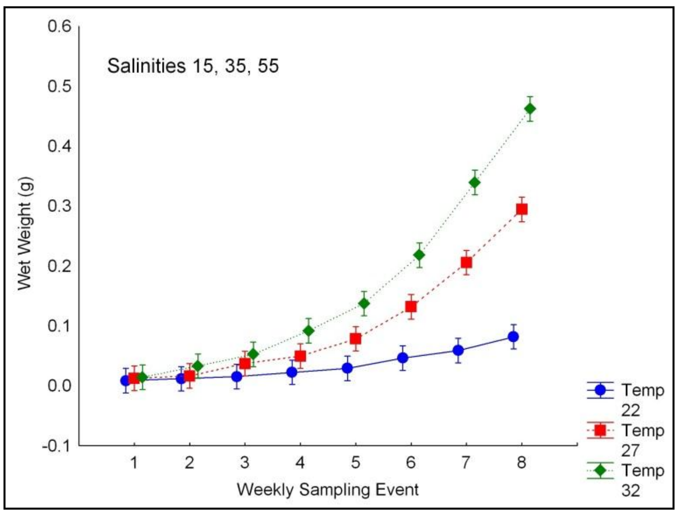


Figure 2: Weekly sampling event average wet weight (mean ± 0.95 confidence interval) pooled across salinity in each temperature treatment.

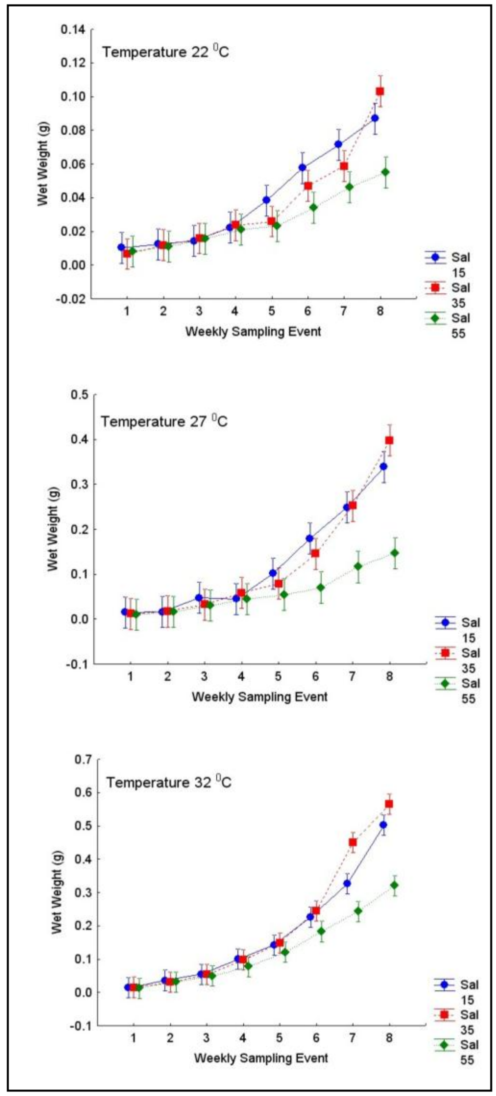


Figure 3: Weekly sampling event average wet weight (mean ± 0.95 confidence interval) by salinity for: 22°C, 27°C and 22°C treatments.

Research Performance Measure: The objectives have been to date partially accomplished; results of these experiments were presented at two scientific conferences (Greater Everglades Ecosystem Restoration 2010 and The Crustacean Society Summer Meeting 2011) and a publication pertaining to salinity tolerance range experiments has been submitted to a peer reviewed journal. Two more publications, one pertaining to the temperature and salinity influences on growth and survival and another pertaining to ammonia and salinity tolerance interactions, are in preparation and will also be submitted to peer reviewed journals.

The Effect of the Florida Current on the Dispersal of Larval Fish at 27N Latitude

Project Personnel: S. Privoznik, B. Muhling, A. Ender and E. Malca (UM/CIMAS)
NOAA Collaborators: J. Lamkin (NOAA/SEFSC); M. Baringer, C. Meinen and R. Smith (NOAA/AOML)

Long Term Research Objectives and Strategy to Achieve Them:

Objectives**:** Forecast the temporal distribution of larval fish assemblages
Strategy**:** Collect and assess larval fish assemblages and distribution in the Florida Current through oceanographic shipboard survey and use the present data to help predict the future distributions

CIMAS Research Theme:

Theme 5**:** Ecosystem Modeling and Forecasting

Link to NOAA Strategic Goals:

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

Funding Unit: NMFS/SEFSC **NOAA Technical Contact:** Theo Brainerd

Research Summary:

This project examines the impact of the Florida Current, a Western boundary current, on the distribution and abundance of larval fish. The Florida Current flows northward past the Florida Keys to the eastern shore of Florida transporting water and biological particles. In collaboration with the Quarterly 27N cruises that have been measured along the 27N latitude between South Florida and the Bahamas, our objectives are:

1. Assess the abundance and composition of larval fish occurring in the Florida Current
2. Determine the distribution of ecologically and commercially important species in South Florida waters
3. Evaluate temporal variation of the larval composition and abundance in South Florida

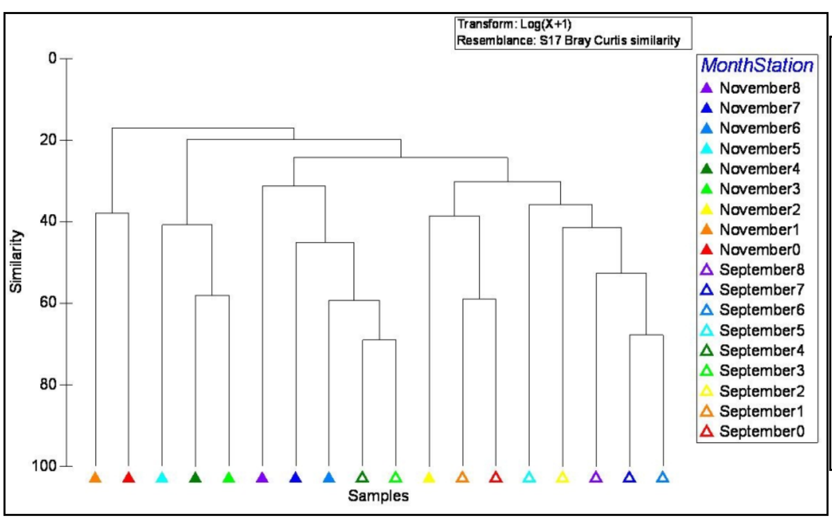


Figure 1: Cluster analysis shows grouping of stations based on similarity. Key specifies cruise (September or November) and station number (0 through 8). Open symbols indicate September cruise stations, while closed symbols indicate November cruise stations. Stations group strongly according to cruise and distance from shore.

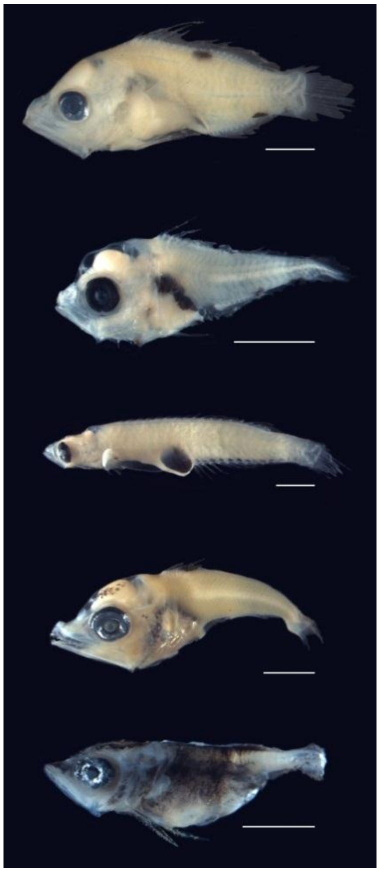


Figure 2: Larval fish collected from various neuston samples during cruises aboard the R/V Walton Smith. From top, Serranidae, Lutjanidae, Scaridae, Scombridae, Istiophoridae. Scale indicates 1 mm.

Research Performance Measure: The research program is on schedule. Seven cruises have been carried out since September 2009 with 80 plankton samples collected. Preliminary analyses indicate that temporal and spatial variation between the first two cruises can be observed, and results were presented at the poster session during the Larval Fish Conference 2010 (**Figures 1 and 2**). Additional sampling will be continued in 2011. The remaining samples will be sorted, identified, and analyzed in 2011.

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Caribbean Sea and Gulf of Mexico Bluefin Tuna Research

Project Personnel: B. Muhling, E. Malca and A. Shiroza (UM/CIMAS)
NOAA Collaborators: J. Lamkin (NOAA/SEFSC)

Long Term Research Objectives and Strategy to Achieve Them:
Objectives: To assess the importance of the Caribbean Sea as a spawning ground for bluefin tuna in addition to the Gulf of Mexico.
Strategy: To complete a detailed fisheries oceanography survey of the western Caribbean in early spring, including plankton sampling for fish larvae

CIMAS Research Theme:
Theme 5**:** Ecosystem Modeling and Forecasting

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

Funding Unit: NMFS/SEFSC and NASA **NOAA Technical Contact:** Theo Brainerd

Research Summary:
Atlantic bluefin tuna (*Thunnusthynnus*) are known to spawn only in the Gulf of Mexico and Caribbean Sea. However, collections of small bluefin tuna larvae east of the Yucatan Peninsula in recent years have lead to speculation that some spawning activity may be taking place in the Caribbean Sea. To investigate this possibility, scientists from UM/CIMAS, NOAA/SEFSC, InstitutoNacional de Pesca - INAPESCA (Mexican Government), El Colegio de la Frontera Sur - ECOSUR (Mexican Academic) and the Fisheries Department of Belize participated in an exploratory research cruise in the western Caribbean Sea, in April and May 2011. See **Figure 1**. Physical data from CTD casts, and biological data from plankton net tows were collected between Windward Passage and the Yucatan Peninsula. Preliminary identifications of larvae collected indicated that spawning of tunas was widespread across the region, but that bluefin tuna larvae were primarily collected in the far western Caribbean: between the Caribbean Current and the Mexico/Belize coast.

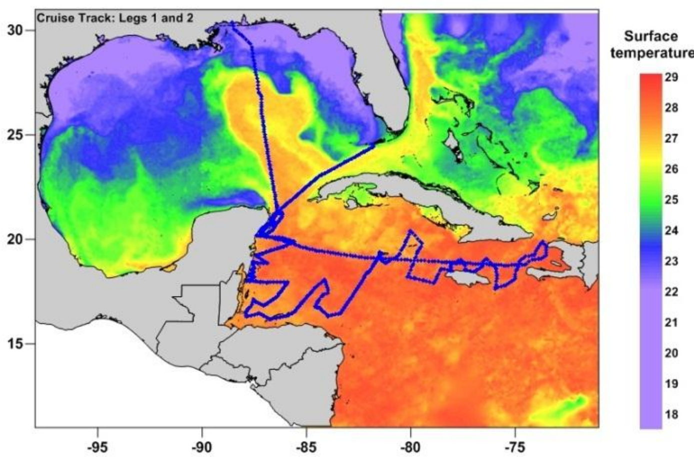

Figure 1: Cruise tracks for first and second legs of the bluefin tuna cruise aboard the NOAA Ship Gordon Gunter in April and May 2011. Participants included scientists from UM/CIMAS, NOAA/SEFSC, InstitutoNacional de Pesca - INAPESCA (Mexican Government), El Colegio de la Frontera Sur - ECOSUR (Mexican Academic) and the Fisheries Department of Belize participated in an exploratory research cruise in the western Caribbean Sea.

Research objectives are to (1) examine the oceanographic conditions in which larvae were collected, and (2) compare spawning habitat in the Caribbean to conditions in the Gulf of Mexico. In addition, (3) genetic analyses may be used to investigate questions of population structure. These results will have particular significance to fisheries scientists and managers, as accepted descriptions of bluefin tuna migration patterns and spawning behaviors have assumed that spawning is largely restricted to the Gulf of Mexico.

Figure 2: Photograph of a larval bluefin tuna collected with our nets aboard the NOAA Ship Gordon Gunter during Spring cruise GU1101. Photograph by A. Shiroza.

Research Performance Measure: The research program is on schedule. Samples from this cruise are currently being sorted, and larvae identified. We aim to have all samples sorted by the end of fall, 2011, and larvae identified early in 2012. After this is complete, analysis of larval assemblage structure, and tuna spawning habitats will be completed.

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Caribbean Reef Fish Stocks Environments and Aging Using Otolith Microchemistry

Project Personnel: E. Malca and S. Privoznik (UM/CIMAS)
NOAA Collaborators: T. Gerard (NOAA/SEFSC); A. Maggied (NOAA Corps)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** To provide information on coral reef fish recruitment processes, as it applies to stock structure and associated environments, in the U.S. Caribbean.

***Strategy*:** To measure isotopic values in the otoliths of adult fish collected from offshore reef habitats.

CIMAS Research Theme:

***Theme 5*:** Ecosystem Modeling and Forecasting

Link to NOAA Strategic Goals:

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

Funding Unit: NMFS/SEFSC **NOAA Technical Contact:** Theo Brainerd

Research Summary:

The project objective is to provide information on coral reef fish recruitment processes, as it applies to stock structure and associated environments, in the U.S. Caribbean - U.S. Virgin Islands (USVI). In partnership with the U.S. Virgin Islands' Department of Planning & Natural Resources (DPNR), Division of Fish and Wildlife, priority habitat areas were identified, and adult parrot fish were collected.

The goals are (1) to measure the stable isotope signature in the otolith core, edge and sub-edge of ach fish (2) establish and age/length curve. The majority of the catch was collected by local fishermen, and weighted and measured by DPNR. The samples were then sent to the NOAA SEFSC ELH laboratory for otolith removal and processing. Additional processing will take place at the NOAA SEFSC Panama City for ageing and stable isotope analysis at the Rosenstiel School of Marine and Atmospheric Science Stable Isotope Lab (SIL).

Figure 1: Capacity building otolith workshop was carried out in the Fall 2010. Ruth Gomez from U.S. Virgin Islands' Department of Planning & Natural Resources, Division of Fish and Wildlife was invited to the ELH Laboratory to learn otolith removal techniques to train additional staff at DPNR to collaborate in the project.

Research Performance Measure: The research program is on schedule. 115 adult parrotfish (*Sparisomaviride* and *Sparisomachrysopterum*) have been collected and their otoliths removed. 70 otoliths have been sent to the Panama City laboratory of SEFSC for aging, while the remaining otoliths are currently being processed for stable isotope measurements.

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Potential Impacts of the Loop Current on Downstream Marine Ecosystems in the Gulf of Mexico and Florida Straits: Ichthyoplankton Abundance, Diversity and Connectivity

Project Personnel: S. Privoznik, A. Walton and B. Muhling (UM/CIMAS)
NOAA Collaborators: G. Goni, M. Wood, S. Cummings, R. Smith, M. Baringer, R. Lumpkin, L. Johns and C. Kelble (NOAA/AOML); J. Lamkin (NOAA/SEFSC)

Long Term Research Objectives and Strategy to Achieve Them:
***Objectives*:** To understand transport pathways and areas that can be affected by the DWH event.
***Strategy*:** To conduct in situ physical, chemical, and biological observations collected during an oceanographic survey in the Loop current and associated eddies; downstream of the spill area in order to determine how oil, dispersants, and tarballs are spreading through the water column,

CIMAS Research Theme:
***Theme 5*:** Ecosystem Modeling and Forecasting (*Primary*),
***Theme 7*:** Protection and Restoration of Resources (*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

Funding Unit: NMFS/SEFSC **NOAA Technical Contact:** Theo Brainerd

Research Summary:
As part of NOAA's response to the Deepwater Horizon oil spill, interdisciplinary measurements were conducted in the Gulf of Mexico from the NOAA Ship *Nancy Foster*, between June 30 and July 18, 2010.

Our research objectives are (1) To obtain and analyze interdisciplinary observations to assess the connectivity between mesoscale features in the Gulf of Mexico, including the Loop Current and eddies, over the entire water column. (2)To investigate the surface and subsurface pathways of waters between the northern Gulf of Mexico to the southern Gulf and the Florida Straits (3)To collect samples of phyto-, zoo-, and icthyoplankton species across the region to determine species present in the water column, physiological condition (where possible), abundance, and diversity.

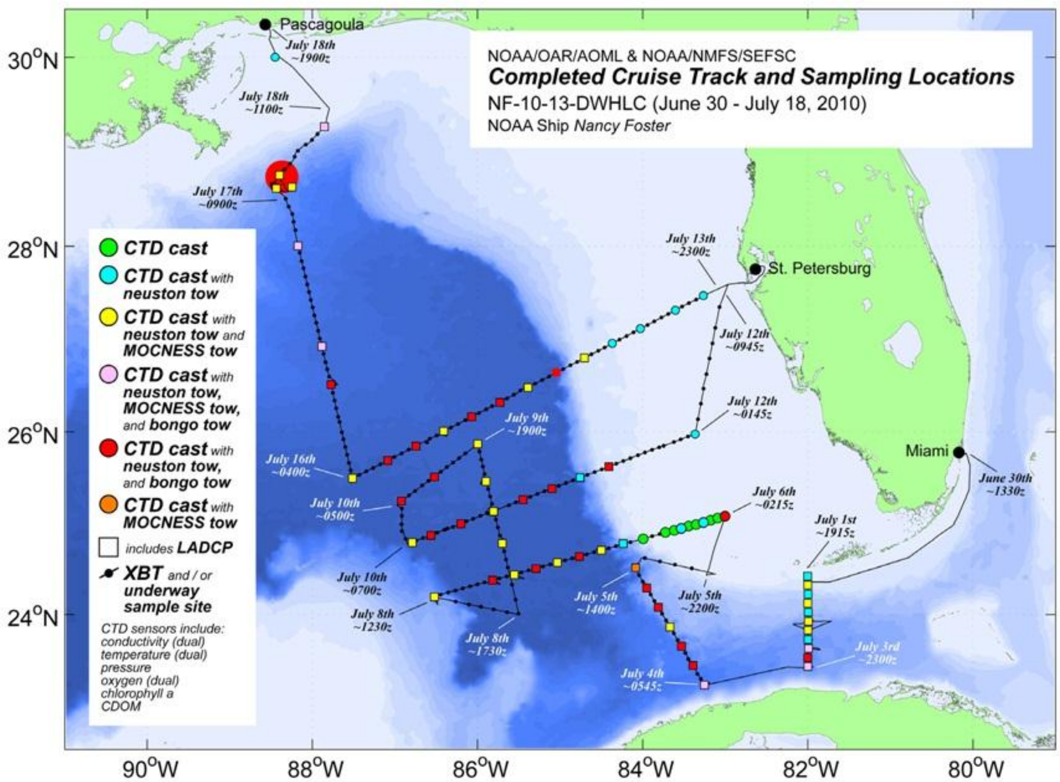

Figure 1: Cruise track for Deepwater Horizon Oil Spill aboard the NOAA ship Nancy Foster in 30 June – 18 July, 2010 in the Gulf of Mexico and Loop Current.

Research Performance Measure: The research program is on schedule. So far, 209 plankton samples have been sorted for larval fish specimens. Family level identification will follow. Oceanographic parameters will be combined in the analyses.

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

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

Long Term Research Objectives and Strategy to Achieve Them:
Objectives: To establish research priorities in the Mesoamerican region in order to provide baseline data (oceanographic and larval fish distributions) to support connectivity and fisheries management decisions in the region.
Strategy: Our strategies are: to carry out larval and oceanographic collections to assess larval transport & recruitment pathways in the Mesoamerican reef system. In addition, to carry out an international capacity-building workshop to discuss the topic of connectivity as it relates to research and management with local and regional practitioners in the Mesoamerican Reef.

CIMAS Research Theme:
Theme 5**:** Ecosystem Modeling and Forecasting

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

Funding Unit: NMFS/SEFSC and NOS/CRCP **NOAA Technical Contact:** Theo Brainerd

Research Summary:
We utilized existing regional capacity-building initiatives (El Colegio de la Frontera Sur, Healthy Reefs Initiative and the Mesoamerican Reef Fund) in order to carry out a capacity building workshop focusing on connectivity along the Mesoamerican Reef this past May 2010 (**Figure 1**).

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

Figure 1: Field work conducted at Contoy National Park Ranger Station with CIMAS, El Colegio de la Frontera Sur and ComisiónNacional de ÁreasNaturalesProtegidas.

Research Performance Measure: The program is in progress and proceeding on schedule.The research portion took place in June, July and in August 2010 with participation of research staff and students from ECOSUR, (El Colegio de la Frontera Sur) CONANP, (ComisiónNacional de ÁreasNaturalesProtegidas) and local guides. Data collected is being examined and will be analyzed this fall. Preliminary results have been presented at an oral presentation during the International "Larval Fish Conference" in Santa Fe, New Mexico, May 2010 and as a poster presentation during the "Linking Science to Management Workshop and Conference", Florida Keys, FL, Oct 2010 titled: Larval fishes, Connectivity, and Management: A Mesoamerican Reef Case Study.

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

Project Personnel: B. Muhling, E. Malca and S. Privoznik (UM/CIMAS)
NOAA Collaborators: J. Lamkin and T. Gerard (NOAA/SEFSC)

Long Term Research Objectives and Strategy to Achieve Them:

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

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

CIMAS Research Theme:
Theme 5**:** Ecosystem Modeling and Forecasting (*Primary*)

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

Funding Unit: NMFS/SEFSC **NOAA Technical Contact:** Theo Brainerd

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

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

Research Performance Measure: The program is meeting its goals on schedule. Initial results obtained from this study suggest that stable isotope projects involving snapper in Florida Bay should be species-specific to report any future findings with confidence. Preliminary results of the study were presented as an oral presentation at the International Otolith Symposium in August 2009, Monterrey, California. In addition, using samples from this project, we carried out research plan, data analysis that resulted in the publication of scientific manuscript involving novel technique to improve visualization of otolith rings in a peer reviewed journal. A portion of the data was utilized as Christine Quigley's undergraduate senior thesis at the University of Miami and was also presented as a poster for University of Miami's Research, Creativity, and Innovation Forum 2010. The poster was titled "Spatial Isotopic Variability of Gray Snapper in the Dry Tortugas and the Mexico" and won second place.

Habitat Modeling of Atlantic Blue Marlin with SEAPODYM and Satellite Tags

Project Personnel: J. Luo (UM/CIMAS)
NOAA Collaborators: M.J. Schirripa and E. Prince (NOAA/SEFSC)
Other Collaborators: J. Rooker (Texas A&M); P. Lehodey and I. Senina (CLS/FRANCE)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:**To produce a stock assessment based on a spatially based habitat model (SEAPODYM) and compare the biomass and mortality estimates to those coming from the current stock assessment model (Stock Synthesis) that does not consider habitat.

***Strategy*:** To use data from PSAT tagged Atlantic blue marlin to parameterize and calibrate the SEAPDAYM model.

CIMAS Research Theme:

***Theme 5*:** Ecosystem Modeling and Forecasting

Link to NOAA Strategic Goals:

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

Funding Unit: NMFS/SEFSC **NOAA Technical Contact:** Theo Brainerd

Research Summary:

This study is aimed at identifying the main sources of variability of Atlantic blue marlin habitats and spatial dynamics, through the combined use of a state of the art ecosystem model and movement data from electronic tags. The increased availability of recent data on the ocean scale movements for blue marlin using electronic tags facilitated our species selection process. We are using SEAPODYM as the main tool to achieve the goals of this project. This model was developed to simulate the spatial dynamics of tuna populations in the pelagic ecosystem. It uses bio-physical environmental fields to simulate the upper trophic levels of marine ecosystem organized in two groups: the Atlantic blue marlin or associated species and their prey species of the mid-trophic levels (i.e. micronekton). Modeling the habitat and vertical structure of micronekton distribution, as well as the age-structured spatial dynamics of blue marlin (through an advection-diffusion framework) is based on first biological principles, such as thermal habitat, oxygen tolerance, prey and predator interactions. The parameterization of these components defines a movement index with seasonal switching between feeding and spawning habitats, defining in turn the spatial dynamics of the target species. The emphasis of this one-year project will be put on defining the feeding habitat, based on mechanisms developed in the model for other billfish species, in order to recreate the key movement patterns of individuals, as described by archival tags. A review covering biology, ecology, fisheries and population structure of Atlantic blue marlin will be conducted to gather all the necessary information needed to parameterize the model SEAPODYM for a second phase study. Finally, a statistical analysis will help to investigate the link between CPUE and predicted habitat. One key issue for these modeling studies is to obtain high resolution-3D environmental data covering the entire habitat of the species considered. Unfortunately there is no observation database providing such information. Only ocean reanalyses based on ocean circulation model can provide this type of dataset. Thus, we will use the physical reanalysis GLORYS (GLobal Ocean ReanalYsis and Simulations) that is provided by the French Groupe Mission Mercator Coriolis, at a resolution of ¼ deg x 6 days, and using data assimilation to provide higher realistic prediction. We will use satellite derived primary production at the same resolution to run a simulation with the micronekton, for the period 2002-2009.

We have compiled and analyzed 80 Popup Archival Transmitting (PAT) tags deployed on Atlantic blue marlin 2002 to 2004. Of the 80 tags, 46 tags were determined to contained useful data. Wildlife Computers (www.wildlidfecomputers.com, Redmond, WA, USA) PAT (popoff archival transmitting) tags were used in this study. The tags were programmed to sample depth (pressure), temperature and light once every 30s. The depth and temperature records for were summarized by the on-board software into histograms at 6-hour bin intervals. We programmed the tag to summarize temperature bins starting at <12°C, then each successive 2°C interval ending with >32°C. Likewise, depth bins started at <-1 m, then successive intervals of 25 m until ending at depths >250 m. Eight profiles of depth and temperature (PDT) were also summarized by the on-board software at 6-hours intervals, which gave minimum and maximum temperatures for the shallowest and deepest depths, and for 6 depths between. Fish movement tracks were derived from light-level, temperature, andbathymetric data. Light-level geolocation data were initially processedusing the global positioning software WC-AMP (Wildlife Computers), andthen applying a sea-surface temperature-corrected Kalman filter to the light-level-derived locations. Finally, we used acustom bathymetry filter to relocate the points that were on land or inshallow water, based on 2 x 2 minute grid ETOP02 bathymetry data and the daily maximum depth from the PSAT. To make the fish movement tracks compactable with the SEAPODYM model, each track was aggregated into 6 day time step locations and its 95% confidence interval (**Figure 1**). Our French colleagues are in the process of parameterizing the SEAPODYM model using the 6 day aggregated fish movement tracks. We have also compiled the conventional tagging data base to analyze the distribution of conventionally tagged Atlantic blue marlin **(Figure 2**). Depth distribution and temperature distribution of PAT tag data were also analyzed (**Figures 3, 4**), which will be used to parameterize the SEAPODYM model. A first parameterization of habitats has been achieved using assimilation of PAT data and general knowledge on tuna and billfishes (**Figure 5**).

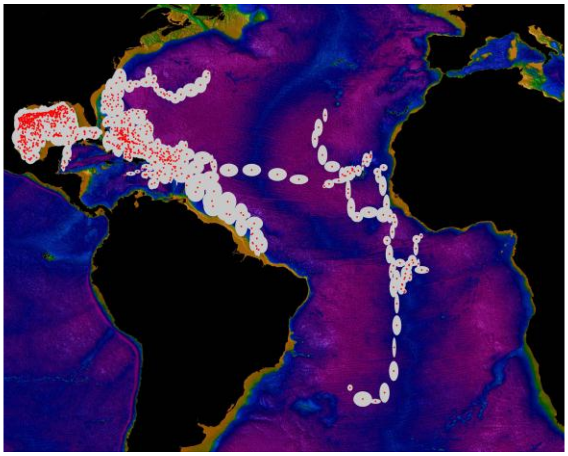

Figure 1: Six day aggregated blue marlin location (red dots) and 95% confidence ellipses (light grey ellipse) based on PAT tag data.

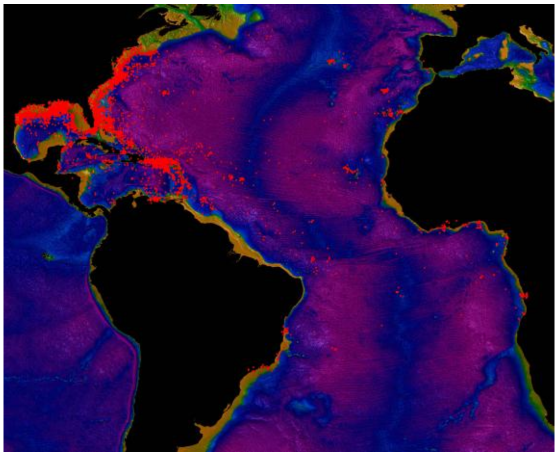

Figure 2: Locations of conventionally tagged Atlantic blue marlin.

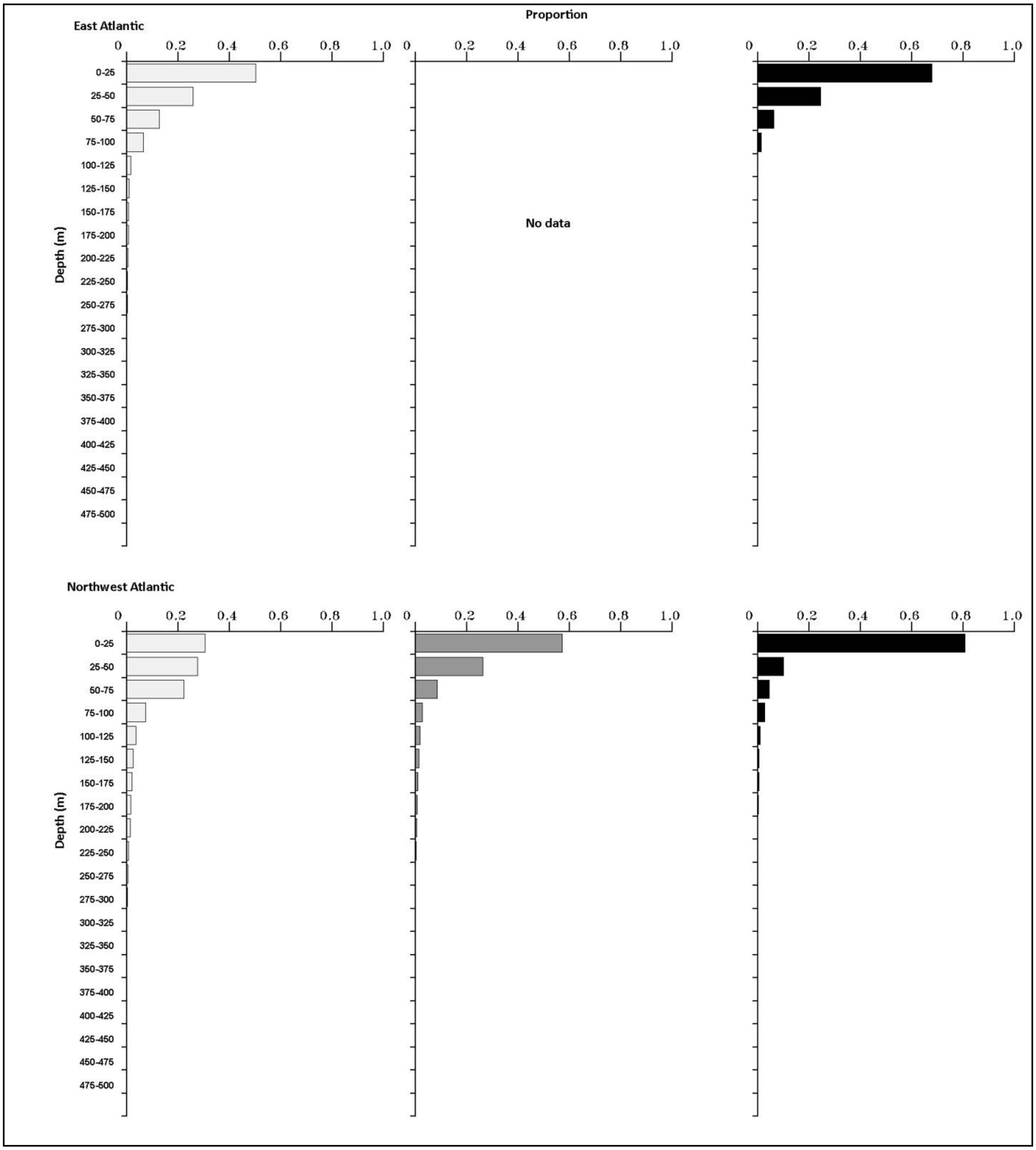

Figure 3: Depth distribution histogram of Atlantic blue marlin by day (light bar), twilight (grey bar), and night (dark bar) for East Atlantic (upper panels) and Northwest Atlantic based on data from PAT tags.

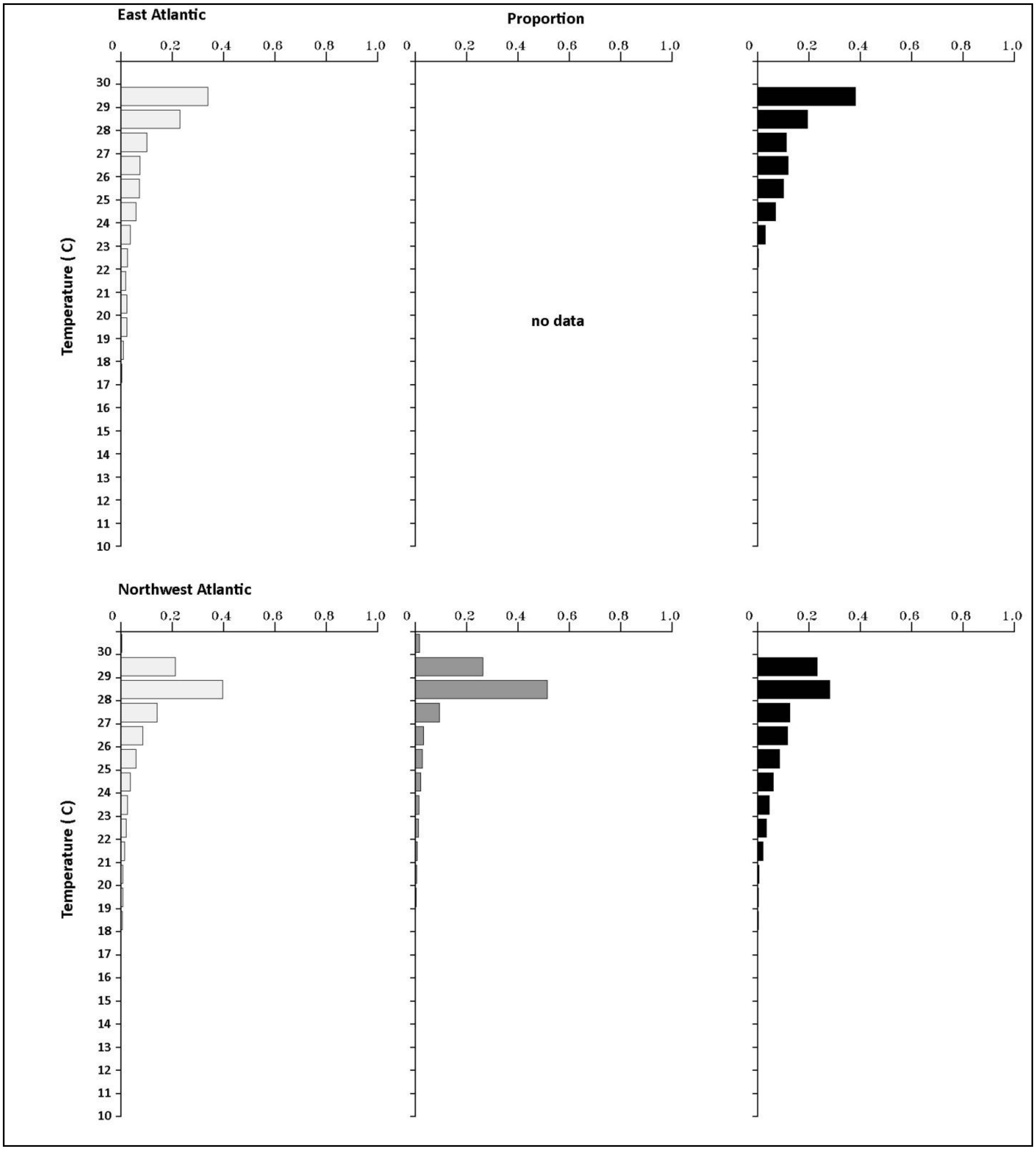

Figure 4: Temperature distribution histogram of Atlantic blue marlin by day (light bar), twilight (grey bar), and night (dark bar) for East Atlantic (upper panels) and Northwest Atlantic based on data from PAT tags.

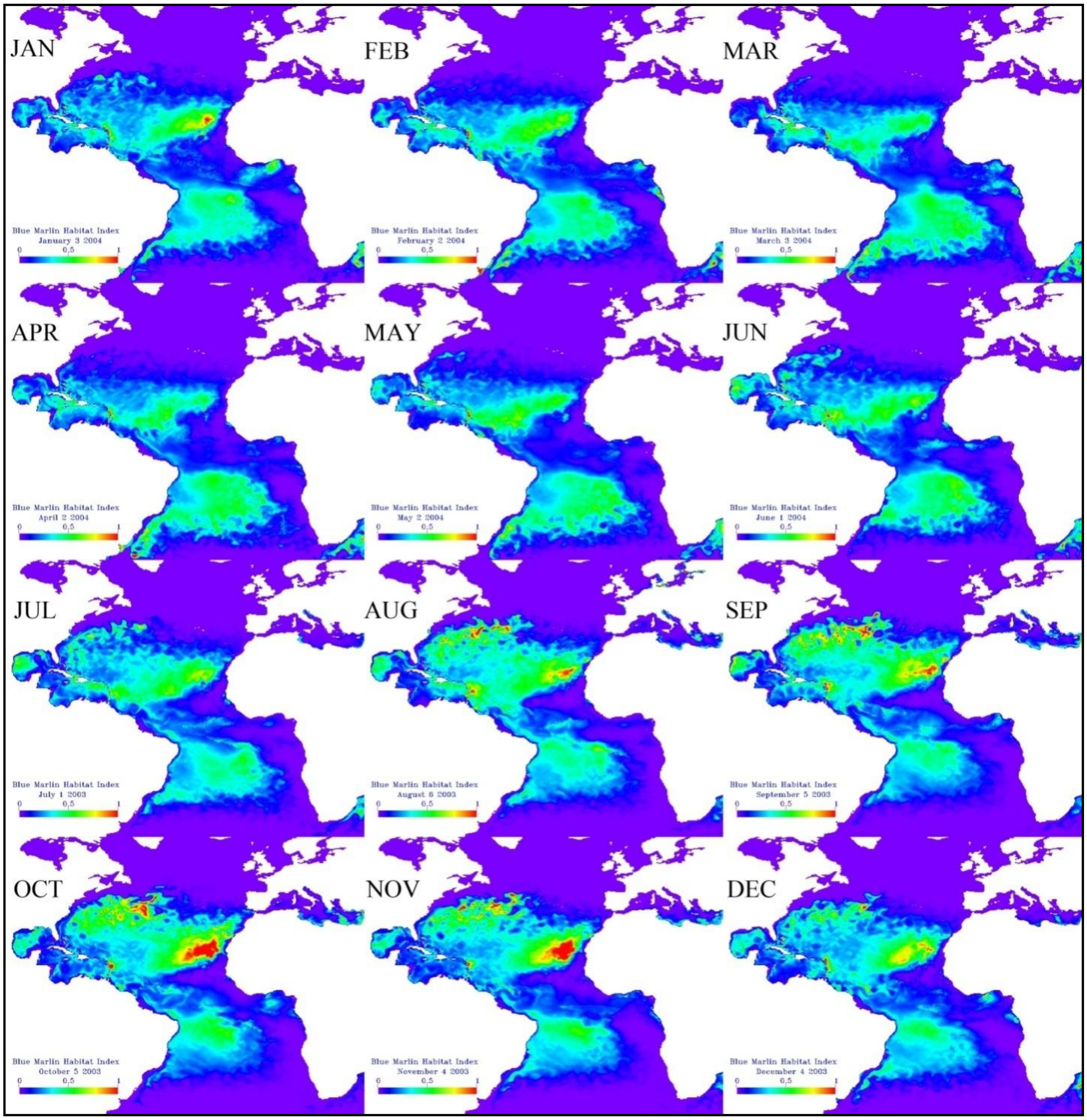

Figure 5: Monthly spatial distribution of Atlantic blue marlin habitat.

Research Performance Measure: We have archived our goal of developing a preliminary Atlantic blue marlin habitat model.

RESEARCH REPORTS

THEME 6: Ecosystem Management

Shallow-Water Grouper Distribution, Habitat Characteristics and Spawning Behavior

Project Personnel: D.J. Die (UM/RSMAS)
NOAA Collaborators: T. Kellison (NOAA/SEFSC)

Long Term Research Objectives and Strategy to Achieve Them:
***Objectives*:** This work aims at both understanding EFH of black grouper, by studying the habitats that they occupy, and thus relating these habitats to the communities that inhabit them, but also by investigating the movement behavior of black groupers to be able to evaluate the usefulness of protection from harvesting.
***Strategy*:**1) To characterize black grouper habitat types, site fidelity and movement patterns through a telemetry study and relate these to diel, lunar and seasonal periods. 2) To gather information on these same variables from stakeholders in the area of the Florida Keys and compare both sources of information.

CIMAS Research Theme:
***Theme 6*:** Ecosystem Management

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

Funding Unit: NMFS/SEFSC **NOAA Technical Contact:** Theo Brainerd

Research Summary:
Using an interdisciplinary approach, the ecology of black groupers was characterized in the Upper Florida Keys through a combination of an acoustic telemetry study and a political ecology study.

Self-contained acoustic receivers were placed in an array around Conch Reef and tracked 16 tagged juvenile black groupers for 483 days. Patterns of movement behavior and habitat usage were modeled using presence-absence data for hypothesis testing (Figure 1). The capture-recapture program MARK was used to estimate the model parameters. It was found that spur and groove habitat was the most frequented during the study period, along with artificial reef structure. Movement behavior followed patterns according to changes in seawater temperature, as well as sunrise and sunset.

In-depth life and work histories were conducted with stakeholders of the Upper Florida Keys to determine the stakeholder groups involved in the political ecology of this natural resource. Seven stakeholder groups and eight subgroups were interviewed over a 3 month period and shared with us their perceptions and experiences about black groupers as a natural resource and on their interactions with other stakeholder groups. The struggle for access to black groupers is intensified by the struggle among groups, but most stakeholders saw this as an unavoidable fact of life.

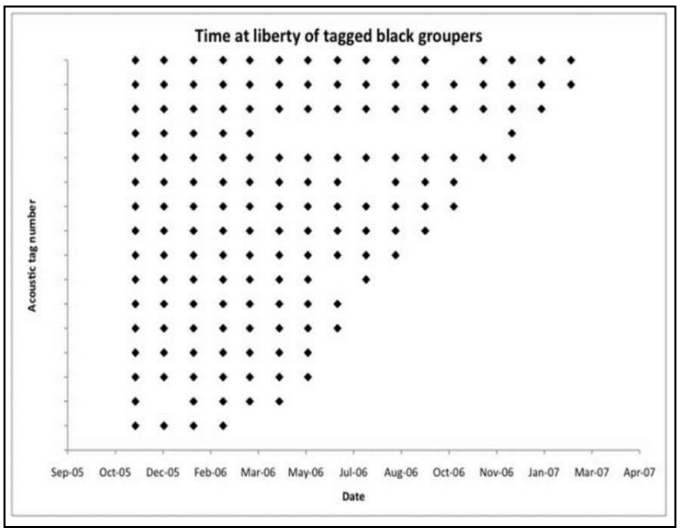

Figure 1: Presence of tagged groupers within the acoustic telemetry study array in Conch Reef, Florida Keys. Each point represents presence of a fish in a given month.

Research Performance Measure: The study achieved it objectives of helping describe essential fish habitat of black grouper through a combination of ecological and anthropological research. It culminated in the completion of an MSc. thesis for Veronique Koch who graduated in 2011.

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International Symposium on Circle Hooks

Project Personnel: D.J. Die (UM/CIMAS)
NOAA Collaborators: J. Serafy (NOAA/SEFSC)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** To produce an updated, science-based assessment of the management and conservation utility of circle hooks in commercial and recreational fisheries around the globe.

***Strategy*:** To provide a forum for individuals, organizations and agencies to share relevant research results and perspectives and to subject their findings to peer-review through publication in an internationally-recognized scientific journal.

CIMAS Research Theme:
Theme 6**:** Ecosystem Management

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

Funding Unit: NMFS/SEFSC **NOAA Technical Contact:** Theo Brainerd

Research Summary:
The international scientific, management and conservation communities require consensus as to what defines a circle hook and under what circumstances this relatively inexpensive technology should, and should not, be applied. Benefits of circle hooks can be fully realized only if this consensus is achieved. The general lack of uniformity among empirical research efforts, absence of hook size standards and disagreements as to those specifications or characteristics that define a circle hook have hindered achievement of this consensus.

The US National Marine Fisheries Service, with the support of CIMAS and several non-governmental entities, held in Miami Florida, from 4 to 6 May, 2011, an international symposium to assess the state of circle hook science and identify key needs in circle hook research, management and conservation (**Figure 1**). The goal of the symposium was to produce an updated, science-based assessment of the management and conservation utility of circle hooks in commercial, recreational and artisanal fisheries around the globe.

The symposium addressed research outcomes in the following areas: (1) circle hook definitions; (2) circle hooks and commercial fisheries; (3) circle hooks and recreational fisheries; (4) circle hooks and sharks; (5) circle hooks and sea turtle bycatch; (6) circle hooks and human dimensions; and (7) circle hooks in assessment and management.

The symposium represented an initial step in the process of evaluating the pros and cons of circle hook use in a variety of different fisheries around the globe.

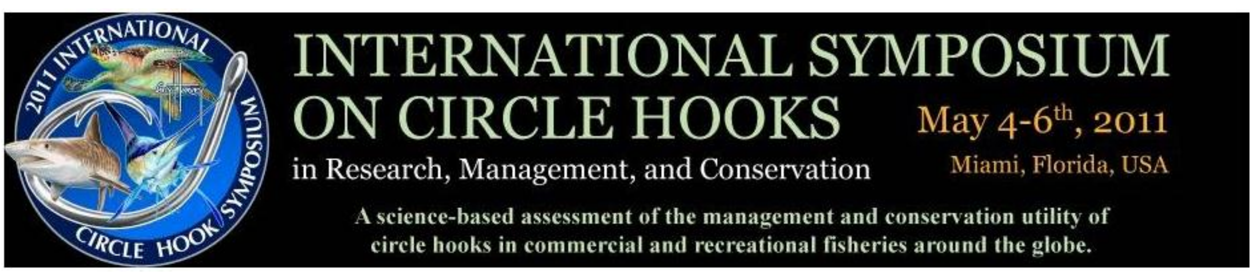

Figure 1: Announcement and logo of the International Circle Hook Symposium.

Research Performance Measure: The symposium attracted over 180 attendees, which included researchers, resource managers and outreach specialists from 20 nations around the world. A total of 52 oral and 30 poster presentations were made during the event and 25 manuscripts have been submitted for the Proceedings thus far. The manuscripts that emerge successfully from peer review will be published in a special issue of the scientific journal Bulletin of Marine Science.

Integrated Coral Observing Network (ICON) Project

Project Personnel: I.C. Enochs, L.J. Gramer, K.P. Helmle, M. Jankulak and D.P. Manzello (UM/CIMAS)
NOAA Collaborators: J.C. Hendee, M. Shoemaker and J. Craynock (NOAA/AOML)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** To: 1) Facilitate in situ observations at coral reef areas, 2) integrate in situ, remote-sensing, and other environmental data so as to better understand the physical and biogeochemical processes that affect the health and life cycles of organisms in the reef ecosystem, 3) compile ecological forecasts for coral reef ecosystems to help to understand them, and to aid in decision support for Marine Protected Area management, 4) reconstruct coral growth and calcification records along with proxy seawater pH and temperature records over the past centuries in order to identify baseline values, variability, and limiting environmental controls on coral growth over time, 5) assess the effects of naturally-occurring CO2 gradients in the Florida Keys on the persistence of reef structures and biodiversity of their associated fauna and growth/calcification rates of multiple species of coral, 6) develop climatologies and near real-time anomaly products for remote and in situ sensing of physical and biochemical conditions on monitored coral reefs.

***Strategy*:** Construct and operate meteorological and oceanographic monitoring platforms near key coral reef areas; provide data archiving and artificial intelligence tools to facilitate the acquisition and integration of high-quality data from these and other reef areas worldwide; and, enable rapid science-based assessment of the physical and biogeochemical environment at these reefs. Such an assessment will enable better ecosystem-based management of resources. Utilize an integrated analysis of coral growth records, bioerosion plates, settlement plates, and long-term records of carbonate chemistry, oceanographic, and meteorological conditions, to identify the past and present limiting controls on coral growth, reef structure, and community composition in order to improve ecosystem-based management of threatened coral reef resources.

CIMAS Research Theme:
***Theme 6*:** Ecosystem Management (P*rimary*)
***Theme 3*:** Sustained Ocean and Coastal Observations (*Secondary*)
***Theme 1*:** Climate Research and Impact (*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
***Goal 2*:** Understand Climate Variability and Change to Enhance Society's Ability to Plan and Respond

Funding Unit: OAR/AOML and CRCP **NOAA Technical Contact:** Alan Leonardi

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 2010-2011 year, the ICON project continues to focus on five existing research 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; (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; (3) field and paleo-climate research on the effects of ocean acidification (OA) on reef building and loss; (4) analysis of long (decadal) time records of coral growth and physical environmental variables, for evidence of climate impacts on coral reef ecosystems; and (5) research on dominant physical forcing processes for sea temperature variability on shallow reefs.

ICON Coral Reef Early Warning System (ICON/CREWS) collaboratively maintained stations continue to operate at Salt River, St. Croix in the U. S. Virgin Islands ("SRVI2"), at La Parguera in Puerto Rico ("LPPR1"), at Central Caribbean Marine Institute (CCMI) in Little Cayman ("LCIY2") adjacent to Bloody Bay Marine Park, at Molasses Reef ("MLRF2") in Florida Keys National Marine Sanctuary, and at Port Everglades channel ("PVGF1") in southeast Florida.

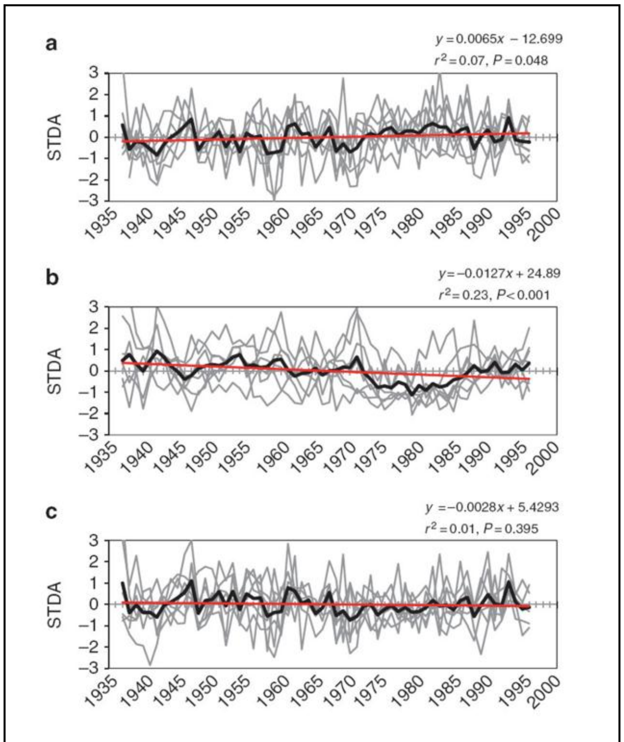

Figure 1: Coral growth from 1937 to 1996. Master chronologies (n = 7 corals) are presented in standardized anomaly (STDA) units for the period of 1937–1996 and depicted by bold black lines with the individual coral records comprising the master chronology depicted by grey lines. Linear regression lines for the master chronology data are depicted by red lines. Annual linear extension (a) exhibits a slight, but significant increasing trend. Annual skeletal bulk density (b) exhibits a significant decreasing trend. Annual calcification (c) exhibits no significant trend over the 60-year period (from Helmle *et al.* 2011).

Coral growth time series along with proxy pH records spanning the past century were determined from coral cores collected at the site of the Atlantic Ocean Acidification Testbed near La Parguera, Puerto Rico. X-radiographs revealed a growth history spanning 111 years over the period 1898 – 2009. Annual coral extension, density, and calcification data were collected from the coral X-radiographs and boron isotopes were measured at 5-yr intervals from the skeletal slabthrough a collaboration with Dr. Ryan P. Moyer of USGS. No linear trends or declines were present in extension, calcification or the boron proxy pH over this time period. The findings contribute to the understanding of *in situ* seawater pH variability and its control on coral calcification. Understanding the historical variability of pH and sensitivity of coral calcification to these changes provides important baseline information for implementation of future conservation/management actions.

Coral growth rates over a 60-year period were measured from annual density bands in coral colonies from the upper Florida Keys. Annual coral extension and calcification rates did not decline as of 1996 (**Figure 1**). The ability of these corals to maintain their growth and calcification rates has several possible explanations. The corals growing on these subtropical reefs may be more tolerant to environmental change due to the less than optimal conditions to which they have historically been exposed. The environmental conditions under which these corals grow may not be representative of global estimates of ocean acidification and warming temperatures. Local processes such as benthic community metabolism, mineral buffering, and coastal geochemical processes may have a large effect on the growth of these corals.

Investigation into framework bioerosion and bioeroder community responses associated with ocean acidification is underway (**Figure 2**). Bioerosion is currently being assessed across in-shore and off-shore CO_2 gradients at six sites in the Florida Keys. Clean carbonate skeletons have been deployed at each of these sites to determine both macro- and micro-borer erosion rates. Additionally, both cryptic and epibenthic settlement plates have been deployed in the field and will be collected, and subsequently analyzed in experimentally manipulated laboratory facilities currently under construction.

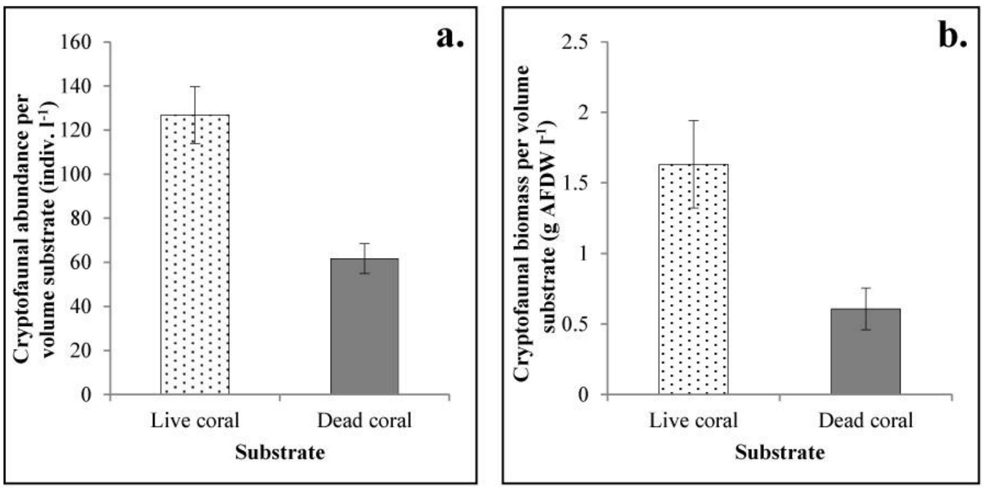

Figure 2: Coral mortality and cryptic fauna. The impacts of coral mortality on cryptic coral reef animal abundances (a) and biomass (b). This figure clearly shows that coral mortality associated with anthropogenic stressors such as climate change and ocean acidification will have direct impacts on reef-associated animals.

Investigation of coral growth and calcification of four species of reef-building coral, intraskeletal carbonate cement abundance, and seawater CO_2 is being conducted across the Florida Reef Tract (**Figure 3**). Approximately 250 corals have been sampled, weighed, and redeployed at 6 sites across the Florida Reef Tract to provide repeatable, non-lethal determinations of coral calcification. Additionally 180 coral samples have been stained for determination of linear extension rates. Also, 12 small coral cores have been obtained for comparison and corroboration of aforementioned growth estimates and to understand interannual variability. Hundreds of discrete bottle samples have been collected and analyzed for Total inorganic carbon (TCO_2) and total alkalinity (TA). These data will be used to characterize the seasonal CO_2 variability of the Florida Reef Tract.

ICON's Coral Reef Early Warning System (CREWS) stations located in Puerto Rico, the U.S. Virgin Islands (USVI) and the Cayman Islands each had their annual maintenance operations consisting of the replacement of all meteorological and oceanographic sensors. Shallow-water temperature sensors were installed on the stations in Puerto Rico (Sea-Bird prototype) and the Cayman Islands (Solint Levelogger) as part of a collaboration among NOAA, the University of Miami's Rosenstiel

School of Marine and Atmospheric Science, the University of Puerto Rico and the Little Cayman Research Centre. The CREWS station located within the Salt River Bay National Historical Park and Ecological Preserve, St. Croix, USVI (**Figure 4**), began operating under a new partnership between NOAA and the USVI Department of Planning and Natural Resources (DPNR), and under this arrangement DPNR and will carry out regular maintenance visits throughout the coming years. All CREWS stations continue to report their measurements in near-real time and their data are uploaded to the National Data Buoy Center (NDBC). From NDBC the data are included in the World Meteorological Organization's Global Telecommunications System, making them available for use by national weather services all over the world.

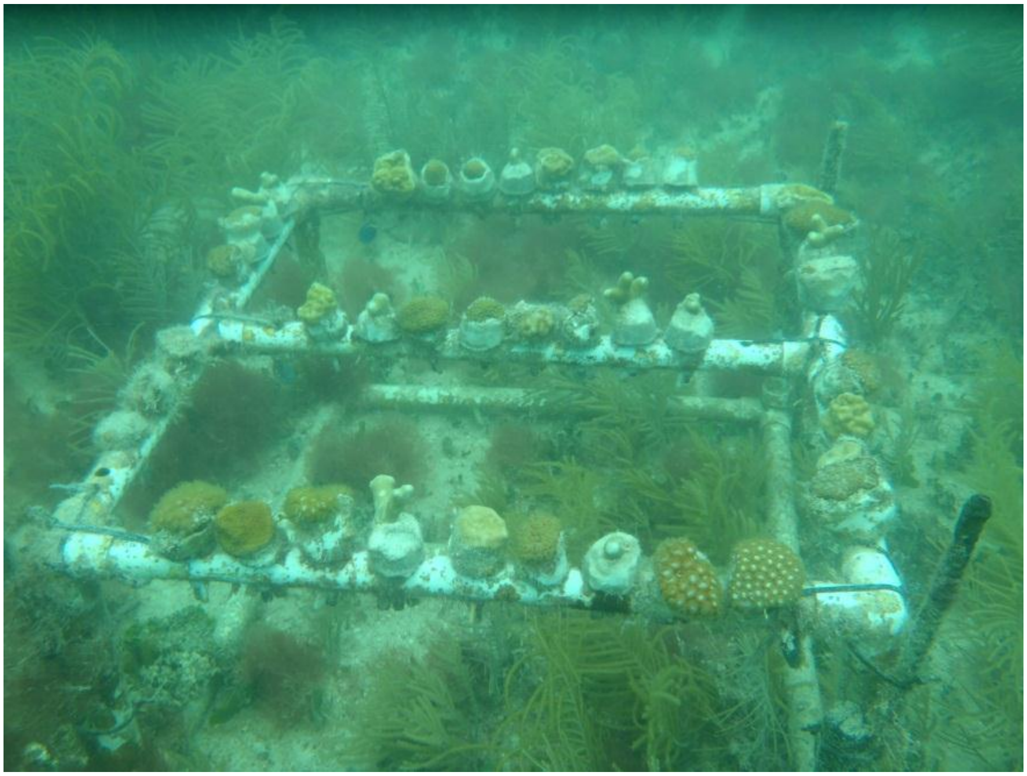

Figure 3: Coral sample array. Several species of corals mounted to underwater array for use in buoyant weight measurements of coral growth.

Meteorological, oceanographic, and light measurements from all ICON/CREWS stations are reported and archived in near-real time, delivering hourly updates by Geostationary Operational Environmental Satellite (GOES), and their data are uploaded to the National Data Buoy Center (NDBC). From NDBC the data are included in the World Meteorological Organization's (WMO) Global Telecommunications System (GTS), making them available for use by national weather services all over the world. All ICON/CREWS station data and related products also continue to be made available in near-real time via the automated ICON Ecological Forecasting Web site at http://ecoforecast.coral.noaa.gov. Additionally, ICON's Coral Health And Monitoring Program (CHAMP) website was redesigned and is now online with an entirely new look: http://www.coral.noaa.gov/.

Figure 4: ICON/CREWS station. ICON/CREWS station located within the Salt River Bay National Historical Park and Ecological Preserve, St. Croix, USVI.

The addition of prototype loggers at ICON/CREWS station "LPRR1", and Leveloggers at station "LCIY2", are both part of a new research collaboration with Dr. Peter Minnett of UM/RSMAS MPO, funded by NASA and the National Ocean Partnership Program (NOPP). These logger data will be used in combination with ICON/CREWS meteorological and oceanographic data, to improve models of diurnal warming within the water column over coral reefs. Together with complementary research by CIMAS ICON staff member Lewis J. Gramer on models of longer-period sea-temperature variability over coral reefs, the ultimate aim of this work is to allow more accurate, timely estimation of sub-surface sea temperature on coral reefs from remote-sensing data.

Research Performance Measure: Project research addressed the defined objectives in 2010-2011 first by determining historical baselines and variability, establishing change and trends in coral growth and seawater pH, and relating the annual growth rates to records of climatic and environmental change. Secondly, the establishment of bioerosion plates, settlement plates, in situ coral samples, and bottle samples meet the required measures for assessing the persistence of reef structure and biodiversity. Thirdly, ICON/CREWS stations have been maintained and updated to provide continuous oceanographic and meteorological data for coral reef environments. Finally, automated assessments of likely ecological impacts from measured environmental variables ("ecoforecasts") and other products continue to be made available to managers, researchers, and the public in near real-time via the Web and email.

Investigation of the Movement of Adult Billfish in Potential Spawning Areas

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

Long Term Research Objectives and Strategy to Achieve Them:

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

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

CIMAS Research Theme:

***Theme 6*:** Ecosystem Management

Link to NOAA Strategic Goals:

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

Funding Unit: NMFS/SEFSC **NOAA Technical Contact:** Theo Brainerd

Research Summary:

We used a combination of recreational and commercial fishing vessels to (1) catch pelagic fish known to interact with pelagic longline fishing gear, (2) attach pop-up satellite archival tags (PSATs) to them and (3) release them to study their horizontal and vertical movements for periods up to 150 days. Over 300 PSATs have been deployed by the NOAA-SEFSC Migratory Fisheries Biology Branch and about 78% of them reported summarized data via the Argos satellite system. In addition, we have physically recovered 18 PSATs that had previously transmitted summarized data. PSAT's non-volatile memory retains large volumes of high resolution data that is available for download. This augmented the PSAT data base with detailed information that is not available through Argos transmissions. One example of recent PSAT analysis was a description of sailfish vertical habitat use. Specifically, time spent at temperature relative to the sea surface temperature (termed Delta T). The Delta T metric represents an important input variable for habitat standardization models, which are used to predict vertical distributions and abundance needed for stock assessments (Figure 1).

Research Performance Measure: (1) High recovery rate for data collected by pop-up satellite tags indicates that fish tagging protocols and deployment durations are appropriate. (2) Successful acquisition of high resolution data on pelagic longline gear "behavior" and the effects of gear modifications on animal interactions with pelagic longline fishing gear. (3) Many joint authored (NOAA/RSMAS) peer review papers have resulted over the last few years. Those from 2009-2011 are listed below. Other can be accessed at: http://www.sefsc.noaa.gov/fisheriesbiology.jsp

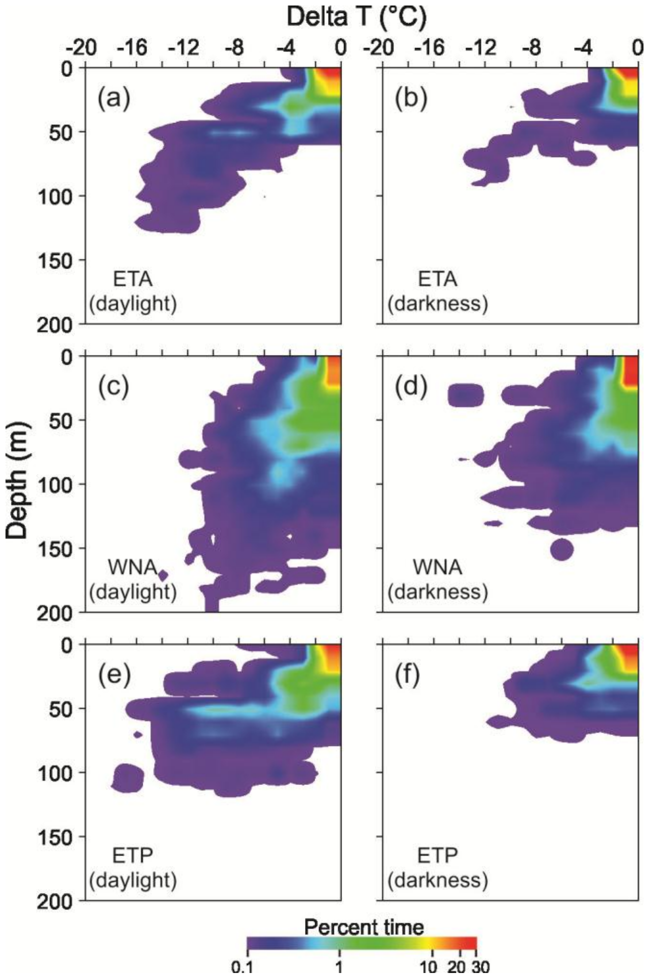

Figure 1: Day and night vertical habitat envelopes derived from PSAT data of 63 sailfish monitored in the eastern tropical Atlantic (ETA), western North Atlantic (WNA), and eastern tropical Pacific (ETP). Plots depict percent time at Delta T and depth for (a) ETA daylight, (b) ETA darkness, (c) WNA daylight, (d) WNA darkness, (e) ETP daylight, and (f) ETP darkness (image courtesy of Fisheries Oceanography, Hoolihan *et al.*, 20: 192-205).

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Reef Visual Census (RVC): Reef fish monitoring in the Florida Keys

Project Personnel: J. Blondeau (UM/CIMAS)
NOAA Collaborators: B. Ruttenberg (NOAA/SEFSC)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** To provide continued reef fish and habitat monitoring in Florida's coral reef tract to assess population and habitat trends, fish-habitat associations, and ecosystem responses to natural events (e.g. hurricanes, extreme temperature events, etc.), management measures and anthropogenic impacts. In particular, to examine the effectiveness of marine reserves and other management zones in the Florida Keys National Marine Sanctuary (FKNMS —Sanctuary Preservation Areas SPAs, Tortugas Ecological Reserves TERs and Dry Tortugas National Park – Research Natural Area RNA).

Strategy**:** Using a multi agency approach (UM/CIMAS, NOAA/SEFSC, Florida Fish and Wildlife Commission FWC, and the National Park Service NPS) to carry out spatially-based, fishery-independent monitoring of coral reef fish composition, occurrence, abundance, size structure and habitat along the Florida reef tract.

CIMAS Research Theme:
Theme 6**:** Ecosystem Management (*Primary*)
Theme 7**:** Protection and Restoration of Resources (*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

Funding Unit: NMFS/SEFSC **NOAA Technical Contact:** Theo Brainerd

Research Summary:
Our fishery-independent monitoring of Florida Keys reef fishes and coral reef habitat began in 1979. Continuing this monitoring time series enables us to detect changes in populations over annual to decadal time scales across the ecosystem. Since 1979, sampling has greatly expanded in intensity and spatial coverage, from a relatively small number of samples annually on a relatively small number of reefs, to hundreds to thousands of samples spanning the entire Florida Keys coral reef tract. This research allows us to evaluate the effectiveness of management actions, including the establishment of marine reserves and allows us to examine the impacts of fishing and overfishing. Additionally, this research allows us to quantitatively assess reef fish population changes, ontogenetic habitat shifts and associations, and ecosystem responses to fishing, management actions (including MPA zoning), and other human activities.

Augmented by previous years habitat data, a spatially explicit sampling strategy was designed including ~600 sampling sites along the Florida Keys reef tract (400) (Figure 1) and in the Dry Tortugas National Park (200). To date, two successful census cruises were completed in the summer of 2011. The NOAA/SEFSC led cruise in the FKNMS completed 188 sites which included 726 individual dives and the NPS led cruise in the Dry Tortugas National Park completed 226 sites which included 893 individual dives. An additional 212 sites are scheduled for completion by the end of September 2011, followed by a comprehensive quality assessment and quality control procedure.

Preliminary results from the Florida Keys coral reef tract data alone show a marked increase in the frequency occurrence of the invasive Red Lionfish (*Pterois volitans*). In 2010, frequency occurrence of lionfish was 10% on fore reef habitat. In 2011, with only half the sites completed, the frequency occurrence of lionfish is estimated at 30% on fore reef habitat. This dramatic increase in Lionfish will likely have implications on Florida's reef ecosystems, but the extent of its implications is unknown. Continued, spatially-based monitoring throughout the Florida Keys will help us quantitatively assess its population dynamics, habitat associations, and impacts on reef fish communities in hopes of aiding successful mitigation programs.

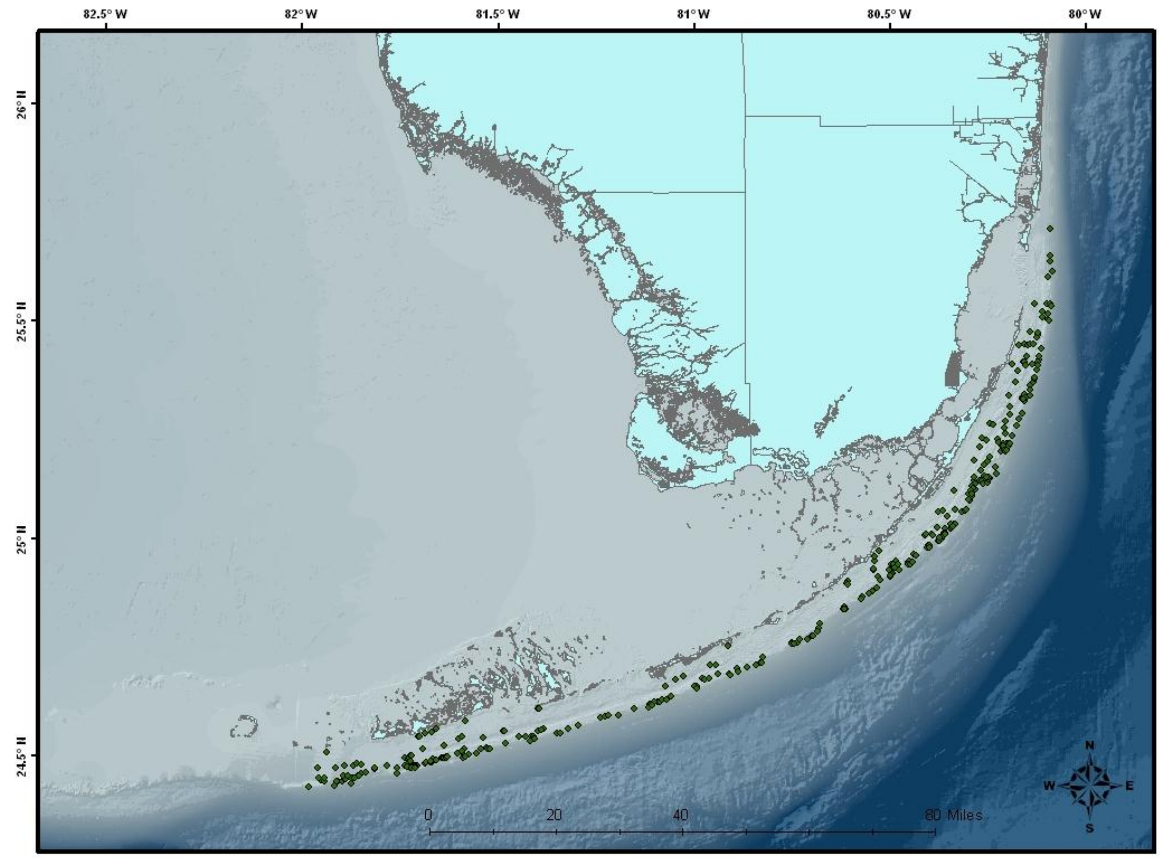

Figure 1: Sampling site locations for 2011 in the Florida Keys reef tract.

Research Performance Measure: The objectives of this project are being met and currently on schedule. Two successful multi-agency cruises (June 2-12, June 18-28) are completed and the remaining sites are expected to be complete by the end of September 2011.

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

Project Personnel: M. Gidley, D. Wanless, D. Aranda, J. Bartkowiak (UM/CIMAS)
NOAA Collaborators: C. Sinigalliano (NOAA/AOML)
Other Collaborators: L. Johns, M. Phillips (UM OHHCenter); S. Hower (UM Miller School of Medicine); F. Johnson and D. Adebanjo (NOAA Hollings Scholars); M.J. Absten (FIU)

Long Term Research Objectives and Strategy to Achieve Them:
***Objectives*:** Utilization of molecular microbial source tracking tools to assess potential improvements of surface water quality in residential canals and near-shore coastal waters of the Florida Keys National Marine Sanctuary (FKNMS) in the region of the Little Venice Service Area (Vaca Key,

Florida) following the implementation of a new sewer infrastructure in the region. This study is part of a larger integrated on-going water quality assessment of the FKNMS, and the impacts of this water quality on both human health and coastal ecosystem and coral reef health.

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

CIMAS Research Theme:

Theme 6: Ecosystem Management *(Primary)*

Theme 7: Protection and Restoration of Resources ***(****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*)

Funding Unit: EPA subtract from FIU and NSF/NIEHS

NOAA Technical Contact: Alan Leonardi

Research Summary:

The ocean-side coastal residence canal area of Vaca Key known as the "Little Venice (LV) Service Area" in the Florida Keys (Fig. 1) has historically been observed to frequently contain elevated levels of fecal indicator bacteria in surface waters of the canals and nearshore coastal waters. This region has previously been identified as one of the fecal indicator bacteria (FIB) "hot spots" of the Florida Keys National Marine Sanctuary, (FKNMS). The historical sanitary infrastructure of the Little Venice Service Area has consisted of individual septic fields or even old cess pits. These aging sanitation structures along the Little Venice area residential canals were subject to significant leakage to the surrounding coastal waters and have been replaced with a municipal area sewer system with expectations for improved regional near-shore water quality

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

This surveillance study investigated the fecal indicator bacterial load in the canal waters using culture based regulatory methods, and using quantitative Polymerase Chain Reaction (qPCR) assays targeting FIB strains specific to human or animal host sources. Although primary work on this project was completed in the early part of this fiscal year, a followup 48-hour intensive diurnal study of molecular microbial source tracking markers at these sites was conducted during the wet season of the summer of 2011. Surface waters from remediated canals and from canals with homes still on septic systems were sampled on a semi-monthly basis, and also during three 48-hour intensive diurnal sampling events (Fig. 2) in Jan 2010, July 2010, and again in July 2011. Viable fecal indicator bacteria were measured by regulatory culture-based methods and molecular source tracking markers were measured by quantitative PCR. The remediated canals where homes have been connected to the municipal sewer system show lower levels of Enterococci fecal indicator bacteria and substantially lower levels of human-host-source Bacterioides fecal indicator bacteria than the canal where homes are still on aging septic systems. The human fecal marker was most abundant in the septic canal and during the dry winter season, but during the wet summer seasons substantial dog-host-source Bacteroides fecal indicator bacteria indicative of runoff and stormwater discharge were found in most of the canals (and particularly a canal with a stormwater discharge at its head. Results suggest that the sanitary infrastructure improvements implemented in the Little Venice Service Area have significantly improved the nearshore water quality of the region, but that runoff and stormwater discharge are still fecal indicator input sources that may continue to negatively impact the region's coastal water quality.

Figure 2: Dr. Maribeth Gidley, an environmental public health physician with CIMAS, collects water samples for culture and genetic analyses from an autosampler at the head of the Little Venice residential canal with a storm-water discharge drain at 100th Street canal. Summer, 2010.

Figure 3: The head of the 112th Street Canal at Little Venice, Summer 2011.

Figure 4: Counter-clockwise from top – Lisa Johns (UM student intern at AOML), Frank Johnson (NOAA Hollings Scholar at AOML), and Susan Hower (Post-Doc from UM Miller School of Medicine) prepare an ISCO autosampler for water collection from the 91st Street Canal in Little Venice, Summer 2011.

These continued monitoring efforts aid in regional water quality management. Measuring the relative abundance of multiple human-source fecal indicator markers can help researchers and water quality managers better assess if the implemented sanitary improvement activities of the region are having an impact on the microbial population composition and thus resulting in reduced potential risk to humans and the ecosystem from human fecal contamination of the local coastal waters.

Figure 5: NOAA Hollings Scholar Frank Johnson filters water samples from Little Venice at the Keys Marine Lab (KML) to extract community DNA for molecular microbial source tracking of fecal indicator bacteria.

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

Evaluation of ESA Listed Acropora spp. Status and Actions for Management and Recovery

Project Personnel: D.E. Williams and A. Bright (UM/CIMAS)
NOAA Collaborators: M.W. Miller (NOAA/SEFSC)

Long Term Research Objectives and Strategy to Achieve Them:

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

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

CIMAS Research Theme:

***Theme 6*:** Ecosystem Management (*Primary*)
***Theme 7*:** Protection and Restoration of Resources (*Secondary*)

Link to NOAA Strategic Goals:

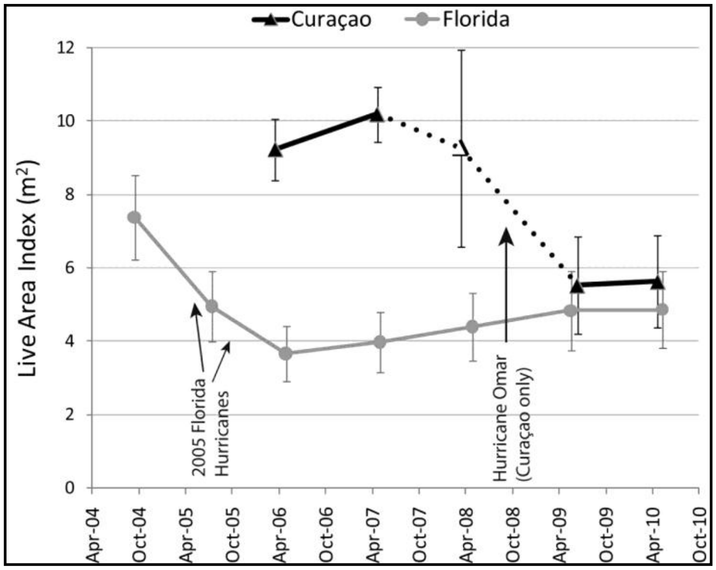
***Goal 1*:** Protect, Restore, and Manage the Use of Coastal and Ocean Resources through an Ecosystem Approach to Management

Funding Unit: NMFS/SEFSC **NOAA Technical Contact:** Theo Brainerd

Research Summary:

Since the 1980s, elkhorn and staghorn corals (*Acropora* spp*.)* have declined by more than 90% on reefs throughout the Caribbean. Because of its fast growth rates and structural complexity, it is ecologically irreplaceable on Caribbean reefs. Acroporid corals are listed as 'Threatened' species under the U.S. Endangered Species Act. NMFS is in the process of designating critical habitat and developing a recovery plan based on the current status and threats to these corals in U.S. waters. Data collected for this project are directly supporting the critical habitat designation and recovery plan development by NMFS. Additionally, the protocol developed based on this project is being implemented to other reef areas through state and territorial partners. The design of this ESA Section 6 effort is contingent upon our existing monitoring effort and assistance in implementing the protocol in a consistent manner.

The overall objectives of this project are to document the dynamics of the remaining Elkhorn populations in the upper Florida Keys and compare its performance to other Caribbean locations. Individually tagged *Acropora palmata* colonies are surveyed periodically to document their condition. Based on these observations, we can estimate basic population parameters including recruitment, growth and mortality, along with the causes of mortality and the sources of recruitment (asexual or sexual). These data are directly used in a population model being developed by a colleague at Scripps Institute of Oceanography and the projections will assist in the development of a recovery plan by NMFS. Data from the Florida Keys population indicates continued decline of the adult *A. palmata* population, and an alarming failure of asexual and sexual recruitment. This decline was the direct result of the 2005 hurricane season. Recovery from this disturbance has been slow and the population continues to suffer losses from disease and predation. *Acroporapalmata* in Curacao suffered similar losses (~50%) due to Hurricane Omar in 2008 (Fig. 1) but is showing signs of a more robust recovery with evidence of greater inputs from recruitment.



Figures 1: The average Live Area Index (LAI), for *Acropora palmata* study plots in the upper Florida Keys and Curacao since the start of the study in each location. Four hurricanes affected the Florida Keys between July and November 2005 (Dennis, Katrina, Rita, & Wilma) for the Florida Keys and hurricane Omar affected Curaçao in October 2008. Error bars represent standard error. Dashed lines connecting to the 2008 Curaçao survey indicate fewer plots (n=3) were mapped in 2008 (compared to n=9 for the other years).

Additionally our data allows us to estimate that in the Florida Keys population most common source of tissue loss on *Acropora palmata* is white disease, followed by breakage and feeding by the corallivorous snail *Coralliophila abbreviata*. The surveys have revealed that disease, storm associated fragmentation and predation by corallivorous snails are the top three sources of tissue mortality. This study has begun to assess the effectiveness of removal of the predatory snails as a management tool.

Research Performance Measure: All major objectives of this project are ongoing and progress is on schedule. Three surveys of the Florida Keys sites were conducted. Additional study sites were established in August 2010 and the predator removal project began in June 2011. Survey sites around Curacao were re-surveyed in May 2011. Data has been processed for use in population models by our research partner at Scripps Institute of Oceanography and a manuscript reporting on the modeling results is in prep. A manuscript reporting on sources of mortality in *Acropora palmata* has also been submitted to a peer reviewed journal.

Oceanographic and Spectroscopic Analysis Relating to the Deepwater Horizon Oil Spill

Project Personnel: M. A. Roffer, G. Gawlikowski and M. Upton (Roffer's Ocean Fishing Forecasting Service, Inc.)
NOAA Collaborators: M. Wood and G. Goni (NOAA/AOML)
Other Collaborators: F. Muller-Karger (USF); G. Maul (FIT); K. Schaudt (Schaudt.US); T. Lee, UM/RSMAS, Retired)

Long Term Research Objectives and Strategy to Achieve Them:
***Objectives*:** Understanding the distribution and time history of the surface and subsurface oil, dispersants, and water mixture from the Deepwater Horizon oil spill episode is critical for designing sampling regimes, studying the impact on the ecosystem, and identifying areas for restoration. The objectives for this research were: (1) To provide oceanographic information to researchers and emergency managers showing the distribution of the Deepwater Horizon surface oil and suspected subsurface oil-water-dispersant mixture along with the near-field and far field ocean circulation. (2) To develop new oceanographic data products derived from satellites and other sources for use in monitoring the distribution of the oil water mixture and ocean circulation.
***Strategy*:** To produce a daily "Oil Oceanographic Analysis (Oil OA)" for the areas affected by the Deepwater Horizon Oil to designated scientific staff at the CIMAS and NOAA.

CIMAS Research Theme:
***Theme 6*:** Ecosystem Management (*Primary*)
***Theme 3*:** Sustained Ocean and Coastal Observations (*Secondary*)
***Theme 4*:** Ocean Modeling (*Secondary*)
***Theme 5*:** Ecosystem Modeling and Forecasting (*Secondary*)
***Theme 7*:** Protection and Restoration of Resources (*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 2*:** Understand Climate Variability and Change to Enhance Society's Ability to Plan and Respond (*Secondary*)
***Goal 3*:** Serve Society's Needs for Weather and Water Information (*Secondary*)
***Goal 4*:** Support the Nation's Commerce with Information for Safe, Efficient, and Environmentally Sound Transportation (*Secondary*)
***Goal 5*:** Mission Support (*Secondary*)

Funding Unit: OAR/AOML **NOAA Technical Contact:** Alan Leonardi

Research Summary:
This project encompasses three subcontracts: "*Flow Cytometric Analysis Relating to the Deepwater Horizon Oil Spill*" to Nicole Poulton, Bigelow Laboratory for Ocean Sciences; "*Fluorescent Hydrocarbon Analysis Relating to the Deepwater Horizon Oil Spill* – Nancy Foster Cruise" to Paula Coble, University of South Florida; and "*Integrated Satellite and Ocean Data Products in Support of Ecosystem Studies in the Gulf of Mexico and Straits of Florida*" to Roffer's Ocean Fishing Forecasting Service, Inc.) This annual report focuses on the results and accomplishments of the third

subcontract to Roffer's Ocean Fishing Forecasting Service. Data analysis is in progress for the other two subcontracts.

This project provided a unique satellite derived "Oil Oceanographic Analysis" (Oil OA) for the areas affected by the Deepwater Horizon Oil to research scientists, emergency managers, and the general public including the media. There were three main phases of this effort: 1) providing real-time daily oceanographic analyses of the surface water that was contaminated by the surface oil – dispersant mixture; 2) providing real-time oceanographic analyses of surface and subsurface water motion after the primary recoverable oil was removed to help understand the distribution of the subsurface oil-dispersant cloud plume; and; 3) develop new satellite data products for use in monitoring the distribution and movements of the oil-water mixture and ocean circulation.

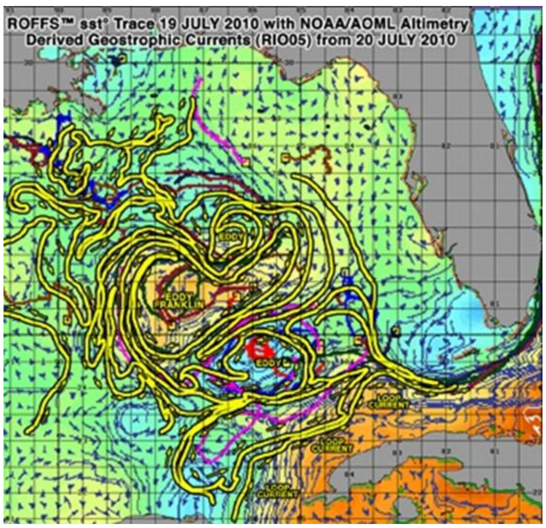


Figure 1: Oil Oceanographic Analysis May 27, 2010. This is the initial Oil Oceanographic Analysis (Oil OA) derived on May 27, 2010 that is a color enhanced infrared satellite composite for the eastern Gulf of Mexico. Sea surface temperature (SST) is shown and the current direction is indicated based on sequential image analysis of the coherent Lagrangian structures (water masses). The water mass boundaries are outlined. The surface oil from the Deepwater Horizon spill (red x shows site), shown in dark brown, was derived from synthetic aperture radar and visible (ocean color, RGB and sun glint) satellite data. The areas that are colored in gray are the water masses that passed through the oil that contained an unknown concentration of oil, dispersant and water.

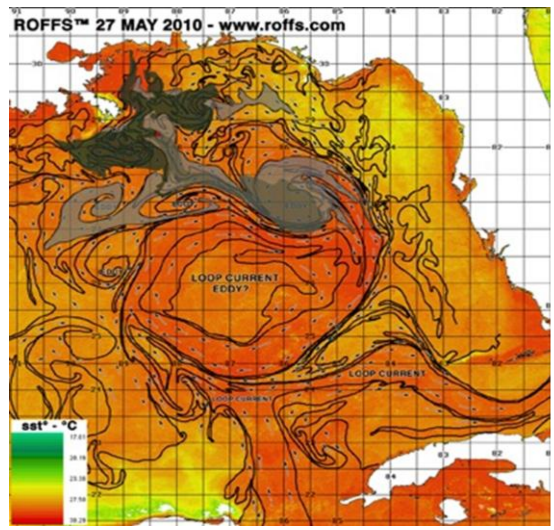


Figure 2: Merged satellite data Oil Oceanographic Analysis June 29-July 03, 2010. This a Oil Oceanographic Analysis (Oil OA) for the eastern Gulf of Mexico that is a new merged data product. Different types of satellite data including infrared (ocean frontal analysis schematic for July 3 shown as red outlines derived), synthetic aperture radar and visible satellite data (the surface oil distribution shown in grey along the coast of Louisiana, Mississippi, Alabama, and Florida from June 29- July 03, 2010), and altimeter derived currents (July 03, 2010 NOAA AOML product). The suspected water oil mixture (WOM) of unknown concentration is labeled.

The Oil OA, composed of a text analysis and graphic surface oceanographic features analysis, was developed and provided to NOAA, CIMAS, and the general public in real-time. The text provided a description of the overall ocean circulation and focuses on the significant flow fields in the area of interest (e.g. Gulf of Mexico and Straits of Florida). It included a discussion of the distribution of: 1) any observed surface oil; 2) the water masses associated with the oil spill; 3) likely short-term movements of the water masses; and 4) other pertinent information including validation evidence (e.g. fixed buoys, drifting buoys, and in situ data). The graphic component was an enhanced ocean frontal analysis and was derived primarily from polar orbiting NOAA, NASA, and European infrared and ocean color satellite data and secondarily from satellites with synthetic aperture radar (SAR) and altimeters. For the second phase subsurface current data derived from acoustic doppler current profilers (ADCP) were added to the graphic analysis.

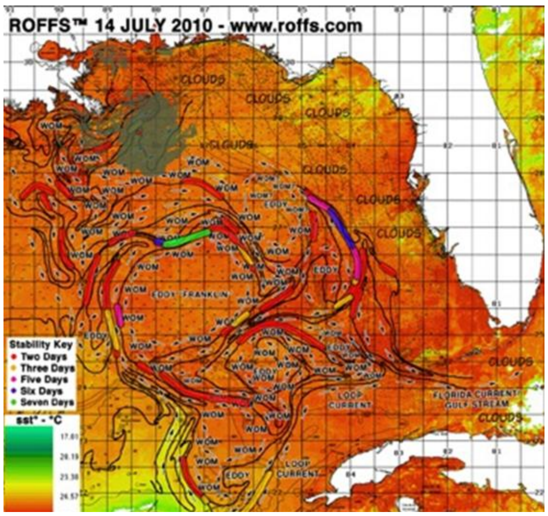


Figure 3: Oil Oceanographic Convergence Stability Analysis July 14, 2010. This is a new Oil Oceanographic Analysis (Oil OA) derived on July 14, 2010 that is a color enhanced infrared satellite composite for the eastern Gulf of Mexico. Sea surface temperature (SST) is shown and the current direction is indicated based on sequential image analysis of the coherent Lagrangian structures (water masses). The water mass boundaries are outlined. The surface oil from the Deepwater Horizon spill (red x shows site), shown in dark brown, was derived from synthetic aperture radar and visible (ocean color, RGB and sun glint) satellite data. The water mass boundary convergences that overlapped for two to seven days are color coded. The working hypothesis is that the longer time that a convergence zone occurred over a particular area, the greater chance that oil and organisms (e.g. fish larvae, Sargassum, birds, and turtles) would be concentrated in that area.

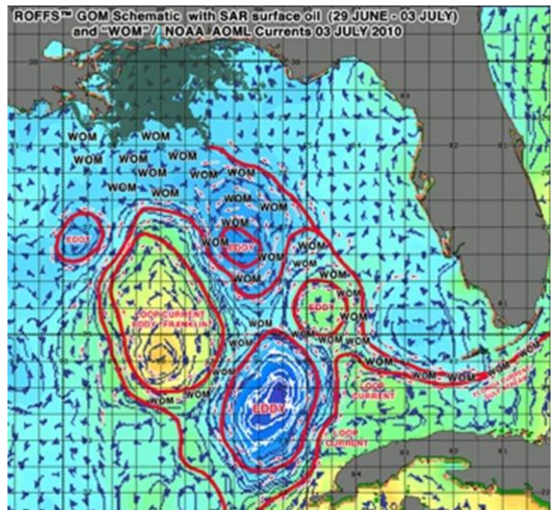


Figure 4: Merged, buoy, altimetry, and ocean frontal Analysis July 19-20, 2010. This a oceanographic analysis for the eastern Gulf of Mexico that is a new merged data product. Different types of satellite data including infrared (ocean frontal analysis shown as yellow outlines derived from July 19), altimeter derived currents (July 20, 2010 NOAA AOML product using the RIO05 mean) and seven days of surface drifting buoy data derived from NOAA AOML are combined. This illustrates the complementary nature of these data and that one data type verifies the other data.

For the third part of the research effort new satellite data products were developed. These products fused the data derived from the Oil OA with the satellite data derived from NOAA AOML's altimetry product and from data derived from surface drifting buoys, and acoustic doppler current profilers (ADCP).

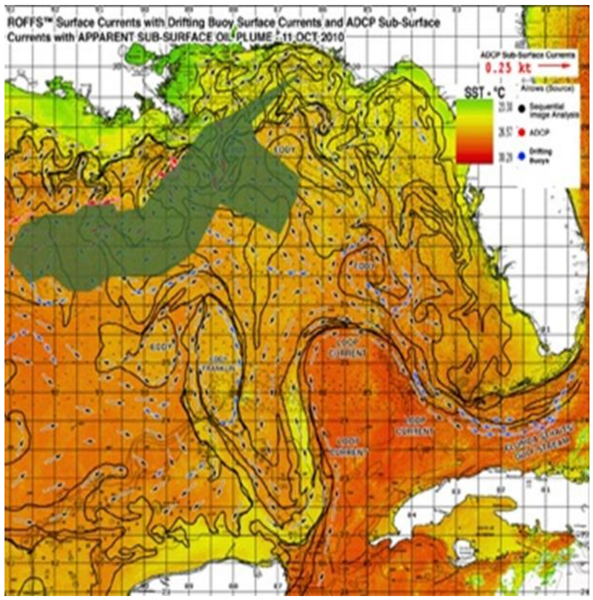


Figure 5: Surface and subsurface currents with apparent sub-surface oil plume October 11, 2010. This is a new merged ocean data product that combines: 1) infrared satellite data derived ocean frontal analysis (Sea surface temperature (SST) is shown and the current direction is indicated based on sequential image analysis of the coherent Lagrangian structures (water masses) and the water mass boundaries are outlined in black); 2) acoustic doppler current profile derived 24 hour mean subsurface current at approximately 600m (red arrows); and 3) Surface drifting buoys from Horizon Marine, Inc. (blue arrows). The apparent subsurface oil-dispersant mixture plume (NOAA) is overlaid as a green shape. This was used to evaluate if the surface currents and the subsurface currents were moving in the same direction as an evaluation of the possibility of upwelling in the area where the subsurface oil-dispersant mixture occurred. The surface buoy data validated the satellite derived surface current analysis.

Data analyses derived during this research were used to increase our understanding the distribution and time history of the surface and subsurface oil, dispersants, and water mixture is critical for designing sampling regimes, studying the impact on the ecosystem, and identifying areas for possible restoration. The data analyses were used by researchers on the R.V. Nancy Foster as an aide for selecting sampling stations (June 30-July 18, 2010). In addition, the analyses were used to support the interpretation and publication of the scientific data derived from the R.V. Walton Smith research cruise (June 6-10, 2010).

Research Performance Measure: Daily analyses were provided to the designated personnel. On days when the clouds obscured the ocean surface using infrared and ocean color data, analyses were provided using a combination of data derived from satellite derived synthetic aperture radar (University of Miami CSTARS) and altimeters (NOAA AOML), ocean models (e.g. HYCOM), ocean drifting buoys (Horizon Marine and NOAA AOML), and ADCP data (NOAA National Data Buoy Center).

Puerto Rican Small Scale Fleet Costs and Earnings Study

Project Personnel: F. Tonioli (UM/CIMAS)
NOAA Collaborators: J. Agar (NOAA/AOML)

Long Term Research Objectives and Strategy to Achieve Them:
***Objectives*:** Develop a socio-economic profile of small-scale fishing fleets in the Commonwealth of Puerto Rico to support fishery management decisions.
***Strategy*:** The collection of socio-economic data will assist fishery managers by establishing socio-economic baselines, monitoring the financial and economic performance of the industry, and developing economic models to evaluate management proposals.

CIMAS Research Theme:
Theme 6: Ecosystem Management

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

Funding Unit: NMFS/SEFSC **NOAA Technical Contact** Theo Brainerd

Research Summary:
This is an on-going project. Over 360 small-scale fishermen in the Commonwealth of Puerto Rico were interviewed for this study. The survey inquired about household demographics, fishing practices, capital investment on vessels and equipment, revenues and fixed and variable costs.

Research Performance Measure: On-going project. Fieldwork component of the project was completed.

RESEARCH REPORTS

THEME 7: Protection and Restoration of Resources

Simulation of Management Strategies

Project Personnel: E.A. Babcock and D.J. Die (UM/RSMAS)
Other Collaborators: J. Hoenig (Virginia Institute of Marine Science)

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

CIMAS Research Theme:
***Theme 7*:** Protection and Restoration of Resources (*Primary*)
***Theme 5*:** Ecosystem Modeling and Forecasting (*Secondary*)
***Theme 6*:** Ecosystem Management (*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

Funding Unit: NMFS/SEFSC **NOAA Technical Contact:** Theo Brainerd

Research Summary:
This project developed improved methodologies for simulating fisheries population dynamics in time and space for the purposes of ecosystem based management strategy evaluation. PI Babcock contributed to the SEDAR stock assessment of sandbar, blacknose and dusky sharks, by standardizing the Marine Recreational Fisheries Statistics Survey (MRFSS) abundance index data, and participating in the data and stock assessment working groups.

Fish reproductive strategies can vary between sub-populations, although fishery management measures tend to be applied at larger spatial scales. UM Ph.D. student Elizabeth Martin Council is comparing the impact of seasonal, multi-seasonal, and year-round spawning strategies, differences in ages of maturity, differences in longevity, differences in type and strength of density dependence in younger age classes, and the mortality by age induced by commercial and recreational fisheries among subpopulations. She has developed a Leslie matrix model for highly migratory species dynamics including alternative reproductive strategies as is continuing to add complexity to the model. The theoretical model will later be applied to bluefin tuna, Atlantic tarpon, and Atlantic skipjack tuna.

UM Ph.D. student Mandy Karnauskas has been analyzing indicators of marine reserve effectiveness. She demonstrated that the spatial distribution of fish species at a Caribbean atoll was a better predictor of whether they would benefit from a reserve than their trophic level or whether they were heavily targeted. She has shown that there is very little correlation between catch per unit effort (CPUE) and underwater visual census (UVC) data for most species at Glover's Reef atoll, Belize, even if the data were collected at nearly the same time and place (Figure 1), which has implications for the evaluation of marine reserve effectiveness based on either fishery dependent or fishery independent data.

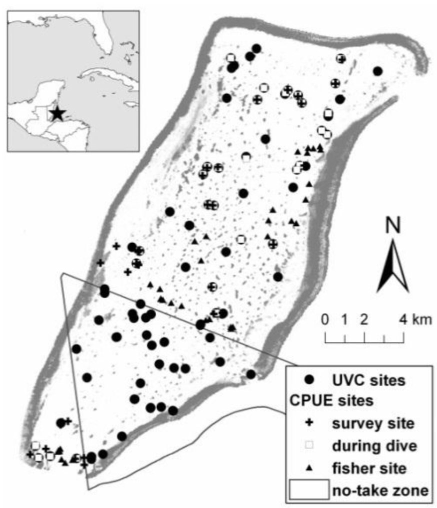


Figure 1: Glover's reef marine reserve, showing sites for underwater visual census (UVC) and catch per unit effort (CPUE) data collection, from Mandy Karnauskas' dissertation.

UM PhD student Bill Harford, is developing methodology to characterize trade-offs in reef fish management objectives for spatial management strategies under uncertainty about the spatial dynamics of marine populations. He is currently developing and testing the grouper movement models that comprise the core of his management strategy evaluation model. He has also developed an Ecopath with Ecosim (EwE) model of the Northwest Atlantic, focusing on abundance of and prey selection by shortfin mako sharks. He has submitted an abstract to present the results at the Mote Symposium in November, 2011.

Lynn Waterhouse completed her Master's degree in Marine Science at VIMS and graduated in January, 2011. Her thesis was entitled "Partial Year Tagging Models: accounting for changing tag visibility and delayed mixing." It dealt with methodology for estimating fishing and natural mortality rates for fisheries management. Mathew Smith at VIMS is assessing the impact of emergent chronic diseases on striped bass, American lobster and snow crab and determining the management implications of the diseases.

Research Performance Measure: All seven of the proposed research tasks have been accomplished or are in progress and all of the students involved in the project are making the expected progress toward their degrees. At UM, Elizabeth Martin has turned in her proposal to her committee. She is preparing to take the Mathematics and Marine Biology and Fisheries qualifying exams this year. Mandy Karnauskas is nearing completion of her dissertation on indicators of marine reserve effectiveness, and has two papers published, two in press, and one in review. William Harford has finalized his proposal, passed his qualifying exam and advanced to candidacy. At VIMS, Lynn Waterhouse completed her Master's degree in Marine Science at VIMS and graduated in January, 2011. She has one paper in press and one in revision. Mathew Smith completed his Master's degree in statistics and he has successfully petitioned to bypass the Master's requirements in marine science so he can pursue his doctorate directly. He is presently completing his last required course and will then focus on completing his research.

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Marine Mammal Stranding and Research

Project Personnel: L. Aichinger Dias (UM/CIMAS)
NOAA Collaborators: L. Garrison (NOAA/SEFSC)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** To support the Marine Mammal Health and Stranding Response Program (MMHSRP) at Southeast Fisheries Science Center (SEFSC) in data validation and collection. To assist the SEFSC's Protected Resources and Biodiversity program in management and conservation of protected species during data collection programs within the Marine Mammal Program.

***Strategies*:** To validate the stranding historical data collected by the Southeast Region Marine Mammal Stranding Network from 1996 to 1999 working closely with the SEFSC staff to implement effective data auditing and correction. To respond and coordinate response actions with the Southeast Region (SER) Stranding Coordinator in case of cetaceans stranding dead or alive as well as entanglement reports of cetaceans along the US Southeast Region (from North Carolina to Texas, Puerto Rico and the U.S. Virgin Islands). To assist on management of data from stranding network agencies located in the states bordering the Gulf of Mexico in response to the **Deepwater Horizon Oil Spill**. To perform and assist in necropsies at the SEFSC. To support field work and management of data onboard NOAA Research Vessels in the Gulf of Mexico and Atlantic Ocean. To assist on the Biscayne Bay's bottlenose dolphin population monitoring program by means of photo-identification. To assist on management of data coming from damage assessment studies of the Deepwater Horizon Oil Spill in the Gulf of Mexico.

CIMAS Research Theme:

***Theme 7*:** Protection and Restoration of Resources

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 5*:** Provide Critical Support for NOAA's Mission (*Secondary*)

Funding Unit: NMFS/SEFSC **NOAA Technical Contact**: Theo Brainerd

Research Summary:

The data management and collection I conducted at the Marine Mammal Health and Stranding Response Program and at the Marine Mammal Program have proven essential in order to fulfill each program's research goals. As a critical part of the team, I managed complex data collected during research cruises, assisted in small boat photo-identification surveys (See **Figure 1**), collected samples from stranded animals and utilized appropriate skills associated with the management of data coming from the Deepwater Horizon Oil Spill event. Specifically, completing the auditing and validation of the historical stranding data is improving the accuracy in which the scientific analysis of cetacean strandings can be performed. Similarly, responding to strandings and gathering consistent data is providing the necessary baseline for scientific analysis. This is especially crucial, considering the increasing interest in examining the impacts of military and other human activities on the rate and location of stranding events nowadays. Gathering data from dead animals is important and so is the monitoring of live populations, especially wild population living in highly human influenced areas such as Miami and along the Gulf of Mexico. Given the recent oil spill incident in the Gulf of Mexico, special attention has been given to the area by means of increasing planned research efforts as well as diverting personnel to the area from this and other SEFSC projects.

Figure 1: Marine mammal stock assessment onboard NOAA Research vessel Gordon Gunter in the Atlantic Ocean_30 Jun 11.

Research Performance Measure: All goals were completed on time.

- Completed nearly 3 years of historical data validation;
- Responded to and coordinated several stranding events in the Miami area and FL Keys;
- Inventoried samples collected from stranded cetaceans during and after the oil spill incident in several stranding network agencies in the Gulf of Mexico (MS, LA, and FL);
- Performed and assisted in necropsies at the SEFSC either as part of standard sampling procedures or training of network members;
- Supported field work and conducted data management onboard the NOAA Research vessel Gordon Gunter (GU10-05: Oct-Nov 2010 and GU11-02: Jun 2011);
- Assisted in small boat photo-identification surveys in Biscayne Bay as part of the bottlenose dolphin population monitoring program;
- Acted as a liaison for field procedures and chain of custody requirements between field teams conducting damage assessment studies of the Deepwater Horizon Oil Spill and the NRDA (Natural Resource Damage Assessment) program.

Coastal Fisheries Logbook Program

Project Personnel: J. Diaz (UM/CIMAS)
NOAA Collaborators: D. Gloeckner, M. Judge, N. Baertlein and J. Hall (NOAA/SEFSC)

Long Term Research Objectives and Strategy to Achieve Theme:
Objectives**:** To determine the fishing effort of federally-permitted commercial fishers in the South Atlantic and Gulf of Mexico.
Strategy**:** To collect fisheries dependent catch data by providing trip report logbooks to all federal South Atlantic Snapper/Grouper, Gulf of Mexico Reef Fish, Shark, King Mackerel, Spanish Mackerel, and Dolphin/Wahoo permit holders in the U.S. Atlantic and Gulf of Mexico.

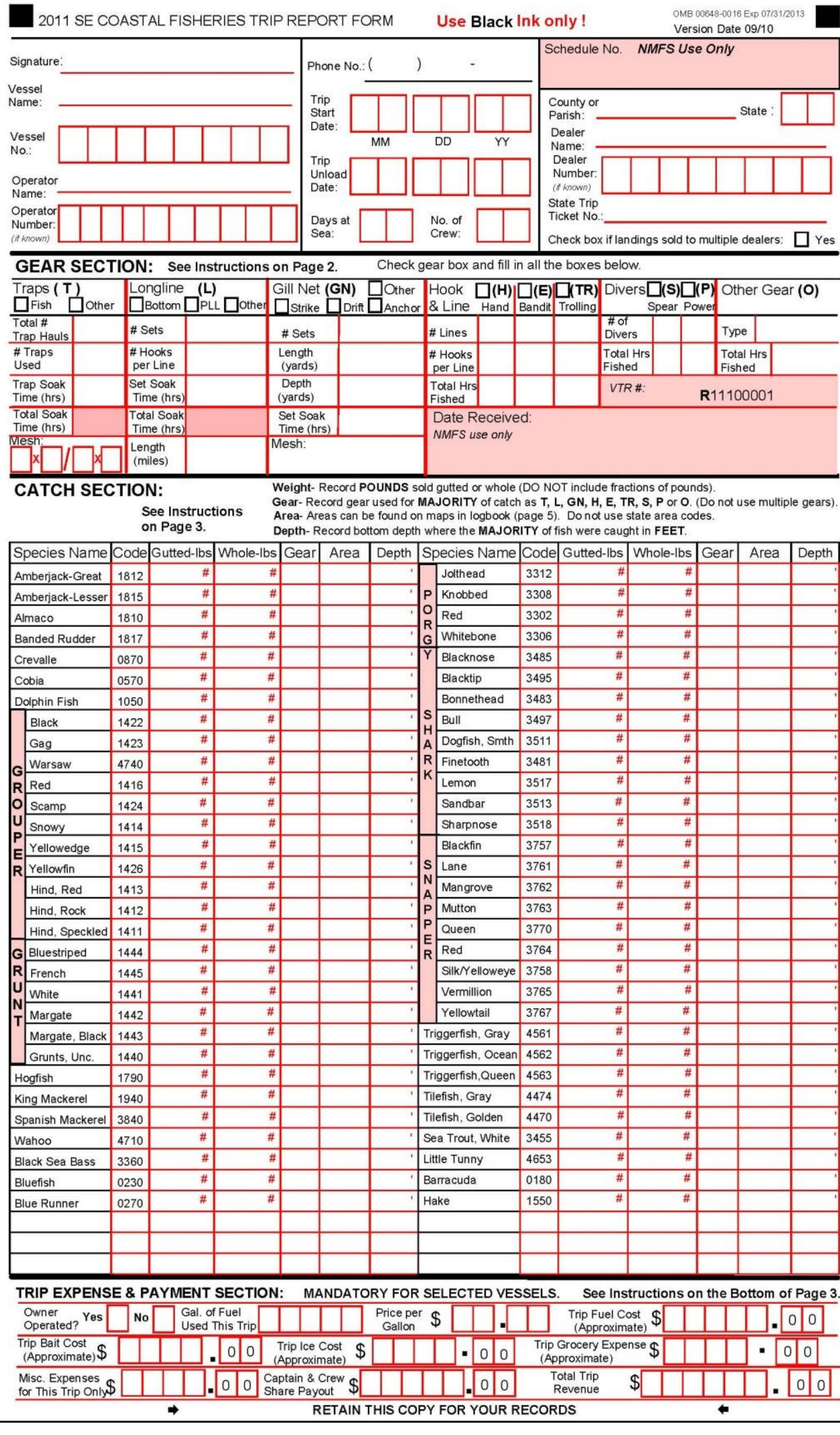
CIMAS Research Theme:
Theme 7**:** Protection and Restoration of Resources

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

Funding Unit: NMFS/SEFSC **NOAA Technical Contact:** Theo Brainerd

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 21 years, fishers in the SA and GOM who possess federal commercial fishing permits (SA Snapper-Grouper, GOM Reef fish, King Mackerel, Spanish Mackerel, Shark, & Atlantic Dolphin/Wahoo) have been required to submit a trip report form which primarily aims to collect landings and fishing effort data. Data collected is therefore used for fisher permit compliance. Data is also used in conjunction with other fisheries-dependent, and independent, data sets for stock assessments and fisheries management decisions. A recent stock assessment of Gulf of Mexico red grouper utilized a indices of abundance created from logbook data (**Figure 1**).

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



2011 SE COASTAL FISHERIES TRIP REPORT FORM **Use Black Ink only !** OMB 00648-0016 Exp 07/31/2013 Version Date 09/10

Signature: Phone No.: ( ) - Schedule No. *NMFS Use Only*

Vessel Name: Trip Start Date: MM DD YY County or Parish: State:

Vessel No.: Dealer Name:

Operator Name: Trip Unload Date: Dealer Number: (if known)

Operator Number: (if known) Days at Sea: No. of Crew: State Trip Ticket No.:

Check box if landings sold to multiple dealers: ☐ Yes

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

Traps (T) ☐Fish ☐Other — Total # Trap Hauls; # Traps Used; Trap Soak Time (hrs); Total Soak Time (hrs); Mesh: x / x

Longline (L) ☐Bottom ☐PLL ☐Other — # Sets; # Hooks per Line; Set Soak Time (hrs); Total Soak Time (hrs); Length (miles)

Gill Net (GN) ☐Other ☐Strike ☐Drift ☐Anchor — # Sets; Length (yards); Depth (yards); Set Soak Time (hrs); Mesh:

Hook & Line ☐(H) Hand ☐(E) Bandit ☐(TR) Trolling — # Lines; # Hooks per Line; Total Hrs Fished

Divers ☐(S) Spear ☐(P) Power — # of Divers; Total Hrs Fished

Other Gear (O) — Type; Total Hrs Fished

VTR #: R11100001

Date Received: *NMFS use only*

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	Species Name	Code	Gutted-lbs	Whole-lbs	Gear	Area	Depth
Amberjack-Great	1812	#	#			'	PORGY Jolthead	3312	#	#			'
Amberjack-Lesser	1815	#	#			'	PORGY Knobbed	3308	#	#			'
Almaco	1810	#	#			'	PORGY Red	3302	#	#			'
Banded Rudder	1817	#	#			'	PORGY Whitebone	3306	#	#			'
Crevalle	0870	#	#			'	PORGY Blacknose	3485	#	#			'
Cobia	0570	#	#			'	SHARK Blacktip	3495	#	#			'
Dolphin Fish	1050	#	#			'	SHARK Bonnethead	3483	#	#			'
GROUPER Black	1422	#	#			'	SHARK Bull	3497	#	#			'
GROUPER Gag	1423	#	#			'	SHARK Dogfish, Smth	3511	#	#			'
GROUPER Warsaw	4740	#	#			'	SHARK Finetooth	3481	#	#			'
GROUPER Red	1416	#	#			'	SHARK Lemon	3517	#	#			'
GROUPER Scamp	1424	#	#			'	SHARK Sandbar	3513	#	#			'
GROUPER Snowy	1414	#	#			'	SHARK Sharpnose	3518	#	#			'
GROUPER Yellowedge	1415	#	#			'	SNAPPER Blackfin	3757	#	#			'
GROUPER Yellowfin	1426	#	#			'	SNAPPER Lane	3761	#	#			'
GROUPER Hind, Red	1413	#	#			'	SNAPPER Mangrove	3762	#	#			'
GROUPER Hind, Rock	1412	#	#			'	SNAPPER Mutton	3763	#	#			'
GROUPER Hind, Speckled	1411	#	#			'	SNAPPER Queen	3770	#	#			'
GRUNT Bluestriped	1444	#	#			'	SNAPPER Red	3764	#	#			'
GRUNT French	1445	#	#			'	SNAPPER Silk/Yelloweye	3758	#	#			'
GRUNT White	1441	#	#			'	SNAPPER Vermillion	3765	#	#			'
GRUNT Margate	1442	#	#			'	SNAPPER Yellowtail	3767	#	#			'
GRUNT Margate, Black	1443	#	#			'	Triggerfish, Gray	4561	#	#			'
GRUNT Grunts, Unc.	1440	#	#			'	Triggerfish, Ocean	4562	#	#			'
Hogfish	1790	#	#			'	Triggerfish,Queen	4563	#	#			'
King Mackerel	1940	#	#			'	Tilefish, Gray	4474	#	#			'
Spanish Mackerel	3840	#	#			'	Tilefish, Golden	4470	#	#			'
Wahoo	4710	#	#			'	Sea Trout, White	3455	#	#			'
Black Sea Bass	3360	#	#			'	Little Tunny	4653	#	#			'
Bluefish	0230	#	#			'	Barracuda	0180	#	#			'
Blue Runner	0270	#	#			'	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) $. 0 0

Trip Bait Cost (Approximate) $. 0 0 — Trip Ice Cost (Approximate) $. 0 0 — Trip Grocery Expense (Approximate) $. 0 0

Misc. Expenses for This Trip Only $. 0 0 — Captain & Crew Share Payout $. 0 0 — Total Trip Revenue $. 0 0

➡ RETAIN THIS COPY FOR YOUR RECORDS ⬅

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.

Monitoring Shoreline Fish Assemblages of Biscayne and Florida Bays

Project Personnel: D. Johnson and B. Teare (UM/CIMAS); J. Luo (UM/RSMAS)
NOAA Collaborators: 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, 13-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 7*:** Protection and Restoration of Resources (*Primary*)
***Theme 2*:** Ecosystem Management (*Secondary*)

Link to NOAA Strategic Goal:
***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*)

Funding Unit: NMFS/SEFSC **NOAA Technical Contact:** Theo Brainerd

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, frequency of occurrence and concentration. No clear annual trends emerged within shoreline segments with the exception of *G. cinereus* which was found to decline from 1998-2010 along the Mainland shoreline. Densities of the four major taxa were higher at the leeward key shorelines than the mainland shorelines. Along the Mainland shoreline, wet and dry season 2010 delta densities were significantly lower than the historical mean for *S. barracuda*, *Eucinostomus spp.*, and *G. cinereus*. Wet season densities of *L. griseus* were significantly lower than the historical mean but dry season densities of *L. griseus* were not different. Low densities were attributed to extreme cold temperatures which occurred in January of 2010. Low water temperatures (<15^{o}) persisted over a long period of time, especially close to shore (12 days, **Figure 1**).

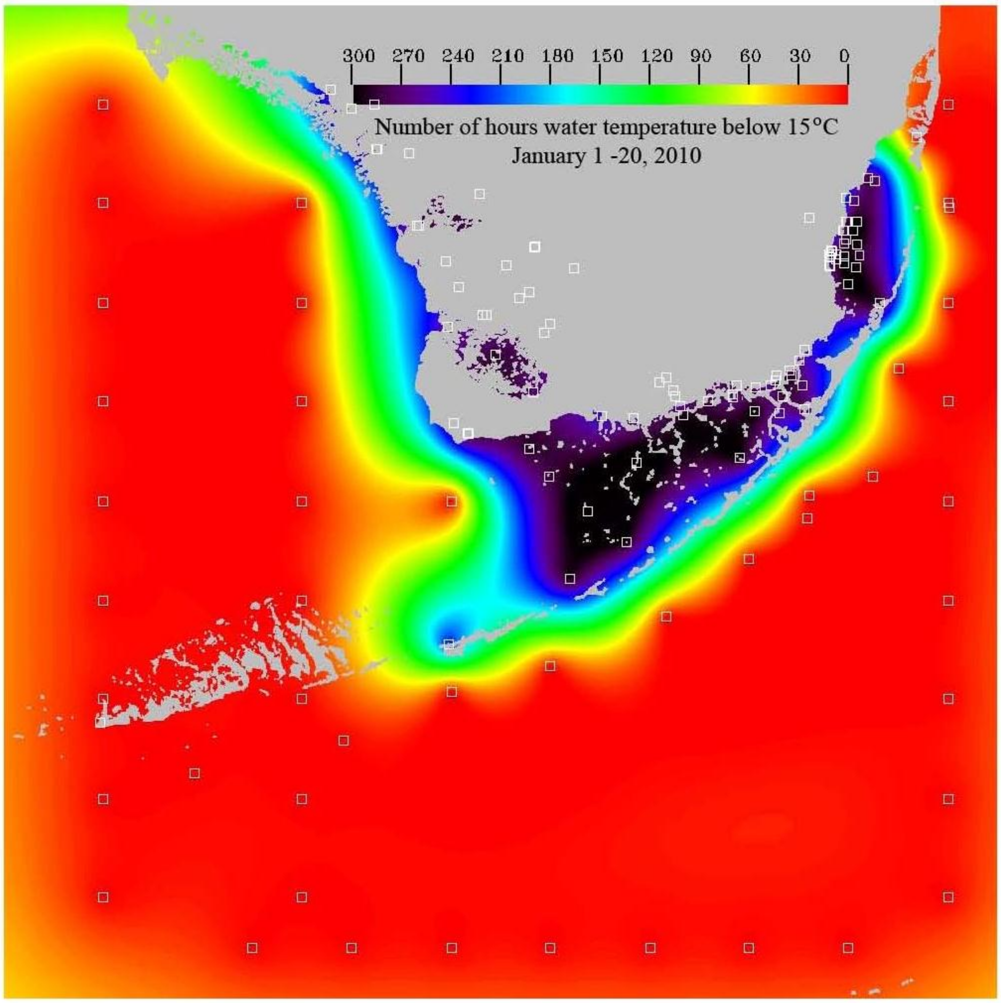


Figure 1: Spatial distribution of hours of low temperature < 15 (^{o}C) during January 1-20, 2010.

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 13 years of visual census fish monitoring effort.

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

3. Community Analyses

We calculated average taxonomic richness across years for the composite and subdivided mainland shoreline and the leeward key shoreline. We examined seasonal and annual variation of yearly indices of taxonomic richness using multivariate regression and analysis of variance. We found that dry season differences in species richness along the Mainland shoreline were primarily due to depth, dissolved oxygen, and temperature, while wet season differences were correlated with salinity, depth, and dissolved oxygen.

We found that richness was higher along the Leeward Key where the environment was more stable than along the Mainland Shoreline. Taxonomic richness during both 2010 seasons was significantly lower than the historical mean (1998-2009) for both the Mainland shoreline and the Leeward Keys. A significant decline in taxonomic richness was found from 1998-2010 for the Leeward Keys strata.

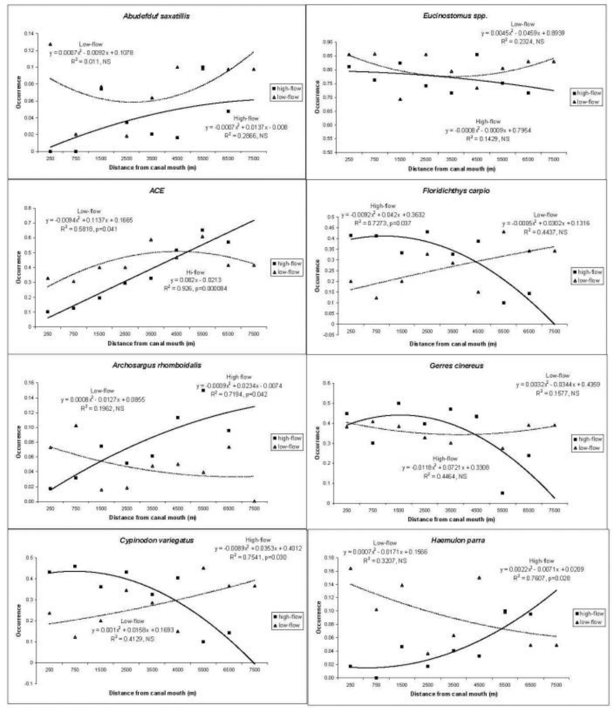
4. Canal Analyses

We also investigated on how proximity to freshwater canal mouths and/or magnitude of freshwater flow explain(s) variation in a suite of fish metrics (assemblage- to taxon-specific level). We found eleven species with a significant relationship ($p<0.10$) with distance from a canal: seven species for a high-flow canal and six species for a low-flow canal (**Figures 2A, 2B, 3A, 3B**). Five species (*A. saxatillis, H. parra, H. sciurus, L. parva,* and *A. rhomboidalis*) were never sighted within 500m of a high-flow canal, and six species (*S. barracuda, L. apodus, L. rhomboids, L. griseus, S. notata,* and the ACE group had their lowest densities in the vicinity of high-flow canals. Species that appeared to avoid areas near canals were reef-related and species that congregated near canal mouth tended to estuarine forage species that may have been seeking refuge from predatory fishes.

5. Laboratory Studies

Field observations of taxon-specific distribution and abundance often reflect a largely unknown mix of environmental and behavioral factors, making it difficult to predict fish response to variation in a single habitat variable, such as salinity. We are performing laboratory-based salinity preference trails for selected fishes as an independent means of validating apparent salinity affinities (or lack thereof) derived from exclusively field-collected data (**Figure 4**).

(2A)



(2B)

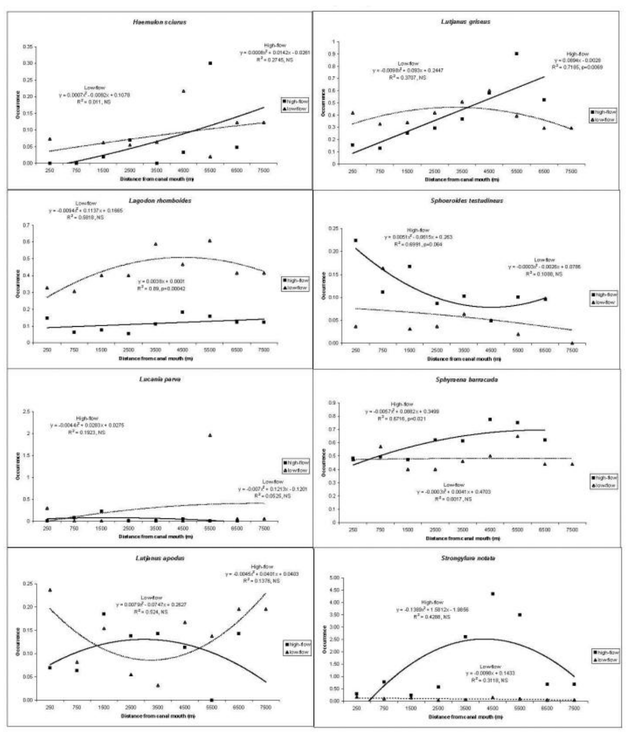
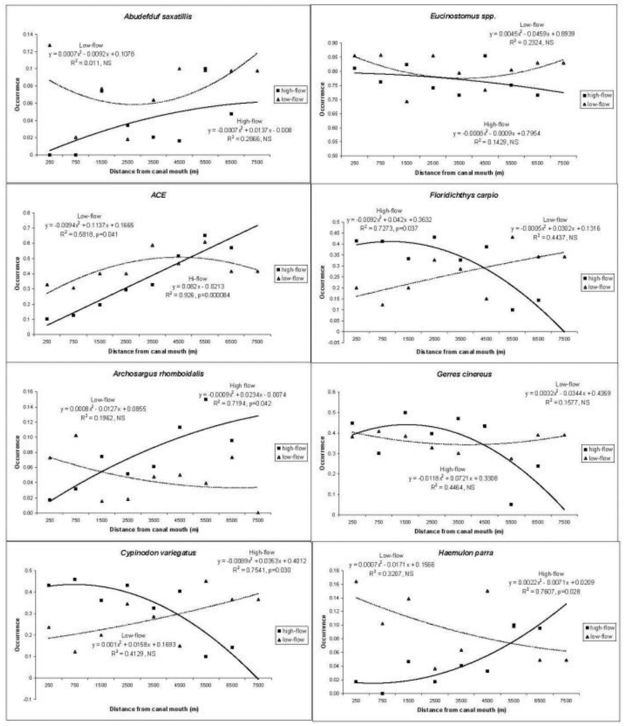


Figure 2A and 2B: Dry season frequency of occurrence of mangrove species sampled in visual census in relationship to distance from high-flow and low-flow canals. NS=not significant.

(3A)



(3B)

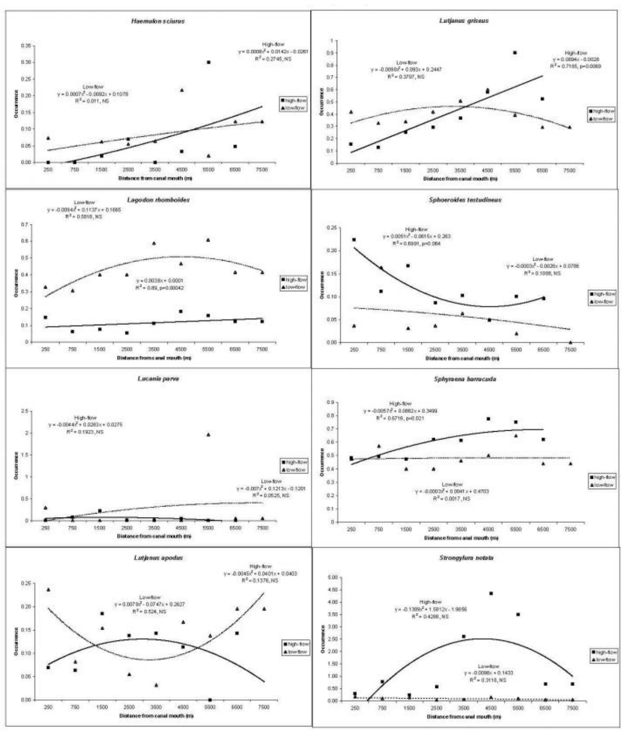


Figure 3A and 3B: Wet season frequency of occurrence of mangrove species sampled in visual census in relationship to distance from high-flow and low-flow canals. NS=not significant.

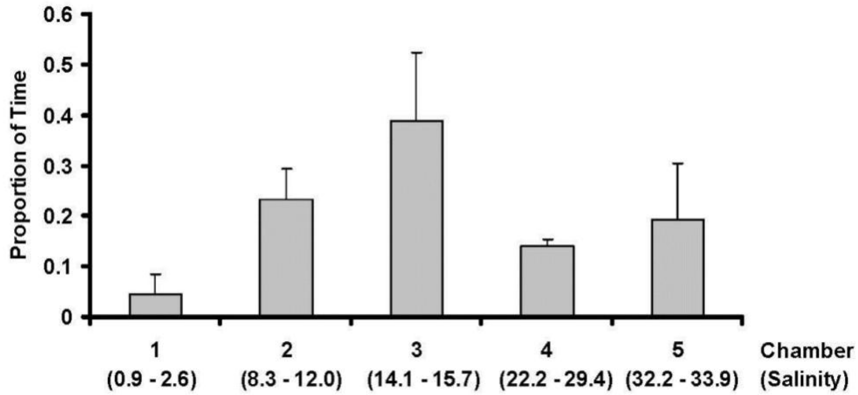


Figure 4: Results of salinity preference experiments (n = 4 trials) for *Floridichthyscarpio*using 5-chamber salinity gradient aquaria. In each trial, groups of ten, wild caughtindividuals were distributed evenly along the gradient (i.e., 2 fish per chamber)and their subsequent distribution monitored for 24 hrs via overhead video cameras.Shown are mean (+ 1 SE) proportions of time spent by fish groups in each chamber asdetermined from examination of frames captured every 5 minutes. Values in parenthesesare salinity ranges recorded over the four trials for each chamber.

Research Performance Measure: Our primary objectives were to continue our baseline visual census surveys and develop habitat suitability models to evaluate the impact of salinity on major organisms in Biscayne Bay. These objectives were accomplished. We have completed year 13 of our visual census survey and developed models for the six major species. The modeled relationships were found to be significant.

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Oxygen Winkler Titrations in Support of the Deep Water Horizon Oil Spill Response

Project Personnel: C. Langdon (UM/RSMAS); G.-H. Park and G.A. Berberian (UM/CIMAS)
NOAA Collaborators: R. Wanninkhof (NOAA/AOML); L. Baskin and C. Sumner (NOAA/NEFSC)

Long Term Research Objectives and Strategy to Achieve Them:
***Objectives*:** To improve the accuracy and precision of in situ measurements taken near the DWH well- head that might have been biased by oil.
***Strategy*:** Compare Winkler/bottle titration data to in situ prove data and look for patterns in systematic offset that might be explainable by relative oil exposure.

CIMAS Research Theme:
***Theme 7*:** Protection and Restoration of Resources

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

Funding Unit: NOAA/NOS (Mark Dix) **NOAA Technical Contact:** Alan Leonardi

Research Summary:
Discrete oxygen (O_2) analyses by the Winkler method were performed at sea on samples collected on the ships *Nancy Foster*, *Ocean Veritas*, *Brooks McCall*,*Henry B.Bigelow*, and *Pisces*in response to the oil spill of the Deepwater Horizon 252 well. Most of the samples were from near the well and were obtained from July 1, 2010 to August 30, 2010. The purpose of these measurements was to assess the accuracy of the oxygen sensors on a conductivity-temperature-depth (CTD) sensor, henceforth referred to as CTD/O_2, and to determine if the CTD/O_2 sensor provided (low) biased readings in the presence of oil. Based on the analyses, we believe that the O_2 analyses from the CTD/O_2 and Winkler systems on the ships were accurate to within 2% (≈4 μmol/l, ≈0.1 ml/l, or ≈0.15 ml/l), with exceptions noted in the technical report, Wanninkhof, R., G.-H. Park, and G. Berberian (2011). The depression in O_2 values observed by the CTD/O_2 at depths of 1000-1300 m in the layer with diffuse oil were verified by the Winkler measurements and are attributed to oxidation of the oil and associated gas.

Based on the Winkler measurements, we cannot conclusively recommend adjustments to the CTD/O_2 data. A qualitative assessment suggests that the output of CTD/O_2 sensors on the *Brooks McCall* and *Ocean Veritas* agreed with each other and with the Winkler measurements to within 2%. The CTD/O_2 sensor on the *Pisces* appeared to read low by about 3% when compared with the *Henry B. Bigelow* CTD/O_2 and Winkler O_2 values that agreed well with each other. The *Nancy Foster* had the largest dataset of Winkler O_2 values for comparison. These values were about 2.6 ± 2% higher than the CTD/O_2 values in water depths of 100-1000 m but showed larger positive deviations of up to 10% at the surface and in deep water which we cannot explain.

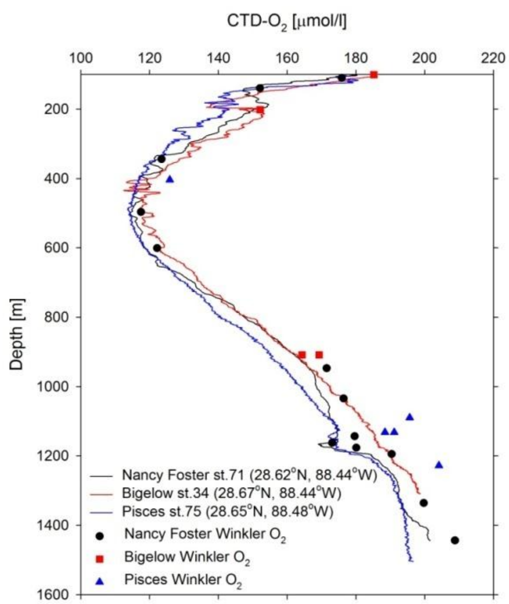

Figure 1: Comparison of CTD/O_2 and Winkler O_2 titrations for *Nancy Foster* station 71 (occupied on July 17, 2010), *Henry B. Bigelow* station 34 (occupied on August 15, 2010), and *Pisces* station 75 (occupied on August 20, 2010). The figure and other analyses suggest that the CTD/O_2 sensors on the *Pisces* were reading about 7 μmol/l (≈0.2 ml/l) lower when compared to the actual values. The Winkler O_2 values from the *Pisces* (blue triangles) are not deemed accurate.

Research Performance Measure: All objectives have been met.

Biscayne Bay Alongshore Epifauna Community and their Relationship to Salinity

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

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** Characterize the epifaunal community of nearshore Biscayne Bay and relate distribution, abundance, and community characteristics to salinity, and other environmental factors.

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

CIMAS Research Theme:

***Theme 7*:** Protection and Restoration of Resources (*Primary*)
***Theme 3*:** Sustained Ocean and Coastal Observations *(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

Funding Unit: NMFS/SEFSC **NOAA Technical Contact:** Theo Brainerd

Research Summary:

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

Figure 1 shows the species composition for major groups observed in Biscayne Bay in 2005-2010. Each group is characterized by a >50% dominance of one species (rainwater killifish – fish; hermit crab – crabs; caridean shrimp spp. – shrimp; and brittle star spp. – echinoderm), followed by some other relatively common species and many minor ones.

For the first time, we were able to identify caridean shrimp to genus and species level. The major caridean taxa are Thor spp., Hippolyte spp. and Palaemonetes spp. Those three species showed distinctive distributions relative to salinity regimes; while Thor and Hippolyte species mainly were found in the mid and higher salinity areas, Palaemonetes species were found at sites with lower salinity levels.

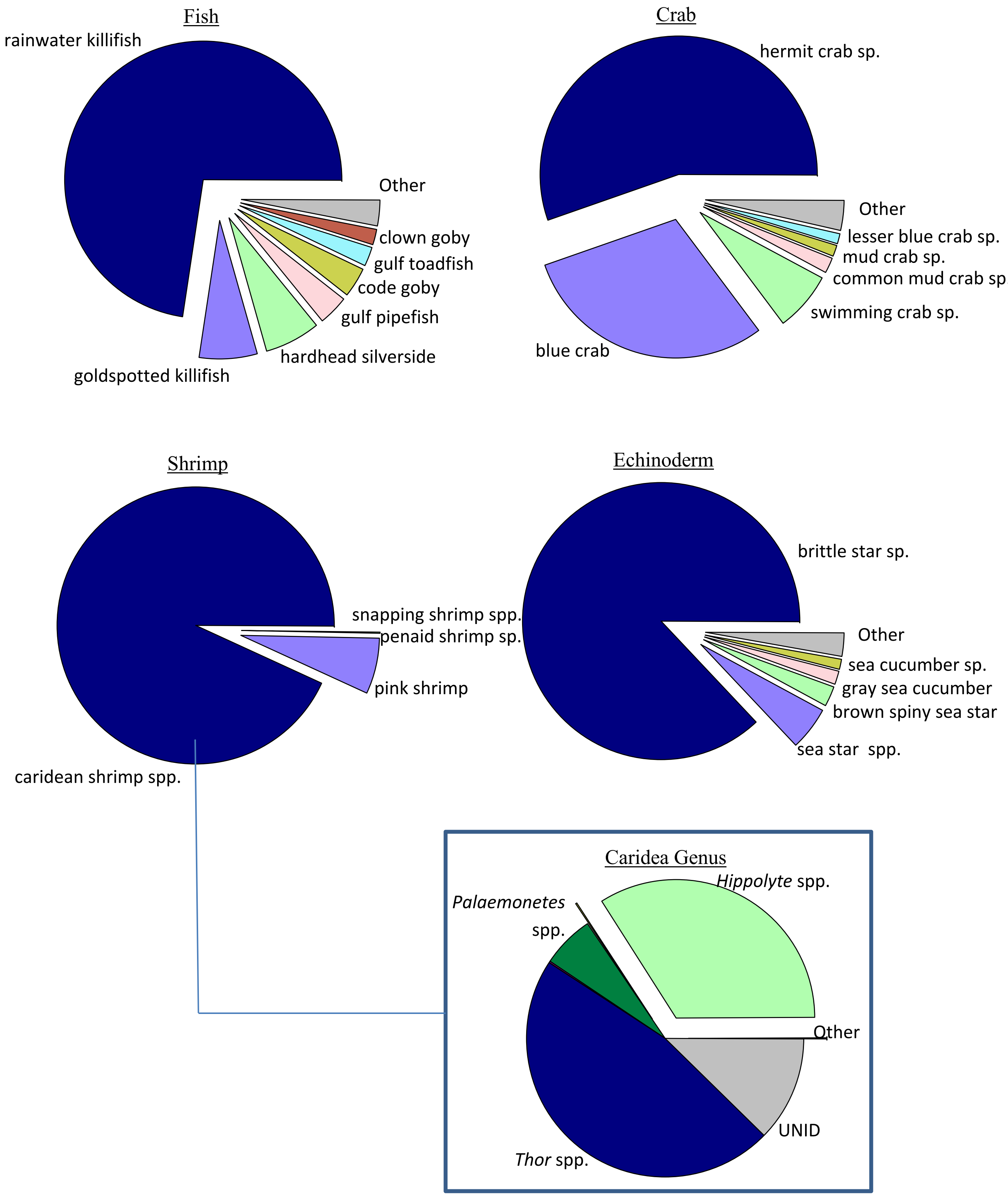

Figure 1: Pie chart of species composition. By group: fish, crabs, shrimp, and echinoderms 2005-2010. Additional, the fifth pie chart represents specific caridea genus composition between 2008 and 2010.

From project inception we focused on classifying our species according to “halohabitat”, or the salinity regime in which individuals of the species most commonly occurred in our samples so that we could separately follow an increase or decrease in number of species, or “richness”, and other community metrics by halohabitat category. In the Venice System, waters are distinguished as oligohaline, mesohaline, polyhaline, euhaline, and hyperhaline. We refined the Venice system to specify the terminology and salinity ranges of the halohabitat categories of our species. In particular, we combined or split Venice-system categories to provide better resolution in characterizing our species distributions in relation to salinity. Figure 2a shows our halohabitat categories and their salinity ranges. Figure 2b summarizes the salinity distributions of all individuals in our samples, per faunal group, in the context of halohabitat. We found that most of the fish species, some crabs, and pink shrimp are distributed within the polyhaline range (18-30), whereas other crab species, the caridean shrimp (incl. Alpheus spp.), and all echinoderms are distributed within the euhaline range (30-40), some can be defined more narrowly or broadly.

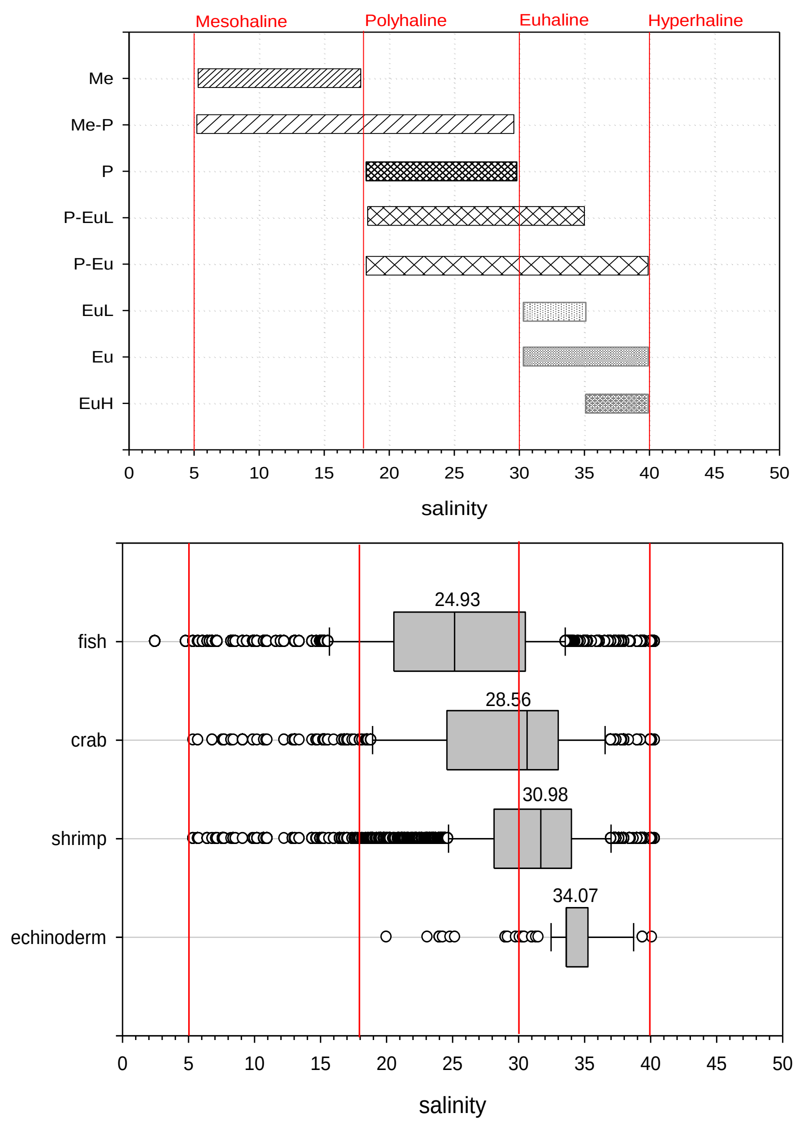

Figure 2: (a) Illustrative overview for new halohabitat classification after Brower et al. (2011) and (b) boxplot of distribution of major taxa group in relation to salinity, 2005-2010.

In 2010, we began to address the concept of species rarity and how to categorize the species in our collections so that we could follow species by halohabitat category according to the degree of rarity. We specifically wanted to know, once CERP is implemented, whether an increase in rare species is occurring and whether new species are recruiting to one halohabitat or another. This might provide an early warning or early indication that restoration of a characteristic estuarine community is occurring.

Knowledge about the rare species in a community can be useful for many reasons. Rare species may play an important role in maintaining the overall ecosystem functionality (Flather, C.H. and C.H. Sieg (2007). Species rarity: Definition, Causes, and Classification, Rocky Mountain Research Station Publications, 26pp). Some focus on rare species is important in a monitoring project to assess the effectiveness of restoration efforts because some of the rare species—or some parameter associated with rare species—may provide a good performance measure. In this study we classified our species using all three common measures of rarity: (1) number of events in which species occurred, (2) number of seasons in which species occurred, and (3) number of individuals of the species found in sampling years 2005-2010. The classification of rarity follows a traffic light system from pink to blue to green (rare, uncommon, and common). Of the 66 fish species found, 79% are classified as rare, 11% as uncommon, and 11% as common. The fish species we classified as common are hardhead silverside, clown goby, code goby, gulf pipefish, gulf toadfish, goldspotted killifish and rainwater killifish. Of the 22 sampled crab taxa, 77% were rare, 14% as uncommon, and 9% as common. Hermit crab spp. and blue crab were the common crab taxa. Pink shrimp and caridean shrimp spp. are considered common (50% of 4 shrimp groups) and snapping shrimp (a member of the caridean group, but for analytical reason dealt with separately from the caridean group) are considered uncommon (25% of 4 shrimp groups). Almost all echinoderms are classified as rare except for brittle star spp., which were classified as uncommon (11% of 9 echinoderm species). Overall, out of 101 species collected, we classified 77% as rare, 12% as uncommon, and 11% as common (Fig. 3).

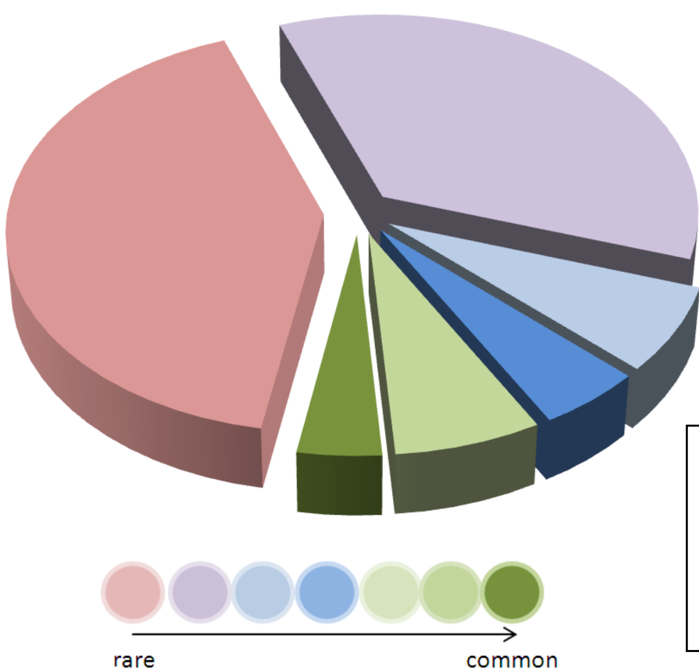

Figure 3: Pie chart of species rarity/commonness. Calculation was developed out of classification of 66 fish species, 22 crab species, 4 shrimp species and 9 echinoderm species collected during 2005-2010.

Another 2010 emphasis was to investigate length-weight relationships and relative condition factors (described by the equation: W=a*Lb) in relation to salinity. Data for length and weight can be useful information to predict the sustaining power of the fishery stock and can be a helpful tool for predicting the condition of fish. We examined the length-weight relationships, relative condition factors, and salinity of the seven most dominant and ecological important epifaunal fish species along the Biscayne Bay shoreline (Table 1, Fig. 4). Investigation of the length and weight relationship has been of great importance in fish assessment and ecological studies. The value of the exponent b in the regression W=a*Lb varied between 3.23 (gulf toadfish) and 3.99 (gulf pipefish), showed no significant difference between season ($p<0.5$), and indicated an allometric growth for most of the species (Table 1). The relative condition factor (Kn) for any species was not statistically significantly different between seasons in any year ($p=0.251$) (Table 1). Most species were found within a salinity range of 18-34 (polyhaline-lower euhaline waters) and showed a significant correlation of condition metrics to salinity (Fig. 4). The rainwater killifish condition factor significantly correlated with salinity in both dry and wet seasons ($p<0.05$). In the wet season, rainwater killifish's relative condition factor increased from low to moderate salinities; in the dry season, it decreased at higher salinities (Fig. 4). The relationship of code goby Kn to salinity was significant only in the dry season ($p<0.05$), and relationships of gulf toadfish and gulf pipefish Kn's to salinity were significant only in the wet season ($p<0.1$) (Fig. 4).

Table 1 Number of species (n), standard length (mean, 95% confidence interval, minimum, and maximum) and parameter of length-weight relationship of 7 major epifaunal fish species caught in Biscayne Bay, 2005 and 2010.

Season	Species	n	Length characteristics				Length-Weight Relationship				*Kn*	
			Mean	CI	Min	Max	a	b	R^2	p	Mean	CI
Dry	***rainwater killifish***	6802	1.75	0.01	0.4	4.17	0.013	3.4346	0.9330	<0.0001	1.08	0.01
	clown goby	278	2.26	0.09	0.7	4.8	0.0049	3.7887	0.9219	<0.0001	1.20	0.08
	code goby	776	2.34	0.04	0.9	4.0	0.0113	3.4396	0.8981	<0.0001	1.01	0.02
	goldspotted killifish	816	1.99	0.05	0.7	4.6	0.0223	3.2869	0.9630	<0.0001	0.98	0.01
	gulf toadfish	115	4.99	0.38	0.8	12.6	0.0134	3.2315	0.9825	<0.0001	1.13	0.05
	gulf pipefish	880	6.03	0.14	1.7	12.8	0.0002	3.6488	0.9402	<0.0001	1.02	0.03
	hardhead silverside	163	3.96	0.10	2.2	5.5	0.0083	3.4068	0.9462	<0.0001	1.00	0.02
Wet	***rainwater killifish***	13099	1.60	0.01	0.4	3.9	0.0157	3.1999	0.8973	<0.0001	0.99	0.01
	clown goby	212	2.23	0.9	0.4	4.2	0.0085	3.2584	0.9147	<0.0001	1.08	0.10
	code goby	238	2.03	0.08	0.6	3.9	0.0126	3.2669	0.9401	<0.0001	1.04	0.07
	goldspotted killifish	1067	1.72	0.05	0.4	5.8	0.0242	3.2165	0.9626	<0.0001	0.93	0.01
	gulf toadfish	534	3.47	0.18	0.7	15.0	0.019	3.0415	0.9859	<0.0001	1.01	0.02
	gulf pipefish	112	7.31	0.37	2.9	11.8	0.00009	3.9907	0.9536	<0.0001	1.09	0.06
	hardhead silverside	1579	3.29	0.05	0.5	6.2	0.0103	3.2323	0.9646	<0.0001	0.96	0.05

We used salinity-bin analyses to explore species/salinity relationships (Fig. 5) and found that relationships were similar to that found using other techniques (Fig. 2b). Maximum frequency of occurrence was at 30-35 psu for shrimp, crabs, and echinoderms. The highest occurrence of fish was in salinity bins 20-25 to 30-35 (polyhaline to euhaline-low). We found that fish were represented over a larger salinity range than mobile macro-invertebrate fauna. MLR models found a significant relationship between fish species richness and salinity during the dry season, but not during the wet season (Fig. 6). Dry-season fish species richness was linearly related to salinity - the higher the salinity, the lower fish species richness (Fig. 6a).

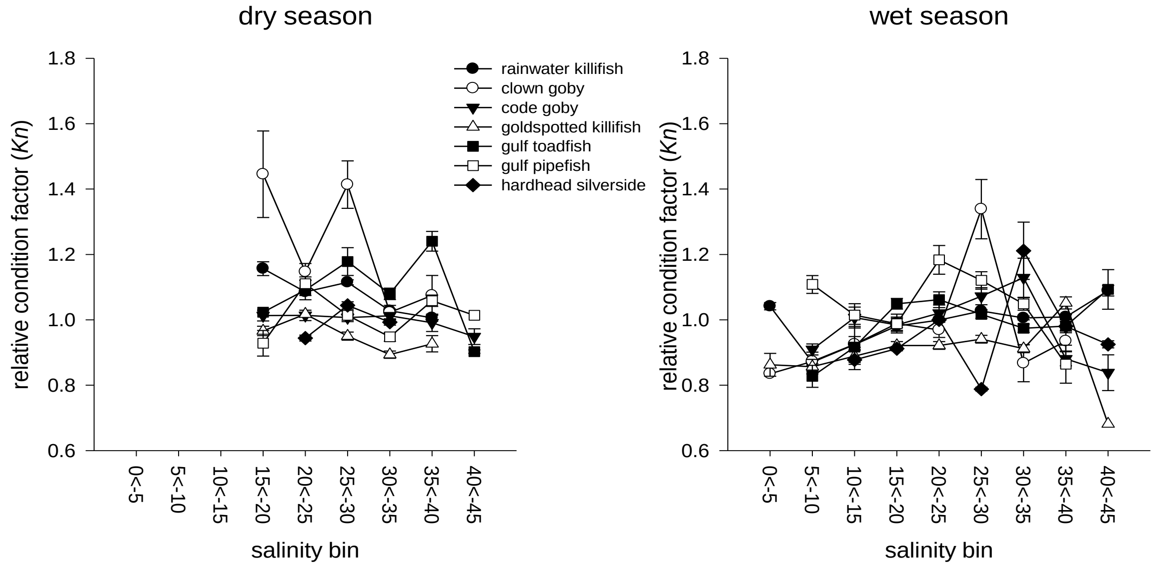

Figure 4: Relative condition factor (*Kn*) of major fish species per 5psu salinity bin, (a) dry season and (b) wet season, 2005-2010.

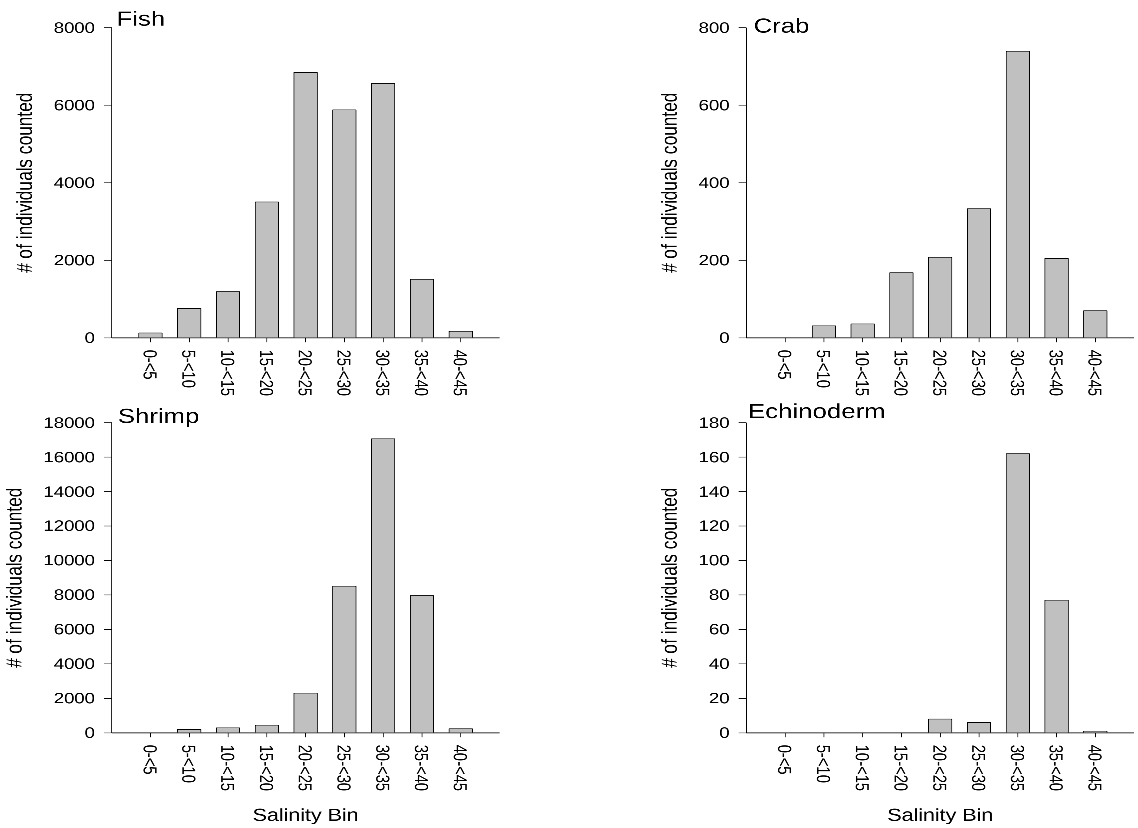

Figure 5: Histogram of total faunal abundance, 2005-2010, by 5psu salinity bin: (a) fish, (b) crab, (c) shrimp, and (d) echinoderms.

Another major focus during the 2010/2011 period was to determine the number of samples required to detect changes of various degrees (percents) with given levels of power (=power analysis). As an example, we present the results of power analyses for fish species richness (Fig. 7). Looking at power over all sites sampled in all years, we found that we could detect a 10% change in fish richness at a power of 0.8 ($\alpha = 0.05$) with 180 samples in the dry season and 213 samples in the wet season. At the sampling rate of 72 per season, it would require 3 yrs (180 / 72 = 2+, 213 / 72 = 2+) of pre-implementation sampling to detect a 10% change in fish richness in each season. For further detailed information see "Browder, J. A. et al. 2011. Epifaunal Communities of Mainland Nearshore South Biscayne Bay. Annual report to the U. S. Army Corps of Engineers and the RECOVER Group of the Comprehensive Everglades Restoration Program. SE MAP Project 3.2.3.5 & 3.2.4.7, USACE WO 9".

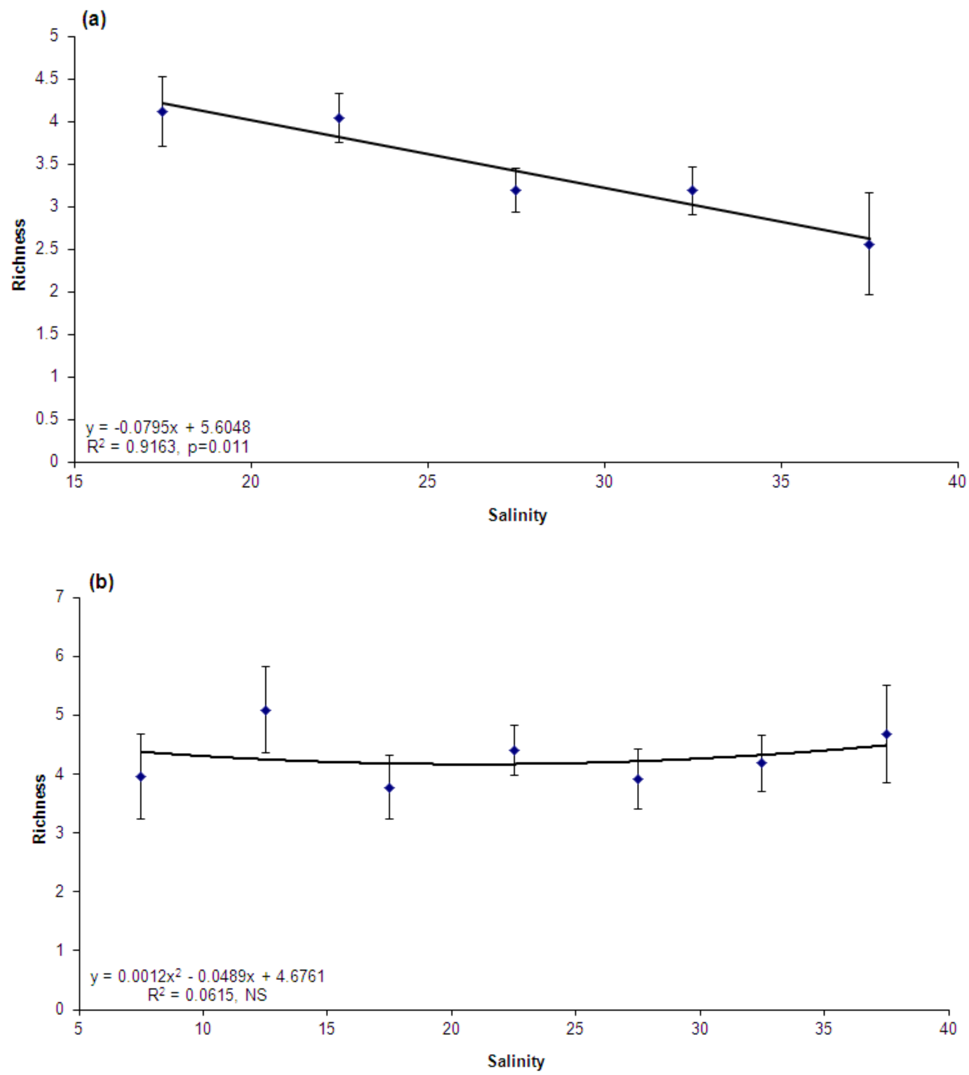

Figure 6: (a) dry and (b) wet season average fish richness from Biscayne Bay throw-trap sampling by salinity (2005-2010) with trendline and 95% confidence intervals.

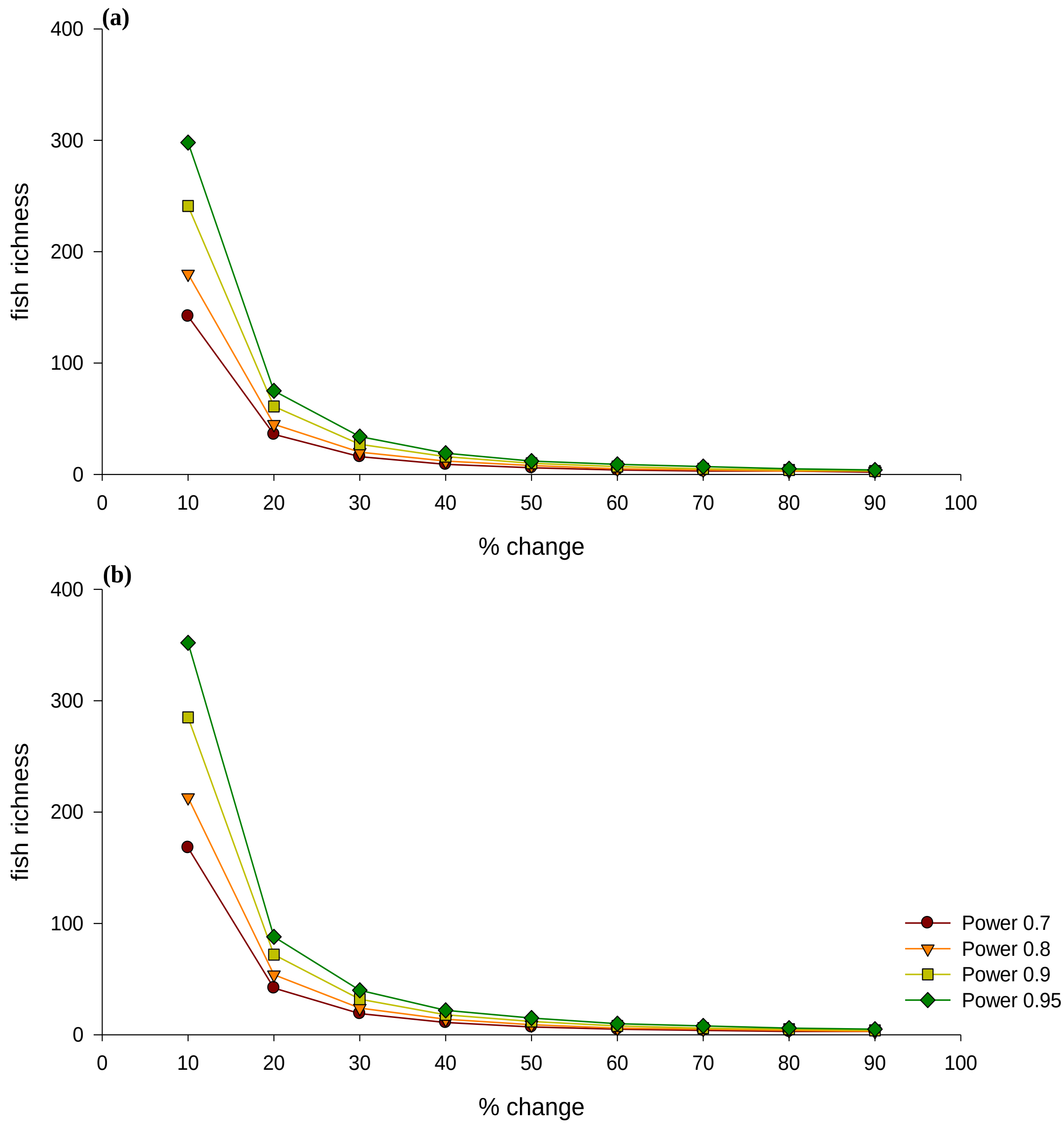

Figure 7: Number of samples required to detect change in (a) dry season and (b) wet season fish species richness across all 72 sites, 2007-2010.

Research Performance Measure: The primary purpose of our work is to characterize the epifaunal community, determine relationships with halohabitat, and explore analytical means to develop species-based and community-based performance measures. We have made substantive progress in exploring analytical approaches to addressing our objectives. Furthermore, we are now able to evaluate the needed sampling effort to detect changes in the community when CERP becomes operational.

Biscayne Bay's Nearshore Submerged Aquatic Vegetation (SAV)

Project Personnel: D. Lirman (UM/RSMAS)
NOAA Collaborators: 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 7*:** Protection and Restoration of Resources

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

Funding Unit: NMFS/SEFSC **NOAA Technical Contact:** Theo Brainerd

Research Summary:
This project concentrates on the shallow (< 1.5 m in depth), near-shore (< 500 m from shore) bottom habitats along Biscayne Bay's western margin. These habitats are important nursery grounds for key fisheries species and, due to their location, are likely to be highly impacted by changes in hydrology and water quality caused by Everglades restoration activities. Surveys in this project are conducted with the image-based Shallow Water Positioning System (SWaPS), a methodology that collects geo-tagged, high-resolution digital images of the bottom with high spatial accuracy. These images are analyzed to extract information on abundance, diversity, and distribution of seagrasses and macroalgae, key components of the submerged aquatic vegetation (SAV) community. In addition to these photographic surveys, water quality information is collected to document relationships between biotic and physical data that will help managers and scientists develop forecasting tools within an adaptive management framework.

Since 2008, we have collected data on the seasonal abundance and distribution of SAV communities in > 2400 sites in central and southern Biscayne Bay. These surveys have revealed that the abundance and distribution of seagrasses are tightly linked to water quality and, more specifically, to salinity patterns. Near-shore habitats with low and variable salinity are dominated by the manatee seagrass *Halodulewrightii*, a species with a wide tolerance for salinity fluctuations, while habitats with more constant and higher salinity are dominated by the turtle seagrass *Thalassia testudinum*, a species known to be favored under constant salinity conditions. The documented relationships between seagrass abundance and distribution and salinity are important to the understanding and forecasting of potential future impacts of changes in the hydrology of the Everglades watershed as the activities and projects of the Comprehensive Everglades Restoration Plan proceed. During 2009-2010, research activities also expanded to evaluate the potential role of macroalgal community abundance and diversity as early-warning indicators of changes in salinity and nutrient patterns.

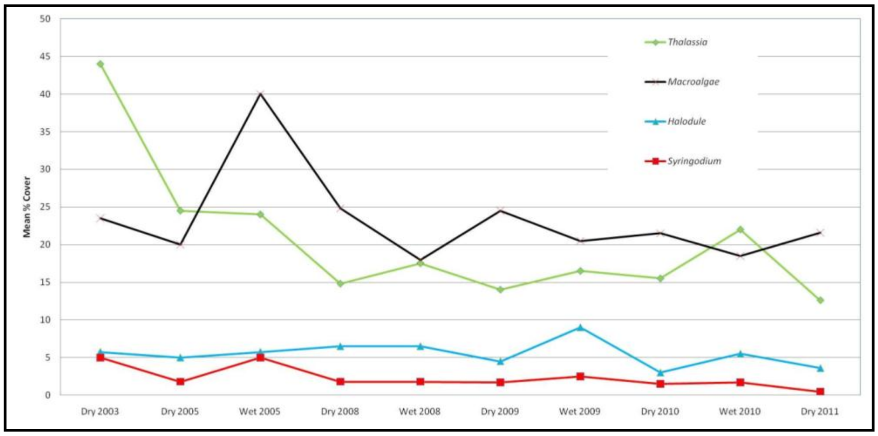

Figure 1: Percent cover of primary seagrass species and macroalgae from 2003-2011. Graph shows average cover calculated from all points collected on a seasonal basis.

While annual variation in seagrass community structure is evident, macroalgal communities respond faster (monthly to seasonally) to environmental changes in both salinity and nutrient availability. Through field surveys and microcosm experiments, we were able to investigate the relationships between the distribution and growth of abundant macroalgal species and salinity levels. The field study, conducted at Black Point, Biscayne Bay, showed clearly that macroalgal community structure can be a dynamic indicator of changes in water quality and that macroalgal communities can be classified into three groups: estuarine, transitional, and marine. Maximum growth of algal species belonging to the estuarine group (*Chara*, *Batophora*) was highest under mesohaline (10-15 psu) conditions. Analyses of tissue nutrient levels revealed that SAV communities in Biscayne Bay (as is the case for Florida Bay) are significantly P-limited and that higher availability of P can be detected in areas where fresh water is delivered into the Bay through water management canals. Based on this information, we propose that macroalgae can provide early-warning indicators of changes in water quality and can be useful within the adaptive management framework of Comprehensive Everglades Restoration Plan.

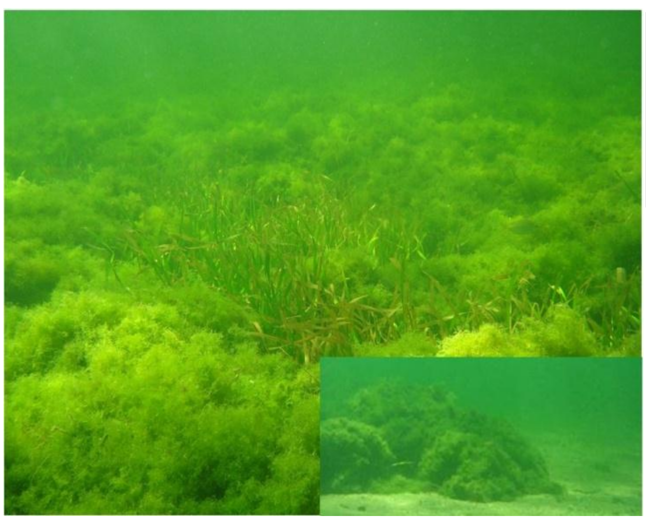

Figure 2: The seagrass *Thalassia testudinum* being outcompeted by the green macroalga *Anadyomene sp*. that shaded the seagrass. The inset shows the edge of the algal mat over areas that were previously occupied by seagrass.

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.

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

Project Personnel: P.B. Ortner and N. Amornthammarong (UM/CIMAS)
NOAA Collaborators: J.-Z. Zhang, S. Cummings and C. Fischer (NOAA/AOML)

Long Term Research Objectives and Strategy to Achieve Theme:

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

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

CIMAS Research Theme:

***Theme 7*:** Protection and Restoration of Resources

Link to NOAA Strategic Goals:

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

Funding Unit: NOPP/ONR-NSF **NOAA Technical Contact:** Alan Leonardi

Research Summary:

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

The UM/CIMAS and AOML/OCD collaborators on this project have developed such an analyzer based on a novel fluorescence technique and chemistry we have already published upon as shown in Figure 1. A small inexpensive (<50$) fluorescence detector has been developed and replaced the large and expensive (>$13,000) commercial fluorescence detector. The Autonomous system was operated in Lake Mabel (Port Everglades) near Florida Atlantic University from 17 May to 20 May 2011. Results in Figure 2 clearly show ammonium cycles every 25 hours. Moreover, a new design of fluidic handling technique named Autonomous Batch Analysis (ABA) was developed and has now been accepted for publication (Amornthammarong *et al.*, 2011).

Figure 1: Photographs of an autonomous ammonium fluorescence analyzer.

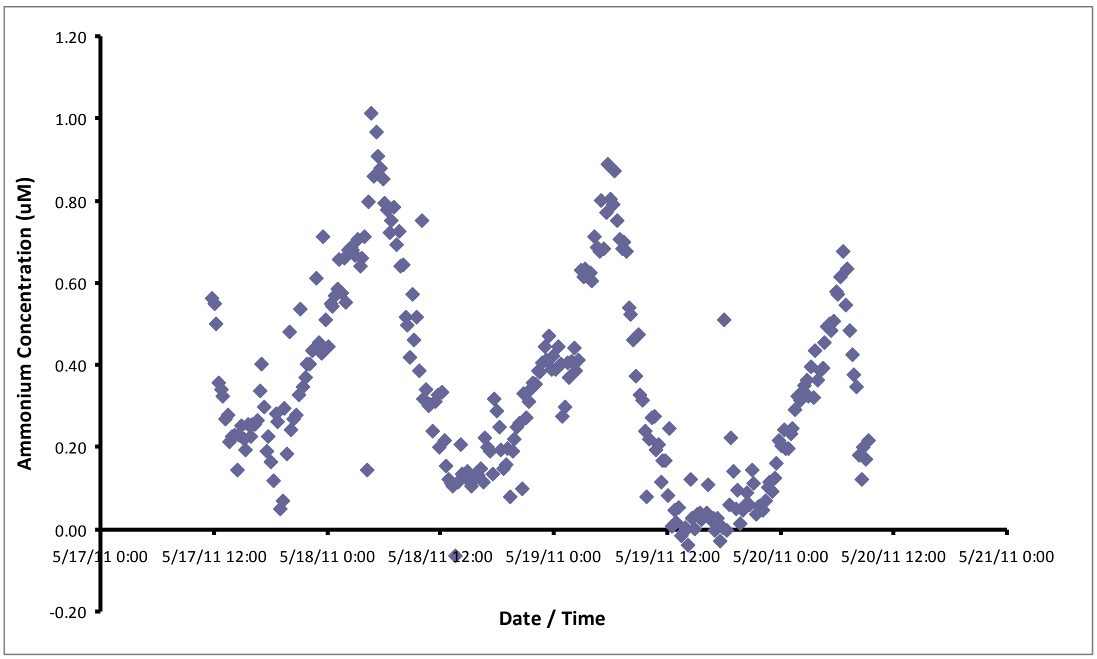

Figure 2: The in-situ measurement of ammonium in the surface water at Florida Atlantic University (FAU) in Lake Mabel (Port Everglades) from 17 May to 20 May 2011.

Research Performance Measure: Our objective in Year 2 of this three year project was to finalize, test and deploy the autonomous system with actual environmental waters. This step has been completed and the instrument was tested in the field. The project is ahead of schedule in that we are now working upon an in situ version that can be deployed underwater..

Coral Ecological Restoration in the Florida Keys National Marine Sanctuary

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

Long Term Research Objectives and Strategy to Achieve Them:

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

***Strategy*:** To (a) culture larvae of reef-building coral species including *Acropora palmata* (ESA Threatened) and *Montastraea faveolata*, and conduct experimental studies to elucidate factors affecting success of early life stages; and (b) undertake experimental studies to evaluate factors affecting the success of coral transplant/restocking projects.

CIMAS Research Theme:

***Theme 7*:** Protection and Restoration of Resources

Link to NOAA Strategic Goals:

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

Funding Unit: NMFS/SEFSC **NOAA Technical Contact:** Theo Brainerd

Research Summary:

During the research year (2010/2011) we continued ongoing research efforts to address recruitment failure by reef-building coral species in the Florida Keys via experiments on enhancing coral rearing techniques to advance the goal of increasing survivorship of cultured coral larval settlers. Unfortunately, there was no spawning by elkhorn coral during the predicted spawning nights in August 2010, so no larval experiments were conducted with this species. Two, two-factor experiments were conducted using larvae of *Montatstraea faveolata*. In the first experiment examining settlement response, two different types of crustose coralline algae (Titanoderma prototypum and Hydrolithon bourgnii, which were reported to enhance post-settlement survivorship (Ritson-Williams et al 2010)) were tested while a second factor constituted a rapid dip of settlement substrates in freshwater (suggested to help limit the risk of ciliate infection in our experimental seawater system which caused immense damage to our coral larval cultures in 2009). In the second post-settlement experiment, settled substrates from the first experiments were placed in the field for 5 weeks and then survivorship of settled polyps was examined. The two factors in this experiment were CCA-type of substrate and the orientation of the substrates (horizontal vs. vertical) in the field.

Results showed that settlement rates were significantly lower on substrates that were quickly dipped in freshwater upon transfer into the experimental system. However, settlement by *M. faveolata* larvae was still substantial (~100 polyps per substrate in 24 hours) on these 'dipped' plugs. Although settlement rates were decreased, we feel that the freshwater dip is a good practice to minimize risk of infestation of the experimental systems with ciliates and/or other marine pests. Contrary to our hypothesis, we saw no significant difference in the settlement levels on the supposedly 'preferred' CCA types (indeed, nominally higher settlement was observed on controls; Fig. A) and poorer survivorship (Fig B) as compared to controls (clean substrates that had been conditioned in the field for one week prior to the settlement assays). Significantly high survivorship was also observed on Vertical as opposed to horizontal substrates, consistent with less (photosynthetic) microalgal competitors and sediments accumulating in the vertical (less light) substrates. Previous studies showing preference for these CCA species used *Acropora* spp. larvae (Ritson-Williams et al. 2010) and it is possible that *M. faveolata* have different preferences. We intend to repeat this experiment with both coral species in 2011.

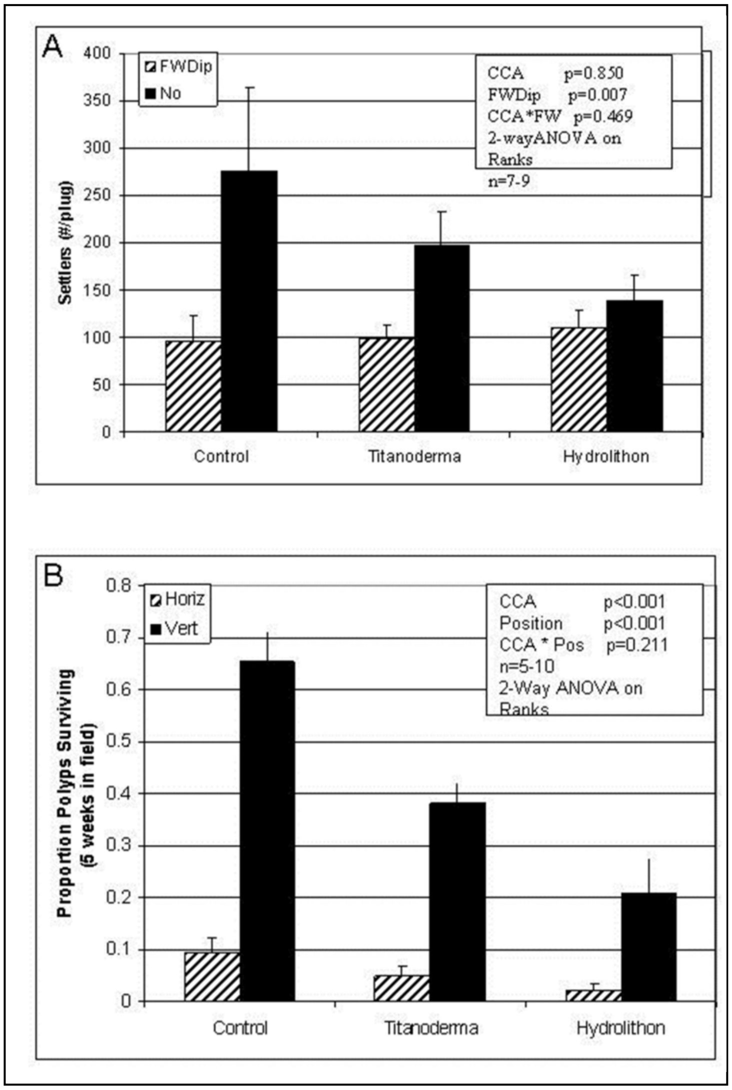

Figure 1: A) CCA substrates and the effect of freshwater dipping of the substrates prior to offering for settlement. **B)** Results of early stage (5 weeks) field survivorship of *M. faveolata* settlers on three types of CCA substrates (as in settlement experiment) placed in either horizontal or vertical position at Sand Island reef.

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

Research Performance Measure: Lack of spawning by focal elkhorn coral in 2010 was a significant hindrance in that it precluded planned experiments with this species' larvae. The planned experiments are re-slated for August 2011. Sampling of the ACRRE transplant experiment was wound up in 2010, while sample analyses are ongoing.

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Photo-Identification of Bottlenose Dolphins in Biscayne Bay, Florida

Project Personnel: J. Wicker (UM/CIMAS)
NOAA Collaborators: L. Garrison, J.P. Contillo, J. Litz and A. Martinez (NOAA/SEFSC)

Long Term Research Objectives and Strategy to Achieve Them:

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

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

CIMAS Research Themes:

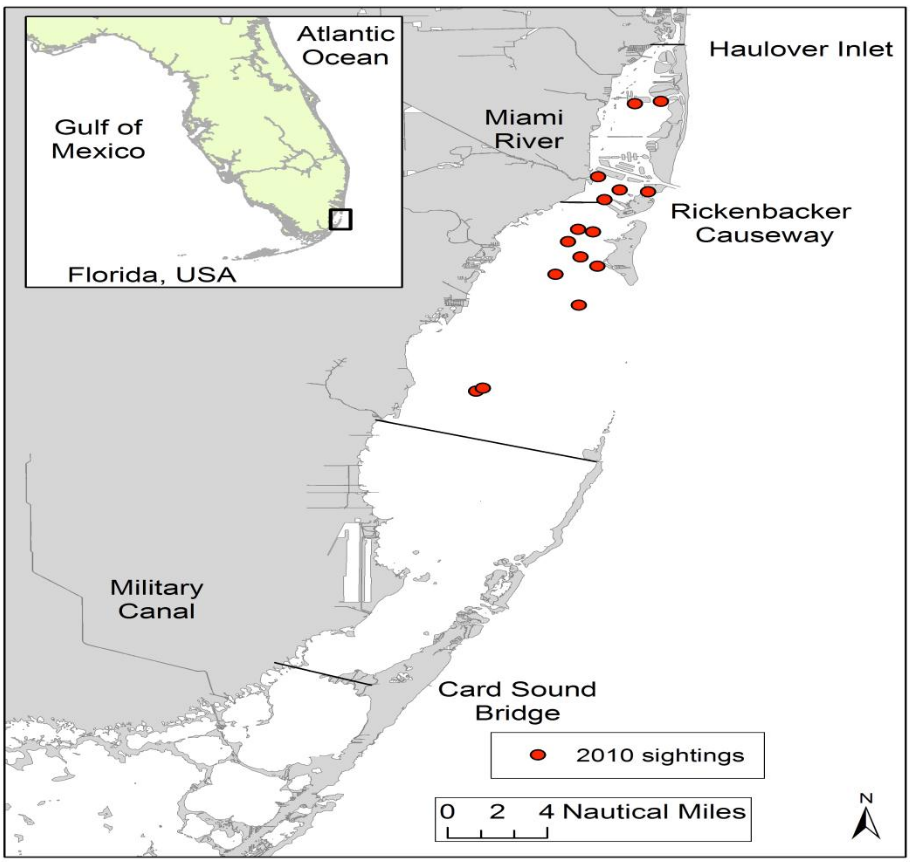
***Theme 7*:** Protection and Restoration of Resources

Link to NOAA Strategic Goals:

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

Funding Unit: NMFS/SEFSC **NOAA Technical Contact:** Theo Brainerd

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 16 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.



2010 Dolphin Sightings.

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.

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.

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Coral Reef Restoration Monitoring, Biscayne National Park

Project Personnel: D.E. Williams, A. Bright (UM/CIMAS)
NOAA Collaborators: M.W. Miller (NOAA/SEFSC)

Long Term Research Objectives and Strategy to Achieve Them:
***Objectives*:** To implement monitoring/evaluation of two coral reef restoration projects (Allie B, Igloo Moon) in Biscayne National Park
***Strategy*:** To address four components of existing restoration projects through monitoring: coral recruitment, benthic community development, colony health assessment, and substrate stability.

CIMAS Research Theme:
***Theme 7*:** Protection and Restoration of Resources (*Primary*)
***Theme 6*:** Ecosystem Management (*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

Funding Unit: NPS/CESI **NOAA Technical Contact:** Theo Brainerd

Research Summary:
The National Park Service restored the structure and some benthic community components destroyed by three ship groundings: Igloo Moon, Allie B, and Allie B Tug. This UM/CIMAS - NMFS/SEFSC collaborative project is aimed at evaluating the restoration by comparing the existing restored sites with adjacent, unimpacted ‘reference’ sites. The monitoring approach of this project addressed four components: scleractinian coral recruitment, benthic community development, coral colony health assessment, and substrate stability.

Coral recruitment will be monitored by mapping all juveniles in replicate 1.5m^2 plots (n=10) in both the restored and reference sites and identifying new recruits annually. The colony density, species composition, and colony growth rates were also documented.

The colonization and succession of benthic organisms will be documented within the restoration sites and adjacent undisturbed reference sites by looking at percent cover of various functional groups. A subset of corals re-attached during the restoration effort, as well as a group of undisturbed, intact "reference" colonies of similar number, size, and species composition will be measured, and photographed at each restoration site to document condition (e.g. disease, bleaching, predation) survivorship and growth.

The physical integrity of materials stabilized during the restoration effort will be assessed by determining the reattachment status of a subset of substrate pieces at each restoration site. The stability of the rubble-filled blowholes will be assessed by documenting the surface elevation of the blowholes to determine if erosion is occurring.

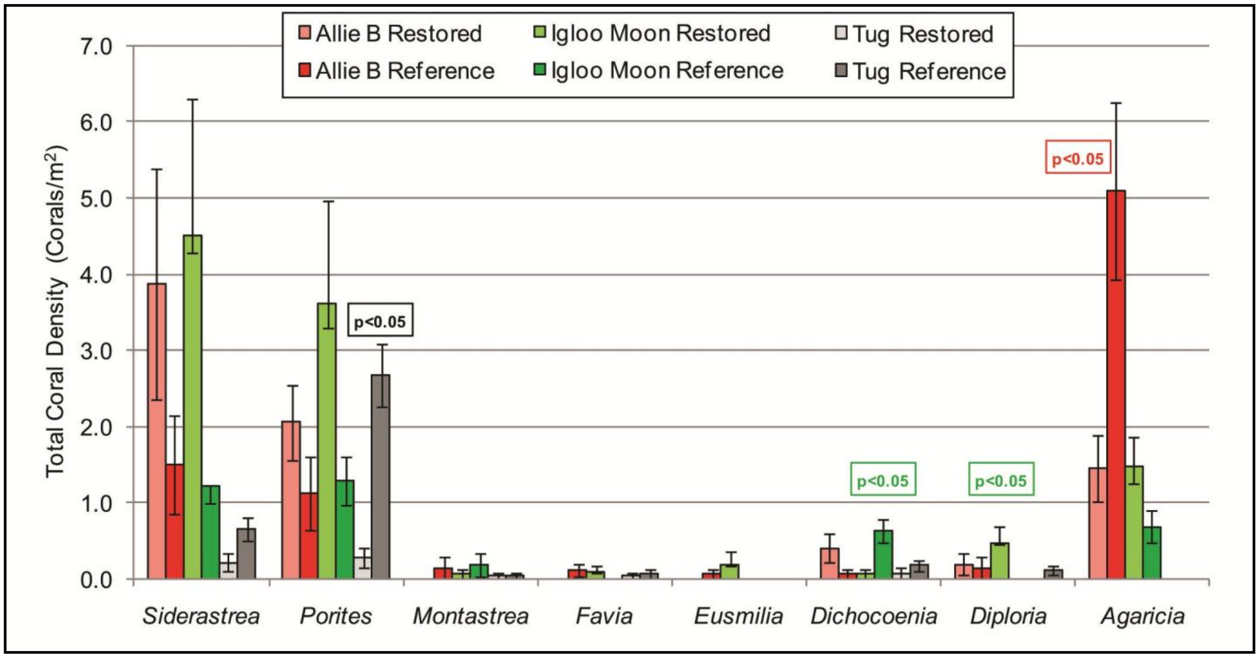

Figure 1: Total colony density for the dominant 8 scleractinian genera observed in the 1.5m^2 recruitment plots. Significant p-values based on Mann-Whitney U-tests are shown for within-site comparisons of the restored and reference areas (mean ±SE).

Research Performance Measure: Two surveys were conducted as proposed and two detailed reports were submitted to the National Park Service (funding source).

VII. EDUCATION AND OUTREACH

With respect to Education and Outreach CIMAS activities have not yet reached beyond UM/RSMAS to the wider set of Partner Universities. The Rosenstiel School and CIMAS are active in education at the graduate, 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 facilities. Here we present a brief overview of some of the education and 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 education or outreach component.

Graduate Education

The Rosenstiel School of Marine and Atmospheric Science offers graduate instruction leading to the Doctor of Philosophy (PhD) and Master of Science (MS) degrees through academic divisions that include Marine Biology and Fisheries, Marine and Atmospheric Chemistry, Marine Geology and Geophysics, Meteorology and Physical Oceanography, and Applied Marine Physics. Though graduate students typically concentrate in one of these curricular areas, interdisciplinary study is encouraged and coursework can be tailored to the individual student. In addition, we offer the Master of Arts (MA) and MS degrees in Marine Affairs and Policy for students who wish to pursue careers in marine policy and management. Currently there are about 250 students enrolled in the RSMAS graduate program, two thirds of which are PhDs.

Many graduates of these UM/RSMAS programs have joined the NOAA workforce, mainly at the NOAA AOML and SEFSC laboratories and at NOAA headquarters but also at other NOAA laboratories throughout the US. This training pipeline for NOAA jobs was greatly facilitated by CIMAS activities such as 1) collaborative research teams between NOOA Scientists, and CIMAS faculty and graduate students; 2) funding of graduate students with the support of NOAA fellowships and graduate research assistantships; and 3) participation of NOAA scientists from Miami laboratories in student mentoring and teaching.

The University of Miami has recently developed Masters of Professional Science (MPS) intended for students who seek advanced training in marine and atmospheric science, while also cultivating a blend of team-building and communication skills, legal and regulatory knowledge, and business savvy, that should be highly valued by potential employers. In addition to two semesters of intensive course work this degree will offer internship in government NGOs and business to their graduates. The MPS foci especially relevant to NOAA are the ones developed for Meteorology and Fisheries science.

Undergraduate Education

The Rosenstiel School offers two undergraduate degree options, a Bachelor of Science in Marine and Atmospheric Science with majors in Marine Science and Meteorology and a Bachelor of Arts in Marine Affairs. For academic year 2009, a record number of 248 students enrolled in the program. The MSC curriculum is designed to take full advantage of the University's subtropical location, with year-round access to a variety of specialized marine environments including the deep ocean waters offshore, the coral reef tracts of the Florida Keys, and the estuarine sea grass beds and mangrove shoreline of South Florida. The transfer of the administration of this program to RSMAS has created a more vibrant undergraduate experience for students and enhanced opportunities for undergraduate research. Many of these research experiences take advantage of the collaborative research links between RSMAS and the AOML and SEFSC NOAA labs that are available through CIMAS.

The MAST Academy and High School Student Education

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

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

RSMAS participates in education-related activities at MAST by providing faculty and graduate students, including CIMAS-linked personnel, to deliver lectures and to teach courses. Every summer, 12-18 students are selected to participate in summer research programs supported through CIMAS. The students assist in programs at AOML and SEFSC as well as at RSMAS. In addition to the summer program, CIMAS hires MAST students during the course of the year. As a result of these activities MAST students have co-authored papers with RSMAS and NOAA scientists; students have attended national conferences and presented the findings of their research.

MAST is one of three schools involved with the South Florida Student Shark Program (SFSSP). The SFSSP is a collaborative, multi-disciplinary research and education program that exposes students to marine science field research. They focus on the study and conservation of coastal Florida shark species, mangrove fish habitats, and the Florida watershed through in-service learning, education and research (see below). MAST students have also participated in other field programs, for example in a comprehensive habitat study of Biscayne Bay. In this way, the School and CIMAS scientists have developed a solid working and teaching relationship with the MAST Academy.

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

- Assisted in the NMFS-SEFSC fish tagging program. Prepared tagging kits for distribution to fishery constituents, coding incoming tagging data, data entry of both tag release and tag recapture, and interacting with constituents about tag requests and tag recovery reports.
- Assisted in sorting and identifying postlarval pink shrimp from the Florida Bay program and working with bird by-catch data.
- Assisted in downloading sea-surface temperature (SST) data from the NOAA Coast Watch web site and using it in analyses of fisheries and environmental data.

- Assisted in a study modeling connections between life stages and habitats of pink shrimp in South Florida.
- Assisted in using bioinformatics software in a study to identify, detect, and quantify microbial contaminants in coastal waters. Students worked on the development of a microbial contaminant database using FileMaker Pro Software.

University of Miami (UM), a Minority Serving Institution

The National Oceanic and Atmospheric Administration (NOAA) has established research and education centers to advance the community of under-represented minority scientists in the US and, especially, in the NOAA workforce. UM participates under the leadership of Dr. D. Letson, a CIMAS Fellow. This program is lead by Florida A & M University (FAMU) through the Environmental Cooperative Science Center (ECSC). The Center is funded through a cooperative agreement between NOAA and FAMU. Other partners are Morgan State University, Delaware State University, South Carolina State University and Jackson State University. Located on the campus of FAMU, the science center was established to study and address ecological and coastal management issues.

The goals of the science center are to increase the number of under-represented minority scientists in NOAA-related sciences, develop ways to monitor coastal ecosystems and assess impacts of human and natural actions, improve the scientific knowledge base used in coastal resource management, and facilitate community education and outreach relating to coastal ecosystems. The central research themes of ECSC focus on the human environment interactions involving the coastal environment and the development of conceptual models of those interactions.

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

The Rosenstiel School’s role in the center is to:

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

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

Characterization of Ocean Acidification in Coral Reef Waters

Dwight Gledhill and Derek Manzello (UM/CIMAS)

Completed a video- taped presentation for the Coral Reef Conservation Programs Climate & OA outreach curriculum to high school teachers.

Synoptic Estimates of Sea Surface Ocean Acidification

Dwight Gledhill and Denis Pierrot (UM/CIMAS)

The product is delivered in partnership with NOAA Coral Reef Watch which provides numerous manager enjoyment workshops each year. The OAPS is included as an important contributing resource towards these workshops (http://coralreefwatch.noaa.gov/satellite/oa/).

New Infrared Satellite Imagery for Detecting Changes in Tropical Cyclone Structure

J.P. Dunion (UM/CIMAS)

- Guest Speaker, Marlborough Elementary School, Marlborough, CT (February 2010)
- Guest Lecturer, Massachusetts Institute of Technology seminar series (March 2010)
- Guest Lecturer, University of Wisconsin-Madison seminar series (April 2010)
- Guest Speaker, Jack Jackter Middle School, Colchester, CT (May 2010)
- Guest Lecturer, Third Tri State Weather Conference, Western CT State University (October 2010)
- Guest Lecturer, Three Rivers College seminar series (October 2010)
- Guest Expert Lecturer, National Ocean Sciences Bowl Webinar Series (December 2010)
- Guest Speaker, Marlborough Elementary School (6th grade), Marlborough, CT (January 2011)
- Guest Speaker, Marlborough Elementary School (1st grade), Marlborough, CT (February 2011)
- Guest Speaker, Walsh Intermediate School, Branford, CT (March 2011)
- Guest Speaker, Marlborough Elementary School Career Day, Marlborough, CT (June 2011)

Characterization of the Kinematic and Turbulent Structure of the Hurricane Boundary Layer Using Doppler Measurements

Sylvie Lorsolo, Altug Aksoy and Jun Zhang (RSMAS/CIMAS)

Edumin Corrales, an undergraduate at the University of Miami, learned to process and analyze Doppler radar data during an internship at AOML/HRD.

Real-Time Hurricane Wind Analysis

Bachir Annane, Sonia Otero and Russell St. Fleur (UM/CIMAS)

John Opatz, a Hollings Scholarship recipient, from University of North Dakota Dept. of Atmospheric Science served at internship in collaboration with Ian Sears, Meteorologist/Flight Director at the NOAA/Aircraft Operations Center (AOC) on the H*WIND project.

Surface Water pCO$_2$ Measurements from Ships

Kevin Sullivan, Denis Pierrot, Francis Bringas, Geun-Ha Park and Leticia Barbero (RSMAS/CIMAS)

- Investigators presented public lectures; and are members of national and international steering committees. Of note in the context of this program are the international coordination efforts in the GOSUD (Global Ocean Surface Underway Data Pilot Project) and SOCAT (Surface Ocean CO_2 Atlas) programs focused on expanding and coordinating ship of opportunity projects and the synthesis of global surface water CO_2 fields.
- Barbero and Park contributed to the international activity SOCAT (Surface Ocean CO2 Atlas) by providing data, quality control and assessment of data quality. 30% of the 10 million data points in the SOCAT analysis were obtained from this analysis.

The CLIVAR CO$_2$ Repeat Hydrography Program

Kevin Sullivan, Denis Pierrot, George Berberian, Geun-Ha Park and Leticia Barbero (UM/CIMAS); Chris Langdon and Rik Wanninkhof (NOAA/AOML)

- Pierrot, Wanninkhof, and Langdon are actively involved in the international coordination and data quality control efforts such as CARINA, GO-SHIPS and CLIVAR-CO2 repeat hydrography.
- Park, Barbero and Wanninkhof are participating in the international RECCAP effort (Regional carbon assessment project).

Biscayne Bay Alongshore Epifauna Community and their Relationship to Salinity

Gladys A. Liehr, Darlene R. Johnson, E. Buck, Hernando Cardenas

Starting June 2011, NOAA Holling Scholarship recipient, Zayani Sims, will begin working on Comparison of species composition from two different sampling gear, throw trap and seine, in Biscayne Bay alongshore habitat.

Caribbean Sea and Gulf of Mexico Bluefin Tuna Research Cruise

Barbara Muhling, Estrella Malca and Akihiro Shiroza (UM/CIMAS)

- Open house and early life history workshop activity on April 11, 2011 in Grand Cayman with Department of the Environment officials, Cayman Preparatory School and High School. http://www.caymannewsservice.com/science-and-nature/2011/04/12/noaa-helps-out-cayman%E2%80%99s-fish-larvae-count
- Outreach activity with high school students from Corporate Academy South, Homestead FL. This is a school for at-risk low income students. The students sent personalized styrofoam cups to 2,000 meters deep attached on one of the instruments used to collect scientific data in order to engage their interest in a unique way in the classroom. The cups shrink a lot at that depth and once they get the cups back, the teacher is able to discuss pressure at depth with this demonstration activity.
- International participation and exchange between government agencies including Mexico's Instituto Nacional de Pesca, Belize's Fisheries Department and Cayman's Department of the Environment..

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

Estrella Malca and Samantha Whitcraft (UM/CIMAS)

In addition to undergraduate & graduate students from ECOSUR, international and regional NGOs participated in the capacity building workshop. Websites were created to promote communication and exchanges

- http://www.ecosur.mx/unidades/chetumal/ofe/ocean/mpa/workshop.html
- http://www.marfund.org/en/new_projects/first_connectivity_regional_workshop.html

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

Barbara Muhling, Estrella Malca and Sarah Privoznik (UM/CIMAS)

Open house and otolith workshop was conducted with Homestead High School students visiting during the "Teacher in the Lab field trip" (March 21, 2011 at SEFSC). Children conducted dissections and learned about otoliths and fisheries science.

International Symposium on Circle Hooks

David J. Die (UM/CIMAS)

Seven industry and fishery agencies set up their booths in the trade show sessions as well as contributed to the funding of the symposium.

Shallow-water grouper distribution, habitat characteristics and spawning behavior

David J. Die (UM/CIMAS)

Veronique Koch was part of the NSF funded study entitled "Science Made Sensible" and had the opportunity through this study to talk to middle school students about her black grouper research.

Integrated Coral Observing Network (ICON) Project

Ian C. Enochs, Lew J. Gramer, Kevin P. Helmle, Mike Jankulak and Derek P. Manzello (UM/CIMAS)

- Contributed coral core samples, X-radiographs, and descriptive text for upcoming paleoclimate exhibit at the Koshland Museum of Science in Washington D.C.
- Presentations at the Miami Science Museum as part of Climatology Career Day and the Summer Camp program which consist of Youth EXPO, Digital WAVE, and Upward Bound programs

Investigation of the Movement of Adult Billfish in Potential Spawning Areas

John P. Hoolihan (UM/CIMAS)

Adopt-A-Billfish program has been been able to generate the funds for almost half the 300 PSAT deployments to date.

Global Drifter Program

Shaun Dolk and Erik Valdes (UM/CIMAS)

In conjunction with the Adopt A Drifter Program, CIMAS is developing a drifter information packet to distribute to schools, both domestically and internationally. Along with information about drifting buoys, their benefits, and their uses model drifters will be distributed for teachers to incorporate into their lesson plans.

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

Maribeth Gidley, David Wanless, Diana Aranda and Jakob Bartkowiak (UM/CIMAS)

The education/outreach components of this project have been integrated into the larger outreach programs of the UM Oceans and Human Health Center, NOAA AOML, and the Gulf of Mexico Alliance. This has included training and support of student interns through UM and NOAA, public informational presentations, and participation in the National Ocean Sciences Bowl program and incorporation and data and information from project in educational brochures and products by NOAA, UM OHH Center, FIU, and GOMA.

Oceanographic and Spectroscopic Analysis Relating to the Deepwater Horizon Oil Spill

Mitchell A. Roffer, Gregory Gawlikowski and Mathew Upton (Roffer's Ocean Fishing Forecasting Service, Inc.)

The oceanographic analyses were distributed to a broad audience via email and internet website (http://www.roffs.com/deepwaterhorizon.html) to inform other researchers, emergency managers, the media (print, broadcast, internet) and to educate the public (including K-12, undergraduate and graduate student activities).

Marine and Estuarine Goal Setting (MARES)

P. Ortner (UM/CIMAS); J. Ault, D. Lirman and G. Hitchcock (UM/MBF)

The core of the project is essentially outreach and public awareness however not of K-12 or undergraduate populations but the South Florida stakeholder community. Briefings were conducted at a number of public forums including South Florida Ecosystem Restoration Task Force, Southeast Florida Coral Reef Inititiative, Florida Keys Sanctuary Advisory Panel, Gulf Coast Fisheries Management Council and Committee of Independent Science Review of the Everglades Plan

Coral Ecological Restoration in the Florida Keys National Marine Sanctuary

Dana E. Williams, Rachel Wilborn, Alan Bright and L. Johnston (UM/CIMAS)

- Invited public lecture on coral reef status and restoration @ 50th Anniversary celebration of John G. Pennekamp State Park.
- Oral presentation to Florida Keys coral reef managers at 'Linking Science to Management' conference, Duck Key FL, Oct 2010.
- Oral presentation at ARRA coral nursery 'Outplanting Workshop' (coordinated by The Nature Conservancy) to advise on successful design, 2 Nov 2011.

VIII. CIMAS FELLOWS AND EXECUTIVE ADVISORY BOARD

The Fellows provide guidance to the Director on matters concerning the ongoing activities and future direction of CIMAS. The Fellows are nominally to meet on a quarterly basis although scheduling has been difficult because of the extensive travel schedules. Many Fellows-related matters are now addressed and implemented by means of email exchanges and all meetings other than the Annual one will be conducted as teleconferences via GOTOMEETING.

COUNCIL OF FELLOWS

FELLOWS	AFFILIATION
Dr. Manhar Dhanak	**Florida Atlantic University**
Dr. Marguerite Koch	Florida Atlantic University
Dr. Joseph Boyer	**Florida International University**
Dr. John Proni	Florida International University
Dr. Eric Chassignet	**Florida State University**
Dr. Markus Huettel	Florida State University
Dr. Silvia Garzoli	**NOAA/AOML**
Dr. Gustavo Goni	N OAA/AOML/Physical Oceanography
Dr. Frank Marks	NOAA/AOML/Hurricane Research Division
Dr. Michelle Wood	NOAA/AOML/Ocean Chemistry Division
Dr. Richard J. Pasch	**NOAA/National Hurricane Center**
Dr. James Bohnsack	**NOAA/Southeast Fisheries Science Center**
Dr. Lance Garrison	NOAA/Southeast Fisheries Science Center
Dr. John Quinlan	NOAA/Southeast Fisheries Science Center
Dr. Joseph Serafy	NOAA/Southeast Fisheries Science Center
Dr. Mahmood Shivji	**NOVA Southeastern University**

Dr. Alex Soloviev	NOVA Southeastern University
Dr. Ellen E. Martin	**University of Florida**
Dr. Yeayi (Peter) Sheng	University of Florida
Dr. Jerald S. Ault	**University of Miami/RSMAS**
Dr. Rana Fine	University of Miami/RSMAS
Dr. Brian Haus	University of Miami/RSMAS
Dr. Ben Kirtman	University of Miami/RSMAS
Dr. David Letson	University of Miami/RSMAS
Dr. Sharan Majumdar	University of Miami/RSMAS
Dr. Richard Appeldoorn	**University of Puerto Rico**
Dr. Kent Fanning	**University of South Florida**
Dr. Frank Muller-Karger	University of South Florida
Dr. Rick Nemeth	**University of Virgin Islands**
Dr. Tyler Smith	University of Virgin Islands

Chair:

Dr. Peter B. Ortner, Director	UM/CIMAS

***Ex Officio*:**

Dr. David Die, Associate Director	UM/CIMAS

EXECUTIVE ADVISORY BOARD

Ms. Camille Coley	Florida Atlantic University
Dr. Andrés G. Gil	Florida International University
Dr. Kirby W. Kemper	Florida State University
Dr. Philip Hoffman	NOAA CI Office
Dr. Robert Atlas	NOAA/AOML, Director
Dr. Bonnie Ponwith	NOAA/Southeast Fisheries Science Center
Dr. Bill Read	NOAA/National Hurricane Center
Dr. Richard Dodge	NOVA Southeastern University
Dr. Winfred M. Phillips	University of Florida
Dr. Nilda E. Aponte	University of Puerto Rico
Dr. Jacqueline E. Dixon	University of South Florida
Dr. LaVerne Ragster	University of the Virgin Islands
Dr. Roni Avissar	UM/RSMAS Dean
Dr. Peter Ortner	UM/CIMAS – *ex officio*
Dr. David Die	UM/CIMAS – *ex officio*

IX. AWARDS AND HONORS

Characterization of Ocean Acidification in Coral Reef Waters
Dwight Gledhill (UM/CIMAS)

- FY11 AOML OCD Award of Recognition for leadership efforts in support of the AOAT.

Ensemble-Based High-Resolution, Vortex-Scale Data Assimilation for Hurricane Model Initialization
Altug Aksoy (UM/CIMAS)

- Dr. Aksoy received the 2011 Monthly Weather Review Editor's Award from the American Meteorological Society for "providing a large number of high-quality reviews to several of the editors." Dr. Aksoy also received a certificate of recognition from NOAA for receiving this Editor's Award from the American Meteorological Society.

New Infrared Satellite Imagery for Detecting Changes in Tropical Cyclone Structure
Jason. P. Dunion (UM/CIMAS), Christopher S. Velden (University of Wisconsin)

- Co-Recipients: NOAA AIRS Team for outstanding contributions to improving weather forecasting using data from the Atmospheric Infrared Sounder (AIRS).

Advanced Modeling and Prediction of Tropical Cyclones
Xuejin Zhang and Kao-San Yeh (UM/CIMAS)

- Drs. Zhang and Yeh both received Certificates of Merit issued by NOAA's Atlantic Oceanographic and Meteorological Laboratory.

Investigation of the Movement of Adult Billfish in Potential Spawning Areas
John P. Hoolihan (UM/CIMAS)

- Dr. Hoolihan received NOAA Fisheries Service Team Member of the Year Award in the Program Management/Scientific/Technical, GS 11-15 or pay band equivalent category.

Global Drifter Program
Erik Valdes (UM/CIMAS)

- Mr. Valdes received a Certificate of Appreciation for his efforts in Providing Quality Data for the Scientific Community. This certificate was issued by NOAA's Atlantic Oceanographic and Meteorological Laboratory.

X. POSTDOCTORAL FELLOWS AND GRADUATE STUDENTS

CIMAS-Supported Postdoctoral Fellows and Graduate Students

Postdoctoral Fellows

Barbero Munoz, Leticia
Enochs, Ian
Hormann, Verena
Le Henaff, Matthew
Liu, Hailong
Liu, Yanyun
Yang, Haoping
Zabalo, Joaquin

Graduate Students

Task I
Council, Elizabeth
Johnston, Lyza
Jones, Robert
Wylie, Jennifer

Task III
Albright, Rebecca
Bhatia, Kieran
Buck, Eric
Ditrolio, Benjamin
Dolan, Tara
Huntington, Brittany
Harford, William
Karmauskas, Mandy
Martin, Elizabeth
Mason, Benjamin
McCaskill, Claire
Meyers, Patrick
Perryman, Holly
Santos, Rolando
Waters, Jason
Woosley, Ryan

Employees
Enochs, Ian
DiNezio, Pedro
Forteza, Elizabeth
Grammer, Lewis
Kelble, Christopher
Malca, Estrella
Sellwood, Kathryn
Shiroza, Akihiro

Other Participants in CIMAS Projects

Postdoctoral Fellows

Sebille,, Erick Van
Jaimes, Benjamin

Graduate Students

Drury Crawford
Ender, Alexandra
Fischer, Michael
Kotkowski, Rachel
Lerner, Justin
Liu, Diantig
Melendez, Melissa
Meng, Teo
Smith, Mathew
Vasquez-Yeomans, Lourdes
Waterhouse, Lynn
Yurek, Simeon

XI. RESEARCH STAFF

Aksoy, Altug	Assistant Scientist
Amornthammarong, Natchanon	Assistant Scientist
Annane, Bachir	Senior Research Associate III
Aranda, Diana	Research Associate II
Barbero Munoz, Leticia	Postdoctoral Associate
Berberian, George	Research Associate II (PT)
Blondeau, Jeremiah	Senior Research Associate I
Bright, Alan	Research Associate II
Bringas Gutierrez, Francis	Research Associate III
Brown, Cheryl	Research Associate II
Cameron, Caitlin	Research Associate I
Cardenas, Hernando	Research Associate I
Di Nezio, Pedro N.	Research Associate III
Dias, Laura	Research Associate II
Diaz, Jose E.	Research Associate II
Dolk, Shaun	Research Associate II
Dong, Shenfu	Assistant Scientist
Dunion, Jason	Senior Research Associate III
Enochs, Ian	Postdoctoral Associate
Enfield, David	Scientist (PT)
Erickson, Kristin L.	Research Associate III
Festa, John	Senior Research Associate III (PT)
Forteza, Elizabeth	Research Associate III
Garcia, Rigoberto F.	Research Associate III
Gidley, Maribeth	Assistant Scientist
Gledhill, Dwight	Associate Scientist
Goes, Marlos	Assistant Scientist, MAS
Gonzalez, Caridad	Research Associate II
Gramer, Lewis J.	Research Associate III
Halliwell, Vicki	Senior Research Associate III

Helmle, Kevin	Assistant Scientist
Hoolihan, John	Associate Scientist
Hormann, Verena	Postdoctoral Associate
Jankulak, Michael L.	Research Associate III
Johnson, Darlene R.	Scientist
Kelble, Christopher R.	Assistant Scientist
Klotz, Bradley	Research Associate III
Le Henaff, Matthieu	Postdoctoral Associate
Lee, Sang-Ki	Scientist
Liehr, Gladys	Assistant Scientist
Lindo Atichati, David	Research Associate I
Liu, Hailong	Postdoctoral Associate
Liu, Yanyun	Postdoctoral Associate
Lorsolo, Sylvie	Assistant Scientist
Malca, Estrella	Research Associate III
Manzello Derek	Assistant Scientist
Melo, Nelson	Senior Research Associate II
Molina, Jonathan	Research Associate I
Muhling, Barbara	Assistant Scientist
Otero, Sonia	Senior Research Associate II
Park, Geun-Ha	Assistant Scientist
Peng, Tsung-Hung	Scientist (PT)
Perez, Renellys	Assistant Scientist
Pierrot, Denis P.	Assistant Scientist
Privoznik, Sarah	Research Associate I
Rawson, Grant T.	Research Associate III
Sabina, Reyna	Research Associate III (PT)
Seaton, Kyle	Research Associate II
Sellwood, Kathryn J	Research Associate III
Shiroza, Akihiro	Research Associate II
St. Fleur, Russell	Programmer Intermediate
Sullivan, Kevin F.	Senior Research Associate III
Teare, Brian	Research Associate II

Thacker, Carlisle	Scientist (PT)
Tonioli, Flavia	Senior Research Associate I
Valdes, Erik	Research Associate II
Visser, Lindsey	Research Associate I
Wanless, David R.	Research Associate II
Whitcraft, Samantha R.	Senior Research Associate I
Wicker, Jesse A.	Research Associate III
Wilborn, Rachel	Research Associate II
Willey, Debra	Senior Research Associate I
Williams, Dana E.	Scientist
Willis, Paul	Research Associate II (PT)
Yang, Haoping	Postdoctoral Associate
Yao, Qi	Senior Research Associate I
Yeh, Kao-San	Scientist
Zabalo, Joaquin	Postdoctoral Associate
Zhang, Jun	Assistant Scientist
Zhang, Xuejin	Assistant Scientist

XII. VISITING SCIENTISTS PROGRAM

Prof. Johann R.E. Lutjeharms
Professor Emeritus
Department of Oceanography
University of Cape Town
770 Rondebosch
Cape Town, South Africa
1 – 15 November, 2010

November 3, 2010 *“What Do We Know About the Agulhas Current After 30 Years of Research?”*

Prof. Dr. Edmo J.D. Campos
Professor Titular – Physical Oceanography
Oceanographic Institute – University of Sao Paulo
Pca. Do Oceanografico 191 – Cid. Universitaria
05508-120 S. Paulo, SP, Brazil
12 December, 2010 – 12 March, 2011

Dr. Yehe Mathieu Dietoa
Laboratory of Environment and Aquatic Biology
University of Abobo-Adjamé
01 B.P. 801 Abidjan 02, Côte d’Ivoire
5 January – 15 February 2011

XIII. PUBLICATIONS

Table 1: Publication Record 2010-2011

	Institute Lead Author 2010-2011	**NOAA Lead Author 2010-2011**	**Other Lead Author 2010-2011**
Peer Reviewed	52	26	29
Non-Peer Reviewed	22	13	2

Refereed Journal Articles

Albright, R., B. Mason, M. Miller, C. Langdon (2010), Ocean acidification compromises recruitment success of the threatened Caribbean coral, *Acropora palmata*, Proceedings of the National Academy of Sciences, 107(47), 20400-20404. 10.1073/pnas.1007273107.

Amornthammarong, N., J.-Z. Zhang and P.B. Ortner (2011), An autonomous batch analyzer for the determination of trace ammonium in natural waters using fluorometric detection, Anal. Methods., 2011, DOI: 10.1039/C1AY0595H.

Babcock, E. A. and A. D. MacCall (2011), How useful is the ratio of fish density outside versus inside no-take marine reserves as a metric for fishery management control rules? *Can. J. Fish. Aquat. Sci.* 68: 343–359. doi:10.1139/F10-146.

Barbero, L., J. Boutin, L. Merlivat, N. Martin, T. Takahashi, S. C. Sutherland, and R. Wanninkhof (2011), Importance of water mass formation regions for the air-sea CO_2 flux estimate in the Southern Ocean, Tellus, 25, GB 1005, doi:1010.1029/2010GB003818.

Baringer, M. O., T. O. Kanzow, C. S. Meinen, S. A. Cunningham, D. Rayner, W. E. Johns, H. L. Bryden, E. Frajka-Williams, J. J-M. Hirschi, M. P. Chidichimo, L. M. Beal and J. Marotzke (2011), The Meridional Overturning Circulation, in State of the Climate in 2010, D. Arndt, J. Blunden and M.O. Baringer (eds.), *Bull. Am. Met. Soc*., in press.

Brandt, P., A. Funk, V. Hormann, M. Dengler, R. J. Greatbatch, and J. M. Toole (2011), Interannual atmospheric variability forced by the deep equatorial Atlantic Ocean, *Nature*, 473, 497-501, doi:10.1038/nature10013.

Brassington, G. B., N. Summons, and R. Lumpkin (2010), Observed and simulated Lagrangian and eddy characteristics of the East Australian Sea and Tasman Sea, *Deep-Sea Res. II*, 58, 559-573, doi:10.1016/j.dsr2.2010.10.001.

Bunya, S., J. C. Dietrich, J. J. Westrink, B. A. Ebersole, J. M. Smith, J. H. Atkinson, R. Jensen, D. T. Resio, R. A. Luetich, C. Dawson, V. J. Cardone, A. T. Cox, M. D. Powell, H. J. Westerink, and H. J. Roberts (2010), A High-Resolution Coupled Riverine Flow, Tide, Wind, Wind Wave, and Storm Surge Model for Southern Louisiana and Mississippi. Part I: Model Development and Validation, *Mon. Wea. Rev.*, 136, 345-377.

Cai, W.-J, L. Chen, B. Chen, Z. Gao, S. H. Lee, J. Chen, D. Pierrot, K. Sullivan, Y. Wang, X. Hu, W.-J. Huang, Y. Zhang, S. Xu, A. Murata, J. M. Grebmeier, E. P. Jones, and H. Zhang (2010), Decrease in the CO_2 uptake capacity in an ice-free Arctic Ocean basin, Science, 1, DOI: 10.1126/science.1189338.

Collado-Vides, L., V. Mazzei, T. Thyberg, and D. Lirman. (2011). Spatio-temporal patterns and nutrient status of macroalgae in heavily managed region of Biscayne Bay, Florida, USA, *Botanica Marina*, in press.

Criales, M. M, M. B. Robblee, J. A. Browder, H. Cardenas, and T. L. Jackson (2011), Field observations on selective tidal-stream transport for postlarval and juvenile pink shrimp in Florida Bay, *J.. Crust. Biology*, 31(1): 26-33. Online ISSN: 1937-240X.

Criales, M. M., J. A. Browder, and E. Little (2010), Species composition and seasonality of the smallest size class shrimp in the Tortugas shrimp fishery of Florida, *Gulf Mex. Sci*., 102-108.

Criales, M. M., M. B. Robblee, J. A. Browder, H. Cardenas, and T. L. Jackson (2010), Nearshore concentration of pink shrimp *Farfantepenaeus duorarum* postlarvae in northern Florida Bay in relation to the nocturnal flood tide, *Bull. Mar. Sci.*, 86(1): 51-72.

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