Cooperative Institute for Marine and Atmospheric Studies

Second 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 including 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 Science Goals. These Research Themes were specified by NOAA in the request for proposals (RFP) to which CIMAS responded during 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 funding (Tasks 1, II, III and IV) related to this Cooperative Agreement (CA) during this reporting period was $19.4M. Task I which includes not only Administration but also Research Infrastructure (shiptime, computing resource access etc.), Education and Outreach was ca. $3.3M. The University of Miami contributed $.24M towards Administration. Task II, which supports CIMAS employees conducting research off- campus was ca. $ 7.9M.

Project research funding (Tasks III and IV) totaled ca. $8.2M. The largest portions of Tasks III and IV were the research projects within Themes (3, 6) Sustained Ocean & Coastal Observations and Ecosystem Management which together account for 67%. The smallest portions were in Themes (4, 5) Ocean Modeling and Ecosystem Modeling & Forecasting which together account for only 5%. These percentages are somewhat misleading in that these Theme assignments reflect only the "primary" not secondary or tertiary "theme" designations. In many cases which Theme is primary is arbitrary given the interdisciplinary character of the research. Moreover the above expenditures refer only to those under this new CA initiated October 2010. They do not include continuing funding during these same time period under prior agreements.

During this reporting period a total of 122 individuals at UM were directly provided salary support through CIMAS. Of these, 104 received over 50% of their support through CIMAS. Of the 104 research employees who received over 50% NOAA support, 69 worked with AOML, 34 with SEFSC and one with the NHC. Twenty three of these employees were Research Scientists including 8 part time former NOAA employees. 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, 17%. The population of CIMAS is relatively young in comparison with NOAA overall (or the local laboratories) and has an average age of only 39. This is very close to last year's demographic profile.

During this last year there were 94 peer-reviewed publications and another 25 non-peer reviewed technical reports or other publications resulting from CIMAS research. The results from a few individual projects are highlighted below. They were selected from various themes to be representative of the wide diversity of activities carried out within CIMAS and are sorted with respect to three of NOAA's scientific goals. A more detailed description of these projects can be found in the body of the Report within the full sets of individual project summaries provided for each of the seven CA Themes and separately for individual competitive program awards to CIMAS investigators under the new CI policy in that regard.

Research, educational and outreach activities conducted by CIMAS during the twelve months summarized herein but related to prior Cooperative Agreements will be separately reported in subsequent reports as directed by the NOAA CI Program Office.

SOME RESEARCH HIGHLIGHTS

Goal 1: Climate Adaptation and Mitigation: *An informed society anticipating and responding to climate and its impacts*

***Western Boundary Time Series Project*:**

- This project studies the along-stream change in Labrador Sea Water as it travels from the formation region to 26.5°N along the eastern seaboard of North America. Results obtained confirm the transit time from the formation region into the study area is roughly 10 years. Bulk mixing of this water was estimated using water property data for various source waters.

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

- Analyses of temperature/salinity field from Argo and models suggest that the models do not capture the seasonal variation in geostrophic transport estimated from observations, which may be related to wind forcing.
- A nine-year time series of the MOC and MHT estimated from trans-basin XBT measurements suggest that MOC and MHT are highly correlated and a one Sverdrup increase in the MOC would cause an increase of 0.05 PW in MHT.
- Assimilating Argo measurements into models has greatly improved the model performance 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.

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

- Coupled models can show a very weak AWP because of a cold sea surface temperature (SST) bias in the northwest tropical Atlantic moreover the models demonstrate very different interannual variability.
- Empirical Orthogonal Function (EOF) analysis of tropical Atlantic SST indicates there are two dominant modes (zonal and meridional) of variability. While some coupled models are able to display the meridional mode correctly most misrepresent the zonal mode due to the southeast tropical Atlantic SST warm bias included in the interannual variability.
- Both the positive ENSO phase and the negative NAO phase in winter correspond to anomalous westerlies in the AWP region. This leads to local heating and subsequent warm SST. This feature is well-captured by models.

***Development and Evaluation of an Ocean OSSE System*:**

- In energetic regions of the ocean such as the Gulf of Mexico, data assimilation greatly reduces velocity errors compared to unconstrained ocean models. However, velocity errors still remain large, indicating that additional improvements are needed with respect to ocean data assimilation if the models are to accurately forecast the transport and dispersion of oil and marine debris.

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

- Low-resolution models underestimate Loop Current (LC) change and the cooling induced. Higher resolution models show minimal cooling.
- The area of spawning habitat for the bluefin tuna may not be as drastically reduced as predicted based upon the IPCC-AR4 model projection.

Relationship of the Atlantic Warm Pool with the Atlantic Meridional Overturning Circulation

- A large (small) AWP is associated with a local freshwater gain (loss), a less (more) moisture transport across Central America and a local low (high) sea surface salinity.
- Results suggest a novel mechanism for North Atlantic SST variability – a positive feedback between North Atlantic SST, African dust, and Sahel rainfall on multi-decadal timescales.

Simulation of the Argo Observing System

- The Argo array has been brought to full strength, and is now providing the oceanographic community with reliable three-dimensional global measurements of the ocean temperature and salinity. These data are used to detect changes in the oceanic state and climate of the Earth, which has a large societal importance.
- The results from this project have identified regions, in which the reconstruction of oceanic variables from the Argo data can be less reliable than in the rest of the World Ocean, and where additional, dense spatial sampling is needed.

PIRATA Northeast Extension (PNE)

- After quantifying the interannual NECC variability based on a synthesis product of the surface geostrophic circulation, this study investigated the relation to the coupled tropical

Atlantic climate modes and found indications of a connection with both the meridional and zonal mode.

- An analysis of the mechanisms modulating Atlantic tropical instability wave (TIW) intensity found that interannual variations of off-equatorial TIWs (with maximum amplitudes near 2°N or 5°N) can be largely explained by dynamic effects such as the meridional shear between the northern branch of the South Equatorial Current and the North Equatorial Countercurrent.
- In an effort to start measuring the upper ocean with new technology, the Physical Oceanography Division at NOAA/AOML evaluated an Underway CTD system with two CTD probes from *Oceanscience* (http://www.oceanscience.com/uctd.html) during the PNE cruise in July – August 2011.

Developing the Operational Calibration/Validation Components for VIIRS SST Retrievals

- Following launch of the NPP satellite in Fall, 2011 and the subsequent activation of the VIIRS sensor in late January, 2012, the performance of the VIIRS sensor has been monitored and compared to global in situ observations. Results from analyzing these observations have been communicated to the VIIRS SST team, NOAA Lead Sasha Ignatov, during bi-weekly telecons and through submission of analysis reports. Significant have been observation of a 0.15K offset in retrieved VIIRS SST stemming from a change introduced into the VIIRS Sensor Data Record (SDR) radiance file by the JPSS/SDR team and non-physical brightness temperatures > 400K in the 4μm band over open ocean during nighttime observations. These anomalies have been reported to the appropriate JPSS teams for investigation and remediation. In addition, the global matchup VIIRS-in situ database has enabled comparison of various team member proposed SST retrieval algorithms using both proposer supplied SST retrieval coefficients and equivalent coefficient sets estimated at RSMAS. This has facilitated selection of the best SST retrieval approach and enabled calculation of an uncertainty budget. In situ validation observations are being acquired by the M-AERI Mark I and Mark II radiometers on board ships of opportunity. Installation of one or two of the radiometers on board RCCL cruise line ships is being undertaken this year.

Goal 2: Weather Ready Nation: *Society is prepared for and responds to weather-related events*

Impacts of Non-Canonical El Niño Patterns on Atlantic Hurricane Activity

- Non-canonical El Niño patterns, namely central Pacific warming, El Niño Modoki, (+) phase Trans-Niño, and (+) phase Pacific meridional mode, have insubstantial impact on Atlantic TC activity because the .tropical Pacific SSTs associated with these patterns are not strong enough to cause a substantial warming of the troposphere in the Atlantic region.

Advanced Modeling and Prediction of Tropical Cyclones

- The operational HWRF modeling system has become the highest resolution hurricane model ever implemented operationally by the National Weather Service and has cloud-permitting resolution. Retrospective experiments show improvements of both track and intensity 20% and 10%, respectively.

Studies in Support of NOAA's Operational Ocean Heat Content Analysis Using Deep Water Horizon Measurements

- Aircraft-based ocean measurements acquired during Deep Water Horizon incident provided an independent measure of the satellite-derived isotherm depths and OHC products from the SMARTS climatology.
- Using an archive dating back to 1998, data have been provided to CIRA to update regression parameters for OHC in the Statistical Hurricane Intensity Prediction Scheme for hurricane intensity forecasting at NHC during the upcoming season.

Marine Optical Buoy (MOBY) Operations Bridge Through NPP Launch

- For the ocean color data record to be compared, merged, and maintained over a significant time period between international satellite sensors requires a common calibration point, maintained at the highest accuracy possible. The MOBY calibration site, supported by this work, provides that single reference point used by the international community of ocean color satellite systems to tie these measurements together and is a key asset to the current, recently launched, NOAA satellite instrument, VIIRS.

Goal 3: Healthy Oceans: *Marine fisheries, habitats, and biodiversity sustained within healthy and productive ecosystems*

Integrated Marine Protected Area Climate Tool (IMPACT). Planning and Implementation of a Standardized Web-based Data Access Service for IMPACT Data Layers Using NOAA's IOOS Data Management and Communication (DMAC)

- This is the first attempt to incorporate biogeochemical data from water quality monitoring programs into IOOS. The U.S. EPA, the Florida Department of Environmental Protection and the National Park Service have recently adopted the biogeochemical segmentation of the Florida Keys National Marine Sanctuary and the SW Florida Shelf waters derived from from this research, for the determination of numeric nutrient criteria.

Vieques Sound and Virgin Passage Transport Study Modeling

- Simulated current are being used to assess regional linkages and biophysical connectivity between marine habitats in order to assess the effectiveness of MPA management and to develop adaptive strategies for the future. To improve the accuracy of the connectivity network, the model is constrained by observations. A specific data assimilation scheme for ADCP profiles was being developed specifically for the model of this region.

Investigation of the Movement of Adult Billfish in Potential Spawning Areas

- Major peer-reviewed contributions describing ocean scale hypoxia-based habitat compression of billfishes, vertical habitat use by sailfish, and post-release behavior modification of tagged fish.

Assessing the Locations and Status of Reef Fish Spawning Aggregations in the Florida Keys

- The question being addressed is whether there is a consistent relationship between seabed geomorphology and the locations of FSAs in the Florida Keys. Over 55% of the benthic habitat of the FKNMS remains unmapped, mostly in water deeper than 20 m, which is primarily where the FSAs of commercially important as grouper and snapper species were historically found. Through a combination of acoustic seabed classification, fisheries acoustic surveys, aerial and diver observations, we are investigating the current status of historical spawning aggregation sites as well as patterns of seabed features common to those sites. Knowledge of such a relationship is essential to refine the FKNMS zoning plan.

Dispersal, Habitat Use and Behavior of Neonate Sea Turtles in the Gulf of Mexico and Waters Impacted by the Deep Water Horizon MSC 252 Oil Spill

- This project is attempting to bridge gaps in our understanding of early sea turtle life history in order to provide improved estimation of threats at foraging areas and along migration routes for oceanic stage sea turtles in the Gulf. Novel satellite tracking methods coupled with theoretical ocean circulation simulations have provided the first tracks of oceanic stage sea turtles in the Gulf of Mexico.

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 includes 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 Memorandums, Research Plans and Strategic Plans.

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: Climate Adaptation and Mitigation - *An informed society anticipating and responding to climate and its impacts*
Goal 2: Weather-Ready Nation - *Society is prepared for and responds to weather-related events*
Goal 3: Healthy Oceans - *Marine fisheries, habitats, and biodiversity sustained within healthy and productive ecosystems*
Goal 4: Resilient Coastal Communities and Economies - *Coastal and Great Lakes communities that are environmentally and economically sustainable*

These NOAA's scientific mission goals are consistent with the broader scientific mission of CIMAS and each research project in CIMAS must contribute to 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 participating 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 research scientists or research associates 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 Research Scientists can serve as project principal investigators and submit proposals to NOAA and other agencies. See Tasks 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 offices. Support for individual Task III projects is based on proposals submitted to specific NOAA units or funding programs often <u>but not necessarily</u> 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. Non-UM CIMAS University Partners are funded by NOAA through Task III.

III. PERSONNEL

Distribution of Personnel

CIMAS personnel participate in a wide range of NOAA-related activities. During the past twelve months a total of 125 persons were associated with CIMAS in various capacities. Of these, 104 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 104 who received over 50% NOAA support, 69 are associated with AOML, 34 with SEFSC and one with NHC. Two of these work out of state. All but two were research personnel.

Table 1: CIMAS Research Personnel 2011 – 2012

Category	Number	BS	MS	Ph.D
Research Associate/Scientist	68	18	24	25
Part Time Research Associate/Scientist	8	3	2	3
Postdoctoral Fellow	7			6
Research Support Staff	21	3	2	
Total (> 50% NOAA support)	**104**	**24**	**28**	**34**
Administration	5			2
Task I Undergraduate Students	5			
Task I Graduate Students	8			
Visiting Scientists	3			
NOAA Association	69-AOML 34-SEFSC 1-NHC			
Obtained NOAA employment within the last year	2			

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 twelve months, there were in addition a total of 7 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). At present there are only two such employees.

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 (including both the CIMAS Director and Associate Director). University faculty are not counted in the listing of the 125, not even those who serve as CIMAS Fellows or conduct Task III research projects. All the graduate students who work on CIMAS Task I programs and are included in the 125 total also 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 twelve months, CIMAS has continued its efforts to improve the working environment of its many off-campus employees. Specific efforts included:

1. Updating its' 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 part-time liaison positions 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 is expected to be held next year.

CIMAS Executive Advisory Board

The Board includes the Directors of the local NOAA facilities (R. Atlas, OAR/AOML; B. Ponwith, NMFS/SEFSC and R. Knabb, 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, 17%. 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 49. 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 8 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:

This reporting period, funding from all sources totaled ca. $19.4M under the new Cooperative Agreement. A summary of funding under the four Tasks is shown in Table 1.

Table 1: Summary of Funding

Period	Task I	Task II	Task III	Task IV	TOTAL
Year 1	1,742,457	7,924,090	1,583,572	824,640	12,074,459
Year 2	3,269,557	7,880,380	6,236,972	2,012,573	19,399,482
TOTALS	**5,012,014**	**15,804,470**	**7,820,544**	**2,837,213**	**31,474,241**

The sources of that funding are shown in Table 2. The major source of funding continued to be OAR which provided 41% of the total. NESDIS, NMFS and NOS were second at 19% , 16% and 13% 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, NOPP and private industry as well as sub-contractual awards from FIU and USF.

Table 2: Funding by Source

1 July 2011 - 30 June 2012		
Source	**Funding $M**	**% Total**
OAR	7.95	41%
NESDIS	3.77	19%
NMFS	3.20	16%
NOS	2.48	13%
Dept of Defense	0.43	2%
CRCP	0.30	2%
NWS	0.56	3%
Other	0.71	4%
GRAND TOTAL	**19.40**	**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 researchers and support personnel 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 by CIMAS research scientist employees. Task IV includes projects supported by other (non-NOAA) funding sources. The approval of the Director (as the designate of the RSMAS Dean), is required for CIMAS employees to submit Task III or 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 53.5%) 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 support toward which that IDC would have contributed.

The total of Task I Funding (including the UM contribution) was $ 3.50M, of which $0.58M 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.

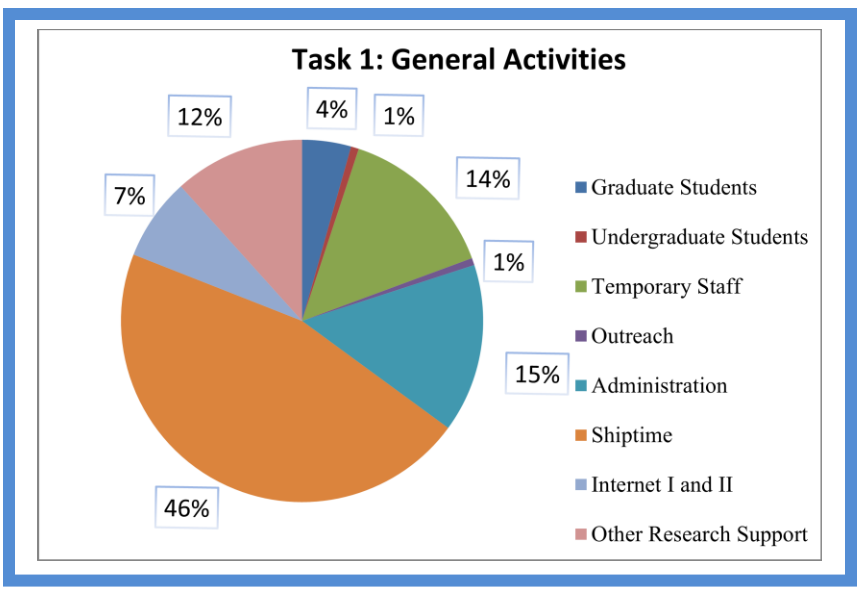

Figure 1: Distribution of Task 1Funding

The total NOAA-supported Task 1 budget was $ 3.27M. The category "Administration" 15% 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 $.237M.

The category "Other" 12% 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.), and access to high performance computing or other university owned research facilities. Research ship-time accounts for 46% of the total; this is the first year in which NMFS/SEFSC not just AOML provided funding for ship-time. Temporary Staff (14%) covers persons hired on a temporary basis to support research.

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

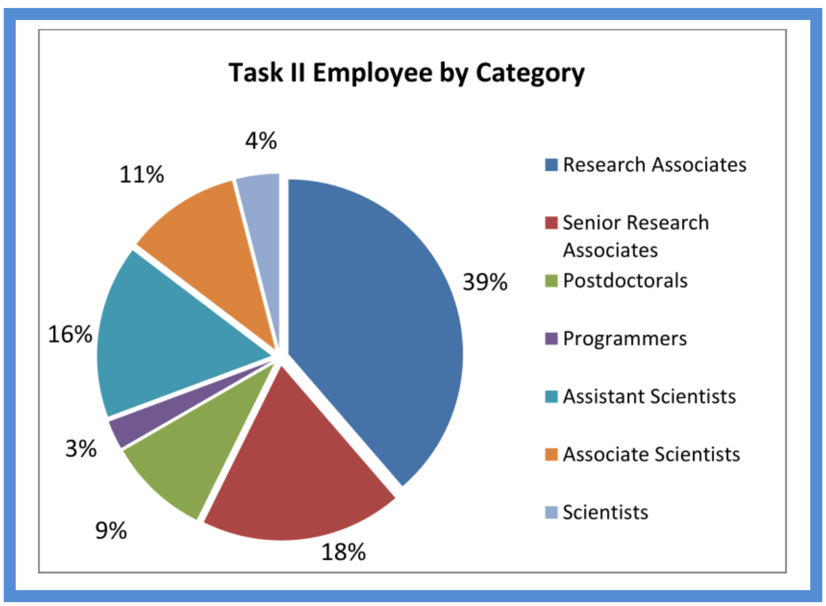

Figure 2: Distribution of Task 2: Funds by Employee Category

Funding By Theme

Project specific research funding (Tasks III and IV) under the new CA totaled ca. $8.2M 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 twelve months. Of total CIMAS research funds, Theme 3: Sustained Ocean and Coastal Observations accounts for the largest portion of the funding - 48%. The smallest portion of funding was in Theme 5: Ecosystem Modeling and Forecasting – 2%.

The distribution of project specific 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 research that necessarily falls 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.

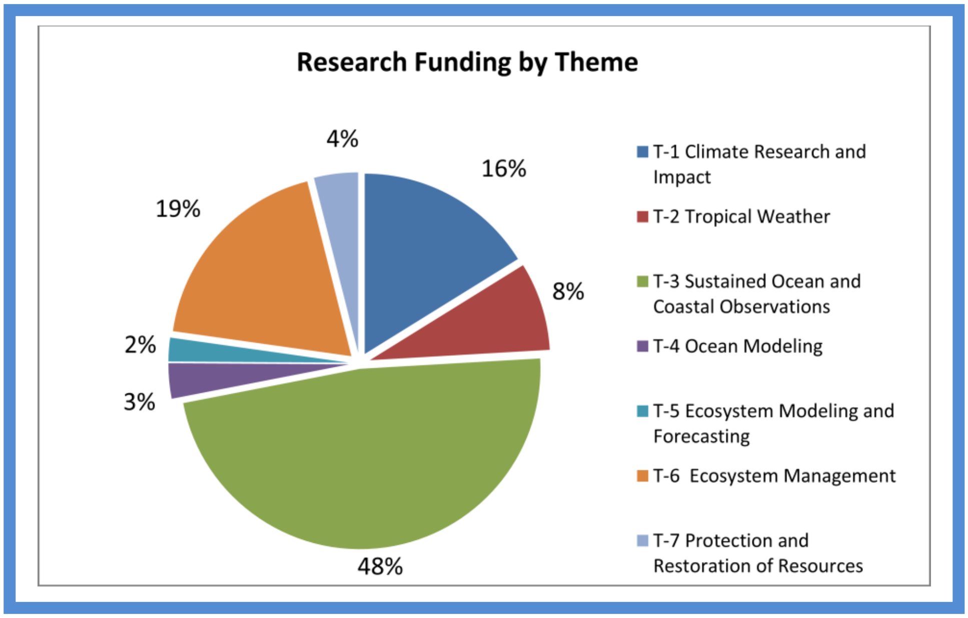

Figure 3: Percentage of Task 3 and Task 4 (Research) funding in the CIMAS Themes

Table 3 below tabulates NOAA current funding received by CIMAS under the present Cooperative Agreement as well as its immediate predecessors. Note that the Continuation and Shadow continue to be operative and in effect during the present reporting period although 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: Recent NOAA Funding

Award Number	Award Period	Total Funds
NA08OAR4320892 Continuation	07/01/08 - 06/30/12	$ 6,809,019
NA08OAR4320889 Shadow	07/01/08 - 06/30/13	$ 3,068,262
NA10OAR4320143	09/01/10 - 08/31/15	$ 28,637,028
NA11OAR4310207	09/01/11 - 08/31/13	$ 71,964
NA11NOS4780045	09/01/11 - 08/31/16	$ 1,491,950
NA11OAR4310077	09/01/11 - 08/31/14	$ 99,959

Funding distributed through CIMAS to the Partner Universities during the present reporting period was $.92M or 16% of Task III (Partner Universities are only eligible for Task III funding through CIMAS).

Conclusion

In our funding summary we report only expenditures during the twelve months project period under the new Cooperative Agreement. 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.

V. RESEARCH THEME 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

Western Boundary Time Series Project

Project Personnel: R. Garcia, K. Seaton, J. Hooper, N. Melo, G. Rawson, R. Roddy, R. Domingues and G. Berberian (UM/CIMAS)
NOAA Collaborators: M. Baringer, C. Meinen, S. Garzoli, R. Smith, U. Rivero, P. Pena, A. Stefanick and Y-H. Daneshzadeh (NOAA/AOML)

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

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

Link to NOAA Strategic Goals:
***Goal 1*:** Climate Adaptation and Mitigation - *An informed society anticipating and responding to climate and its impacts*

Funding Unit: OAR/AOML and OAR/CPO **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 over a wide range

of locations around the globe. In the Atlantic, near 27˚N, 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. Almost 30 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. 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, small sport fishing boats charter from Sailfish Marina in West Palm Beach, and on the NOAA/AOML Research Vessel Hildebrand. During the past year, the monitoring and data distribution systems for the Florida Current cable program have continued, providing Florida Current volume transports in near real time via the web page http://www.aoml.noaa.gov/phod/floridacurrent (See Figure 1).

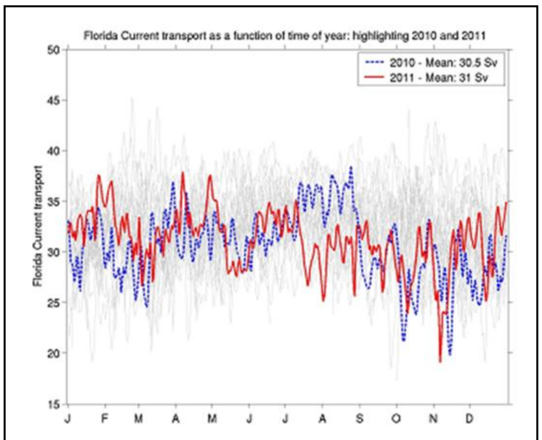

Figure 1: Volume transport of the Florida Current at 27ºN. The two most recent years are highlighted in color.

This project also maintains moored instruments and 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. 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. 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 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 (NOCS), United Kingdom.

Research Performance Measure: Most research goals were met during this last year. We continue to achieve our major main objective – to maintain the continuity of this long term data set and to continually improve the calibration of the data obtained. One research cruise was canceled due to ship time availability issues (November 2011).

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

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

CIMAS Research Theme:

Theme 1**:** Climate Research and Impact

Link to NOAA Strategic Goals:

Goal 1**:** Climate Adaptation and Mitigation - *An informed society anticipating and responding to climate and its impacts*

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

Research Summary:

(1) Analysis of T/S measurements from Argo profiling floats for MOC/MHT in the South Atlantic: The objective of the study is to examine the model-data differences in the seasonality of the meridional overturning circulation (MOC) and meridional heat transport (MHT) in the South Atlantic, and to investigate the causes for the possible differences. Temperature and salinity climatology from Argo profiling floats and from GFDL models are used to estimate the MOC/MHT at 34S. The MOC from model T/S fields show strong transport in the ocean interior region compared to the MOC estimated from Argo T/S fields. The geostrophic component of the MOC estimated from Argo data shows a seasonal variation with the maximum value in January and minimum value in August (Figure 1). However, the seasonal variations of the geostrophic contributions to the MOC from model T/S fields is very weak. Differences are seen in all three regions: western boundary, interior region, and eastern boundary, with the largest difference in the eastern boundary. Examination of the density field suggests that the difference in the eastern boundary is related to the vertical coherent density variations in the Argo measurements, which is not shown in the model field. Those differences may be related to the differences in the wind stress curl between model and observations, where strong differences are seen in the eastern boundary. Further investigation will be conducted to link model-data difference in MOC/MHT with forcing fields.

(2) Analysis of GFDL CM2.1 and GFDL coupled data assimilation (GFDL CDA) models: 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°S in the South Atlantic. 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

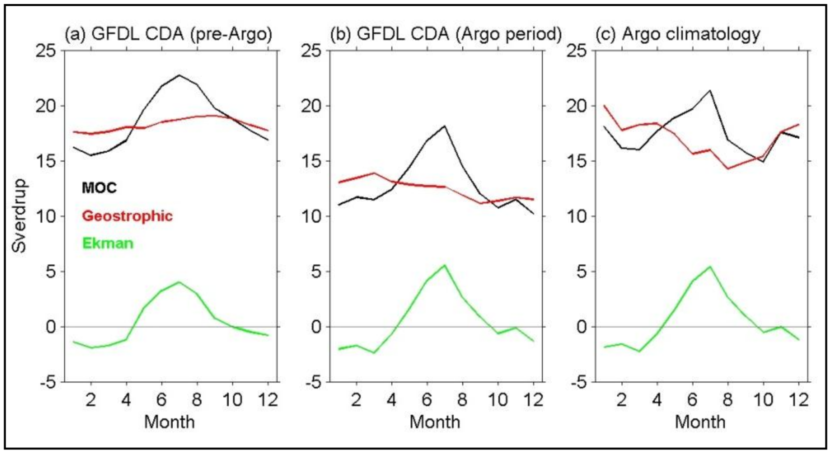

Figure 1: Estimates of MOC (black) and it contributions from geostrophic (red) and Ekman (green) components based on temperature and salinity climatology constructed from GFDL coupled data assimilation during pre-Argo period (a), and Argo period (b), and from Argo profiling float measurements (c).

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 (Figure 2). The improvement of the boundary currents, despite the lack of Argo data at the boundaries, is probably due to better temperature/salinity representation at the interior side of the boundaries. Those comparisons suggest the importance of the Argo float measurements in improving data-assimilating model performance in representing the MOC processes. The lack of Argo data at the boundaries may be responsible for the weak MOC and MHT during the Argo period (2003-2007), suggesting that measurements from other platforms are needed at the boundaries to further improve MOC processes in data-assimilating models.

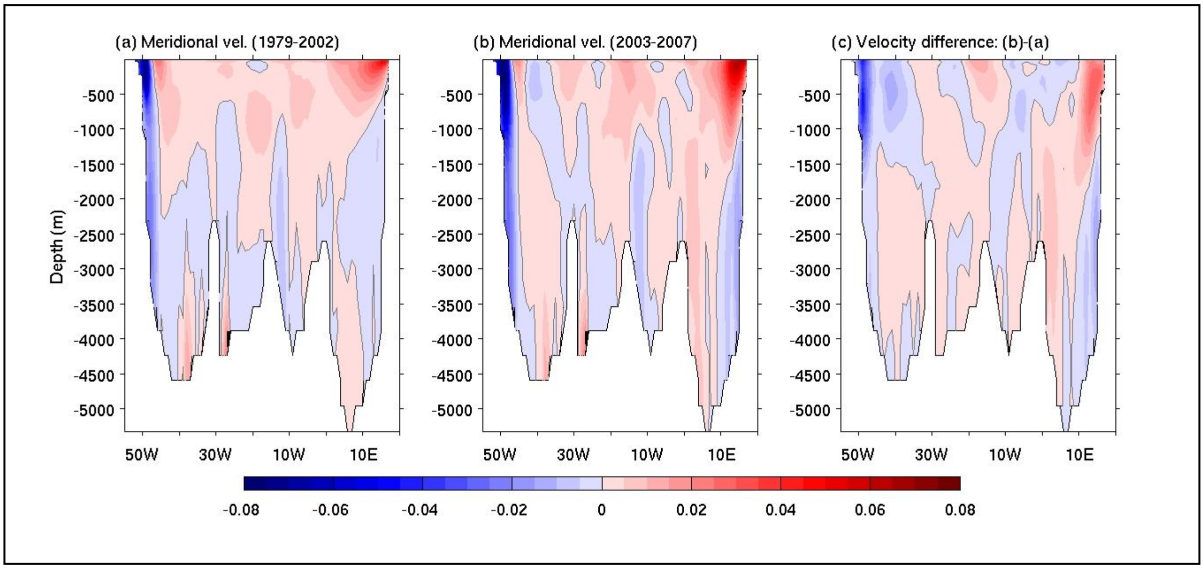

Figure 2: Meridional velocity from GFDL CDA averaged (a) during 1979-2002, (b) during 2003-2007, and differences in averaged meridional velocity for the two periods, 2003-2007 and 1979-2002. Unit is $m\ s^{-1}$.

3) Analysis of high-density XBT measurements in the South Atlantic:

The properties of the meridional overturning circulation (MOC) and associated meridional heat transport (MHT) and salt fluxes are analyzed in the South Atlantic. The oceanographic data used for the study consist on Expendable bathythermograph (XBT) data collected along 27 sections at nominally 35°S for the period of time 2002 to 2011 and Argo profiles data collected in the region. Previous estimates obtained with a shorter record are improved and extended, using new oceanographic sections and wind fields. Different wind products are analyzed to determine the uncertainty in the Ekman component of the MHT due to the use of different products. Results of the analysis provide a nine-year time series of MHT, and volume transport of the upper layer of the MOC (Figure 3). Salinity fluxes at 35°S are estimated using a parameter introduced by numerical studies, the M_{ov} that represents the salinity flux and helps determine the basin scale salt feedback associated with the MOC. Volume transport by the boundary currents are estimated, and the irrelation to the heat transport carried within each current are analyzed. Analysis of the data shows that the South Atlantic is responsible for a northward MHT with a mean value of 0.54 ± 0.14 PW. The MHT exhibits no significant trend from 2002 to 2011. The MOC varies from 14.4 to22.7 Sv with a mean value of 18.1 ± 2.3 Sv and the maximum overturning transport is found at a mean depth of 1250 m, which is deeper than that in the North Atlantic. Statistical analysis suggests that an increase of 1 Sv in the MOC leads to an increase of the MHT of 0.04 ± 0.02PW. Contrary to model results that yields positive values for the M_{ov}, the analysis conducted in this paper indicates that the MOC has a net transport of salt to the northern hemisphere (mean Mov of -0.16 Sv). Observations indicate that the mean value of the Brazil Current is -8.6 ± 4.1 Sv at 24°S and -19.4 ± 4.4 Sv at 35°S, increasing towards the south. East of 3°E,the northward flowing Benguela Current and Agulhas ringshave a net northward transport of 22.5 Sv ± 4.7 Sv. Products from the Ocean general circulation model For the Earth Simulator (OFES) are used to validate methodology used to extend the XBT record, and to aid in the interpretation of the observed findings.

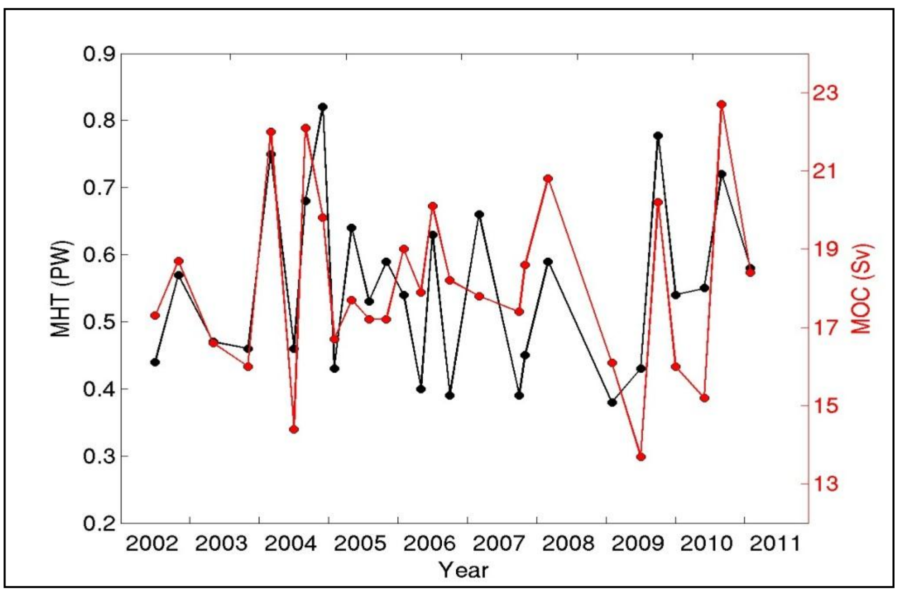

Figure 3: Time series of the MHT (black) and the AMOC (red) along nominally 35°S for the time period 2002 to 2011.

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

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

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

Long Term Research Objectives and Strategy to Achieve Them:

Objectives: To access and improve the Atlantic Warm Pool (AWP) predictability and its climate impact.

Strategy: To diagnose the mechanisms and climate impacts of the AWP in the IPCC models, and apply NCAR CESM1 to develop an experimental forecasting system.

CIMAS Research Theme:

Theme 1: Climate Research and Impact

Link to NOAA Strategic Goals:

Goal 1: Climate Adaptation and Mitigation - *An informed society anticipating and responding to climate and its impacts*

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

Research Summary:

The AWP variability in the 20^{th} century climate simulations of 22 coupled general circulation models (CGCMs) submitted to the Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report (AR4) is investigated. Based on AWP area index definition, most coupled models show very weak AWP and variability because of the cold sea surface temperature (SST) bias in the northwest tropical Atlantic. The box-averaged SST in AWP region is defined as AWP index for this study. Only for four models the seasonal cycles are in good accordance with observations. Wavelet analysis reveals only multidecadal band variability of AWP is significant in observations. Most models successfully capture this character but a few models show either interannual or decadal variability is dominant. Time series of AWP SST index further shows that each model demonstrates very different interannual variability. Empirical Orthogonal Function (EOF) analysis on observational SST of July to October in the tropical Atlantic shows zonal mode as the first mode and meridional mode as the second mode. A majority of the coupled models are able to display the second mode (meridional mode) correctly. But a part of models misrepresent the first mode (zonal mode) due to the southeast tropical Atlantic SST warm bias included in the interannual variability. Regression of global SST onto AWP SST index at multidecadal band shows the AWP multidecadal variability resembles the Atlantic Multidecadal Oscillation (AMO) for most coupled models.

Observation analysis indicates both positive ENSO phase and negative NAO phase in winter correspond to anomalous westerlies in the AWP region. The ENSO (NAO) induced westerlies anomaly leads to local heating and warm SST during March to May (during February to April). This feature is well captured by four models.

Research Performance Measure: We evaluated the performance of CGCMS provided by IPCC AR4 and CMIP5 in simulating the AWP variability and its climate impacts.

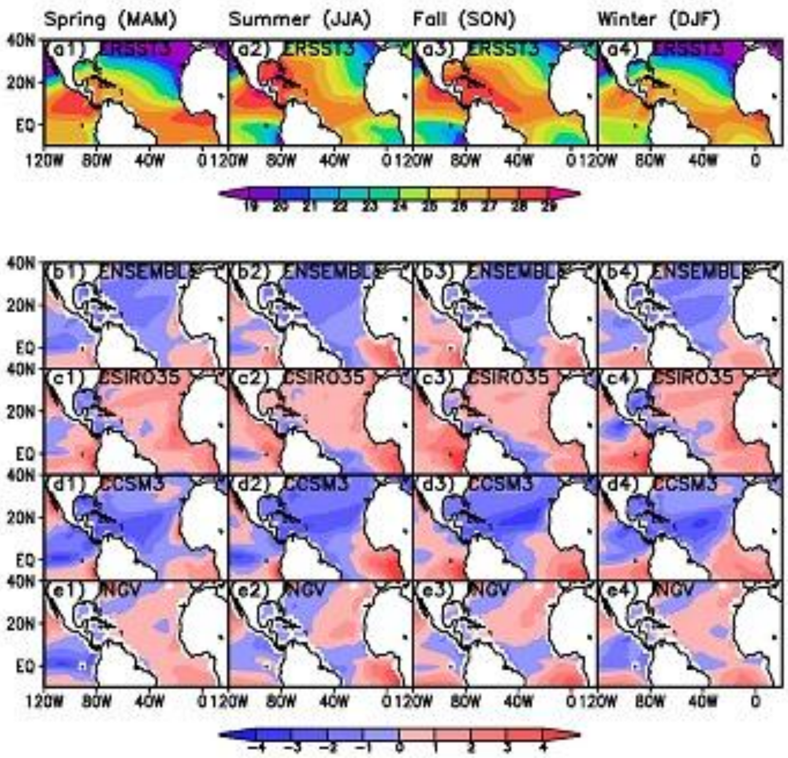

Figure 1: Observational SST and model SST bias in four seasons. Shown are (a1-a4) ERSST SST averaged in four seasons, (b1-b4) the seasonal SST bias of the 22 model ensemble, and (c1-c4, d1-d4, e1-e4) the seasonal SST bias for selected models. Unit is ˚C. Model data is from IPCC AR4 20C3M simulations.

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Development and Evaluation of an Ocean OSSE System

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

Long Term Research Objectives and Strategy to Achieve Them:
Objectives**:** Perform Observing System Experiments (OSEs) and Observing System Simulation Experiments (OSSEs) to evaluate.
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 1**:** Climate Research and Impact (*Primary*)
Theme 3**:** Sustained Ocean and Coastal Observations (*Secondary*)
Theme 4**:** Ocean Modeling (*Tertiary*)

Link to NOAA Strategic Goals:

Goal 1**:** Climate Adaptation and Mitigation - *An informed society anticipating and responding to climate and its impacts* (*Primary*)

Goal 2**:** Weather-Ready Nation - *Society is prepared for and responds to weather-related events* (*Secondary*)

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

Research Summary:

The primary goal of this project is to develop and test an ocean OSSE system that can be used to design observing strategies for a wide range of oceanographic problems. A particular focus of this effort is to develop an OSSE system that can be used to evaluate monitoring strategies for the Atlantic Meridional Overturning Circulation (AMOC). Another focus is to test observing strategies in the Gulf of Mexico that will be used to improve the accuracy of ocean forecasts to improve our capability to forecast the dispersion of oil spills and marine debris. The primary effort focuses on developing an ocean data assimilation system optimized for use with the HYbrid Coordinate Ocean Model (HYCOM) along with the software toolboxes required to perform both Observing System Experiments (OSE) to evaluate existing observing systems and OSSEs to evaluate new observing systems and strategies. The initial OSSE system will employ the "fraternal twin" approach; i.e., using one configuration of HYCOM as the nature run and a second configuration of HYCOM in 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 ocean features of interest that is achieved by present-day state-of-the-art ocean models with respect to the actual ocean.

The work to date has focused on development and testing of the data assimilation system and the OSE/OSSE toolboxes. As this development progresses, we have focused on evaluating the performance of HYCOM in the two different configurations to be used for the fraternal twin OSSE system, and also evaluating HYCOM performance in comparison to other ocean models, with the overarching goal of identifying and verifying potential nature runs. As an example, 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), and they both reproduce ocean features in a statistically realistic manner. As a result, these two HYCOM configurations are suitable for use in the Gulf of Mexico fraternal twin OSSE system, one as the nature run and the other as the data-assimilative operational model Evaluations are performed against observations taken during the Deepwater Horizon oil spill, particularly airborne profilers deployed by NOAA WP-3D hurricane research aircraft and surface drifters released as part of the AOML surface drifter program by Rick Lumpkin. Evaluations using surface drifters are illustrated in Figure 2. The growth rate in mean separation distance between actual surface drifters released in the ocean (data provided by R. Lumpkin, AOML/PhOD) and synthetic drifters released in the two models (named Candidate models 1 and 2 in Figure 2) at the same locations as actual drifters is very similar. The slopes of the lines in Figure 2 at t=0 equal the rms velocity error. These results demonstrate that the two candidate HYCOM configurations for the OSSE system represent ocean variability with similar error magnitudes, which supports their use in the OSSE system. Also shown in Figure 2 are the growth rates in mean separation distance for some research and operational ocean forecast systems. Data assimilation tends to substantially reduce velocity errors as expected.

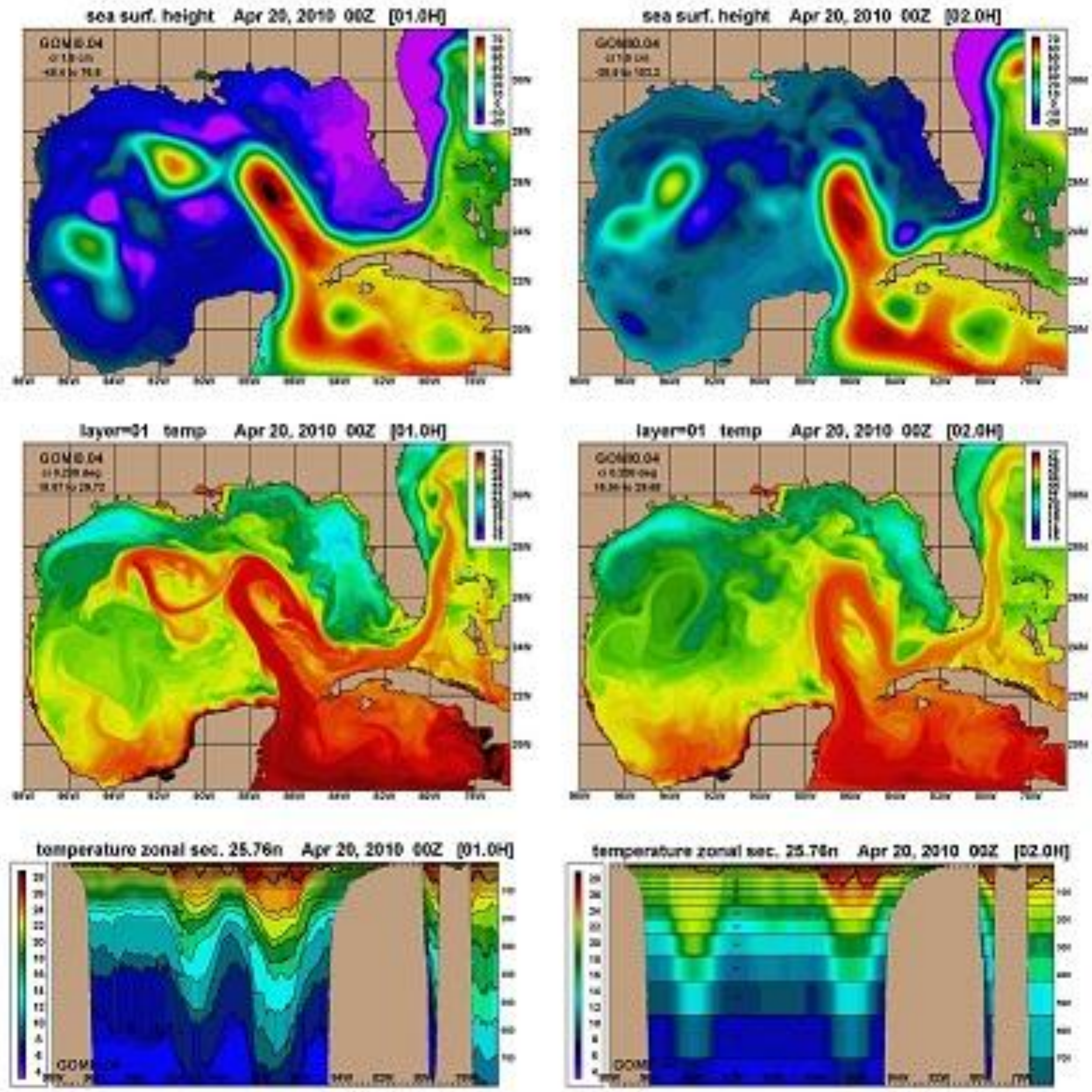

Figure 1: Maps of SSH (top panels) and SST (middle panels) along with temperature cross-sections (bottom panels) for the hybrid coordinate model run (left panels) and the sigma-z model run (right panels) on 20 April 2010.

Development of our new state-of-the-art data assimilation system is being tested and will soon be compared to other assimilation systems as shown in Figure 2. Before using our system to perform OSSEs and ocean forecast studies, we will first make sure that the performance is at least comparable to the best existing assimilation systems. Ashwanth Srinivasan is the primary developer of our system. 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). It is being optimized to work within the framework of the Lagrangian vertical coordinates used by HYCOM.

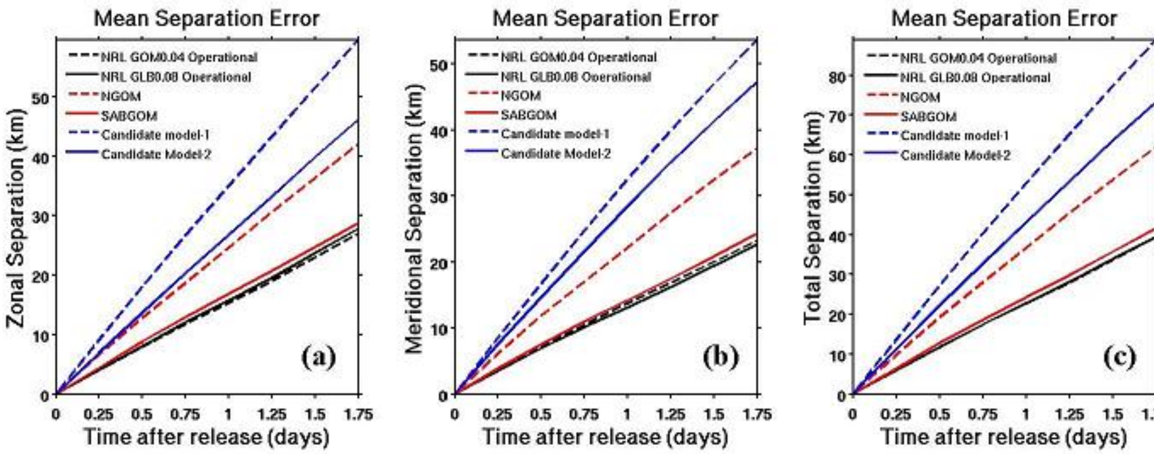

Figure 2: A multi-model comparison of the mean separation distance between model and actual surface drifters as a function of time. The three panels represent the error growths for (a) zonal, (b) meridional and (c) total separations, respectively. The rates of separation (slopes of the lines) at t=0 equals RMS velocity error. The model results labeled Candidate models 1 and 2 are for the free HYCOM runs to be used in the GOM fraternal twin OSSE system. The fact that they have very similar RMS velocity errors supports their use as the two candidate models in the OSSE system. Other model results illustrate the error reduction achieved by data assimilation. The new AOML data assimilation system optimized for HYCOM will be compared to the other model assimilation systems during the upcoming testing phase.

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.

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NOAA Climate Test Bed (CTB) National Mult-model Ensemble (NMME) Prediction System Phase 1 NMME Implementation Plan

Project Personnel: B. Kirtman (UM/RSMAS)

Long Term Research Objectives and Strategy to Achieve Them:

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

***Strategy*:** The research is carried out as part of the CIMAS program, and addresses the CIMAS climate impacts and research theme in that the objectives include improving understanding of seasonal-to-interannual prediction using multi-model ensembles. In addition, the results of the proposed research serve NOAA's goal of understanding climate variability and change to enhance society's ability to plan and respond using quantitative information from a US National multi-model seasonal-to-interannual predictive system.

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

Link to NOAA Strategic Goals:
Goal 1**:** Climate Adaptation and Mitigation - *An informed society anticipating and responding to climate and its impacts*

NOAA Funding Unit: OAR/CPO **NOAA Technical Contact:** Annarita Mariotti

Research Summary:
The recent US National Academies *Assessment of Intraseasonal to Interannual Climate Prediction and Predictability* [NRC 2010 (http://www.nap.edu/catalog.php?record_id=12878)] was unequivocal in recommending the need for the development of a US NMME operational predictive capability. Indeed, the national effort is required to meet the specific tailored regional prediction and decision support needs of the emerging National Climate Service. The challenge is to meet this national need without diluting existing model development activities at the major centers and ensure that the forecast products continue to improve and be of societal value.

There is little doubt that US participation in EUROSIP is beneficial to both the US and European forecasting communities. However, as a US National Climate Service emerges and as the possible National Center for Predictions and Projections (NCPP) develops, the need for a NMME system becomes paramount for supporting continued research on MME based prediction that can transition to operations. For example, a NMME system facilitates modifications (e.g., extending the forecast to longer time-scales) to the forecast strategy, allows for better coordination of the forecast runs compared to EUROSIP (e.g., hindcast period, forecast scheduling etc.) and allows free exchange of data beyond what is supported by EUROSIP. Also, by testing various national models on weather and seasonal time-scales, the NMME system will accelerate the feedback and interaction between US ISI prediction research, US model development and the decision science that the forecast products support. For instance, the prediction systems can potentially be used to evaluate and design long-term climate observing systems, because US scientists will have open access to the prediction systems (i.e. data, data assimilation and forecast models). Our national interests require that we (1) run these ISI prediction systems operationally in the US, (2) retain the flexibility to modify the prediction systems and how they are used based on emerging national needs, and (3) ensure that there is a robust communication and collaboration network open among operational ISI forecasting, research and model development.

We have begun the transition from CCSM3 (T85) to CCSM4 (0.9x1.25_g1v6 resolution), although if CCSM3 continues to be a useful contributor to the NMME, we will continue the real-time predictions. The new atmospheric component has extensive changes in the parameterization of sub-grid-scale processes that have resulted in a significant improvement in the simulation of tropical variability relative to CCSM3.0 (Neale et al. 2008). Changes in the other component models, while less extensive, have also contributed to a reduction in systematic biases. The initialization procedure is to use the operational CFSR ocean, land and atmospheric states to initialize CCSM4 much in the same manner as we have done for CCSM3 using the GFDL ocean data assimilation. We have begun testing the CFSR ocean states in hindcast experiments CCSM4, and Figure 1 shows the hindcast SSTA correlation for a parallel set of experiments using CCSM4 with the original GFDL ocean states (top panel) and using the CFSRR ocean states (bottom panel). Clearly, the correlation is quite comparable and there is some suggestion that it might even be superior with the CFSR data.

Although, not shown, CCSM4 has better SSTA correlation than CCSM3. As with CCSM3, we are in the process of developing procedures for using CFSR data for the atmosphere and land.

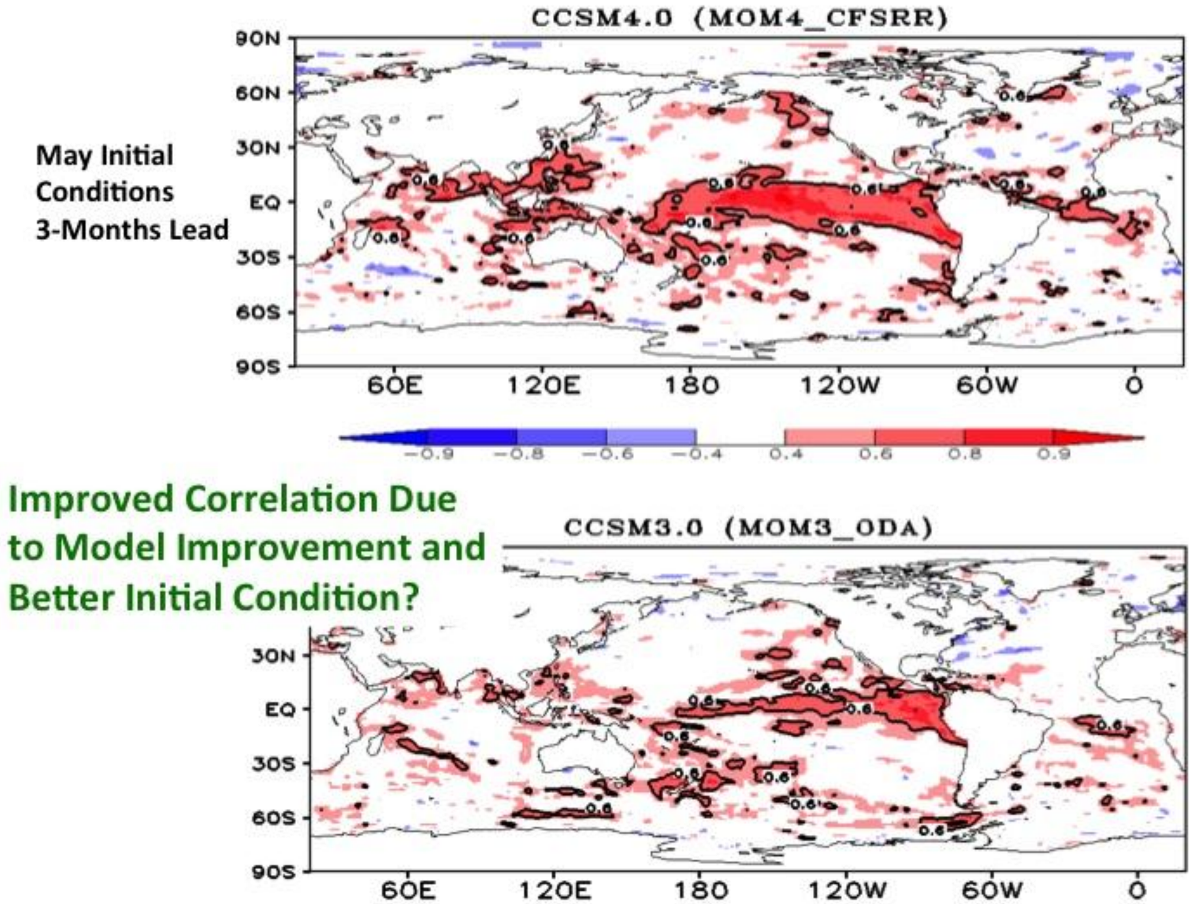

Figure 1: SSTA hindcast correlation with observational estimates for May start dates (1982-1999) verifying for the following November. For these testing experiments there is only one ensemble member.

Research Performance Measure: The performance metric for this project is continuing to run CCSM3.0 predictions in real-time and to generate CCSM4 retrospective forecast for calibration and prediction quality assessment.

Potential for Recovery/Resilience of Corals and Algal Interference Under Climate Change

Project Personnel: C. Langdon and J. Fisch (UM/RSMAS)
NOAA Collaborator: M. Miller (NOAA/SEFSC)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** To document the potential for coral recovery and resilience in the face of climate change, experiments were conducted documenting the effects of increased temperature and carbon dioxide levels on coral early life history stages. In addition, changes in benthic substrate communities may provide insight on the potential secondary effects to coral reef recovery.

***Strategy*:** To measure the survivorship, settlement success, and post-settlement growth of several species of Caribbean coral larvae (*Acropora palmata*, *Montastrea faveolata* and *Diploria strigosa*). Settlement tiles are established on the reef and following recruitment of benthic algae, metabolic processes of settlement communities and reef associated macroalgae are measured to investigate the effects on benthic microhabitats utilized by coral during early life history stages.

CIMAS Research Theme:

Theme 1: Climate Research and Impact

Link to NOAA Strategic Goals:

Goal 3: Healthy Oceans - *Marine fisheries, habitats, and biodiversity sustained within healthy and productive ecosystems* (*Primary*)

***Goal 4*:** Resilient Coastal Communities and Economies - *Coastal and Great Lakes communities that are environmentally and economically sustainable* (*Secondary*)

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

Research Summary:

1. Effects of increased temperature and carbon dioxide levels on coral early life history stages.
Montastrea faveolata larvae were subjected to two temperatures (27°C and 30°C) and two carbon dioxide concentrations (targeted at 400 ppm and 800 ppm, but measured to be 507.1 ± 16.4 ppm and 886.2 ± 17.4 ppm respectively). Larvae were exposed to one of four treatments, 27°C_400 ppm (LTLC=low temp, low CO_2), 30°C_400 ppm (HTLC), 27°C_800 ppm (LTHC) and 30°C_800 ppm (HTHC). Survivorship was quantified after two days (Figure 1). The highest survivorship was seen in the control treatment, LTLC, while the lowest survivorship was observed at the HTHC treatment. Settlement experiments were carried out following this experiment using two day old larvae that were held at control temperatures prior to the experiments. The same treatments were used for the settlement experiments. Variability was very high in these experiments, but at LTLC 11% settled, at HTLC only 1% settled, at LTHC 4% settled, and at HTHC 5% settled successfully. Further experiments are planned for this summer to look at the combined effects of increased temperature and CO_2 with greater replication.

Larvae of *Acropora palmata*, *Montastrea faveolata* and *Diploria strigosa* were batch settled and deployed into the field. Forty five days post spawning, a subset of settlement tiles were moved to four closed system tanks with regulated temperature and CO_2 levels corresponding to the four treatments used in the previous experiments. 1 month post-exposure all of the A. palmata larvae died, while 14 % of *M. faveolata* and 23% of *D. strigosa* larvae remained alive, with the highest

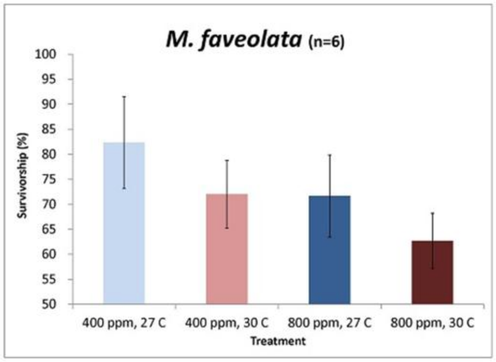

Figure 1: Survivorship of *Montastrea faveolata* larvae under two carbon dioxide and temperature levels. Six replicates per treatment. Initial number of larvae per replicate was fifty individuals. Data represents percentage of surviving individuals after two days in treatment conditions. Error bars represent standard error within the treatment.

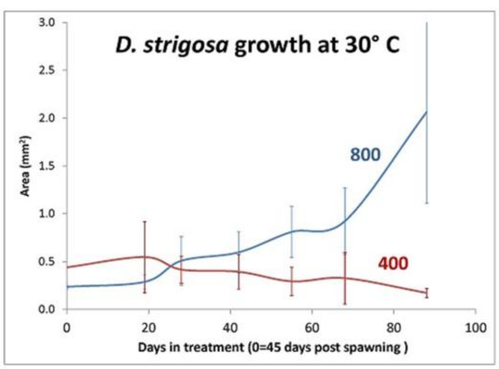

Figure 2: Post-settlement growth of *Diploria strigosa* larvae. Data displayed in surface area (mm^2) of coral juveniles each time point. One individual had three mouths so surface area was divided by three.

survivorship found in the HTLC treatment. Additional *D. strigosa* larvae were transported from the field into the experimental conditions 97 days post spawning. Growth was measured biweekly for three months under a compound microscope alongside picture analysis using coral point count (CPCe). *M. faveolata* did not show clear trends, but at 30°C *D. strigosa* grew significantly more when exposed to elevated CO_2 levels as opposed to ambient levels (Figure 2, data does not include *D. strigosa* larvae transported 97 days post spawning). These preliminary results indicate that this species may be able to take advantage of the combined effects of elevated temperature and CO_2 as the oceans change in the coming century (at least in terms of overall growth, further tradeoffs will need to be investigated). Further experimentation will be carried out this coming season to verify these findings.

2. Field measurements of macroalgae and benthic algae productivity.

A permit from FKNMS (# FKNMS-2012-016) was obtained and a field site has been established near the MAP CO_2 buoy site in Cheeca Rocks. The initial visit to the site involved the deployment of ceramic settlement tiles attached to a PVC frame adjacent to a patch reef at the site. These tiles will be left to accumulate a benthic algal community. The colonizing species will be identified and measurements of the tile community photosynthesis, respiration and calcification will be quantified using *in-situ* metabolic chambers. In addition, three species of macroalgae were sampled from the reef during the initial visit to the site. Three samples each of *Halimeda tuna* (green alga), *Dictyota sp.* (brown alga) and *Asparagopsis taxiformis* (red alga) were enclosed in the metabolic chambers for one hour. At the end of the hour, samples were taken for oxygen and dissolved inorganic carbon. These samples were later analyzed and normalized to the dry weight of the individual samples of algae. Results were variable as the sample size was small, but an average photosynthetic yield for the algae was 1.1 which falls within the range of values expected for synthesizing carbohydrates. This proved to be a successful test of the method and the experiment will be carried out again next month (June 2012) and once every two or three months following.

Research Performance Measure: All research objectives are progressing satisfactorily as we are sticking to the plan outlined in the proposal.

Impacts of Non-Canonical El Niño Patterns on Atlantic Hurricane Activity

Project Personnel: S.-K. Lee and D. Enfield (UM/CIMAS), S. Larson and E.-S. Chung (UM/RSMAS)
NOAA Collaborator: C. Wang (NOAA/AOML)

Long Term Research Objectives and Strategy to Achieve Theme:
***Objectives*:** To understand the impact of non-canonical El Niño patters on Atlantic hurricane activity.
***Strategy*:** To perform composite analysis of key Atlantic TC indices and tropospheric vertical wind shear over the Atlantic main development region.

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

Link to NOAA Strategic Goals:
***Goal 2*:** Weather-Ready Nation - *Society is prepared for and responds to weather-related events* (*Primary*)
***Goal 1*:** Climate Adaptation and Mitigation - *An informed society anticipating and responding to climate and its impacts* (*Secondary*)

NOAA Funding Unit: OAR/CPO, OAR/AOML and NOAA/OEd (Office of Education)
NOAA Technical Contact: Alan Leonardi

Research Summary:
The impact of non-canonical El Niño patterns, typically characterized by warmer than normal sea surface temperatures (SSTs) in the central tropical Pacific, on Atlantic tropical cyclone (TC) is explored by using composites of key Atlantic TC indices and tropospheric vertical wind shear over the Atlantic main development region (MDR). The highlight of our major findings is that, while the canonical El Niño pattern has a strong suppressing influence on Atlantic TC activity, non-canonical El Niño patterns considered in this study, namely central Pacific warming, El Niño Modoki, positive phase Trans-Niño, and positive phase Pacific meridional mode, all have insubstantial impact on Atlantic TC activity. This result becomes more conclusive when the impact of MDR SST is removed from the Atlantic TC indices and MDR wind shear by using the method of linear regression. Further analysis suggests that the tropical Pacific SST anomalies associated with the non-canonical El Niño patterns are not strong enough to cause a substantial warming of the tropical troposphere in the Atlantic region, which is the key factor that increases the wind shear and atmospheric static stability over the MDR. During the recent decades, the non-canonical El Niños have been more frequent while the canonical El Niño has been less frequent. If such a trend continues in the future, it is expected that the suppressing effect of El Niño on Atlantic TC activity will diminish and thus the MDR SST will play a more important role in controlling Atlantic TC activity in the coming decades.

Research Performance Measure: We achieved our main objective - To understand the impact of non-canonical El Niño patters on Atlantic hurricane activity.

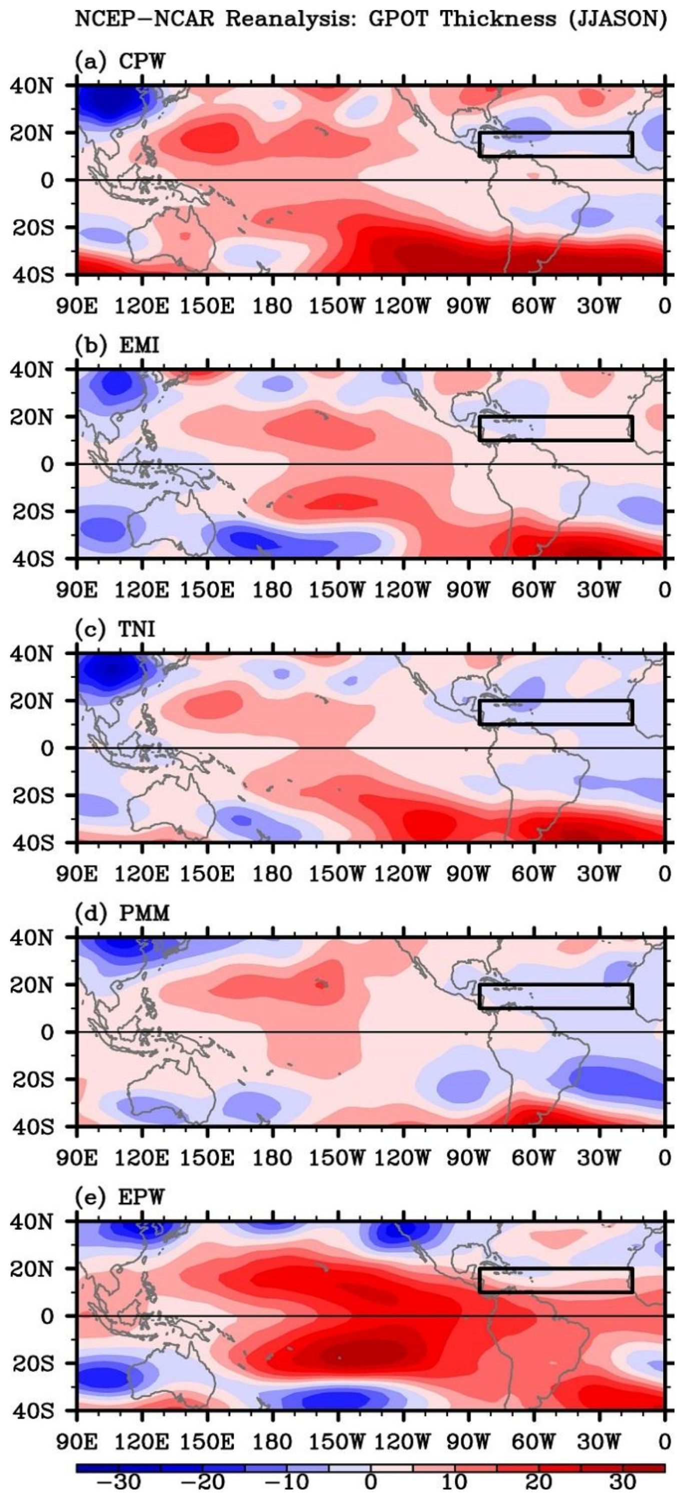

Figure 1: Composites of geopotential thickness (200 minus 850 hPa) anomalies in June-November (JJASON) for the eight strongest (+) phase central Pacific warming (CPW), El Niño Modoki Index (EMI), Trans-Niño Index (TNI), Pacific Meridional Mode (PMM) and canonical El Niño composites by using the (or eastern pacific warming) years. The influence of MDR SST is removed prior to making these methods of linear regression. The unit is gpm. The black box in each plot indicates the main development region (MDR, 85°W – 15°W, 10°N – 20°N).

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 1: Climate Adaptation and Mitigation: *An informed society anticipating and responding to climate and its impacts.*

NOAA Funding Unit: NWS/CPC

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 implement a regional Stochastic Production Frontier (**SPF**) analysis for the Southeast U.S. The SPF method is used because of its 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 is measured as the total value-added. That is, we are able to measure the monetary change in the contribution of this sector to the whole economy due to the use of climate information. A sensitivity analysis measures the impact for alternative climatic scenarios. The difference between the current estimates and the estimates obtained from the sensitivity analysis gives 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.

Empirical Model

We use the SPF method for this study (Figure 1). The empirical specification is:

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

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 use the well-known approach originally proposed by Eldon Ball. A set of climate indexes is 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 disaggregate the output variable into it three components crop, forestry and livestock production.

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

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

To implement this model we 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 has been collected from the USDA Economic Research Service and the USDA National Statistical Service. The climate information has been collected from the South East Regional Climate Service.

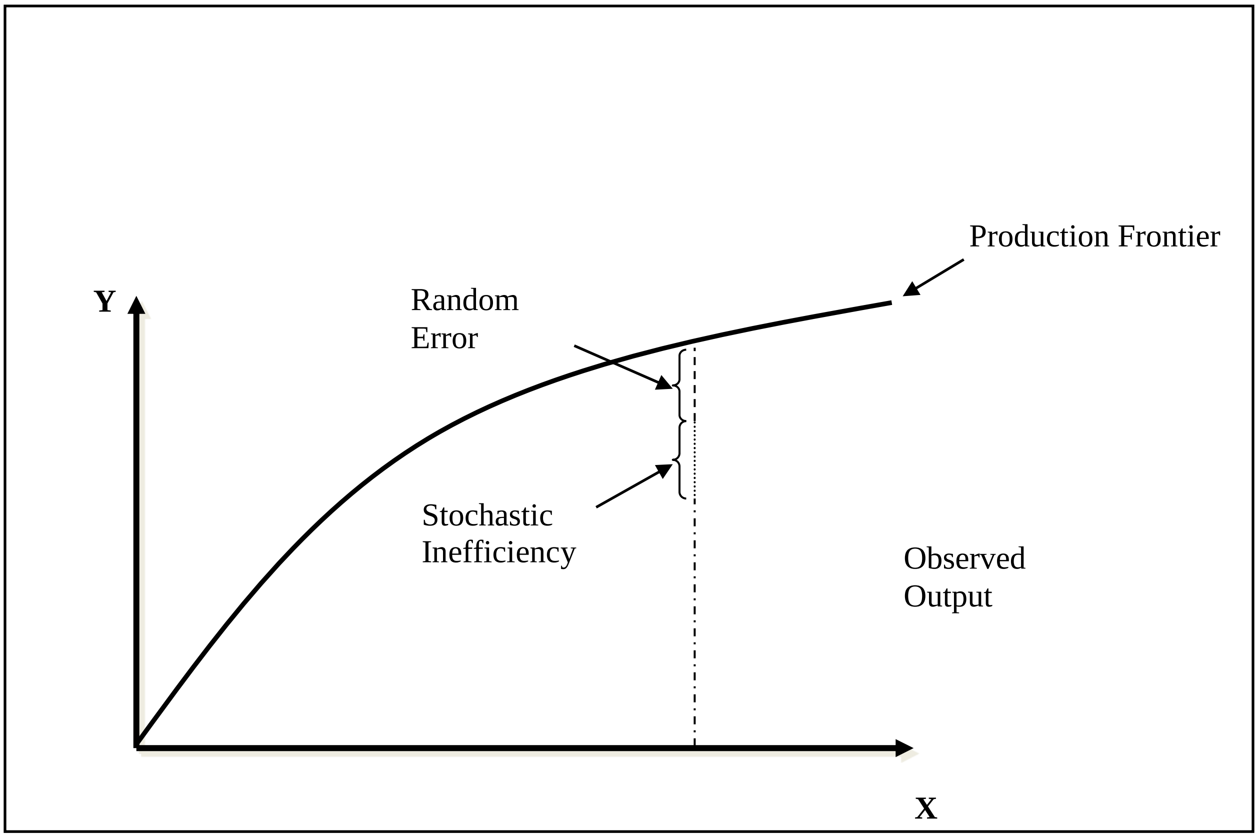

Figure 1: Stochastic Production

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

Relationship of the Atlantic Warm Pool with the Atlantic Meridional Overturning Circulation

Project Personnel: S.-K. Lee, L. Zhang, D. B. Enfield (UM/CIMAS)
NOAA Collaborator: C. Wang (NOAA/AOML)

Long Term Research Objectives and Strategy to Achieve Theme:

***Objectives*:** To understand interactions between the tropics and the high latitude Atlantic Meridional Overturning Circulation (AMOC) variations, particularly the influence of tropical Atlantic climate on the AMOC.

***Strategy*:** To diagnose the observations, reanalysis data, IPCC-AR5 simulations and perform coupled model experiments using NCAR Community Climate System Model (CESM1).

CIMAS Research Theme:

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

Link to NOAA Strategic Goals:

Goal 1: Climate Adaptation and Mitigation - *An informed society anticipating and responding to climate and its impacts*

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

Research Summary:

The response of freshwater flux and sea surface salinity (SSS) to the Atlantic warm pool (AWP) variations from seasonal to multidecadal timescales is investigated by using various reanalysis products and observations. All of data sets show a consistent response for all timescales: A large (small) AWP is associated with a local freshwater gain (loss), a less (more) moisture transport across Central America and a local low (high) SSS. Our moisture budget analysis demonstrates that the freshwater change is dominated by the mean circulation dynamics, while the effect of thermodynamics is of secondary importance. Further decomposition points out that the contribution of the mean circulation dynamics primarily arises from its divergent part which mainly reflects the wind divergent change in the low level as a result of SST change. In association with a large (small) AWP, warmer (colder) than normal SST over the tropical North Atlantic can induce an anomalous convergence (divergence), which favors an anomalous ascent (decent) and thus generates more (less) precipitation. On the other hand, a large (small) AWP weakens (strengthens) the trade wind and its associated westward moisture transport to the eastern North Pacific across Central America, which also favors more (less) moisture resided in the Atlantic and hence more (less) precipitation. The results imply that variability of freshwater and ocean salinity associated with the AWP may have the potential to affect the Atlantic meridional overturning circulation.

Local freshwater flux response to a large (small) Atlantic warm pool (AWP) is excessive (deficient) freshwater or negative (positive) evaporation minus precipitation (EmP) anomalies. However, the EmP anomalies in the AWP region are also influenced by the SST anomalies in the equatorial eastern Pacific and in the tropical South Atlantic. These remote influences are operated through the inter-basin mode (represented by the SST gradient between the tropical North Atlantic and eastern Pacific) and the Atlantic meridional mode (defined as the SST gradient between the tropical North and South Atlantic). When either of these modes is in the negative phase, the EmP anomalies in the AWP region can be positive although the AWP is large. This indicates that the remote influences of the inter-basin mode and/or the Atlantic meridional mode can overwhelm the local effect and induce an opposite freshwater response. Additionally, ENSO and the North Atlantic oscillation can influence the SST anomalies in the tropical North Atlantic which indirectly affect the freshwater response in the AWP region.

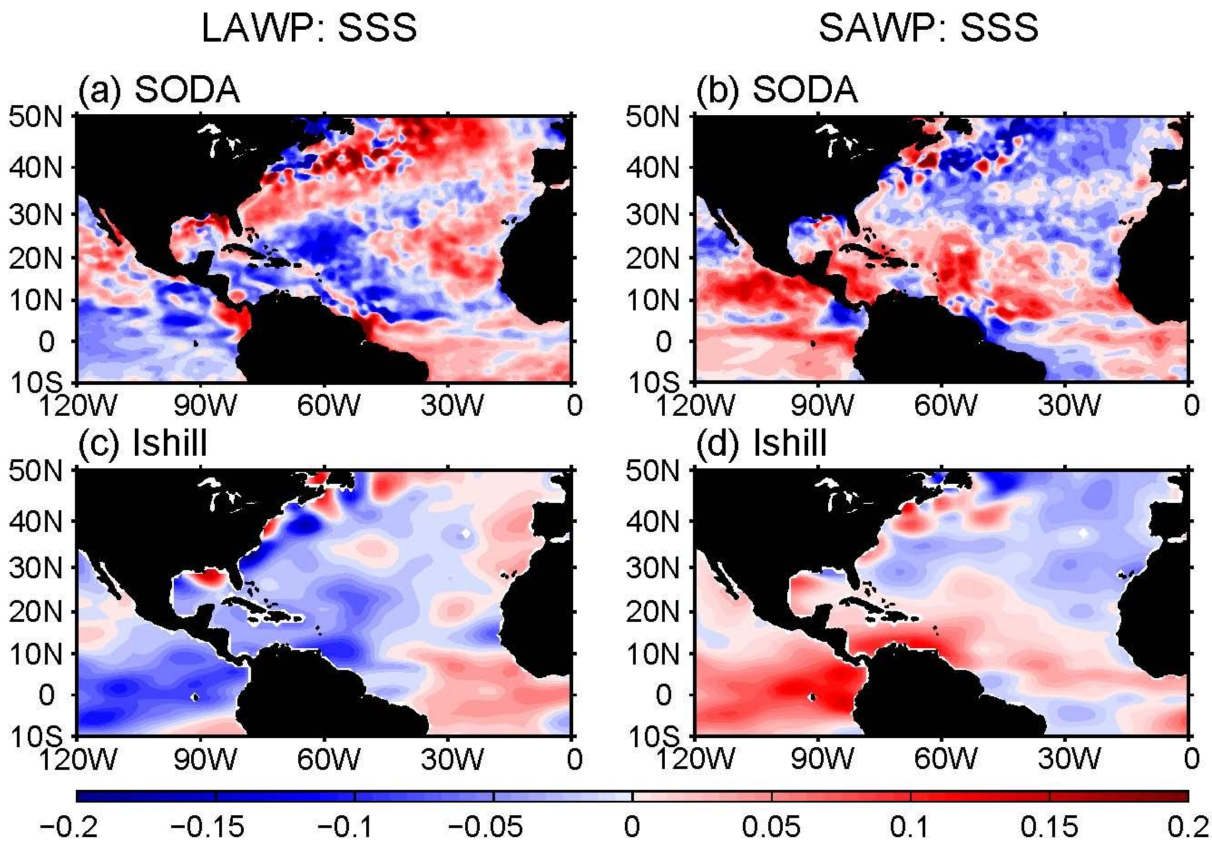

Figure 1: Composites of the sea surface salinity (SSS) anomalies (psu) on interannual timescales for large AWP and small AWP during the summer (JJA) based on the SODA and Ishill data.

Research Performance Measure: We achieved our first year work plan: to analyze oceanic and atmospheric variations associated with the AWP, AMO. Meanwhile, we also analyzed the AMOC variability and its relationships with the AWP and AMO.

Predicting the Effects of Climate Change on Bluefin Tuna (Thunnus thynnus) Spawning in the Gulf of Mexico using Downscaled Climate Models

Project Personnel: Y. Liu, S.-Ki Lee, B. Muhling, D. Enfield and D. Lindo (UM/CIMAS)
NOAA Collaborators: J. Lamkin, W. Ingram and M. Schirripa (NOAA/SEFSC); G.J Goni (NOAA/AOML)
Other Collaborators: M. Roffer (Roffer's Inc); F.E Muller-Karger (USF)

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 Impact (*Primary*)
***Theme 5*:** Ecosystem Modeling and Forecasting (*Secondary*)

Link to NOAA Strategic Goals:
***Goal 1*:** Climate Adaptation and Mitigation - *An informed society anticipating and responding to climate and its impacts* (*Primary*)
***Goal 3*:** Healthy Oceans - *Marine fisheries, habitats, and biodiversity sustained within healthy and productive ecosystems* (*Secondary*)

NOAA Funding Unit: NMFS/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.

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, we examine the potential impact of future anthropogenic global warming on the Gulf of Mexico by using a downscaled high-resolution ocean model. This study shows that the simulated transport by the Loop Current is reduced considerably by 20 - 25% during the late 21st century, resulting in a mitigation of AGW-induced surface warming, particularly in the northern GoM. The reduced warming in the northern GoM will have important implications for marine ecosystems, including the spawning of Bluefin tuna.

The observed SST in the GoM during the 20th century shows long-term SST variability similar to the Atlantic Multidecadal Oscillation (AMO). The amplitude of this multi-decadal signal is as large as

0.5^{o}C, which is comparable to the AGW-induced SST increase in the GoM by 2030. This means that the AGW-induced SST increase in the GoM can be doubled or nearly canceled out due to natural variability until the mid-21st century. Therefore, we further explore the impact of natural climate variability on the forced response of the GoM during the 20th century. We show for the first time that the AMO is also linked to the North Atlantic Ocean gyre variability. We used both observations and an ocean reanalysis simulation to show that the inter-hemispheric winds, associated with the AMO, give rise to a robust wind stress curl influence over the tropical and subtropical North Atlantic, and thus influence the subtropical North Atlantic gyre variability. Around 26^{o}N, for instance, the AMO-induced gyre variability explains up to 25% of the total variance in the wind-driven gyre variability. Figure 1 shows the monthly wind stress and wind stress curl (WSC) regressed onto the AMO index from 1871 to 2008. As clearly shown in Figure 1, the spatial pattern of AMO-WSC co-variability leads to a positive WSC anomaly in the subtropical North Atlantic and a negative WSC anomaly in the tropical Atlantic region during a positive phase of the AMO. During a positive phase of the AMO, both the westerly winds in the subtropical region the northeasterly trade winds in the tropical North Atlantic are weakened. This, in turn, causes a positive WSC anomaly and anomalous Ekman divergence over the subtropical North Atlantic, and thus leads to a weakening of the subtropical North Atlantic gyre circulation.

The 30-year long measurement of the volume transport across the Florida Straight is used to confirm the important role played by the AMO. Our analysis of the ocean reanalysis simulation reveal that the volume transport across the Yucatan Channel is both wind-driven and thermohaline-driven, with the wind-driven component dominating the variation of the total volume transport. Further analysis of the ocean simulation shows that, for the volume transport across the Yucatan Channel, the wind-driven gyre variability linked to the AMO explains about 20% of the total variance of the wind-drive component, while the 20% of the residual (non wind-driven component) can be explained by using the Atlantic Meridional Overturning Circulation variability at 30^{o}N.

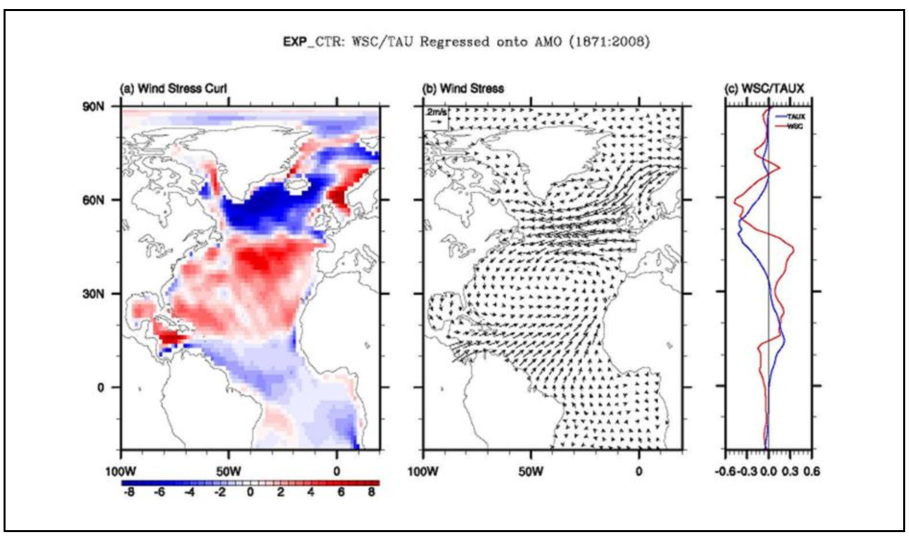

Figure 1: Regression of (a) monthly wind stress curl and (b) wind stress component on the AMO index from 1871 to 2008 obtained from CCSM_POP. (c) Zonal averaged wind stress (blue) and wind stress curl (red) for 1871–2008 period, obtained from the CCSM_POP.

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

Southwest Atlantic Meridional Overturning Circulation ("SAM") Project

Project Personnel: R. Garcia, R. Perez (UM/CIMAS)
NOAA Collaborators: C. Meinen, S. Garzoli, M. Baringer, G. Goni, U. Rivero, and P. Pena (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 1*:** Climate Research and Impacts (*Primary*)
***Theme 3*:** Sustained Ocean and Coastal Observations (*Secondary*)
***Theme 4*:** Ocean Modeling (*Tertiary*)

Link to NOAA Strategic Science Goals:
***Goal 1*:** Climate Adaptation and Mitigation - *An informed society anticipating and responding to climate and its impacts*

NOAA Funding Unit: OAR/AOML and OAR/CPO **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.

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, December 2010, and July 2011 during cruises jointly sponsored by NOAA and the Argentine Naval Hydrographic Service. During the July 2011 cruise a problematic instrument was lost while trying to be recovered. That CPIES instrument was replaced by a PIES. The next cruise is scheduled for July 2012.

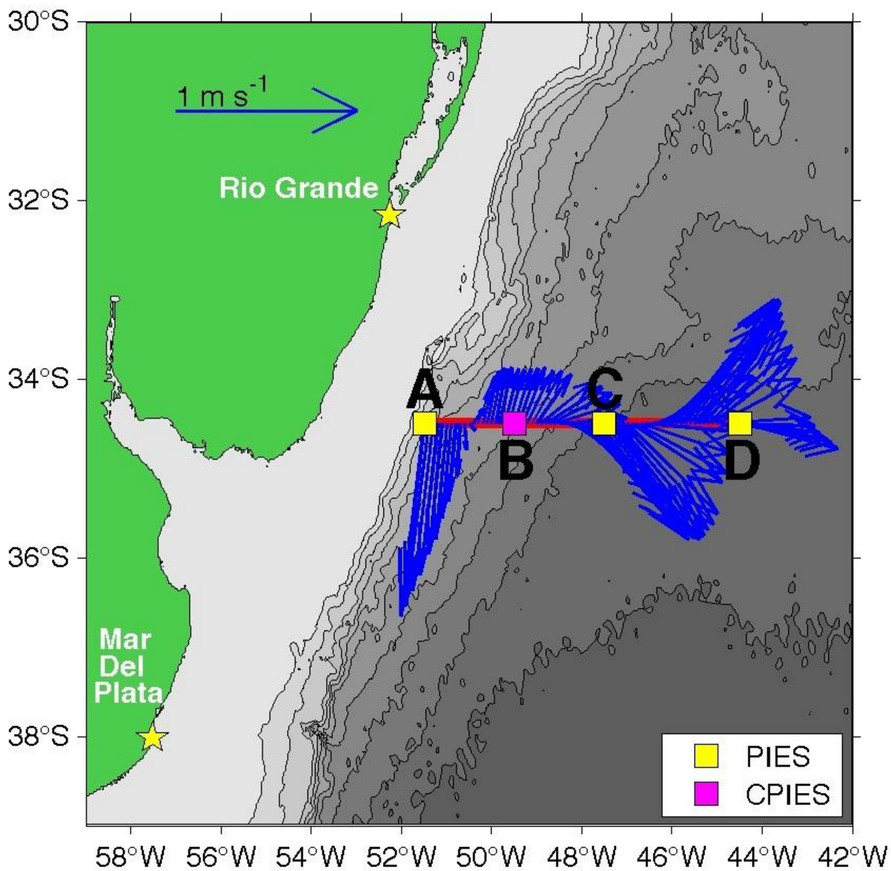

Figure 1: Map indicating the location of the four PIES/CPIES making up the SAM array. Blue vectors indicate the water velocity at 21 meters measured via shipboard acoustic Doppler current profiler on the Brazilian naval research vessel Cruzeiro do Sul in March 2009 during the array deployment cruise. Black letters indicate site names – instrument types are noted in legend. In July 2011 the CPIES was replaced by a PIES.

Research Performance Measure: Most research goals were met during this last year. Some difficulties were present with the loss of one of the instruments and a planned cruise was cancelled due to ship problems (December 2011).

Global Carbon Data Management and Synthesis Project

Project Personnel: F.J. Millero, F. Huang and G. Ingram (UM/RSMAS); K. Sullivan, D. Pierrot, F. Bringas, G.-H. Park and T.-H. Peng (UM/CIMAS);

NOAA Collaborators: R. Wanninkhof (NOAA/AOML); C.L. Sabine, R.A. Feely and S. Hankin (NOAA/PMEL)

Other Collaborators: A. Kozyr (CDIAC); R. Key (Princeton); A. Dickson (UCSD); J.A. Trinanes (University of Santiago de Compostela)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** NOAA's Office of Climate Observations (OCO) funds researchers from NOAA laboratories Pacific Marine Environmental Laboratory (PMEL) and Atlantic Oceanographic and Meteorological Laboratory (AOML), as well as the Carbon Dioxide Information Analysis Center, Princeton University, University of California San Diego and the University of Miami to participate in a project to manage, synthesize and interpret data in an endeavor to understand how the ocean carbon cycle changes over time. NOAA's Office of Climate Observations (OCO) oversees this group project and recognizes the need for proper data management and synthesis.

***Strategy*:** As a member of this global carbon data management and synthesis project, principal investigators participate in national and international planning efforts to evaluate and improve the global ocean observing system. The principal investigators of this multi institutional project gather data and bring it together. They collaborate to discuss and provide tools and methods to manage the data, insure accuracy and facilitate easy access.

CIMAS Research Theme

***Theme 1*:** Climate Research and Impact (*Primary*)

Theme 3: Sustained Ocean and Coastal Observations (*Secondary*)

Link to NOAA Strategic Goals:

***Goal 1*:** Climate Adaptation and Mitigation - *An informed society anticipating and responding to climate and its impacts*

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

Research Summary:

The goal of the Global Carbon Data Management and Synthesis Project is to work together with the OCO carbon measurement projects to take the fundamental carbon observations and turn them into products that are useful for scientists and the public for understanding the ocean carbon cycle and how it is changing over time. This effort ranges from ensuring that the observations are of the highest quality and are mutually consistent with each other to combining the observations into a common data set that is available and easy for the community to use and explore to evaluating the time rate of change in global ocean carbon uptake and storage. This project brings together ocean carbon measurement experts, information technology experts and data managers to ensure the most efficient and productive processing possible for the OCO carbon observations.

Last year we participated in two CLIVAR cruises. One was the S4P cruise in the Antarctic aboard the RVIB Palmer (McMurdo to Punta Arenas, Chiles) and the second was the A10 cruise in the Atlantic. After a month delay because of equipment malfunction, the R/V Ronald H. Brown A10 cruise departed Cape Town, South Africa 26 September 2011 and arrived in Rio de Janeiro, Brazil 31

October 2011. The data set for these cruises will be available for distribution to the scientific community next year.

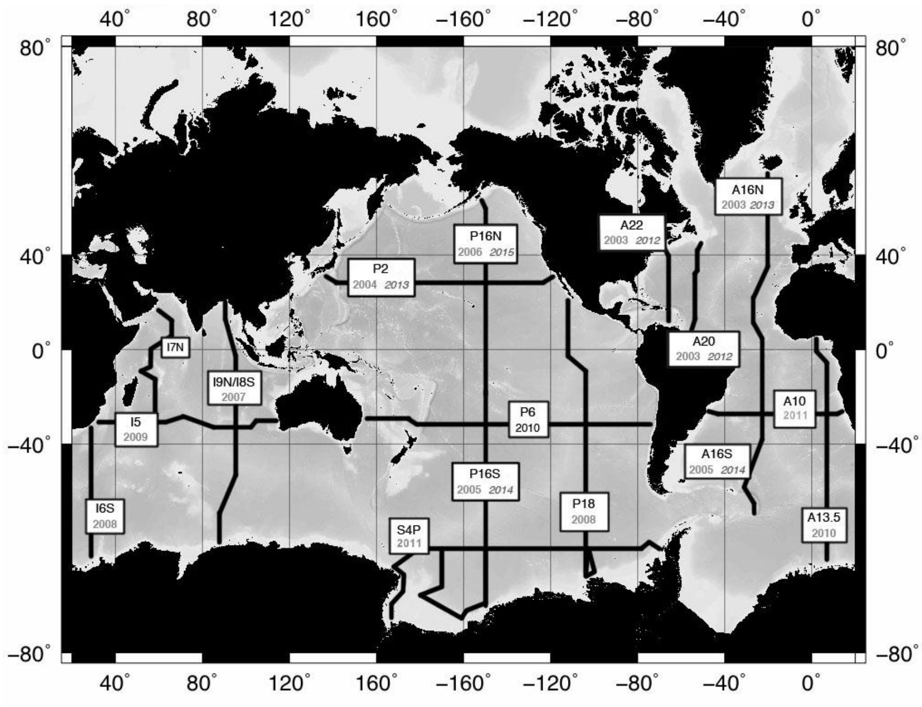

Figure 1: Research Cruises for the U.S. Global Ocean Carbon and Repeat Hydrography Program 2003-2014.

As a result of the standardized measurements from the Climate Variability (CLIVAR) and Volunteer Observing Ships (VOS) cruises, several publications have resulted.

A paper published in Aquatic Geochemistry by Millero et al. (2011) discusses the effect of dissolved organic carbon and alkalinity on the density of Arctic Ocean waters. Waters et al. (2011) studies changes in anthropogenic CO_2 and pH on the CLIVAR research cruises P06 and P18. Research by Millero and Huang (2011) was partially supported by this grant.

Several refereed publications have been written using this data with graduate students as co-authors (Millero et al. (2011); Waters et al. (2011); Rodriguez and Millero, (2012); Woosley et al. (2012). Feely et al. (2012) with NOAA collaborators Sabine, and Wanninkhof have a paper in press in Global Biogeochemical Cycles on decadal changes in the Pacific Ocean.

CDIAC has prepared or is preparing reports from all the participating investigators on the chemical data obtained during the research cruises. The reports are a compilation of all the data obtained during the cruises and briefly describes the methods of obtaining data consistent with community standards, issues with the data and the resulting quality data.

Research Performance Measure: All objectives have been met.

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 and 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 1: Climate Adaptation and Mitigation - *An informed society anticipating and responding to climate and its impacts*

NOAA 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. The carbon survey completed in 2009-2010 as a part of CLIVAR CO_2 Repeat Hydro program along 32^{o}S, the South Pacific cruise track P06, provides an opportunity for evaluation of anthropogenic CO_2 increases since the last CO_2 surveys along the same cruise track in 2003 and 1992. The isopycnal method used in this study provides estimates of anthropogenic CO_2 increase for the decades 1992 to 2003 and 2003 to 2010. For Sub-Antarctic Mode Water (SAMW) the anthropogenic CO_2 increases are 7.6 to 8.7 umol/kg between 1992 and 2003, and 4.7 umol/kg between 2003 and 2010. For the Antarctic Intermediate Water (AAIW), the CO_2 increases are estimated to be 1.3 to 5.0 umol/kg from 1992 to 2003, and approximately 3.3 umol/kg from 2003 to 2010. These estimates are slightly lower than Murata et al. (2007) results. The rate of inventory change is estimated to be 0.52 Mol/m^2/yr for the decade of 1992 to 2003, and 0.70 Mol/m^2/yr for the decade of 2003 to 2010. This estimate is about 50% lower than that estimated by Murata et al. (2007) of 1.0 ± 0.4 Mol/m2/yr for the decade of 1992 to 2003. The average water column AOU is estimated to decrease approximately 3.8 umol/kg from 1992 to 2003, while it is estimated to increase approximately 1.5 umol/kg from 2003 to 2010. However, the magnitude of these estimated AOU changes is relatively small, and is very close to the uncertainty derived from precision of the oxygen determination and the integration error.

As shown in Figure 1, the change in total dissolved CO_2 as a function of density shows a general trend that higher increases of DICn are observed in water mass represented by Sub-Antarctic Mode Water (SAMW) as isopycnal surfaces 26.6 to 26.8, while lower increases of DICn are seen in the Antarctic Intermediate Water (AAIW) as represented by isopycnal surfaces 27.0 to 27.4.

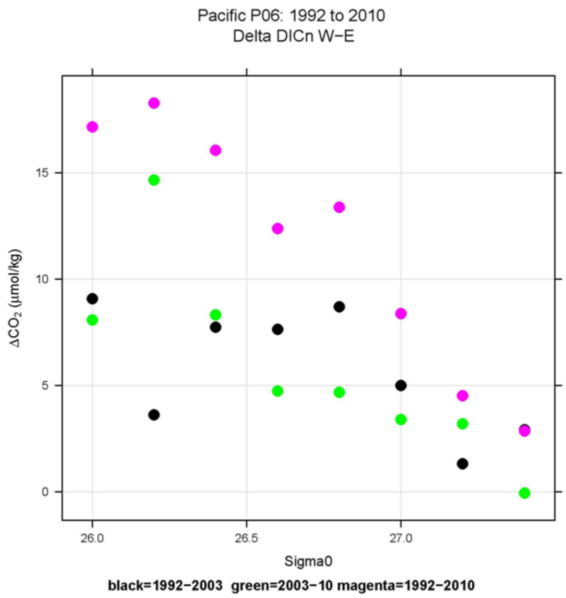

Figure 1: The P06 cruise wide average DICn increases along the isopycnal surfaces for decades 1992-2003 (black), 2003-2010 (green), and 1992-2010 (magenta).

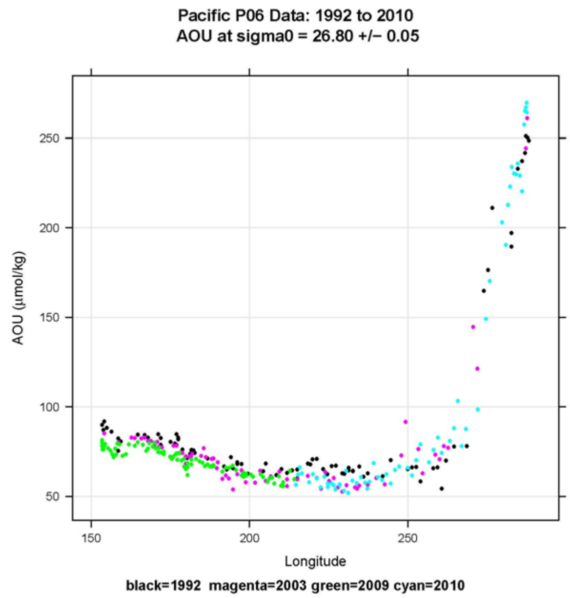

Figure 2: Distribution of AOU with longitude along isopycnal surface $\sigma\theta = 26.8$ from 1992 to 2010 in the Pacific cruise line P06 along latitude of 30°S. The color represents year of survey: 1992 (black), 2003 (magenta), 2009 (green), and 2010(cyan).

The variations of AOU along the isopycnal surface 26.8 are shown in Figure 2. The temporal variations of AOU from 1992 to 2010 are apparent in this isopycnal horizon. However, the magnitude of variations is small. Results of analysis are shown in Figure 3.

Over the 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 decided to 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 shows a tight linear relationship between Alkalinity and Salinity which gives a best fit line as Alk = 540.82 + 50.6073*Sal. The deviation of alkalinity distribution from this trend (dAlk) is an indication of the possible variations of sources of extra alkalinity. Analysis of dAlk near the coastal regions should shed more lights on sources and sinks of surface Alkalinity. Shown in Figure 4 is the distribution of dAlk in the Atlantic Ocean. We are searching for available Alkalinity data collected in global coastal regions.

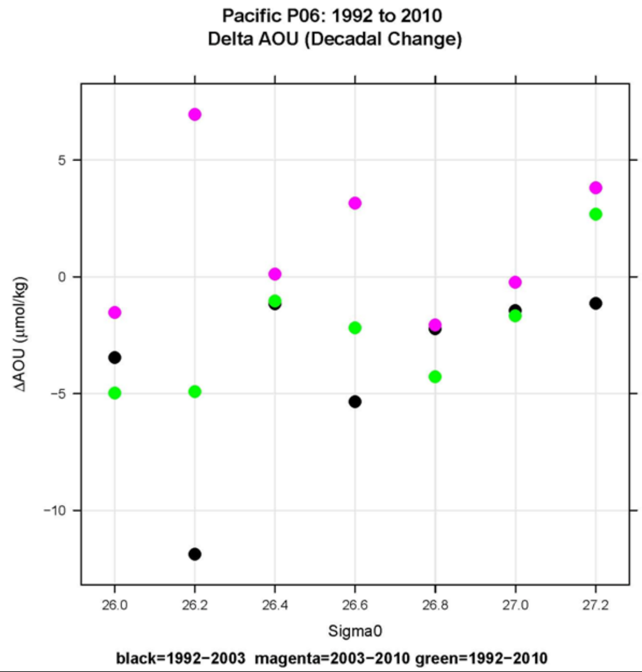

Figure 3: Decadal AOU changes along the isopycnal surfaces. Black dots are for decade 1992 to 2003, magenta dots are for decade 2003 to 2010, and the green dots are for decades 1992 to 2010.

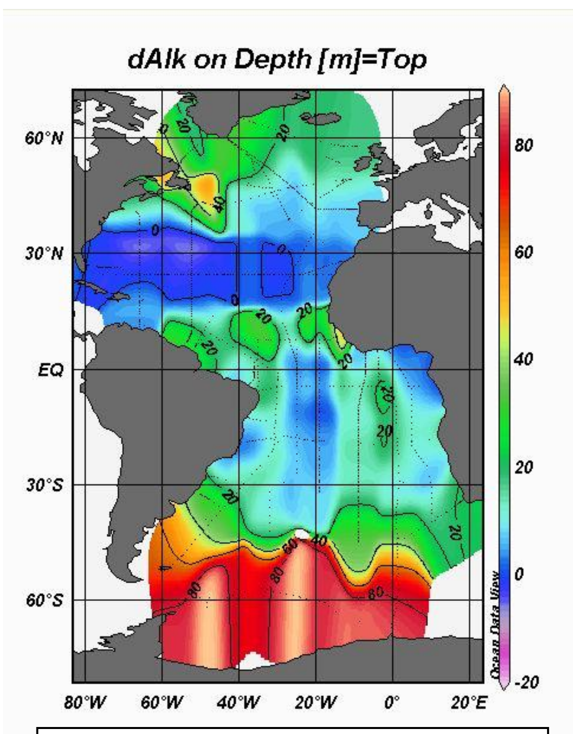

Figure 4: Distribution of dAlk of surface Alkalinity in the Atlantic Ocean.

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

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 Collaborator: 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 1*:** Climate Research and Impact (*Primary*0
***Theme 4*:** Ocean Modeling (*Secondary*)

Link to NOAA Strategic Goals:
***Goal 1*:** Climate Adaptation and Mitigation - *An informed society anticipating and responding to climate and its impacts*

NOAA 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/PIES) 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/PIES) of approximately 20 instruments along the nominal latitude of 34.5°S. More details of the planned array can be found at http://www.aoml.noaa.gov/phod/SAMOC_international/.

Research Performance Measure: Based on our findings, several national and international proposals have been proposed and/or funded to request support for components of a trans-basin array along 34.5°S (Figure 1). One paper has been published in Journal of Atmospheric and Oceanic Technology – Oceans, and International CLIVAR has endorsed the SAMOC project.

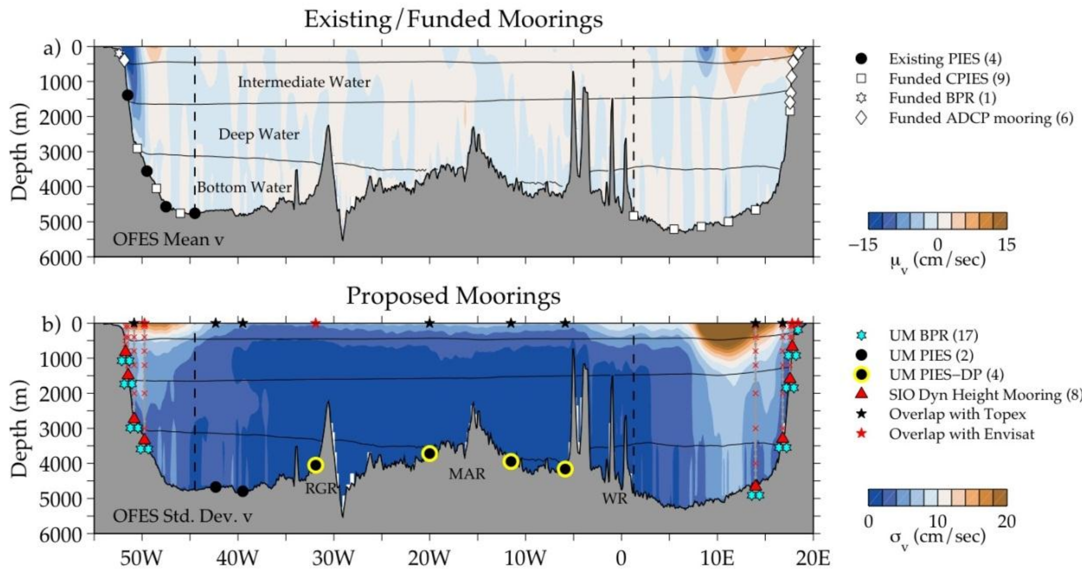

Figure 1: Schematic of (a) existing (filled symbols) and funded (open symbols) moorings on the boundaries, and (b) proposed slope-to-slope interior array along 34.5°S. The proposed array consists of dynamic height moorings (red triangles) with full-water column T, S, p and discrete current measurements, bottom pressure recorders at the base of the dynamic height moorings and on the eastern slope (cyan stars), pressure equipped inverted echo sounders (black circles) and pressure equipped inverted echo sounders with data pods (yellow circles) in the interior. Mean and standard deviation of model-derived (OFES) meridional velocity are shown in panels a) and b), respectively. Boundaries between water masses are indicated.

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Upper Ocean Processes Associated with the Madden-Julian Oscillation in the Indian Ocean

Project Personnel: X. Wang (UM/CIMAS)
NOAA Collaborator: C. Wang (NOAA/AOML)
Other Collaborators: T. Shinoda (NRL) and W. Han (UC)

Long Term Research Objectives and Strategy to Achieve Them:

Objectives**:** To improve our understanding of upper ocean processes that control SST variability in the tropical central Indian Ocean on the diurnal to intraseasonal time scales, which may play an important role in MJO initiation and evolution.

Strategy**:** To diagnose the observations, and perform OGCMs and1-D Ocean models.

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

Link to NOAA Strategic Goals:
Goal 1**:** Climate Adaptation and Mitigation - *An informed society anticipating and responding to climate and its impacts*

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

Research Summary:
Canonical El Niño, El Niño Modoki I, and El Niño Modoki II are classified based on the distinct SST anomaly pattern in the tropical Pacific during the El Niño developing year. For canonical El Niño, the warm SST anomalies originate along the coast of South America in boreal spring, and then propagate toward the central tropical Pacific with the maximum warming SST anomalies in the eastern tropical Pacific. Consistent with the previous studies, a positive Indian Ocean Dipole (IOD) during summer and autumn tends to co-occur with canonical El Niño. The warming SST anomalies for El Niño Modoki I appear in the central tropical Pacific symmetric to the equator in summer, intensify and reach the peak in the equatorial central Pacific. Similar to canonical El Niño, a positive IOD is seen in the Indian Ocean during summer and autumn, and disappears in winter. However, for El Niño Modoki II, the warm SST anomalies originate in the subtropical northeastern Pacific in spring, and further develop reaching the equatorial central Pacific in summer and autumn. Such warm SST anomaly pattern in the tropical Pacific is characterized to be asymmetric to the equator with the maximum in the subtropical north Pacific during summer and autumn. Accompanying with El Niño Modoki II, a negative IOD is seen in summer and autumn, which is opposite to the conditions of canonical El Niño and El Niño Modoki I. In summary, canonical El Niño and El Niño Modoki I are related to the positive IOD events, whereas El Niño Modoki II is in association with the negative IOD event.

It is shown that the Walker circulation variations play a key role for different influences on the IOD. Canonical El Niño features a significant weakening of the Walker circulation. Air rises in the eastern tropical Pacific, flows westward aloft, sinks in the western tropical Pacific and the eastern Indian Ocean, which produces the easterly wind anomalies in the eastern Indian Ocean and westerly anomalies in the tropical Pacific at the lower troposphere, respectively. The descent branches of the Walker circulation result in precipitation decreasing and easterly wind anomalies enhancing in the eastern Indian Ocean, which supports the positive IOD commence and development. The anomalous Walker circulations induced by El Niño Modoki I are similar to these by canonical El Niño, and thus the positive IOD is expected to be forced. In contrast, the El Niño Modoki II-induced Walker circulation anomalies enhance a little rather than significantly weaken, in which ascent motion branches are seen in the eastern Indian Ocean (90°-120°E) and the central tropical Pacific (150°-210E°). The increase diabatic heating and the lower-level westerly wind anomalies in the eastern Indian Ocean associated with the ascent motion of the Walker circulation support the favorable external force conditions to form a negative IOD event in term of the Bjerknes feedback.

Research Performance Measure: We analyzed the SST variability in the Indian Ocean associated with El Niño.

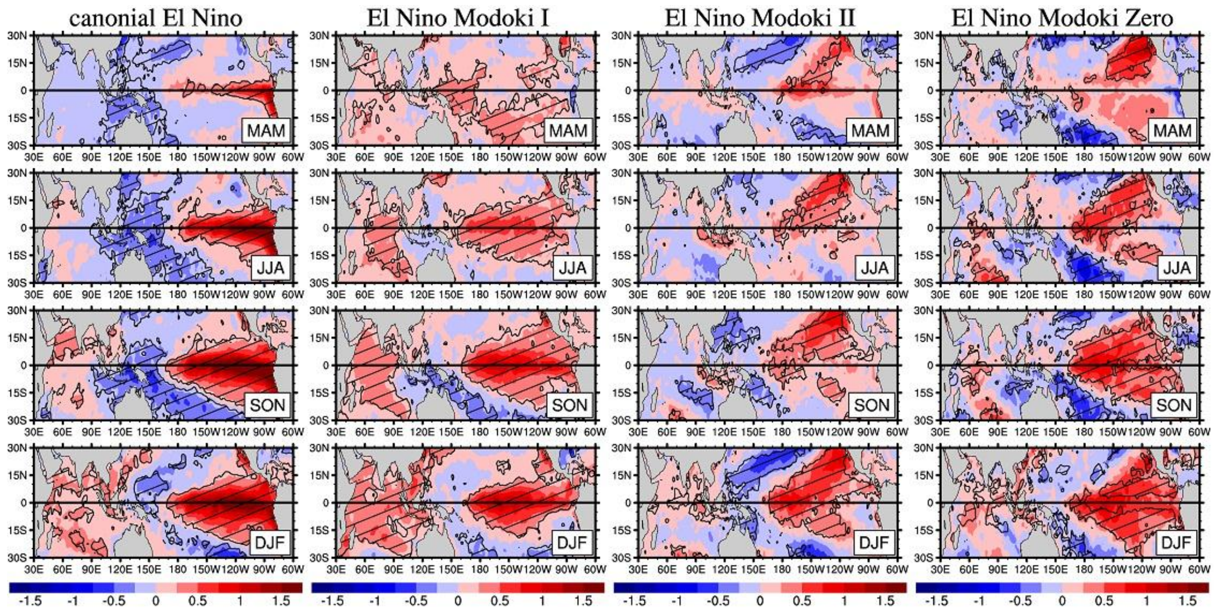

Figure 1: Evolution of composited SST anomalies for canonical El Niño (the first column), El Niño Modoki I (the second column), El Niño Modoki II (the third column), and El Niño Modoki 0 (the fourth column). The first, second, third and fourth row represents the different El Niño phases of MAM (March[0] to May[0]), JJA (June[0] to August[0]), SON (September[0] to November[0]) and DJF (December[0] to February[+1]), respectively. The hatched represents exceeding 90% significant level, which is calculated by Student's *t* test.

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)

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 2*:** Weather-Ready Nation - *Society is prepared for and responds to weather-related events*

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

Research Summary:
The Hurricane Ensemble Data Assimilation System (HEDAS) is an ensemble Kalman filter (EnKF) data assimilation system 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) The value of the Doppler radar wind observations in ensemble-based data assimilation using HEDAS has been demonstrated in observing system simulation experiments (OSSEs). The results of this investigation have been published in Monthly Weather Review (Aksoy et al. 2012a).

(2) Using the OSSE infrastructure of research topic (1), the value of assimilating hurricane observations in a storm-relative framework has been investigated. A manuscript that summarizes the results of this work is currently under review in Monthly Weather Review (Aksoy 2012) and is conditionally accepted for publication.

(3) HEDAS has been tested in retrospective experiments for the hurricane seasons 2008-2011. Eighty three cases are investigated that span intensities from tropical depression to category-4 hurricane. Overall, it is found that when high-resolution observations are assimilated with HEDAS, the result is analyses of the primary circulation that are realistic in terms of intensity, wavenumber-0 radial structure, as well as wavenumber-1 azimuthal structure. Representing the secondary circulation in the analyses is found to be more challenging with systematic errors in the magnitude and depth of the radial inflow. This is believed to result from a model bias in the experimental HWRF due to the over-diffusive nature of the planetary boundary layer parameterization utilized. The results of this work are summarized in a manuscript that is currently in internal review and will be submitted to Monthly Weather Review (Aksoy et al. 2012b).

In Figure 1, the distribution of the 83 cases for storm center and intensity is provided. The geographical distribution of the observed position of the cases, as obtained from the National Hurricane Center's (NHC) best track database (Fig. 1a) shows a general proximity of the cases to land, which is due to the range limitations of the NOAA P-3 aircraft. In Figure 1b, a skewed distribution of intensity that peaks at tropical storm intensity is evident. Overall, more than half of the cases have intensities of tropical storm or category-1 hurricane.

The distribution of the storm centers in analyses is compared to the best track storm centers at respective verification times (Fig. 2a). It is inferred from the centroid of displacements that analyses exhibit a slight left and forward bias relative to the best track storm position. When the distribution of the radial distance between analysis and best track storm centers is analyzed (Fig. 2b), most of the cases are found to exhibit 40 km or smaller position errors. Moreover, the cases with the greatest position errors (~100 km or greater) are of tropical-storm intensity or weaker. This is likely the result of a combination of two possible scenarios: (a) The HEDAS system is better capable of analyzing storm position in stronger storms. This would mainly result from better-defined radial gradients that lead to stronger correlation signals between wind observations and position. (b) The procedure of center finding itself is easier (and therefore more accurate) in stronger storms, mainly due to stronger radial gradients and fewer local surface pressure minima in stronger storms.

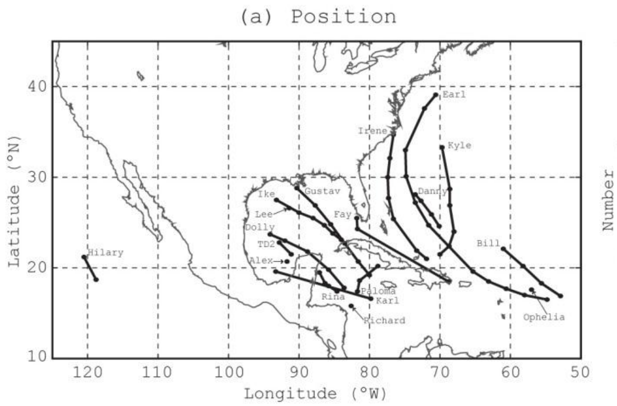

Figure 1: (a) Geographical distribution of the case position as observed in the best track dataset. (b) Frequency distribution of the case intensity category as observed in the best track dataset. Cases that do not exist in the best track database are assigned "<TS" category. "TS" and "H" stand for tropical storm and hurricane, respectively.

In terms of intensity, analyses compare well against the best track. Figure 3a shows that, for maximum 10-m wind speed, which is the standard measure of intensity, analyses explain ~87% of the variance in the best track. There is also a 1.1 m s-1 negative bias in analysis intensity (i.e., under-estimation of intensity), although it is not statistically significant at the 95% confidence level. An even better linear regression fit is achieved for minimum sea-level pressure (97% variance explained, Fig. 3b). However, this is now accompanied by a more distinct, positive bias of 3.7 hPa (under-estimation of intensity) that is statistically significant. The analysis-best track similarities in maximum intensity and minimum sea-level pressure are also reflected in the wind-pressure relationship (Fig. 3c). For the cases analyzed here, both HEDAS and the best track depict a linear relationship with 82-83% variance explained. The separation between the two regression lines reflects the positive bias in analysis minimum sea-level pressure, although it is not statistically significant at the 95% confidence level (not shown).

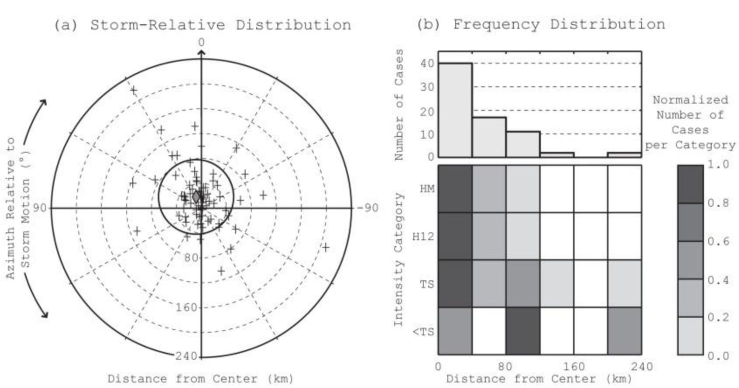

Figure 2: Position error in the final analysis as compared to the best track. (a) Analysis storm centers (plus markers) relative to the best track. Azimuth is measured relative to observed storm motion where 0° represents the direction of storm motion. Radial distance is measured from the best track storm center. The centroid location of all cases is shown with the diamond marker. The standard deviation of position errors is indicated with the circle around the centroid location. (b) Number of cases as a function of the analysis-observed radial distance of storm centers and intensity category (2-d matrix plot, color scale on right), and cumulative as a function of the analysis-observed radial distance of storm centers (histogram). The 2-d matrix plot population bin values are normalized by the respective maxima of populations for each intensity category.

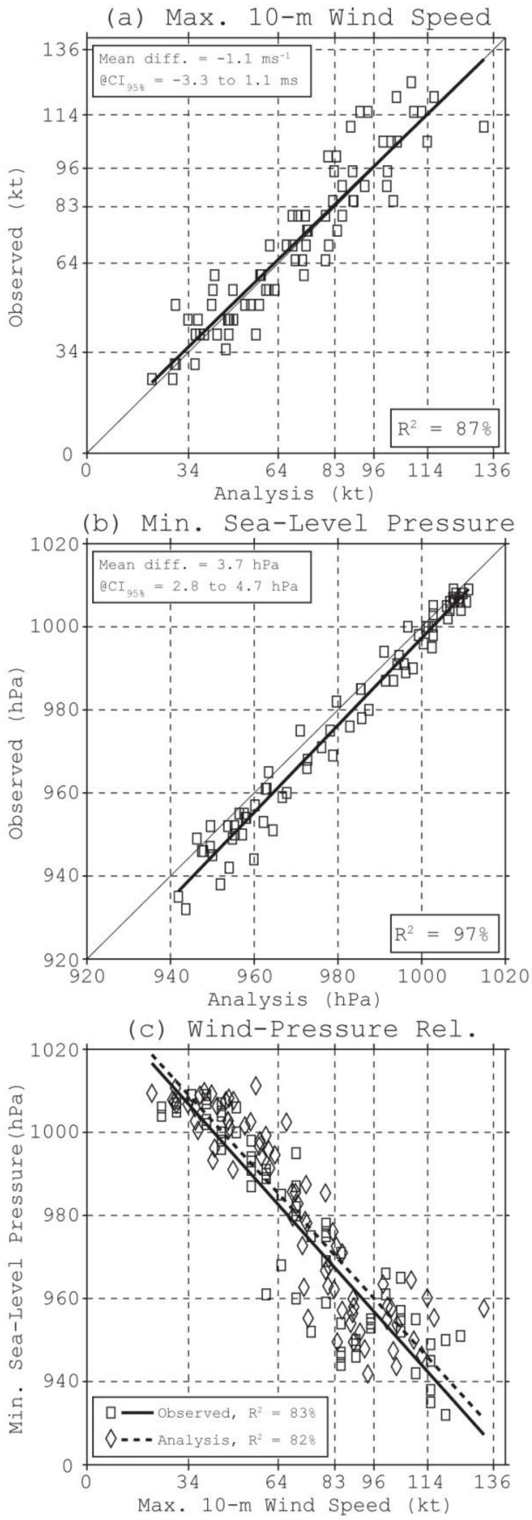

Figure 3: Intensity error in the final analysis as compared to the best track. (a) Analysis vs. observed scatter diagram of maximum 10-m wind speed (kt) for all cases in the best track database. The thick line represents the linear regression between analysis and observations. The coefficient of determination (R^2) is presented in the lower-right box. The mean analysis-observation difference along with its 95% confidence interval bounds is given in the upper-left box. The dashed gridlines represent intensity category thresholds. (b) As in (a), but for minimum sea-level pressure. (c) Wind-pressure relationship in observed (square markers, solid linear regression line) and analysis (diamond markers, dashed linear regression line) data.

(4) HEDAS is currently being prepared to run in real time during the 2012 hurricane season as a demonstration system for NOAA's Hurricane Forecast Improvement Project (HFIP). Several advancements have been implemented for the 2012 version of HEDAS: (a) Upgrades have been made to the HWRF model. In 2012, HEDAS will be integrated with the latest operational version of HWRF. (b) Changes have been made in HEDAS to update the time derivative of vertical wind speed for better non-hydrostatic initialization. (c) It is planned to assimilate observations in a storm-relative framework based on the results in Aksoy (2012). (d) Additional data types, such as dropwindsondes from unmanned vehicles and flight-level and radar data from the NOAA Gulfstream-IV aircraft are being tested.

(5) Using the OSSE infrastructure of research topic (1), the current Doppler radar wind super-observation 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.

(6) Using the OSSE infrastructure of research topic (1), optimal sampling strategies using the new radar platform on the NOAA Gulfstream -IV aircraft are being investigated.

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

Hybrid Data Assimilation System for HWRF

Project Personnel: B. Annane (UM/CIMAS)
NOAA Collaborator: T. Vukicevic (NOAA/AOML/HRD)

Long Term Research Objectives and Strategy to Achieve Them:
Objectives**:** Develop hybrid data assimilation capability for operational use with HWRF basin scale system.
Strategy**:** Integrate global and regional hybrid DA. Cycled data assimilation at all scales resolved by HWRF; synoptic, meso and inner core.

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

Link to NOAA Strategic Goals:
Goal 2: Weather-Ready Nation - *Society is prepared for and responds to weather-related events*

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

Research Summary:
The Hybrid Variational-Ensemble Data Assimilation System (HVEDAS) combines aspects of the EnKF and 3D-VAR (GSI). This system is under development at NOAA/NCEP/EMC, NOAA/OAR/ESRL and NOAA/AOML/HRD. It is expected to be ready for testing in the 2014 season. This hybrid approach is likely to define the operational regional data assimilation system for NOAA in the 5-year time-frame.

The Gridpoint Statistical Interpolation (GSI) system is a unified variational data assimilation (DA) system for both global and regional applications. GSI is constructed in physical space and is designed to be a flexible and efficient on available parallel computing platforms.

The GSI analysis system became operational as the core of the North American Data Assimilation System (NDAS) in June 2006 and the Global Data Assimilation System (GDAS) in May 2007 at NOAA. Some of the assimilated observations are: rawinsonde, pibal, class sounding, profiler, dropsonde, AIRCFT, AIRCAR, GPSIPW, surface marine/land/splash-level/mesonet, satellite wind, satellite radiance data: HIRS, AMSU-A, AMSU-B/MHS, AIRS, GOES sounder, NOAA P3 TDR, and Pseudo-MSLP.

The activities of the past year have focused on the following tasks:
1) Reviewed, extracted and modified GSI-hybrid scripts from NOAA-ESRL and NCEP/EMC. Incorporated these into HWRF scripts for GSI-3D var related testing.
2) The following experiments, for the month of July and August 2011, were performed using model configuration with single basin scale domain, at 27 km resolution:
    a) No-GSI (baseline) : Sequence of 126 h forecasts on single basin scale grid, using downscaled, GFS analysis to initialize the model every 6 h.
    b) GSI without cycling: Assimilation with GSI at frequency of 6 h, starting each cycle from global analysis. At end of each cycle performed 126 h forecast
    c) Partial GSI cycling : Several experiments with 126 h forecast at end of each 6 h cycle. Re-started from GFS analysis every 1 day

The results indicated that HWRF-GSI data exchange has some bugs that need to be addressed.

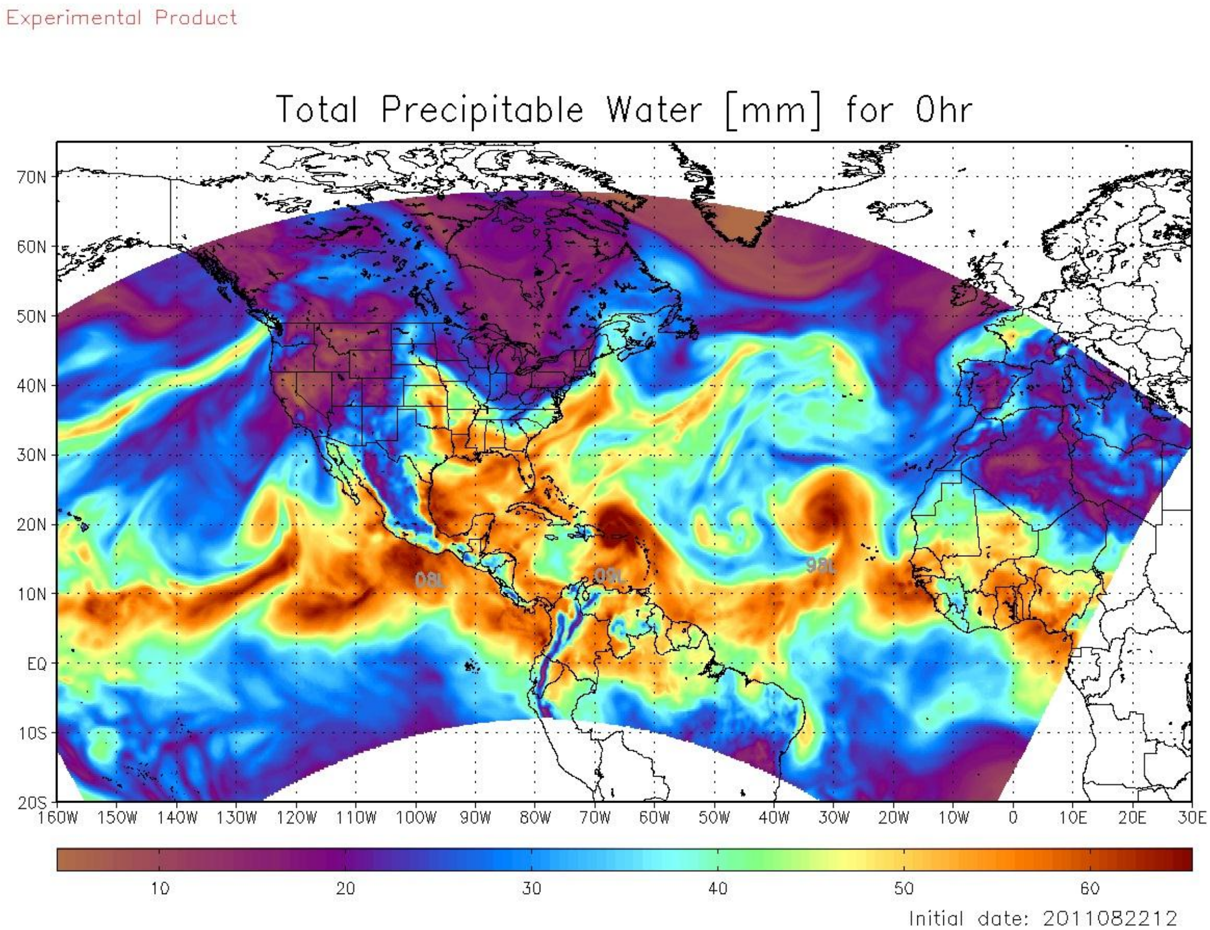

Figure 1: HWRF basin scale initialized with GSI: Precipitable water at hour zero.

Research Performance Measure: All objectives were met on schedule.

Investigating Tropical Cyclone Diurnal Pulsing

Project Personnel: J.P. Dunion (UM/CIMAS); D. Nolan (UM/RSMAS)
Other Collaborators: C. Thorncroft (SUNY-Albany) and C. Velden (Univ. Wisconsin-CIMSS)

Long Term Research Objectives and Strategy to Achieve Them:

Objectives: To develop an experimental real-time web page for monitoring the tropical cyclone diurnal cycle for active storms around the globe and advance the understanding of this newly discovered phenomenon.

Strategy: Collaborate with scientists at the University of Wisconsin-CIMSS to implement a real-time web page for monitoring the tropical cyclone diurnal cycle during the 2012 Atlantic hurricane season; visit the University of Wisconsin-CIMSS to collaborate with scientists at CIMSS and facilitate completion of the experimental web page; conduct research to advance the understanding and monitoring capabilities of the tropical cyclone diurnal cycle under two successfully-funded proposals: 1) NASA Roses proposal titled, "*Utilizing NASA Reconnaissance Assets to Investigate Hurricane Upper-level Warm Core Evolution, Inner Core Pulsing, and Near-Environment Moisture Interactions*" and 2) NOAA GOES-R travel grant proposal titled, "*Development of Geostationary Satellite Products for Observing Tropical Cyclone Intensity Change and Saharan Dust Storms*".

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

Link to NOAA Strategic Goals:
***Goal 2*:** Weather-Ready Nation - *Society is prepared for and responds to weather-related events*

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

Research Summary:
Although numerous studies have documented the existence of diurnal maxima and minima associated with tropical convection and the tropical cyclone upper-level cirrus canopy, predicting the timing and extent of this variability remains a difficult challenge. This research is investigating a new area of research related to an intriguing diurnal pulsing pattern that may represent an unrealized, yet fundamental process of mature tropical cyclones. New infrared GOES satellite imagery reveals a "cool ring", or pulse, that begins forming in the storm's inner core near the time of sunset each day. This pulse continues to move away from the storm overnight, reaching areas several hundred kilometers from the storm center by the following afternoon. There appear to be significant structural changes and disruptions to a storm as this pulse moves out from the inner core each day to peripheral radii hundreds of kilometers from the center. Additionally, the timing/propagation of these "cool rings" also appear to be remarkably predictable. Therefore, the GOES infrared imagery can readily be used to anticipate "cool ring" locations around a storm and provide guidance for targeting of these features by aircraft (e.g. the NASA Global Hawk, NOAA P-3 Orions, and NOAA G-IV jet).

Figure 1 shows an example of diurnal pulsing for 2005 Hurricane Emily on 15 July, 2-3 days before NOAA and NASA began flying the storm during their IFEX and TCSP field experiments respectively. The top left panel shows a GOES IR differencing image and depicts 6-hr changes in the storm's infrared temperature field from 0045-0645 UTC. The "cool ring" (yellow to red shading) had already began to propagate away from the inner core and was ~150 km from the storm center. Emily was a powerful, compact storm at this time (Fig. 1, lower left panel). By 1445 UTC that day, the “cool ring” had propagated to a radius of ~250-350 km from the center and the inner core cloud tops inside (0-200 km radius) of the “cool ring” had warmed by 5-40^{o}C (Fig. 1, upper right panel). The GOES IR images from those corresponding times (Fig. 1, lower panels) reveal a storm with a much larger cloud shield and a structure that had visibly deteriorated (NHC Best track intensity for Emily dropped 10 m s^{-1} during that afternoon). Additional tropical cyclone cases investigating diurnal pulsing have exhibited similar “cool ring” features that propagate away from the storm center after local sunset and reach the 400-500 km radii during early afternoon (local time) the following day. The phases of these pulses of cooling and warming of the TC cloud shield are remarkably predictable and aligned when the local time is referenced. It is hypothesized that radiational cooling at the top of the storm near/after sunset is the driving mechanism behind tropical cyclone diurnal pulsing and the associated “cool rings” that can be observed propagating away from the storm.

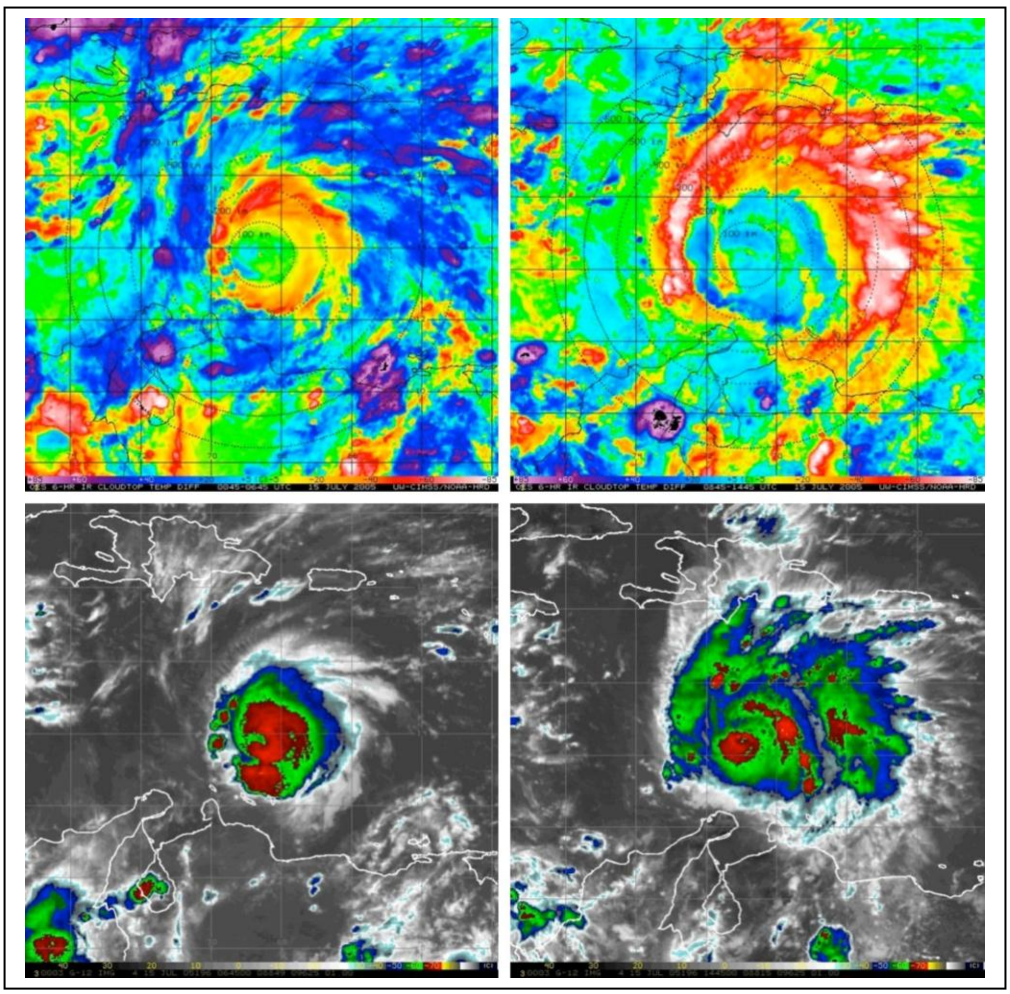

Figure 1: (Top panels) GOES infrared image differencing for 2005 Hurricane Emily on 15 July at (left) 0645 UTC and (right) 1445 UTC. The (top) yellow to red shading indicates a “cold ring” propagating away from the storm during this 8-hour period. The corresponding GOES infrared images for these times are shown in the lower panels.

Microwave satellite imagery is also suggesting that diurnal pulsing may be associated with significant changes in tropical cyclone structure as the pulse propagates away from the storm's inner core region. Current efforts are examining the relationship between the tropical cyclone diurnal cycle, short-term intensity changes, and changes in Dvorak satellite intensity estimates. Project findings continue to suggest that the tropical cyclone diurnal cycle is an important physical process that may be a fundamental characteristic of all tropical cyclones and tropical convection in general. The experimental real-time diurnal cycle web page will be used to monitor this phenomenon during the 2012 Atlantic hurricane season and is available at:
http://tropic.ssec.wisc.edu/real-time/tc_diurnal_cycle/tc_diurnal_cycle.php

Research Performance Measure: Although this research project is just 1-year in maturity, the following tasks have been completed to facilitate continued development of this project:

- The PI presented preliminary findings and results of the tropical cyclone diurnal cycle project *Diurnal Pulsing of Tropical Cyclones: An Overlooked Yet Fundamental TC Process?*; at the following invited seminars/conferences:
    1) NASA Goddard Space Flight Center, Guest Lecturer (Nov 2011)
    2) 65th Interdepartmental Hurricane Conf., Charleston, SC (March 2012)
    3) University of Wisconsin-Madison Department of Atmospheric & Oceanic Sciences, Guest Lecturer (March 2012)
    4) 30th Conference on Hurricane and Tropical Meteorology, Ponte Vedra Beach, FL (April 2012)
- The PI traveled to the University of Wisconsin-CIMSS to collaborate with scientists at CIMSS under a successfully funded proposal to the NOAA/NESDIS/GIMPAP Visiting Scientist Program. These two trips facilitated the development of an experimental real-time web page for monitoring the tropical cyclone diurnal cycle in storms around the globe and will be run throughout the 2012 Atlantic hurricane season;
- The PI submitted a successful proposal to the NASA Roses HS3 announcement titled, "*Utilizing NASA Reconnaissance Assets to Investigate Hurricane Upper-level Warm Core Evolution, Inner Core Pulsing, and Near-Environment Moisture Interactions*". This effort will facilitate continued advancements in the understanding of tropical cyclone diurnal pulsing;

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Development of an Objective Scheme for Predicting Tropical Cyclone Genesis

Project Personnel: J.P. Dunion (UM/CIMAS)
NOAA Collaborator: J. Kaplan (AOML/HRD)
Other Collaborators: A. Schumacher (Colorado State University); J. Cossuth (FSU)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** To develop and objective probabilistic scheme for predicting the likelihood of tropical cyclone genesis for tropical disturbances of interest. To design a scheme that provides a unique tool to forecasters that specifically focuses on insipient tropical systems and provides objective guidance of the probability of genesis in both the 0-48 and 0-120 hr timeframes.

***Strategy*:** Submitted a successfully funded proposal to the NOAA Joint Hurricane Testbed titled, "*Development of a Probabilistic Tropical Cyclone Prediction Scheme*". Development and testing of this new Tropical Cyclone Genesis Index (TCGI) began in late summer 2011. Current year-1 efforts include identifying and testing potential environmental, "inner core", and satellite-based predictors that will be used in the operational version of the TCGI.

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

Link to NOAA Strategic Goals:
***Goal 2*:** Weather-Ready Nation - *Society is prepared for and responds to weather-related events*

NOAA Funding Unit: NWS/NHC/JHT
NOAA Technical Contact: Jiaan-Gwo Jiing

Research Summary:
Forecasts for Atlantic tropical cyclone (TC) track have been steadily improving over the past several decades. However, advancements in predicting TC intensity have been much more modest. This relates to our limited understanding of the various synoptic and mesoscale influences that can impact TC intensity, as well as the fact that successful intensity forecasts are highly affected by the accuracy of the associated track forecast. TC genesis represents an intensity forecasting challenge and is perhaps one of the more difficult stages of the tropical cyclone lifecycle to diagnose and predict. Tropical disturbances are vastly under sampled phenomenon in the North Atlantic and account for <10% of all NOAA aircraft missions that have been conducted since the middle 1970s. Unfortunately, there are also limited resources available to forecasters to objectively identify and predict TC genesis in the North Atlantic basin. Although NOAA's National Hurricane Center (NHC) has developed a 0-48-hr operational and 0-120-hr experimental "in-house" probabilistic scheme for identifying TC genesis potential, it is a highly subjective process. Additionally, Colorado State University/CIRA has developed an operational NESDIS TC Formation Probability (TCFP) product that determines the 24-hour probability of TC formation in each 5 x 5 degree latitude/longitude grid box in its basin-wide domain. However, the TCFP product is not disturbance-specific and simply determines the probability of TC genesis across the entire basin. Its 5 x 5 degree grid spacing is also relatively course. Finally, although the Statistical Hurricane Intensity Prediction Scheme (SHIPS) represents a valuable tool for forecasting the prediction of TC intensity change, it was developed for storms of tropical depression and greater intensity and was not intended for predicting TC genesis.

This project combines some of the strengths of both the NHC genesis scheme and the NESDIS TCFP product to develop a storm-centric TC Genesis Index (TCGI) to provide forecasters with an objective tool for identifying the probability of TC genesis (0-48 hr and 0-120 hr) in the North Atlantic basin. Two new predictors are also being incorporated that show promise for improving the prediction of TC genesis and are not currently being utilized operationally: total precipitable water (TPW) microwave satellites and Dvorak T-numbers (a technique employed by forecasters that uses pattern recognition in infrared satellite imagery to estimate TC intensity). Dvorak T-numbers range from 1.0 to 7.5 and increment by 0.5 T-number values. Tropical disturbances that are not sufficiently organized to attain a 1.0 T-number are assigned as "TWTC (Too Weak to Classify) and systems generally reach tropical storms intensity near 2.0. Research under this project indicates that pre-genesis Dvorak T-number information is a robust predictor of possible storm development and is routinely available for analysis across the North Atlantic basin (Fig. 1). These satellite-based and other top TC genesis predictors are currently being used to develop the objective TCGI that will be utilized by forecasters to provide estimates of the probability of TC genesis over a period of 0-48 and 0-120 h.

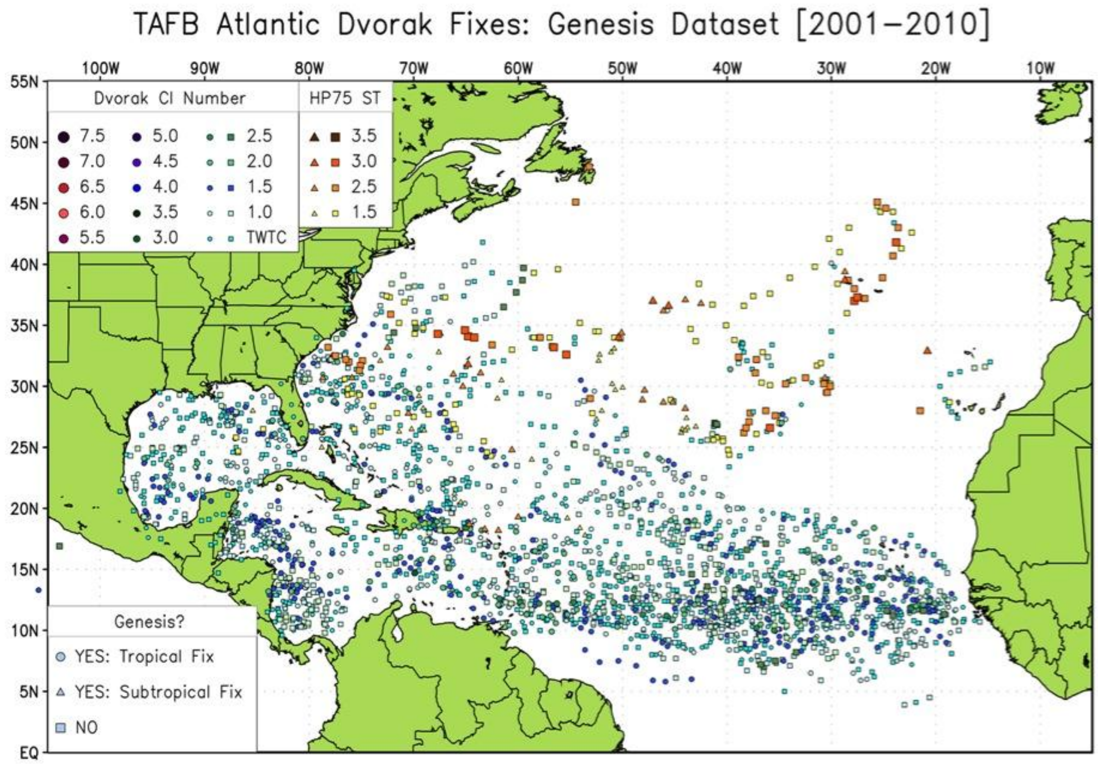

Figure 1: North Atlantic Dvorak intensity fixes conducted by the NOAA Tropical Analysis and Forecast Branch from 2001-2010. The initial Dvorak CI (current intensity) numbers (TWTC through 7.5) are indicated by the color shading. Circles (triangles) indicated that the tropical (subtropical) disturbance eventually developed into a tropical cyclone, while squares indicate that the storm did not develop.

Research Performance Measure: This project is in the year-1 phase of a proposed two-year effort. Accomplishments that focus on the objective of creating a real-time TC Genesis Index for operational use include:

1. The PI was successfully funded by the NOAA Joint Hurricane Testbed to develop the TCGI;
2. The proposal team has completed the development of the Dvorak Database and incorporated disturbance positions, T- numbers, and CI (current intensity) numbers into the TCGI database;
3. The proposal team is currently working to complete a special tropical disturbance forecast model that will be utilized in the TCGI scheme to determine various genesis predictor values along the forecast track (out to 5 days);
4. The proposal team is currently working to identify/develop potential environmental predictors for the TCGI database;
5. The PI presented year-1 project results at the 65th Interdepartmental Hurricane Conf., Charleston, SC (March 2012): *Development of a Probabilistic Tropical Cyclone Genesis Prediction Scheme*;
6. The PI submitted a mid-year report (Feb 2012) and year-2 renewal proposal (April 2012) to NOAA JHT.

Ocean Modeling to Improve Coupled Forecast Model Intensity Forecast for the Hurricane Forecast Improvement Project (HFIP)

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

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** Improve ocean model performance in coupled hurricane forecast models for improving intensity forecasts.

***Strategy*:** 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 in coupled forecast models. Evaluate and improve ocean model performance in the HWRF coupled forecast model.

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*:** Weather-Ready Nation - *Society is prepared for and responds to weather-related events*

NOAA Funding Unit: NWS/HFIP
NOAA Technical Contact: Dr. Robert Gall, NWS/OST

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. It is also critically important to quantify the importance of the ocean in hurricane intensity evolution. The ocean impact on intensity is a function of ocean heat content, storm size, storm intensity, and storm translation speed, and we presently have a poor quantitative understanding of the importance of the ocean compared to the impact of atmospheric processes such as shear and dry air entrainment. This project has two primary goals: (1) improve the accuracy of data-assimilative ocean analysis products used to initialize the ocean component of coupled hurricane forecast models and (2) collaborate with NOAA/NCEP/EMC to evaluate ocean model performance in the HYCOM-HWRF coupled hurricane forecast model.

For model initialization, our strategy 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. 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. The next step will be to evaluate and calibrate if necessary the OSSE system in the Gulf of Mexico, then perform OSSEs to evaluate targeted observing strategies to optimize pre-storm ocean model initialization for coupled forecasts.

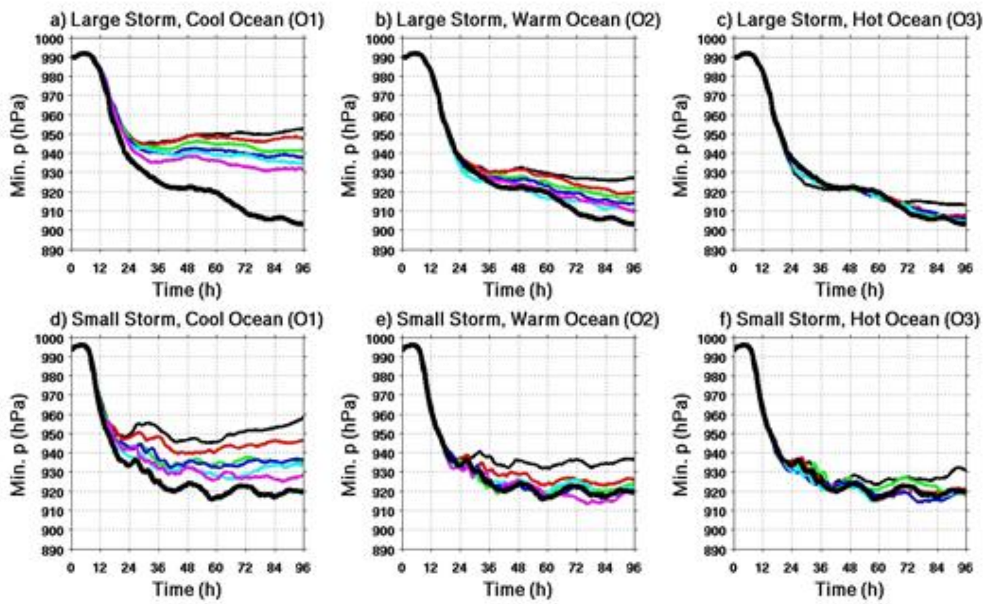

Figure 1: Evolution of minimum central pressure in idealized coupled forecast experiments. The final storm intensity is a function of storm size (large storms in the top row and small storms in the bottom row), ocean heat content (cool ocean in the left panels, warm ocean in the middle panels, and hot ocean in the right panels), and storm translation speed. In each panel, colors represent stationary storms (thin black lines) and translation speeds of 2, 4, 6, 8, and 10 m s^{-1} (red, green, blue, cyan, and magenta lines). The thick black lines represent uncoupled experiments.

To evaluate ocean model performance in coupled forecasts, two approaches are being used. The first is to evaluate ocean model performance in the HYCOM-HWRF forecast model that is now being tested for possible operational implementation within the next two or three years. Ocean model output from test forecasts will be analyzed against available ocean observations to identify errors and biases in the forecast ocean response, and then use this information to devise strategies to improve ocean model performance. The second approach is to collaborate with HRD modelers to perform idealized studies of the impact of ocean and storm parameters on the intensity evolution in coupled forecasts. A large set of experiments were designed to minimize the impact of atmospheric processes on intensity and thus allow the impact of the ocean to be unambiguously identified and quantified. Figure 1 demonstrates that ocean heat content, storm size, and storm translation speed have significant impact on the equilibrium intensity of hurricanes. This study aims to understand the processes responsible for this impact. Figure 2 illustrates the impact of SST cooling on reducing the enthalpy flux from ocean to atmosphere that is the source of fuel for the storms. The idealized experiments are being analyzed to identify the physical processes controlling the complex interactions between the oceanic and atmospheric surface boundary layers that controls SST cooling and enthalpy flux.

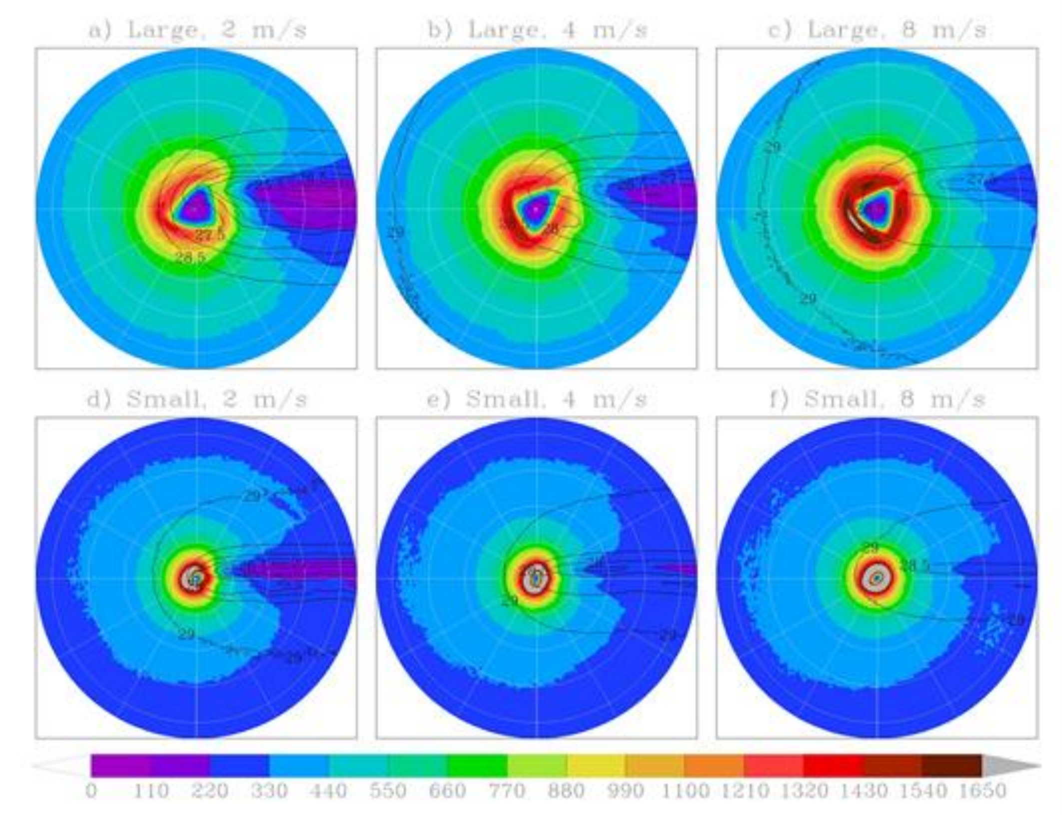

Figure 2: Surface enthalpy flux (colors) and SST (contours) for six idealized experiments representing large storms (top row) and small storms (bottom row) for three different storm translation speeds: 2 m s^{-1} (left panels), 4 m s^{-1} (middle panels) and 8 m s^{-1} (right panels).

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.

Multimodel Ensembles for Hurricane Forecasts

Project Personnel: T.N. Krishnamurti and R.O. Lawton (FSU)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** To advance the state of hurricane forecast (for track and intensity) out to day 5 of forecasts.

***Strategy*:** The strategy we deploy here is to utilize a multimodel superensemble method using the results from a suite of mesoscale hurricane forecast models.

CIMAS Research Theme:

***Theme 2*:** Tropical Weather

Link to NOAA Strategic Goals:

***Goal 2*:** Weather-Ready Nation - *Society is prepared for and responds to weather-related events*

NOAA Funding Unit: NWS
NOAA Technical Contact: Stephen J. Lord

Research Summary:

First it should be stated that the results from the FSU multimodel superensemble are far better than those of all members of the suite of models. It is important for NOAA to find means to make this operational since the results are quite impressive, as we noted from many years of research. The hurricane forecasts covering the seasons 2010 and 2011 are included in our proposal's task line and those results are summarized here. The member models utilize a variety of physical parameterization schemes, a variety of assimilation schemes, initial vortex bogussing and the treatment of the atmosphere-ocean interface fluxes. Forecasts are made every 12 hours. The method for ensemble forecasting follows our recent papers, Krishnamurti et al (2010, 2011). We have a training phase where the x and y coordinates of the storm position and the storm intensity are used as the prime variables for the construction of the multimodel superensemble. Those data sets are first collected for some 100 recent hurricane forecasts of a previous year. The training phase of the multimodel superensemble finds the statistical weights from regression (against observed storm positions and intensity) for the three variables using each 6 hourly forecast for all the recent past storms. Those statistical weights are next used in the forecast phase for hurricanes of the 2010 and 2011 seasons. An important step in this exercise is the exclusion of outliers during the training phase. The outliers for position and intensity variables exceeding twice the standard deviation with respect to the mean are excluded from the training inventory. This step is very important for improving the training phase statistical weights. The results on track and intensity forecast errors for the hurricanes of 2010 and 2011 seasons are shown in figures 1a and 1b. The results from the multimodel superensemble are shown by a red bar. Here the ordinate denotes the errors for the position (in nautical miles) and intensity (in knots), the abscissa denotes the hours of forecast, and the vertical bars denote the performance for the members of the mesoscale model suite. Overall the results, based on the multimodel superensemble, of the mesoscale model suite stand out quite glaringly. These vertical bars also include a baseline for the expectation of NOAA (defined by NHC) which is exceeded by the multimodel superensemble in its performance.

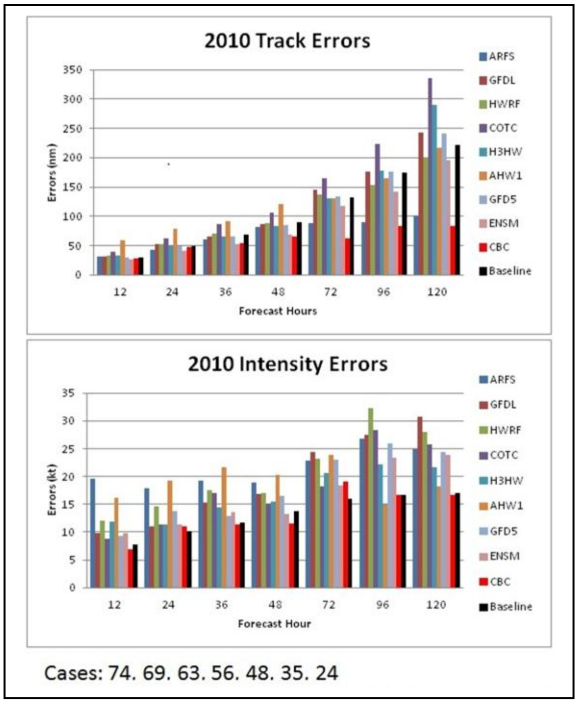

Figure 1a: Track and intensity forecast errors for all the hurricanes of 2010.

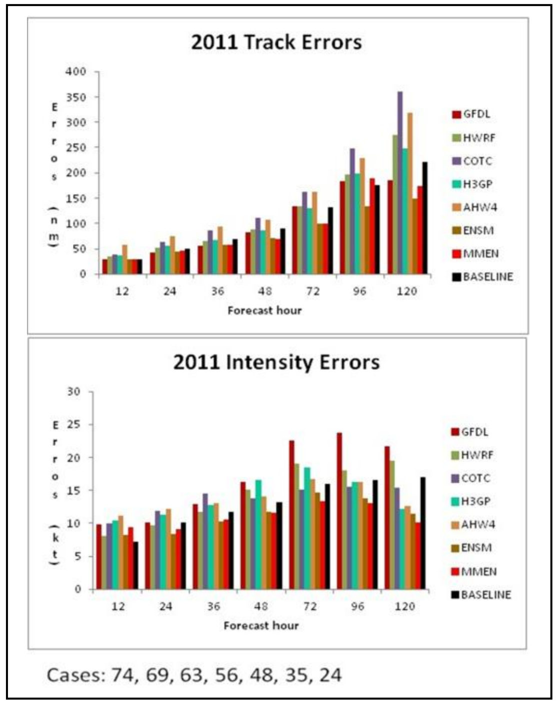

Figure 1b: Track and intensity forecast errors for all the hurricanes of 2011.

Research Performance Measure: The track forecast improvements of the multimodel superensemble are of the order of 150 nm for day 5 of forecasts and the corresponding intensity forecast improvements are of the order of 10 knots.

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

Project Personnel: S. Lorsolo, A. Aksoy, 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 investigate the Hurricane Boundary Layer (HBL) kinematic and turbulent structure to better understand the HBL physical processes impacting hurricane intensity change and to help evaluate numerical weather prediction models. To improve intensity forecasting by providing high-resolution observational data of the HBL to the data assimilation and model community.

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 2*:** Weather-Ready Nation - *Society is prepared for and responds to weather-related events*

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

Research Summary:
The hurricane intensity forecast problem has long been one of the main challenges of the hurricane research and forecasting community. Various aspects and regions of the hurricane structure have been investigated to better understand the physical processes impacting hurricane intensity and thus improve intensity forecast.

The present research project focuses on 2 main objectives:
1. Identify and characterize the role of the HBL in the intensification process
2. Provide an accurate representation of the kinematic and turbulent structure of the HBL for a better evaluation of mesoscale numerical models.

The primary observations used in this project are the NOAA tail Doppler radar data and more particularly the two-dimensional profiles of reflectivity, wind (Fig. 1) and turbulent kinetic energy produced by HRD radar analysis software. Accuracy in the retrieved wind is essential to best diagnose numerical models, so an additional step was taken in the project: evaluation of the software. This evaluation is under way. Doppler radar data were simulated using HRD Observing System Simulation Experiments (OSSE) system, run through the radar analysis software and compared to the original "truth" field. Because part of this work is also related to a study from the Hurricane Forecast Improvement Project (HFIP) requiring large data sets, one other task was to expand the Doppler radar database. More data were processed. The data were categorized by intensity, change in intensity and shear direction and magnitude to help model diagnosis. Results from last year's gap experiment project were used as guidance to produce merged analyses. Doppler analyses from 7 storms were produced and added to the database.

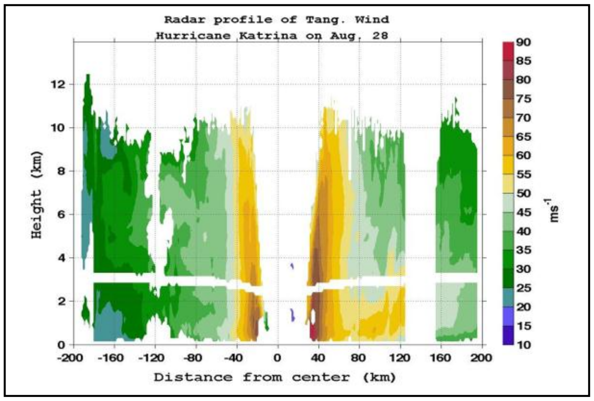

Figure 1: Tangential wind profile from Hurricane Katrina

The other focus of this project is to better understand the role of the HBL in the intensification process. Doppler observations are used to investigate theoretical work on hurricane intensification. The analysis focuses on comparing the HBL structure between strong (best track intensity > 120 kt) and weak storms (best track intensity < 105 kt) and assessing the angular momentum budget and supergradient wind between these 2 groups, using the Doppler radar analyses. Figure 2 presents the distribution of inflow magnitude at 150 m altitude near the eyewall and shows that stronger storms exhibit statistically significantly stronger inflow than weaker storms. Figure 3 shows a comparison of the advection of angular momentum between the groups, suggesting that stronger storms might produce more supergradient wind. This result supports the hypothesis that the advection of angular momentum is a critical mechanism in the intensification process.

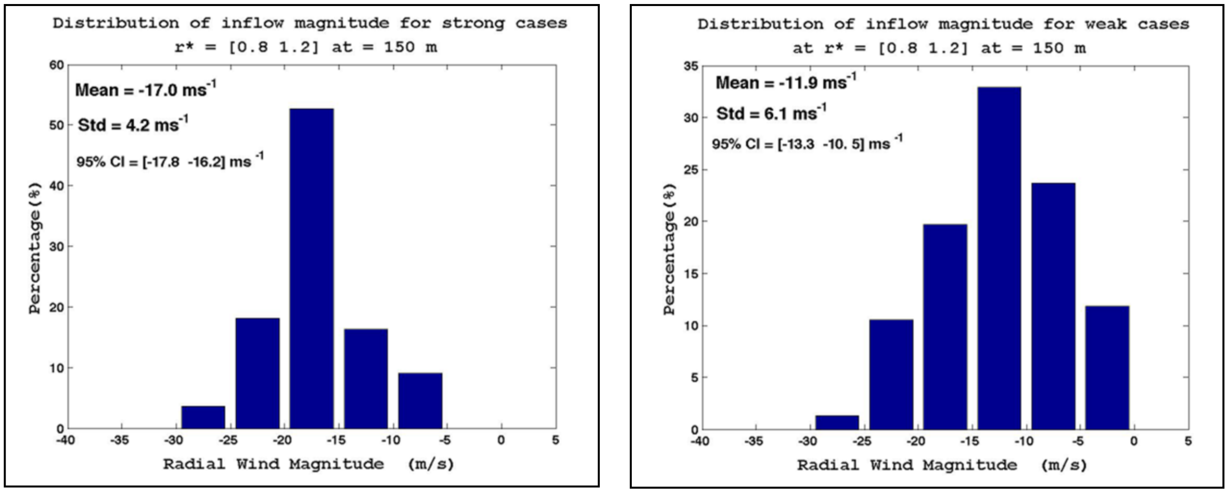

Figure 2: Distribution of inflow magnitude for strong (left) and weak (right) storms

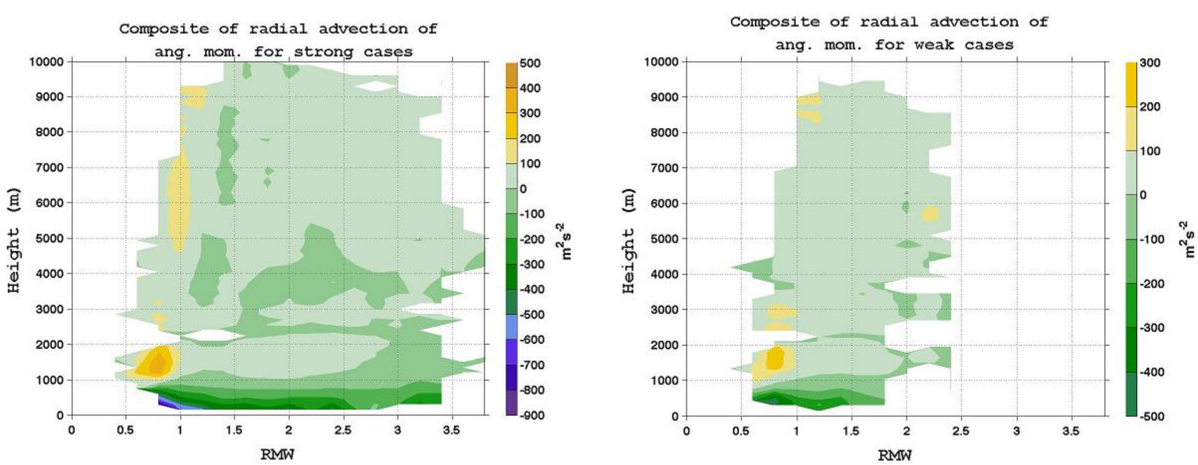

Figure 3: Composites of angular momentum advection for_strong (left) and weak (right) storms.

Research Performance Measure: Project is on schedule. Preliminary findings were presented at the AMS Hurricane Conference. Results from the gap experiment project were published in the Monthly Weather Review journal. Work on HFIP is on schedule, with the Doppler radar database constantly expanding. Initially, the goal was to compare the HBL structure between intensifying storms versus steady state storms, but the current data set does not yet allow for such comparison. Thus, the HBL work was delayed. However, with the expansion of the dataset, this initial idea will be revisited in the future. Progress was however made using the comparison between storms of different intensity. Finally, the first draft on the evaluation of the analysis software is being completed.

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

Project Personnel: D.S. Nolan (UM/RSMAS)
NOAA Collaborator: R. Atlas (NOAA/AOML)

Long Term Research Objectives and Strategy to Achieve Them:
***Objectives*:** To contribute to the development of a complete observing system simulation 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 2*:** Weather-Ready Nation - *Society is prepared for and responds to weather-related events* (*Primary*)
***Goal 4*:** Resilient Coastal Communities and Economies - *Coastal and Great Lakes communities that are environmentally and economically sustainable* (*Secondary*)

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

Research Summary:
The goal of this project 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.

In the past year, the nature run simulation was completed and has ben archived at the University of Miami Center for Computational Sciences data storage system. The simulation took about 3 weeks running on 96 processors, using about 48,000 CPU hours. Before successful completion, the nature run simulation had to be restarted about halfway through, twice, to address obvious flaws in the simulation.

Since completion of the simulation, our work has focused on "validating" the simulation; that is, determining how well it reproduces the structure and behavior of a real hurricane. Since the simulation is based on a hurricane that occurred within a global nature run (another free-running simulation), it does not correspond to a hurricane that actually occurred. Thus, we must compare our simulated hurricane to composites of data from real storms. To date, we have validated the simulation in the following ways: we have evaluated its wind-pressure relationship; we have compared its boundary layer to composites from observed hurricane boundary layers; we have compared to a data set of the outward slope of the eyewall; and we have evaluated the diurnal cycle of convection. The nature run hurricane is remarkably realistic in all of these aspects except for its eyewall slope: similar to many previous simulations, the eyewall slopes outward much more than it should when compared to real storms.

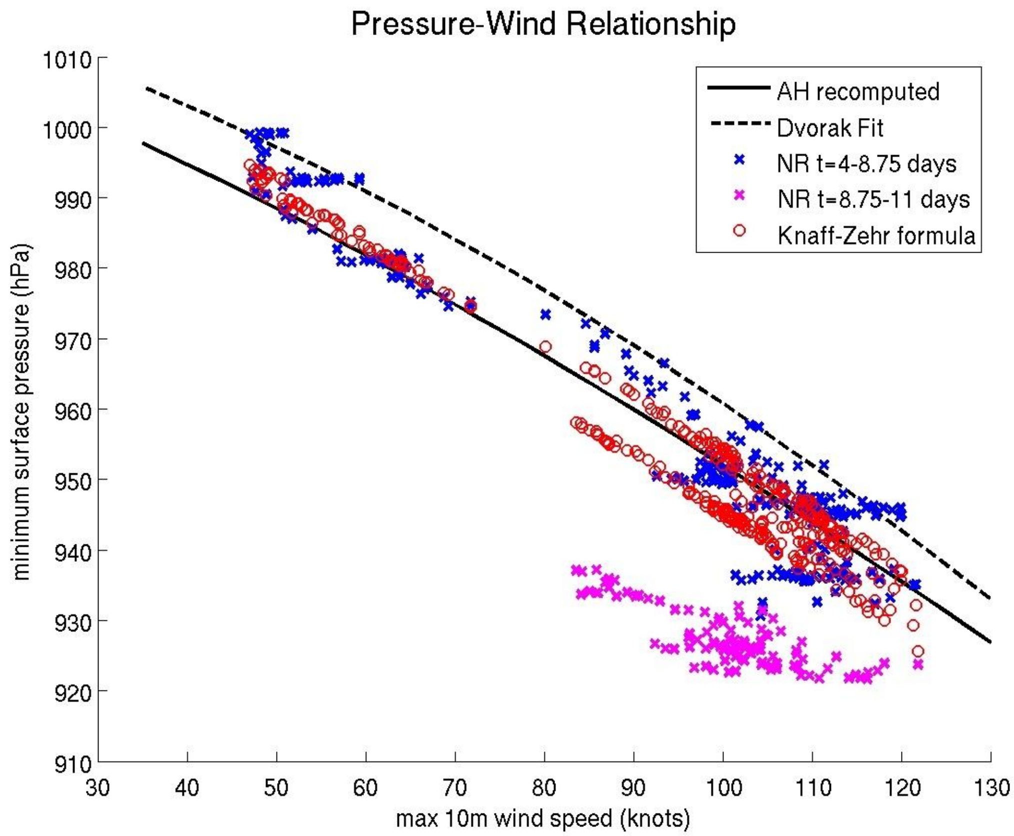

Figure 1: This figure plots instantaneous values of the minimum surface pressure versus the peak surface wind speed every 30 minutes from day 4 through day 11. Also shown are a curve for the Atkinson-Holliday formula, a curve that fits the Dvorak table, and pressure values predicted by wind speed from a new formula developed by Knaff and Zehr (2007). During the period of days 4-8.75, the RMS error between the nature run and the Knaff-Zehr formula is 4.5 hPa, which is less than the error between the formula and the data to which it was fit. After 8.75 days, the simulated hurricane expands and its pressure becomes anomalously low, much like Hurricane Irene (2011).

Research Performance Measure: Most of the goals for the project in the past year have been met. What remains is to further validate the simulated hurricane against other known aspects of real hurricanes, such as the spatial distributions of reflectivity and vertical velocity. A publication documenting the development and validation of the simulation is in preparation.

Real-Time Hurricane Wind Analysis

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 2*:** Weather-Ready Nation - *Society is prepared for and responds to weather-related events*

NOAA 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, wind contour plots compatible with Google framework, wind swaths, and Hovmoller diagrams. Each analysis is published with a self-explanatory metadata file compliant with FGDC (Federal Geographic Data Committee).

HRD researchers expressed interest to use H*Wind past and future analyses to evaluate forecast model in terms of surface wind structure, and potentially introduce new model diagnostic tools. It was determined that additional analysis results should be appended to the ATCF-formatted file currently produced to easily share results with others. The database was altered to store observed maximum wind vector components, its radius, central pressure and uncertainty errors. Additional effort will be required to pull those results from all operaional analyses since 2008 and ingest them according to the new database schema, in order to utlimately reproduce the desired ATCF-like files for historic events.

Experiments were conducted with the objective of producing wind analyses larger than the traditional 8x8-degree domain size. For a higher quality representation, it is important to adapt analysis domain size to the extensive wind field of hurricanes like Betsy in 1965 or, more recently, tropical storm Debby, which covered a large area in the Gulf of Mexico.

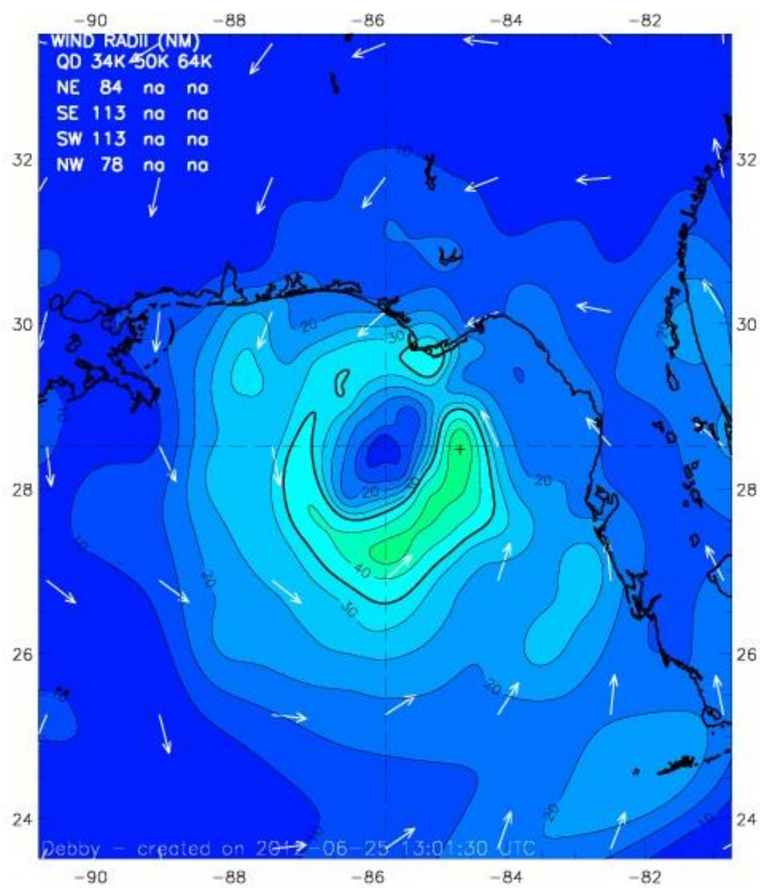

Figure 1: A 10x10-degree H*Wind analysis of tropical storm Debby, June 25, 2012, 0430 UTC.

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

A Sixteen-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 Them:

***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 1*:** Climate Adaptation and Mitigation - *An informed society anticipating and responding to climate and its impacts* (*Primary*)

Goal 2: Weather-Ready Nation - *Society is prepared for and responds to weather-related events* (*Secondary*)

NOAA 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 vertical profiles of wind velocity, temperature, humidity, and mass 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 thermo-dynamics, and in studies of targeted observations and predictability, as well as in climate research and numerical model evaluation. Hundreds of these profiles are obtained annually in the Atlantic and northern Pacific Oceans, and may soon become available in the Indian Ocean.

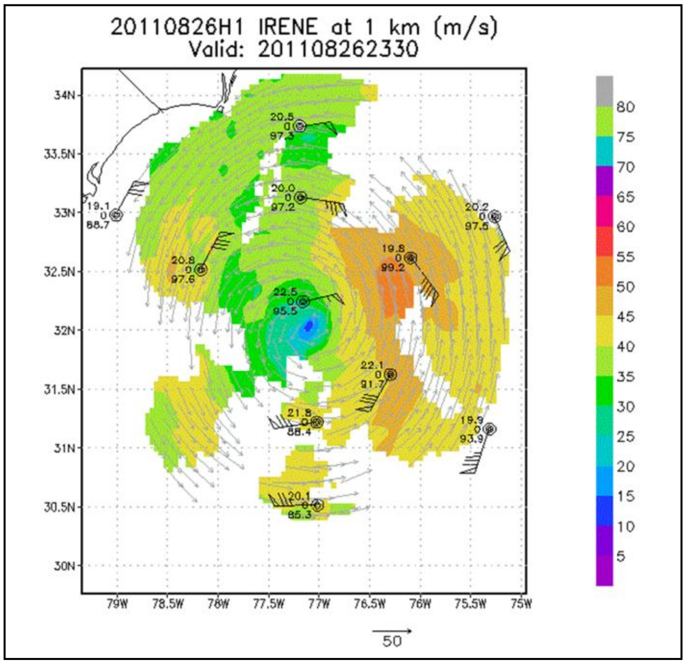

Figure 1: Wind field at a height of 1 km. for hurricane Irene, valid 0Z, August 27, 2011 produced from a composite of radar and dropwindsonde data. Graphics such as these provide a quick look at the hurricane inner core structure.

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 so that it can be easily ingested into numerical models. One such program produces estimates of the missing fields and formats the information in a manner that enables a quick look at the data and provides high-resolution observation times and locations that are essential for data assimilation with advanced hurricane forecasting models. These programs have been successfully implemented for real-time data assimilation into HRD's experimental version of the Hurricane Weather Research and Forecasting model (HWRFx) during the 2010 and 2011 Atlantic hurricane seasons and in retrospect for the 2008 and 2009 seasons (See Figure 2). The codes are publicly available upon request and are frequently refined 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.

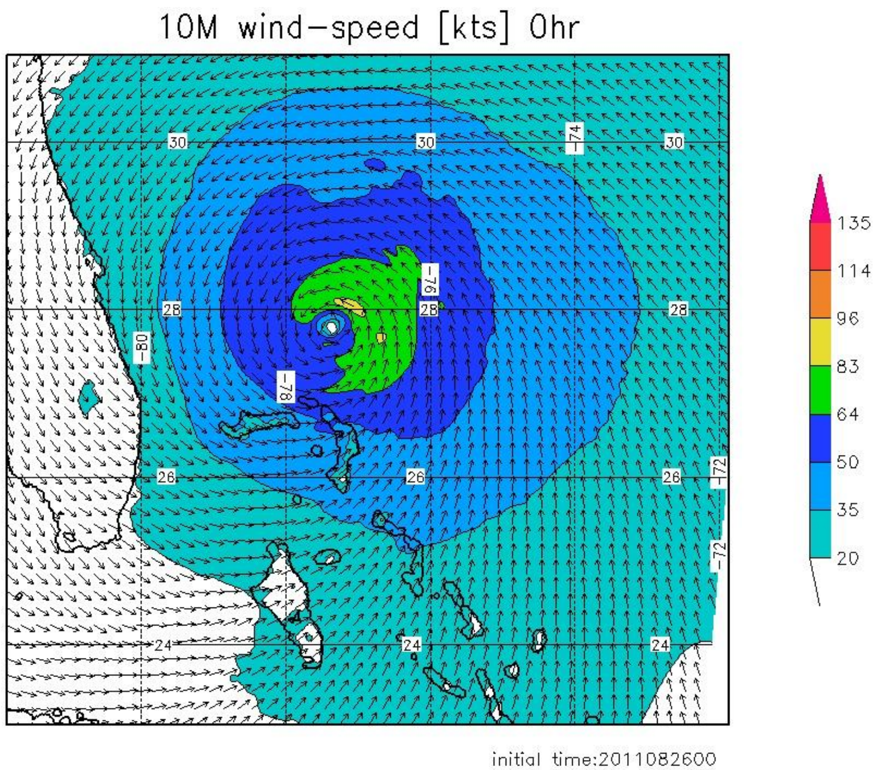

Figure 2: Initial condition for the high-resolution HWRF model produced by assimilating dropwindsonde and other date collected using NOAA and USAF aircraft.

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

Extreme Surface Wind Observations in Recent Category-5 Tropical Cyclones

Project Personnel: B. Klotz (UM/CIMAS), J. Zhang (UM/CIMAS)
NOAA Collaborator: E. Uhlhorn (NOAA/AOML)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** To examine the surface and boundary layer fields within extreme tropical cyclones to evaluate the nature of the extreme surface wind speeds

***Strategy*:** To use radial profiles of flight-level and stepped frequency microwave radiometer (SFMR) data from several extreme tropical cyclones and extend previously defined flight-level to surface relationships to extreme conditions

CIMAS Research Theme:

***Theme 2*:** Tropical Weather

Link to NOAA Strategic Goals:

***Goal 2*:** Weather-Ready Nation - *Society is prepared for and responds to weather-related events*

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

Research Summary:

On rare occasions, tropical cyclones (TCs) reach extreme intensities ($\geq$ 155 kts, 80 m s^{-1}) when environmental conditions allow. Such storms are characterized by extremely peaked wind radial profiles, small maximum wind radii, and compact eyes in satellite imagery. This set-up can be found at the conclusion of a rapid intensification period and tends to remain for one to two forecast cycles, at which point the eyewall tends to collapse or an eyewall replacement cycle begins. Some wind data recently obtained in several intense category-5 TCs indicate that surface-to-flight-level wind speed ratios may exceed 1.0 in these extreme cases where more typical values are on the order of 0.85-0.90. Recent analyses of flight-level reduction factors suggest that slant reduction factors tend to increase with inertial stability (I) at the radius of maximum wind (RMW).

Flight-level (700 mb) and stepped-frequency microwave radiometer (SFMR) surface wind data are used to construct radial profiles of axisymmetric wind speed and gradient wind for 36 individual hurricane flights, including Hurricane Felix (02 Sept. 2007) and Supertyphoon Megi (17 Oct. 2010). Additionally, 700 mb flight-level data were obtained in Hurricane Wilma (19 Oct. 2005). Individual radial profiles are averaged together to compute a symmetric mean. Flight level geopotential height (Z) observations are utilized to estimate the radial profile of gradient wind. Ratios of maximum surface to flight-level axisymmetric average wind speed are computed for each case, and placed within the context of results of previous studies, which found that ratios tended to increase with I, as measured at the flight level radius of maximum wind (RMW). Extending this work, ratios of maximum surface wind to maximum flight-level gradient wind are computed here for several hurricanes. Linear regression is used to develop statistical relationships between flight-level reduction ratios and wind speeds relative to gradient-balanced winds, for a broad range of storms, including Felix and Megi. These relationships are extended to estimate maximum surface winds for Wilma, in which no SFMR data were obtained on the day of interest.

Figure 1 shows the ratios of maximum axisymmetric average flight-level wind speed to maximum gradient winds as a function of I at the flight-level RMW. From this figure it is possible to see that the extreme cases fit fairly well into this previously defined relationship. While the Wilma case has a much higher value for inertial stability, the ratio fits well into the relationship defined by the weaker storm cases as well. If the ratio between the maximum surface wind and the maximum gradient wind is considered in relation to both flight-level and surface inertial stability parameters (calculated at the respective RMWs), the extreme cases also compare well with the relationship previously determined with the weaker storms, which is shown in Fig. 2. Figure 2a implies that with extreme TCs, it is expected that the maximum surface wind speed will be super-gradient. Due to the lack of surface wind speed measurements from the SFMR in this particular hurricane Wilma case, the relationships given in Fig. 2 can be used to extrapolate maximum axisymmetric average wind speeds of 94 m s^{-1} (182 kts). Surface wind speeds of this magnitude have never been physically observed to date in a tropical cyclone.

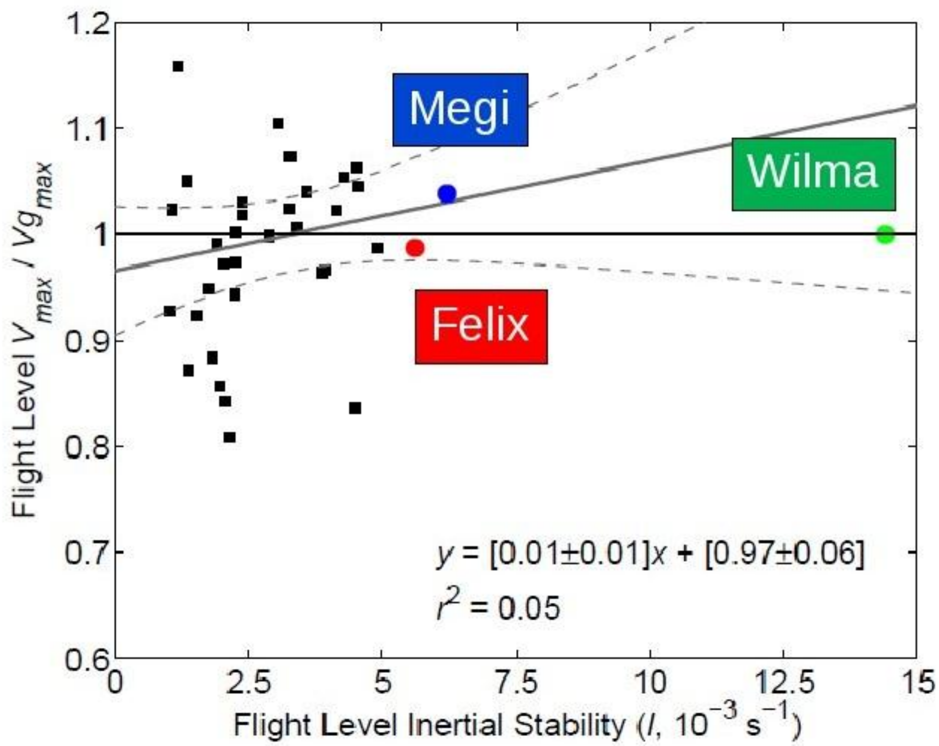

Figure 1: The ratio of flight-level maximum wind to flight-level gradient wind (both axisymmetrically averaged) as a function of flight-level inertial stability. The black squares indicate the weaker cases initially used in development of the relationship, and the three extreme cases of interest are shown in red (Felix), blue (Megi), and green (Wilma). The black line indicates the linear regression relationship as denoted by the equation presented on the figure.

The ideas presented here show that even though extreme TCs are a rare event, they do produce results that fit existing intertial stability relationships. These results also show that if no surface measurements exist for extreme cases, surface measurements can be extracted within a reasonable amount of error spread.

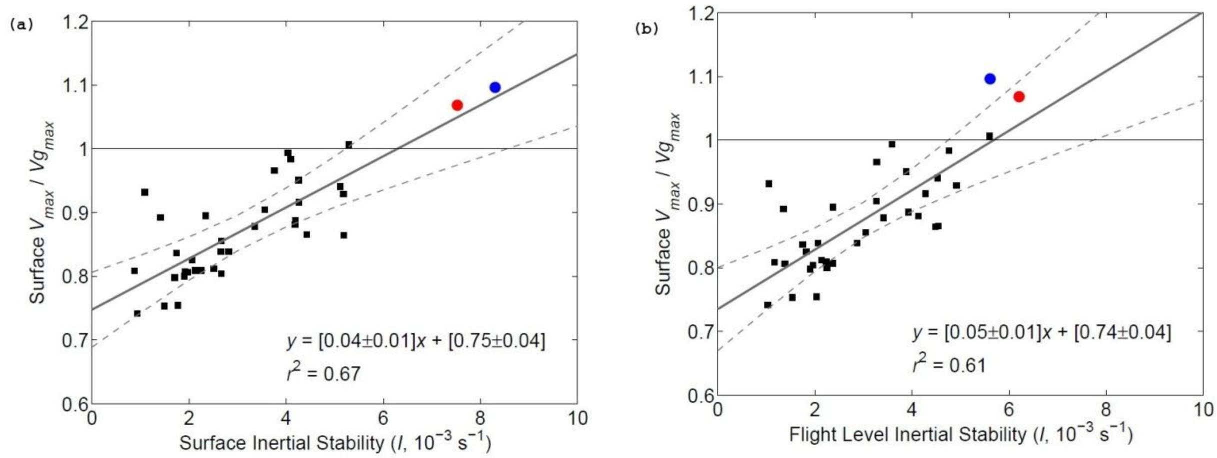

Figure 2: Similarly to Fig. 1, the ratio of maximum surface wind to maximum surface gradient wind as a function of (a) surface inertial stability and (b) flight-level inertial stability are shown. As in Fig. 1, red indicates the Felix case and blue indicates the Megi case.

Research Performance Measure: All major research objectives related to this project have been met. The project personnel are beginning to draft a manuscript for publication.

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Improved SFMR Surface Wind Measurements in Intense Rain Conditions

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

Long Term Research Objectives and Strategy to Achieve Them:
***Objectives*:** To reduce the SFMR wind speed bias in the presence of heavy precipitation
***Strategy*:** To quantify the wind speed errors associated heavy precipitation conditions and to expand the SFMR vs. dropwindsonde database in order to develop a bias correction model that can be applied to real-time SFMR wind speeds

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

Link to NOAA Strategic Goals:
***Goal 2*:** Weather-Ready Nation - *Society is prepared for and responds to weather-related events*

NOAA Funding Unit: NWS/NHC/JHT
NOAA Technical Contact: Jiann-Gwo Jiing

Research Summary:
The airborne stepped frequency microwave radiometer (SFMR) estimates surface winds and rain rate in most conditions, but is particularly useful in tropical cyclones. However, due to a couple of potential factors, retrieval accuracy has been shown to be degraded in weak-to-moderate winds

coupled with strong precipitation. In particular, winds are typically overestimated in such conditions. Quantifying the errors associated with these situations will be helpful for resolving this problem.

To accomplish this goal, an SFMR vs. GPS dropwindsonde database has been expanded to include a broader distribution of wind speed and rain rate combinations to assess accuracy in all expected conditions. In a previous observational sample, only 103 of the 1591 dropwindsondes were collected in weak-to-moderate winds and heavy precipitation. With our efforts to collect the data, especially during the 2011 season, this number increased by over 20%. Although direct observations were obtained, these conditions continue to remain relatively under-represented in the overall data sample. To improve the representation, synthetic dropwindsonde surface wind observations were estimated from the observed flight-level wind speeds. An average relationship between the "WL150" dropwindsonde wind speed (U_{WL150}) and ~700-mb flight-level wind speed U_{FL} is developed based on observations obtained in 2010-2011 and is used to obtain expected U_{WL150} wind speeds that can be adjusted to the surface.

With the database sufficiently expanded, a random sample of 80% of the total population was extracted for developing a bias correction model. The remaining paired samples (20%) are subsequently used to evaluate the results of the bias correction. The SFMR surface wind speed and dropwindsonde surface-adjusted wind speed differences were binned into four rain rate (R) bins and five wind speed (U_{SFMR}) bins. Synthetic dropwindsondes were weighted relative to the real dropwindsonde surface-adjusted wind speed least-squares fit to the SFMR wind speed. All real data are given the highest weight in this process. Weighted mean differences and error statistics are computed for each bin, and a polynomial function is fit to the bin-averaged differences. Figure 1 shows this relationship and includes the bin averages, counts, and relative weights applied for the calculation of the polynomial fit. Figure 1 indicates that for low wind speeds and high rain rates, the SFMR wind speed bias is largest, and conversely, the bias is smallest for high winds and low rain rates. In particular, at minimal tropical-storm force winds (~17 m s^{-1}), the SFMR tends to over-estimate the wind speed by at least 4.5 m s^{-1} when the rain rate exceeds 30 mm hr^{-1}.

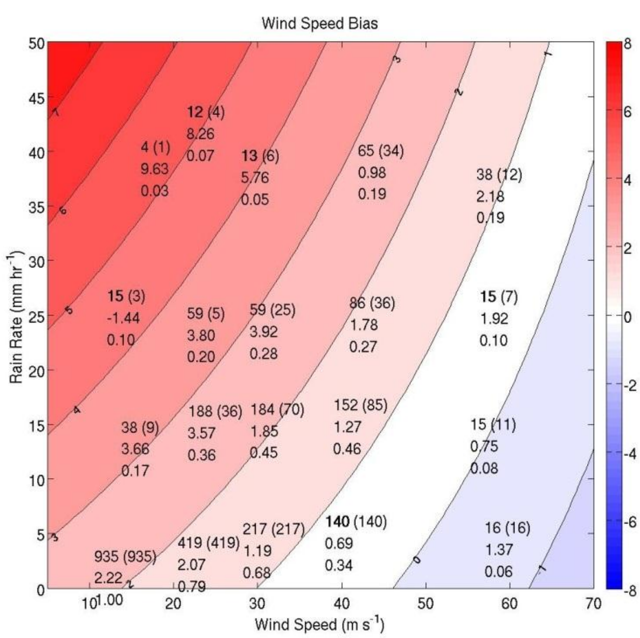


Figure 1: Fitted wind speed bias (ΔU) function showing contours every 1 m s^{-1} with warmer colors representing higher biases and colder colors representing lower biases. Values are located at the mean wind speed

The improvement in the SFMR surface wind estimate by applying the bias model is evaluated using the remaining 20% of the sample not used for model development. For each paired dropwindsonde and SFMR (U_{sfc} vs. U_{SFMR}) sample, the ΔU is computed from U_{SFMR} and R, and is then subtracted from U_{SFMR} to obtain a "corrected" SFMR surface wind (U_{corr}). The overall accuracy of corrected observations relative to U_{sfc} data is found to be within 3.2 m s^{-1}, or an improvement of 1.4 m s^{-1} (31%). The overall bias is reduced to 1.0 m s^{-1}, which is a 50% improvement. Since we are specifically interested in improving the wind speed estimate at weak-to-moderate winds and heavy precipitation, we have examined the improvement where $U_{SFMR} < 33$ m s^{-1} and R > 20 mm hr^{-1} (Fig. 2). In this particular range, the accuracy improves from 5.4 m s^{-1} to 2.6 m s^{-1} (51%), and the bias is reduced from 2.9 to 0.8 m s^{-1} (72%). These results are encouraging and provide a substantial foundation for resolving the issue of rain-contaminated wind speeds from the SFMR. With these improvements, forecasters will be able to better assess the surface wind speed of tropical cyclones, especially weaker and developing systems.

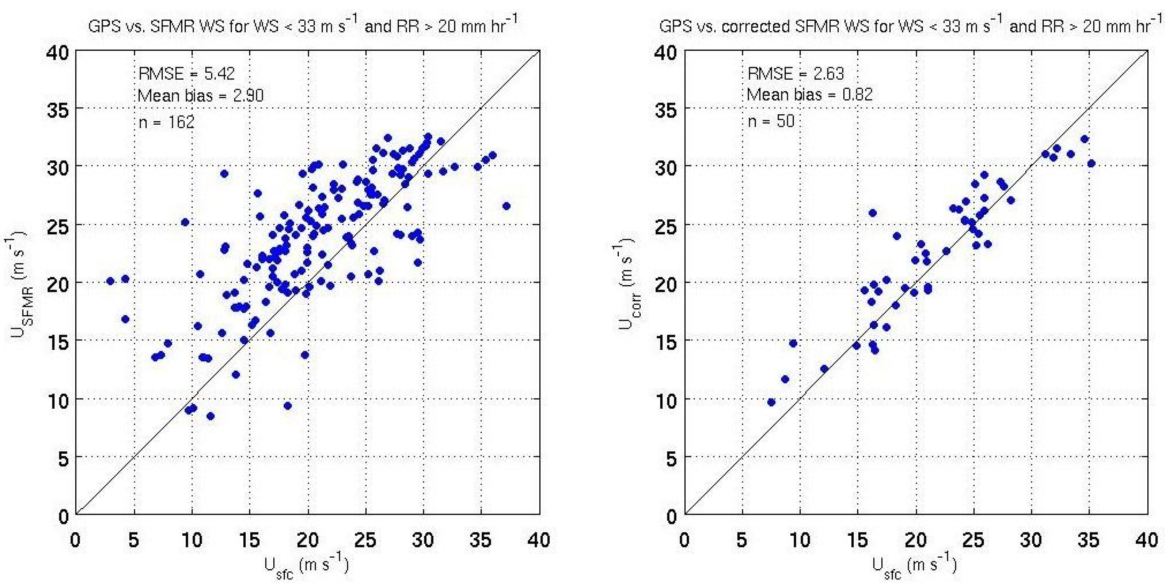


Figure 2: Comparison of U_{SFMR} vs. U_{sfc} for wind speeds < 33 m s^{-1} and R > 20 mm hr^{-1} (left), and comparison for U_{corr} vs. U_{sfc} for same range based on independent observation sample.

Research Performance Measure: All major research objectives have been met for the first year of this project. Research towards improving the SFMR algorithm is ongoing through the next fiscal year.

Microphysics of Deep Convection

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

Long Term Research Objectives and 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 2*:** Weather-Ready Nation **-** *Society is prepared for and responds to weather-related events*

NOAA 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 has centered on the rapid development of ice from well-developed warm rain distributions at the -2C level (all liquid); to virtually all ice at the -11C level. The analysis has focused on the development of proto ice (first ice), and the role of secondary ice production (very likely Hallett-Mossop). The distributions of vertical wind, which make the condensed water mass available, as measured in the cloud system were analyzed in some detail (Fig. 1).

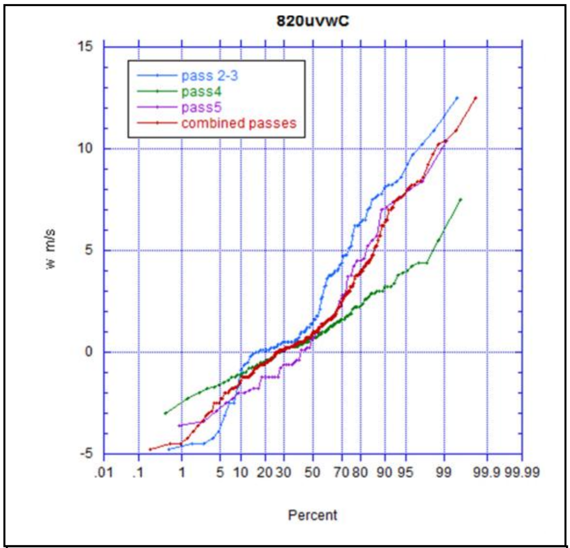


Figure 1: Distributions of vertical winds (w) for 3 sampling transects and the combined distributions.

The first ice is found to be frozen raindrops in concentrations consistent with the concentration of drop of diameter > .8mm in the warm rain distributions. There is considerable evidence in the image data of drops having fragmented upon freezing. In the strongest updraft regions at -11C there are copious concentrations of small liquid cloud droplets. Downshear of the most active updrafts the distributions are characterized by high concentrations of small to medium sized columnar crystals, consistent with a Hallettt-Mossop ice splintering mechanism, and subsequent growth of the secondary ice particles.

Figure 2 presents the data from the cloud transect at -2C, to be compared to the data presented in Figure 3 from the -11C level. The vertical winds, the relative humidity with respect to water, and the concentrations of four sizes of hydrometeors are presented. Figure 4 shows the high resolution 2DS images in the all water level in the cloud arriving at the freezing level with developed warm rain. Figures 5 and 6 show the complete dramatic conversion to all ice by T -11C; characterized by riming frozen drops. Figure 7 shows another all frozen drop frame, and two frames in the copious column region of the cloud at -11C. Note that the rimed graupel coexists in close proximity to the copious columns. Figure 8 shows one frame of columns and two frames from -22C showing remarkable growth of fragile dendritic spicules on the surface of the graupel.

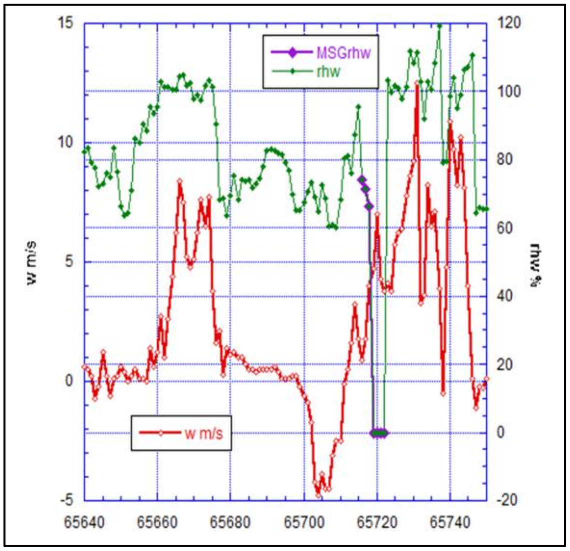


Figure 2a: Vertical winds for cloud transect 2-3 at T=-2C and the relative humidity w/r to water upshear is to the right and downshear to the left. There are missing relative humidity relative to water (rhw) data near 65720s.

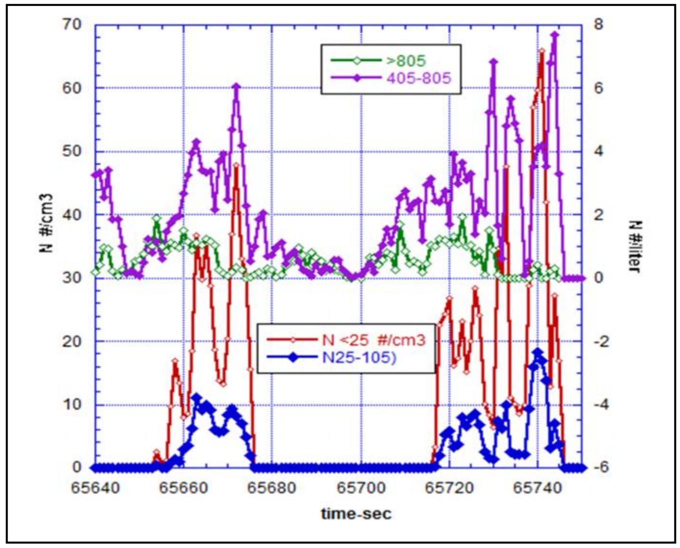


Figure 2b: Concentrations of cloud droplets D<25 um, and D 25-105 um; and rain drops D> 805 um and D 405-805 um.

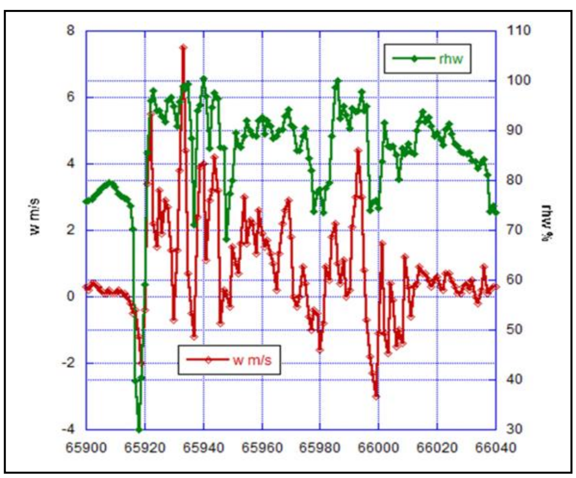


Figure 3a: Cloud 4 transect at T=-11C, vertical wind and relative humidity w/r to water.

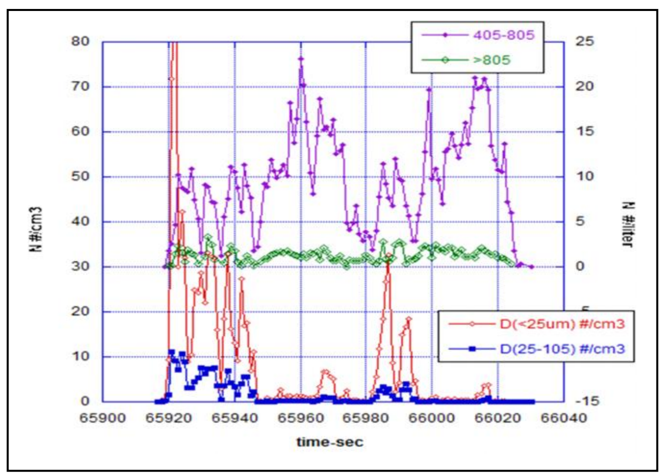


Figure 3b: Concentrations of cloud droplets D<25 um, and D 25-105 um; and large hydrometeors D> 805 um and D 405-805 um.

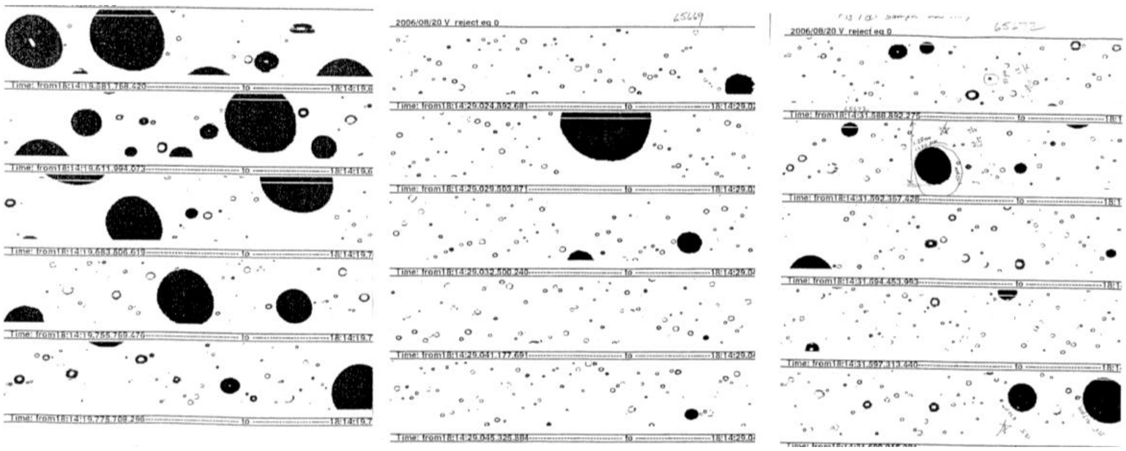


Figure 4: Cloud 2-3 transect 2DS image samples at 65659s, 65669s, 65672s, illustrating images in all rain at T=-2C. Size is indicated by horizontal bars which are dimension of 1.28 mm apart.

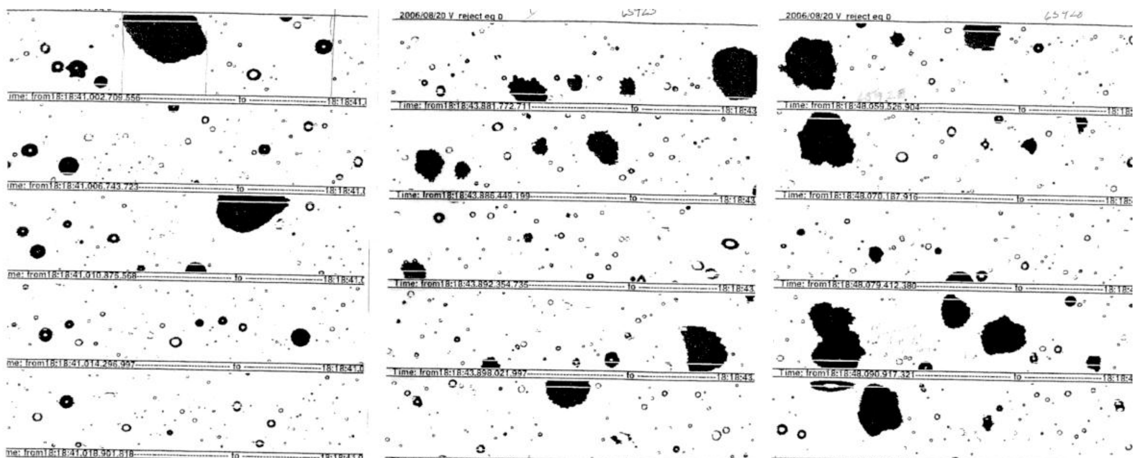


Figure 5: Cloud 4 transect 2DS image samples at 65921s, 65923s, 65928s, illustrating images in upshear active updrafts at T=-11C. Size is indicated by horizontal bars which are dimension of 1.28 mm apart.

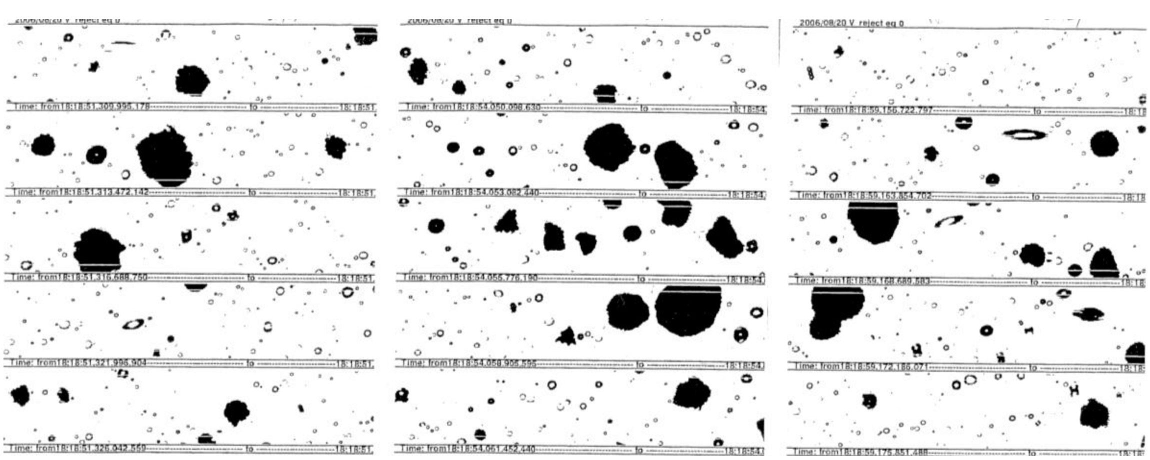


Figure 6: Cloud 4 transect 2DS image samples at 65931s, 65934s, 65939s, further illustrating images in upshear active updrafts at T=-11C. Size is indicated by horizontal bars which are dimension of 1.28 mm apart.

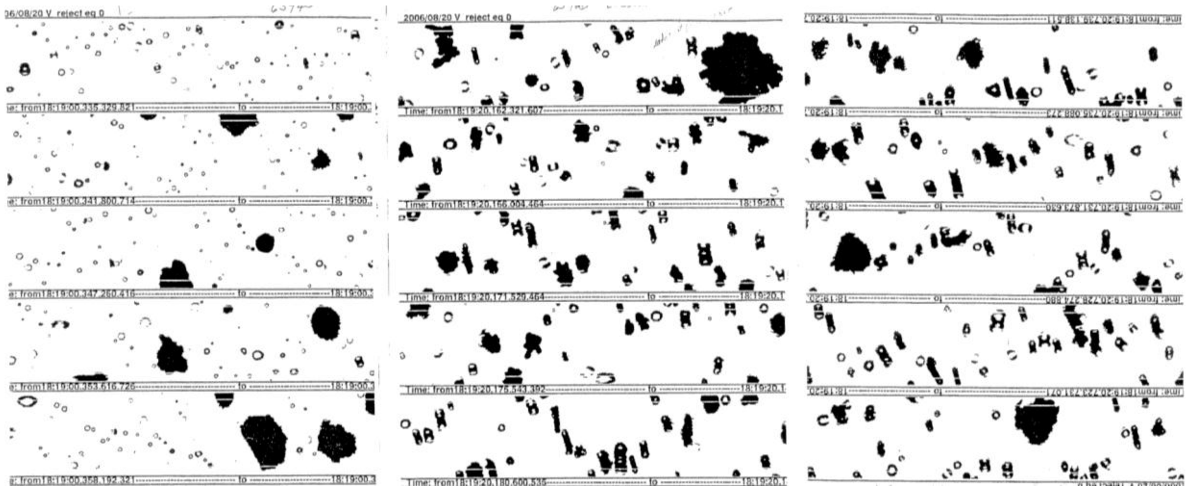


Figure 7: Cloud 4 transect 2DS image samples at 65940s, illustrating images in active updrafts at T=-11C and transition to columns in images at 65960s, 65961s. Size is indicated by horizontal bars which are dimension of 1.28 mm apart.

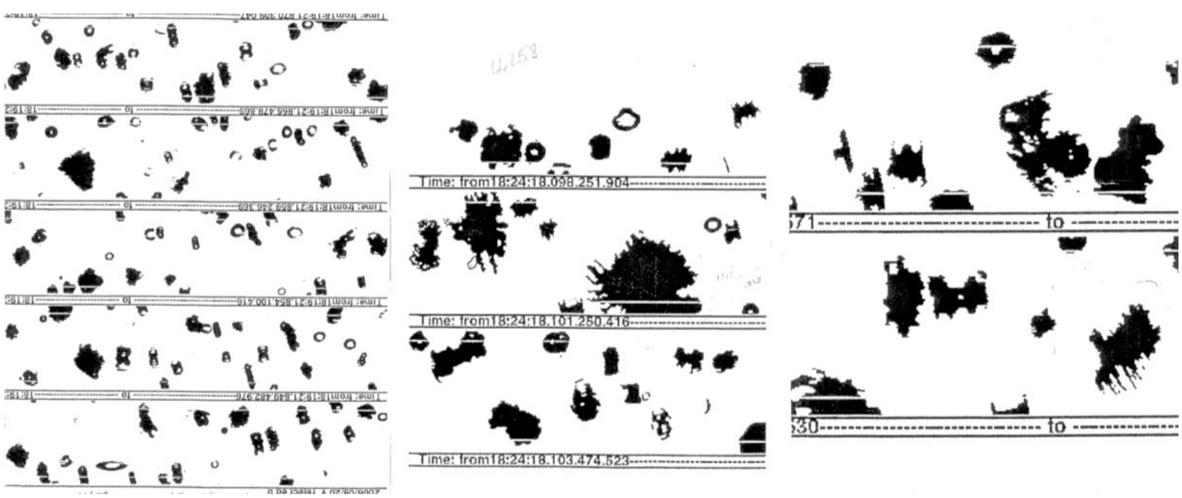


Figure 8: Cloud 4 transect 2DS image sample at 65961s, further illustrating images in column region, and images from cloud transect 5 at T=-22C illustrating dendritic growth spicules on graupel in images at 66258s. Size is indicated by horizontal bars which are dimension of 1.28 mm apart.

The dropsonde soundings in Hurricane Earl have been examined for the development of the warm core versus height. The comparison of measured microphysics to HWRFX model microphysics has been suspended because NOAA's Hurricane Forecast Improvement Project (HFIP) did not fund it.

A new analysis of the soundings in deep convection over tropical oceans is being explored with Jason Dunion as an expansion of his effort on the diurnal behavior of hurricanes.

Research Performance Measure: All research objectives have been met.

Investigation of the Mean and Turbulence Structure of the Hurricane Boundary Layer

Project Personnel: J.A. Zhang (UM/CIMAS)
NOAA Collaborator: R.F. Rogers (OAR/AOML)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** To study the mean and turbulence structure of the hurricane boundary layer in order to improve our understanding of hurricane boundary layer structure and to 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 2*:** Weather-Ready Nation - *Society is prepared for and responds to weather-related events*

NOAA 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. However, understanding the hurricane boundary layer has been limited by a lack of in-situ observational studies. This project aims to provide better knowledge of the hurricane boundary layer structure.

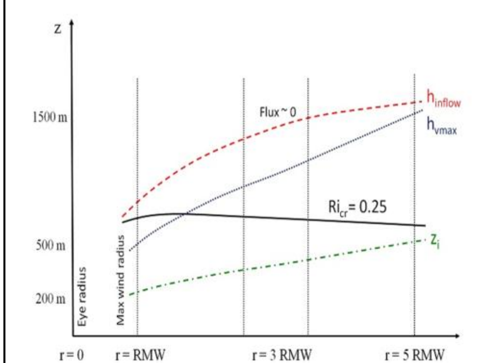


Figure 1: Schematic diagram of the characteristic height scales of the hurricane boundary layer. The height scales are based on the composite analysis of the dropsonde data. h_{inflow} is the inflow layer depth (red dashed line); z_i is the mixed layer depth (green dash-dotted line); and h_{vmax} is 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.

The first part of this project focuses on the investigation of the mean boundary layer structure. The dropsonde 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 (Figure 1). The data analyses show that there is a clear separation of the thermodynamical and dynamical boundary layer heights. Consistent with previous studies on the boundary layer structure in individual storms, the dynamical boundary layer height is found to decrease with decreasing radius to the storm center. The thermodynamic boundary layer height, which is much shallower than the dynamical 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. We also analyzed 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; and 2) multiplying the 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.

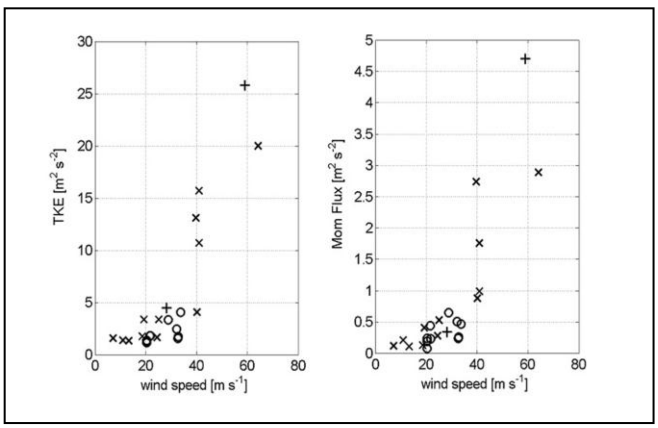


Figure 2: Plots of turbulent kinetic energy (TKE) and momentum flux as a function of the mean wind speed at the flight level for all the good runs in Hurricanes Allen (x), Hugo (+) and Frances (o).

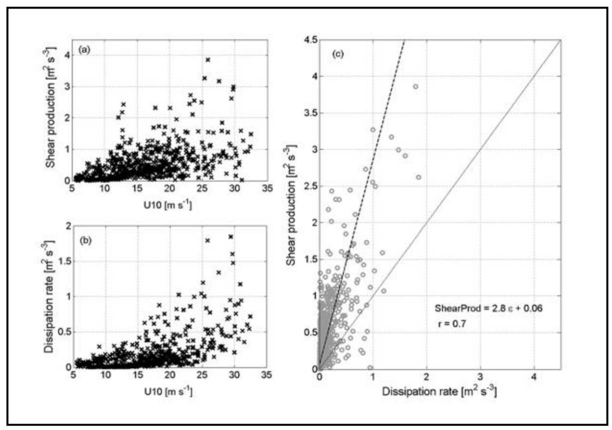


Figure 3: Plots of shear production as a function of 10 m wind speed (a); dissipation rate as a function of 10 m wind speed (b); and comparison between the shear production and dissipation rate (c). The light solid line shows the 1:1 ratio. The black dashed line denotes the least-square best fit of the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

Future work includes investigating the asymmetric boundary layer structure in relationship to the environmental vertical wind shear, and evaluating the surface layer and boundary layer schemes used in the high-resolution Hurricane Weather and Research Forecast System (HWRF) using the observational data.

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

Advanced Modeling and Prediction of Tropical Cyclones

Project Personnel: X. Zhang, L. Bucci and K.-S. Yeh (UM/CIMAS)
NOAA Collaborators: S. Gopalakrishnan, T. Quirino, F. Marks, S. Goldenberg, and R. Black (NOAA/AOML/HRD)
Other Collaborators: V. Tallapragada, Q. Liu and S. Trahan (NOAA/NCEP/EMC)

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 2*:** Weather-Ready Nation - *Society is prepared for and responds to weather-related events*

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

Research Summary
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 ten years (2008-2018), 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 nests) in collaboration with the Hurricane Research Division (HRD) at the Atlantic Oceanographic and Meteorological Laboratory (AOML) and Environmental Modeling Center (EMC) at National Centers for Environmental Prediction (NCEP). The system was tested through real-time parallel forecasts in 2011 hurricane season. We also developed vortex initialization that contributed to substantial improvement on the intensity forecast within the operational HWRF model in retrospective test. The verification showed track and intensity forecasts improved averaged 20% and 10% respectively from the retrospective forecasts compared to 2011 operational HWRF forecasts (Fig. 1). The high-resolution modeling system was adopted by NCEP/EMC and approved by NCEP/NHC to be the operational implementation in 2012. The modeling system becomes the highest resolution hurricane model ever implemented for operations in the National Weather Service.

During the development of the high resolution modeling system, we investigated the influence of model grid resolution, initial conditions, and physics through experimental HWRF (HWRFx) developed in HRD. Our results indicated that the high-resolution could result in better intensity and track prediction with selected 87 cases during 2005, 2007, and 2009 hurricane seasons. We showed the sensitivity on the physics parameterization such as drag coefficient. We also suggested the weak storm at the forecast initial time posed special challenges for the models including HWRFx.

We also developed a basin-scale HWRF modeling system with multiple movable nests. The new effort is to further improve the guidance of both the track and the intensity forecasts. We are working on extending forecast up to 7 days and providing products to local weather forecast office. We have completed the code development of the multiple movable nests since 1 January 2012. We are preparing for the real-time forecast during 2012 hurricane peak season (1 August-31 October).

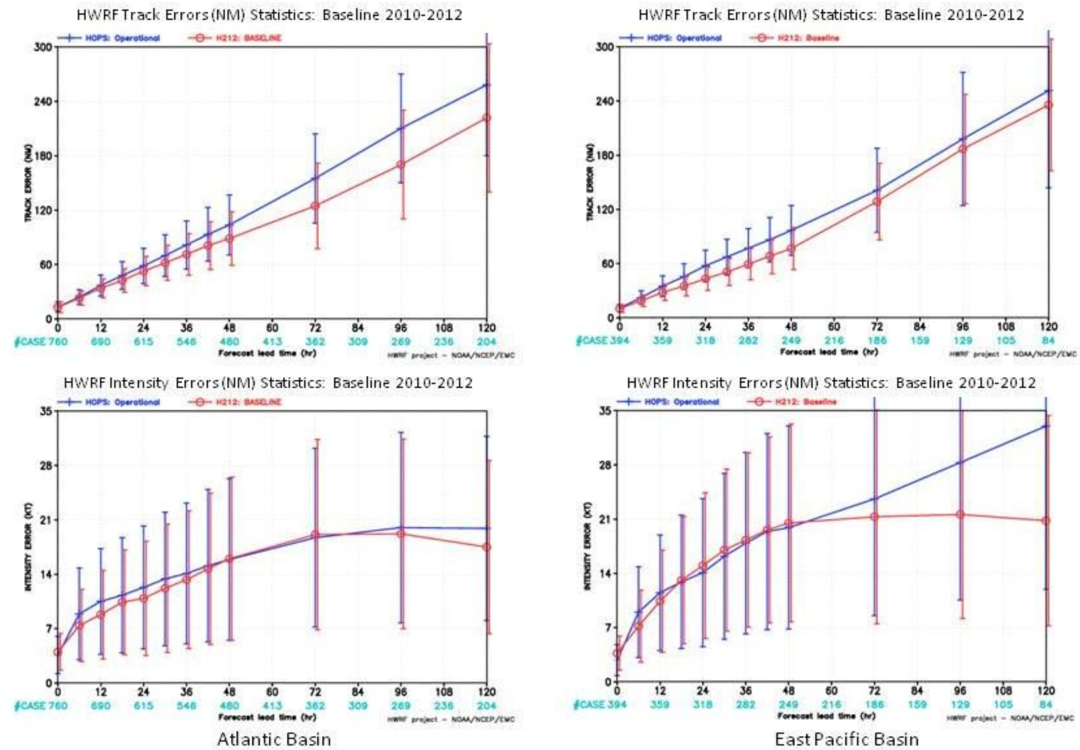
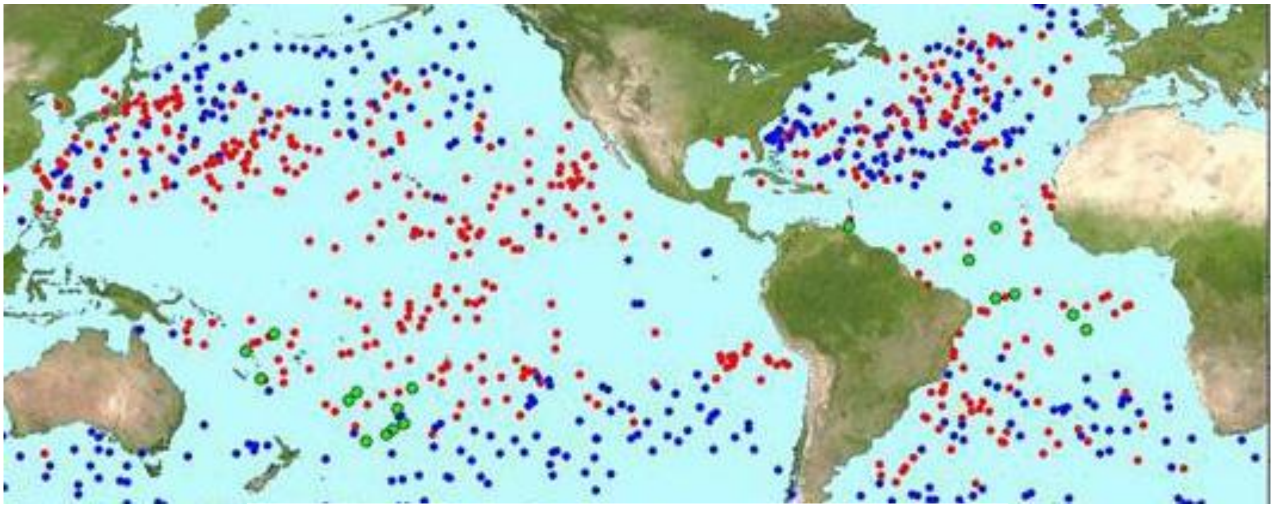


Figure 1. Comparison of forecast error statistics between 2011 operational HWRF (27-9 km) and 2012 proposed operational HWRF (27-9-3km)

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



RESEARCH REPORTS

THEME 3: Sustained Ocean and Coastal Observations

The Ocean, Coastal, and Estuarine Network for Ocean Acidification monitoring

Project Personnel: K. Sullivan, D. Pierrot, G.H. Park, L. Barbero, G. Berberian and D. Gledhill (UM/CIMAS); C. Langdon (UM/RSMAS)
NOAA Collaborators: R. Wanninkhof, J.-Z. Zhang and M. Baringer (NOAA/AOML)

Long Term Research Objectives and Strategy to Achieve Them:
Objective: Develop and implement a program for monitoring carbon-cycle-related oceanographic parameters in U.S. coastal, Great Lakes, and open-ocean waters
Strategy: To reoccupy coastal transects, deploy moorings, and ships of opportunity to quantify the changes in and causes of ocean acidification.

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

Link to NOAA Strategic Goals:
Goal 3: Healthy Oceans - *Marine fisheries, habitats, and biodiversity sustained within healthy and productive ecosystem*

NOAA Funding Unit: OAR Ocean Acidification Program
NOAA Technical Contact: Libby Jewett

Research Summary:
This effort is to implement the North Atlantic Ocean, East and Gulf Coast ocean acidification (OA) observing system as outlined in the NOAA OA plan in response to the requirements of the

FOARAM act. The observing system will be used to determine patterns and trends in key indicators of ocean acidification. The observing network of the East and Gulf Coast is based on the following:

- Surface water measurements using autonomous systems on 7 ships of opportunity (SOOP) and 3 buoys.
- A dedicated research cruise, the Gulf of Mexico and East Coast Carbon (GOMECC-2) cruise on the *Ronald H Brown* with surface and subsurface measurements to develop process level understanding of the controls on ocean acidification.
- The continued development of the observing system.

The development component includes analysis of total alkalinity (TA) and dissolved inorganic carbon (DIC) samples taken on the SOOP and mooring efforts. Data reduction, quality control and data management of the large data sets that are obtained are a critical component of the observing system. Data products and algorithms to extrapolate the OA indices in time and space will be developed as part of the effort. Assistance with analyses and protocols will be provided to other groups including those studying OA impacts on coral reef systems. The work involves partners at the NOAA/OAR entities AOML, PMEL, and NOAA/NMFS/NEFSC. Four academic institutions contribute to maintaining and augmenting the observing system and are sponsored through the Northern Gulf Institute.

Research Performance Measure: The main deliverable in this effort is quality-controlled data that can be used to determine patterns and rates of OA in the realm .The second important deliverable are data based products showing regional trends in OA products such as the Ocean Acidification Product Suite (OAPS).

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The CLIVAR CO_2 Repeat Hydrography Program

Project Personnel: K. Sullivan, G.-H. Park, L. Barbero, G. Berberian, J. Hooper and K. Seaton (UM/CIMAS) C. Langdon (UM/RSMAS)

NOAA Collaborators: R. Wanninkhof, J.-Z. Zhang and M. Baringer (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 1*:** Climate Adaptation and Mitigation – *An informed society anticipating and responding to climate and its impacts*

NOAA Funding Unit: OAR/AOML and OAR/CPO **NOAA Technical Contact:** Joel Levy

Research Summary:
The CLIVAR/CO_2 Repeat Hydrography Program is a global re-occupation of select hydrographic sections to quantify changes in storage and transport of heat, fresh water, carbon dioxide (CO_2), oxygen, nutrients, chlorofluorocarbon tracers and related parameters. The effort started in 2003 and to date sections have been completed in the Atlantic, Pacific and Indian Ocean.

Data from these cruises are 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-2012 we completed occupation of a zonal line in the Southern Atlantic between Cape Town and Rio de Janeiro, (A10) with full physical and chemical characterization of 140 water column profiles.

A recent focus has been on the changes in carbon in the deep ocean and attribution of changes. Geun-Ha Park is a co-investigator in looking at changes in the deep ocean based on observations of partial pressure of carbon and chlorofluorocarbons in collaboration with project scientists and Doney (WHOI) and PMEL scientist Bullister. Figure 1 shows an estimate of anthropogenic carbon inventory at depths greater than 2000 m based on our novel analysis.

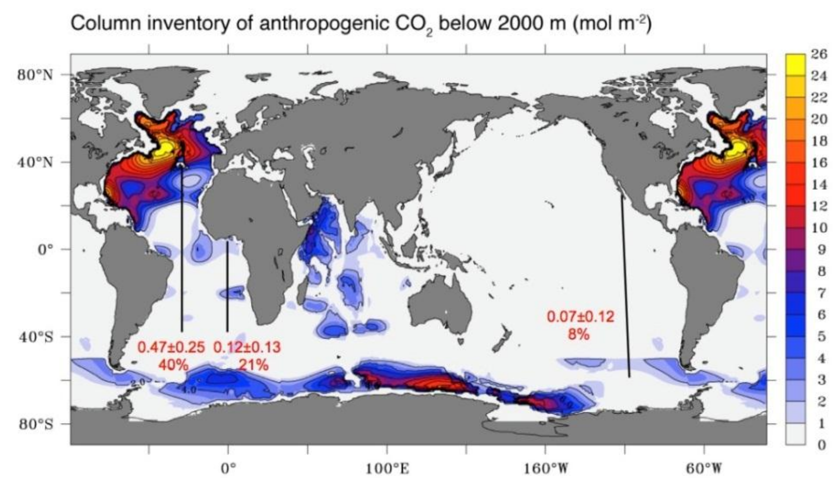

Figure 1: Estimated change in deep water inorganic carbon content [mol m^{-2} yr^{-1}] based on pCO_2 and % change compared to total water column inventories along the transects A16, A13.5, and P18 (shown as black lines).

Research Performance Measure: The Repeat Hydrography Sections are progressing according to timeline of the CLIVAR CO2 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.

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 Collaborator: J.A. Trinanes (University of 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 1*:** Climate Adaptation and Mitigation – *An informed society anticipating and responding to climate and its impacts*

NOAA Funding Unit: OAR/AOML and OAR/CPO **NOAA Technical Contact:** Joel Levy

Research Summary:
The ship-based surface pCO_2 program is designed to provide sustained measurements of regional oceanic carbon sources and sinks on seasonal timescale by measuring surface water and marine boundary pCO_2 on ships of opportunity. It is a collaboration of investigators at the NOAA laboratories AOML and PMEL; and the following academic institutions: Columbia University, the University of Miami, and the Bermuda Institute of Ocean Sciences. It is the largest program in the world. 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-12 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 sea-air fluxes

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. A major product, the Surface Ocean Carbon Atlas (SOCAT) version 1.5 containing over 6 million pCO_2 data points, has been released in September 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.

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

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Integrated Marine Protected Area Climate Tool (IMPACT) Planning and Implementation of a Standardized Web-based Data Access Service for IMPACT Data Layers Using NOAA's IOOS Data Management and Communication (DMAC)

Project Personnel: J.N. Boyer and H.O. Briceño (FIU)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** To ensure the mandatory data values, naming conventions, and units included in the Florida International University water quality data records are consistent and accurate

***Strategy*:** To achieve the above mentioned Objective, FIU has worked with CCMA and IOOS partners to produce time-series data records of the biogeochemical variables for SOS implementation.

CIMAS Research Theme:

***Theme 3*:** Sustained Ocean and Coastal Observations (*Primary*)
***Theme 1*:** Climate Research and Impact (*Secondary*)
***Theme 5*:** Ecosystem Modeling and Forecasting (*Secondary*)
***Theme 6*:** Ecosystem Management (*Secondary*)

Link to NOAA Strategic Goals:

***Goal 2*:** Weather-Ready Nation - *Society is prepared for and responds to weather-related events* (*Primary*)

***Goal 1*:** Climate Adaptation and Mitigation - *An informed society anticipating and responding to climate and its impacts* (*Secondary*)

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

Research Summary:

This document describes results of the QA/QC procedures applied to FIU Water Quality data to implement an element of IOOS into the existing Integrated Marine Protected Area Climate Tool (IMPACT) project framework. Period of record for FIU dataset is Mar. 1995 – Nov. 2010 and includes water quality data from 62 quarterly sampling events at 205 stations within the Florida Keys National Marine Sanctuary and the SW Florida Shelf (Fig 1).

Reported field parameters measured at each station include salinity, temperature, dissolved oxygen, turbidity, relative fluorescence, and light attenuation. Water quality variables include the dissolved nutrients nitrate, nitrite, ammonium, dissolved inorganic nitrogen, and soluble reactive phosphate.

Total unfiltered concentrations include those of nitrogen, organic nitrogen, organic carbon, phosphorus, silicate and chlorophyll a.

FIU Standard Operating Procedures (SOP) for field operations and laboratory determinations have been kept constant since the beginning of the monitoring program, and biogeochemical data is NELAC certified. Hence, our corrections were mostly on site location, and sampling date, time and depth.

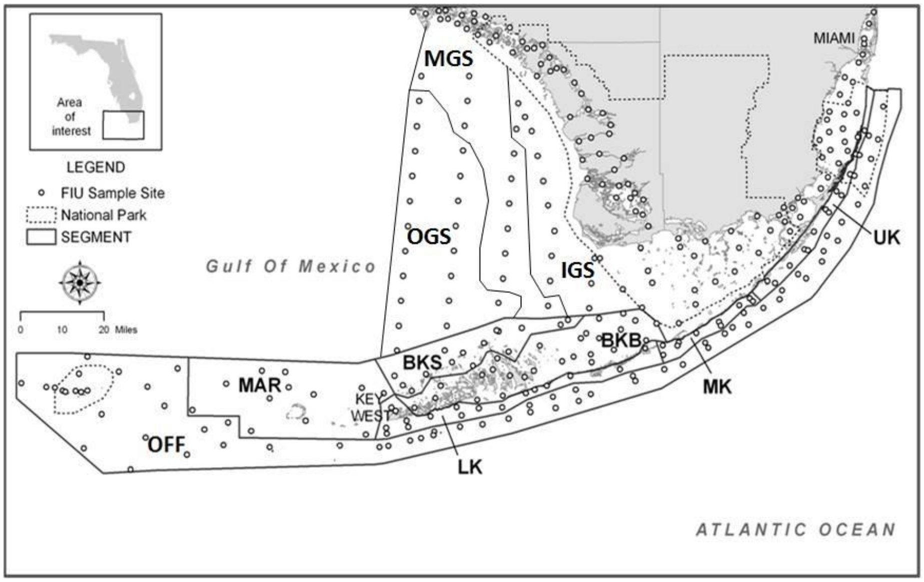

Figure 1: Sampling sites in the Florida Keys National Marine Sanctuary and the SW Florida Shelf. Segments: OFF=Offshore; MAR=Marquesas; LK=Lower Keys; MK= Middle Keys; UK= Upper Keys; BKS=Back Shelf; BKB=Back Bay; OGS= Outer Shelf; MGS= Middle Shelf; IGS= Inner Shelf.

Research Performance Measure: Some field data from the beginning of FIU's monitoring had been lost, causing some delay for delivering the final results of our QA/QC process. We have obtained the original logs from the RV Bellows and final corrections are under way.

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Biscayne Bay Alongshore Epifauna Community and Relationships to Salinity

Project Personnel: G.A. Liehr, D.R. Johnson (UM/CIMAS)
NOAA Collaborators: 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 3*:** Sustained Ocean and Coastal Observations
***Theme 7*:** Protection and Restoration of Resources

Link to NOAA Strategic Plan:
***Goal 4*:** Resilient Coastal Communities and Economies - *Coastal and Great Lakes communities that are environmentally and economically sustainable*

NOAA 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. Project purposes are 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 taxonomic groups observed in Biscayne Bay in 2007-2011. Each group is characterized by a >50% dominance of one taxon (rainwater killifish for fishes; hermit crab for crabs; caridean shrimp spp. for shrimps; and brittle star spp. for echinoderms), followed by several other relatively common species and many minor ones. Rainwater killifish is our best fish species candidate for detecting short-term and fine-scale change, both wet and dry season. On the broad scale, goldspotted killifish in both seasons, gulf pipefish, pink shrimp, and caridean shrimp in the dry season, and goldspotted killifish in the wet season may be other good candidates. We found gulf pipefish were much more abundant during the dry season than the wet season, which likely is the reason the power performance of this species was better for the dry season.

The major caridean taxa *Thor* spp., *Hippolyte* spp., and *Palaemonetes* spp. showed distinctive distributions relative to salinity regimes. *Thor* and *Hippolyte* species occurred primarily in the mid and higher salinity areas, and *Palaemonetes* species occurred primarily at sites with lower salinity levels.

We separately analyzed segments of the coastline for comparison and contrast. Six segments were delineated, each including 12 sites. Each segment covered one or more major canal (Fig. 2). In dry season, segments 1 to 3 (involving sites 1-3) were dominated by fish, while segment 4 through 6 (site 37-72) were dominated by shrimp species. In the wet season, fish were the dominating taxon in segments 1 through 4. Shrimps dominated segments 5 and 6.

The caridean genus *Hippolyte* dominated segments 1, 2, 4, and 5 during the dry season but not during the wet season (Fig. 3). *Palaemonetes*, a genus preferring lower salinity, dominated segments 1-3 in the wet season, while *Thor*, a genus with higher salinity preferences, dominated segments 4-6.

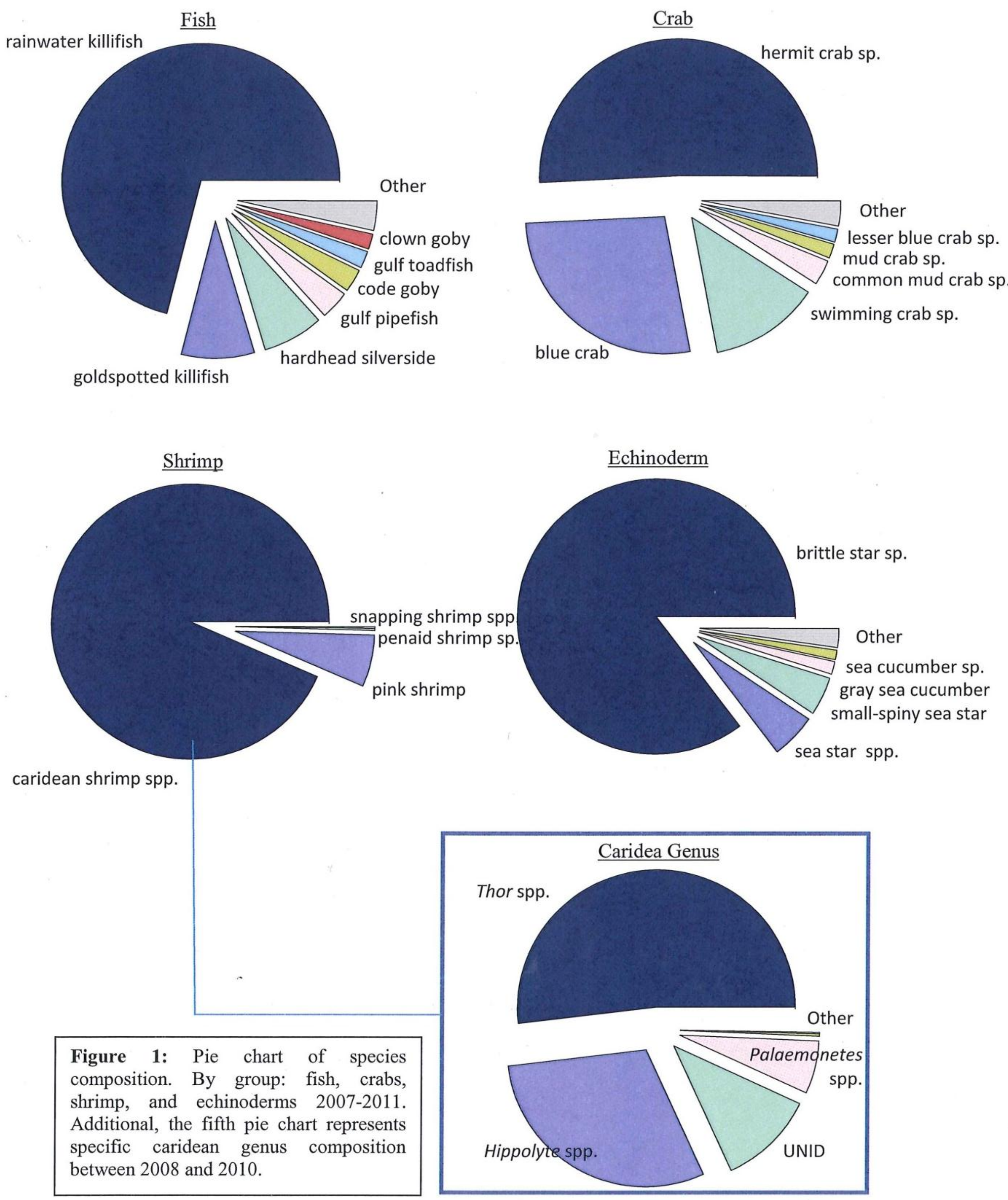


Figure 1: Pie chart of species composition. By group: fish, crabs, shrimp, and echinoderms 2007-2011. Additional, the fifth pie chart represents specific caridean genus composition between 2008 and 2010.

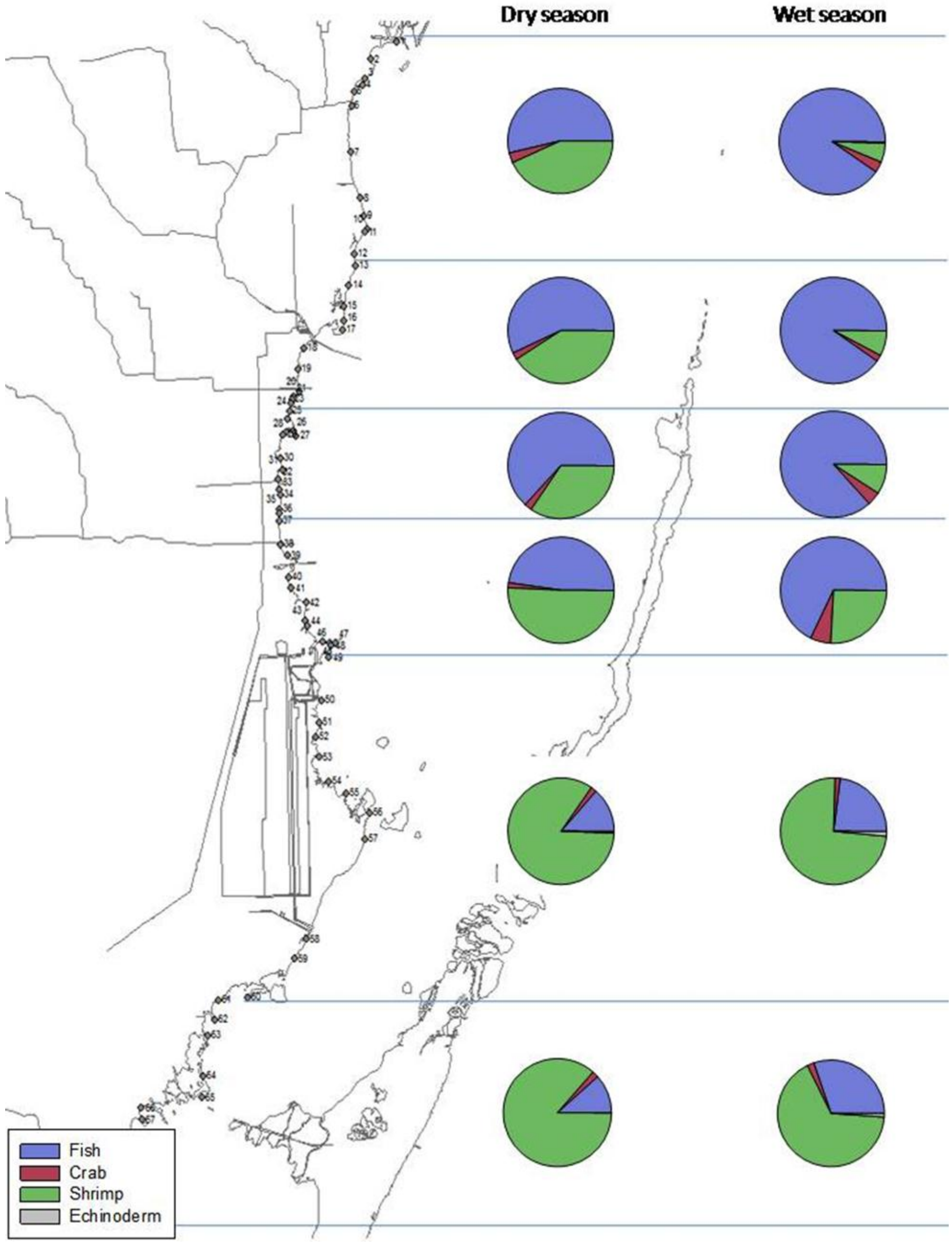


Figure 2: Pie chart of taxon composition by site segment, along Biscayne Bay shoreline, dry and wet season, 2007 through 2011.

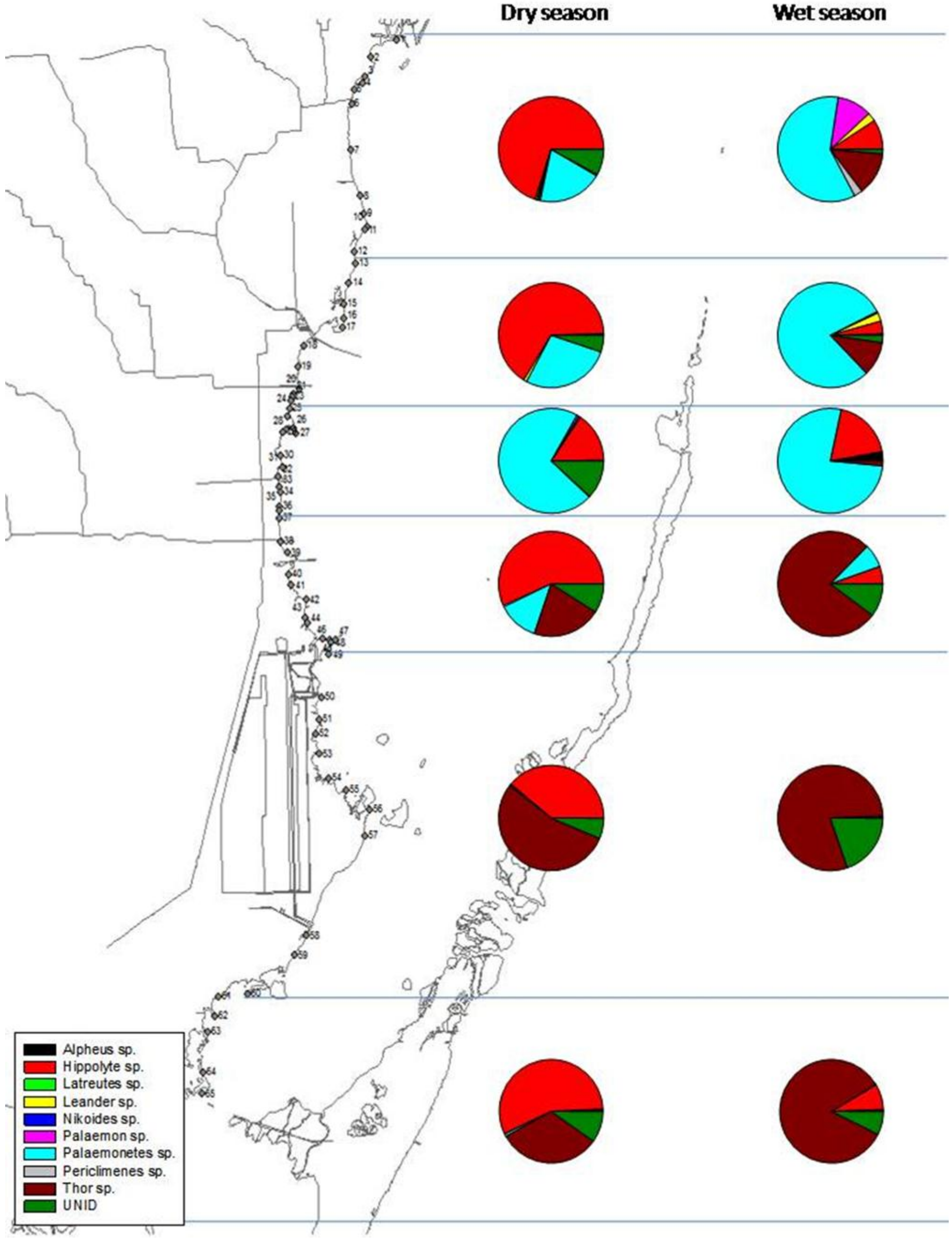


Figure 3: Pie chart of caridean genera composition by site segments along Biscayne Bay shoreline, dry and wet season, 2007 through 2011.

Salinity, which is variable in both space and time in the study area, appears to affect the distribution, abundance, and species composition of the epifauna. We used PCA analysis to explore species/salinity relationships (Fig. 4 and 5). In the dry season, gulf pipefish, clown goby, and goldspotted killifish were negatively related to salinity. Hermit crab, hardhead silverside, and pink shrimp were positively related to salinity. Pink shrimp and caridean shrimp were positively correlated with canopy height. In the wet season, clown goby, blue crab and goldspotted killifish were negatively correlated with salinity; gulf pipefish, hardhead silverside, and caridean shrimp were positively correlated with salinity. Rainwater killifish was positively correlated with percent seagrass cover, while pink shrimp was positive correlated with canopy height (as also seen during the dry season).

(a)

(b)

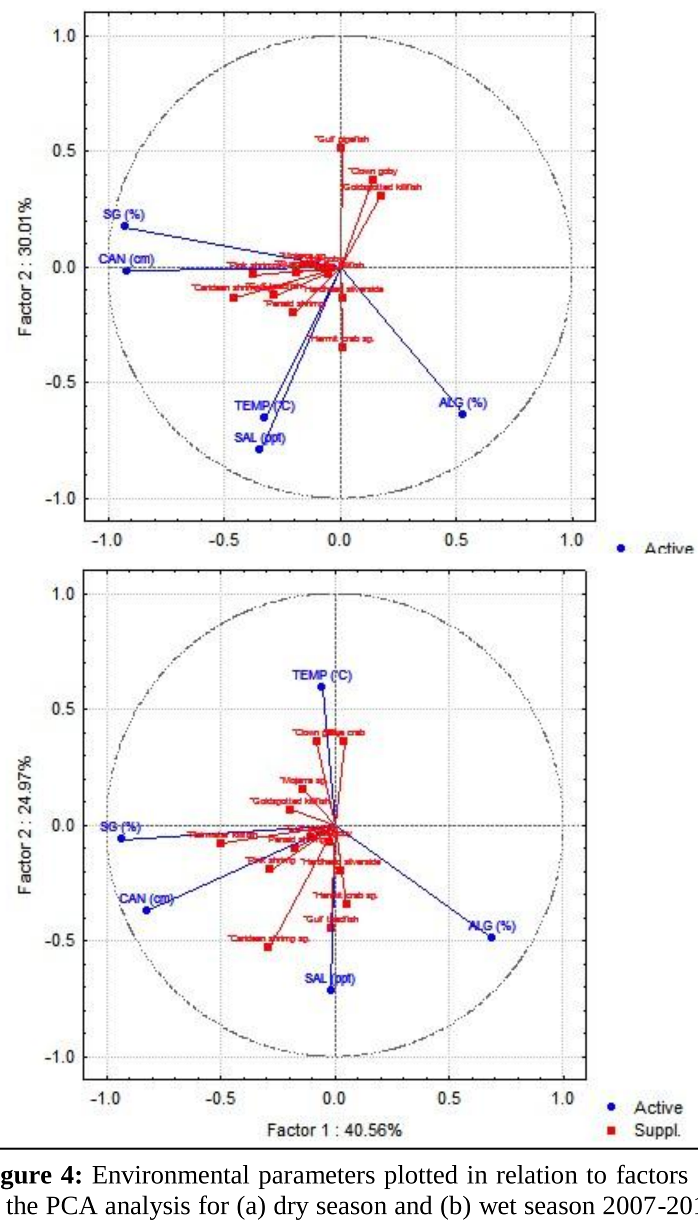


Figure 4: Environmental parameters plotted in relation to factors 1 and 2 of the PCA analysis for (a) dry season and (b) wet season 2007-2011, with faunal density by species superimposed.

PCA results revealed a negative relationship of *Palaemonetes* with salinity during dry and wet season (Fig. 5). This genus is mainly found in lower salinities and, therefore, is a good indicator of lower salinities. *Thor* and *Hippolyte* showed a stronger positive correlation with canopy height than with salinity during the dry season, but during wet season both genera showed a slightly stronger correlation with salinity. Like *Thor*, but to a lesser extent *Hippolyte*, mainly occurs at higher salinity. Both of these taxa provide good indicators for higher salinities.

(a)

(b)

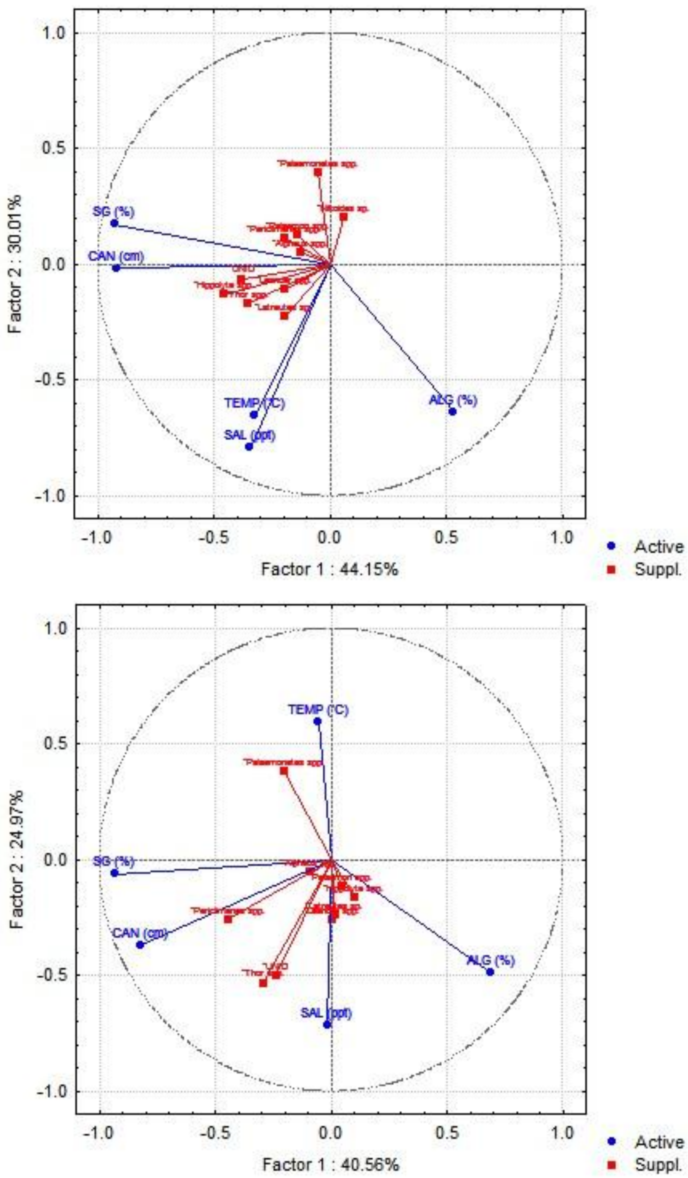


Figure 5: Environmental parameters plotted in relation to factors 1 and 2 of the PCA analysis for (a) dry season and (b) wet season 2007-2011, with caridean density, by genera, superimposed.

We conducted power analyses to determine the effectiveness of our samples sizes in detecting change. As an example, we present the results of power analyses for fish species richness (Fig. 6). 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 (α = 0.05) with only 210 samples. Since 72 samples were collected each year (within each season, dry and wet), we could detect a 10% change with only 3 years of sampling. Power analyses indicated that change detection could be conducted at a finer resolution with fewer samples with richness than with species abundance indices such as density or occurrence.

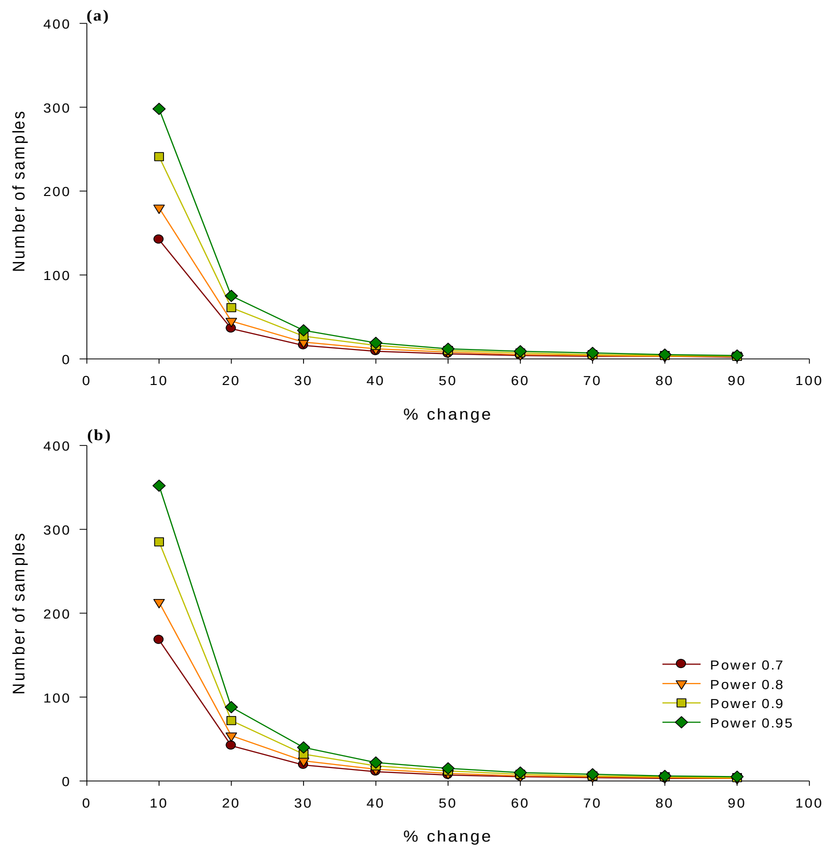


Figure 6: Number of samples required to detect change in (a) dry season and (b) wet season fish species richness across all 72 sites, 2007-2010.

Research Performance Measure: The primary purpose of our work was to characterize the epifaunal community, determine relationships with halohabitat (salinity), and explore analytical means to develop species-based and community-based performance measures. We made substantive progress in exploring analytical approaches to addressing our objectives. Furthermore, we are now able to evaluate the sampling effort required to detect changes in the community when CERP becomes operational.

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, C. Featherstone, C. Sinigalliano and J. Stamates (NOAA/AOML); H. Casanova, R. Kotkowski and M. Kosenko (NOAA/OMAO)

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 (*Primary*)
***Theme 6*:** Ecosystem Management (*Secondary*)
***Theme 7*:** Protection and Restoration of Resources (*Tertiary*)

Link to NOAA Strategic Goals:

***Goal 3*:** Healthy Oceans - *Marine fisheries, habitats, and biodiversity sustained within healthy and productive ecosystems*

NOAA 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 sensing of plumes, and microbiological measurements. This year, a sequence of monthly water quality measurement cruises were operational off of Broward County, twelve off of Hollywood TWWP outfall and Port Everglades inlet, and twelve off of Hillsboro Inlet and the Broward TWWP outfalls. Some typical results are shown in Figure 1, which shows the contours of the concentrations of nitrate (NO_3^-) for the entire experiment are shown. The dominance by the Port Everglades inlet on the surface sample concentrations is clearly notable, with the Hollywood outfall less dominant, and with very little elevation of concentration noted from the Broward outfall and Hillsboro inlet to the north. Both surface and mid-depth contours show the inlet plume's effect on the nearshore environment north of the Inlet.

Work commenced on a series of tracer experiments at the Broward and Hollywood outfalls using rhodamine-wt dye, to be completed during the spring and summer of 2012.

We have proceeded with a CRCP-funded project to monitor the flux of nutrients from the Port Everglades, Hillsboro, and Boca Raton Inlets. A central question is the extent of the plume as it merges into the coastal waters and the consequent effect on the benthic ecosystems. An example is seen in Figure 2, where normalized concentrations of nutrients and related constituents are plotted to demonstrate the consistent decrease in concentration as the plume dissipates into the receiving waters. The HW9 location, south of the inlet, was taken to be representing the unperturbed coastal ocean.

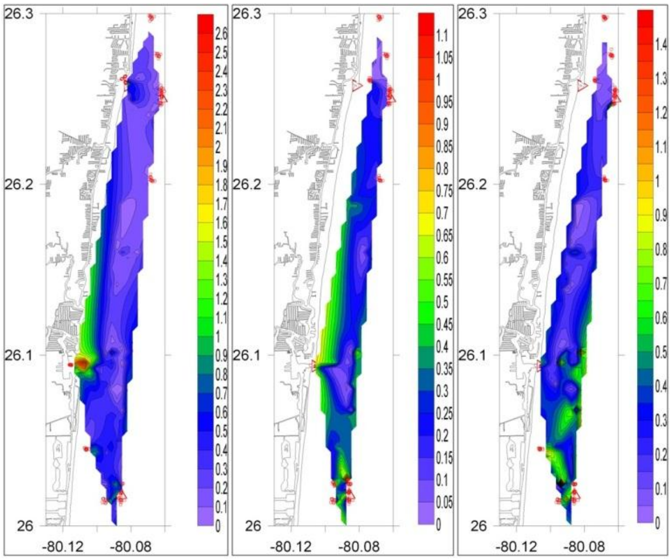


Figure 1: Contour plots of nitrate from twenty-four cruises off of Broward County. Left: surface samples; center: mid-depth samples, right: bottom samples. Concentrations are denoted by the vertical color bar. Sample locations are denoted by the small red circles; outfalls (Broward and Hollywood) by the red right arrow (▷); inlets Port Everglades and Hillsboro) by the red up-arrows (△).

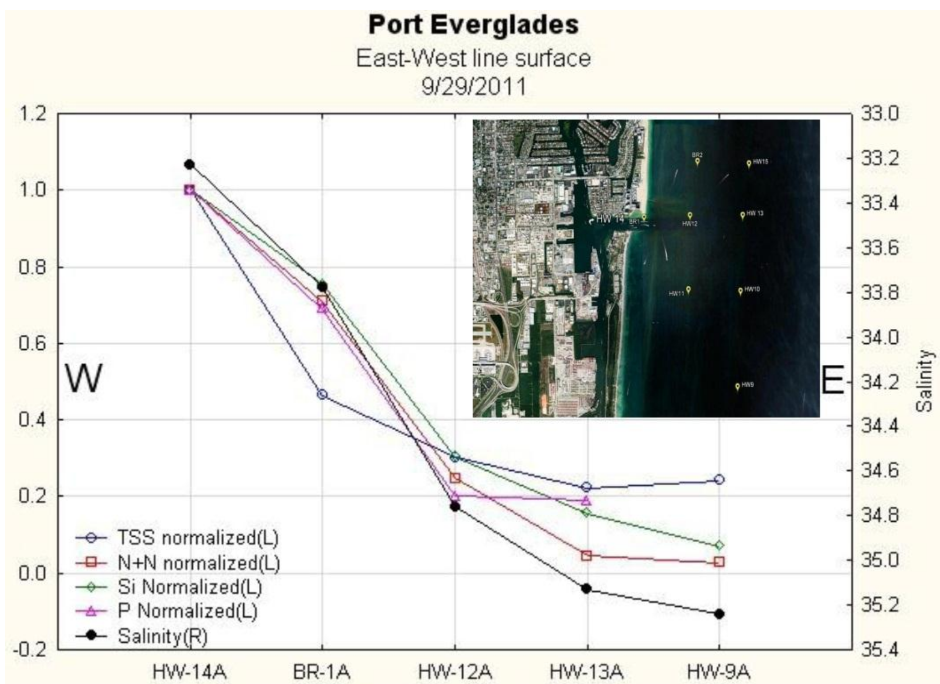


Figure 2: Nutrient and related concentrations from the vicinity of Port Everglades inlet. Concentrations of total suspended solids (TSS), nitrate+nitrite (N+N), silicate (Si), and orthophosphate (P) have been normalized by dividing by the concentration within the lagoon (HW14) and plotted by sample location (a proxy for distance). Salinity has been plotted without normalization (right-hand axis). The inset shows the location of the sampling sites and the Port Everglades inlet (GoogleEarth).

Research Performance Measure: The R/V Hildebrand has completed a sequence of twenty-four one-day 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).

Ocean Conditions in the Gulf of Mexico

Project Personnel: P.G. Coble Rhodes and, F. Muller-Karger (USF College of Marine Science)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** Perform an assessment of blended satellite and radar estimates of the extension of the oil field and assist in the estimation of subsurface oil concentration from fluorometer data by utilizing information obtained from fluorometer validation/intercalibration experiments.

***Strategy*:** Develop products relating fluorometer output to oil concentrations in situ to inform analysis of shipboard profiles of oil fluorescence and estimate uncertainty associated with quantitative estimation of oil from fluorescence profiles. Assess methodologies that use complementary set of visible, infrared, and microwave (including SAR) satellite images, and other radar observations collected over the northern Gulf of Mexico used to monitor the extent of surface oil.

CIMAS Research Theme:

***Theme 3*:** Sustained Ocean and Coastal Observations (*Primary*)
***Theme 7*:** Protection and Restoration of Resources (*Secondary*)

Link to NOAA Strategic Goals:

***Goal 3*:** Healthy Oceans - *Marine fisheries, habitats, and biodiversity sustained within healthy and productive ecosystems*

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

Research Summary:

Fluorescence spectroscopy has been utilized for decades to characterize colored dissolved organic matter (CDOM), a naturally-occurring component of the marine environment. Due to the inherent sensitivity and selectivity of this method, it has also been used extensively by the petroleum industry for analysis and classification purposes. The Deepwater Horizon spill—the largest accidental petroleum release in history—provided researchers with an opportunity to test the unique capability of fluorescence spectroscopy in assessing the extent of subsurface petroleum. Many different *in situ* fluorometers, calibrated to various excitation and emission wavelengths, were employed with this goal in mind. It is important to note that these instruments are set to collect data typically characteristic of naturally-occurring CDOM. Since the spectral properties of petroleum are affected not only by concentration and weathering, but also by physical and chemical dispersion, instrument sensitivity and detection capabilities were likely to be highly wavelength dependent. As crude oil is a complex mixture of hundreds to thousands of individual hydrocarbons, it is likely that most of the *in situ* instruments used in the Gulf of Mexico following the Deepwater Horizon spill were capable of detecting at least some portion of the fluorescence due to petroleum hydrocarbons; however, it is possible that the strongest signal from that source may have been outside the target range of those fluorometers.

We utilized a HORIBA benchtop spectrofluorometer to analyze the fluorescence of water samples over a wide range of excitation and emission wavelengths, producing 3D excitation/emission matrix (EEM) spectra. These analyses enabled the identification of the peak fluorescence (F_{max}) characteristic of the specific petroleum hydrocarbons present in MC252 petroleum, in addition to detection of the presence of fluorescence components typical of CDOM present in the normal marine environment. Initial water samples were collected onboard the R/V Weatherbird II in the DeSoto Canyon region of the Gulf of Mexico, to the northeast of the Deepwater Horizon wellhead, in May 2010. Replicate samples were collected aboard cruises in August and December of 2010 and in February and May 2011. Additionally, controlled tank experiments were conducted in June 2011 at the Bedford Oceanographic Institute in Nova Scotia, Canada, in which MC252 petroleum, with and without the addition of Corexit 9500 dispersant, was introduced to the tank and water samples were collected at specific time intervals. EEMs of those water samples, collected with a HORIBA spectrofluorometer, were compared with those collected in the Gulf of Mexico over the preceding year and used to verify oil concentrations in field samples. Data will also be used to revise recommended field protocols for spill responders in future oil spill accidents.

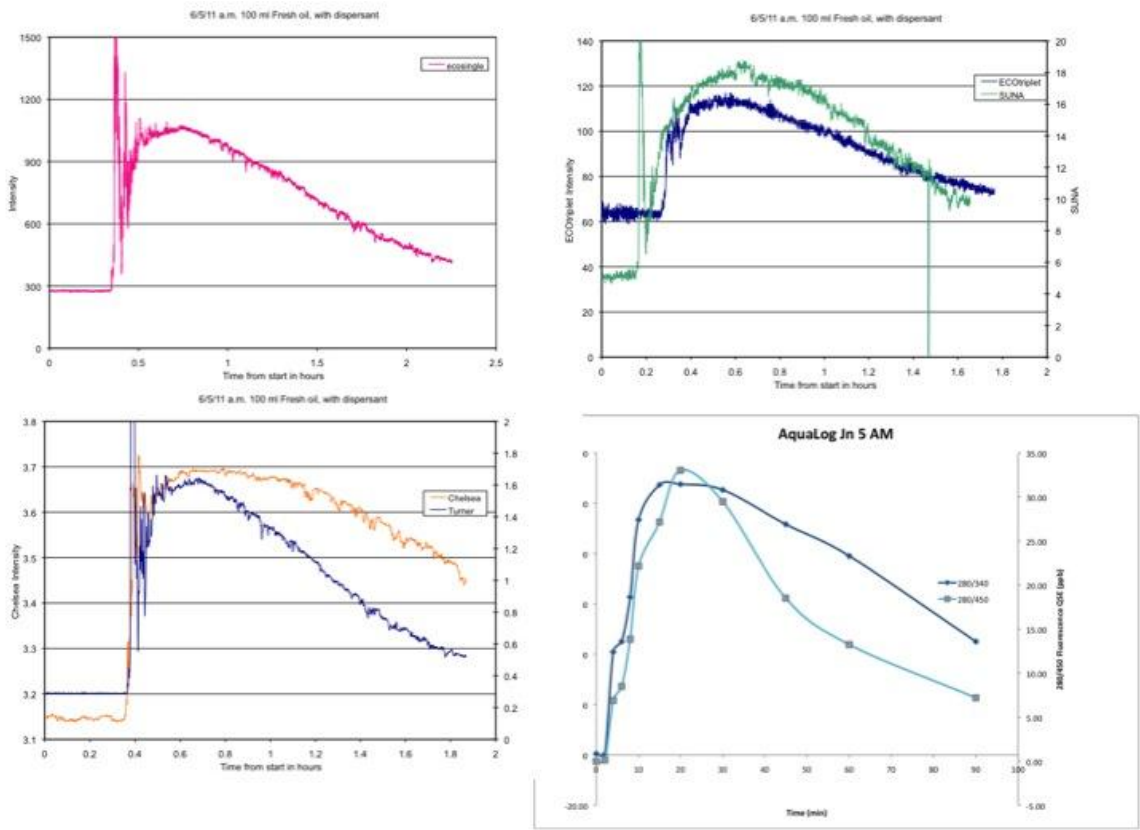


Figure 1: Individual instrument response (intensity) for five in situ fluorometers and for discrete samples at two emission wavelengths during a time course experiment in the BIO wave tank. The experiment consisted of adding100ml fresh MC252 oil with Corexit 9500 dispersant (DOR 1:25) and observing the fluorescence of oil vs. time. This experiment took place on the morning of June 5, 2011. The Aqualog data (bottom right panel) shows that emission at both wavelengths responds proportionately in the first 20 minutes of the experiment, but the 450 nm emission tails off sooner and more rapidly. This behavior was also observed for the Turner, Ecosingle and the SUNA instruments. The Chelsea and ECOtriplet instruments showed responses more similar to the 340 nm emission signal of the AquaLog. These results reflect both the varying configurations of the in situ instruments as well as the changing composition of dissolved and particulate oil in the wave tank as the crude oil and dispersant were mixed and diluted.

In our effort to define circulation patterns in the Gulf of Mexico and understand the impacts on the ecosystem including fisheries, we performed a background study using historical NOAA fisheries surveys and satellite imagery of the region. Muhling et al. (2012) examined the overlap between Bluefin Tuna (BFT) spawning habitat and surface oil in the northern GOM using satellite-derived estimates of oil coverage, and spawning habitat models. Results suggested that although eggs and larvae were likely impacted by oil-contaminated waters in the eastern GOM, high abundances of larvae were located elsewhere, especially in the western GOM. Overall, less than 10% of BFT spawning habitat was predicted to have been covered by surface oil, and less than 12% of larval BFT were predicted to have been located within contaminated waters in the northern GOM, on a weekly basis.

The variability of mesoscale circulation structures in the Gulf of Mexico was further examined in Lindo-Atichati et al. (2012) using satellite altimeter data collected between 1992 and 2008 to assess linkages between circulation and the spatial and temporal distribution of larval fish. The abundance and distribution of five species of larval fish were estimated from in situ surveys conducted by the NOAA National Marine Fisheries Service each spring between 1993 and 2007. We observed a tendency for higher northward extension of the Loop Current (LC) during spring each year, with maximum northern penetration in summer, although the exact location of the Loop Current was variable from year to year. Generally, higher larval concentrations occurred during years of high northward penetration. Further, results show that larvae of bluefin tuna (Thunnus thynnus), little tunny (Euthynnus alleteratus), and Auxis spp., were located within the boundaries of anticyclonic features (generally between 140-150 cm of sea surface height) and within GOM common waters, defined as the background waters in between the boundaries of mesoscale features. Our findings suggest that the position and strength of anticyclone mesoscale features in the GOM define favorable spawning habitat for these species.

Research Performance Measure: Individual EEMs as well as depth profiles of fluorescence intensities show the fluorescence signature characteristic of MC252 petroleum hydrocarbons as well as temporal changes in hydrocarbon signatures found in the northeast Gulf of Mexico in the year following the Deepwater Horizon spill. Subsurface hydrocarbon plumes were detected at two depths. The EEM signatures of water samples collected one year following the spill show a return to fluorescence characteristic of CDOM that is naturally present in the marine environment. Continued collection and spectrofluorometric analyses of water samples from the Gulf of Mexico will enable the characterization of true background fluorescence, a metric which has not yet been well established for this important marine ecosystem.

We have made significant progress in understanding the circulation of waters in the Gulf of Mexico using various satellite data including ocean color, infrared and satellite altimeters. These data have been examined together with historical NOAA fisheries survey observations. The analysis continues to help provide additional information on ecosystem impacts.

Ship of Opportunity (SoOP) Program

Project Personnel: Q. Yao, G. Rawson, N. Melo, S. Dong, J. Soto, M. Goes, R. Domingues, Z. Barton, R. Roddy, C. Gonzalez, F. Bringas and K. Seaton (UM/CIMAS)

NOAA Collaborators: G. Goni, M. Baringer, S. Garzoli, P. Chinn, J. Harris, U. Rivero, P. Pena, A. Stefanik, J. Farrington and Y. Daneshzadeh (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 closely spaced across large ocean regions along repeated transects (the high density XBT program) to measure the mesoscale ocean temperature structure 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 1: Climate Adaptation and Mitigation - *An informed society anticipating and responding to climate and its impacts* (*Primary*)

Goal 2: Weather-Ready Nation - *Society is prepared for and responds to weather-related events* (*Secondary*)

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

Research Summary:

This project is designed to measure the upper ocean thermal structure along major shipping lines globally with high resolution in key regions of the Atlantic and Pacific Oceans (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 high density mode: AX01, AX02, AX07,

AX08, AX10, AX18, AX20, AX22, AX25, AX32 and AX97. The program also collaborate with the Scripps Institution of Oceanography in the XBT data quality control and transmission in real-time from six transects 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°S (AX18) and 30°N (AX07), the variability of the Gulf Stream (AX10) and the zonal current system in the tropical Atlantic (AX08). Moreover, in the South Atlantic, transect AX18 provides information on major boundary currents, such as the Brazil, Malvinas, Benguela and Agulhas, and their associated eddies. Additionally transect AX02 crosses the North Atlantic subpolar gyre near 60°N, in an area of large decadal change both for the gyre circulation and in temperature and salinity, which has increased since 1992 according to data from other observing systems in the region. These are all important components of the Meridional Overturning Circulation in the Atlantic Ocean.

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. 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.

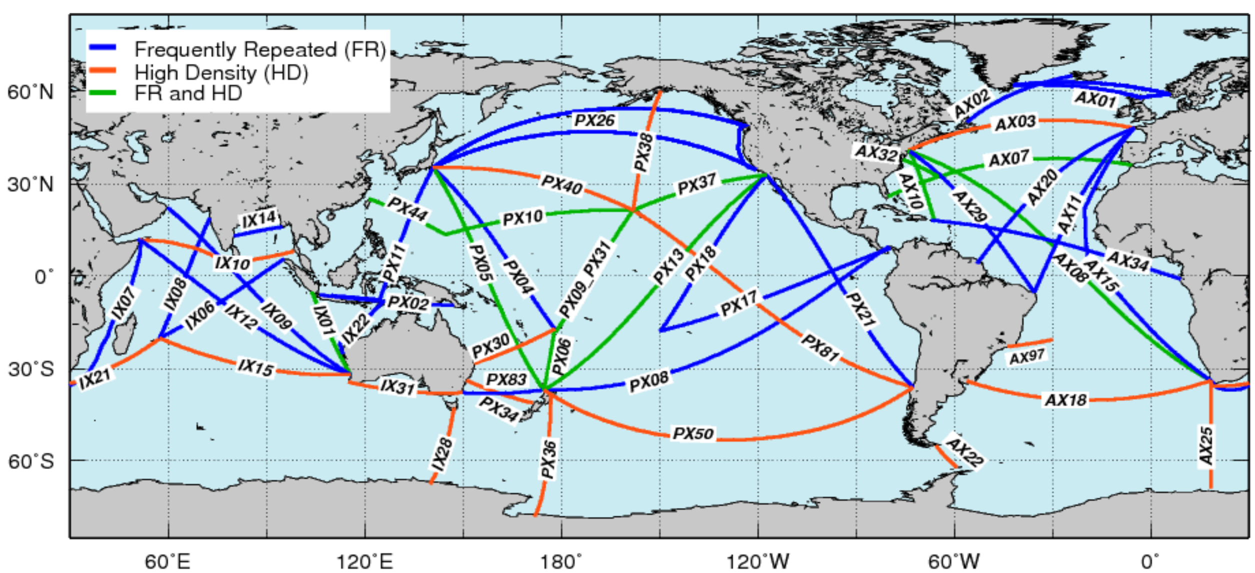


Figure 1: OceanObs09 XBT transects recommended by the scientific community to be occupied in frequently repeated mode (FR, in blue), high density mode (HD, in orange) or both (in green).

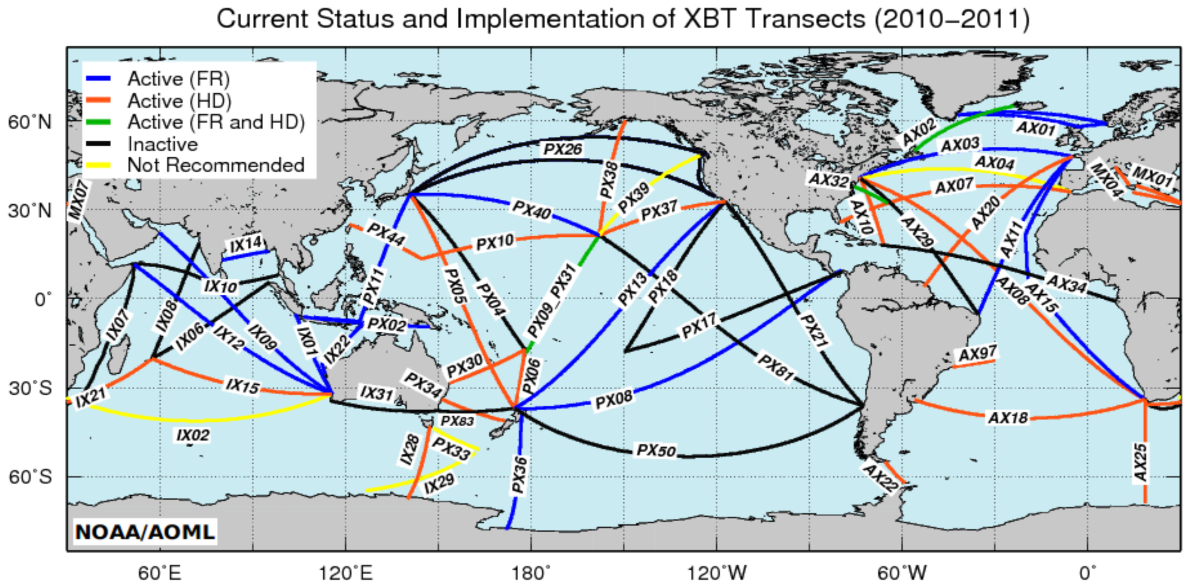


Figure 2: Current status and implementation of XBT transects recommended by the international community. Transects in black were not sampled during 2010-2011. Other colors indicate transects sampled in frequently repeated mode (FR, in blue), high density mode (HD, in orange) or both (in green). During 2010 and 2011 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.

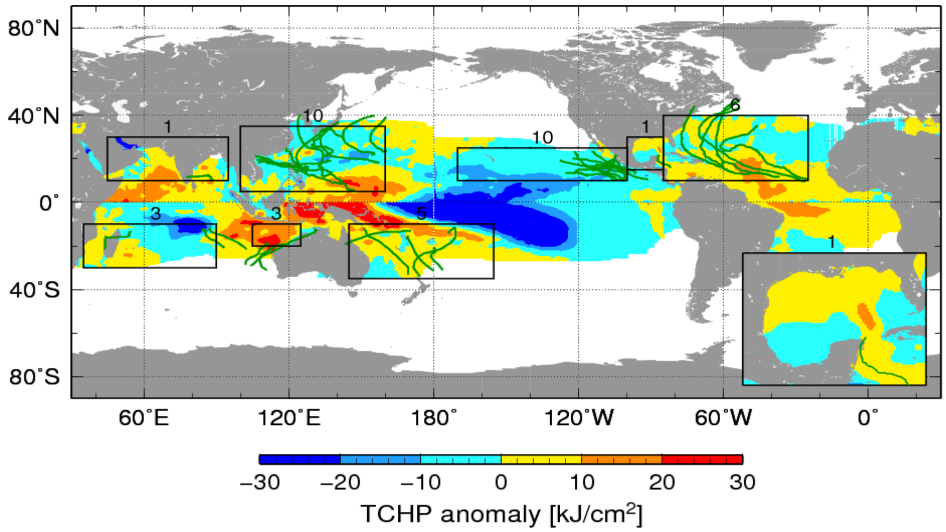


Figure 3: Global anomalies of TCHP corresponding to 2011. The boxes indicate the seven regions where TCs occur: from left to right, Southwest Indian, North Indian, West Pacific, Southeast Indian, South Pacific, East Pacific, and North Atlantic (shown as Gulf of Mexico and tropical Atlantic separately). The green lines indicate the trajectories of all tropical cyclones reaching at least category 1 (1-minute average wind ≥119 km/h) and above during November 2010-April 2011 in the Southern Hemisphere and June- November 2010 in the Northern Hemisphere. The numbers above each box correspond to the number of category 1 and above cyclones that travel within each box. The Gulf of Mexico conditions during June-November 2011 are shown in the lower right corner insert.

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.

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.

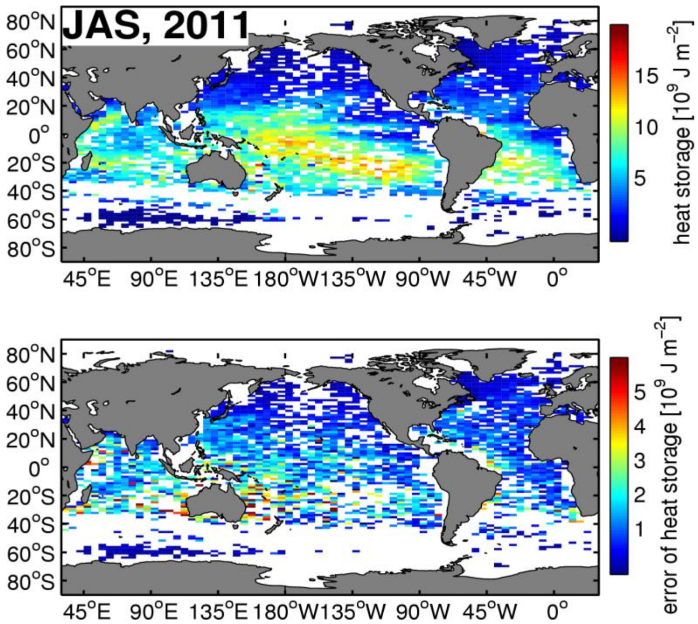


Figure 4: (top) Global map of *in situ* estimates of heat storage of the mixed layer and (bottom) error of these estimates for the period July – September, 2011.
Available online at *www.aoml.noaa.gov/phod/soto/ghs/reports*.

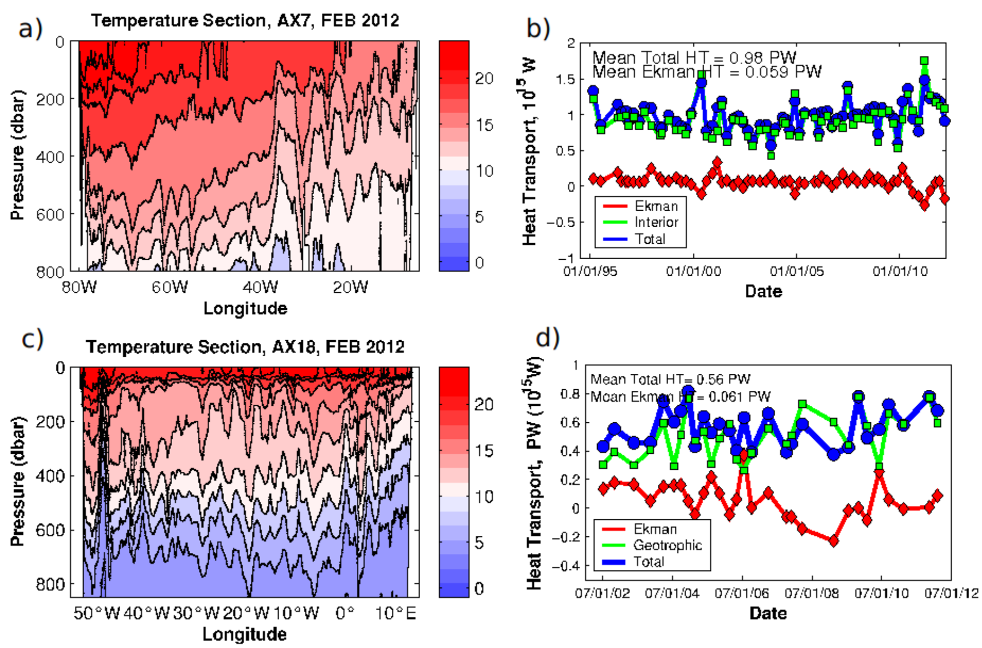
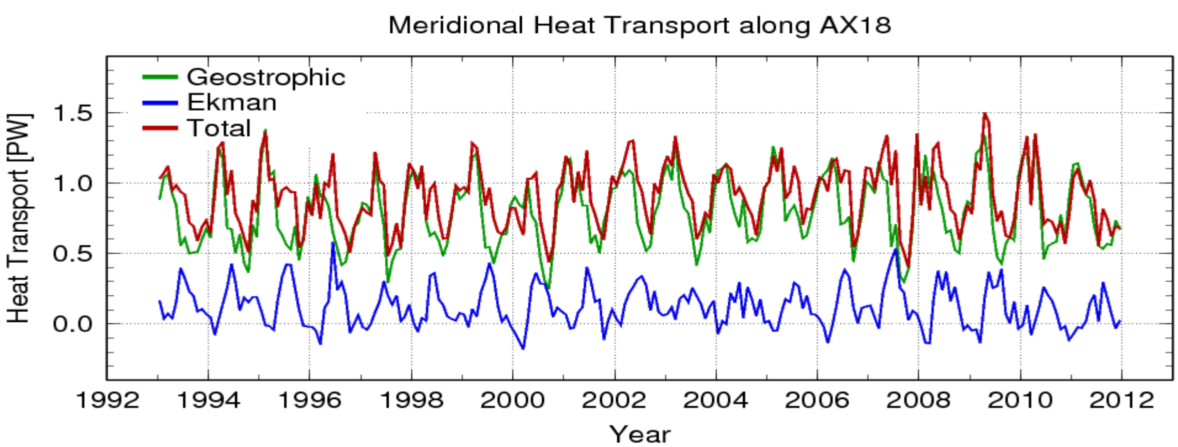


Figure 5: a) Temperature section and b) Ekman, Interior and Total heat transport in the North Atlantic obtained with the XBT data from the high density AX07 cruise on February, 2012. c) Temperature section and d) Ekman, Interior and Total heat transport in the South Atlantic obtained with the XBT data from the high density AX18 cruise on February 2012.
Available online at: *www.aoml.noaa.gov/phod/soto/mht/ax7/report.php*.

Studies using XBTs deployed along the zonal transect AX18 at nominally 35°S in the South Atlantic Ocean, which runs between Cape Town and Buenos Aires since 2002 have shown that the geostrophic component of the circulation dominates the net meridional heat transport (MHT) and that, at the seasonal time scale, the geostrophic and Ekman components of the circulation are out of phase. Both XBT observations and numerical model simulation have shown that the MHT in the South Atlantic has important contributions not only from the boundaries (Agulhas and Brazil-Malvinas Confluence regions) but also in the ocean interior. These analyses provide the backbone information to further investigate and validate longer time series derived from satellite altimetry observations. The XBT combined with altimetry data are used to investigate the seasonal and year-to-year variability of the MHT along 35°S since 1993. The geostrophic component is extracted from the altimetric record using a methodology demonstrated previously in the Brazil-Malvinas Confluence region (Goni et al., 1996). The Ekman contribution to the MHT is estimated using monthly wind fields. Preliminary results (Figure 6) confirm previous estimates showing that Ekman and geostrophic out of phase on seasonal time scales. These results demonstrate the importance of satellite altimetry observations for large scale studies in the South Atlantic Ocean and, in particular, to extend the analysis to latitudes where in situ observations are not available.



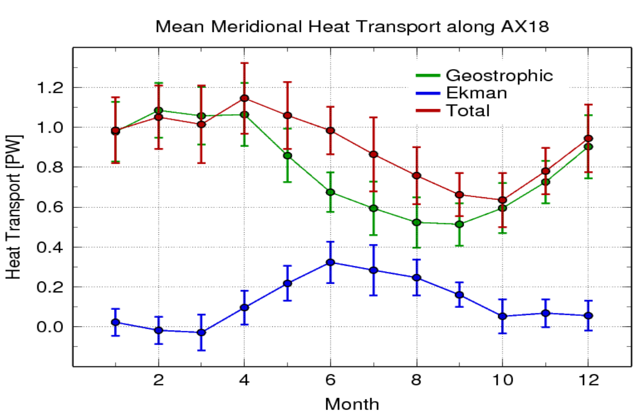


Figure 6: (top) time series of the altimetry-derived Meridional Heat Transport along 35°S in the South Atlantic, including its geostrophic and Ekman components, and (bottom) their mean seasonal estimates, where bars denote one standard deviation.

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 NECC shows a strong annual cycle of volume transport, with largest values from July to December (Figure 7). The NEUC reveals largest transport values (up to 10 Sv) from January to July and is correlated on interannual timescales with SSTs in the Gulf of Guinea and southeastern equatorial Atlantic as well as zonal equatorial winds. The EUC exhibits strong semi-annual and annual variability (Figure 7). This study shows that for a long-term monitoring system both altimetry and XBT data are needed for near-real-time inference of dynamic and thermodynamic properties of the tropical Atlantic current system.

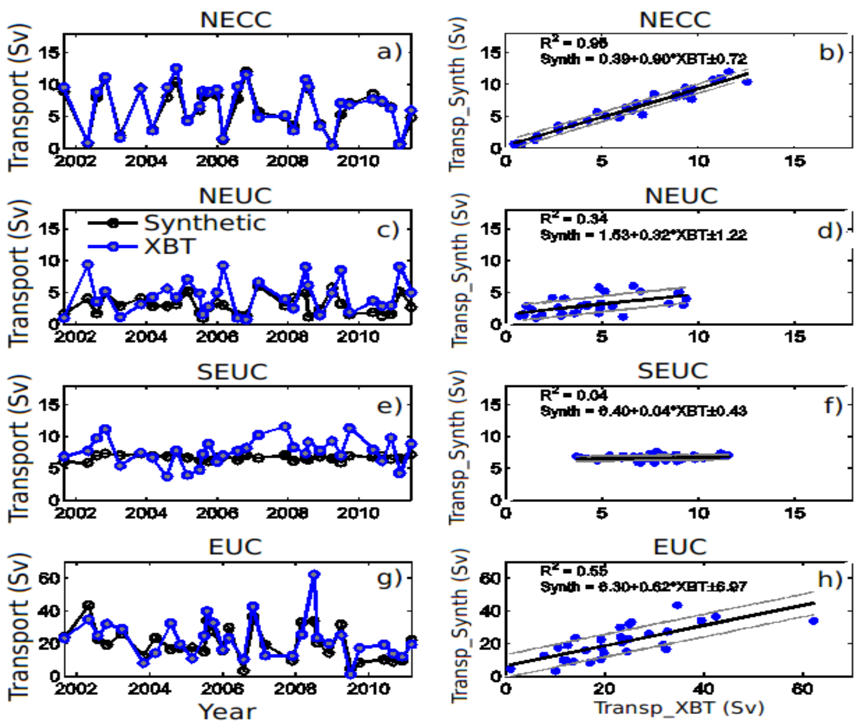


Figure 7: Geostrophic transports estimated from the synthetic method (black line with open dots) and from the XBT data (blue dots), with corresponding linear fit between the two transport estimates: (a, b) NECC, (c, d) NEUC, (e, f) SEUC, and (g, h) EUC.

Observations indicate a consistent warming of the Southern Ocean confined in the region that is known to be the domain of the Antarctic Circumpolar Current (ACC). The variability of this current is thought to be intimately related to the atmosphere, and frontal motions as well as transport changes are expected to be forced by changes in the wind pattern. Results obtained using XBT data along the AX25 transect in combination with wind observations indicate that changes in the zonal wind stress occur associated to the Southern Annular Mode (SAM), and, during positive SAM, easterly (westerly) anomalies were observed within 35°S-45°S (50°S - 60°S). Results suggests that wind-induced Ekman transport anomalies (Figure 8) may be affecting the dynamics of this region at interannual time-scales as follows: anomalous poleward Ekman transports develops north of 45°S, advecting warmer waters to the south and driving divergent anomalies within the SAF region, potentially relaxing the pressure gradient. Meanwhile to the south of 50°S, anomalous equatorward Ekman transport develop, generating convergent anomalies within the SAF region, potentially generating a steeper pressure gradient.

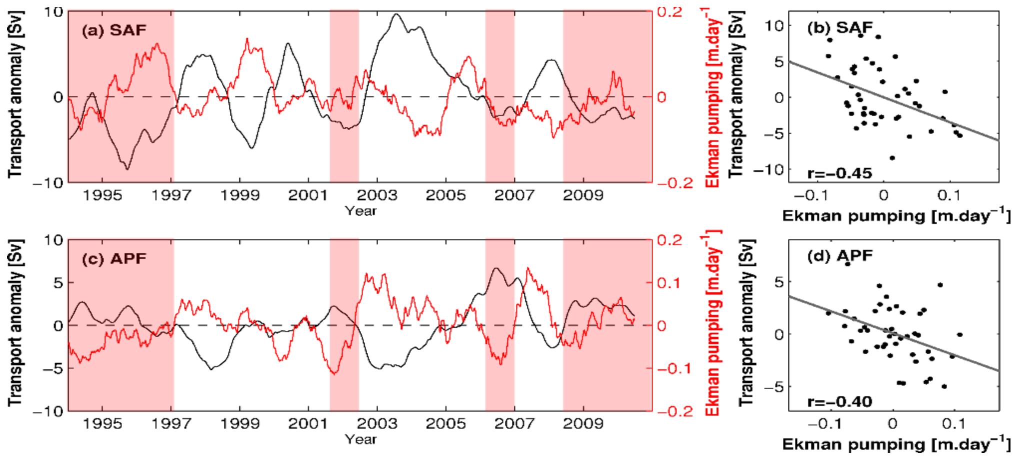


Figure 8: Relationship between frontal transport anomaly (black) and Ekman pumping velocities (red) for the SAF (a,b) and APF (c,d). Negative vertical velocities translate into convergent Ekman transport anomalies, and the opposite is true for positive velocities. The regions emphasized in red illustrate periods when warm temperature anomalies were observed within the ACC domain.

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

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Simulation of the Argo Observing System

Project Personnel: I. Kamenkovich and A. Haza (UM/RSMAS)
NOAA Collaborators: C. Schmid (NOAA/AOML); Z. Garraffo (NOAA/EMC/IMSG)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** To examine how well the Argo observing system determines the state of the global upper ocean, and to understand factors that control accuracy of the reconstruction of the oceanic state.

***Strategy*:** To employ a suite of Observation System Simulation Experiments (OSSE) in ocean general circulation models, to sub-sample oceanic fields in these experiments in ways similar to how the Argo float array samples the ocean, to quantify errors in reconstructions of the oceanic state, and to study factors that control these errors.

CIMAS Research Theme:

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

Link to NOAA Strategic Goals:

***Goal 1*:** Climate Adaptation and Mitigation - *An informed society anticipating and responding to climate and its impacts*

NOAA Funding Unit: OAR/AOML and OAR/CPO **NOAA Technical Contact:** Joel Levy

Research Summary:

The main goal of this study is to examine how well the Argo observing system determines the state of the global upper ocean. For this purpose, this study employs a suite of Observation System Simulation Experiments (OSSE) in ocean general circulation models. Oceanic fields in these experiments are sub-sampled in ways similar to how the Argo float array samples the ocean, reconstructed and compared with the direct model fields. This procedure leads to quantification of errors in reconstructions of the oceanic state by the actual Argo array and understanding of factors that control these errors. The results are expected to assist interpretation of the real Argo data.

We carried out three types of OSSEs, using: (i) a coarse-resolution global ocean model (completed); (ii) an idealized high-resolution ocean circulation model of the North Atlantic (completed); (iii) a comprehensive high-resolution global ocean circulation model (in progress).

1) In coarse-resolution simulations, we analyzed the expected accuracy of the Argo system in reconstructing the annual-mean values, annual cycle, and the interannual difference in oceanic variables. The results demonstrate an overall good performance of the simulated Argo system, but emphasize the importance of sustained measurements in the regions with strong currents.

2) In idealized high-resolution simulations, we analyzed the importance of mesoscale variability. The results demonstrate that mesoscale eddies generally help to achieve more uniform spatial sampling coverage. High-frequency variability in temperature and salinity leads to larger reconstruction errors, especially if the Argo sampling is carried only for a few years. Reconstruction of horizontal velocities from profiler trajectories is capable of detecting concentrated currents (such as multiple zonal jets in Figure 1).

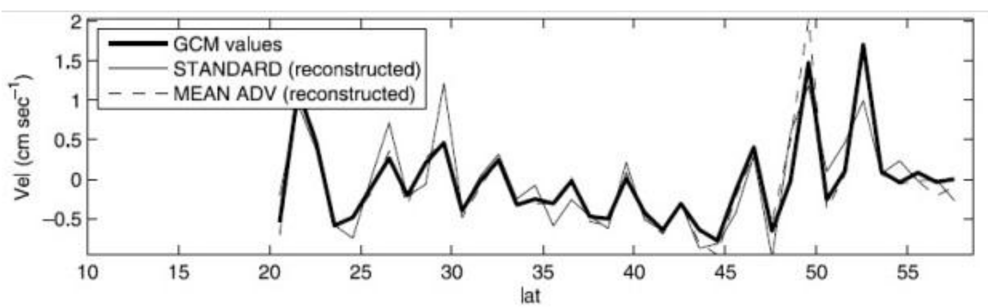

Figure 1: Effects of eddies on reconstruction of horizontal velocities in the North Atlantic. Shown are the zonally averaged zonal velocities at 1500 meter depth: actual GCM-simulated values (thick solid) and reconstructed from the simulated Argo trajectories (thin solid and dashed). Units are cm sec^{-1}. Multiple zonal jets are seen as local maxima in velocity magnitude; they are successfully detected by the reconstruction. From *Kamenkovich et al.* (2011).

3) The comprehensive high-resolution simulations are being carried out, using a state-of-the-art numerical model of the World Ocean: a high-resolution (1/12^o) global Hybrid-Coordinate Ocean Model (HYCOM). These simulations exhibit realistic mean state of the ocean and its mesoscale variability. Our activities so far have focused on the development and testing algorithms for float advection and software for data transfers. The simulations are competed for years 2004-2006 and are continued for later periods with new synthetic floats added (and removed) in agreement with the actual Argo floats. The float trajectories exhibit strong signature of the mesoscale variability

(Figure 2), particularly in such eddy-rich regions as the vicinity of the western boundary currents and the Southern Ocean.

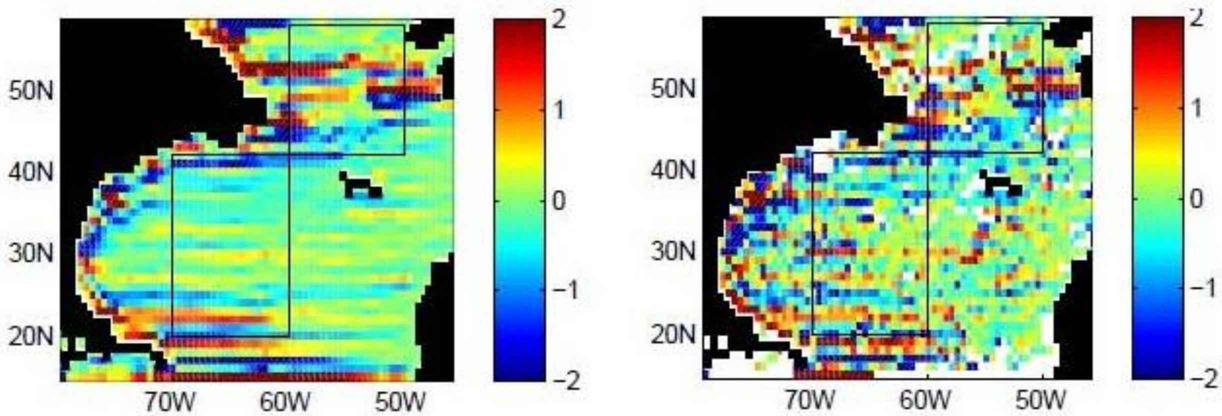

Figure 2: Global high-resolution HYCOM simulations of the Argo array: Float trajectories at 1000m depth during Sep-Oct 2005. Note the signature of mesoscale eddies.

We will also set up an internet data portal, which will contain simulated float trajectories and temperature/salinity profiles. The site will also contain links to existing HYCOM data portals, as well as instructions on how to download these data. This site is expected to be very useful for researchers who need to carry out their own OSSEs designed to assess various applications of Argo data and to help to design new analysis techniques.

Research Performance Measure: The project achieves the original objectives, by analyzing the factors that affect the expected accuracy of the Argo-based reconstructions of the oceanic state.

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Biogeochemical Measurements

Project Personnel: C. Langdon (UM/RSMAS)

Long Term Research Objectives and Strategy to Achieve Them:

Objectives**:** To: 1) Determine decadal changes in the chemistry of the ocean interior and to constrain ocean CO_2 inventories to 2 Pg C/ decade. 2) Determine decadal changes of dissolved oxygen in the ocean interior and use that data to infer changes in the ocean ventilation rate and primary production of overlying waters.

Strategy**:** Reoccupy transects on a decadal timescale and use the observed changes in dissolved oxygen and nutrients to determine what fraction of the observed change in dissolved inorganic carbon is due to natural processes and what is due to invasion of anthropogenic CO_2. Relate changes in the size (vertically and laterally) and location of the ocean's oxygen minimum zones (OMZs) to changes in factors that would affect the rate of subduction water of oxygenated from the surface i.e. winds, temperature, salinity, precipitation and evaporation (all factors that would reflect a change in climate on a decadal time scale). Changes in the rate of primary production in the waters overlying the OMZs and the rate of particle settling (i.e. rain rate) also will be considered.

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

Link to NOAA Strategic Goals:
***Goal 1*:** Climate Adaptation and Mitigation - *An informed society anticipating and responding to climate and its impacts* (*Primary*)
***Goal 3*:** Healthy Oceans - *Marine fisheries, habitats, and biodiversity sustained within healthy and productive ecosystems* (*Secondary*)

NOAA 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.

During FY-2011 I participated on a cruise that occupied 120 stations along the A10 line across the South Atlantic. I was responsible for the discrete oxygen measurements, quality control and data reduction and submission to the CCHOD data base.

Dissolved oxygen is proving to be sensitive indicator of the effects of climate change on the ocean. Changes in ocean circulation, ventilation of subsurface waters, changes in biological productivity and remineralization all impact the dissolved oxygen concentration of a parcel of water. Estimates of the amount of dissolved inorganic carbon taken up since the start of the industrial revolution (so called anthropogenic carbon) requires precise measurements of dissolved oxygen and nutrient concentrations. I am working with the ocean carbon group at PMEL to utilize the discrete oxygen data in a number of ways including quantifying changes in the anthropogenic carbon inventory of the ocean (Sabine et al. 2008), climate variability in the thermocline waters in the North Pacific (Mecking et al. 2008) and using oxygen data to improve our understanding of the temporal and spatial variability of aragonite saturation state during upwelling events along the northwest coast of the US (Fassbender et al. 2011).

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

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 1*:** Climate Adaptation and Mitigation – *An informed society anticipating and responding to climate and its impacts*

NOAA 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 ARGOS-tracked surface drifting buoys to meet the need for an accurate and globally dense set of in-situ observations of mixed layer currents, sea surface temperature (SST), atmospheric pressure, winds and salinity.
- *Drifter Data Assembly Center (DAC)* whose tasks are: to arrange data dissemination to the Global Telecommunications System (GTS); to provide uniform quality-controlled data from the historical data sets of SST and surface velocity, web access, archival and distribution. These data support short-term (seasonal to interannual) climate predictions as well as climate research and monitoring.

The design of the Global Drifter Program drifter has continued to evolve - as demonstrated by the recent introduction of hurricane drifters with wind measurements - while its qualitative characteristics and water-following properties have remained relatively stable since the earliest deployments. Incremental improvements in design and manufacturing continue to increase drifter lifetime, and alternative methods for detecting drogue presence (such as tether strain) are being evaluated. We continue to develop new methodologies for drifter data analysis, aided by increasing information from the ever-growing drifter array and from other sources of complimentary observations. Dense deployments in eddy-rich, frontal regions will help us improve our understanding of eddy fluxes and their role in modifying air-sea heat fluxes and water mass formation.

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

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

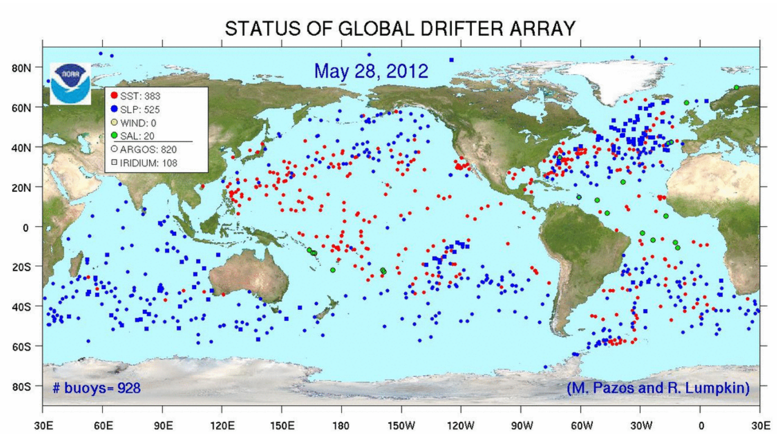

Figure 1: Status of the Global Drifter Array (updated weekly)

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

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

PIRATA Northeast Extension (PNE)

Project Personnel: V. Hormann, R.C. Perez, M. Goes and G. Rawson (UM/CIMAS)
NOAA Collaborators: R. Lumpkin, G.R. Foltz, C.S. Meinen and C. Schmid (NOAA/AOML)

Long Term Research Objectives and Strategy to Achieve Them:

Objectives**:** PIRATA stands for "Prediction and Research moored Array in the Tropical Atlantic". PIRATA is a multinational observation network, established to improve our knowledge and understanding of coupled ocean-atmosphere variability in the tropical Atlantic. It is a joint project of Brazil, France, and the United States of America. PIRATA is motivated by fundamental scientific issues and by societal needs for improved prediction of climate variability and its impact on the countries surrounding the tropical Atlantic Ocean.

Strategy**:** 1) To improve the description of the intraseasonal-to-interannual variability in the atmospheric and oceanic boundary layers of the tropical Atlantic Ocean; 2) to improve our understanding of the relative contributions of air-sea fluxes and ocean dynamics to the variability of sea surface temperature and subsurface heat content; 3) to provide a set of data useful for developing and improving the predictive models of the ocean-atmosphere coupled system; 4) to document interactions between tropical Atlantic climate and remotely forced variability, such as El Niño Southern Oscillation and the North Atlantic Oscillation; 5) to design, deploy, and maintain an array of moored oceanic buoys and collect and transmit a set of oceanic and atmospheric data, via satellite in near-real time, to monitor and study the upper ocean and atmosphere of the tropical Atlantic Ocean.

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

Link to NOAA Strategic Goals:
Goal 1**:** Climate Adaptation and Mitigation - *An informed society anticipating and responding to climate and its impacts*

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

Research Summary:
NOAA's contribution, the PIRATA Northeast Extension (PNE), is a project that expands the PIRATA array of ATLAS (Autonomous Temperature Line Acquisition System) moorings into the northern and northeastern sectors of the tropical Atlantic Ocean. This region has strong climate variations from intraseasonal to decadal timescales, with impacts upon rainfall rates and storm strikes for the surrounding regions of Africa and the Americas. Important processes in this region include formation of Cape-Verde-type hurricanes, seasonal migration of the Intertropical Convergence Zone (ITCZ) and the Guinea Dome, interannual variations of the ITCZ migration associated with rainfall anomalies in Africa and the Americas, off-equatorial eddy heat advection by tropical instability waves, and ventilation of the oxygen minimum zone.

The PNE buoys and moorings are serviced by annual cruises, during which opportunistic oceanographic and meteorological observations are collected. Post-cruise processing and distribution on the PNE web site (http://www.aoml.noaa.gov/phod/pne/index.php) adds value by making the data available to the scientific community. Research using PNE cruise data is conducted by CIMAS scientists as well as the climate research community and is aimed at advancing our understanding and improving numerical simulation of climate signals in the tropical Atlantic.

PIRATA is a three-party project involving Brazil, France, and the United States that seeks to monitor the upper ocean and near-surface atmosphere of the tropical Atlantic via the deployment and maintenance of an array of moored buoys and automatic meteorological stations.

The array consists of a backbone of ten moorings that run along the equator and extend southward along 10ºW to 10ºS, and northward along 38ºW to 15ºN. Given the widely varying dynamics of various sub-regions of the tropical Atlantic, future extensions of the array had been anticipated by the PIRATA Science Steering Group to further the scientific scope of the observing system and improve weather and climate forecasts. In August 2005, a Southwest Extension of three moorings was added off the coast of Brazil (PIs: P. Nobre, E. Campos, P. Polito, O. Sato, and J. Lorenzzetti).

The northeastern and north central tropical Atlantic (Figure 1) is a region of strong climate variations from intraseasonal to decadal timescales, with impacts upon rainfall rates and storm strikes for the surrounding regions of Africa and the Americas. In 2004, Rick Lumpkin and collaborators proposed a formal PIRATA Northeast Extension (PNE), to consist of four moorings (see Figure 1). This extension was approved and funded by NOAA's Climate Program Office for implementation starting in June 2006.

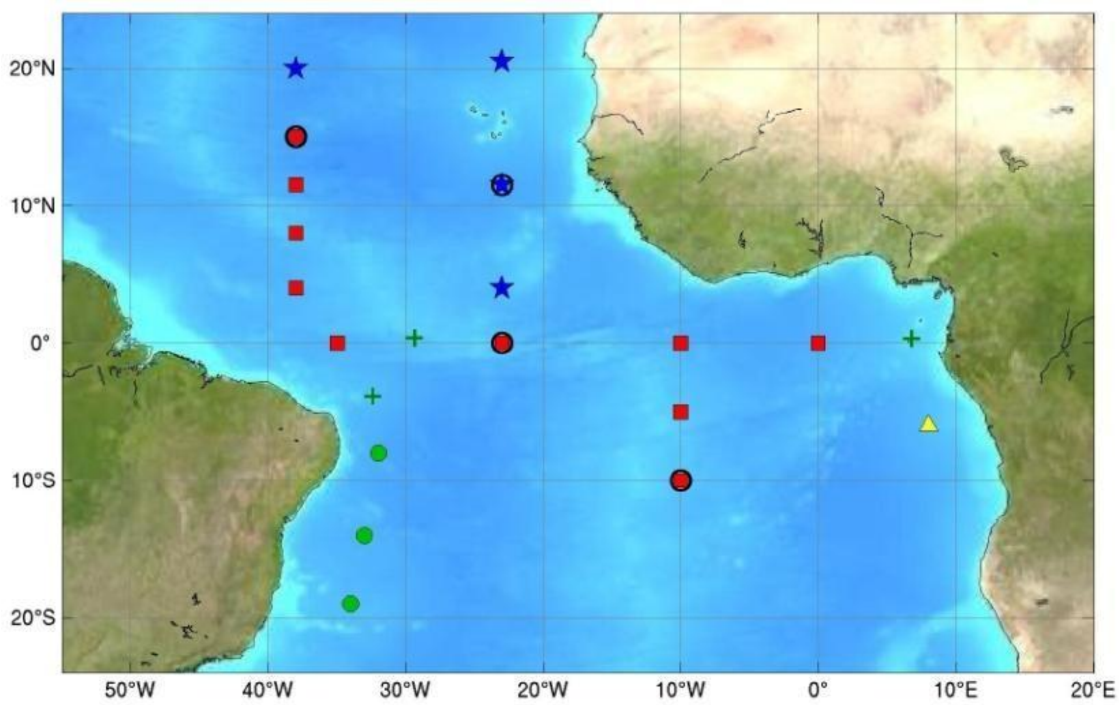

Figure 1: The PIRATA array, showing the backbone of buoys (red squares), the Northeast Extension (blue stars) led by the United States (NOAA), the Southwest Extension (green circles) led by Brazil, the Southeast Extension pilot site (yellow triangle), and island-based observation sites (green crosses). Buoys with barometers and long-wave radiometers are indicated by black circles.

In July - August 2011, the PNE servicing cruise was conducted aboard the NOAA ship Ronald H. Brown on a cruise from Charleston, SC to Cape Town, South Africa (Figure 2). The chief scientist was Rick Lumpkin (NOAA/AOML), and Verena Hormann and Grant Rawson were the CIMAS personnel in attendance. The cruise served to recover and redeploy all four of the PNE moorings, and collect CTD casts at the mooring sites for instrument calibration and validation. Two additional components of the cruise were (1) the deployment of drifters, floats, and collection of underway shipboard measurements along the track line, and (2) the AEROSE project which collects and analyzes aerosol data to improve the understanding of their impact on, for example, heat fluxes into the ocean.

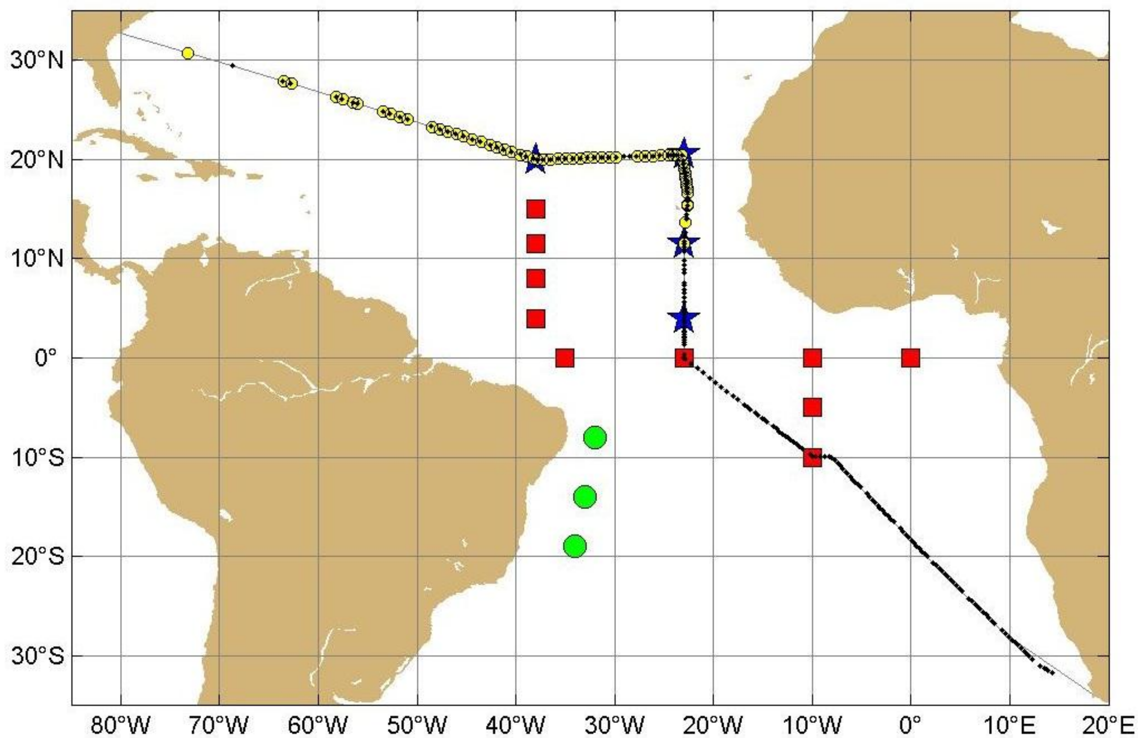

Figure 2: Map showing the cruise track of the PNE cruise in July – August 2011 aboard the NOAA ship Ronald H. Brown (gray line), with PNE mooring sites (blue stars), PIRATA backbone moorings (red squares), Southwest extension moorings (green circles), XBT drop locations (black dots), and UCTD deployment locations (yellow circles).

In an effort to start measuring the upper ocean with new technology, the Physical Oceanography Division at NOAA/AOML rented an Underway CTD (UCTD) system with two CTD probes from *Oceanscience* (http://www.oceanscience.com/uctd.html) for evaluation during the PNE cruise. The UCTD system is capable of collecting temperature and salinity profiles down to a depth of about 500 m at underway speeds. During the cruise, approximately 60 UCTD casts were conducted and the collected data revealed a subsurface salinity maximum associated with subduction earlier in the year of saltier mid-latitude surface water beneath fresher water that had been exposed to rainfall associated with the ITCZ (Figure 3).

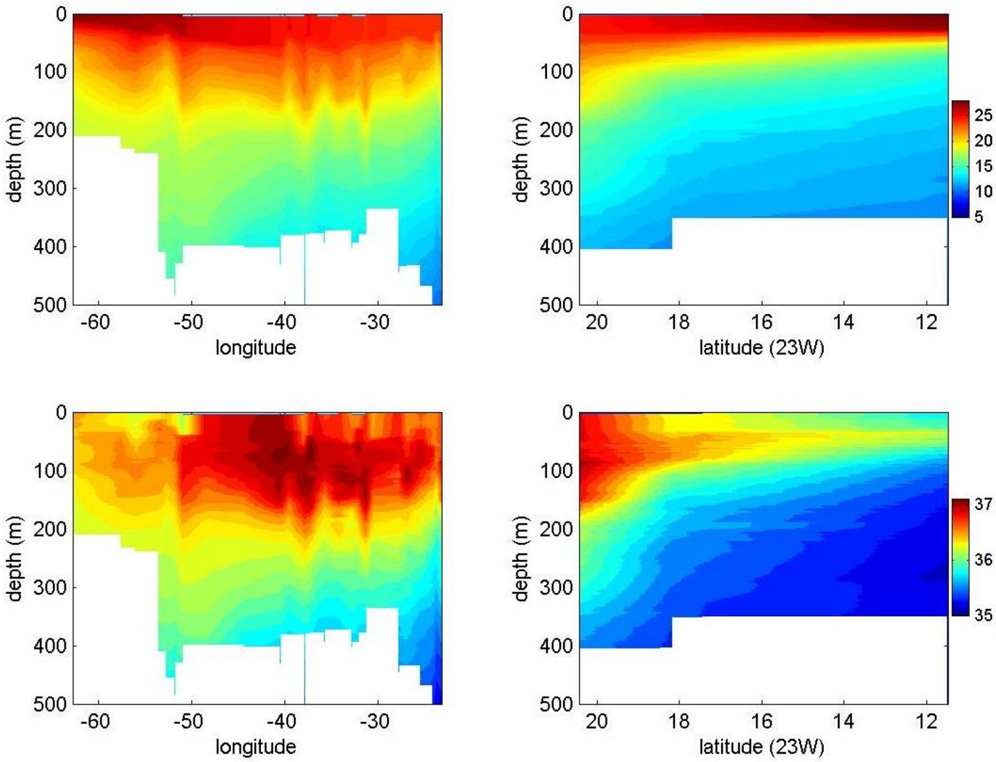

Figure 3: UCTD temperature (top, in °C) and salinity (bottom, in psu) sections from the PNE cruise in July – August 2011: (left) transit from Charleston, SC to 20.5°N, 23°W; (right) transit south along 23°W.

Research Performance Measure: All major objectives are being met. Three PNE-related papers have been published this year in the Journal of Geophysical Research and the Journal of Climate.

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

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

Long Term Research Objectives and Strategy to Achieve Them:

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

***Strategy*:** To monitor ocean parameters over large areas of the ocean through the 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

Link to NOAA Strategic Goals:

***Goal 1*:** Climate Adaptation and Mitigation - *An informed society anticipating and responding to climate and its impacts* (*Primary*)

***Goal 2*:** Weather-Ready Nation - *Society is prepared for and responds to weather-related events* (*Secondary*)

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 profilers provide measurements of temperature and salinity to depths of 1000-2000 meters, and currents at the drift depth of the floats. Researchers in many scientific disciplines, including meteorology, climatology and oceanography, use data collected from the floats. The Argo array achieved its goal of a total of 3000 floats in November 2007 and is maintaining the number of floats.

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

- 437 floats were deployed by the USA
- 84 of these floats were deployed by AOML
- 2195 US floats are actively reporting.
- 62031 profiles have been sent to Global Data Centres
- 52309 profiles were sent to GTS by the US DAC

Due to the departure of a Federal employee in February, additional software maintenance and development duties were acquired by two CIMAS employees, one long-time employee and one recently hired.

Software was implemented for tracking the real-time data in BUFR format sent to the Global Telecommunication System.

Argo software and data has been migrated to a new machine running a new operating system which has required extensive testing. The operational software and data is presently synchronized on the new machine until fully operational.

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.

Analysis of T/S measurements from Argo profiling floats for MOC/MHT in the South Atlantic: The objective of the study is to examine the model-data differences in the seasonality of the meridional overturning circulation (MOC) and meridional heat transport (MHT) in the South Atlantic, and to investigate the causes for the possible differences. Temperature and salinity climatology from Argo profiling floats and from GFDL models are used to estimate the MOC/MHT at 34S. The MOC from model T/S fields show strong transport in the ocean interior region compared to the MOC estimated from Argo T/S fields.The geostrophic component of the MOC estimated from Argo data shows a seasonal variation with the maximum value in January and minimum value in August (Figure 1). However, the seasonal variations of the geostrophic contributions to the MOC from model T/S fields is very weak. Differences are seen in all three regions: western boundary, interior region, and eastern boundary, with the largest difference in the eastern boundary.

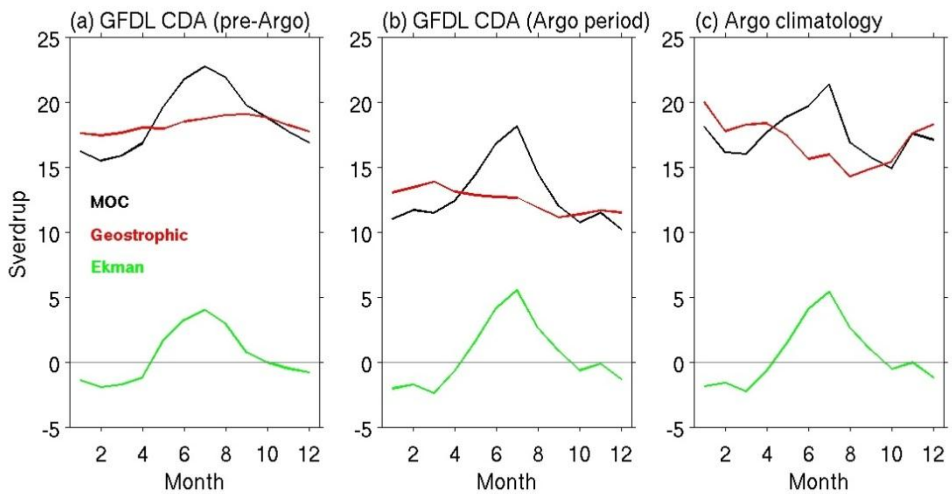


Figure 1: Estimates of MOC (black) and its contributions from geostrophic (red) and Ekman (green) components based on temperature and salinity climatology constructed from GFDL.

Examination of the density field suggests that the difference in the eastern boundary is related to the vertical coherent density variations in the Argo measurements, which is not shown in the model field. Those differences may be related to the differences in the wind stress curl between model and observations, where strong differences are seen in the eastern boundary. Further investigation will be conducted to link model-data difference in MOC/MHT with forcing fields.

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 on an ongoing basis. 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 2) 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.

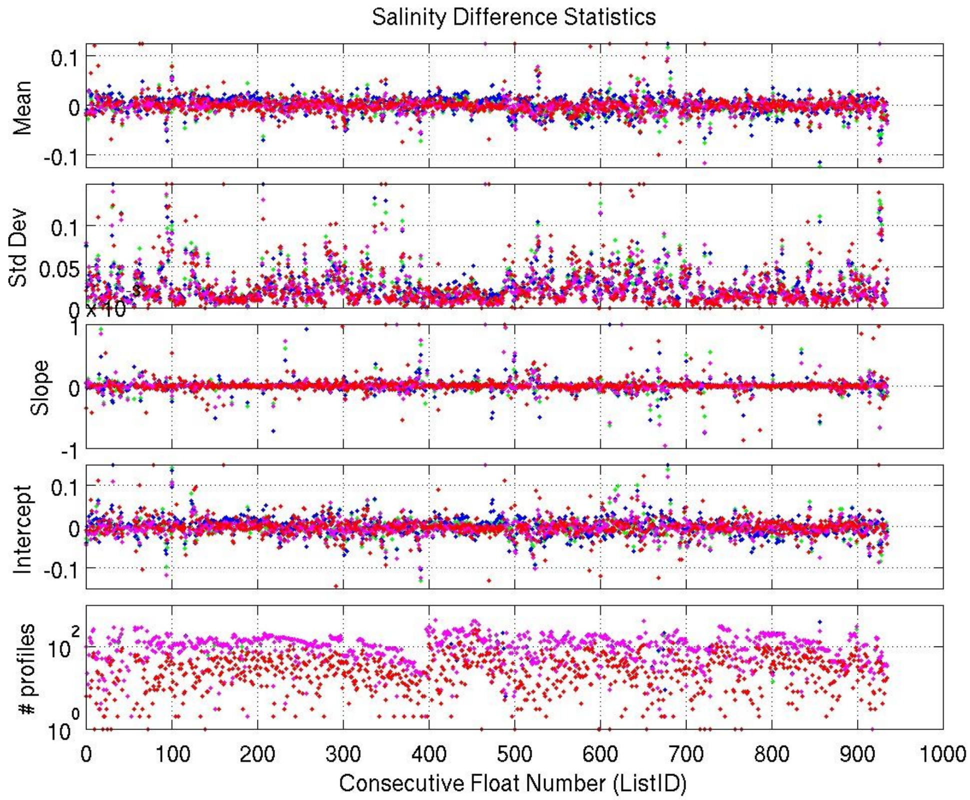


Figure 2: Summary plots of the statistical analysis performed on the salinity of the delayed-mode profiles of Argo floats in the region covered by the South Atlantic Argo Regional Center.

The fourth comparison dataset above underwent extensive renovation this year. It was found that some of the monthly ascii combined data files from GTSPP (the Global Temperature-Salinity Profile Program) were corrupted and/or incomplete. We first tried the combined netCDF files, but these had the same problem. We then adapted to use the individual-profile netCDF files, and these were complete. We then rebuilt the entire dataset from these, and from all available ARGO profiles. All of our on-line data products (see next section) are in the process of being updated.

Products web pages:
http://www.aoml.noaa.gov/phod/sardac/products/index.php currently shows three types of products that are derived from hydrographic profiles collected by Argo floats and other instruments:

- Properties of the mixed layer (thickness, temperature and heat storage rate) as monthly fields.
- Zonal sections of temperature, salinity and dynamic height across the Atlantic as semi-annual and annual means. These are at 14 latitudes between 20N and 45S, and cover 4 degrees of latitude.
- Meridional sections of temperature, salinity and dynamic height across the Atlantic as semi-annual and annual means. These are at 3 longitudes, 22.5W, 27.5W and 32.5W, and cover 5 degrees of longitude.

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

Studies in Support of NOAA's Operational Ocean Heat Content Analysis Using Deep Water Horizon Measurements

Project Personnel: L.K. (Nick) Shay (UM/RSMAS)
NOAA Collaborators: E. Maturi and J. Sapper (NESDIS)

Long Term Research Objectives and Strategy to Achieve Them:

***Objective*:** To provide a high resolution Oceanic Heat Content (OHC) product (0.25^o) from altimeter derived fields for the North Atlantic and North Pacific Ocean Basins to NOAA NESDIS for 24/7 operations. A key aspect of this product is that the isotherm depths (20 and 26^oC), ocean mixed layer depth, and OHC will be carefully evaluated from *in-situ* data from floats, drifters, expendable bathythermographs (XBT) transects, long-term PIRATA and TOGA TAO moorings and airborne expendable profilers (AXBTs, AXCTDs, AXCPs) including data recently acquired from the Deep Water Horizon monitoring over about 90 days following the incident using NOAA research aircraft.

***Strategy*:** To build realistic climatology for a two-layer model and evaluate a daily OHC product based on satellite altimetry-derived sea surface height anomalies and high resolution sea surface temperatures from GEOS/POES with observations from various in-situ platforms. This product is being transitioned to NOAA NESDIS for 24/7 operations.

CIMAS Research Theme:

***Theme 3*:** Sustained Ocean and Coastal Observation (*Primary*)
***Theme 2*:** Tropical Weather (*Secondary*)

Link to NOAA Strategic Goals:

***Goal 2*:** Weather-Ready Nation - *Society is prepared for and responds to weather-related events*

NOAA Funding Unit: NESDIS/STAR
NOAA Technical Contact: Dr. Eileen Maturi

Research Summary:

A daily, Systematically Merged Atlantic Regional Temperature and Salinity (SMARTS) and a Systematically merged Pacific Ocean Regional Temperature and Salinity (SPORTS) climatology has been constructed from GDEM 3.0 and latest WOA for the two layer model using a 15-day running mean to insure continuity between the months for mean isotherm depths and reduced gravities. Temperature profiles acquired from various platforms including ARGO floats, XBT transects (see Figure 1), PIRATA moorings and AXBTs for a fourteen-year period. In addition, the measurements from the Deep Water Horizon response in 2010 were also entrained into the Atlantic Ocean basin analysis to improve the satellite-derived algorithm. These measurements significantly improved the predictive ocean models by reducing the biases and RMS errors by ~30% compared to the same model that assimilated altimetry only (Shay et al., 2011). Altimeter-derived se surface heights have been blended and objectively analyzed from various satellites using the Mariano and Brown (1992) approach to estimate satellite based values of isotherm depths and OHC variability. Based on in situ measurements, we have found high correlations and low RMS differences between observed and space-based estimates of the product fields based on the SMARTS climatology for the North Atlantic Ocean basin (Meyers, 2011). Initial estimates from the SPORTS are quite encouraging as well.

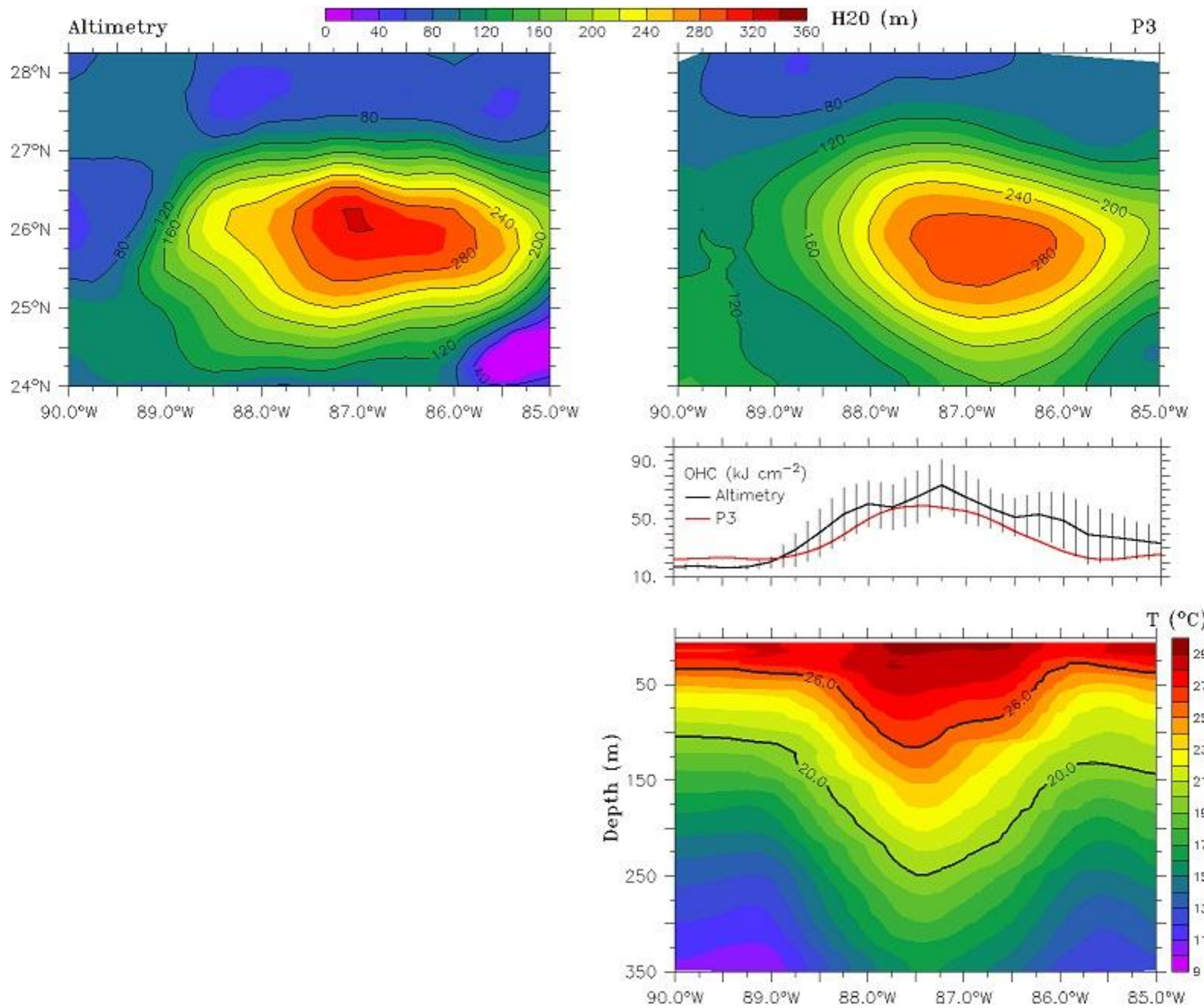


Figure 1: Comparisons of the 20°C isotherm depth (m) from a) SMARTS and b) objectively mapped airborne profiler data, c) cross Loop Current temperature section (lower panel) at 26°N and the corresponding comparison between satellite-derived and in situ OHC along the transect (upper panel) with error bars. Temperature section in the lower panel depicts depths of the 26 and 20°C isotherms as noted. Note expendable measurements are primarily used in the Gulf of Mexico due to the lack of profiling float measurements in the Loop Current and warm eddy field because of strong currents in the upper ocean (Adapted from Shay et al., 2011).

Research Performance Measure: The new SMARTS climatology has been compared to over 50,000 temperature profiles acquired from various platforms in the North Atlantic Ocean basin. The RMS differences between satellite inferred and observed have been lowered significantly in the process compared to previous estimates. This product should thus become operational over the next couple of months at NESDIS. We have essentially utilized a similar approach in the North Pacific Basin by developing SPORTS. We expect to assess SPORTS in much the same way including the recent measurements from the joint US/Taiwan ITOP experiment conducted in 2010 when they become available. There has been about a few months slippage in developing SPORTS.

Remote Sensing in Support of Climate Research

Project Personnel: R.C. Perez (UM/CIMAS)
NOAA Collaborator: G.J. Goni (NOAA/AOML)
Other Collaborators: J.A. Trinanes (University of 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 1*:** Climate Adaptation and Mitigation - *An informed society anticipating and responding to climate and its impacts (Primary)*

***Goal 2*:** Weather-Ready Nation - *Society is prepared for and responds to weather-related events (Secondary)*

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

Research Summary:

A key outcome of this project is to develop and implement the technologies 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 that are used by this project includes sea surface height, sea surface temperature, 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 data from NOAA/POES satellites. Within this project, we provide NOAA/NESDIS Office of Satellite Data Processing and Distribution with rapid access to the raw telemetry and Level-1 products from a variety of sensors (HIRS, AMSU, MHS, DCS, SEM, etc.). We are currently working on an agreement between NOAA/NESDIS and CNES to perform an upgrade to the station for ARGOS telemetry reception from the new SARAL mission.

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. Through the implemented interfaces, users can download satellite products in a variety of data and image formats such as MAT-files, NetCDF and KML.

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. This approach makes extensive use of open Web Services such as Web Map Services, Web Feature Services and Web Coverage Services. These standards provide an 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 own computing environments.

Raw and Level1 satellite data serve as basis to generate higher-level products. In collaboration with the Physical Oceanography Division at NOAA/AOML, daily and 3-day aggregated fields of MODIS/Aqua and MODIS/Terra Rrs667 and K490 are routinely generated and distributed. These products provide information to monitor Mississippi river water discharge and with other products, they improve the monitoring activities in the Gulf of Mexico (Figure 1).

(a)

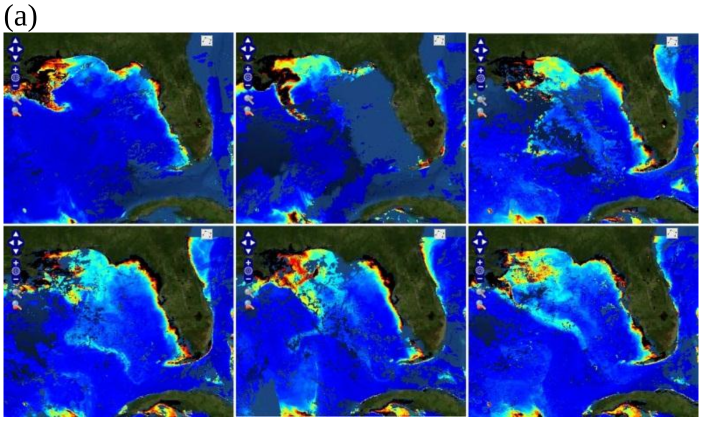
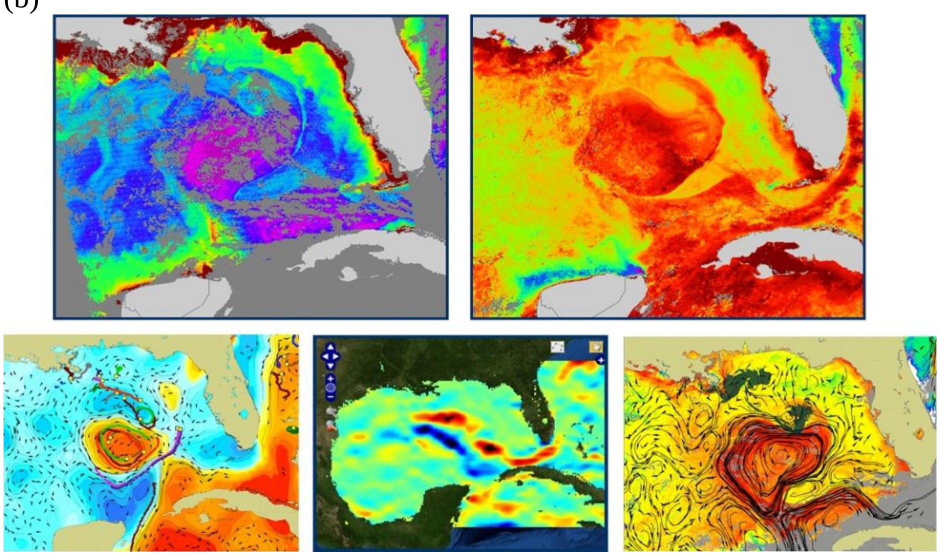


Figure 1: a) Time series showing the fields of K490 (which are an indicator of water turbidity) obtained from MODIS/Aqua during Jun, Jul and Aug 2011. These fields serve to study and monitor the conditions in the Gulf of Mexico. b) Other datasets which are routinely being created and made available for general distribution include (from left to right and from top to bottom): Chlorophyll a, sea surface temperature (SST), dynamic topography (with overlaid drifter tracks), zonal (and meridional) geostrophic velocities, composite products (SST+geostrophic flow in this case).

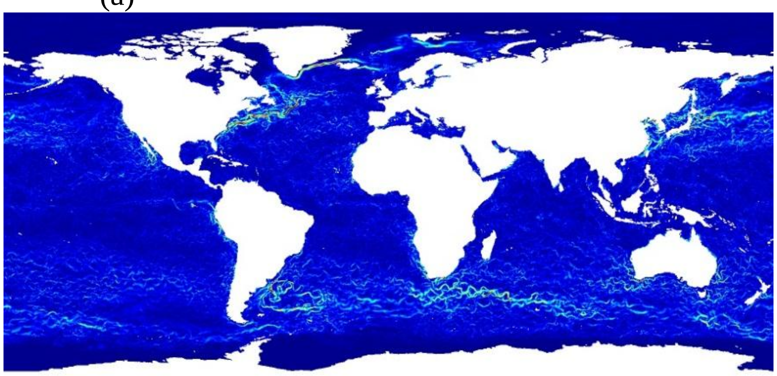
(b)



During last year, MERIS processing routines have been updated to account for changes in Kiruna, Matera and ESRIN sites. The latter has been added to have access to global onboard-recorded Full Resolution (FRS) data, which provides passes over other continental United States areas not previously covered by land stations (e.g., Hawaii and Puerto Rico). The new data processing system enables the quick production of high-resolution (~300m) oil-spill detection products for NOAA/NESDIS/SAB and other near-real-time (NRT) products from the FRS and reduced resolution datasets. Using Beam's Graph Processing Framework, which allows us to connect operations and provides multi-threading, processing times were improved by up-to a factor of 80 when compared to the previous algorithms. These changes greatly minimized processing latency (products were available for NRT use only a few minutes after availability at Kiruna, ESRIN or Matera DDSs). The new upgrade allowed NOAA to retrieve all the different subsets that form the complete NRT FRS dataset, and greatly improved the coverage in the Gulf of Mexico and Caribbean where both direct-transmission and recorded data were available until ENVISAT services were interrupted last April. We expect that current developments could be applied to the data received from OCLI (Ocean and Land Colour Instrument on the new Sentinel-3 spacecraft, which is planned to be launched in 2013.

Research efforts are also aimed to develop other value-added services (Figure 2), such as frontal products and techniques and algorithms for public health applications (e.g. to determine risk for Vibrio infections using Remote Sensing).

(a)



(b)

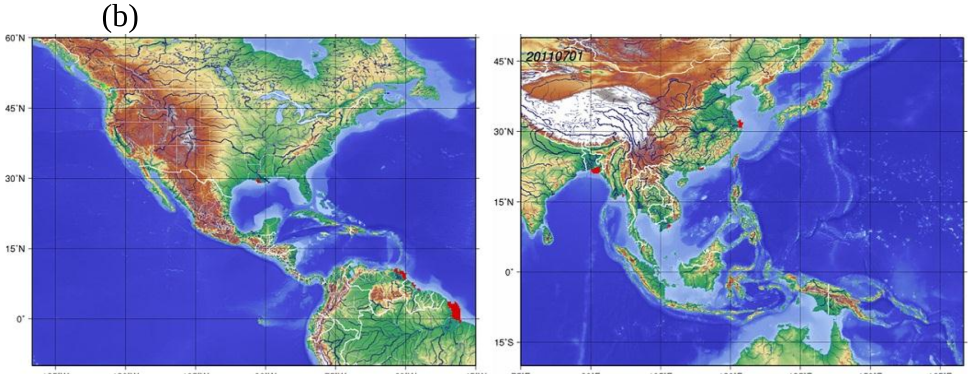


Figure 2: a) Frontal boundaries on May 20, 2012 estimated from daily 5-km SST fields obtained from combining polar and geostationary satellite fields. The SST, associated errors and frontal products are all available from NOAA/AOML and NOAA/CW servers. b) Monthly regional risk model analysis in Central and North America (left) and West Asia (right). The regions in red color denote high risk of Vibrio infections.

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 SOA framework.

Marine Optical Buoy (MOBY) Operations Bridge Through NPP Launch

Project Personnel: K. J. Voss (UM/Physics)
Other Collaborators: M. Yarbrough (SJSU/Moss Landing Marine Lab)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** To provide the most accurate measurement of the water leaving radiance to be used as the primary calibration point for the international community of ocean color satellites, but primarily the recently launched VIIRS instrument.

***Strategy*:** We are maintaining the operation of the Marine Optical Buoy (MOBY), moored off of the island of Lanai, Hawaii. In addition, to provide for future operation of this instrument, we are moving towards replacing many of the MOBY subsystems with modern optics and electronics as funding allows.

CIMAS Research Theme:

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

Link to NOAA Strategic Goals:

***Goal 2*:** Weather-Ready Nation - *Society is prepared for and responds to weather-related events*

NOAA Funding Unit: NESDIS **NOAA Technical Contact:** Kent H. Hughes

Research Summary:

The largest portion of this work is maintaining MOBY operations at the highest level of radiometric accuracy (schematic of MOBY shown in Figure 1). This includes exchanging the MOBY instrument each quarter and replacing the main mooring for MOBY in alternate years. Each MOBY buoy system must be calibrated pre- and post-deployment, diver calibrations must be done monthly, and all of these calibrations must be processed to keep a real time data stream along with a post-calibrated archive. The data is processed then provided, through the NOAA CoastWatch site, to users around the world.

For several years we have known that the current MOBY system was nearing its end of life and it was critical that a technology refresh occur. With small grants we have been able to procure and test various components that could form the basis of the new system, and currently have a defined path towards this new state-of-the-art ocean color vicarious calibration system. The hyperspectral nature/requirement of this instrument is important to emphasize. To properly provide a vicarious calibration dataset useful to a broad set of satellite sensors requires a hyperspectral instrument that can match the varied spectral characteristics of the satellite sensors. It is also important that a single site provides data that can be used by a variety of sensors, so that their datasets can be tied together in a consistent manner.

Thus we are working towards implementing a newer optical design into the MOBY system, shown in Figure 2. This system, once built, will be fully characterized and calibrated with SI traceability (NIST) and is designed to reduce the primary uncertainty components in the MOBY radiometric uncertainty budget (Brown *et al.,* 2007). Improvements include multi-channel simultaneous acquisition capability, internal radiometric response validation sources, and UV anti-biofouling sources to keep the external optical windows clean. Because strict attention has been paid to the

MOBY uncertainty budget in the concept development of the new system, it will function with lower uncertainties than the current, extremely successful, MOBY system.

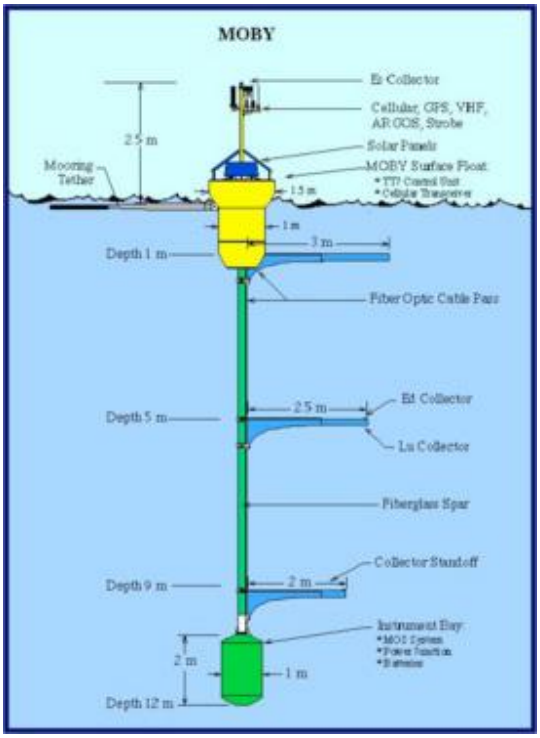


Figure 1: Schematic of the MOBY buoy currently operated off of Lanai, Hawaii, and the central focus of our work. The buoy collects hyperspectral (1 nm resolution) upwelling radiance at 3 different depths, and downwelling irradiance above the water and at 3 different depths below the surface. This data is combined to calculate the water-leaving radiance, just above the water surface, a fundamental output of an ocean color satellite instrument, hence our data provides a primary calibration point for these satellites.

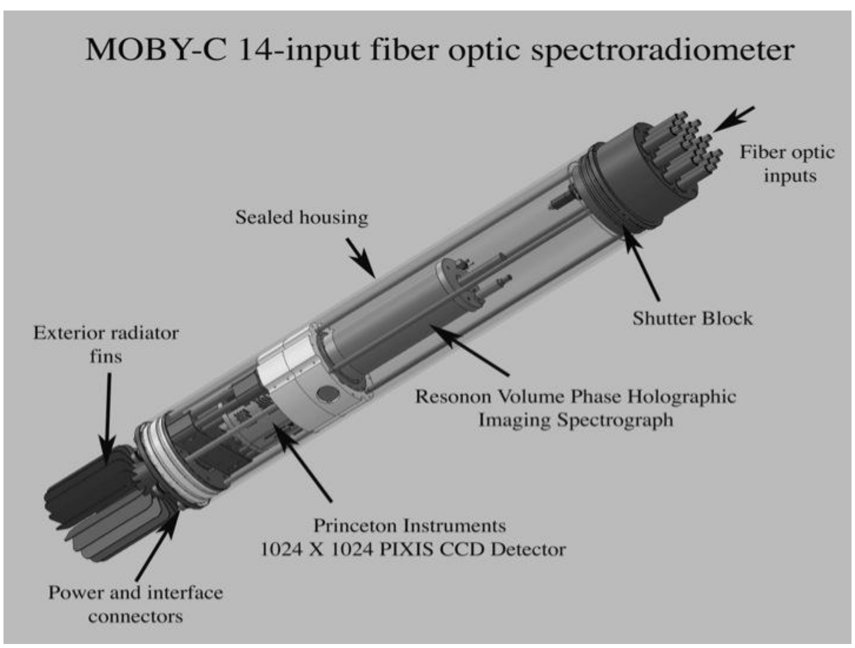


Figure 2: This is the current design of the spectrometer that will be used in the new MOBY system. The central feature is the Resonon Volume Phase Holographic Imaging spectrometer, which allows multiple channels (depths/sensors) to be spectrally measured simultaneously. This will allow all of the irradiance and radiance measurements shown in Figure 1 to be performed at the same instant, greatly increasing the accuracy of the derived water leaving radiance.

Research Performance Measure: We have been maintaining current MOBY operations over this period. An example is the time series shown in Figure 3. In this figure the most current deployment, starting in December of 2011 (on right of figure, then continuing in 2012 on the left of the figure) is shown as the data points. The overall annual variation is due to the seasonal variation of surface solar irradiance. On this graph the overall time series mean is shown as the black line (starting in 1997), with plus or minus one standard deviation indicated by the grey region. Bad data on this graph are predominately cloudy days, when the data would be invalid. Questionable data usually results from days for which the GOES imager may not show clouds, but the data is unstable over the measurement period, indicating the presence of small clouds. Good data is data that has passed all the quality control steps and is suitable for use in Satellite Vicarious calibration.

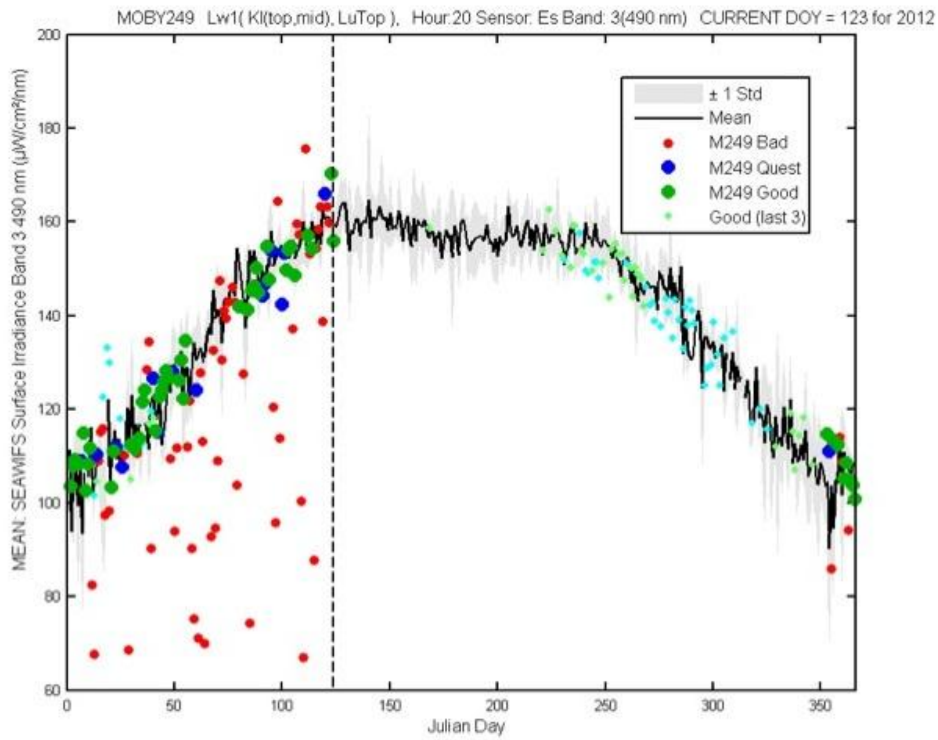


Figure 3: The MOBY time series, started in 1997 with the data from the most recent deployment. The data points are explained in the text, but this deployment began in December 2011 (data shown as dots on the right of the figure) and has continued into 2012 (data points shown as dots on the left of the figure). This deployment, M249, is scheduled to end on May 14th, when this MOBY instrument will be exchanged in the field for another instrument.

Figure 4 shows the MOBY data being used in action (courtesy of Menghua Wang, NOAA/NESDIS). This shows the MOBY data plotted with two versions of the VIIRS ocean color satellite retrieved water leaving radiance, since the launch of VIIRS. The discontinuity on February 6, 2012 was caused by the VIIRS operators putting in place the first true, post-launch, calibration table. One can see the improvement at that time, and since the current VIIRS processing is operational mode without re-processing any data, the effect of this calibration data does not propagate backwards in time. For the data from this date forward, MOBY becomes the critical calibration point to improve the satellite data quality. This is particularly important as the ocean color bands on VIIRS are apparently degrading rapidly at the current time.

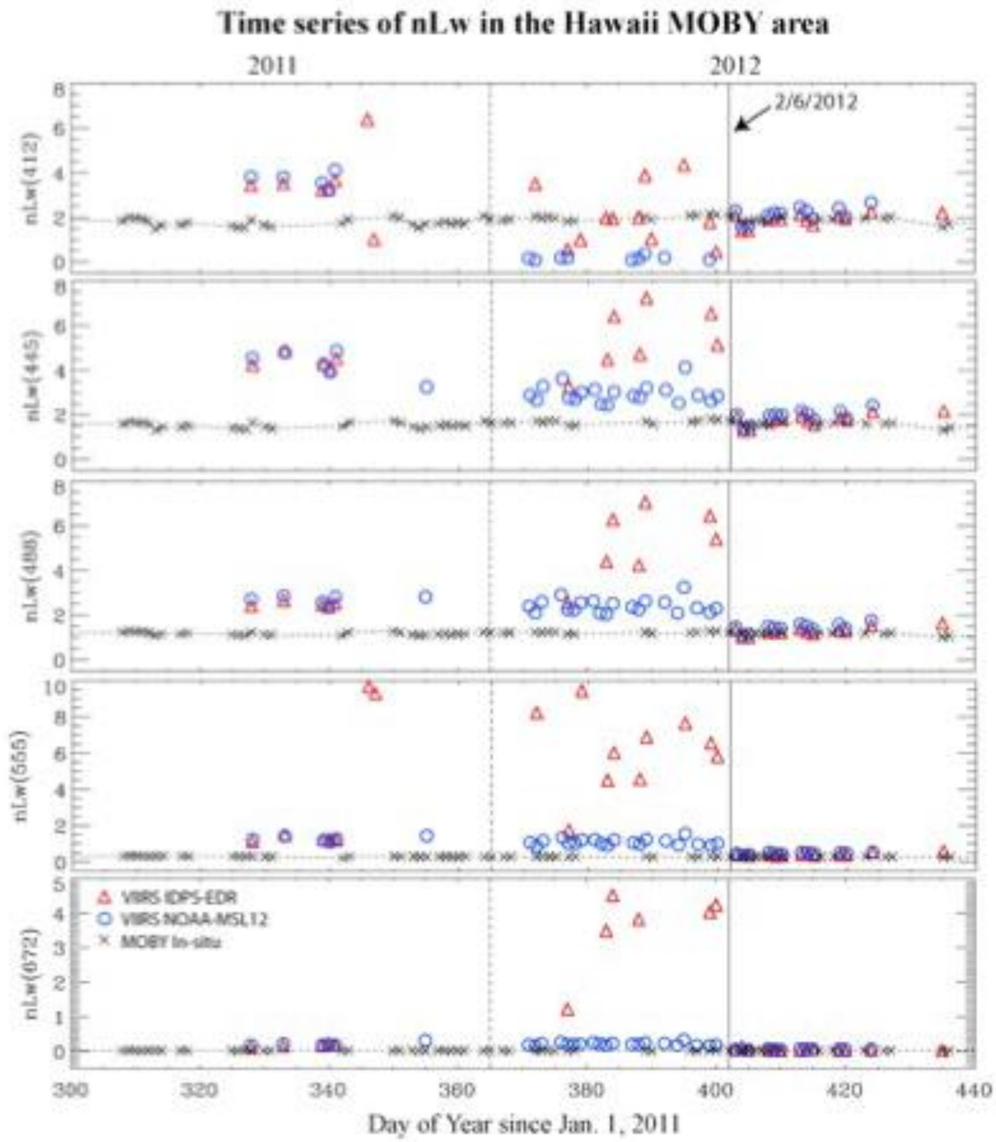


Figure 4: An illustration of the MOBY data being used for vicarious calibration of the VIIRS ocean color satellite, and two processing systems. The VIIRS IDPS-EDR is the current operational data processing system, while the NOAA-MSL I2 is the processing done by a group at NOAA/NESDIS. This figure is courtesy of Dr. Menghua Wang, NOAA/NESDIS.

While we have designed and tested many of the components of the new optical design for MOBY, due to current budgetary constraints we have not been able to begin building these instruments. We are looking forward to doing this in the near future, as without this there is a greatly increased risk of failure in the MOBY system.

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, D. Manzello, G. Rawson, L. Visser, S. Dolk, K. Seaton and P. Ortner (UM/CIMAS)

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

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** To 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*:** To 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 3*:** Healthy Oceans - *Marine fisheries, habitats, and biodiversity sustained within healthy and productive ecosystems*

NOAA Funding Unit: NOAA/AOML **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, 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.

In addition to the interdisciplinary suite of parameters regularly sampled by the SFP, bio-optical profiling has recently been added to assess water clarity over the water column, and to provide valuable light transmissivity data which is used by satellite ocean color experts from University of South Florida (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.

During the August 2011 SFP cruise a plume of anomalous surface water originating in the Mississippi River was sampled and compared to satellite ocean color imagery (Figure 1). The Loop Current was in an elongated northward position at the time of the Mississippi River flood. This event provided an example of the potentially rapid transport of materials from the northern Gulf of Mexico to the Florida Keys, which can occur on the order of days to weeks. It also highlighted the importance of having a regular monitoring program such as the SFP in place in order to capture such anomalous events and to have the ability to place them in a quantitative, long-term context.

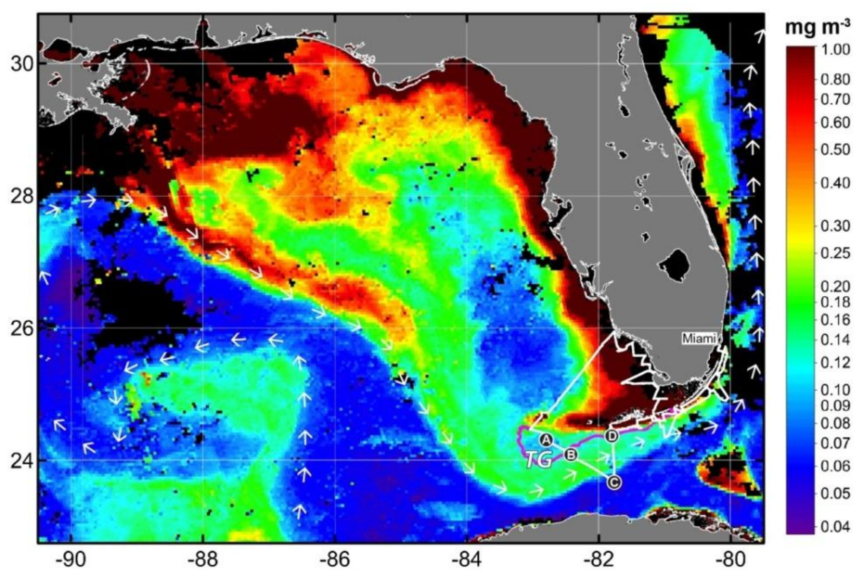


Figure 1: MR image and August 2011 cruise track.

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. The project data (and one of the project co-Principal Investigators) regularly provide critical contributions to the relevant components of the congressionally mandated System Status Reports.

Developing the Operational Calibration/Validation Components for VIIRS SST Retrievals

Project Personnel: R. Evans, P. Minnett, K. Kilpatrick, L. Williams, and G. Szczodrak (UM/RSMAS)

Long Term Research Objectives and 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*:** Climate Adaptation and Mitigation - *An informed society anticipating and responding to climate and its impacts*

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

Research Summary:

The VIIRS sensor was launched on the NPP satellite in Fall, 2011 and the infrared bands used to retrieve Sea Surface Temperature (SST) were activated in late January, 2012. Our activities are focused on providing SST retrieval algorithms and associated coefficients based on radiative transfer (RT) code simulations and VIIRS-in situ matchups. Post launch, radiometric measurements of in situ SST are being to validate VIIRS retrievals. Initial implementation of the VIIRS retrieval codes have been tested using MODIS observations and RT simulations. Initial post launch SST retrieval coefficients have been estimated using the NOAA Optimal Interpolation global SST fields derived from in situ, AVHRR infrared and AMSR microwave retrievals. Validation is based on the in situ radiometric skin temperature measured by the M-AERI infrared interferometer together with in situ buoy SST observations.

Figure 1: VIIRS validation:

An alternate VIIRS nighttime algorithm incorporating the M13 4.05µm waveband was investigated using the following equation:

$$SST = a_0 + a_1*T_{4.05} + a_2*(T_{3.7}-T_{11})*RSST + a_3*(sec(z)-1)$$

These plots show the time trends in the near equatorial latitude bands from sensor activation through May. Good points are that the StdDev is lower than that seen with the nighttime 3 band algorithm and the bias trends with time present with the nighttime 3band algorithm are also not present. An outstanding problem with the M13 based algorithm is that the bias is not stable with time showing offsets of order 0.2K. At this point it is not known if these bias jumps are a calibration or sensor problem. Another point is that some brightness temperatures over the ocean at night exceed 400K. Again while these are easy to filter out, the cause of these elevated temperatures is not know unless it possibly is related to band M13 being dual gain and that the gain is not being properly processed during calibration.

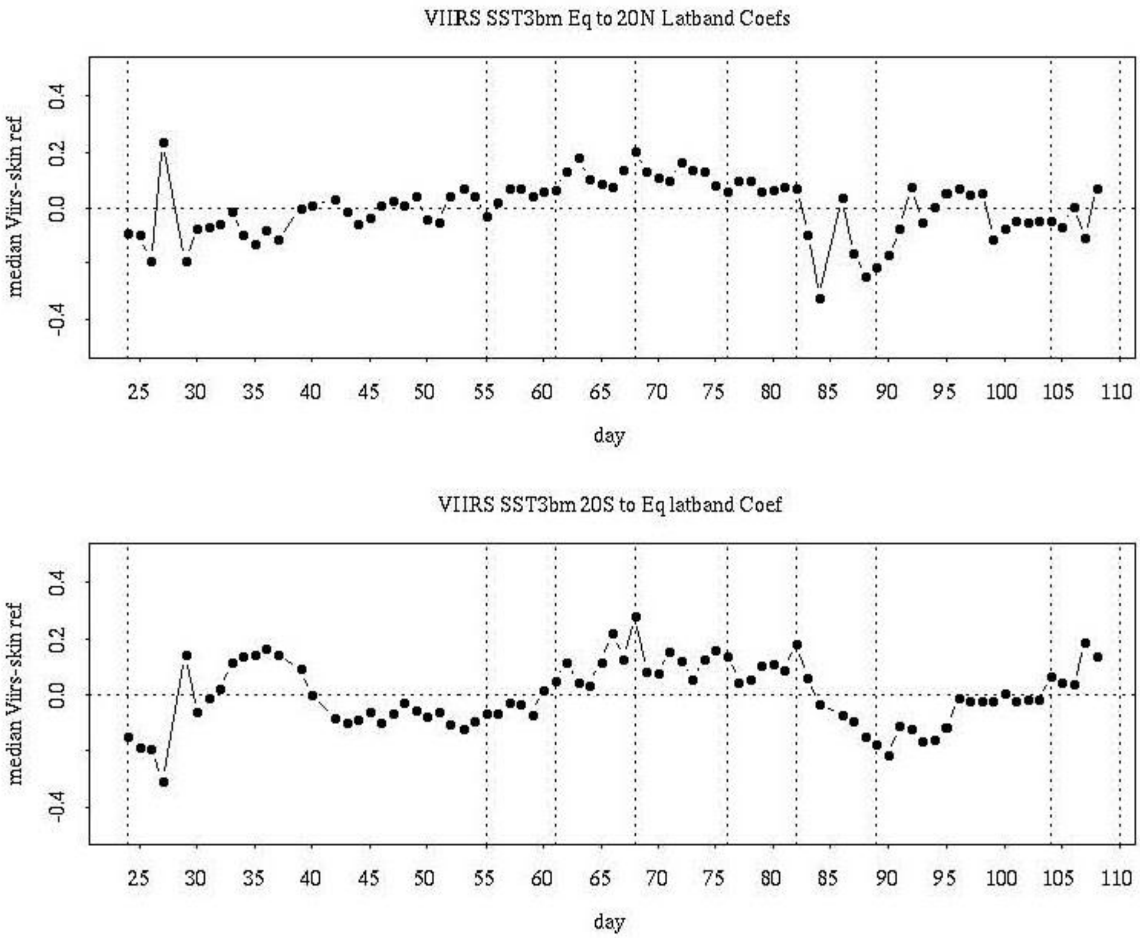
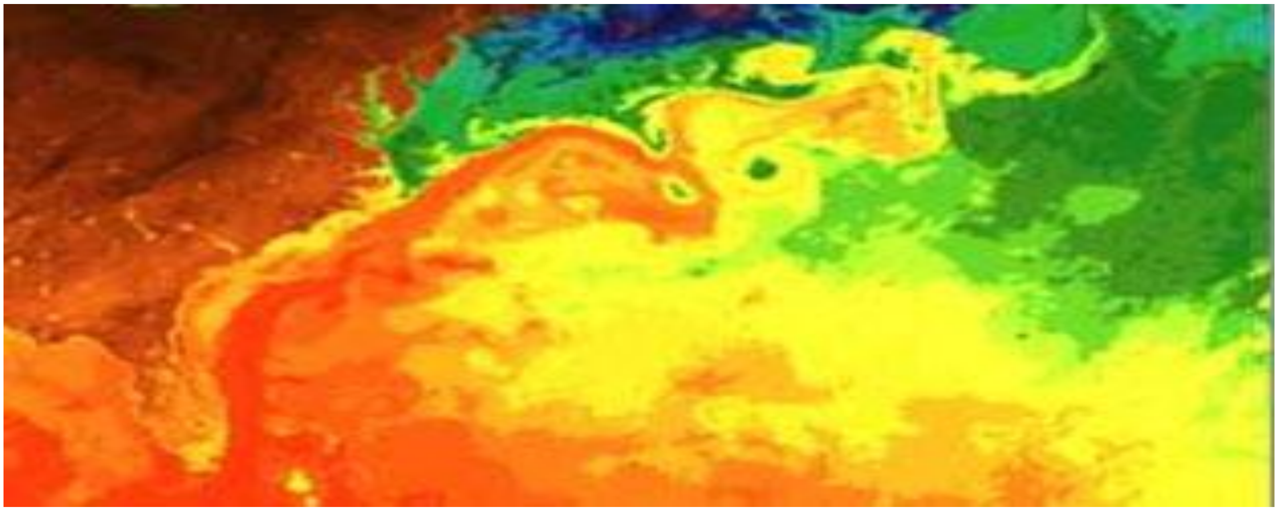


Figure 1: VIIRS 4.05µm alternate 3band Latband algorithm bias relative to Reynolds daily OI for 0-20N and 0-20S. Time trends following yearday 90 better behaved than for the equivalent zonal bands using the standard 3band night algorithm.

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



RESEARCH REPORTS

THEME 4: Ocean Modeling

Monitoring of Surface and Subsurface Ocean Conditions During the Period of April-October, 2010

Project Personnel: F.J. Beron-Vera (UM/RSMAS)

Long Term Research Objectives and Strategy to Achieve Them:
***Objectives*:** To produce synthetic drifter trajectories in the Gulf of Mexico under conditions similar to those reigning during the DWH oil spill.
***Strategy*:** Use a simulation of the Gulf of Mexico based on the Navy Coastal Ocean Model (NCOM).

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

Link to NOAA Strategic Goals:
***Goal 1*:** Climate Adaptation and Mitigation – *An informed society anticipating and responding to climate and its impacts*

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

Research Summary:
Calculations of synthetic drifting buoy trajectories over the period 20 April 2010 through 15 July 2010 have been completed. Specifically, synthetic drifters have been launched every day at the DWH oil spill site over the period indicated. The surface velocity field used to advect the drifters was produced by an NCOM simulation of the GoM. The trajectory data is available via ftp from ftp://ftp.aoml.noaa.gov/phod/pub/DHI_Response/ncom_drifters/.

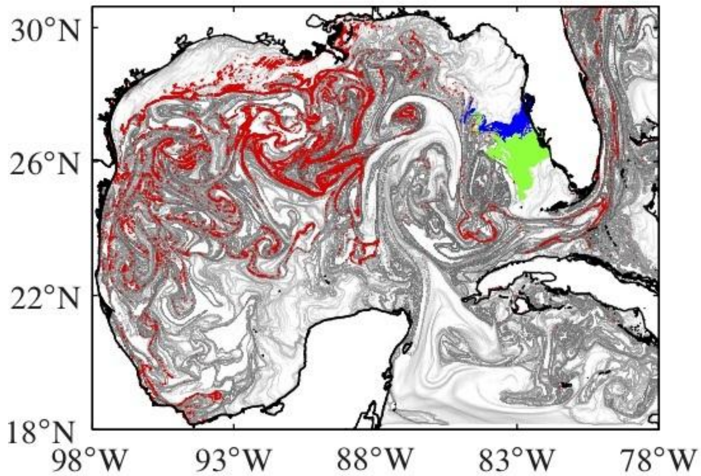


Figure 1: Finite-Time Lyapunov Exponents (FTLEs) with synthetic drifter positions overlaid. The positions shown in red correspond those taken by the synthetic drifters after three months of deployment in the vicinity of the DWH oil spill site.

Research Performance Measure: Goal was achieved.

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Vieques Sound and Virgin Passage Transport Study Modeling Component

Project Personnel: L. Cherubin (UM/RSMAS)
NOAA Collaborator: R. Smith (NOAA/AOML)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** To provide high-resolution North Eastern Caribbean Circulation model (Baums et al, 2006; Chérubin and Richardson, 2007) simulations for comparison and analysis with data gathered from the field.

***Strategy*:** The Regional Oceanic Modeling System (ROMS) will be implemented with a variable 2 km - 330 m horizontal resolution in order to simulate the circulation in the northeastern Caribbean (14-22°N, 70-62°W).

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

Link to NOAA Strategic Goals:
***Goal 3*:** Healthy Oceans - *Marine fisheries, habitats, and biodiversity sustained within healthy and productive ecosystems*

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

Research Summary:
Project moorings were deployed during the FY10 USVI Larval Distribution and Supply Study research cruise (conducted aboard the NOAA Ship NANCY FOSTER) in March of 2010. Concurrently, biophysical sampling was also performed (bongo tows and water column profiles of current velocity, temperature, salinity, dissolved oxygen, and chlorophyll). Additionally, satellite-tracked drifting buoys were deployed around the region. Twice again in 2010, sections were occupied and similar operations performed. These two cruises were conducted using a UVI small boat. The first was timed with the summer snapper spawning aggregation (FY10). The second survey was conducted in November 2010 (FY11). In early 2011 (approximately 12 months after the initial deployment), the moored array was recovered by the NOAA Ship NANCY FOSTER and redeployed along two north-south sections south of St. Thomas. In similar fashion to the first 12-month deployment in Vieques Sound and Virgin Passage, the redeployment of the array in 2011 will serve to help scientists quantify ichthyoplankton flux across sensitive shelf regions, which encompass Grammanik Bank, Red Hind Bank, and the St. Thomas East End Reserve (STEER).

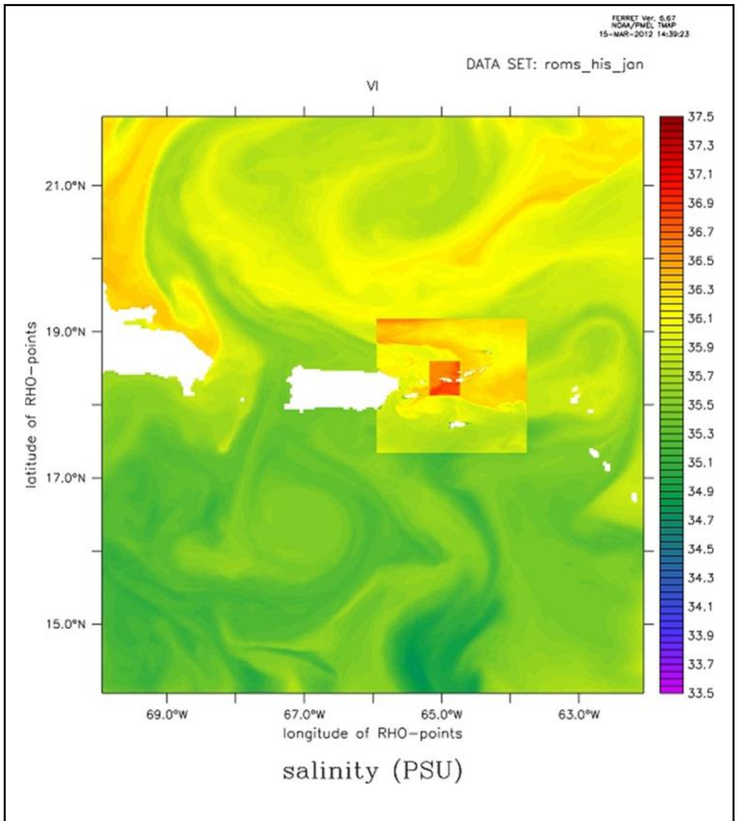


Figure 1: Surface salinity snapshot showing the three embedded grids. The salinity is offset by 0.5 psu in the first nest and 1psu in the second one in order to distinguish them.

Project data associated with the first 12-month deployment will be integrated into a high-resolution North Eastern Caribbean Circulation model and compared with drifter trajectories and ichthyoplankton frequency/ distribution data collected at USVI Larval Distribution and Supply Study biophysical sampling stations on the banks north and south of St. Thomas over the past 4 years. Regional linkages and biophysical connectivity between marine habitats were assessed and quantified in a FY10-FY11 management report. This product will be oriented towards regional fisheries managers and designed as a reference tool for evaluating existing management actions and developing adaptive strategies for the future.

Similar cruises and operations will follow in out years as this 'mobile' acoustic array is relocated every 12 months to critical habitat areas around the region in a targeted effort to provide in situ data needed to improve regional models and assess MPA efficacy.

Research Performance Measure: The ROMS simulation is currently underway. Years 2007 and 2008 have been completed. Year 2009 is underway. The goal is to continue for 2010 and 2011 if possible. The assimilation scheme that will help integrate the current observations in the model is under development.

Estimating Uncertainty in Ocean Models

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

Long Term Research Objectives and Strategy to Achieve Them:
***Objectives*:** To quantify uncertainties of results of oceanic models.
***Strategy*:** To techniques such as polynomial expansions to propagate prior estimates of uncertainty of model inputs and to use Bayesian inference together with observations to improve these estimates.

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

Link to NOAA Strategic Goals:
***Goal 3*:** Healthy Oceans - *Marine fisheries, habitats, and biodiversity sustained within healthy and productive ecosystems*.

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

Research Summary:
Ocean models provide information about the state of the ocean that reflects the values of all the parameters it is given. While this information is useful, it becomes even more valuable when a range of possible values is provided that reflects the uncertainties in the values of the input parameters. The focus of this work has been on quantifying the uncertainties of model outputs, in particular those that the uncertainties of particular inputs and the reduction of uncertainties of both inputs and outputs by exploiting information provided by observational data.

To demonstrate that our approach was practical for ocean models, our first effort was to examine the uncertainties of the circulation within the Gulf of Mexico that might be attributed to the inflow through the Yucatan Straits. As it was necessary to nest the high-resolution numerical model for the Gulf within a wider-area lower-resolution model, the flow through the southern nesting boundary provided a convenient proxy for the inflow through the Yucatan Straits. The nature of uncertainty of this boundary flow was assumed to be a reflection of the variability seen in a long-term simulation, which in turn was characterized by amplitudes of a pair of spatiotemporal patterns in order to make the analysis computationally manageable. This allowed uncertainties of model outputs to be approximated as polynomials of these random amplitudes. The polynomial coefficients were then evaluated by quadrature from the results of an ensemble of simulations dictated by the quadrature points. Once their coefficients have been evaluated, the polynomial expressions provide a highly efficient means of approximating statistics such as means and variances as well as probability distribution functions that can indicate departures from Gaussianity (see figure).

A second study focused on the sensitivity of the modeled circulation in the Gulf of Mexico to parameters influences mixing. By considering the uncertainties of four uncertain input parameters simultaneously, we needed to explore whether sparse quadrature might reduce the computational burden of evaluating the polynomial coefficients. A separate aspect of the work was to explore the use of the coefficients to determine the relative importance of the uncertain parameters in the spirit of analysis of variance with the result that the drag coefficient involved in transfer of wind stress into the ocean had a larger impact than parameters controlling viscosity and diffusivity.

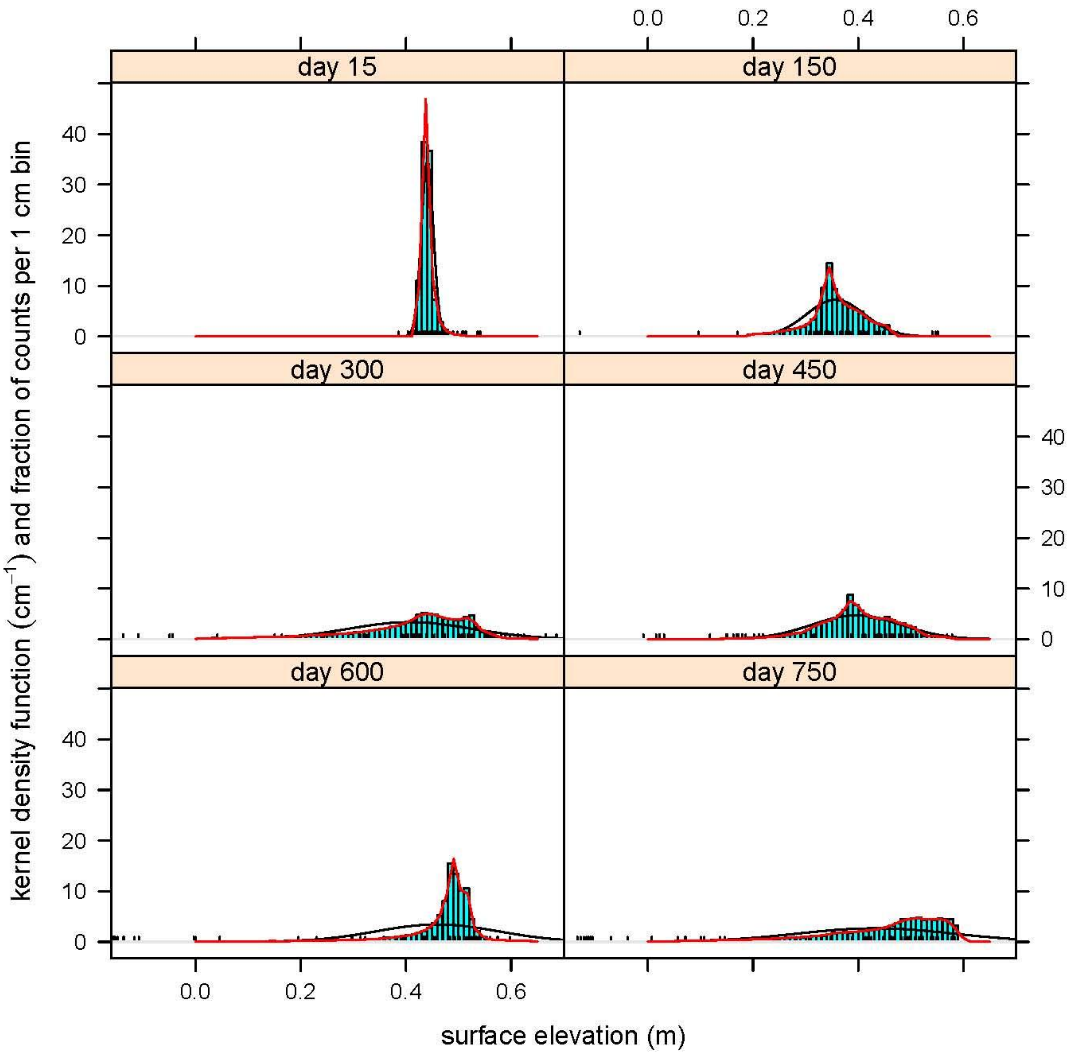
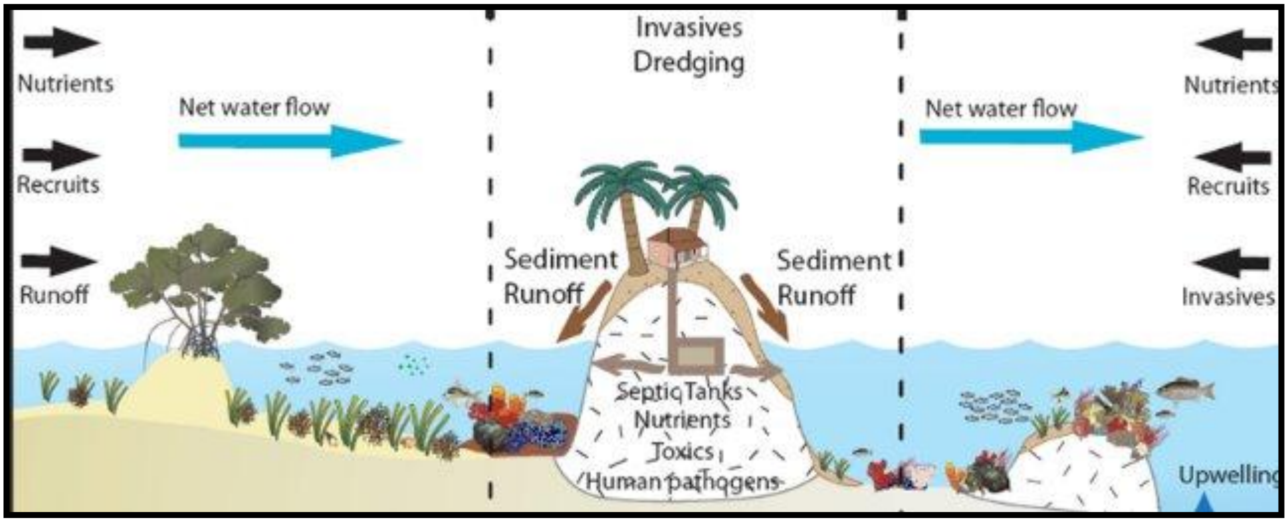


Figure 1: Kernel density estimates and histograms for surface elevation (m) at (86E, 24.1N) for days 15, 150, 300, 450, 600, and 750 generated using polynomial chaos expansion for the mixed layer depths corresponding to 50,000 random boundary conditions. Ticks along the bottom indicate values for the 49 HYCOM simulations. Red curves are kernel density estimates, and black curves are Gaussian densities with means and standard deviations from the polynomial expansions.

An ongoing study is attempting to exploit the available AXBT measurements of upper-ocean temperature during Typhoon Fanapi to infer the dependence of the drag coefficient on surface-wind speed.

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



RESEARCH REPORTS

THEME 5: Ecosystem Modeling and Forecasting

Evaluation of Management Strategies for Fishery Ecosystems

Project Personnel: E.A. Babcock and D.J. Die (UM/RSMAS)
Other Collaborator: J. Hoenig (Virginia Institute of Marine Science)

Long Term Research Objectives and Strategy to Achieve Them:
***Objectives*:** To develop tools for fishery management strategy evaluation within an ecosystem context.
***Strategy*:** To develop ecosystem models based on both individual-based modeling (IBM) and the Atlantis whole-ecosystem modeling framework.

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

Link to NOAA Strategic Goals:
***Goal 3*:** Healthy Oceans - *Marine fisheries, habitats, and biodiversity sustained within healthy and productive ecosystems* (*Primary*)
***Goal 4*:** Resilient Coastal Communities and Economies - *Coastal and Great Lakes communities that are environmentally and economically sustainable* (*Secondary*)

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

Research Summary:
UM Ph.D. student Bill Harford has developed a spatial population dynamics model which was used to simulate the efficacy of marine reserves for fish that differed with respect to their habitat selection

behaviors. He also applied an ecosystem model (Ecosim) for Northwest Atlantic Ecosystem to test several hypotheses about the impact of fishing shortfin mako sharks on bluefish. UM student Mandy Karnauskas developed indicators to evaluate the effectiveness of marine reserves as a management strategy for ecosystem based management.

We are in the process of developing a whole-ecosystem model for the Gulf of Mexico large marine ecosystem in collaboration with Dr. Cameron Ainsworth at USF, and his student, Michael Drexler. UM student Holly Perryman has taken the lead on the pelagic fishes and sharks, and she is in the process of using NMFS observer and logbook data to develop seasonal maps of the distribution of these species. We expect to begin calibrating the GOM-Atlantis model by the end of calendar year 2012.

UM student Steve Saul has developed agent-based models to evaluate the effect of effort redistribution due to fleet heterogeneity and policy implementation on estimating a standardized catch per unit effort index of abundance. UM student Elizabeth Councill Martin is comparing the impact of spawning strategies, ages of maturity, longevity, and type and strength of density dependence in younger age classes, and the mortality by age induced by commercial and recreational fisheries among subpopulations.

VIMS student Matthew Smith has been estimating disease progression rates and disease-associated mortality rates and modeling the disease impacts on population levels and reproductive output. Former VIMS student Lynn Waterhouse has published two papers on tagging and movement models.

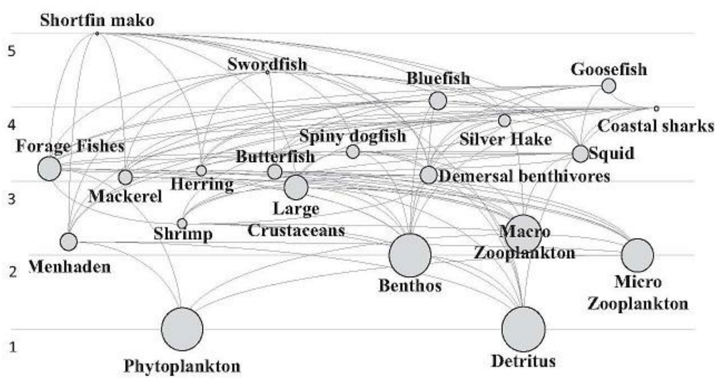


Figure 1: Trophic flow between functional groups of the western North Atlantic food web. Vertical position of circles indicates mean trophic level and circle size indicates relative biomass (Harford, submitted).

Research Performance Measure: The five deliverables of this project are either accomplished or in progress.

1) *Develop operational models describing the structure of fishing fleets in the Gulf of Mexico, David Die:* UM student Steve Saul is scheduled to defend his dissertation in June, 2012. UM student Elizabeth Council Martin is has received the NOAA/SeaGrant Population Dynamics Fellowship and is on track to complete her dissertation.

2) *Develop methodology to characterize trade-offs reef fish management objectives for spatial management strategies under uncertainty about the spatial dynamics of marine populations, Elizabeth Babcock:* UM Ph.D. student Bill Harford presented the results of his grouper spatial distribution model at the annual American Fisheries Society meeting. He presented a paper at the Mote symposium on the Northwest Atlantic Ecosim model, and the paper is currently in review. He completed his comprehensive exams in summer of 2011 and advanced to candidacy. He is on

track to finish his dissertation by the end of the 2012-2013 academic year. UM Student Mandy Karnauskas defended her dissertation in December, with the title: *From physics to fishers: a multidisciplinary approach to evaluating indicators of fishery benefits of marine reserves*. She has published three papers and submitted two others from her dissertation work. She is now working at the Southeast Fisheries Science Center.

3) *Develop an ecosystem model for the Gulf of Mexico using the Atlantis modeling framework, Elizabeth Babcock:* UM student Holly Perryman has received the NOAA/SeaGrant Population Dynamics Fellowship for this work. Dr. Babcock has also recruited a new Ph.D. student, Matt Nuttall, who started in January 2012. After he takes his comprehensive exams in Spring 2012, he will begin working on the Gulf of Mexico Atlantis modeling project.

4) *Develop quantitative methodology to estimate disease mortality of American lobster, striped bass and snow crab*, and 5) *Investigate the implications of disease mortality for assessment and management, John Hoenig:* VIMS student Matthew Smith has completed his course requirements for his Master's degree in statistics and also was admitted into the PhD program at VIMS, thus bypassing the requirement to complete a Master's degree in marine science prior to entering the doctoral program. A paper on disease modeling work has been submitted for publication. Former VIMS student Lynn Waterhouse, published two paper son movement models and tagging (Waterhouse and Hoenig, 2011, 2012) and presented a paper on tagging models allowing for delayed mixing at the American Fisheries Society meeting in Seattle.

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Caribbean Sea and Gulf of Mexico Bluefin Tuna Research

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

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 3**:** Healthy Oceans – Marine fisheries, habitats, and biodiversity sustained within healthy and reproductive ecosystems

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

Research Summary:
Atlantic bluefin tuna (*Thunnus thynnus*) 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, University of South Florida, IEO (Instituto Español Oceanográfico) and El Colegio de la Frontera Sur - ECOSUR (Mexican Academic) participated in a second research survey of the western Caribbean Sea, in April through May 2012. Physical data from CTD casts, and biological data from plankton net tows including surface casts (Neuston), subsurface (10 meter below surface) and additional MOCNESS (50-meter below surface stratified in 10-meter bins) were collected between the Cayman Islands and the Mesoamerican region. Preliminary identifications of larvae collected during the survey indicate that spawning of tunas was widespread across the region however bluefin tuna larvae were primarily collected in the Gulf of Mexico.

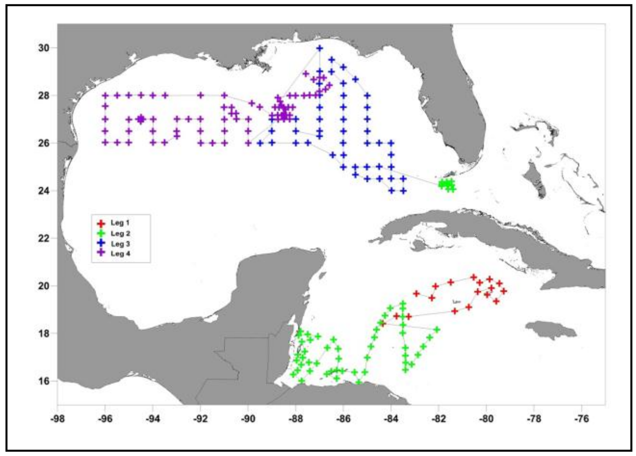


Figure 1: Cruise tracks for first, second, third and fourth legs of the bluefin tuna cruise aboard the NOAA Ship Gordon Gunter in April and May 2012. Participants included scientists from UM/CIMAS, NOAA/SEFSC, University of South Florida, IEO (Instituto Español Oceanográfico) and El Colegio de la Frontera Sur - ECOSUR (Mexican Academic).

Our 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) stable isotope analyses will be used to investigate questions of trophic level dynamics and compare these results with existing Mediterranean bluefin isotope datasets. These results will have particular significance to fisheries scientists and managers in both basins because bluefin tuna spawning occurs in the Gulf of Mexico and the Mediterranean Sea. This additional information will provide valuable comparisons for the Gulf of Mexico to benefit bluefin tuna research.

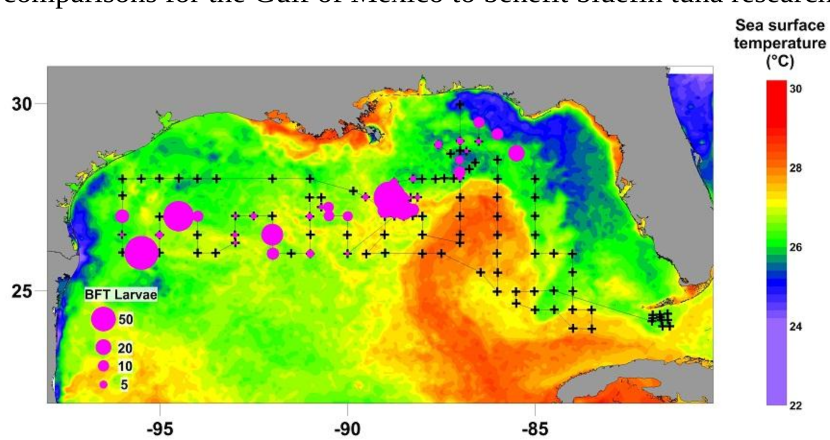


Figure 2: Map illustrates preliminary larval bluefin tuna abundances collected using plankton nets aboard the NOAA Ship Gordon Gunter during legs 3 and 4 of the bluefin Spring cruise GU1201 overlaid with sea surface temperature for the Gulf of Mexico.

Research Performance Measure: The research program is on schedule. Samples from the 2011 cruise are currently being sorted, and all larvae have been identified. After this is complete, analysis of larval assemblage structure and tuna spawning habitats will be completed. This year's cruise successfully ended on May 29, 2012; sample processing and sorting will begin shortly.

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

Project Personnel: S. Privoznik, B. Muhling, A. Ender, E. Malca, K. Griffith, and M. Straney (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*:** Determine distribution of larval fish assemblages temporally along the 27 N transect.

***Strategy*:** Collect and assess larval fish assemblages and distribution in the Florida Current in oceanographic shipboard surveys.

CIMAS Research Theme:

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

Link to NOAA Strategic Goals:

***Goal 2*:** Weather-Ready Nation - *Society is prepared for and responds to weather-related events*

NOAA 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 27 N 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 and (3) evaluate temporal variation of the larval composition and abundance in South Florida

Research Performance Measure: The research program is on schedule. Eleven cruises have been carried out since September 2009 with 116 plankton samples collected to date. Preliminary analyses indicate that temporal and spatial variation between the first two cruises can be observed, as well as varying distribution among larval families. Myctophidae larvae are most abundant within the Florida Current, while Carangidae (jacks) larvae are most abundant inshore and outside of the Current. Scombridae (tunas) larvae are abundant outside the Florida Current during the September cruise, but completely absent during the November sampling effort.

Additional sampling continued quarterly in 2011-2012 and seven cruises have been processed for ichthyoplankton. The remaining plankton samples will be sorted for larval fish, identified to taxonomic family level, and the resulting data will be analyzed to observe trends and identify the overall composition of larval fish in the South Florida region.

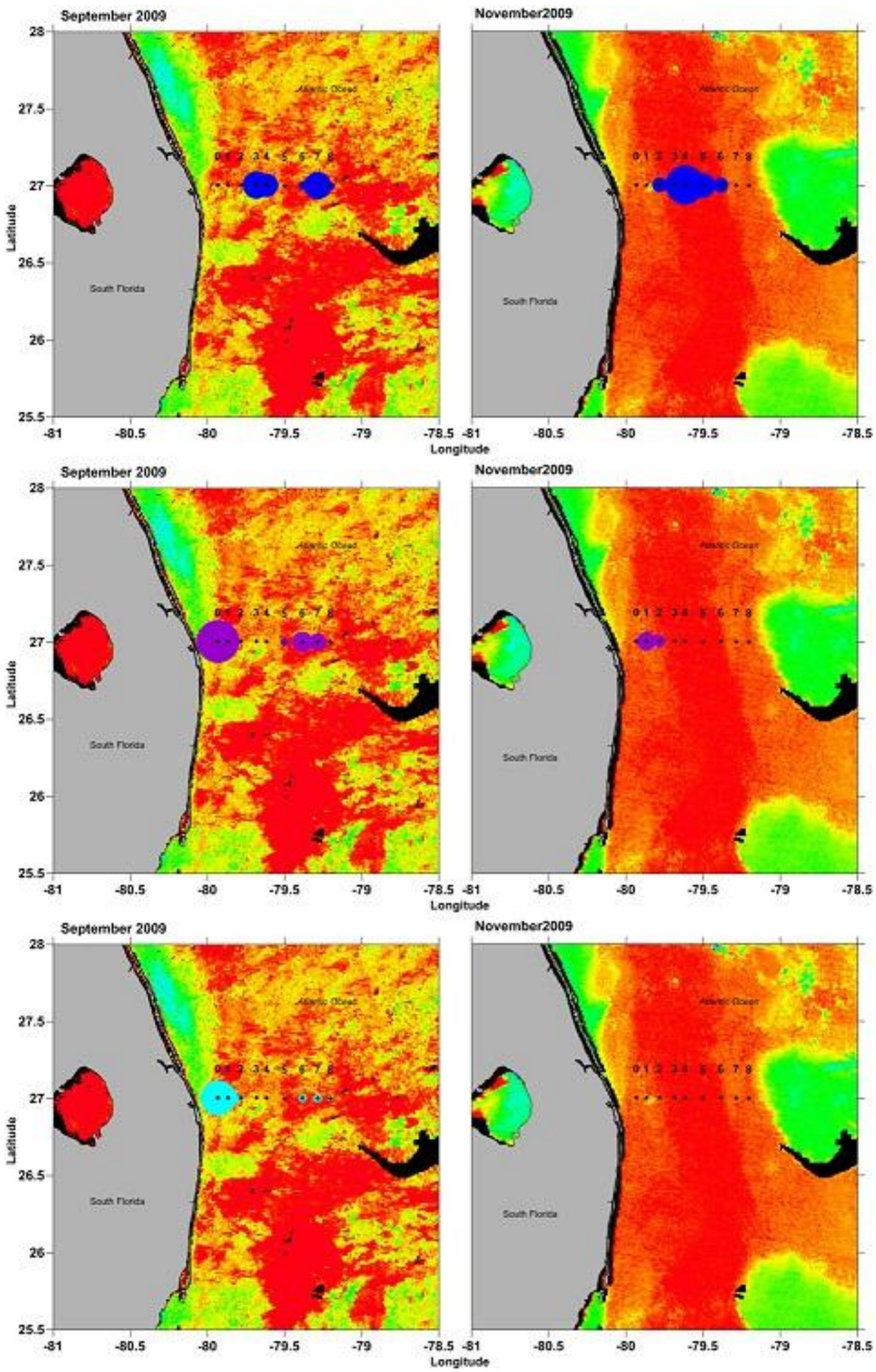


Figure 1: Maps show varying larval abundance and distribution of Myctophidae (blue), Carangidae (purple), and Scombridae (aqua), during the September 2009 and November 2009 cruises. Larger circles indicate higher larval abundance. Map shows the southeast coast of Florida and the Florida Current.

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 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)

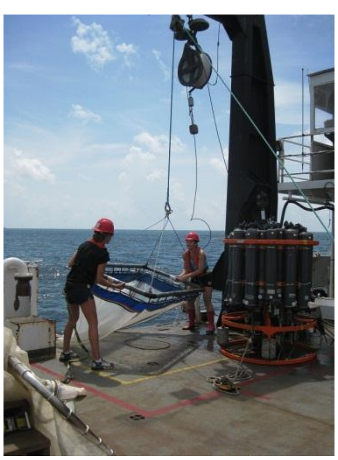
Long Term Research Objectives and Strategy to Achieve Them:
***Objectives*:** To understand transport pathways and areas that can be affected by the DWH event.
***Strategy*:** To conduct in situ physical, chemical, and biological observations collected during an oceanographic survey in the Loop current 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 3*:** Healthy Oceans – *Marine fisheries, habitats, and biodiversity sustained within healthy and reproductive ecosystems*

NOAA 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 meso-scale 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.



Research Performance Measure: The research program is on schedule. All plankton samples have been sorted for larval fish specimens. Taxonomic family level identification has been completed for selected families of fishes including Scombridae (tunas) while the remaining ichthyoplankton are currently being examined. Upon completion of fish identifications, concurrently measured oceanographic parameters will be combined in the final analyses of this cruise. A total of 22,316 larval fish were collected during this cruise.

Figure 1: Undergraduate interns from University of Miami and from Columbia University retrieve neuston net aboard the NOAA Ship Nancy Foster.

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 3*:** Healthy Oceans – *Marine fisheries, habitats, and biodiversity sustained within healthy and reproductive ecosystems*

NOAA Funding Unit: NMFS/MARFIN **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 project goals are (1) to measure the stable isotope signature in the otolith core, edge and sub-edge of each fish (2) establish and age/length curve. The majority of the catch was collected by local fishermen, and were weighted and measured by DPNR. The samples were then sent to the NOAA SEFSC ELH laboratory for otolith removal and processing. In addition, prepared otoliths have been sent to the NOAA SEFSC Panama City for ageing and a subsample was processed for stable isotope analysis at the Rosenstiel School of Marine and Atmospheric Science Stable Isotope Lab (SIL).

Research Performance Measure: The research program is on schedule. A total of 54 redtail parrotfish (*S. chrysopterum*) and stoplight parrotfish (*S. viride*) were collected from four stations around the islands of St. Thomas and St. John, US Virgin Islands. Multiple sampling on single sagittal otoliths (core/early life history and edge) were conducted and analyzed for stable isotopes of carbon and oxygen to examine habitat-use patterns and movements of fishes between multiple habitats. Preliminary results show significant variation for carbon, but no significant variation for oxygen isotopic trends. Preliminary results from this project will be presented at the Larval Fish Conference in Bergen, Norway in July 2012.

Figure 1: These ecologically important herbivores are fished commercially in the US Virgin Islands, redtail parrotfish (*S. chrysopterum*) and stoplight parrotfish (*S. viride*). Photo from Humann & Deloach, p.198, p.204.

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Modeling Intraguild Predation in Marine Ecosystems

Project Personnel: D.J. Die (UM/RSMAS); J. Zabalo (UM/CIMAS)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** To model the complex interactions that can occur in intraguild predation communities and study the impacts of fishing on system stability.

***Strategy*:** To develop agent-based models of existing communities of interest based on the MASON modeling framework. To extend an existing ODE model of intraguild predation with prey switching to a more general PDE model incorporating non-random dispersal and harvesting.

CIMAS Research Theme:

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

Link to NOAA Strategic Goals:

***Goal 3*:** Healthy Oceans - *Marine fisheries, habitats, and biodiversity sustained within healthy and productive ecosystems*

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

Research Summary:

We have developed a three-species intraguild predation model which includes prey switching by the top predator. The model consists of a system of three ordinary differential equations with Holling type II functional responses and logistic growth in the resource. Permanence theory was applied in order to establish the conditions necessary for the permanent coexistence of all three species and an example in which a stable limit cycle occurs was demonstrated. These results were published in a paper (Zabalo 2012). We are currently in the process of extending this ODE model to a PDE model which incorporates non-random dispersal and harvesting. The goal is to develop a general enough model that can realistically capture the behavior of actual populations such as the shark-seal-hake interactions occurring in the False Bay Ecosystem (see below). Several proposals will be submitted to fund this research.

The above deterministic modeling approach can be complemented by also developing agent-based models of the same systems. In preparation for this, Zabalo audited an agent-based modeling class, Object-oriented Programming and Agent-based Modeling RSM620, and development of a preliminary model of the False Bay Ecosystem to demonstrate proof of concept has begun.

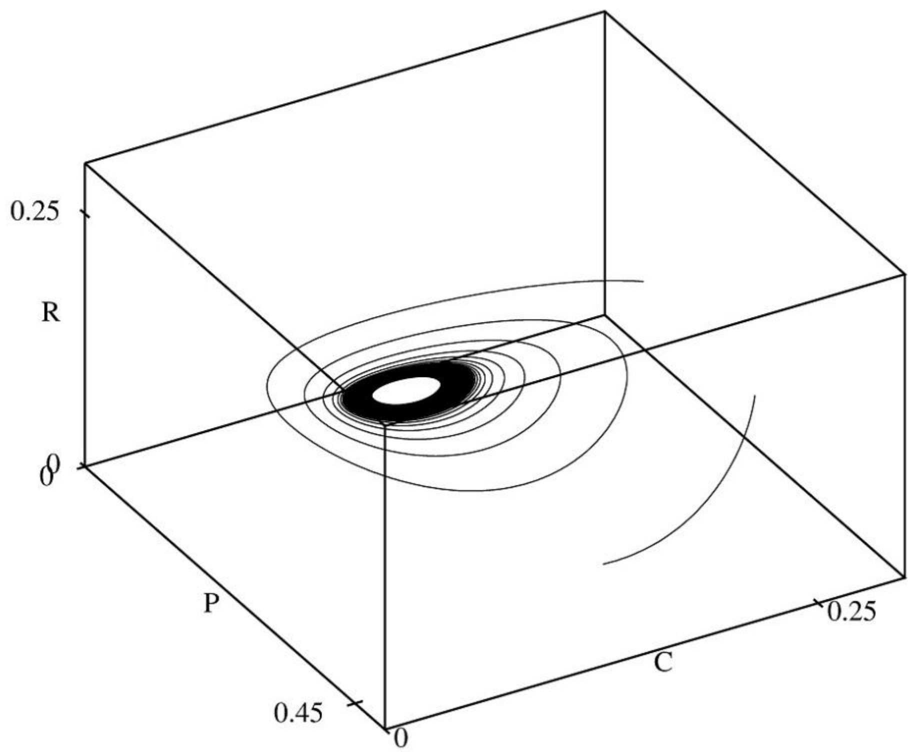

Figure 1: An example of a stable limit cycle which can occur in the intraguild predation system satisfying the necessary conditions for *permanence*. In this example, all three species can coexist.

Research Performance Measure: Initial intraguild predation model developed was published in a peer review article (Zabalo, *Bull. Math. Biol.*, 2012, in press).

Monitoring Shoreline Fish Assemblages of Biscayne and Florida Bays

Project Personnel: D. Johnson and B. Teare (UM/CIMAS)
NOAA Collaborator: 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, 13.5-year visual fish monitoring effort that, for the most part, has focused on southern Biscayne Bay (Figure 1); (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 5*:** Ecosystem Modeling and Forecasting

Link to NOAA Strategic Plan:

***Goal 3*:** Healthy Oceans: *Marine fisheries, habitats, and biodiversity sustained within healthy and productive ecosystems*

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

Research Summary:

1. Annual trends in Taxon-Specific Abundances

An additional 284 visual fish transects have been completed since the previous (seventh) annual report, which analyzed data through the wet season of 2010. Densities of all taxa have been found to be relatively stable over the period of record. All of the taxa examined showed some level of seasonal variation in density, frequency of occurrence and concentration. Along the Mainland shoreline, dry season 2011 delta densities were significantly lower than the historical mean for our four indicator species: *L. griseus*, *S. barracuda*, *Eucinostomus spp.*, and *G. cinereus*. Wet season densities of the two mojarra taxa (*Eucinostomus spp.*, *G. cinereus*) were significantly lower than the historical mean, but densities of *L. griseus* and *S. barracuda* were not significantly different. Delta-densities of *Eucinostomus spp.* and *G. cinereus,* suggested that these species were impacted by the cold weather event of December 2010 and that effect continued into the wet season of 2011.

2. Habitat Suitability Models

We used a delta approach to generate a triad of habitat suitability index (HSI) models per species. Specifically, our approach allowed assessment of abundance-salinity relationships via regressing against salinity three abundance metrics per species: frequency of occurrence, concentration (density when present, exclusive of zeros) and "delta-density" (occurrence x concentration). Statistically-significant trends emerged 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 in general 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 (ML) shoreline and the Leeward key (LK) shoreline. We examined seasonal and annual variation of yearly indices of taxonomic richness using multiple regression and analysis of variance. We found that richness was higher along the LK where the environment was more stable than along the Mainland shoreline. Along the ML shoreline, five out of six of the fish community metrics estimated for 2011 were lower than the historical means in the dry season and two out of the six were significantly lower, and three were within the 95% confidence limits of the historical mean in the wet season.

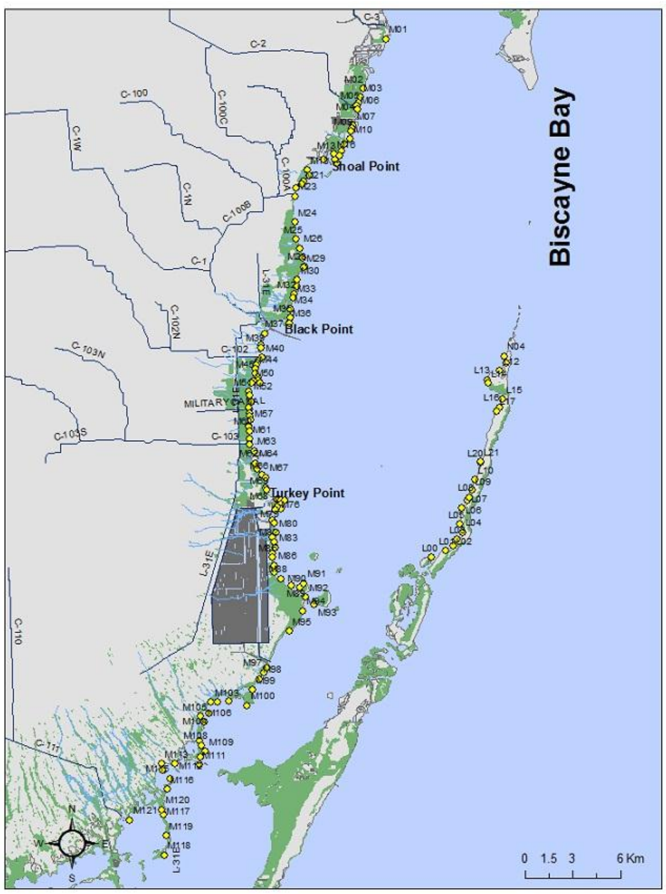

Figure 1: Map of mangrove fish sites surveyed in 2011 within Biscayne Bay's mainland (ML) and Leeward Key (LK) shorelines.

4. 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. A total of 44 laboratory-based salinity choice trials have been performed focusing on *Floridichthys carpio* exposed to salinities ranging from 10 to 50 psu. Results suggested significant avoidance of salinities above 40 psu -- a finding that is consistent with our field-based observations. Fish did not avoid salinities in the lowest (10 psu) chamber, therefore, future efforts (if funding allows) will focus on determining avoidance/preference of salinities ≤ 10 psu. Once these experiments are complete, we can proceed with spatially-explicit habitat suitability index (HSI) modeling, which may prove useful for guiding ecosystem restoration and for predicting its effects on this ecologically important species.

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 13.5 of our visual census survey and developed HSI models for the six major species using field data and, for one species, have additional support from laboratory studies.

RESEARCH REPORTS

THEME 6: Ecosystem Management

The Importance of Parrotfish on the Maintenance and Recovery of Coral- Dominated Reefs

Project Personnel: D. Burkepile and T. Adam (FIU)
NOAA Collaborator: B. Ruttenberg (NOAA/SEFSC)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** To summarize scientific information on the effects of parrotfish on algal and coral communities, identify clear knowledge gaps about the impact of grazers on coral reef communities, and begin addressing some of the critical unanswered scientific questions identified by the synthetic analysis. This project funds a post-doctoral researcher, Dr. Thomas Adam, to spearhead these objectives.

***Strategy*:** To conduct: (1) a thorough review, quantitative analysis, and synthesis of the existing literature and existing datasets that have examined the relationship between parrotfish, parrotfish grazing, and measures of coral demography, status, recruitment, and recovery and (2) take the gaps in knowledge identified in the review and begin addressing these gaps in data with targeted field studies (e.g. studies on size/age-based demographic patterns and grazing rates).

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

Link to NOAA Strategic Goals:
***Goal 3*:** Healthy Oceans - *Marine fisheries, habitats, and biodiversity sustained within healthy and productive ecosystems*

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

Research Summary:
Although the project technically started on June 1, 2011 the hired post-doc, Dr. Adam, will begin his tenure on the project on June 4, 2012. Thus, the main body of research will begin this year. Dr. Adam will take a two-step approach to better understand the importance of parrotfish in maintaining coral communities and coral reefs. During year 1, Dr. Adam will conduct a thorough review, quantitative analysis, and synthesis of the existing literature and existing datasets that have examined the relationship between parrotfish, parrotfish grazing, and measures of coral demography, status, recruitment, and recovery. A review and data synthesis is a critical first step to understand the relationship between parrotfish (and herbivores generally) and coral communities. This review will also examine the circumstances under which the relationship between grazing, algae and coral changes, such as the effects of geography or proximity to large population centers and accompanying effects of land-based sources of pollution and fishing pressure. Other factors, such as protection, species interactions, depth, habitat type and habitat quality may also influence this relationship, and should be considered.

In year 2, Dr. Adam (in collaboration with Drs. Burkepile and Ruttenberg as well as Dr. Burkepile's graduate students) will begin addressing some of the clearest data gaps in our knowledge of the effects of parrotfish on algal assemblages and coral communities. Some of these issues are likely to include size- and age-based demographic patterns and grazing rates and feeding preferences for a number of different parrotfish species in a variety of habitats and geographical locations. Demographic variability can influence grazing rates, which along with feeding preference can significantly influence how effectively different species remove algae.

Figure 1: *Sparisoma viride* is thought to be the most important bioeroding herbivorous fish on Caribbean reefs. Its grazing removes seaweeds and opens up space for coral colonization and growth.

Research Performance Measure:
Although the project technically started on June 1, 2011 the hired post-doc, Dr. Adam, begins his tenure on the project on June 4, 2012. The delay in the initiation of this project was due to a delay in receiving funds and the prior post-doc commitment of Dr. Adam that ends May 31, 2012. Dr. Adam was the ideal candidate for this position so the delay in project initiation is worth being able to hire Dr. Adam onto the project. Given the delay in hiring Dr. Adam, the bulk of the research on the project will be conducted in the latter portion of 2012 and 2013.

Monitoring Coral Reef Fish Populations in the Florida Keys

Project Personnel: J.S. Ault and S.G. Smith (UM/RSMAS)
NOAA Collaborator: J.A. Bohnsack (NOAA/NMFS)

Long Term Research Objectives and Strategy to Achieve Them:

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

***Strategy*:** Carry out regional multispecies reef fish assessments, map coral reef habitats and to conduct spatially-based monitoring of coral reef fish composition, occurrence, abundance, and size structure on the Florida Keys reef tract (e.g., Smith et al. 2011; Ault et al. 2012). Use strategic applications of probabilistic sampling design theory and acoustic telemetry methods (e.g., Farmer and Ault 2011) to obtain key spatial population size-structured abundance and movments data to assess population changes, ontogenetic habitat associations, and ecosystem responses to fishing, recreational use, pollution, MPA zoning and, eventually, Everglades restoration.

CIMAS Research Theme:

***Theme 6*:** Ecosystem Management

Link to NOAA Strategic Goals:

***Goal 3*:** Healthy Oceans - *Marine fisheries, habitats, and biodiversity sustained within healthy and productive ecosystems*

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

Research Summary:

This research emphasizes assessing the effectiveness and impacts of no-take marine reserves and other resource management measures in Biscayne National Park, the FKNMS, and DTNP towards meeting their marine ecosystem management goals. No-take marine reserves (NTMRs) in the National Marine Sanctuary (FKNMS) and Dry Tortugas National Park of the Florida Keys are a joint fishery and ecosystem management effort between the NOAA National Marine Sanctuary Program, National Park Service (NPS), and the State of Florida. The FKNMS has implemented three types of no-take areas: (1) 16 small Sanctuary Preservation Areas (SPAs) totaling approximately 46 km^2 that protect the high-relief coral reef; (2) one large (30 km^2) ecological reserve (ER) that includes several different habitats; and, (3) 4 special-use SPAs designed for research purposes. Two large Ecological Reserves, 206 and 312 km^2, are were added in 2001 west of the Tortugas, Florida. The NPS Service implemented a 100 km^2 Research Natural Area (RNA) in the western half of Dry Tortugas National Park in January 2007.

We continue to evaluate the performance of the SPAs and TERS in the FKNMS. During the past year we conducted spatially-synoptic sampling of reef fish and coral reef habitats in the Florida Keys. Although still early in the recovery process, our results for the Dry Tortugas and Florida Keys are encouraging and suggest that NTMRs in conjunction with traditional management measures can potentially help rebuild sustainable fisheries while protecting the Florida coral reef ecosystem. This is a win-win scenario; good for the fish, ecosystem, fishermen, and Florida's economy! The black groupers provide a particularly compelling example. Fishing pressure typically results in a shift from larger to smaller animals. If we compare a fished area and two protected areas prior to the establishment of the protected areas (1999-2000) with the same three areas after protection, we see that there are significantly more larger fish in the two protected areas but not in the fished area where the number of large animals continued to decrease [see Figure 1].

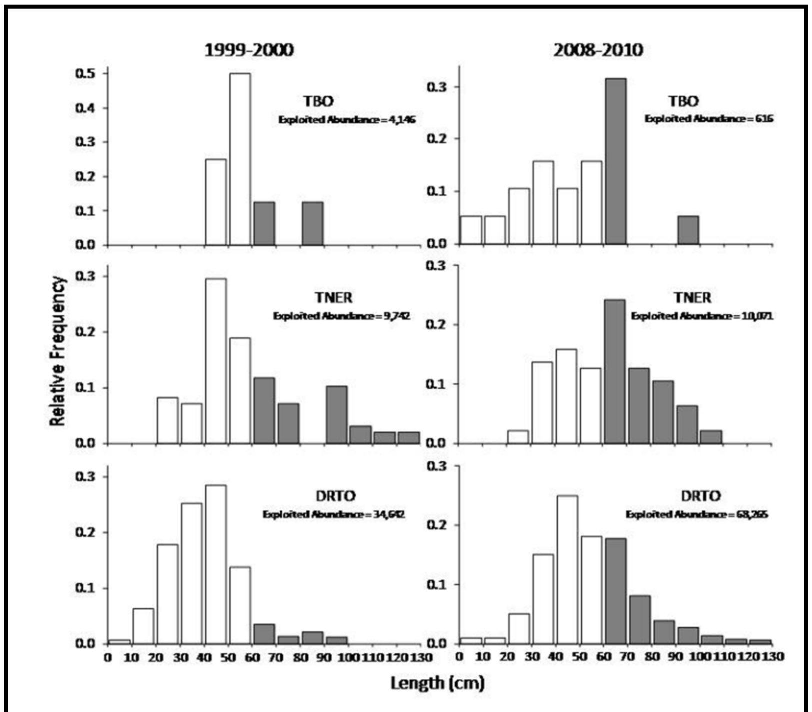

Figure 1: Comparisons of visual survey length compositions for black grouper among 3 management zones for two time periods: the pre-implementation baseline, 1999-2000; and, post-implementation of the TNER and DRTO RNA, 2008-2010. Open bars are the pre-exploited life stage; shaded bars are exploited (fished) life stage animals. Exploited phase abundance is noted on each panel.

In Spring-Summer of 2010-2011, a team of 46 research divers from the University of Miami's Rosenstiel School of Marine and Atmospheric Science, NOAA Fisheries Service, Florida Fish and Wildlife Conservation Commission, and the National Park Service completed a successful 20-day biennial census to measure how the protected status of the Florida Keys National Marine Sanctuary's Tortugas Ecological Reserve and Dry Tortugas National Park's Research Natural Area are helping the regional ecosystem rebound from decades of overfishing and environmental changes. The unprecedented collaboration allowed the team to complete more than 2,100 scientific dives, which will now help to further establish a baseline for the state of reef fish stocks and coral reef habitats in Florida's dynamic marine ecosystem. We were very encouraged to see that stocks have slowly begun to recuperate since the implementation of 'no-take' marine protected areas in the region. We noted particular improvements in the numbers of snapper, grouper, and coral recruits. We are currently crunching the data collected to see what adjustments may need to be made in order to help guide future management decisions to address the issues of biodiversity protection, restoration of ecological integrity, and fishery management which are critical to this area. This year, the team documented changes in fish abundance and habitat quality in this region which was hit by six major hurricanes since 2004. By statistically comparing this year's findings to previous baseline survey information collected, scientists can determine what effects intense hurricane activity had on this marine environment. If we again look at black grouper data we can see that the extent of occupancy markedly increased after implementation of the protected areas (between 1999-2000 and 2004) but has since been highly variable albeit at a consistently higher level than prior to protection. The natural variability associated with storms and other factors is superimposed upon the change due to management [Figure 2].

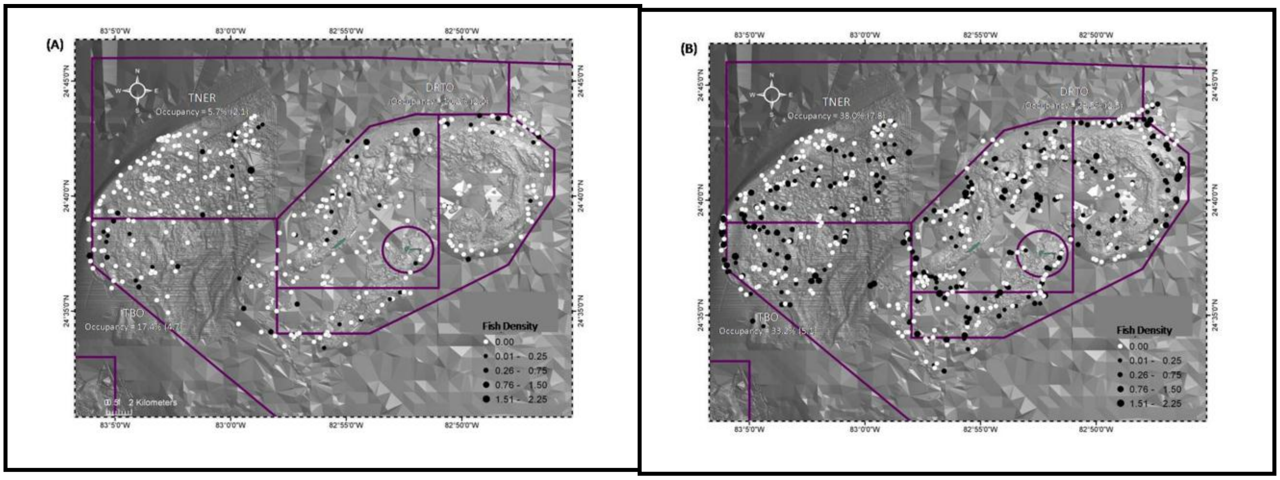

Figure 2: Spatial distribution of density for exploited life-stage mutton snapper (mean number of fish per SSU, 177 m^2) from Tortugas region visual surveys conducted in (A) 1999-2000; and, (B) 2008-2010. Each point is the average sample value within a PSU (200 by 200 m grid cell). Also shown are mean occupancy rates (SE) for three principal management zones.

Figure 3: Vortexing school of permit (*Trachinotus falcatus*) seen in a presumed spawning aggregation in the Tortugas Ecological Reserve during an RVC monitoring survey expedition of the Dry Tortugas region (Smith et al. 2011; Ault et al. 2012).

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

Integrated Coral Observing Network (ICON) Project

Project Personnel: I.C. Enochs, L.J. Gramer, K.P. Helmle, M. Jankulak, D.P. Manzello and R. Carlton (UM/CIMAS)
NOAA Collaborators: J.C. Hendee and M. Shoemaker (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 environmental 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 CO_2 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 (*Primary*)
***Theme 1*:** Climate Research and Impact (*Secondary*)
***Theme 3*:** Sustained Ocean and Coastal Observations (*Secondary*)
***Theme 4*:** Ocean Modeling (*Secondary*)

Link to NOAA Strategic Goals:

***Goal 3*:** Healthy Oceans - *Marine fisheries, habitats, and biodiversity sustained within healthy and productive ecosystems* (*Primary*)
***Goal 1*:** Climate Adaptation and Mitigation - *An informed society anticipating and responding to climate and its impacts* (*Secondary*)

NOAA Funding Units: OAR/AOML, CRCP, and HPCC

NOAA Technical Contact: Alan Leonardi

Research Summary:

Through continuous data collection, real-time monitoring, and ongoing field- and laboratory-based research, ICON provides scientists and managers with data critical to understanding the complex physical, chemical, and biological processes influencing coral reef ecosystems. For the 2011-2012 year, the ICON project continues to focus on 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 laboratory research on the effects of ocean acidification (OA) on reef building and loss; (4) research on coral skeletal records to reconstruct growth and physical environmental variables to assess climate impacts on coral growth and calcification; and (5) research on dominant physical forcing processes for sea temperature variability on shallow reefs.

The Coral Health and Monitoring Program (CHAMP) team (led by CIMAS team member Mike Jankulak) installed its latest Coral Reef Early Warning System (CREWS) station (Figure 1) in Saipan, Commonwealth of the Northern Mariana Islands (CNMI), U.S. This operation was part of a collaboration with the Coastal Resources Management Office and the Division of Environmental Quality, two local CNMI entities. With this station CREWS for the first time uses a communications architecture based on digital cellular modem technology, allowing CIMAS scientists and engineers in Miami unprecedented access to the Saipan station's programming and data reserves in real-time. The Saipan station also features a Conductivity-Temperature-Depth (CTD) instrument (Figure 2) provided by the Pacific Islands Ocean Observing System (PacIOOS), in yet another collaboration with scientists based out of the University of Hawai`i at Manoa near Honolulu. The PacIOOS CTD adds turbidity and chlorophyll measurements to the impressive CREWS data portfolio. As with all other CREWS stations, the Saipan data are reported 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. In addition to installing this new station, CREWS recently celebrated the sixth birthday of its longest continually-operating station in Puerto Rico, and is approaching five years with its station in St. Croix, U.S. Virgin Islands (which, together with a prior CREWS station in the same location, has provided nearly ten years of data continuously). Both the Puerto Rico and St. Croix stations have had their support lines replaced this year in order to ensure their continued operation for the foreseeable future.

Figure 1: Top-side view of recently installed Saipan CREWS station with Mike Jankulak (CIMAS/NOAA AOML) up top and Steven Johnson (DEQ) in the boat.

Dwight Gledhill, Derek Manzello and Ian Enochs conducted multiple research operations in La Parguera, Puerto Rico. Gledhill, with the assistance of PMEL's Sylvia Musielewicz, serviced and re-deployed the MAPCO2 buoy. Manzello and Enochs made coral calcification and growth measurements on four species of reef-building coral from two different sites as part of the Atlantic Ocean Acidification Test Bed Project.

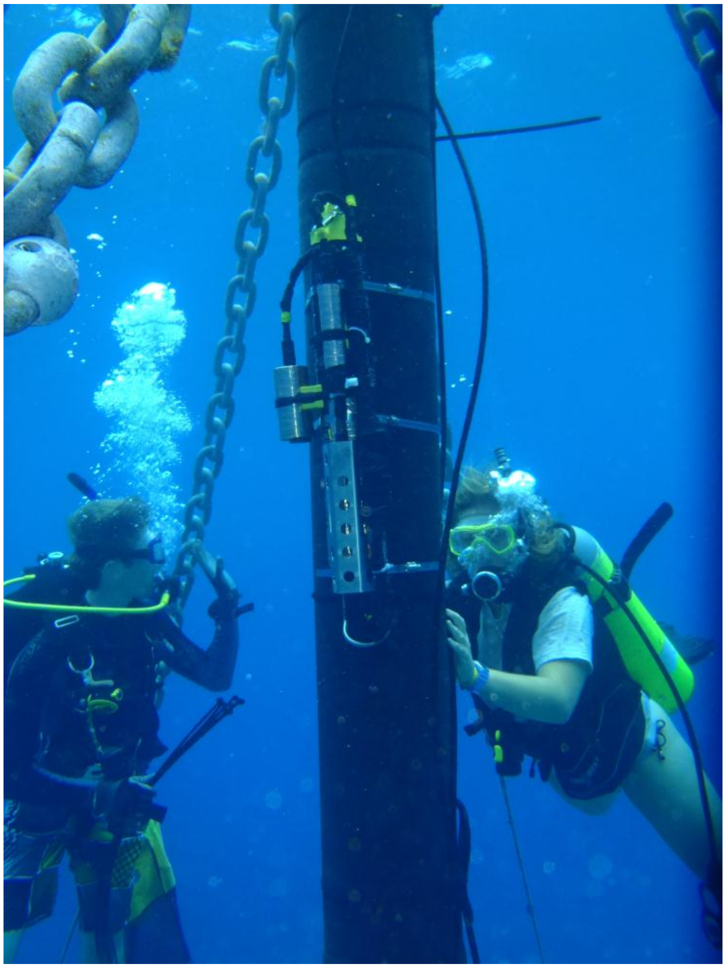

Figure 2: CREWS station outfitted with PacIOOS CTD with the chlorophyll and turbidity add-on sensors. The divers are Ross Timmerman (PacIOOS / UH) and Rachel Kotkowski (NOAA Corps).

In conjunction with CIMAS and NOAA's Coral Reef Conservation Program-funded Atlantic Ocean Acidification Testbed project, PIs Gledhill and Manzello along with CIMAS researcher Ian Enochs installed a MAP-CO2 buoy (Figure 3) at Cheeca Rocks in the Florida Keys. Cheeca Rocks will serve as the new location of the Atlantic Ocean Acidification Test Bed in FY12 and, like La Parguera, Puerto Rico, will ultimately serve double-duty beginning in FY13 as a class 3 climate monitoring site under the planned National Coral Reef Monitoring Plan (NCRMP) of NOAA's Coral Reef Conservation Program. The first of repeated reef metabolic studies at Cheeca Rocks in the Florida Keys subsequently occurred in January 2012. A team of researchers from Columbia University (W. McGillis, D. Hsueh), RSMAS (C. Langdon, A. Venti), and the University of Rhode Island (B. Loose) worked with CIMAS scientists (D. Gledhill, D. Manzello, I. Enochs, L. Gramer). Data were collected on net ecosystem calcification, net community productivity, benthic community coverage, coral growth and calcification, and reef bioerosion. A team of CIMAS and OCD scientists (Gramer, Cummings, Enochs, Gledhill, Manzello, Shoemaker, Stamates) prepared and deployed three new acoustic Doppler current profiler / wave sensors for a year-long study of reef circulation, to complement the ongoing AOAT investigations.

CIMAS scientists Derek Manzello and Ian Enochs worked with Lamont-Doherty's Wade McGillis, University of Rhode Island's Brice Loose, RSMAS's Chris Langdon, Brooke Gintert, and Kasey Cantwell, as well as Ryan Moyer of the Florida Fish and Wildlife Conservation Commission on the second incarnation of the process studies at the Atlantic Ocean Acidification Test-Bed at Cheeca Rocks in the Florida Keys. Manzello and Enochs completed 26 dives over 5 days to 1) conduct biological surveys to estimate the carbonate budget of the Cheeca Rocks patch reef using a census-based approach, 2) deployed/recovered three acoustic doppler current profilers (ADCPs). McGillis, Loose, and Langdon obtained measurements of reef metabolic performance, including net community productivity and net ecosystem calcification. CIMAS's Lew Gramer configured the ADCPs for redeployment, downloading and processing 4.5 months of continuous ocean currents data gathered in the waters surrounding the site so far. RSMAS's Brooke Gintert and Kasey Cantwell utilized high-definition video and still imagery to create landscape mosaic images of the reef that provide a permanent visual archive by which to quantify ecosystem change over time. Moyer conducted classical benthic surveys that will be compared to the landscape mosaic approach to ensure data continuity and comparability. Following field operations, a mini-symposium was held for the primary subcontractors of the test-bed project to present their results from past funding and propose new ideas for consideration in future test-bed operations. Former CIMAS employee and the new deputy director of NOAA's Ocean Acidification Program, Dwight Gledhill, participated in the mini-symposium.

Figure 3: Top-side view of MAPCO2 buoy at Cheeca Rocks in the Florida Keys which is the site of the Atlantic Ocean Acidification Test bed.

Unbored carbonate plugs have been deployed to specifically measure the rates of framework dissolution by endolithic algae and fungi. Four species of corals were collected, stained with Alizarin red, and deployed at 6 sites throughout the keys in order to monitor coral growth rates. Experimental long-term pH sensors were deployed and collected at inshore and offshore sites in order to monitor seasonal and diurnal fluctuations in seawater carbonate chemistry.

Patterns in bioerosion rates observed in the field are being corroborated in experimental aquaria to determine specific causative agents. Research is ongoing to test the effects of elevated CO_2 (predicted for the year 2100) on the erosive rates of clionaid sponges.

Enochs and Manzello adapted 3D scanning technologies to measure coral surface area, height, and volume, to better monitor changes in coral growth rate associated with ocean acidification (Figure 4).

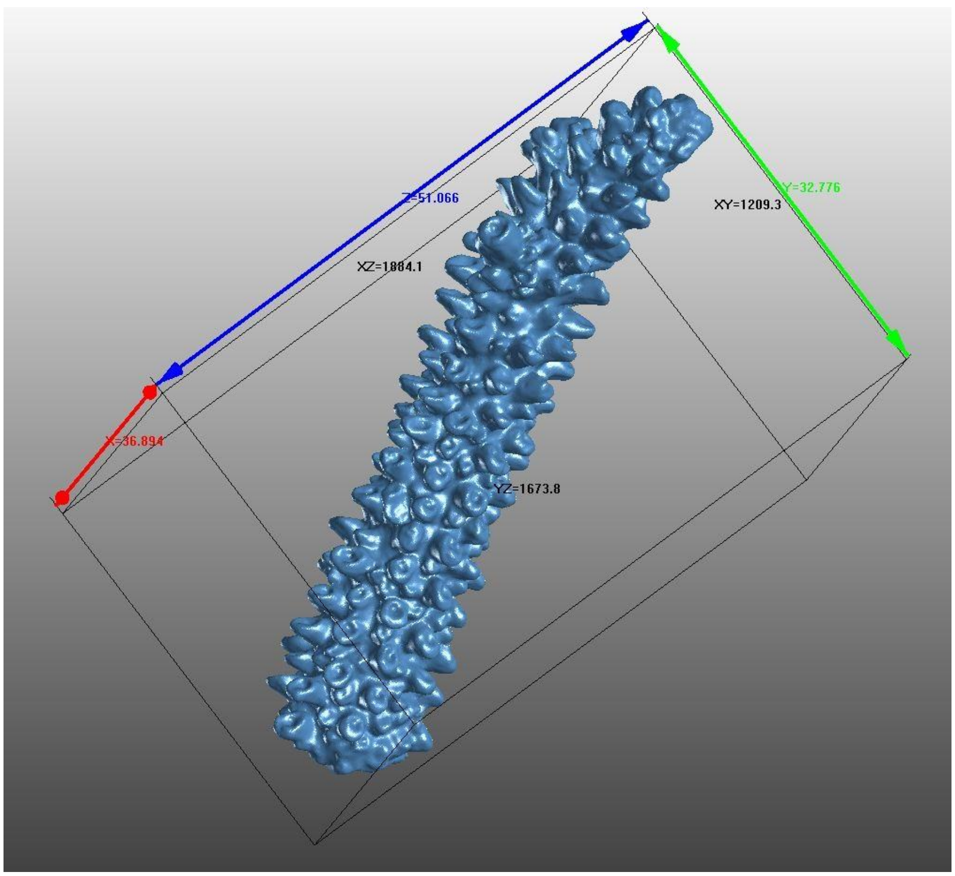

Figure 4: A 3d scan of ESA listed *Acropora cervicornis*, illustrating the complexity of coral surfaces.

CIMAS scientists (Enochs, Manzello, Helmle), developed new techniques for measuring coral calcification using micro computed tomography (micro CT) (Figure 5). Previous methodologies (e.g., buoyant weight, and densitometry) were compared in order to validate these procedures. Utilizing Helmle's CoralXDS software package, growth banding in cores of Montastraea cavernosa were identified and measured.

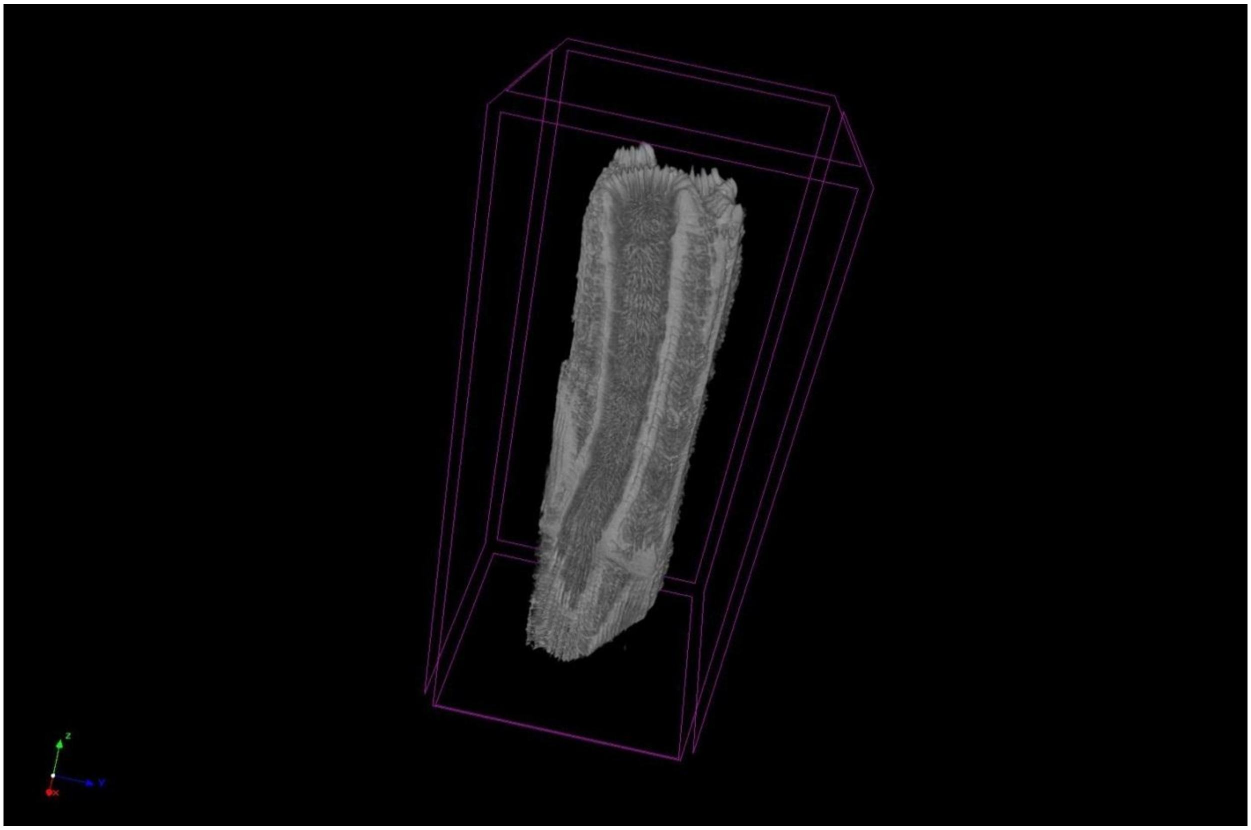

Figure 5: A micro CT scan of the reef-building coral *Montastraea cavernosa* showing the inside of a single coral polyp as it extends down into the colony's skeleton.

Coral sclerochronology is utilized by CIMAS researcher Kevin Helmle to identify relationships between coral size, age, and growth rate of the reef corals Monstastraea faveolata and Diploria labyrinthiformis. The coral size/age relationship is used to establish coral growth curves for these common reef species in order to evaluate the components of time to resource recovery, as pertains to corals, in habitat equivalency analysis (HEA) which has implications to the valuation of coral reef resources for management and mitigation. This research represents a collaboration with the National Coral Reef Institute of the Nova Southeastern University's Oceanographic Center. In conjunction with NOAA's Atlantic Ocean Acidification Test-bed site and MapCO2 buoy located at Cheeca rocks in the upper Florida Keys, sclerochronology is being used to reconstruct historical records of coral growth and calcification along with environmental variables such as sea surface temperature and seawater pH though the use of coral skeletal cores from colonies located nearby the AOAT and MapCO2 buoy. The intent of this study is to establish baseline variability and identify changes in ocean acidification and climate over the past centuries at this test-bed site, and to relate these changes to the annual coral growth and calcification records stored within the coral skeleton.

During 2011-2012, CIMAS researcher Lewis J. Gramer completed an analysis of long-period (weekly to decadal) sea-temperature variability over coral reefs of the Florida Keys National Marine Sanctuary, including the ICON partner-site at Molasses Reef. A reef heat budget model was completed to explain the observed variability in terms of regional-scale meteorological forcing, regional- and local-scale ocean heat advection and mixing, and bottom boundary layer heat exchange (Figure 6). Evidence for a physical process previously unreported in Florida coral reefs, horizontal convection, was discovered. Research has now begun applying this heat budget model to other ICON sites, especially those where long records of in situ data are not readily available, e.g., where remote sensing and models of ocean/atmosphere dynamics must be relied upon for monitoring environmental threats to coral reefs.

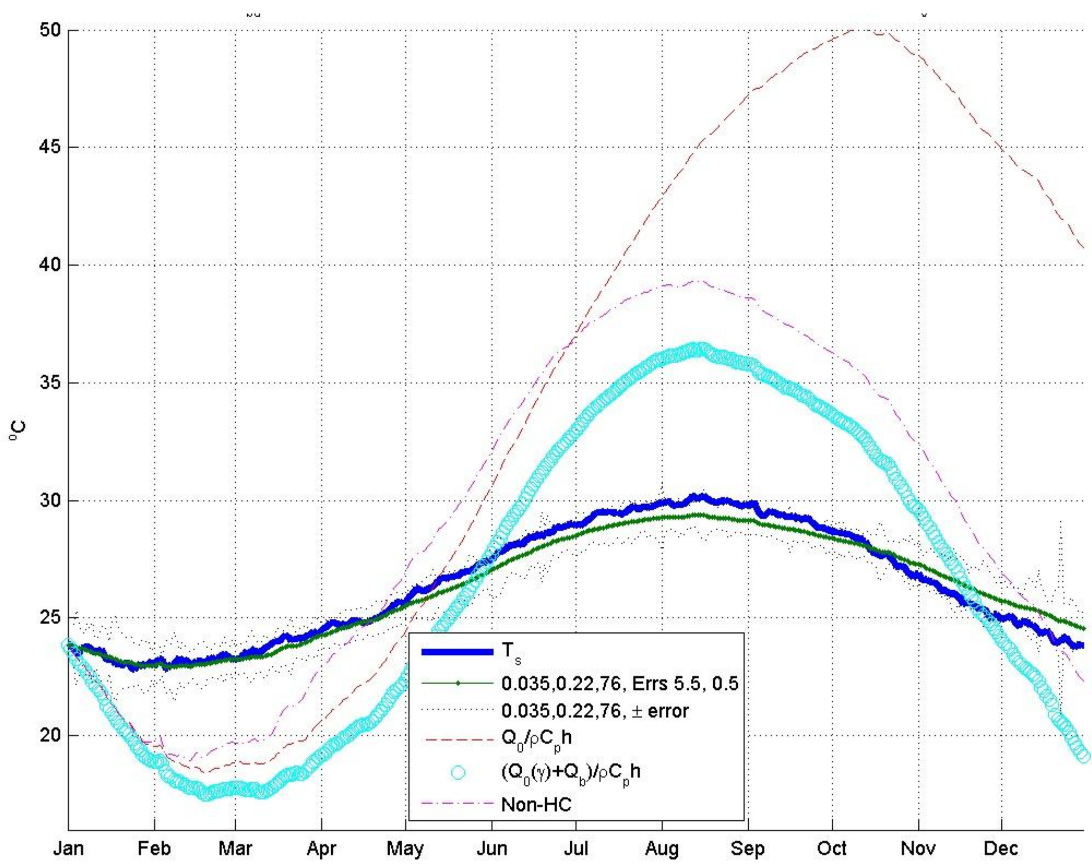

Figure 6: Twenty-year climatology of sea temperature (blue) and heat budget model results employing the novel horizontal convection term (green) in ^{o}C at Fowey Rocks reef-monitoring station in the Florida Keys: conventional heat budget results without horizontal convection (red, cyan, magenta) do not reproduce the observed variability in reef temperature.

Research Performance Measure: The ICON project addressed and met the defined objectives during 2011-2012 through a suite of research components that included installation of the latest Coral Reef Early Warning System (CREWS) system in Saipan and maintenance, data processing, and data delivery of existing CREWS stations throughout the Caribbean along with establishment of the Atlantic Ocean Acidification Test-bed (AOAT) in the Florida Keys and deployment of the MapCO2 buoy including acoustic Doppler current profiler /wave sensors. These in situ measurements were coupled with field-based and laboratory research including studies of net ecosystem calcification, net community productivity, benthic community coverage, reef bioerosion, and coral growth, calcification, and environmental records, all of which which were complemented by reef heat budget modeling efforts that address sub-regional-scale variability and meteorological forcing.

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)

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 integrate pertinent oceanographic data from the World Ocean Atlas web site and other sources.

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

Link to NOAA Strategic Goals:
***Goal 3*:** Healthy Oceans - *Marine fisheries, habitats, and biodiversity sustained within healthy and productive ecosystems*

NOAA 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 movement for periods up to 180 days. This past year's deployments included white marlin off the coast of North Carolina and Aruba; and, black marlin off the western coast of Panama. 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 >20 PSATs that had previously transmitted summarized data. PSAT non-volatile memory retains large volumes of high resolution data that is available for download. This augmented the PSAT data base with detailed

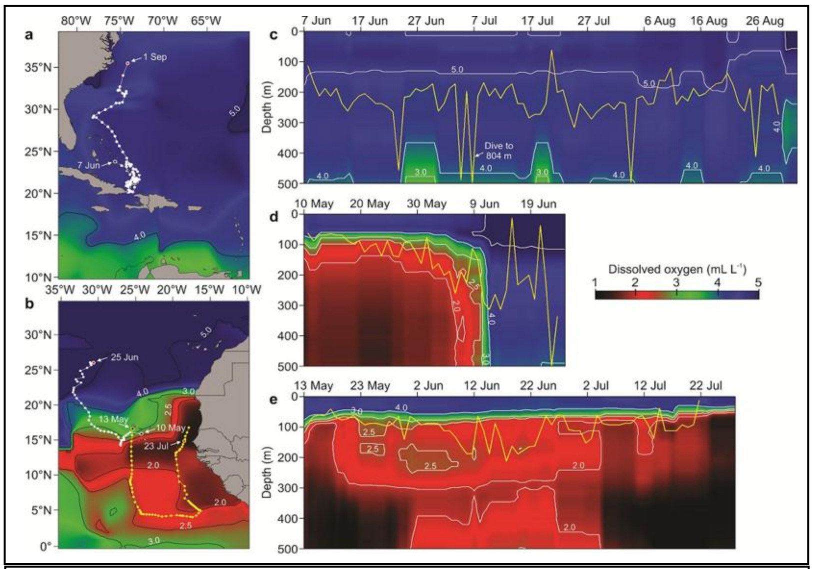

Figure 1: Blue marlin habitat use versus dissolved oxygen depicting track in the western North Atlantic (a), blue marlin tracks (two) in the eastern tropical Atlantic (b), maximum daily depth versus time in the western North Atlantic (yellow line, c), maximum daily depth versus time in the eastern tropical Atlantic (yellow line, d); and, maximum daily depth versus time in the eastern tropical Atlantic nearest the continental shelf in (yellow line, e).

information that is not available through Argos transmissions. One example of recent PSAT analysis was a description of Atlantic blue marlin habitat use. Specifically, time spent at depth and temperature relative to the levels of available dissolved oxygen inside and outside the Atlantic oxygen minimum zone. 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:

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

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Reef Visual Census (RVC): Reef Fish Monitoring in the Florida Keys and Dry Tortugas

Project Personnel: J. Blondeau (UM/CIMAS)
NOAA Collaborator: 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), management measures and anthropogenic impacts. To examine the effectiveness of marine reserves and other management strategies 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**:** To carry out multi agency (UM/CIMAS, NOAA/SEFSC, Florida Fish and Wildlife Commission FWC, and the National Park Service NPS), spatially-explicit, 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 3**:** Healthy Oceans - *Marine fisheries, habitats, and biodiversity sustained within healthy and productive ecosystems (primary)*

Goal 4**:** Resilient Coastal Communities and Economies - *Coastal and Great Lakes communities that are environmentally and economically sustainable (secondary)*

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

Research Summary:
The Florida Keys Reef Visual Census (RVC) project is a continuous, long-term monitoring effort aimed at large-scale tracking of reef fish and coral habitat metrics along the Florida reef tract including the Dry Tortugas. This fisheries independent monitoring effort employs a spatially explicit, stratified random design enabling us to efficiently examine the effectiveness of management actions, as well as the impacts of fishing and other natural stressors, such as hurricanes, on the ecosystem. Specifically, this research allows us to quantitatively assess reef fish population changes, habitat associations, and ecosystem responses to fishing, management actions (including MPA zoning), and other human activities. This longitudinal research approach is a vital component that enables us to detect annual and decadal reef fish population changes across the Florida coral ecosystem.

To accomplish a large-scale monitoring protocol, however, a multi-agency cooperation was needed to ensure success. University of Miami's CIMAS, NOAA's Southeast Fisheries Science Center, National Park Service and the Florida Fish and Wildlife Commission worked closely together to complete over 600 sampling sites, stretching from Miami to the Dry Tortugas. The ability to monitor the entire Florida reef tract enables us to characterize reef fish populations and their habitat associations across a large spatial scale. And the stratified random sampling design allows us to accomplish our objectives efficiently and in the most cost effective way. One of our objectives is to examine the effectiveness of management strategies, such as Sanctuary Preservation Areas (SPAs) and the Tortugas Ecological Reserve and Research Natural Area in the Dry Tortugas. Our data shows that fish abundance and diversity are higher in these protected areas and that large, commercially-important species (i.e. black, red and goliath groupers), reside and gain refuge as a result of this protection. Additionally, this research assesses habitat trends and associations between fish and habitat. Our data, again, shows that fish abundance and diversity are higher in areas of complex habitat, such as spur and groove reef.

The benefit of a healthy coral reef ecosystem goes beyond the intrinsic natural value and has the ability to provide monetarily to the local economies in terms of tourism and recreational and commercial fisheries. However, to track the changes in fish populations and habitat health as a result of anthropogenic impacts, as well as natural events, we need a continuous monitoring effort so that informed management decisions are made.

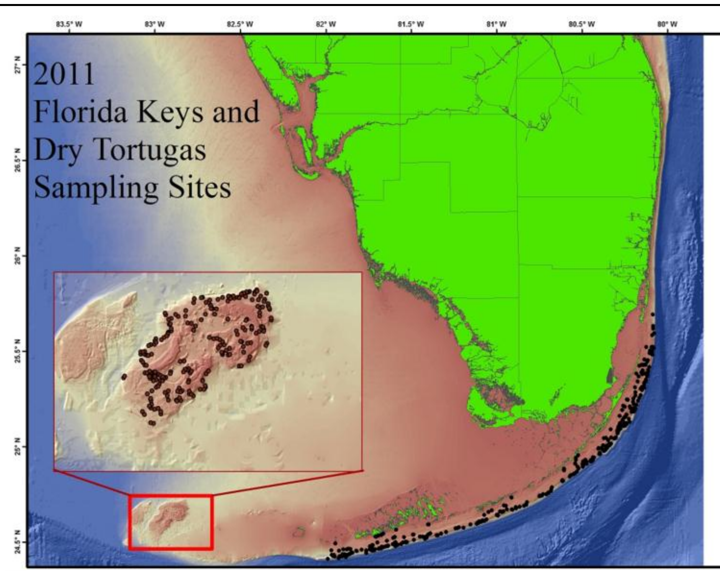

Figure 1: Sampling site locations for 2011 in the Florida Keys and Dry Tortugas.

Research Performance Measure:
A total of 636 sampling sites were completed in the summer of 2011 along the Florida reef tract, including the Dry Tortugas. All milestones were met and objectives completed.

Puerto Rican Small Scale Fleet Costs and Earnings Study

Project Personnel: F. Tonioli (UM/CIMAS)
NOAA Collaborator: J. Agar (NOAA/SEFSC)
Other Collaborators: M. Shivlani and R. Koeneke (CIE)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** To describe the main findings of a socio-economic study that evaluated the economic performance of the small-scale fleet in Puerto Rico.

***Strategy*:** In person surveys were administered to 363 fishermen, using a stratified random sample by region to provide a socioeconomic description of the population of active small-scale fishing fleets in Puerto Rico.

CIMAS Research Theme:

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

Link to NOAA Strategic Goals:

***Goal 3*:** Healthy Oceans - *Marine fisheries, habitats, and biodiversity sustained within healthy and productive ecosystems* (*Primary*)

***Goal 4*:** Resilient Coastal Communities and Economies - *Coastal and Great Lakes communities that are environmentally and economically sustainable* (*Secondary*)

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

Research Summary:

This study describes the main findings of a socio-economic study, which evaluated the economic performance of the small-scale fleet in Puerto Rico conducted between 2008 and 2010. The survey inquired about household demographics, fishing practices, capital investment in fishing vessels, gear and equipment, variable and fixed costs, earnings, and geographic distribution of fishing trips. In person surveys were administered to 363 fishermen, using a stratified random sample by region.

The majority of the interviewees were middle-aged men, with moderate levels of formal education and high levels of fishing dependence. The typical fisherman was 52 years old and had 30 years of fishing experience. Fishermen reported that he derived about 65% of their household income from fishing activities and the remaining came from non-fishing activities (11%) and government assistance (21%). Most of them fished on a full-time basis.

The majority of the fishermen (70%) owned a single fishing boat and few of them (5%) owned 2 or more boats. The average boat was about 20 feet in length, had an outboard engine (61 hp), and had a fiberglass hull. Handlines, SCUBA, fish traps, bottom lines, and gillnets were the most commonly used gears.

Bottom lines and SCUBA were the most expensive gears to operate. On average, bottom line fishermen and SCUBA divers spent about $85 and $66 per trip running their boats, respectively. Gillnets had the lowest variable costs per trip ($36). Fuel accounted for the largest share of the variable cost categories. The percentage of fuel expenses to total variable costs ranged between 60%

(SCUBA) and 68% (fish traps and gillnets). Bait cost were the second most important expenditure category after fuel costs. The percentage of bait expenditures to total variable cost ranged between 0% (SCUBA) and 19% (bottom lines).

The study found that the typical Puerto Rico fisherman spent about $1,938 on annual fixed costs. Office expenses (mainly transportation and communication), and boat and engine maintenance were the main expense categories accounting for 46% and 37% of the total annual fixed expenses, respectively.

Our findings indicate that SCUBA is the most profitable fishing gear in Puerto Rico. SCUBA diving profitability is driven by targeting high valued species such as spiny lobster and conch, and by having moderate fuel and maintenance expenses.

Figure 1: Puerto Rican small scale fishermen's boats.

Research Performance Measure: The presented study accomplished the original goals and its main findings indicate that SCUBA is the most profitable fishing gear in Puerto Rico. However, the study determined that the average reported landings and revenues differed from those averages reported as part of the Puerto Rico trip ticket program; even though the study did not find systematic under-reporting of landings and revenues in the trip ticket database relative to those figures reported in this study.

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

Project Personnel: E. Malca, B. Muhling (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. José 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 6*:** Ecosystem Management

Link to NOAA Strategic Goals:
***Goal 3*:** Healthy Oceans – *Marine fisheries, habitats, and biodiversity sustained within healthy and reproductive ecosystems*

NOAA Funding Unit: NOAA/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 capacity building workshops focusing on connectivity along the Mesoamerican Reef.

In addition, the research component of this project is focused in Isla Contoy National Park, ICNP in order to: 1) Asses 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.

The second connectivity workshop was carried out March 13-14 at the Chetumal campus of ECOSUR and at Parque Nacional Arrecifes de Xcalak in Quintana Roo, Mexico. The 2nd workshop's goals were to provide hands-on training for local managers and to setup an experiment to begin the collection of comparable baseline information along the Mesoamerican Reef region in the fall of 2012.

Figure 1: 2nd Capacity building workshop carried out in conjunction with NOAA, MARFUND, CIMAS, El Colegio de la Frontera Sur and Comisión Nacional de Áreas Naturales Protegidas.

Research Performance Measure: The program is in progress and proceeding on schedule. The research portion was completed in June, July and August 2010 and in January 2011 with participation of research staff and students from ECOSUR, (El Colegio de la Frontera Sur) CONANP, (Comisión Nacional de Áreas Naturales Protegidas) and local guides. All data has been examined for larval fish and results will be presented at the International "Larval Fish Conference" in Bergen, Norway in 2012. The second workshop was a success with participants from academic, government and NGOs representing Mexico, Belize, Honduras and Guatemala's marine protected areas. Initial protocols for sampling are being developed for the simultaneous experiment to be carried out in the Fall of 2012. Two websites and social networking is being utilized to promote the project among participants and stakeholders.

US Virgin Islands Larval Distribution and Supply Research

Project Personnel: E. Malca, N. Melo, B. Muhling, S. Privoznik, G. Rawson and A. Shiroza (UM/CIMAS)

NOAA Collaborators: J. Lamkin and T. Gerard (NOAA/SEFSC); R. Smith and L. Johns (NOAA/AOML)

Long Term Research Objectives and Strategy to Achieve Them:

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

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

CIMAS Research Theme:

***Theme 6*:** Ecosystem Management

Link to NOAA Strategic Goals:

***Goal 3*:** Healthy Oceans – *Marine fisheries, habitats, and biodiversity sustained within healthy and reproductive ecosystems*

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

Research Summary:

This fisheries oceanography research project combines the expertise of fisheries biology, oceanography, and local knowledge from managers to assess the long-term sustainability of coral reef fish populations in the Caribbean, focusing on the U.S. Virgin Islands. Surveys of water properties, currents, dispersal and transport of settlement-stage larvae provide data on and a further understanding of the biological and physical processes that drive production on the Grammanik and Red Hind Banks, which are protected sites of multi-species spawning aggregations for economically important coral reef fish e.g. fisheries management areas established by the Caribbean Fisheries Management Council. Additionally, surveys of inshore juvenile fishes yield an understanding of the spatial variation in the supply of settlement-stage fishes in coastal waters. This is a long term interdisciplinary research project (March 2007, March 2008, April 2009, February - March 2010, and April – May 2011) utilizing the NOAA Ship NANCY FOSTER to conduct biological and physical oceanographic surveys of the Virgin Islands' (VI) bank ecosystems and surrounding regional waters. In addition, inshore biological collections of 2007, 2008 and 2009 took place in St. Thomas using either light traps or seine nets in important nursery habitats targeting juvenile coral reef fishes. The fifth cruise was successfully carried out in conjunction with CRCP project 20416-2011 (US Caribbean Coral Reef Ecosystem Connectivity: Vieques Sound and Virgin Passage Transport Study) in 17 April – 07 May 2011 replicating collections at some historical stations and extending our sampling collections to Mona Passage and the Bahamas.

Research Performance Measure: The research program is on schedule. Data analyses are ongoing for all four cruises: 2007-2011. Oceanographic cruise data has been collected and processed for 2007-2010 and taxonomic family identification has been completed for 2007, 2008, 2009 and despite limited funding we have 30% identification completed for samples from 2010. During the 2011 cruise, we completed a total of 101 stations, yielding 163 plankton samples (97 Bongo, 66 Neuston) and sorting has been completed. Family level identification of the 26,800 larval fish collected will continue this year.

Figure 1: NOAA Core officer Aaron Maggied deploys bongo net aboard the NOAA ship Nancy Foster in the US Virgin Islands.

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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 6**:** Ecosystem Management

Link to NOAA Strategic Goals:
Goal 3**:** Healthy Oceans - *Marine fisheries, habitats, and biodiversity sustained within healthy and productive ecosystems*

NOAA 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.

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

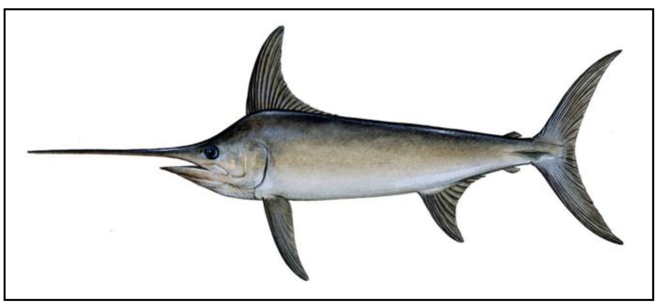


Figure 1: Photo of *Xiphias gladius* the swordfish (www.safmc.net, 2009).

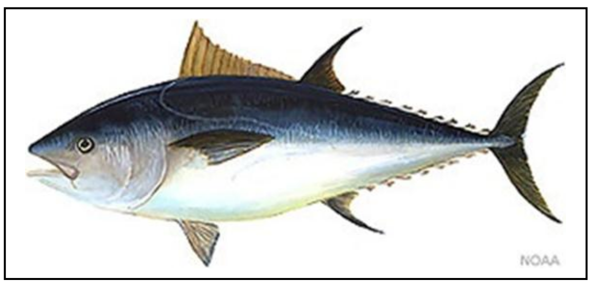


Figure 2: Photo of *Thunnus thynnus* the Atlantic Bluefin Tuna (www.MarineBio.org, 2009).

Research Performance Measure: All major objectives have been met.

Agreement between the University of South Florida College of Marine Science and NOAA Fisheries Support for the Marine Resource Assessment Program-

Project Personnel: E. Peebles and C. Ainsworth (USF-CMS)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** To develop and implement a new, interdisciplinary concentration in Marine Resource Assessment (MRA) at USF-CMS as part of its Ph.D. and M.S. programs in marine science. The new concentration will provide training in quantitative population dynamics and in the emerging field of ecosystem-based management. Its mission will be to train a new generation of scientists that can effectively address issues concerning the sustainability of the world's living natural resources.

***Strategy*:** Students with concentrations in MRA will be expected to engage in thesis or dissertation topics that deal directly with interactions between living resources and anthropogenic factors, including subjects such as bio-physical interactions, changing predator-prey relationships, fishing, and identification of essential linkages that determine habitat quality. It is expected that students who select the MRA concentration will interact strongly with one or more of the state and federal resource-management agencies that are located near USF-CMS in Florida, including the National Marine Fisheries Service, the Fish and Wildlife Research Institute of the Florida Fish and Wildlife Conservation Commission, and the Florida Integrated Science Center of the US Geological Survey.

CIMAS Research Theme:

***Theme 6*:** Ecosystem Management

Link to NOAA Strategic Goals:

***Goal 3*:** Healthy Oceans - *Marine fisheries, habitats, and biodiversity sustained within healthy and productive ecosystems*

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

Research Summary:

At the time of report preparation, all planned courses that are associated with the present Statement of Work have been successfully completed. The planned schedule of course offerings remain once every two years for each of the courses listed below under the "Graduate Students" heading. The MRA program has succeeded in involving NOAA instructors in the design and execution of key coursework, specifically the *Fish Population Dynamics* course, which was team-taught by highly experienced NOAA personnel upon execution of the present agreement in August 2010 and will be taught in the future by Dr. Cameron Ainsworth, a former NOAA fisheries biologist and modeler (contracted by NMFS NWFSC, Seattle). Dr. Ainsworth will also be responsible for future offerings of *Dynamics of Marine Ecosystems*, which engages students in ecosystem-level modeling activities that are directly relevant to future efforts toward ecosystem-based fisheries management. Dr. Christopher Stallings, who is another faculty member recruited to USF under the NOAA-sponsored MRA program, has taken the lead in teaching *Fish Biology* and will also continue to offer *Fishery Ecology Reading Group* on a regularly repeating basis. We will also develop *Design and Analysis of Marine Resource Surveys* as a new course offering.

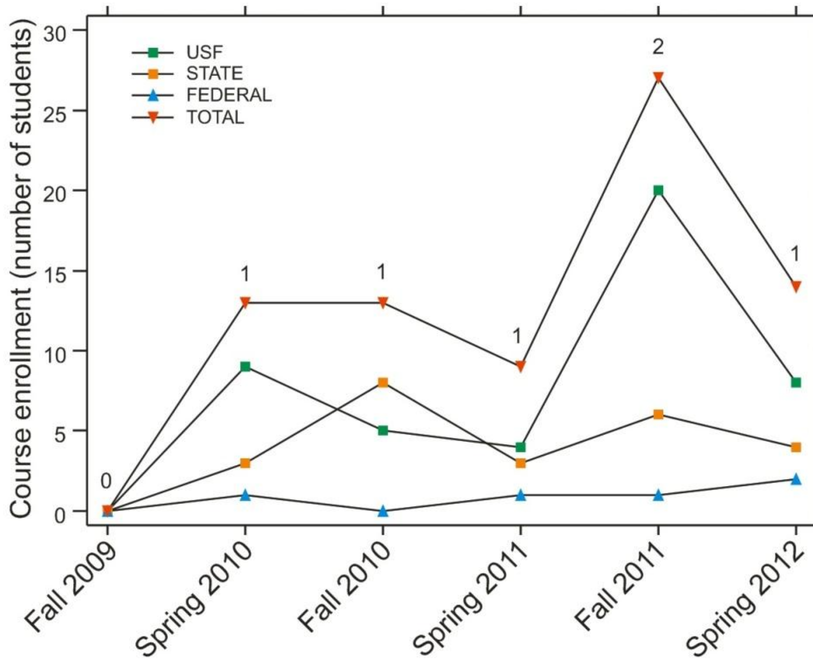


Figure 1: Enrollment in the USF-CMS Marine Resource Assessment (MRA) program by type of student and semester. Numbers above symbols indicate the number of MRA courses being offered per semester. State and federal students are employed full-time by resource management agencies and take courses at USF as non-degree-seeking students. Some of these later obtain degree-seeking status at USF, and are considered USF students from that point forward.

Figure 2: MRA students preparing to remove otoliths from a swordfish caught during a fishing tournament (photo by Dr. Ernst

Dr. Ernst Peebles of USF continues to serve as Chair of the MRA committee at USF-CMS, a position that leads the coordination of future MRA program development under the guidance of appropriate USF Marine Science faculty. Dr. William Hogarth served as the original Principal Investigator for this award. As a result of Dr. Hogarth's transition from Dean of USF-CMS to Director of the Florida Institute of Oceanography, Dr. Peebles assumed the role of Principal Investigator on the present award during 2011.

Research Performance Measure: The new line of MRA-related coursework supported by the present agreement has been very successful at attracting career-minded students in the area of MRA. Participation in the MRA Area of Concentration is a popular request among prospective students; hundreds of qualified prospective students have applied to the program, but the number that is accepted is limited by available resources. MRA students currently represent ~15% of the student body at the USF-CMS, which is comparable to the proportions concentrating in Chemical, Geological, and Physical Oceanography (Biological Oceanography is the largest area of concentration with ~40%).

Enrollment by professional fisheries scientists in MRA courses has exceeded expectations, with average course capacity being 34% occupied by employees of state and federal resource management agencies (range: 21-62%). Of these, 16% are federal (NOAA, USCG) and 84% are state (Florida FWC) employees. Effort should be made to increase future federal employee enrollment in these courses.

Figure 3: Thin section of red grouper fin ray under polarized light. Lifelong trends in the abundance of 26 elements (“elemental fingerprints”) were analyzed using laser-ablation inductively coupled mass spectrometry (LA-ICP-MS) to allow comparison with corresponding trends in an otolith from the same fish. Collecting such information from fin rays is non-lethal, unlike the commonly used otolith-based approach (photomicrograph by MRA student Orian Tzadik).

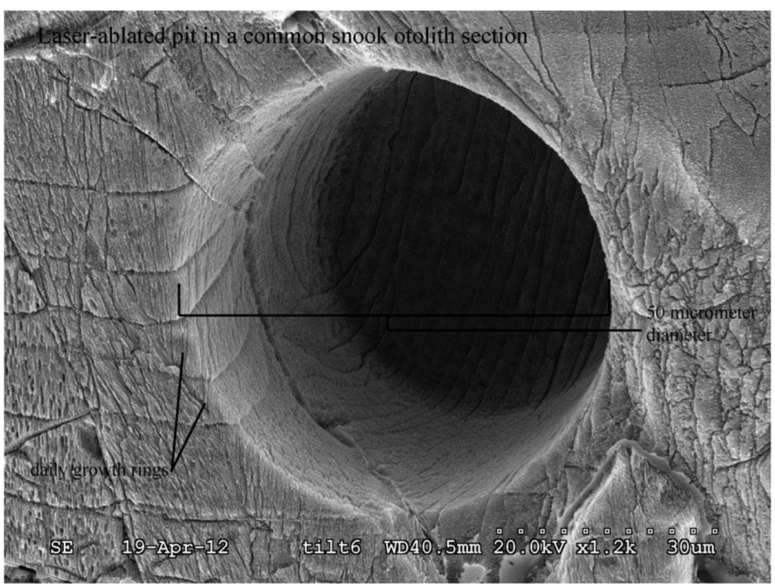


Figure 4: Pit left by laser during LA-ICP-MS analysis of a sectioned snook otolith. More than five daily growth increments are evident on the left side of the laser pit. Laser diameter was 50 µm during this analysis, but can be reduced to 5 µm to improve fine-scale temporal resolution (SEM image by MRA student Holly Rolls).


RESEARCH REPORTS

THEME 7: Protection and Restoration of Resources

Florida Bay Pink Shrimp Project: Effects of Salinity and Other Environmental Factors on Pink Shrimp Growth and Survival

Project Personnel: M.M. Criales (UM/RSMAS); I. Zink (UM/CIMAS)
NOAA Collaborators: J.A. Browder and T. L. Jackson (NOAA/SEFSC)

Long Term Research Objectives and Strategy to Achieve Theme:

***Objectives*:** To develop a pink shrimp (*Farfantepenaeu*s *duorarum*) simulation model and performance measure to determine the impact of the Comprehensive Everglades Restoration Plan (CERP) on Florida Bay.

***Strategy*:** Conduct coordinated field and laboratory experiments on different life history stages of pink shrimp in relation to salinity and other environmental factors to improve our understanding of the recruitment process of this important fishery species.

CIMAS Research Theme:
***Theme 7*:** Protection and Restoration of Resources

Link to NOAA Strategic Plan:
***Goal 3*:** Healthy Oceans - *Marine fisheries, habitats, and biodiversity sustained within healthy and productive ecosystems*

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

Research Summary:

We continued examining the ecology and behavior of this important fishery species in Florida Bay and the SW Florida shelf of the Gulf of Mexico. Activities during the past year consisted of continued analysis of previous laboratory investigations regarding salinity influences on growth and survival of pink shrimp postlarvae and early juvenile life stages.

A laboratory experiment was conducted in fall 2010 to determine the effect of salinity and temperature on growth and survival of postlarval and juvenile pink shrimp stages (see CIMAS Report 2011 for description). Analysis of data during 2011 clearly demonstrated that temperature was more influential on growth rates of weight and carapace length and on survival rates than was salinity (Fig 1A, B). However, no matter the temperature, growth was compromised at high salinities, as was demonstrated by 55-ppt treatments. These findings indicate pink shrimp postlarval growth and survival would be affected by Florida Bay hypersaline events resulting most likely in habitat reduction and thus concentration within more favorable conditions. Based upon laboratory results, a field experiment was designed aiming to investigate growth rate differences between the differing salinity regimes found in Whitewater Bay (WWB) and Johnson Key Basin (JKB), both within Everglades National Park, via deployment and stocking of in-situ mesocosm cages. JKB is characterized as euhaline to hyperhaline (ranging from 33.57 to 41.38 ppt), relatively clear water, and with a benthos dominated by dense seagrasses. Conversely, WWB is polyhaline to mesohaline (8.69 to 23.11 ppt) with turbid/tannic waters and a benthos dominated by sparse algal fronds. These two locales also differ in water quality physical parameters, such as differing ionic composition ratios (Swart et al. Unpub. Data), pH, dissolved oxygen concentrations. During 2011, methods were developed to collect and preprocess shrimp hemolymph in order to analyze its osmolality and ionic composition. Scouting missions were conducted in 2011 to select sites conducive to execution of the in-situ study. Currently, four in-situ mesocosms have been deployed in JKB as an initial test for methods development (Fig. 2A).

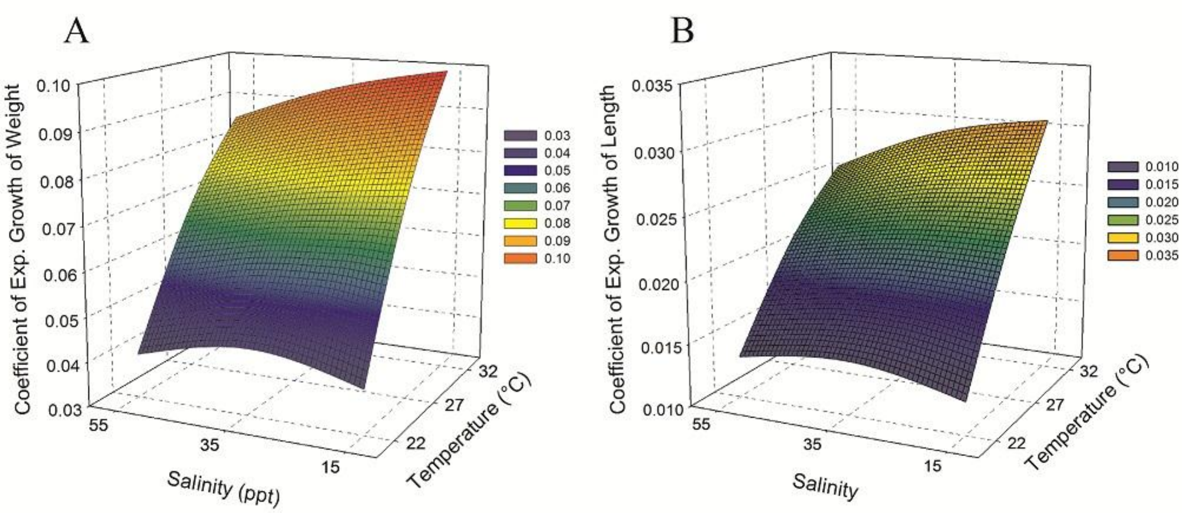


Figure 1: Three dimensional surface curves of coefficient of exponential growth of A) weight and B) length plotted against salinity and temperature treatment levels. Note differing scale for each plot.

An ultraviolet light responsive injectable elastomer tag will be used to differentiate individuals, and thus calculate individual growth rates, in future in-situ mesocosm caging growth studies. During scouting missions, postlarval pink shrimp were collected from near the selected sites (WWB and JKB), and laboratory-based studies were conducted to investigate potential influences of tagging procedures on their growth and survival. Source water (WWB and JKB) was also collected and used within independent recirculating tank systems to maintain postlarval shrimps at conditions similar to their ambient waters. Shrimps were formed into four groups, two from each locale, so that initial sample carapace length and weight distributions did not significantly differ. Within each source, one subgroup of postlarvae were tagged (Fig 2B) while the other was not subjected to these manipulations. Once all tagging procedures were complete, the shrimps selected into the study groups were stocked within a single 37-liter aquarium. Measurements of growth were conducted on a weekly basis for one month. No statistical influence of tagging was detected for WWB shrimps for wet weight (WT) or carapace length (CL). Similarly, no statistical growth influences of tagging were detected for JKB CL and WT. Analysis of length/weight (condition factor) relationships between tagged and untagged shrimps within each location did not reveal statistical differences for the slope or intercept of the relationship. Despite no significant difference between initial CL or WT between JKB and WWB shrimps, ANOVAs revealed a significant difference in one month's growth in both CL and WT between JKB and WWB shrimp (Fig. 3). Results of these preliminary investigations suggest that 1) tagging procedures can be conducted without affecting shrimp growth and 2) there are significant growth differences between WWB and JKB conditions. These results provide valuable rationale and support for the planned in-situ mesocosm growth study.

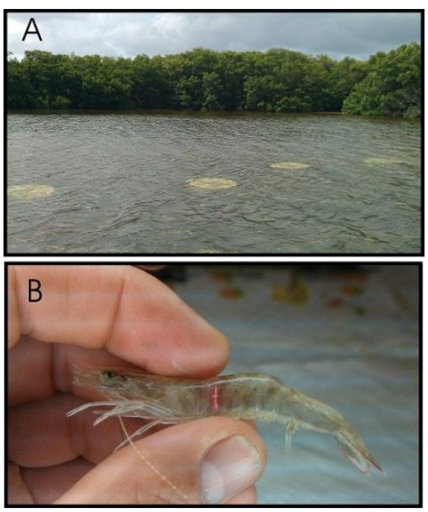


Figure 2: Pictures illustrating A) four in-situ mesocosm cages deployed just north of Johnson Key, Florida Bay and B) ultra violet light responsive elastomer tags within a shrimp test subject.

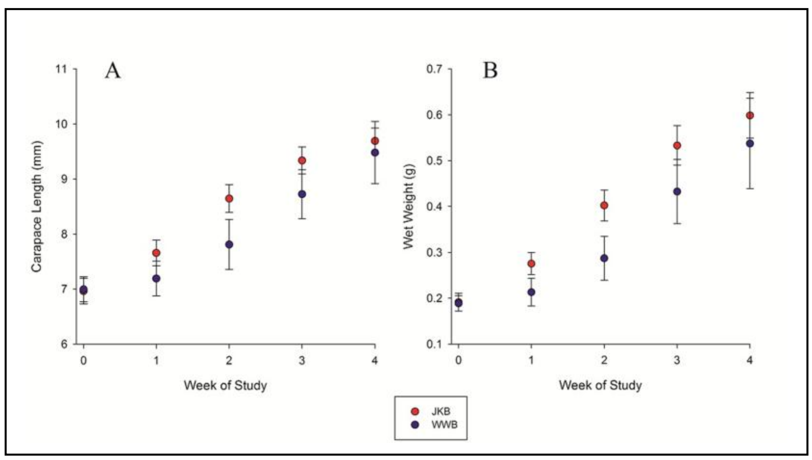


Figure 3: Plots of A) mean carapace length ± CI and B) mean weight ± CI graphed against week of study demonstrating significant differences observed during laboratory-based growth studies between shrimps collected from Johnson Key Basin (JKB) and Whitewater Bay (WWB).

Research Performance Measure: The objectives already have been partially accomplished; results from laboratory investigations regarding salinity influences on growth and survival were presented at The Crustacean Society Mid-Year Meeting in June, 2011, and these data currently are being finalized in a publication to be submitted to a peer reviewed journal.

Marine Mammal Research and Stranding Response

Project Personnel: L. Aichinger Dias (UM/CIMAS)
NOAA Collaborator: L. Garrison (NOAA/SEFSC)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** 1) To support the Marine Mammal Health and Stranding Response Program (MMHSRP) at Southeast Fisheries Science Center (SEFSC) in data validation, collection and stranding response. 2) To assist the SEFSC's Protected Resources and Biodiversity program in management and conservation of protected species during data collection and management within the Marine Mammal Program.

***Strategy*:** 1) To validate the stranding historical data (1996 to 1999) working closely with the SEFSC staff to implement effective data auditing and correction. 2) To respond and coordinate response actions during cetacean strandings dead or alive in the Southeastern Region (from North Carolina to Texas, Puerto Rico and the U.S. Virgin Islands) and assist with marine mammal necropsies at the SEFSC. 3) To perform data management and field work onboard NOAA research vessels in the Gulf of Mexico and Atlantic Ocean. 4) To support the investigation of Marine Mammal Unusual Mortality Events (UME) including the current Northern Gulf of Mexico UME by performing data management, sample intake and distribution, and assisting in necropsies and field work. 5) To perform data management and field work during Natural Resource Damage Assessment (NRDA) studies associated with 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:

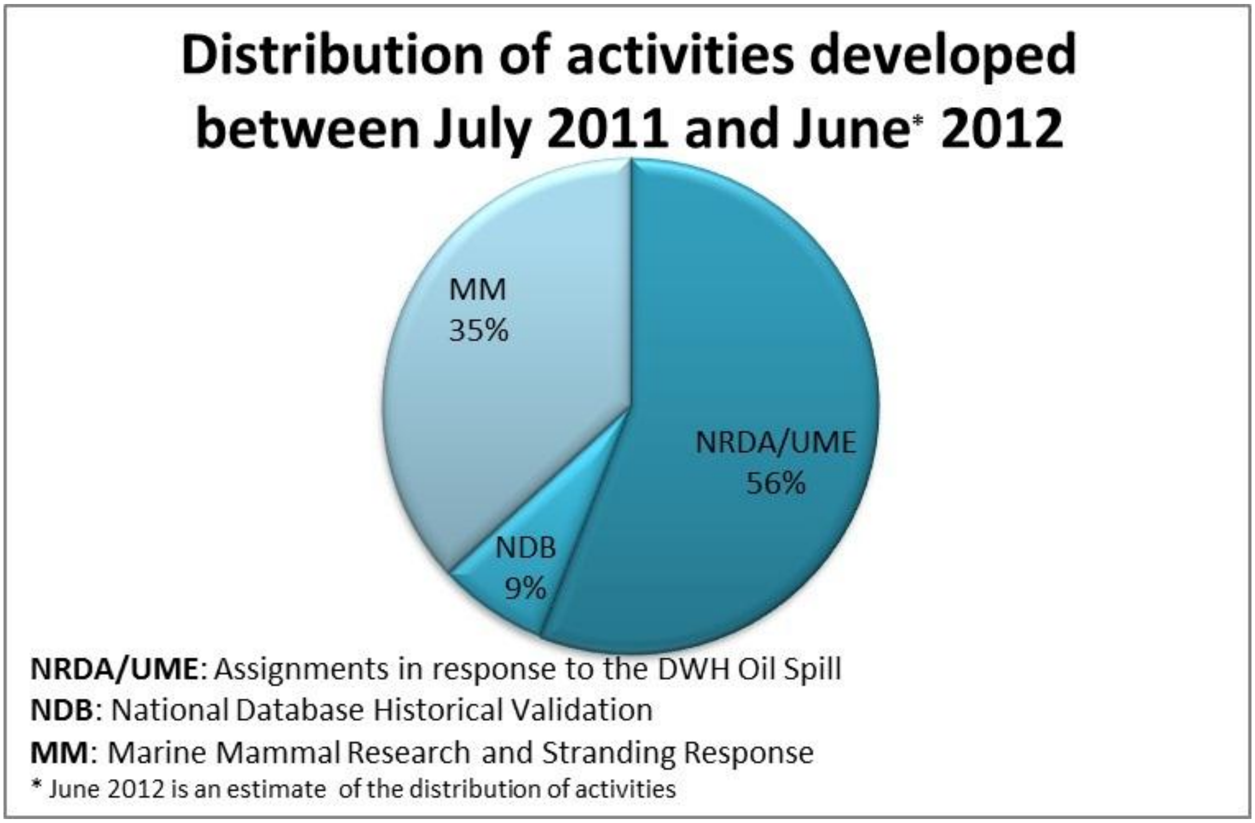
***Goal 3*:** Healthy Oceans - *Marine fisheries, habitats, and biodiversity sustained within healthy and productive ecosystems*

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

Research Summary:

The investigation of the Deepwater Horizon Oil Spill in the Gulf of Mexico continues to be highly active. In the past year, assessments of impacts to marine mammals from the spill were made by collecting and managing a broad variety of data for NRDA studies involving both field research and sample collection from stranded marine mammals. In addition, a marine mammal Unusual Mortality Event in the Northern Gulf of Mexico was declared in 2010 due to elevated stranding rates in Mississippi and Louisiana. This event has proven to be of unprecedented scope and complexity. In addition to directly supporting current studies, my work validating the historical stranding data is providing a better baseline for cetacean stranding rates throughout the region.

The SEFSC Marine Mammal program was also supported by participation in two research cruises: a summer stock assessment cruise of the Southeast Atlantic coast and during a study focused on understanding pilot whale (*Globicephala* sp) habitats and spatial distribution in the mid-Atlantic during October and November. The completion of these studies is fundamental to the SEFSC Protected Resources and Biodiversity Division’s mission to improve management and conservation of protected species.



Specific Accomplishments:

- Audited and validated historical stranding data from 1999.
- Responded to cetacean strandings across the SER (Southeast Region); and assisted during necropsies at the SEFSC.
- Completed numerous assignments in the Gulf States (LA, MS and FL), visiting different stranding agencies where samples for over 600 stranded cetaceans were inventoried and distributed to the analysis laboratories.
- Conducted field work and data management for cetacean samples from the Gulf of Mexico, including a dolphin health assessment study and sample tracking for over 2000 biopsy samples under Chain of Custody procedures.
- Supported field work and data management onboard the NOAA Ship Gordon Gunter during deployments along the US Atlantic coast, totaling nearly 80 sea-days.
- Completed different assignments in support of the investigation of the Unusual Mortality Event (UME) in the Northern Gulf of Mexico, including participation in a neonate necropsy session, data validation and stranding photographs management.
- Attended the 19th Biennial Conference on the Biology of Marine Mammals.

Completed trainings required for different projects in the Gulf of Mexico (DOT/IATA hazmat training, HAZWOPER training).

Research Performance Measures: all objectives were completed on time.

Assessing the Locations and Status of Reef Fish Spawning Aggregations in the Florida Keys

Project Personnel: A. Gleason (UM/CIMAS)
Other Collaborator: G. T. Kellison (NOAA/Beaufort, NC Laboratory)

Long Term Research Objectives and Strategy to Achieve Them:

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

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

CIMAS Research Theme:

***Theme 7*:** Protection and Restoration of Resources

Link to NOAA Strategic Goals:

***Goal 3*:** Healthy Oceans - *Marine fisheries, habitats, and biodiversity sustained within healthy and productive ecosystems*

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

Research Summary:

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

Understanding the relationship between seabed habitat and spawning aggregations is important for the management of fish populations. One example is the design of marine protected area networks. In 1998 a large (~100 individuals) black grouper (*Mycteroperca bonaci*) aggregation was observed less than 100 m outside the Carysfort Sanctuary Preservation Area (SPA) within the Florida Keys National Marine Sanctuary (FKNMS). In 2003 this site was mapped with a single-beam acoustic seabed classification system and the site of the aggregation was observed to fall on the steep slope of the first Carysfort outlier reef, inshore of the deeper outliers. In 2007 four other sites of known historical FSAs in the upper Keys were mapped with the same acoustic system, all of which were found to also be associated with outlier reefs. In 2010 4 FSA sites in the lower Florida Keys were mapped with the same acoustic system. These results, along with those for the areas previously mapped in the upper Keys, were shared with NOAA and Florida Fish and Wildlife Conservation Commission (FWC) partners who used additional hydroacoustic surveys and diver observations to assess the current state of these aggregations.

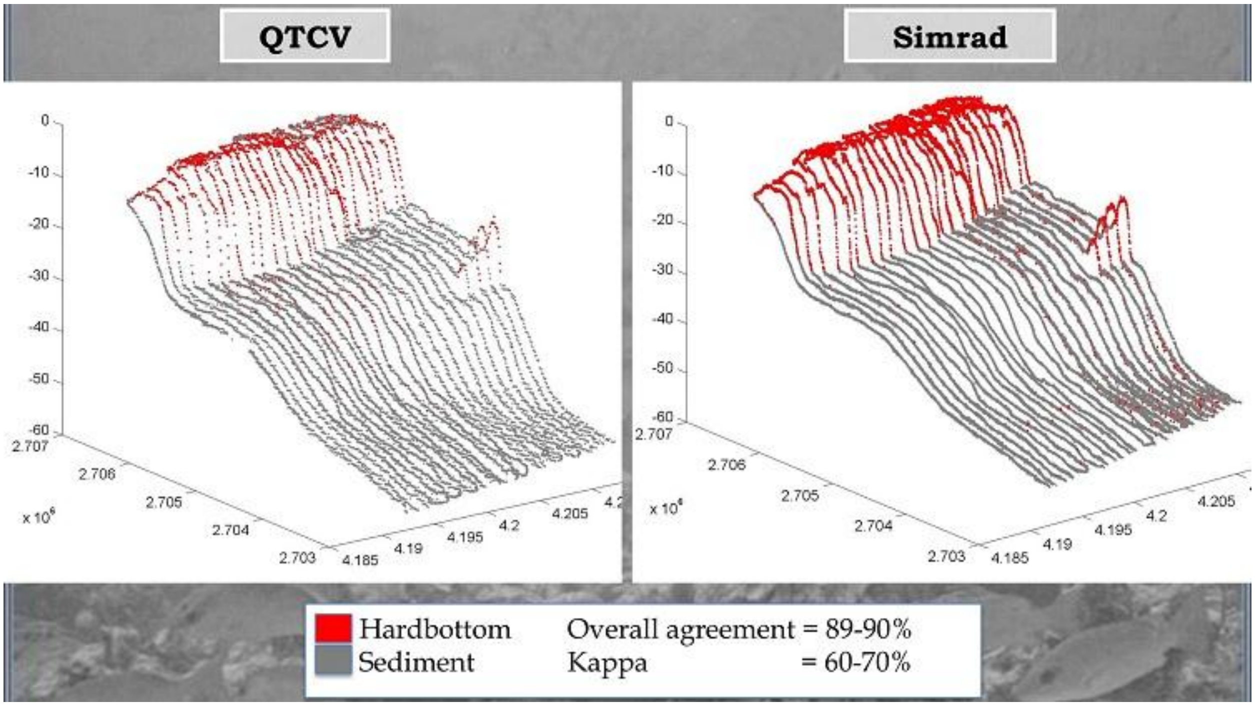


Figure 1: Consistent seabed classes from different systems. One problem with the use of acoustic tools for habitat assessment is the difficulty of generating consistent seabed classes using different equipment. This figure shows the seabed classes for an area near Sand Key, off Key West, derived from a 50 kHz QTC-V system (left) and a 138 kHz SIMRAD system (right) after post-processing using techniques developed in this project. The overall agreement between the two datasets is about 90%. Most of the differences are in shallow water, suggesting that at depths greater than about 10 m multiple systems could be used to increase mapping efficiency.

Loose aggregations of mutton and cubera snapper and several non-snapper-grouper species were observed in the upper Keys on predicted summer spawning moons. These observations suggest that spawning still occurs at these sites, all of which are near but outside of areas closed to fishing (SPAs) and all of which were being fished by commercial and recreational fishers (multiple boats on-site). In the lower Keys, aggregations of 100s of gray and mahogany snapper were documented at the mapped historical sites.

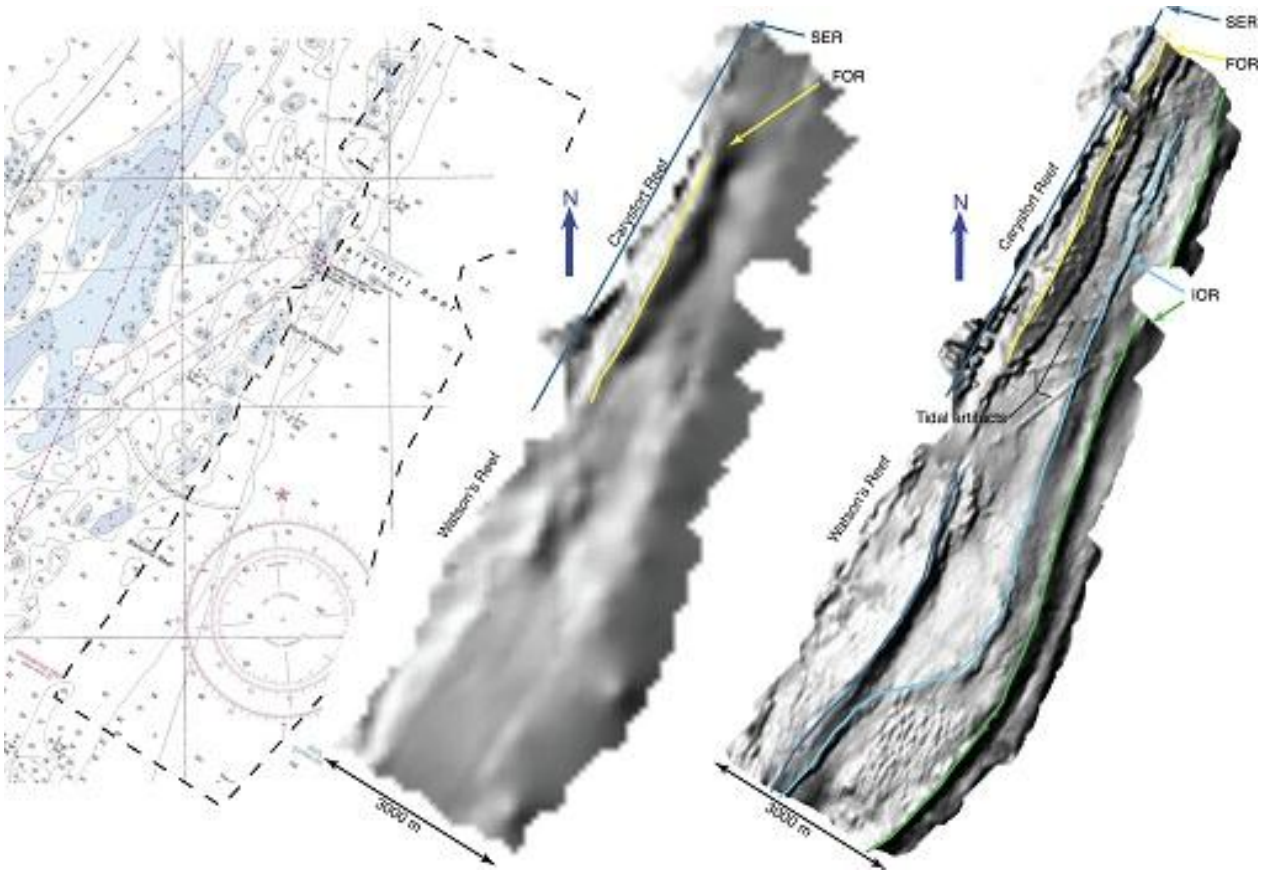


Figure 2: Improved bathymetry available from local acoustic surveys. Left: A portion of NOAA nautical chart 11462 showing the area near Carysfort Reef, in the FL Keys. The area shown in the center and right plots is outlined by a dashed line. Center: Sunshaded relief map of the best available digital bathymetry for the area, provided by the National Geophysical Data Center. Right: Sunshaded relief map produced from single-beam acoustic data acquired in this project. Note the increase in detail available in the right image relative to the NGDC data even though the grid cell size is the same in both datasets (30m).

Research Performance Measure: All planned mapping activities in the lower Keys were accomplished. A total of 344.8 miles of transects have been covered at three separate locations near Key West and a total of 79.6 miles of transects have been covered in the middle Keys, near Big Pine Key. Analysis to determine if the geomorphological and habitat "signatures" of FSA sites in the lower Keys are consistent with those from the upper Keys is still underway and will continue in FY12.

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.

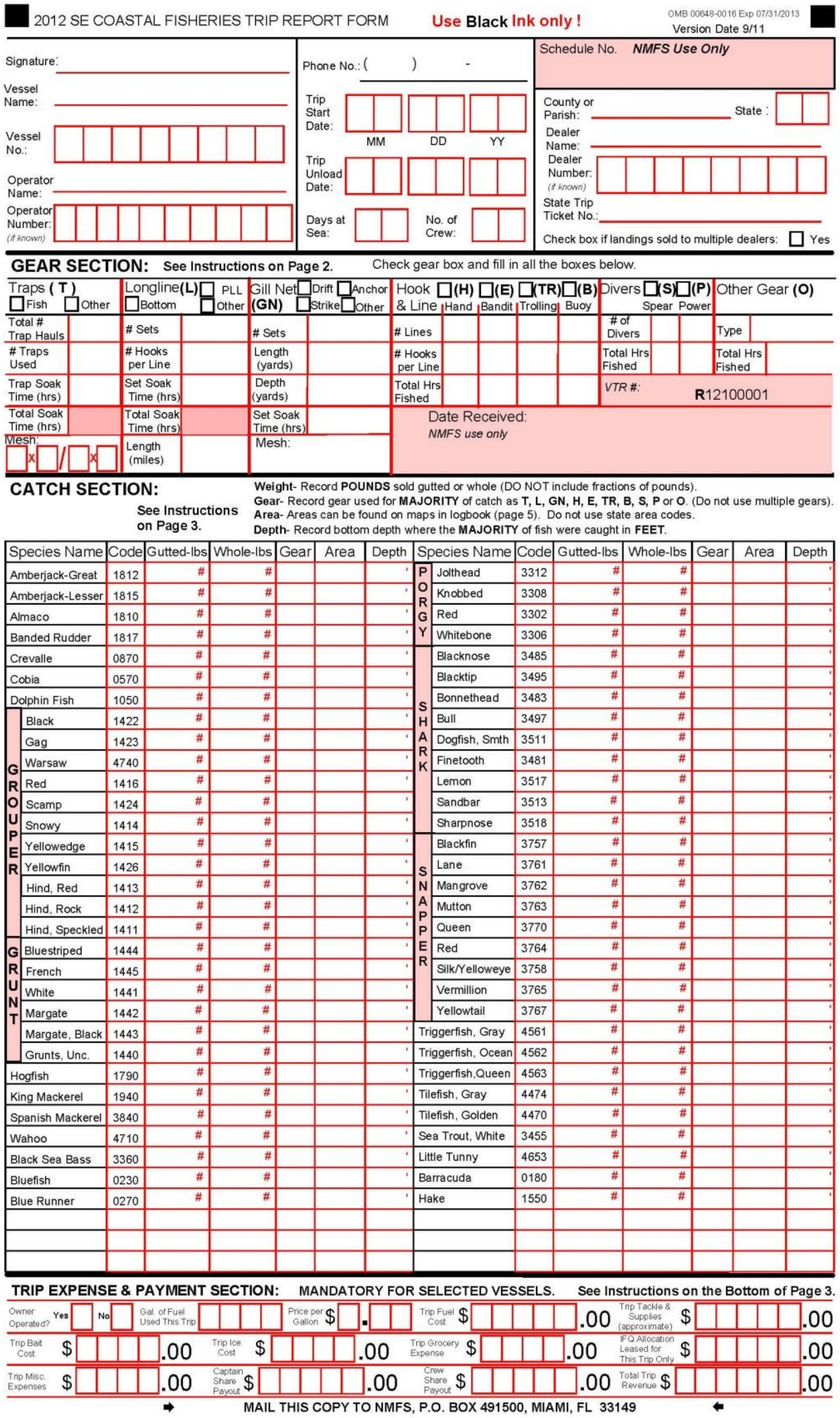
CIMAS Research Theme:
***Theme 7*:** Protection and Restoration of Resources

Link to NOAA Strategic Goals:
***Goal 3*:** Healthy Oceans - *Marine fisheries, habitats, and biodiversity sustained within healthy and productive ecosystems*

NOAA 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 22 years, fishers in the SA and GOM who possess federal commercial fishing permits (SA Snapper-Grouper, GOM Reeffish, King Mackerel, Spanish Mackerel, Shark, & Atlantic Dolphin/Wahoo) have been required to submit a trip report form which primarily aims to collect landings and fishing effort data. Data collected is therefore used for fisher permit compliance. Data is also used in conjunction with other fisheries-dependent, and independent, data sets for stock assessments and fisheries management decisions. A recent stock assessment of Spanish mackerel and cobia utilized indices of abundance created from logbook data.

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



2012 SE COASTAL FISHERIES TRIP REPORT FORM — **Use Black Ink only !** — OMB 00648-0016 Exp 07/31/2013 — Version Date 9/11

Signature: ____ Phone No.: ( ) - Schedule No. *NMFS Use Only*

Vessel Name: ____ Trip Start Date: MM DD YY County or Parish: ____ State:

Vessel No.: Trip Unload Date: Dealer Name: ____ Dealer Number: (if known)

Operator Name: ____ State Trip Ticket No.: ____

Operator Number: (if known) Days at Sea: No. of Crew: Check box if landings sold to multiple dealers: ☐ Yes

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

Traps (T) ☐Fish ☐Other		Longline(L)☐ PLL ☐Bottom ☐Other		Gill Net ☐Drift ☐Anchor (GN) ☐Strike ☐Other		Hook ☐(H) ☐(E) ☐(TR) ☐(B) & Line Hand Bandit Trolling Buoy		Divers ☐(S) ☐(P) Spear Power		Other Gear (O)	
Total # Trap Hauls		# Sets		# Sets		# Lines		# of Divers		Type	
# Traps Used		# Hooks per Line		Length (yards)		# Hooks per Line		Total Hrs Fished		Total Hrs Fished	
Trap Soak Time (hrs)		Set Soak Time (hrs)		Depth (yards)		Total Hrs Fished		VTR #: R12100001			
Total Soak Time (hrs)		Total Soak Time (hrs)		Set Soak Time (hrs)		Date Received: *NMFS use only*					
Mesh: x / x		Length (miles)		Mesh:							

CATCH SECTION: See Instructions on Page 3.

Weight- Record **POUNDS** sold gutted or whole (DO NOT include fractions of pounds).
Gear- Record gear used for **MAJORITY** of catch as **T, L, GN, H, E, TR, B, 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	#	#				SHARK	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	$ .00
Trip Tackle & Supplies (approximate)	$ .00	Trip Bait Cost	$ .00	Trip Ice Cost	$ .00	Trip Grocery Expense	$ .00
IFQ Allocation Leased for This Trip Only	$ .00	Trip Misc. Expenses	$ .00	Captain Share Payout	$ .00	Crew Share Payout	$ .00
Total Trip Revenue	$ .00						

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

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

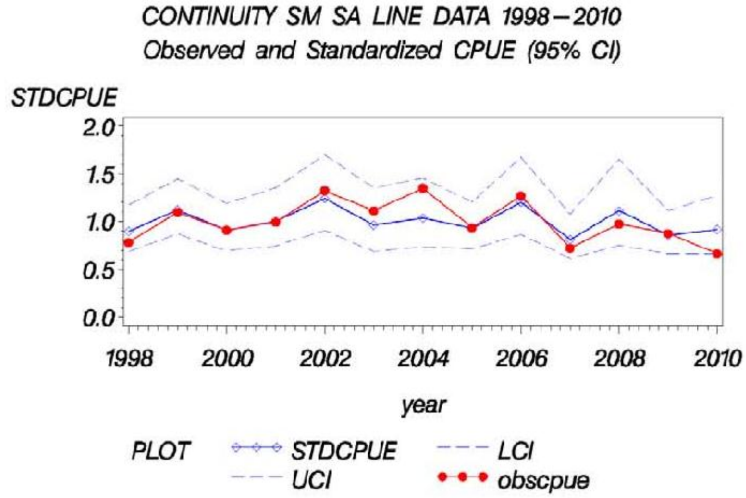


Figure 2. Spanish mackerel (1998-2010) nominal CPUE (solid circles), standardized CPUE (open diamonds) and upper and lower 95% confidence limits of the standardized CPUE estimates (dashed lines) for commercial vessels fishing vertical line gear in the South Atlantic.

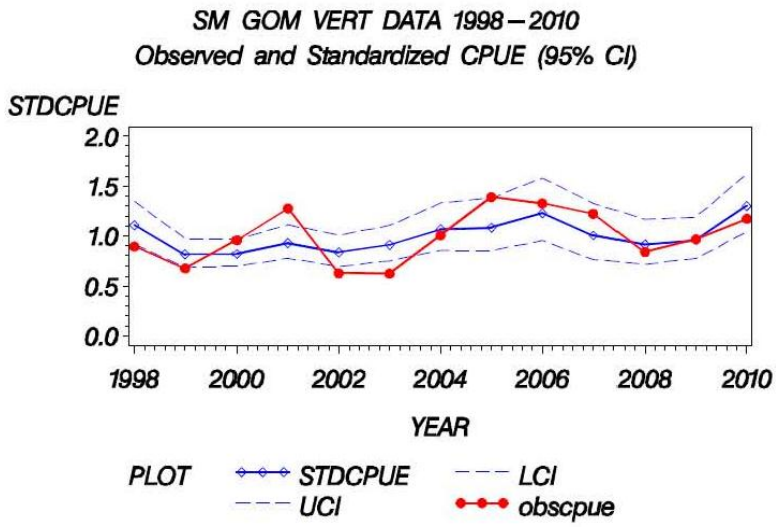


Figure 3. Spanish mackerel (1998-2010) nominal CPUE (solid circles), standardized CPUE (open diamonds) and upper and lower 95% confidence limits of the standardized CPUE estimates (dashed lines) for commercial vessels fishing vertical line gear in the Gulf of Mexico.

Figures 2 and 3: Recent SEDAR28 (SouthEast Data, Assessment, and Review) assessments of mackerel utilized indices of abundance created using logbook data. Figures 2 and 3 shows figures of standardized indices for vertical line gear in the South Atlantic and Gulf of Mexico.

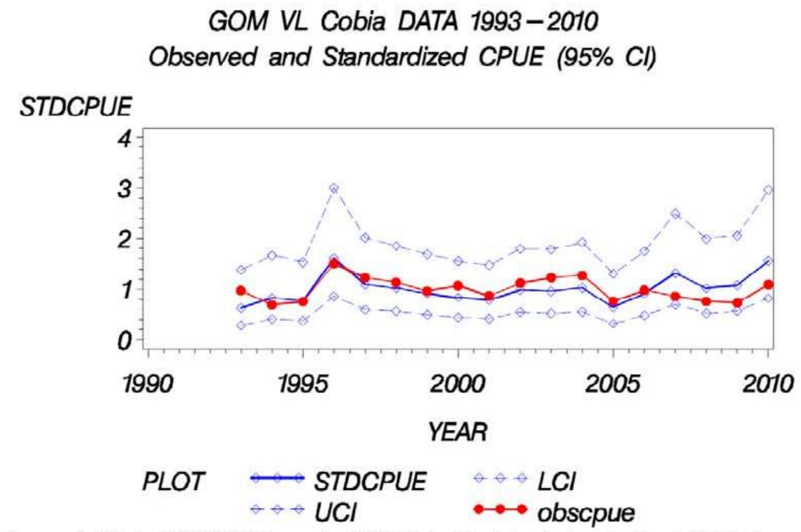


Figure 4. Cobia (1990-2010) nominal CPUE (solid circles), standardized CPUE (open diamonds) and upper and lower 95% confidence limits of the standardized CPUE estimates (dashed lines) for commercial vessels fishing vertical line gear in the Gulf of Mexico.

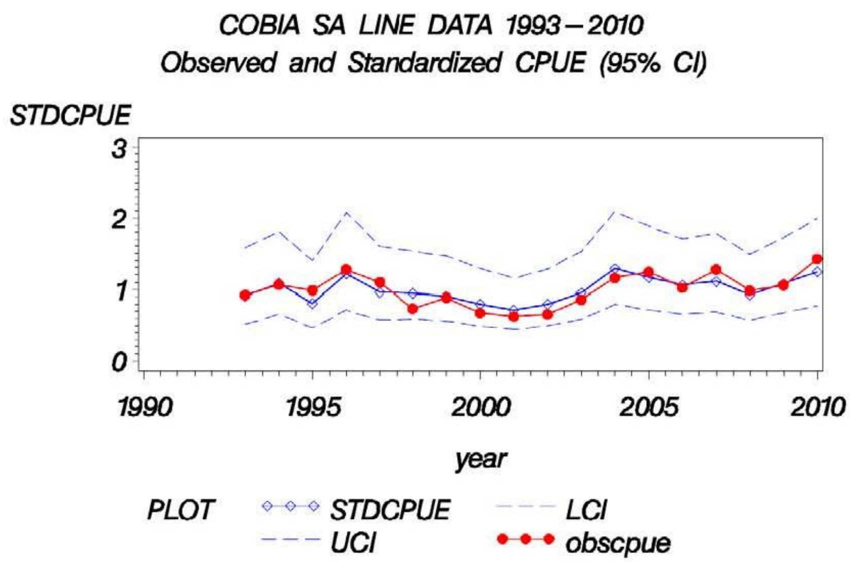


Figure 5. Cobia (1990-2010) nominal CPUE (solid circles), standardized CPUE (open diamonds) and upper and lower 95% confidence limits of the standardized CPUE estimates (dashed lines) for commercial vessels fishing vertical line gear in the South Atlantic.

Figures 4 and 5: Recent SEDAR28 (SouthEast Data, Assessment, and Review) assessments of Cobia utilized indices of abundance created using logbook data. Figures 4 and 5 show figures of standardized indices for vertical line gear in the South Atlantic and Gulf of Mexico.

Natural Resource Damage Assessment (NRDA) of Plankton in Response to the Deepwater Horizon (DWH) Oil Spill

Project Personnel: S. Privoznik, A. Ender, K. Griffith and M. Straney (UM/CIMAS)
NOAA Collaborators: J. Lamkin and T. Gerard (NOAA/SEFSC)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** To identify the nature and extent of resource injuries resulting from the Deepwater Horizon Oil Spill and the amount and type of restoration required to restore those resources to baseline conditions.

Strategy*:* Analyze plankton samples collected within a specific area of interest in the Gulf of Mexico to compare and contrast with previously collected historical plankton collections in the Gulf of Mexico.

CIMAS Research Theme:

***Theme 7*:** Protection and Restoration of Resources

Link to NOAA Strategic Goals:

***Goal 3*:** Healthy Oceans - *Marine fisheries, habitats, and biodiversity sustained within healthy and productive ecosystems*

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

Research Summary:

The Early Life History Lab at SEFSC in Miami, FL, is one of the five institutions (federal and academic) tasked with processing plankton samples collected during the response effort to the Deep Water Horizon (DWH) incident in 2010 and subsequent sampling that took place in 2011. Plankton was collected using multiple nets (neuston , MOCNESS, manta, and bongo) and is processed following a standardized protocol that falls within the Natural Resource Damage Assessment DWH area of interest. Our unit will process samples by measuring displacement volume, removing ichthyoplankton, zooplankton and fish eggs. In addition, a digital image of each sample will be captured to provide a record of zooplankton and fish collections. Our partner institutions will carry out the successive identification of ichthyoplankton and zooplankton. The data generated from this research will serve as the basis for the legal process to determine the type and amount of restoration needed to compensate the public for harm to natural resources and their human uses that occur as a result of the DWH oil spill.

Research Performance Measure: The research program is on schedule. To date, we have completed training of new personnel and implementation of standardized protocols for sample processing to meet NRDA guidelines. In addition, we have completed processing more than 25% of the plankton samples that were assigned to our laboratory in only three months. Plankton processing is ongoing and will soon incorporate digitizing zooplankton images with a ZooScan. Preliminary data has been submitted to a comprehensive database which houses data from all institutions involved. Overall assessments are beginning to be conducted in conjunction with our partners.

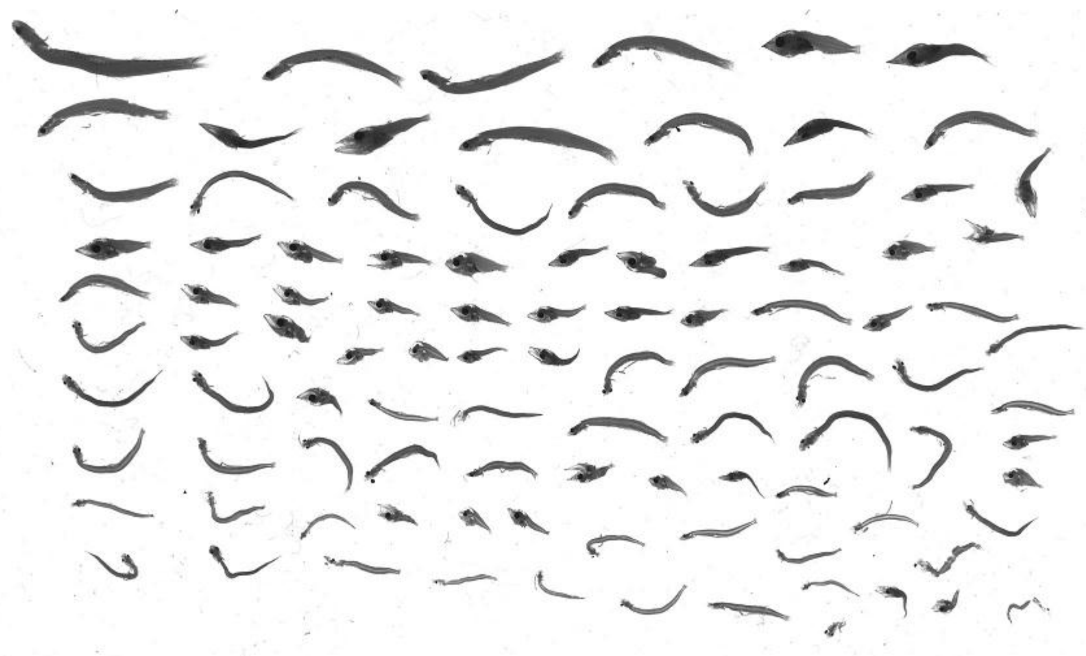


Figure 1: Scanned image of ichthyoplankton removed from Natural Resource Damage Assessment (NRDA) plankton samples collected in the Gulf of Mexico during the 2010-2011 response to the Deep Water Horizon (DWH) oil spill.

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Biscayne Bay's Nearshore Submerged Aquatic Vegetation (SAV)

Project Personnel: D. Lirman (UM/RSMAS)
NOAA Collaborator: J. Serafy (NOAA/SEFCS)
Other Collaborator: 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 as well water quality information.

CIMAS Research Theme:
***Theme 7*:** Protection and Restoration of Resources

Link to NOAA Strategic Goals:
***Goal 3*:** Healthy Oceans - *Marine fisheries, habitats, and biodiversity sustained within healthy and productive ecosystems*

NOAA 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 co-developed by PIs Lirman (UM) and DeAngelo (NOAA/NGS) 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 habitat suitability and forecasting tools within an adaptive management framework.

Since 2008, we have collected data on the seasonal abundance and distribution of SAV communities in > 3000 sites in central and southern Biscayne Bay. These surveys have revealed that the abundance and distribution of seagrasses are tightly linked to salinity and nutrient availability. Near-shore habitats with low and variable salinity and high nutrient availability are dominated by the manatee seagrass *Halodule wrightii*, a pioneer species with a wide tolerance for salinity fluctuations and high growth under high-nutrient conditions, while habitats with more constant and higher salinity are dominated by the turtle seagrass *Thalassia testudinum*, a climax 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 (CERP) proceed. During 2011-2012, the information collected since 2008 was incorporated into Habitat Suitability (HS) models that define the extent of suitable habitat for each species of seagrass under present and future restoration scenarios.

When a CERP restoration scenario of reduced salinity was simulated, both *Halodule* and *Thalassia* had an overall positive response to increases in freshwater deliveries. For the whole region, the amount of suitable habitat increased 71% for *Halodule* compared to only 18% for *Thalassia*. Based on the spatial distribution of these changes it appears that *Halodule* benefits greatly by the reduction in salinity in areas where it is presently virtually excluded by the high mean salinity and lack of freshwater inflow. In contrast, decreased salinity in the same area reduced the niche value for *Thalassia*. The biggest gain in habitat availability for *Thalassia* under a decreased salinity scenario is in habitats where episodic hypersalinity (> 37 ppt) may play a role in limiting the distribution of *Thalassia* presently. Based on the results of the HS simulation, it can be concluded that one of the key goals of the Everglades restoration plan to increase the abundance of *Halodule* and reduce the dominance of *Thalassia* would be achieved by increasing the flow of fresh water (and decreasing salinity) into western Biscayne Bay.

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.

Dispersal, Habitat Use and Behavior of Neonate Sea Turtles in the Gulf of Mexico and Waters Impacted by the Deep Water Horizon MSC 252 Oil Spill

Project Personnel: K.L. Mansfield (FIU)
NOAA Collaborator: S. Epperly (NOAA/NMFS/SEFSC)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** to integrate empirical (satellite telemetry) and theoretical (simulations of sea turtle dispersal in ocean circulation models) techniques to quantify the distribution of young sea turtles in the Gulf of Mexico; and to provide information to better evaluate the impacts of and guide restoration activities associated with the *MCS 252* oil spill.

Strategy*:* to accomplish these objectives, our strategy includes identifying dispersal corridors of post hatchling Kemp's ridleys between different nesting beaches and developmental habitats; identifying the distribution of different Kemp's ridley hatchling cohorts from rookeries in the Gulf, particularly those cohorts most likely impacted by the *MCS 252* spill; determining the movements, fine-scale habitat characteristics and selection, and delineation of nursery areas associated with oceanic neonate turtles in the Gulf of Mexico as derived from satellite telemetry; identifying how neonate turtle distributions correlate with past (and, if applicable, present) oil-impacted areas associated with the *MCS 252* spill.

CIMAS Research Theme:

***Theme 7*:** Protection and Restoration of Resources

Link to NOAA Strategic Goals:

***Goal 3*:** Healthy Oceans - *Marine fisheries, habitats, and biodiversity sustained within healthy and productive ecosystems*

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

Research Summary:

Juvenile oceanic developmental and foraging habitats are not defined for any sea turtle species. As obligate air-breathers and relatively weak swimmers, the distribution of young, oceanic or pelagic stage juveniles is likely strongly constrained by surface currents. This leads to young turtles associating with flotsam and *Sargassum* found in small-scale downwelling zones that entrain passive or weakly swimming animals. Flotsam and *Sargassum* within these zones may also be actively sought by young turtles, as they provide refugia from predation and may concentrate turtles' prey items; however, they may also concentrate oil and other pollutants that are ingested by small turtles. Thus, young turtles may experience extended effects of oil exposure or habitat degradation.

Oceanic stage Kemp's ridley (*Lepidochelys kempii*) sea turtles were observed within oiled regions of the Gulf of Mexico in 2010. This size-range of turtle (typically <25 cm carapace length) is too small to be detected by aerial surveys. The greatest obstacle to recovery efforts and mitigating the impacts of the oil spill for sea turtles is the paucity of data regarding their oceanic stage distribution and habitat use in the Gulf. The immediate and ongoing impacts of the *MCS 252* spill is most difficult to quantify for post-hatchling, oceanic and transitioning neritic stage Kemp's ridleys. This species of sea turtle originates from nesting beaches located within the western Gulf of Mexico the majority spend their developmental oceanic years within Gulf waters.

Following methods by Mansfield *et al.* (2012), we are using solar-powered satellite transmitters to remotely track oceanic stage sea turtles captured in the Gulf of Mexico. Argos-derived and satellite imagery data, allows us to characterize fine-scale habitat selection, oceanographic conditions/features, and oiled areas encountered by the turtles. This is a two-year project with field sampling occurring late summer 2011, and spring-fall 2012.

Figure 1: Oceanic stage Kemp's ridley sea turtle outfitted with small, solar-powered satellite tag. Photo by K. Mansfield (2011).

Research Performance Measure: Due to extensive spring flooding in 2011, the resulting Mississippi river runoff, *Sargassum* habitat (primary habitat for oceanic Kemp's ridleys) was not easily accessible within our sampling locations and the *Sargassum* we encountered was sparse. As such, sampling is continuing in the spring through fall of 2012; however this is a multi-year project and we are on schedule in accordance with our project timetable. We initiated ocean circulation simulations of passive particles and began analyses to characterize the movements and habitat use of Kemp's ridleys in the Gulf of Mexico. We also initiated dispersal simulations of hatchling cohorts from primary Kemp's ridley nesting beaches in the western Gulf of Mexico. A scientific manuscript related to Kemp's ridley hatchling dispersal is in preparation.

Neonate Loggerhead Dispersal, Behavior and Survivorship in the Western North Atlantic

Project Personnel: K.L. Mansfield (FIU)
NOAA Collaborator: S. Epperly (NOAA/NMFS SEFSC)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** to use novel satellite tracking methods to provide improved estimation of threats at foraging areas and along migration routes for oceanic stage sea turtles in the Northeast Distant Region of the Atlantic Ocean (NED); to characterize the in-water habitats used by small, oceanic stage loggerheads (*Caretta caretta*) so that we better understand the features that likely define their nursery habitats and the potential risks and hazards to the smallest life stages of sea turtle.

***Strategy*:** to accomplish these objectives, our strategy includes collaborating with cooperative fishermen in the NED to capture and satellite tag small (<30 cm length) loggerhead sea turtles. Using novel satellite telemetry techniques, we are identifying the fine-scale habitat selection, movements, and dispersal of small oceanic loggerheads in the NED.

CIMAS Research Theme:

***Theme 7*:** Protection and Restoration of Resources

Link to NOAA Strategic Goals:

***Goal 3*:** Healthy Oceans - *Marine fisheries, habitats, and biodiversity sustained within healthy and productive ecosystems*

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

Research Summary:

Juvenile oceanic developmental and foraging habitats and behavior are not defined for any sea turtle species. To meet recovery goals, the status and condition of existing sea turtle stocks must be fully understood across all life history stages (TEWG 2000; Heppell et al. 2005). Understanding the survival of oceanic stage turtles is one of the most important parameters needed for sea turtle population assessments (SEFSC 2009). Following methods by Mansfield *et al.* (2012), we are using solar-powered satellite transmitters to remotely track oceanic stage sea turtles captured in the Gulf of Mexico. Argos-derived and satellite imagery data, allows us to characterize fine-scale habitat selection, oceanographic conditions/features, and oiled areas encountered by the turtles.

Our data are being used to determine locations of management concern (i.e. small and large scale areas where numerous young turtles are likely to be exposed to harmful anthropogenic interactions) and are bridging gaps in our understanding of early sea turtle life history.

Research Performance Measure: Fall 2011 field sampling resulted in the first wild-caught oceanic stage loggerhead >15 cm in length to be successfully satellite tagged and tracked. This is a continuing project; we are progressing to meet all major project objectives.

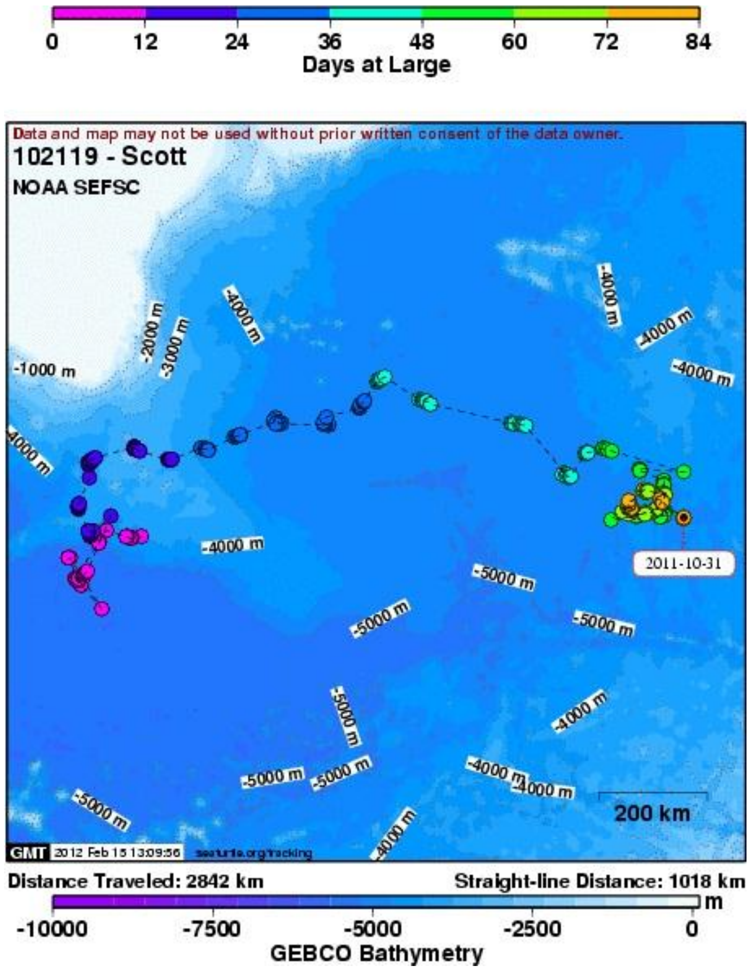

Figure 1: Satellite tracks of an oceanic juvenile loggerhead sea turtle captured in the North Atlantic Ocean, 2011. Map generated by seaturtle.org's Satellite Tracking and Analysis Tool.

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Coral Ecological Restoration

Project Personnel: D.E. Williams, C. Cameron, A. Bright, L. Johnston, and C. Kiel (UM/CIMAS); K .Lohr (UM/RSMAS)
NOAA Collaborator: 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.

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 3**:** Healthy Oceans - *Marine fisheries, habitats, and biodiversity sustained within healthy and productive ecosystems*

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

Research Summary:
During the research year (2011/2012) we conducted preliminary surveys to compare prevalence of disease and predation in outplanted (restored) vs. 'wild' populations of ESA listed Acropora cervicornis (staghorn coral). When disease was encountered, we also began experiments to test low-tech disease mitigation treatments (e.g. epoxy band applied over tissue disease line and excising healthy-looking branches from diseased colonies). These studies are ongoing in 2012 and will be reported later. Second, in our ongoing research efforts to address recruitment failure by reef-building coral species in the Florida Keys, we implemented new experiments on snail grazing to enhance survivorship of cultured coral larval settlers. Grazing by herbivorous fishes and urchins has been long noted to enhance coral recruitment by reducing competition from seaweeds. However, grazing on substrates with earliest stage coral settlers by these large grazers no doubt also involves incidental consumption as the spat are microscopically small. Work in Japan has suggested that survival of cultured *Acropora* spp. settlers is greatly enhanced in co-culture with *Trochus* (grazing snails) and aquarists' common knowledge indicates that snails are important to keeping clean tanks. Hence, we sought to 1) determine what grazing snails were available in appropriate habitats in the upper Keys; 2) develop methods to enhance snail grazing on spawned coral settlers in the field; and 3) test if snail grazing improved early stage survivorship of coral settlers.

We determined that *Cerrithium litteratum*, across a range of sizes, require caging with the coral substrates to maintain high grazing levels over time scale of weeks to months. We conducted field experiments with *Montastraea faveolata* and *Diploria strigosa* spat (which we settled in the lab) by placing them in cages with snails at Sand Island reef in Key Largo (Fig 1A). Cages were visited and cleaned ~ once per week and survivorship was scored after ~ 4 weeks. We determined that snails significantly enhanced early post-settlement survivorship for both spp. We also observed that another larger grazing snail species (*Lithopoma tecta*) was more likely to impose incidental damage to the spat. We hope to repeat these experiments over longer periods of time and, especially with faster-growing *Acropora* spp. larvae.

Research Performance Measure: Lack of spawning by focal elkhorn coral in 2011 was a significant hindrance in that it precluded planned experiments with this species' larvae. However, we were able to implement larval survivorship experiments with two other species (*M.faveolata* and *D.strigosa*). The planned experiments are re-slated for August 2012. Planned disease surveillance and mitigation studies were executed according to plan and will continue through 2012.

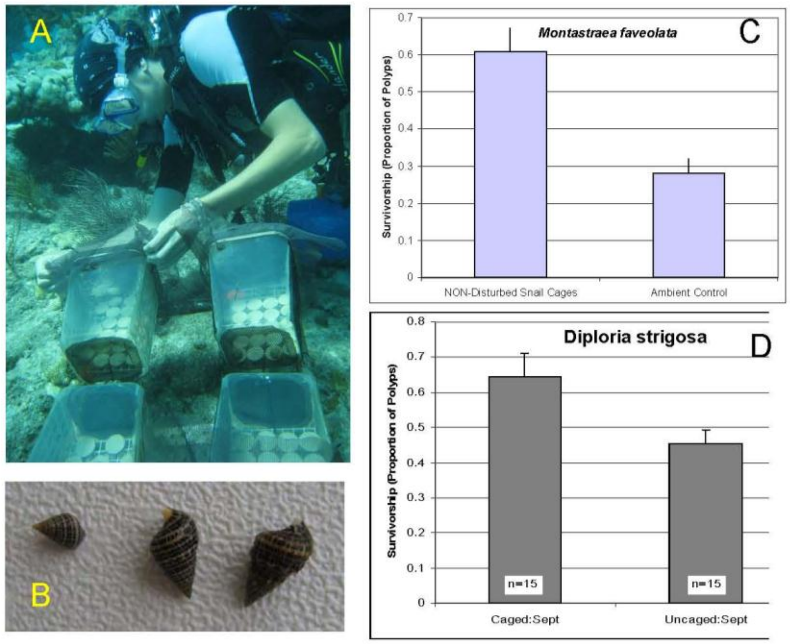

Figure 1: Recently settled coral spat were placed in cages on the reef (A) with grazing snails, *Cerrithium litteratum* (B). Survivorship of recent larval settlers of *Montastraea faveolata* (C) and *Diploria strigosa* (D) are significantly enhanced by intensive snail grazing that limits development of competing organisms on the substrate.

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Marine Mammal Research

Project Personnel: J. Wicker (UM/CIMAS)
NOAA Collaborator: L. Garrison, A. Martinez and J. Contillo (NOAA/SEFSC)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** To assist the SEFSC's Protected Resources and Biodiversity program in management and conservation of protected species during data collection and management within the Marine Mammal Program.

***Strategy*:** 1) To perform field work and data management during studies of marine mammals in the Gulf of Mexico and the US Southeast Atlantic. 2) To lead large and small vessel studies to collect samples and data used to assess the abundance, habitats, and spatial distribution of cetaceans within U.S. waters. 3) To support the Southeast Gulf of Mexico Sperm Whale Study collecting biopsy samples, photographic data, acoustic data and deploying satellite tags on Sperm and Bryde's whales. 4) To assist on the Biscayne Bay's bottlenose dolphin population long term study of photo identification.

CIMAS Research Theme:
***Theme 7*:** Protection and Restoration of Resources (*Primary*)
***Theme 3*:** Regional Coastal Ecosystem Processes (*Secondary*)

Link to NOAA Strategic Goals:
***Goal 3*:** Healthy Oceans - *Marine fisheries, habitats, and biodiversity sustained within healthy and productive ecosystems*

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

Research Summary:
The Southeast Fisheries Science Center Marine Mammal Program is responsible for assessing the populations of marine mammals in the southeastern United States waters including the Atlantic and the Gulf of Mexico. During this year, I have served as the Field Party Chief during two large vessel research cruises occurring in Atlantic waters along the US Southeast and mid-Atlantic coast. During these studies, over 600 marine mammal sightings were made, 82 biopsy samples were collected, and 7,000 (km) of visual effort were completed. Specifically, during an Atlantic Pilot Whale Survey occurring during October and November 2011, biopsy samples, photographic data, and acoustic data were collected to evaluate the distribution of short-finned and long-finned pilot whales along the mid-Atlantic coast. These data will be used to evaluate the impact of bycatch mortality in commercial longline fisheries on these protected species.

Research Performance Measure: All objectives were completed on time.
- Conducted Pre and Post cruise planning and supported the development of procedures and protocols for marine mammal research cruises with a focus on passive acoustic and photographic data collection and management.
- Served as field party chief onboard NOAA Research vessels during the marine mammal summer and fall cruises during 2011.
- Assisted in the development of cruise plans and lead survey teams while in the field.
- Maintained and verified data quality, interacting with principal investigators to effectively execute scientific methodology during the cruises.

- Managed and Updated the Biscayne Bay Photo ID Database and Continued to import historical data into FinBase database
- Supported field work and data management onboard the NOAA Ship Gordon Gunter during deployments along the US Atlantic coast and Gulf of Mexico
- Attended the 19th Biennial Conference on the Biology of Marine Mammals.

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Evaluation of ESA-listed Acropora spp. Status and Actions for Management and Recovery

Project Personnel: D.E. Williams, A.J. Bright, C. Cameron (UM/CIMAS)
NOAA Collaborator: M.W. Miller (NOAA/SEFSC)

Long Term Research Objectives and Strategy to Achieve Them:
***Objectives*:** 1) To document the threats (disease, predation etc.) impacting the remaining elkhorn (*Acropora palmata)* populations in the upper Florida Keys and determine the relative importance of each 'threat'. 2) To document and identify demographic variables (recruitment, mortality etc.) in the Florida Keys *Acropora* spp. population. 3) To continue annual assessment of *Acropora palmata* in Curaçao for comparison to local populations. 4) To assess the effectiveness of predator removal as a management tool.
***Strategy*:** 1) To assess on a quarterly basis the status of individually-tagged colonies of coral at several sites in the upper Florida Keys. 2) Periodic assessments of other Caribbean *Acropora* spp. populations. 3) Remove snail predators and document the re-colonization rates.

CIMAS Research Theme:
***Theme 7*:** Protection and Restoration of Resources

Link to NOAA Strategic Goals:
***Goal 3*:** Healthy Oceans - *Marine fisheries, habitats, and biodiversity sustained within healthy and productive ecosystems*

NOAA Funding Unit: NMFS/CRCP **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 has designated critical habitat and is developing a recovery plan based on the current status and threats to these corals. Data collected for this project directly supported NMFS in this process.

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). Data from the Florida Keys population indicates that the population has not shown significant signs of recovery from the 2005 hurricanes because the population continues to suffer losses from disease and predation and recruitment is inadequate to compensate for mortality. *Acropora palmata* in Curacao suffered similar losses (~50%) due to Hurricane Omar in 2008 and to date has shown slow recovery trends similar to that observed in Florida.

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 predatory snail *Coralliophila abbreviata*. In 2011 we began an experiment to assess the effectiveness of removal of the predatory snails as a management tool. At each of six monitoring sites a study plot was assigned to a snail removal treatment: 1) removal of predatory snails from *A. palmata* colonies only, 2) removal of the snails from all host corals in the plot, and 3) "Control" in which the snails were counted on the host corals in the plots, but the snails were not removed. On the short term, removal of snails by divers has had noticeable impacts on *Acropora palmata* colonies in this study. Although snails were still found in the follow-up surveys, indicating that the initial removal did not completely eradicate all snails present in the study plots, removal during the first survey did dramatically reduce snail abundance and size. Additionally, the findings thus far do not indicate lower snail recurrence on *A. palmata* when snails were removed from all hosts (Figure 1), suggesting that removal of snails from only the *A. palmata* host colonies may be equally effective at reducing predation impact while requiring less effort.

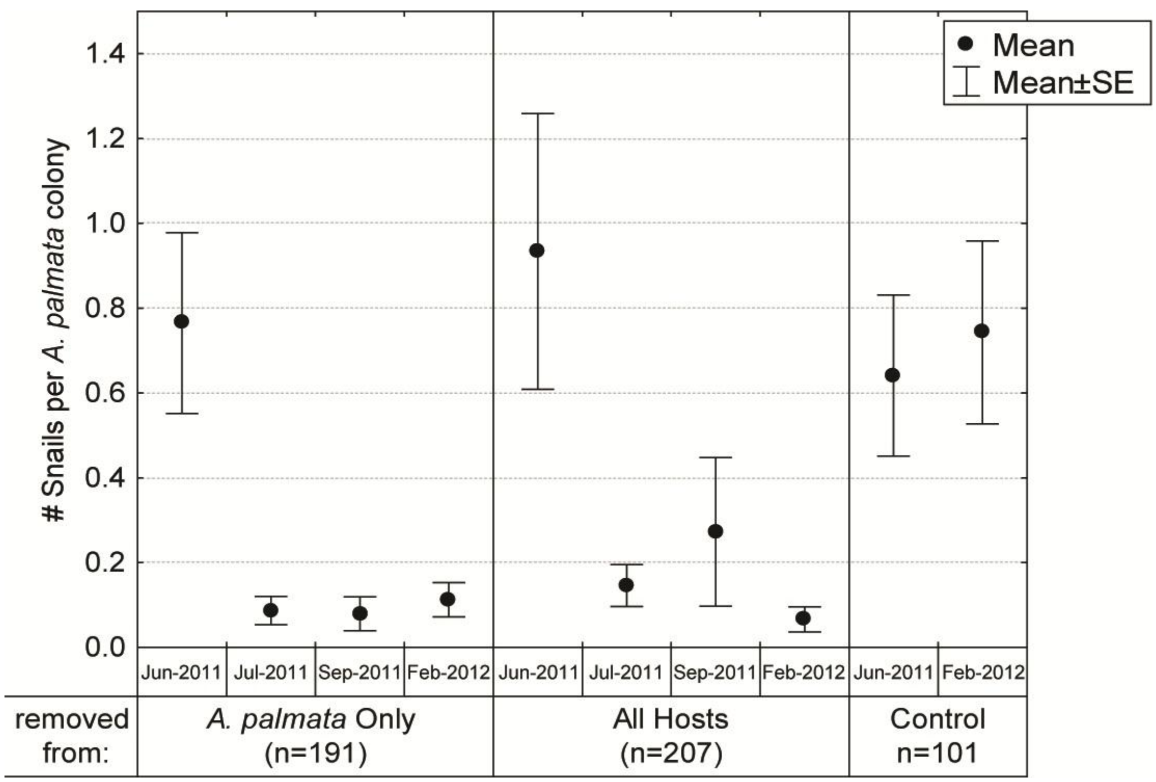

Figure 1: The mean (± standard error) number of snails found on *Acropora palmata* colonies in the predator removal treatments for four surveys and the control treatment at the first and fourth surveys. Findings indicate that removal of predators successfully reduced their numbers compared to the controls and that removal from *A. palmata* only is equally effective.

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. The predator removal experiment began in June 2011. Survey sites around Curacao were re-surveyed in May 2012. Data was used in population models by our research partner at Scripps Institute of Oceanography and a manuscript reporting on the modeling results has been submitted. A manuscript reporting on sources of mortality in *Acropora palmata* was published in April 2012 in a peer reviewed journal. Results from our monitoring in Curaçao were reported and submitted for publication in a peer reviewed journal. Observations on our predator removal experiment were reported to sanctuary managers.

COMPETITIVE PROGRAM PROJECTS

TASK IV AND TASK III COMPETITIVE PROGRAM AWARDS UNDER THE NEW COOPERATIVE INSTITUTE POLICY FOR SUCH AWARDS

The following set does not include a few multiyear projects initiated under the prior Cooperative Agreement (so-called Shadow Awards) that continued to receive NOAA funding during the present period nor NOAA competive program awards received after June 1. There are a significant number of the latter given delays in implementing the new financial administration software within NOAA during May and June. What is provided for each project in the following section is in most cases what was submitted to the program officer in the format they required of the principal investigator(s). **If a project was not yet required (too new) to submit a report no report is include herein.**

Task III awards are from NOAA Competitive Programs and Task IV awards are from other federal, state or private entities or agencies. In both cases, projects have to be consistent with a CIMAS theme and contribute to a NOAA Goal as is the case with all CIMAS research. **In neither case, is the review of these projects the responsibility of the NOAA Cooperative Institute Program Office or its delegate, rather the appropriate program officer has fulfilled that responsibility.**

Development of a Probabilistic Tropical Cyclone Genesis Prediction Scheme

Principle Investigator: Jason Dunion, University of Miami/CIMAS – NOAA/HRD

Co-PIs: John Kaplan, NOAA/HRD
Andrea Schumacher, CSU/CIRA

Co-Investigator: Joshua Cossuth, Florida State University

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

Link to NOAA Strategic Goals:
***Goal 2*:** Weather-Ready Nation - *Society is prepared for and responds to weather-related events*

Funding Source: NWS

Accomplishments:

1. Complete development of the Dvorak Database and incorporate disturbance positions, T-numbers, and CI numbers into the TCGI database

This element of the proposal effort (led by Co-I Cossuth) involved developing a database of all Dvorak analyses (including T-number, CI number, and position) that were conducted by TAFB for the Atlantic basin from 2001-2010 (Cossuth et al. 2012). Information was gathered from tropical cyclones (TCs) before genesis was achieved, invests that did not develop into TCs, and a small number of disturbances not classified as invests. Dvorak analyses were generated for these latter systems when a NHC hurricane specialist or TAFB analyst requested a center and intensity estimate, but there was not enough interest for creating an invest. In all, there were 345 unique systems during this time period, 159 of which achieved genesis and became a TC. Each system was cataloged with a unique identification, which consists of its ATCF number as well as the date and time of the initial Dvorak classification. Every entry is comprised of the date and synoptic time of Dvorak analysis, the location of the system's center, the final T-number, the CI number, and whether the system was considered tropical or sub-tropical. Due to their small sample size, sub-tropical cases were not analyzed. Further, if the disturbance did undergo genesis, the date/time/position of genesis and the TC's name is listed.

Using only the Dvorak dataset, a basic climatological genesis may be created. Figure 1 (previously illustrated in the original proposal submission) shows genesis rate of disturbances using a 2005-2010 subset of the data. There is a clear pattern of genesis likelihood scaling with the Dvorak intensity of disturbances. Systems analyzed as being more intense have a higher probability of achieving genesis. In general, tropical disturbances in a pre-genesis state have CI values less than 2.5 and can be sometimes deemed too weak to classify (TWTC). However, since forecasters were interested enough in the system to label it as an “invest”, such TWTC systems were retained and defined with a CI number of 0.5 (to differentiate them from those disturbances with stronger satellite signatures). Figure 1 indicates that Dvorak classifications (even TWTC) contain valuable information regarding future genesis probability. This figure also supports the methodology to assign TWTC systems a non-zero T-number/CI number in the TCGI database.

The now-completed 2001-2010 Atlantic Dvorak database will provide two vital components to TCGI project: 1) the positions (i.e. nearly-complete tracks) for all invests that will be analyzed in the TCGI database; 2) a potentially robust TCGI predictor (i.e. Dvorak T-numbers and/or CI numbers) that will be evaluated against other possible TCGI predictors (see Table 1).

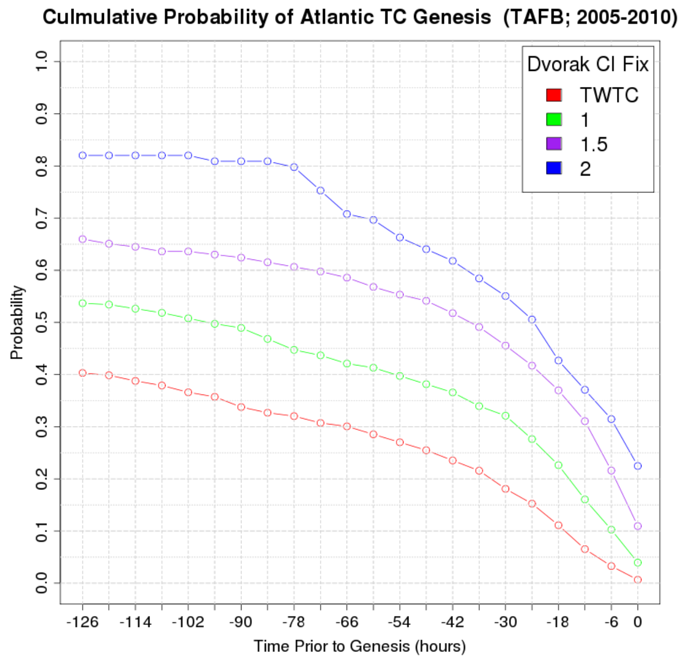

Figure 1: Climatological probabilities of genesis using only the Dvorak CI-number of a tropical disturbance from TAFB, 2005-2010 (omits sub-tropical classifications). The prediction lead-time is found on the abscissa, probability of genesis on the ordinate, and the color of the curve represents the Dvorak CI-number.

2. Complete identification/development of TCFP TCGI environmental predictors into the TCGI database

Co-PI Schumacher is leading the following elements of the proposed effort. The TCGI project requires a complete set of forecast positions out to five days for every Dvorak database disturbance at each 6-hourly synoptic time. Unfortunately, the dataset described above contains discontinuities and missing values, especially for entries in which the disturbance does not eventually form into a TC. To fill these missing forecast positions, a combination of Best Track and Dvorak positions and a BAMM type model were used.

A set of potential TC genesis predictors has been identified for use in the TCGI (Table 1). Predictors identified for testing in this new genesis scheme were chosen based on 1) their established relevance to TC formation (i.e., successful use in other genesis prediction schemes) and 2) their ability to be computed in a disturbance-centric framework. The predictors chosen include most of those used by the NESDIS Tropical Cyclone Formation Probability (TCFP) product. In addition, a few of the predictors used in the Statistical Hurricane Intensity Prediction Scheme (SHIPS) may also be important for TC genesis and have been included in the potential predictor list for the TCGI. Currently, work is underway to generate a developmental dataset of the predictors listed in Table 1 for each entry in the filled-in Dvorak dataset.

Table 1: Potential predictor list for the TCGI.

Potential Predictor	**Data**	**Source**
850-200 mb vertical shear	GFS analyses	TCFP
850-mb vorticity	GFS analyses	TCFP
MSLP	GFS analyses	TCFP
Vertical instability parameter	GFS analyses	TCFP
850-mb horizontal divergence	GFS analyses	TCFP
Sea surface temperature	Reynold's weekly SST	TCFP
Latitude	Dvorak dataset	TCFP
Distance to land	Dvorak dataset	TCFP
% pixels colder than -40 C	GOES-East water vapor	TCFP
Cloud-cleared brightness temperature	GOES-East water vapor	TCFP
Climatological TC formation probability	Dvorak dataset / HURDAT / Best Track	TCFP
Distance to existing TC	Dvorak dataset / HURDAT / Best Track	TCFP
Shear direction	GFS analyses	SHIPS
Potential intensity	GFS analyses / Reynold's weekly SST	SHIPS
200-mb temperature	GFS analyses	SHIPS
700-500 mb relative humidity	GFS analyses	SHIPS
700-850 mb temperature advection	GFS analyses	SHIPS
Total Precipitable Water	Microwave Satellite-derived	SHIPS/RI Index
Dvorak T-number	Dvorak dataset	TCFP
Dvorak CI number	Dvorak dataset	TCFP

3. Current/Future year-1 efforts:

With the completion of the Dvorak database and subsequent building of complete tracks for all 2001-2010 pre-genesis disturbances, the evaluation of the potential TCGI predictors outlined in Table 1 has now begun. This element of the proposed effort will be followed by the sequence of Year-1 efforts listed below:

Feb 2012	Complete identification/development of TCFP TC GI environmental predictors into the TCGI database
Feb 2012	Begin to develop/incorporate the TPW predictor into the TCGI database
March 2012	Present year-1 results at IHC

June 2012	Complete identification/development of TPW & Dvorak T-number/CI value TCGI predictors
June-Nov 2012	Begin sensitivity testing for optimal combination of TCGI predictors (0-48h & 0-120h)

References

Cossuth, J., R. D. Knabb, D. P. Brown, and R. E. Hart, 2012: Tropical cyclone genesis guidance using pre-development Dvorak climatology. *Wea. and Forecasting*, in preparation.

Convective Structure and Environmental Conditions in the MJO Initiation over the Indian Ocean

PI: **Shuyi S. Chen,** RSMAS/University of Miami, 4600 Rickenbacker Causeway
Miami, FL 33149, Email: schen@rsmas.miami.edu
Co-PI: **David Jorgensen,** National Severe Storm Lab/NOAA
Co-PI: **Augustin Vintzileos,** University of Maryland and CPC/NOAA
Co-I: **Jon Gottschalck**, Climate Prediction Center/NOAA

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

Link to NOAA Strategic Goals:
Goal 2: Weather-Ready Nation - *Society is prepared for and responds to weather-related events*

Funding Source: NWS

The goals of this PI team are to better understand the structure of convective cloud systems and their large-scale environment in the MJO initiation process and to improve MJO forecasts. The research project addresses two of the Dynamics of the Madden-Julian Oscillation (DYNAMO) science hypotheses: *i) interaction between environmental moisture and convection and ii) the dynamic evolution of the cloud population*, which is key to MJO initiation over the tropical Indian Ocean. It includes three components: 1) cloud cluster tracking analysis using hourly satellite IR data along with observations of environmental water vapor and SST as well as the global analysis of wind and temperature data, 2) aircraft observation of convective cloud systems during the DYNAMO field campaign, and 3) model evaluation and verification for improving operational MJO monitoring and forecasting.

1. DYNAMO field campaign

The DYNAMO field campaign took place over the equatorial Indian Ocean from 1 October 2011-15 February 2012. In preparation for the field campaign, Dr. Chen and her research group at RSMAS/UM (Dr. B. Kerns and Mr. E Ryan) has set up a realtime cloud cluster tracking site using the METEOSAT data (http://orca.rsmas.miami.edu/~eryan/ConvTracking/dyn_index_rt.php). An example of the cloud clusters during DYNAMO is shown in Fig. 1. The cloud cluster tracking combined with global model forecast guidance have been used for operation planning during the DYNAMO field campaign including planning of daily aircraft missions. Dr. A. Vintzileos provided the GFS, CEFS, and CFS forecasts in realtime. Dr. J. Gottschalck was the lead forecaster for the MJO activities during DYNAMO field campaign. Dr. B. Kerns provided the daily weather briefing for the aircraft operation. The weekly MJO update and forecast as well as the daily weather briefings are posted on the EOL Field Catalog (http://catalog.eol.ucar.edu/cgi-bin/dynamo/report/index).

Dr. Jorgensen, Dr. Chen and two graduate students from RSMAS/UM (Falko Judt and Chiaying Lee) participated in the aircraft operation in Diego Garcia from 3 November-13 December 2011. The NOAA WP-3D aircraft conducted 10 science missions that captured the second MJO initiation event over the Indian Ocean in DYNAMO.

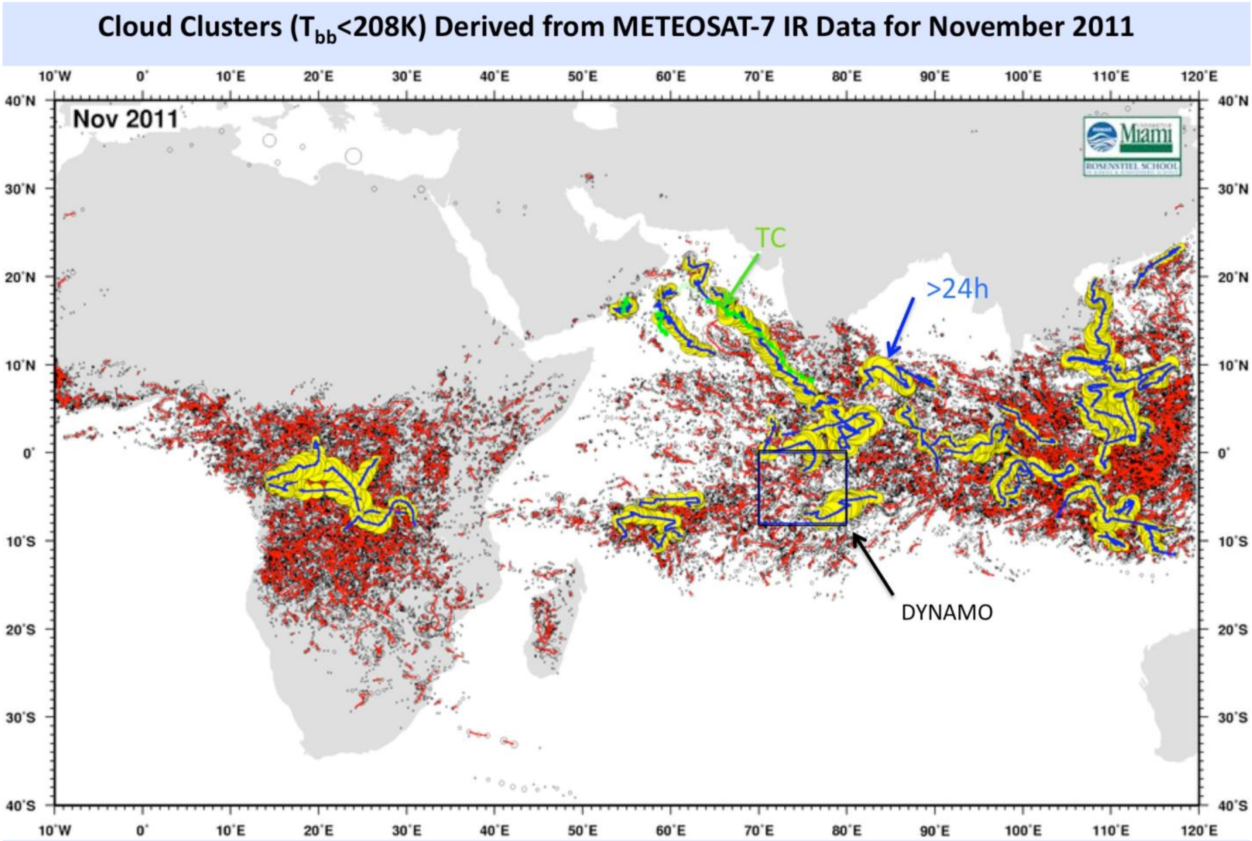

Fig. 1: All cloud clusters from 1-30 November 2011 (black circles). Red tracks are for cloud clusters lasted more than 6 h, blue tracks > 24 h, and green lines indicate tropical cyclone tracks.

The aircraft missions are designed to sample the MJO initiation event from the convectively suppressed phase to active phase (Fig. 2). The corresponding surface observations show a pre-convective onset period of the MJO initiation with mostly rain-free and relatively isolated convective events captured by the surface rainfall and a warm trend in the SST data, which is followed by a more continuous heavy rainfall that marks the onset of organized convection in the MJO initiation. Drs. Jorgensen and Chen served as mission scientists on the P-3 flights. Figure 3 shows a summary of the NOAA WP-3D flights during DYNAMO. The co-PI (Jorgensen) has provided detailed mission summary after each flight, which have been posted on the DYNAMO Field Catalog (http://catalog.eol.ucar.edu/cgi-bin/dynamo/report/index).

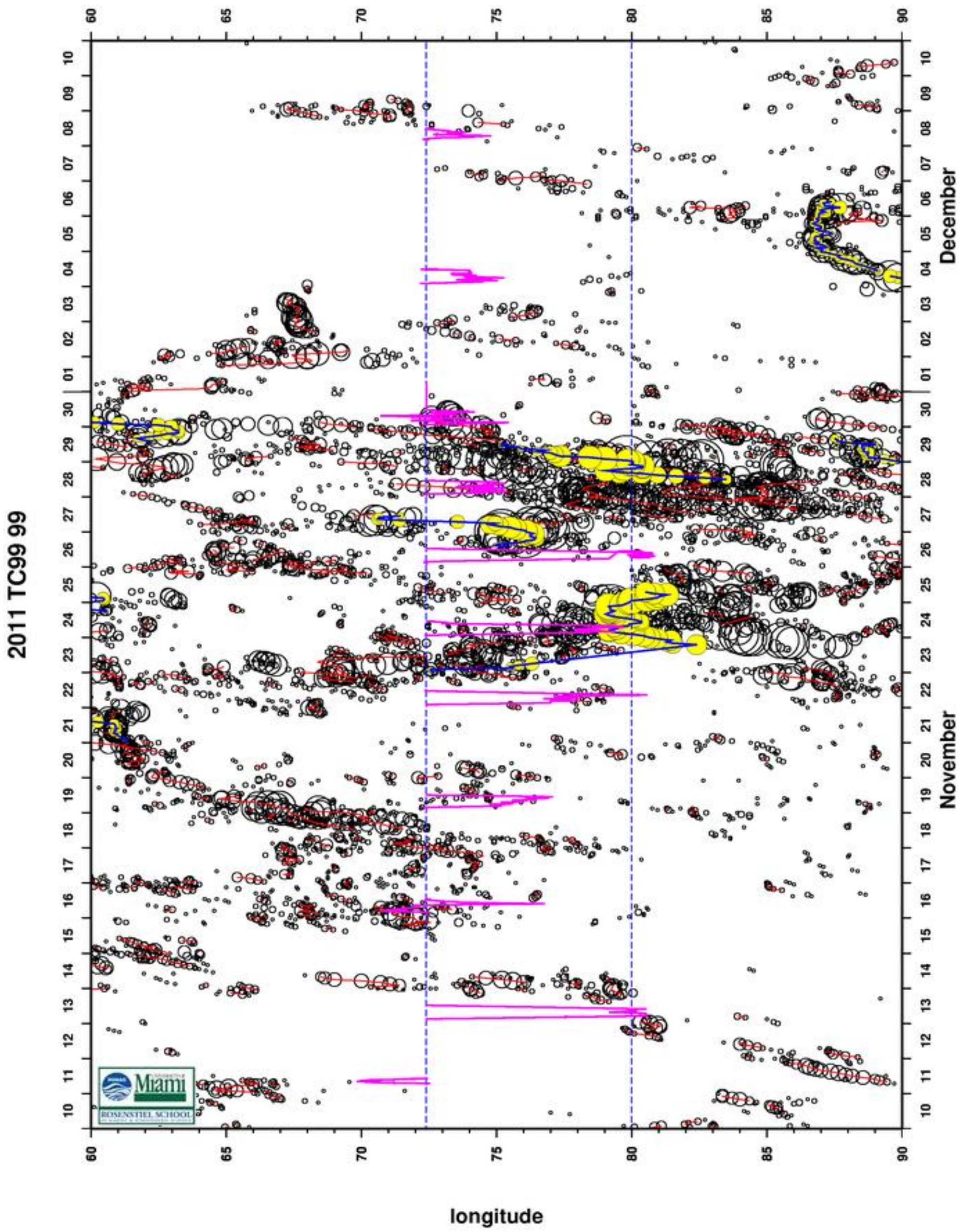

Fig. 2. Time-longitude plot of cloud clusters (Tb < 208 K) from 10 November-10 December 2011. The clusters are within the tropical latitude zone between 10^{o}S-5^{o}N. The size of black circles is proportional to the size of observed cloud clusters. The DYNAMO observing array is within the region between the blue lines (~72-80^{o}E). The NOAA WP-3D aircraft flight tracks are in magenta.

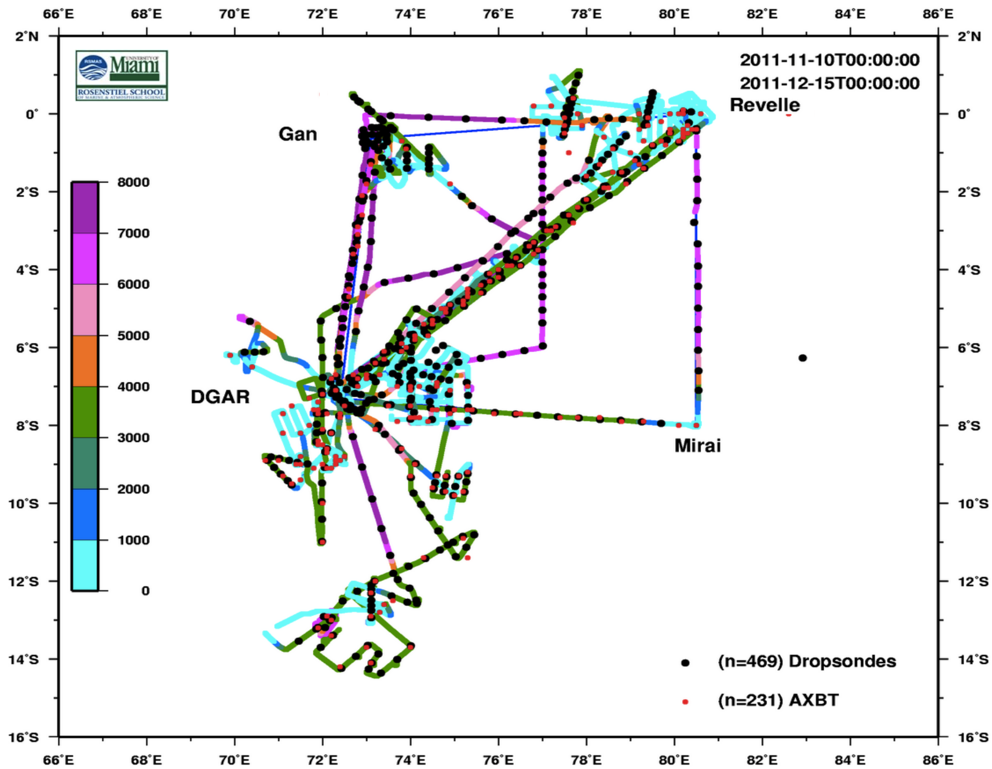

Fig. 3 Summary of the NOAA WP-3D aircraft flight tracks from the ten science missions from 13 November-8 December 2011, a test flight on 11 November and a calibration flight on 13 December. The height of flight level is indicated by the color bar. The air-deployed GPS dropsonde and AXBT locations are indicated by the black and red dots, respectively.

2. Preliminary science results

The PI (Chen) has written science summaries for several aircraft missions during the DYNAMO IOP, which have been posted on the DYNAMO EOL Field Catalog (http://catalog.eol.ucar.edu/cgi-bin/dynamo/report/index). The PIs (Chen, Jorgensen, Vintzileor, Gottchalck) have each presented the research results at the AMS 30th Conference on Tropical Meteorology and Hurricane in April 2012 (Chen et al. 2012, Jorgensen et al. 2012, Gottschalck and Vintzileos 2012, Vintzileos and Gottschalck 2012). Here we provide some examples from the current research results.

1) Cloud cluster analysis

A comprehensive analysis of the characteristics of cloud clusters in comparison with the TOGA COARE results is underway. We have conducted the following analyses:

- Identify the organized convective cloud systems based on the method of cloud cluster analysis used in Chen et al. (1996) and Chen and Houze (1997a and b) using the METEOSAT hourly satellite IR data
- Track cloud clusters in time and space to characterize their size and duration in association of MJO initiation over the tropical Indian Ocean

- Analysis of size and diurnal variation of cloud clusters during DYNAMO (Figs. 4 and 5)

Based on a long term climatology (Mapes and Houze 1992) and comparisons to radar echoes within the satellite inferred convective complex, the median size was approximately 20,000 km^2 with the radar echo roughly outlining the 208 K satellite IR contour (Chen et al. 1996). Dividing the spectrum into quartiles yields five distinct "classes" of systems:

Class	Areal coverage of 208 K IR satellite contour [km^2]	Approximate Length Scale of precipitation cells (km)
0	No 208 K	~10 km
1	<6,000	~20-30
2	6,000 – 20,000	~100
3	20,000 – 60,000	~250
4	>60,000	>250

Other results indicate that the larger the area the better organized and long-lived the system. The *Class 1* systems are very disorganized with life cycles on the order of a few hours, while the *Class 4* systems are very organized on the mesoscale with life cycles extending over a few days. As the areas get larger there is also a tendency for an increasing diurnal modulation of the cloud area (or convection). *Class 1* and *2* systems have only a slight diurnal modulation of their areas. Whereas, *Class 4* systems have a ~40% modulation of the system area, with a peak in area during the early morning hours local time, indicating that the developing stage of these systems is at night and the dissipating stage in during the day.

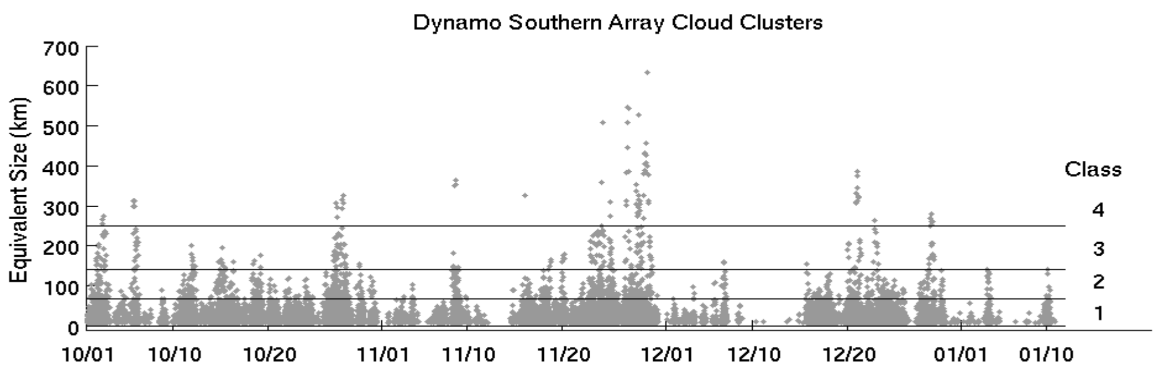

Fig. 4 Time series of 208-K cloud clusters (stratified by size, Class 1-4) in the DYNAMO Southern Array from 1 October 2011-10 January 2012.

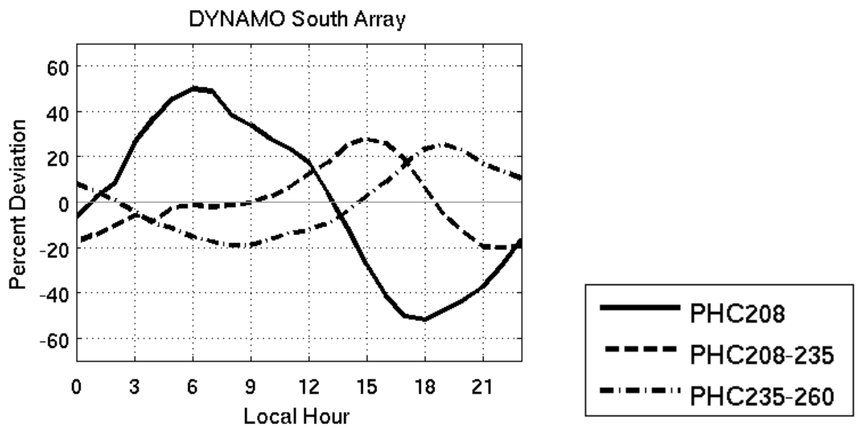

Fig. 5 Diurnal cycle of Percent High Cloud (PHC) <208 K (PHC208), 208-235 K (PHC208-235), and 235-265 K (PHC235-260) in the DYNAMO Southern Array from 1 October 2011-10 January 2012.

2) Aircraft observation of convective cloud systems and the cloud environment

To address the question of convective organization during the MJO initiation, observations of convective cloud systems and their immediate surrounding environmental moisture have been obtained by the airborne Doppler radar, the GPS dropsondes, and flight-level measurements on board of the NOAA P-3 aircraft during the DYNAMO field campaign. During the onset of equatorial convection at the early stage of the 2^{nd} MJO event during DYNAMO, dry air intrusion from the extratropical regions may be instrumental in disrupting the southern ITCZ and help forcing convection toward the equator. Figure 6 shows an example of the GPS dropsonde observed strong RH gradient on 22 November when the convection was forced toward to equatorial region by the dry air from the south.

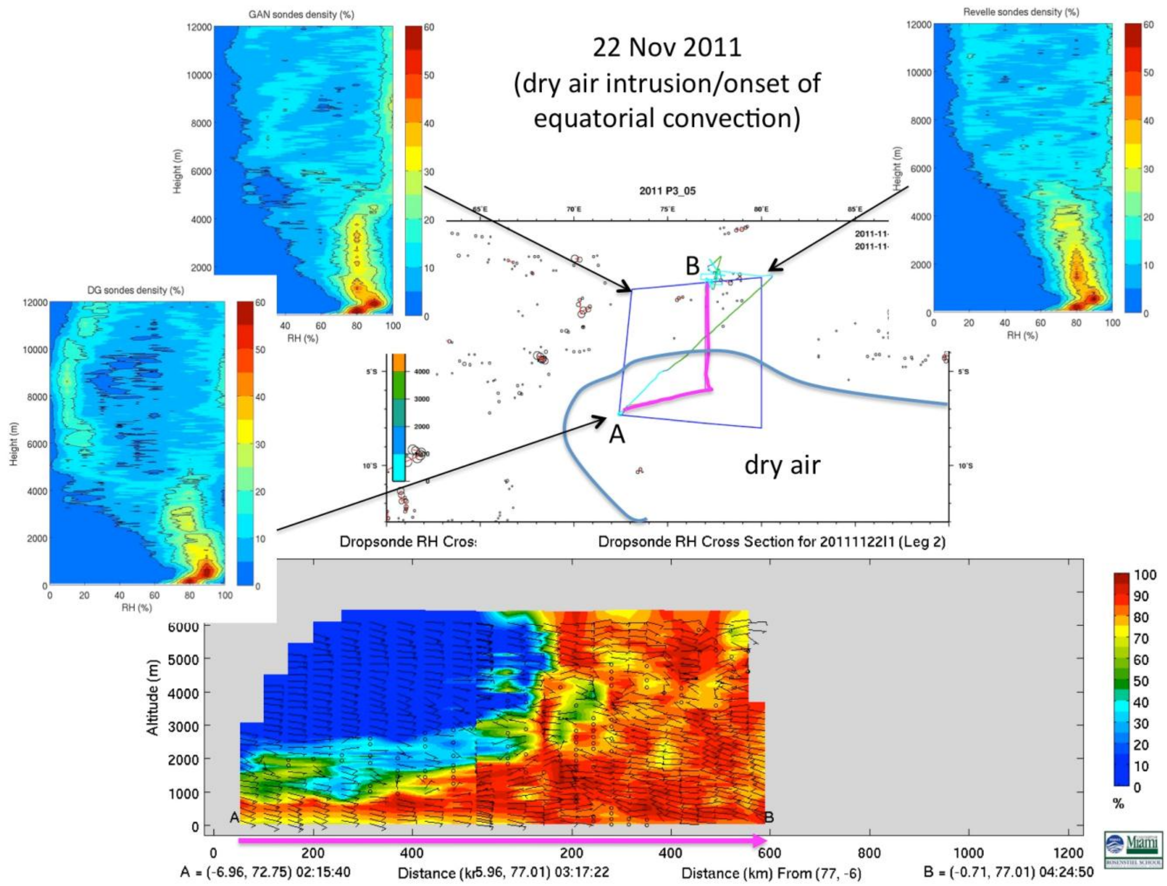

Fig. 6 Relative Humidity (RH) measured by the GPS dropsondes (lower panel) along the NOAA WP-3D aircraft track (magenta lines in the mid-panel) and cloud clusters (black circles) on 22 November. RH distributions from the ISS sounding at Diego Garcia (left), Gan (upper left), and R/V Revelle (upper right) during the month of November 2011 show the contrasting dry air in the south and moist air dominate near the equator.

3) Convective storm morphology and cold pool characteristics

An analysis of the NOAA P-3 airborne Doppler radar data has been carried out for the flight patterns termed "Radar Convective Elements" or RCEs (Fig. 7). There were 12 RCEs executed during the 12 research flights in DYANAMO. The objective of the RCE modules were to gather data sets with which to characterize the nature of the convective systems (e.g., life cycle, updraft/downdraft strength, and cold pool characteristics) in DYANMO to contrast with previous tropical convection studies from, for example, TOGA/COARE (Jorgensen et al. 1997). The primary sensor systems for accomplishing these goals were the tail mounted airborne Doppler radar and dropsonde systems on the NOAA P-3 aircraft.

RCE/FLX Module

Radar Convective Element/Flux

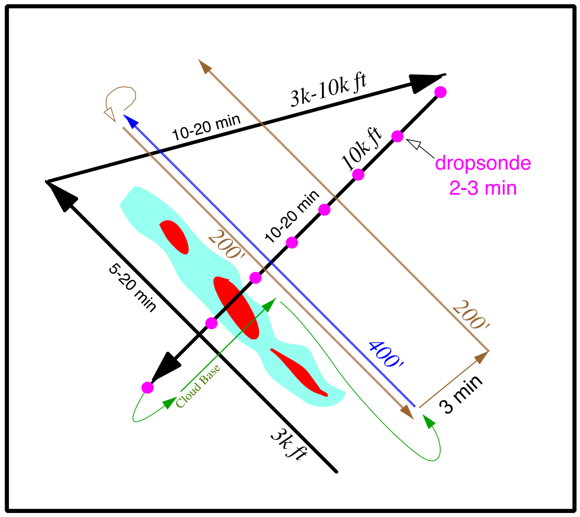

Fig. 7. Radar Convective Element (RCE) flight pattern for a linear convective segment. Dropsonde locations are indicated by the magenta dots. Leg lengths scale with the length of the convective line; typically 50-200 km. Altitudes and flight durations are indicated next to each flight leg segment.

An example of the success of the RCEs in documenting the characteristics of DYNAMO convective systems is shown in Fig. 8. The plot shows a fairly strong east-west oriented convective line with reflectivity exceeding 45 dBZ near the top of the plot. The aircraft flew parallel to the line while sampling using the Doppler radar. The Doppler radar data was cleaned up and interpolated to a Cartesian grid (1 km data spacing). Vertical velocity is determined by downward integration of the continuity equation with the boundary conditions of no vertical motion at echo to and the sea surface. A vertical cross section, A-B (the black line in Fig. 8) roughly oriented perpendicular to the convective line, is shown in Fig. 9. The cross section shows much different structure than the typical tropical or mid-latitude squall line. This case, and others, shows very little evidence of a well-defined “rear inflow jet”. In fact, for this case, there is a clear bifurcation of mid-level inflow from the rear into the convective line. It appears the bottom half of the convective storm contains a downdraft, with the upper half exhibiting a relatively strong updraft. Other cross sections shown different structure, indicating that there was very little organizing structure to the line. This is not surprising given the relatively weak vertical wind shear and weak cold pool seen in the dropsondes.

The line normal flight leg deployed dropsondes every 2 minutes. Two of those soundings, plotted as Skew-T/Log P diagrams, are shown in Fig. 10. The two soundings were chosen to be on either side of the convective line. The region to the north of the line was relatively echo free, while the region to the lines immediate south contained stratiform rain echo. About a 50 mb deep cold pool, with a magnitude of about 1 degree C is seen in the plot. This magnitude of cold pool depth and strength is common to all RCEs examined so far. Also, the environmental wind shear as shown in the dropsonde wind data is relatively weak. In contrast, cold pool strength in other tropical squall line studies have been up to 10 degrees C with highly sheared environmental wind profiles (Jorgensen et al. 1997). Clearly, the DYNAMO convective systems examined so far are relatively less dynamic than their other tropical counterparts.

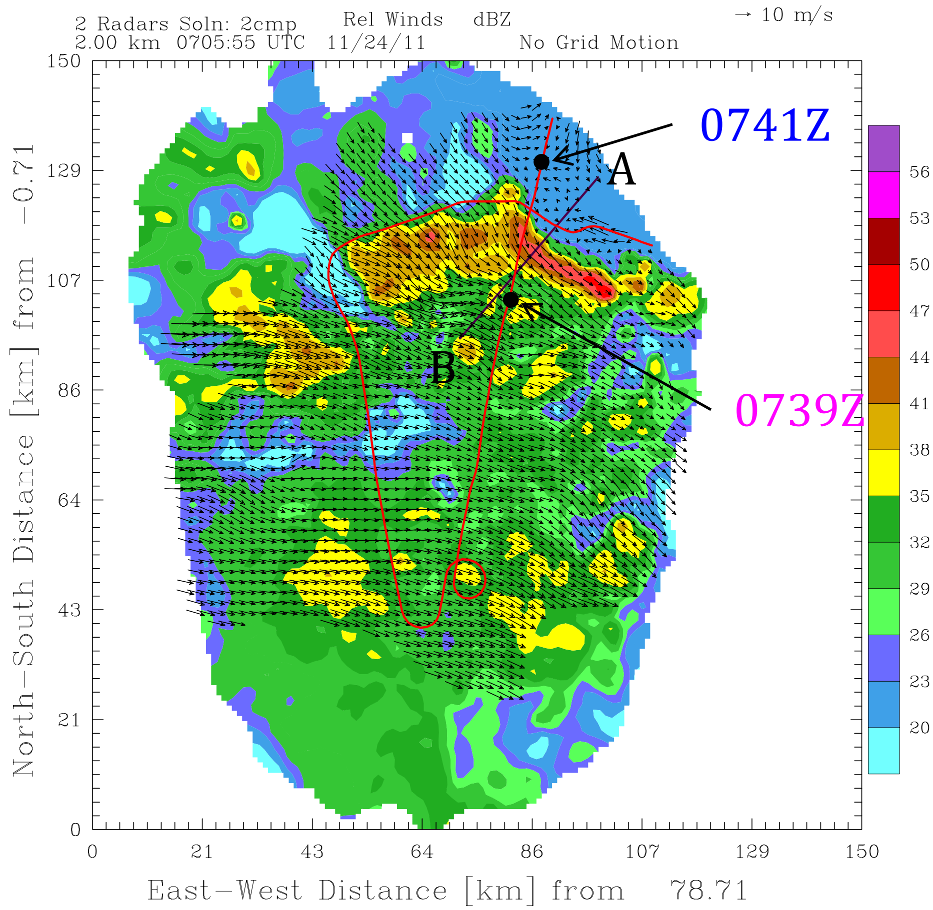

Fig. 8. Horizontal plot of ground relative wind vectors and radar reflectivity at 2 km MSL derived from the vertically-scanning P-3 Doppler radar for the RCE on Nov. 24 2011. Color scale is reflectivity [dBZ] on the right side, red line is the P-3 flight track during the time period of data gathering (07:05:55 GMT to 07:43:09 GMT). Dropsonde locations are shown as black dots with time hack. A 10 m/s scale vector is shown at the upper right. The coordinate system is relative to earth since the no convective band motion was used in the analysis. The black line shows the location of a vertical cross section A-B (Fig. 9).

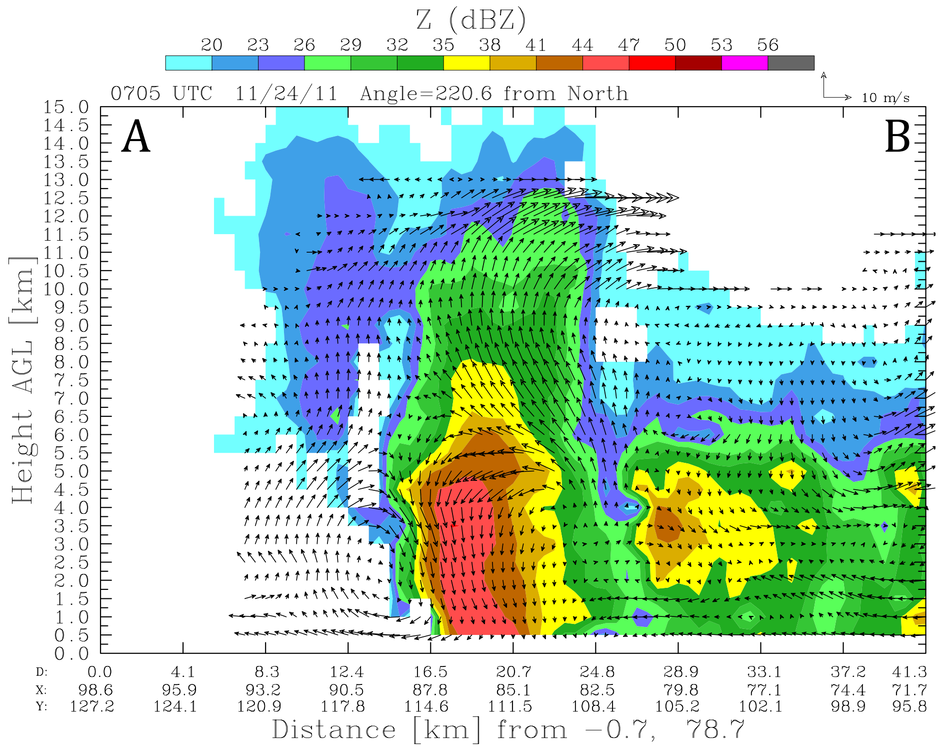

Fig. 9. Vertical cross section A-B.

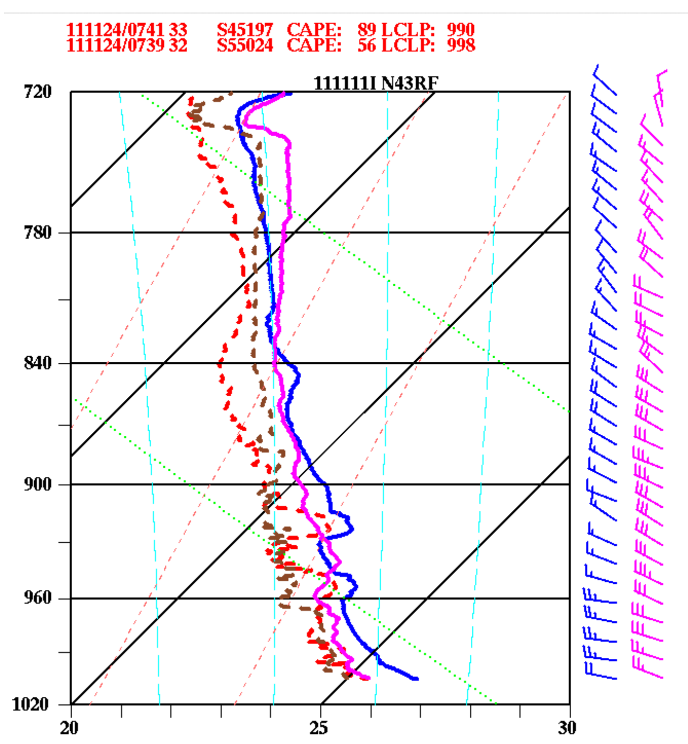

Fig. 10. SkewT-log P plot of the two dropsondes. Blue trace (and blue wind barbs plus brown dashed dewpoint line) are from the dropsonde north of the convective line at 0741 UTC. Magenta trace (and barbs and orange dewpoint dashed line) are from the dropsonde launched south of the line (0739 UTC).

3) Global model forecasts and analysis

Global model forecasts and analysis were provided in real-time to the DYNAMO PIs through the DYNAMO Field Catalog. All three NCEP global models i.e., GFS, GEFS and CFS were used. The GFS provided the advantages of a high resolution (L754L62) deterministic forecast, the GEFS the advantages of an 80-ensemble member probabilistic forecast and the CFS the advantages of a coupled model. The forecast products were organized in three levels. Level A products included hourly forecasts of selected variables at a resolution of 27*km* x 27*km* over the DYNAMO area; these products were updated at each forecast cycle (4 times per day) and were designed to support P3 missions. The day-to-day weather forecast was provided by Level B products covering forecast Day 1 to Day 7. Finally, level C forecast products targeted the large-scale circulation by providing Week 1 and Week 2 averages. Selected forecast variables were saved at high resolution for post-campaign processing.

3. Work in progress and 2nd year plan

During the 2nd year of the project, the PI team will continue the data analysis from the DYNAMO field campaign and use the data for model verification. We will develop methodology to incorporate cloud cluster tracking analysis into NOAA operational MJO monitoring and forecasting system.

The RSMAS/UM group will:

- Further examine the characteristics of the cloud clusters using the TRMM TMI and PR derived surface rainfall and radar reflectivity data as well as the airborne Doppler radar data, which can discriminate the cloud systems with mostly high cirrus clouds
- Characterize the convective active and suppressed phases of MJO environmental moisture (dry vs. moist, using TRMM and SSM/I TPW data), SST (using TMI-AMSR-E data), low-level winds and vertical wind shear, and air-sea fluxes (using satellite data, NCEP CFS-Reanalysis and ECMWF analysis fields, and the airborne GTS dropsonde and AXBT measurements)
- Determine the convectively generate cold pool strength and the surface/boundary layer recovery time using the GPS dropsonde, AXBT, and airborne radiometer and satellite SST data
- Provide a convective organization and large-scale context for other observations made during DYNAMO and a dataset for model evaluation/verification

The NSSL group will:

- Further examine the characteristics of the DYNAMO convective systems using airborne Doppler radar and dropsondes. Every RCE pattern will be processes and analyzed.
- Characteristics of the convective systems (e.g., updraft/downdraft strengths, cold pool structure) will be documented and placed in the context of the larger scale MJO phase.

- Collaborate with the French Falcon aircraft team to document the microphysical properties of the convection investigated on Dec. 8 2011. That case is the only coordinated multi-aircraft investigation, within the S-POL radar range, obtained during DYNAMO.

The University Maryland and NOAA/CPC team will focus on better understand the MJO prediction barriers and relative low predictive skills in global models, we will conduct comprehensive analysis comparing the observed cloud clusters during the MJO initiation over the tropical Indian Ocean as well as its initial eastward propagation toward the Maritime Continent with the global model predicted convection. This diagnostic study, which will necessitate the adaption of the convective cluster tracker to the models, will investigate the divergence of observed and forecast cluster as a function of lead time. Observation and model fields are evaluated in both long-term statistics and event-by-event case studies. These diagnostic studies will not only help provide detailed model verification but also help develop an operational MJO monitoring and forecasting guidance using a combined cloud cluster observation and model forecast fields. These analyses will be examined and compared with the results from Weller and Hendon (2004) using Real-time Multivariate MJO series 1 (RMM1), and 2 (RMM2).

The team will test this combined cluster/model forecasts methodology in DYNAMO. If successful, a transition of this algorithm to operations not only for the NOAA GFS and CFS forecasts but also for monitoring the state of the tropical atmosphere. This can also be used directly by the Global Tropics Hazards outlook team led by Jon Gottschalck at NOAA CPC.

4. Conference presentations

Chen, S. S., C.-Y. Lee, F. Judt, B. W. Kerns, E. Ryan, and D. P. Jorgensen, 2012: Spatial Variability of Tropospheric Water Vapor and Convective Cloud Systems in DYNAMO (https://ams.confex.com/ams/30Hurricane/webprogram/Paper206141.html), AMS 30th Conference on Hurricanes and Tropical Meteorology, 15-20 April 2012, Ponte Vedra Beach, Florida

Gottschalck, J., and A. Vintzileos, 2012: Review of large scale circulation and convection associated with the MJO and other coherent subseasonal tropical variability during DYNAMO, AMS 30th Conference on Hurricanes and Tropical Meteorology, 15-20 April 2012, Ponte Vedra Beach, Florida

Jorgensen, D. P., S. S. Chen, and Q. Wang, 2012: DYNAMO Convective Systems – Insights from Data Provided by the NOAA P-3 Aircraft, AMS 30th Conference on Hurricanes and Tropical Meteorology, 15-20 April 2012, Ponte Vedra Beach, Florida

Vintzileos, A., and J. Gottschalck, J., 2012: Performance of the NCEP model suite during DYNAMO October 2011-March 2012, AMS 30th Conference on Hurricanes and Tropical Meteorology, 15-20 April 2012, Ponte Vedra Beach, Florida

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Chen, S. S., R. A. Houze, Jr. and B. E. Mapes, 1996: Multiscale variability of deep convection in relation to large-scale circulation in TOGA COARE. *J. Atmos. Sci.*, **53**, 1380-1409.

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Gottschalck, J., M. Wheeler, K. Weickmann, F. Vitart, N. Savage, H. Lin, H. Hendon, D. Waliser, K. Sperber, M. Nakagawa, C. Prestrelo, M. Faltau, and W. Higgins, 2010: A Framework for Assessing Operational Model MJO Forecasts: A Project of the CLIVAR Madden-Julian Oscillation Working Group. *Bull. Amer. Met. Soc.*, In press.

Jorgensen, D. P., M. A. LeMone, and S. B. Trier, 1997: Structure and evolution of the 22 February 1993 TOGA-COARE squall line: Aircraft observations of precipitation, circulation, and surface energy fluxes. *J. Atmos. Sci.*, **54**, 1961-1985.

Ray, P., C. Zhang, J. Dudhia, S.S. Chen, 2009: A Numerical Case Study on the Initiation of the Madden-Julian Oscillation. *J. Atmos. Sci*., **66**, 310-331.

Wheeler, M. and Hendon, H. H. 2004: An All-Season Real-time Multivariate MJO Index: Development of the index for monitoring and prediction in Australia. *Mon. Wea. Rev*., **132**, 1917-1932

Zhang, C., 2005: Madden-Julian Oscillation. *Rev. of Geophysics*, 43, RG2003, doi:10.1029/2004RG000158.

2011 REPP- Understanding Coral Ecosystem Connectivity in the Gulf of Mexico-Pulley Ridge to the Florida Keys

Robert Cowen, lead PI
University of Miami, RSMAS, MBF

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

Link to NOAA Strategic Goals:
Goal 3**:** Healthy Oceans - *Marine fisheries, habitats, and biodiversity sustained within healthy and productive ecosystems*

Funding Source: NOS/NCCOS/CSCOR

l. Accomplishments:

a. Brief summary of progress (Note: progress is reported below by sub-group designation):

Program Management (PM)

Program Management has been involved with the establishment of an operational program, from working with UM Sponsored Programs for setting up internal accounts and subcontracts for all PIs, to hosting the first all-PI mtg for the purpose of coordinating groups and initializing planning for the first field season. Following the meeting, further planning has been underway to ensure a successful first year field season. Each of these are briefly discussed below.

Establishment of all budget/subcontracts – all in all, we needed to establish a total of 11 internal accounts, and seven external (subcontract) accounts to accommodate the various PIs and sub-group activities. Though the Sponsored Program team at UM/RSMAS was/is in charge of this accounting task, PM has to work with them to ensure that budgets were properly allocated (both within and between budgets).

Similarly, when we were informed that Year 2 science funds were to be reduced by 43%, PM was responsible for determining how the reduction would be allocated among the PIs/subgroups to minimize overall impact, and to ensure funding was available for the highest priority tasks. Allocation of reductions were discussed with our CSCOR Program Manager (K. Puglise), and then communicated with PIs.

All PI meeting – PM organized and hosted the kick-off all hands meeting held Nov 29-30, 2011 at RSMAS. Over the 1.5 d meeting, 26 people participated. The primary tasks for the meeting were: 1) refresher on the overall goals and coordination of the full research program, 2) provide background information on Pulley Ridge, 3) initiate overview and detailed discussions pertaining to the fieldwork requirements of the project, 4) discuss other project related issues (e.g. database formats, data sharing, reporting, etc.). The meeting agenda is included as an Appendix to this report.

Field work planning – Following from the All-PI mtg, PM has been responsible for maintaining open communication among filled participants and all support personnel. Planning has included discussions of:

i) Mooring designs and placement, as well as schedule for instrument maintenance and turn-around, establishment of cruise dates, personnel, goals, sampling protocol, etc.

ii) Coordination with technical dive team in terms of confirmation of cruise dates, equipment needs (and ordering), safety certification training (to 300'), and sampling protocols from input from relevant project PIs.

iii) Similar relevant coordination with the ROV technical team from UNCW.

iv) Shipboard coordination with ships operation and ships crew as to diversity of sampling equipment requirements, timing/coordination of activities, personnel requirements, etc.

v) Acquisition of all required permits for mooring placement and sample collecting. To this end, the PM coordinated with relevant PIs to ensure each responsible PI obtained all permits – but note that for Pulley Ridge – which is outside of state waters, and not currently within any Federally protected water, per se, we communicated with NOAA (Roy Crabtree and Steve Branstetter) about the requirement for a Letter of Acknowledgement – we received confirmation that such a letter was not required assuming that the work was being performed from a University research vessel, and as such we recognized as conducting scientific research in accordance with 50 CFR Part 600.10; are not subject to the Magnuson-Steven's Act regulations per 50 CFR Part 622 or Essential Fish Habitat requirements at 50 CFR Section 600.805. Our email communications will be carried during the cruise to verify this information exchange.

vi) Established a list of work/task priorities for the initial research cruise (14-28 August).

vii) Initiated further discussion on relevant sampling design for the ROV survey work on the Pulley Ridge – goals to maximize statistical validity of sampling/quantification for project goals and comparison with shallow water methods. Discussion is on-going.

Physical Oceanography (PO)

All Y1 work by the PO subgroup was related to the preparation for the August 2012 field study. This work included an observational and modeling component. Synergy between the two components was achieved through initial planning during the project's workshop (November 29-30, 2011), when discussions were held between scientists, technicians, and divers regarding the design, location selection and deployment logistics of the three PO moorings planned for the project. These initial discussions were followed by e-mail communications and meetings. The participant contributions were as follows:

NOAA-AOML (PIs G. Halliwell and R. Smith): mooring design, deployment logistical planning, bathymetry data; model simulations and preparation of outputs from the regional Gulf of Mexico (GoM) model;

UFL (PI A. Valle-Levinson): preparation and shipment to NOAA-AOML of two 600-kHz ADCPs;

UM-RSMAS (PI V. Kourafalou): model simulations and preparation of outputs from the Florida Straits, South Florida and Florida Keys (FKEYS) model; analysis of GoM and FKEYS model currents over detailed areas around Pulley Ridge and the Dry Tortugas to determine optimal positions for mooring deployment.

All participants agreed on the final mooring designs and 3 deployment locations (Fig. 1): a) northern Dry Tortugas at ~24°46.45'N, 083°05.70'W (51m depth); b) southern Dry Tortugas at ~24°28.55'N, 083°09.25'W (64m depth); c) near Pulley Ridge at ~24°42.0'N, 083°40.5'W (69m depth). Each location was selected for its suitability to support model validation, its proximity to biological sites of interest, and its ability to be serviced by project divers. The PO moorings will be deployed during the first project cruise, scheduled for August 14-28, 2012, and configured to hold a Teledyne RD Instruments ADCP and a Sea-Bird Instruments SBE37 MicroCat CT recorder. These instruments will record hourly measurements of temperature, salinity, pressure/depth, and profiles of ocean current velocity during their 20-month deployment.

Presently, instrumentation has been gathered at AOML in Miami, and is being prepared for deployment. This includes the planned purchase of a new Teledyne RD Instruments 300 kHz ADCP for use on the Pulley Ridge mooring. The three PO moorings are currently under construction and are on schedule to be completed prior to the August 2012 cruise.

Bio-Physical (BP)

Larval distributions along and upstream of the Florida Keys:

Data for 2007-2008 ichthyoplankton cruises have been processed and analyzed to examine the horizontal and vertical distributions of pelagic larvae along and upstream of the Florida Keys. These baseline data were obtained during three ichthyoplankton cruises (NSF Funded). Larval abundances and assemblages have been plotted and analyzed for each cruise. Products will include publications that detail the spatial and vertical distribution of dominant larval fish taxa in the Straits of Florida and Florida Current, thereby providing a context for interpretation of larval assemblage composition in downstream locations from Pulley Ridge.

Invasive lionfish larvae:

Samples of larval scorpaenids collected during the 2007-2008 ichthyoplankton cruises along the Florida Keys and light trap deployments in the upper and lower Keys were extracted and processed for genetic identification to determine whether larvae of the invasive lionfish, *Pterosis volitans*, were collected. Of a total of 2,180 larval samples, 751 sub-sampled larvae were successfully identified to species, while 76 light trap larvae were also identified to species. No lionfish larvae have been identified to date in these archived samples, though when tested against known adult lionfish tissue, the procedure correctly identified the sample as Pterosis. The following sample sizes and identifications were obtained:

Family	**Genus**	**Species**	**n (larvae)**	**n (light trap fish)**
Scorpaenidae	*Neomerinthe*	*hemingwayi*	42	0
Scorpaenidae	*Pontinus*	*rathbuni*	177	4
Scorpaenidae	*Pontinus*	*longispinis*	19	1
Scorpaenidae	*Scorpaena*	*agassizii*	438	1
Scorpaenidae	*Scorpaena*	*bergii*	2	37
Scorpaenidae	*Scorpaena*	*brasiliensis*	50	24
Scorpaenidae	*Scorpaena*	*inermis*	4	1
Scorpaenidae	*Scorpaena*	*plumieri*	8	6
Scorpaenidae	*Scorpaenodes*	*caribbaeus*	0	2
Scorpaenidae	*Scorpaenodes*	*tredecimspinosus*	1	0
Setarchidae	*Setarches*	*guentheri*	10	0

Preparation for the August 2012 Pulley Ridge cruise:

Light traps and associated moorings have been designed and are being assembled in preparation for deployment at mesophotic reefs of Pulley Ridge. Two moorings will enable the deployment of light traps at multiple depths over Pulley Ridge to collect settlement stage fishes. Traps are also being constructed to sample nearby shallow and deep reefs (off American Shoal and Looe Key Reefs) of the lower Florida Keys. To maximize comparisons, these sites will be sampled simultaneously during the cruise as well as during months immediately prior and following the cruise (July, September).

We are also working with the technical divers to train them in juvenile/small adult fish collection techniques so they can collect samples of the bicolor damselfish (*Stegastes partitus*) and blueheaded wrasse (*Thalassoma bifasciatum*) from the mesophotic reefs of Pulley Ridge during the August cruise. Similar samples of juvenile and adult fishes will be collected from the lower Keys sites during the same light trapping periods.

Population Genetics (PG)

CORALS (PI: Andrew Baker; Ph.D. student: Xaymara Serrano)

Field collection of samples

Approximately 270 colonies from the species *Montastraea cavernosa* and *Porites astreoides* from Dry Tortugas and 130 from the lower Keys (vicinity of Key West) at 3 depth zones (<10m, 15-20m and >25m) have been collected to add to our existing collection comprising ~600 samples of the species *Montastraea cavernosa*, *Porites astreoides* and *Agaricia agaricites* (shallow water *Agaricia* species) from various depths at multiple sites along the Florida reef tract.

Ongoing laboratory molecular analyses

This year was dedicated to testing and PCR-optimizing the primers developed for our proposed species and using microsatellite loci to investigate the (1) population structure at deep and shallow sites in the Florida Keys and (2) genetic connectivity between these sites. In addition, we aimed to use a combination of Denaturing Gradient Gel Electrophoresis (DGGE) and real-time (quantitative) PCR to: (1) assess patterns of depth zonation in symbiont communities present in shallow and deep colonies; and (2) assess the extent to which these corals might respond to ongoing climate change by hosting heat-tolerant symbionts (i.e., *Symbiodinium* type D1a). To date, we have completed this two-fold process for *M. cavernosa* using existing samples from the upper Keys, and are currently working towards completing the process for *P. astreoides* and *Agaricia* species. Below the specific progress for these species:

Montastraea cavernosa: To date, 8 new polymorphic microsatellite loci with no significant heterozygote deficiencies (an important assumption for population genetic models) have been developed for this species. Table 1 displays the microsatellite diversity data per marker. These loci were used to assess vertical connectivity between 3 depth zones (<10m, 15-20m and >25m) in reefs in the upper Florida Keys. The program STRUCTURE (Pritchard et al. 2000[1]) was used to determine the most likely number of populations (K) present. Our analyses revealed significant differentiation by depth, suggesting two populations are likely present – one shallow and one deep, with some degree of mixing (Figure 1). Results were also confirmed by pairwise estimates of RST (Table 2). We are in the process of using assignment tests to investigate direction of gene flow (deep to shallow vs. shallow to deep). Overall, these findings provide the first evidence of vertical connectivity in a Caribbean coral or in a broadcasting species and partly support the 'Deep Reef Refugia' hypothesis (DRRH), while also showing that its importance may depend on the specific conditions (e.g., physical, biological) that might enhance or limit connectivity at each location.

[1] Pritchard JK, Stephens M, Donnelly P (2000) *Genetics* 155: 945–959

Table 1. *M. cavernosa* allele data. Given for each marker are the number of samples genotyped (N), number of alleles observed (Na), expected (He) and observed heterozygosity (Ho) and p-value. ns denotes no significant departure from Hardy Weinberg Equilibrium ($p<0.05$).

Population	Marker	29	41	46	4	18	65	49	97
Florida (upper Keys)	**N**	44	44	40	45	44	45	43	43
	Na	8	9	3	35	11	5	14	7
	He	0.774	0.750	0.313	0.960	0.854	0.402	0.822	0.758
	Ho	0.705	0.750	0.275	0.933	0.705	0.378	0.744	0.720
	p value	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**

Figure 1. *M. cavernosa* STRUCTURE output assuming 2 populations (K=2) for all depths in the upper Florida Keys.

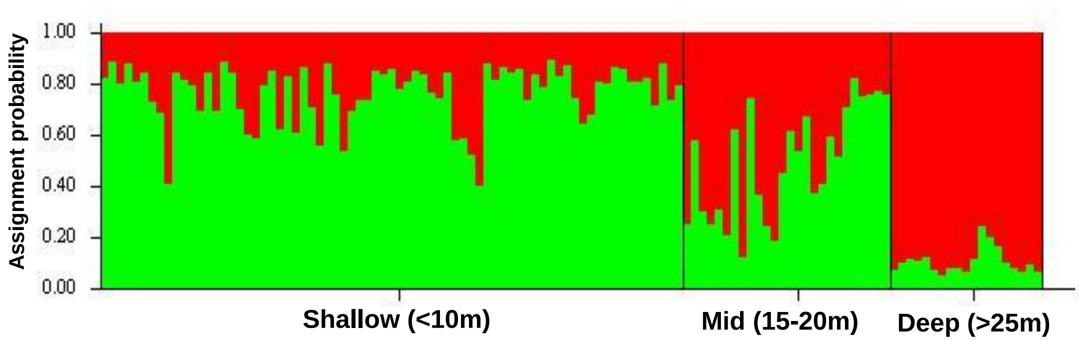


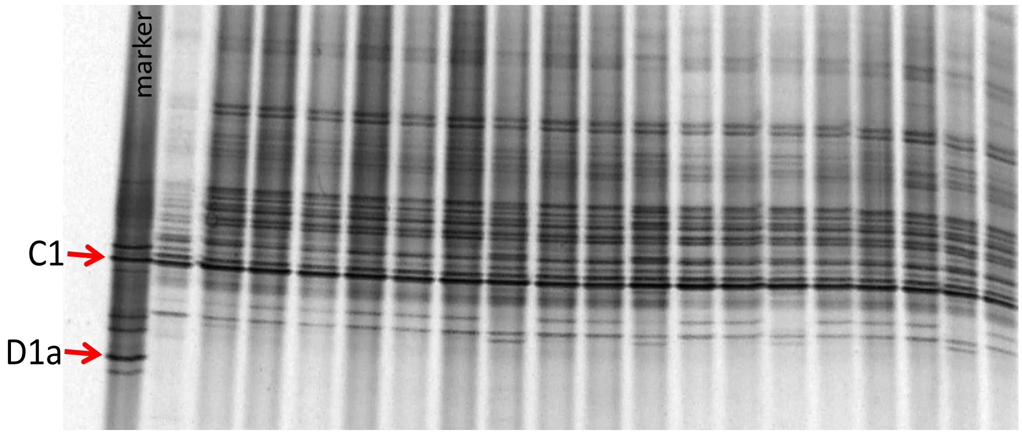
Table 2. *M. cavernosa* pairwise RST among depths in the upper Florida Keys. Values larger than 0.15 (highlighted) are generally considered evidence of strong genetic differentiation.

Population	Shallow	Mid
Mid	0.074	
Deep	0.226	0.021

Algal symbiont (*Symbiodinium* spp.) characterization in *M. cavernosa*

No evidence for depth zonation in algal symbionts was found at any location, as most colonies hosted *Symbiodinium* type C1 (Figure 2). In addition, observations of D1a occurred rarely and only in Florida at shallow depths, with no background D1a detected in mid or deep colonies. Overall, these findings suggest that the ecology of symbiosis is not a limiting factor for vertical connectivity in this species.

Figure 2. DGGE typical profile for *M. cavernosa*. Both shallow and deep colonies are dominated by *Symbiodinium* type C1.



Agaricia species: To date we have designed 67 primer sets for *A. agaricites*, and more primers can be designed as needed. We are currently starting the process of primer testing and PCR optimization using a subset of these primers. The plan is to cross-test the developed primers for *A. agaricites* against the deepwater *Agaricia* we will collect at Pulley Ridge (*A. lamarcki, A. grahami*) to assess whether the markers developed from *A. agaricites* can also be applied to these species.

Porites astreoides: In the event that *A. agaricites* markers do not cross-amplify, *P. astreoides*, brooding species will be very useful for our proposed analyses, as it is abundant throughout the Keys, including deep sites. Although it has been recorded at Pulley Ridge its abundance appears to be rare. Nevertheless we will target the collection of *P. astreoides* at Pulley Ridge (in addition to *M. cavernosa* and *Agaricia* sp.) since our existing dataset will make these samples very valuable. regional interpretation. We already have many samples along the length of the Florida Keys reef tract, and have developed microsatellite loci for proposed analyses. Specifically, we have identified 8 candidates for this species from the 454 sequencing run, which are currently being tested and validated for variability, host-specificity, and conformity to expectations of population models. We will soon begin analyses of population structure and connectivity using these newly developed markers.

FISHES – *S. partitus* (PI: Luiz Rocha; Ph.D. student: Eva Salas)

Field collection of samples

We have a collection of ~200 samples of the species *Stegastes partitus* from various locations across the western Caribbean. Collecting permits were obtained and we are in the process of organizing a field trip to the Flower Gardens National Marine Sanctuary. Our first attempt was cancelled due to bad weather conditions, but we are on the list for two trips with the R/V Manta, operated by the Flower Gardens bank Marine Sanctuary.

Ongoing laboratory molecular analyses

We used our existing samples of *S. partitus* to test microsatellite primers from previous studies (Salas et al. 2010[2]), PCR-optimize the primers and perform additional analyses. During the next year we intend to obtain and work on samples from the Flower Gardens, Pulley Ridge and Florida Keys areas.

FISHES – Groupers (PI: Mahmood Shivji; Ph.D. student: Andrea Bernard)

Field collection of samples

Samples of grouper species *Epinephelus morio*, *Mycteroperca bonaci* and *M. phenax* have been opportunistically collected from recreational fishers and used for development of microsatellite markers (see below). Additional samples of *E. morio* and either *M. bonaci* or *M. phenax* from Pulley ridge and the Florida Keys will be collected by L. Rocha and M. Shivji during the second year of the study with the assistance of field members of the grant team.

Ongoing laboratory molecular analyses.

We have tested and optimized 15 tetranucleotide microsatellite markers that we developed for *Epinephelus striatus* on the above grouper species. The results are excellent to reasonable in terms of the utility of the markers, depending on species. The results of this work have been accepted for publication in the journal *Conservation Genetics Resources* and are summarized in Table 3. Planned activities for year 2 of the grant by PIs Rocha and Shivji are to use these and other (newly developed or from the literature) microsatellite markers to assess detailed population connectivity and genetic diversity of two of the grouper species per stated objectives of the grant.

Table 3. Results from cross-amplification of 15 *Epinephelus striatus* microsatellite primers on grant-relevant grouper species.

Grouper species	**No. loci cross-amplifying**	**No. of alleles observed/locus**
E. morio	12	9-12
M. bonaci	6	2-13
M. phenax	4	4-10

[2] Salas, E., Molina-Urena, H., Walter, R.P. & Heath, D.D. (2010) Local and regional genetic connectivity in a Caribbean coral reef fish. *Marine Biology (Berlin)*, **157**, 437-445.

Population Dynamics (PD)

Task 1a. Assimilate and Synthesize Regional Fishery Ecosystem Databases

The Ault PD group in this first project year was focused on the production of the appropriate statistical methods and mathematical processes required to estimate the spatial abundance distribution and size structure of a number of key economically and ecologically important reef-fish species in PR MCE identified in the PR proposal, and compare these estimates with those in either the upstream (west Florida shelf) or downstream (Dry Tortugas-Florida Keys) areas. Thus, we acquired, assimilated and resolved a number of key regional databases from the upstream and downstream locations (**Table 1**) to facilitate accomplishing this task.

Table 1: Description of the primary data sources available for assessment of reef fish species inhabiting the southern Florida coral reef ecosystem.

Survey Type	**Database & Source**	**Metrics**	**Spatial Resolution**
Commercial Fleet	[1]Florida Trip-Ticket	Catch-effort	Southern Florida, Florida-wide
	[2]Trip Interview Program	Length composition	Southern Florida, Florida-wide
Recreational Fleet	[3]MRFSS	Catch-effort, length composition	Southern Florida, Florida-wide
	[2]Headboat Survey	Length composition	Southern Florida, Florida-wide
	[4]NPS Creel Survey	Catch-effort, length composition	Biscayne National Park
	[4]NPS Creel Survey	Catch-effort, length composition	Dry Tortugas National Park
Fishery-Independent	[5]Reef Fish Visual Survey (< 35 m)	Density-abundance, length composition	Biscayne National Park, Dry Tortugas, FKNMS, southern Florida, Florida Keys
	[6]Reef Fish ROV and Drop Camera Surveys (> 35 m)	Density-abundance, some length composition	Pulley Ridge, Madison-Swanson Reserve, W. FL shelf

[1]Florida Fish and Wildlife Conservation Commission (FWC). [2]NOAA. [3]NOAA Marine Recreational Fisheries. Statistical Survey. [4]National Park Service. [5]Collaboration of NOAA Southeast Fisheries Science Center, University of Miami, FWC, and NPS. [6]Various NOAA-sponsored surveys.

We worked closely with our collaborators (Dr. Steven Miller, Nova Southeastern University, coral reef quantitative ecology; Dr. Carl Walters, University of British Columbia, quantitative assessment methods) to define the appropriate habitat covariates and statistical approaches for efficient spatial population estimation. The data identified above were combined statistically with several spatially-synoptic quantitative datasets defining coral reef habitats (benthic cover, depth, rugosity, etc.) to compute precise and accurate estimates of size-structured spatial abundance for the primary species, plus several more ecological relevant species, across the ecosystem following the methods of Ault et al. (2006, 2012)[3] and Smith et al. (2011a,b)[3]. For the shallow-water (< 35 m) reef component from the fishery-independent data, principles of statistical sampling design were used to guide refinement of a 30-year multispecies fishery-independent diver visual survey of population abundance and size structure of more than 250 exploited and non-target fishes and a number of coral reef species in the Florida coral reef ecosystem. We have found that the melding of the two data classes (FI and FD) has presented some exceptional statistical challenges. Fishery-dependent data (shallow and deep-water components) from the Keys-Tortugas and west Florida shelf are sampled without a real survey design and are much coarser spatially in resolution that their fishery-independent counterparts. To the extent possible, some issues have been rectified in shallow-waters by the RVC, where possible. Going forward, these may potentially benefit from new analyses or SEDARs that may ultimately be incorporated into our models. A tougher piece of work has been shaping the deep-water fishery-independent survey data (ROVs and drop cameras) into something that is statistically defensible. By in large, these data have been collected at relatively small scales and lacked a formal statistical sampling design in their acquisition. All this creates issues when tryng to translate these observations in broader maps of spatial size-structured density and/or abundance. However, the analyses that we have performed in year 1 and will continue into year 2 in our statistical gear intercalibration efforts should greatly aid the acquisition of “new” data in subsequent project years.

Coleman/Koenig- The objective of our section is to estimate the spatial distribution, abundance, and size structure of key economically and ecologically important reef fish species in Pulley’s Ridge MCE compared to other sites along the west Florida shelf. Our approach is to assimilate existing fishery-independent databases from our studies on Pulley Ridge, Madison Swanson Marine Reserve, and Steamboat Lumps Marine Reserve to include where available the distribution, abundance, age and size structure and reproductive condition of economically and ecologically important reef fishes.

During the initial period of this project, we have hired technician (actual start date: July 5) to assimilate existing fishery independent data from our own data and from NOAA databases, as well as acoustic (sidescan and multibeam imagery) and historical maps of the Pulley Ridge region. Maps are used to select habitat areas (e.g., ledge habitat, pavement, slope habitat, rubble fields) for studies of reef fish.

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[3] Ault, J.S., S.G. Smith, J.A. Bohnsack, J. Luo, D.E. Harper, and D.B. McClellan. 2006. Building sustainable fisheries in Florida’s coral reef ecosystem: positive signs in the Dry Tortugas. Bulletin of Marine Science 78(3): 633-654.

Ault J.S., Smith S.G., Bohnsack J.A., Patterson M., Feeley M.W., McClellan D.B., Ruttenberg B.I., Hallac D., Ziegler T., Hunt J., Kimball D., Luo J., Zurcher N., Causey B. 2012. Assessing coral reef fish changes and marine reserve dynamics in the Dry Tortugas, Florida USA. Fisheries Research, *in review*

Smith, S.G., J.S. Ault, J.A. Bohnsack, D.E. Harper, J. Luo, and D.B. McClellan. 2011a. Multispecies survey design for assessing reef-fish stocks, spatially-explicit management performance, and ecosystem condition. Fisheries Research 109(1): 25-41.

Smith, S.G., Swanson, D.W., Chiappone, M., Miller, S.L., & Ault, J.S. 2011b. Probability sampling of stony coral populations in the Florida Keys. Environmental Monitoring and Assessment 183(1-4): 121-138.

Task 1b. Calibration of RVC and ROV Survey Methodologies
Ault - Part of the field component of the gear (survey methods) inter-calibration studies are a little behind schedule due to our inability to get NOAA ship time to bring the ROV and drop camera gears together with the shallow RVC in space and time. However, in the first year we were able to design the formal statistical survey for conduct of the intercalibration experiment. Basically, the issues are defining the sample sites based on the relationships between animal density and "habitat" (e.g., hardbottom, high-slope vs. hardbottom, low-slope) defined by our 200 x 200 m digital map of reef habitats in the shallow waters, and the developing, but much coarser resolution map products for the Pulley Ridge environment. In June & July 2012 we are conducting system-wide Florida Keys-Dry Tortugas RVC (reef-fish visual census) surveys in waters < 35 m using our habitat-stratified sampling design. We hope to have the ROV and drop camera crews in south Florida sometime later this summer and early fall to run formal calibration experiments. We will then use the fall-winter to analyze the data and generate the appropriate statistical models for gear intercalibration of size-structured fish density.

Coleman/Koenig- We currently are evaluating the Bohnsack-Bannerot visual fish-census survey methodology to determine whether the census results of reef-fish species abundance and diversity are affected by diver presence. The Bohnsack-Bannerot method, which is used extensively in the Florida Keys and elsewhere, assumes that diver presence has minimal effect on fish behavior, although few tests of this assumption have been made. It is possible that some species respond to divers and some do not. Thus, the possibility that fish are either attracted or repelled by divers needs consideration. If fish behavior is affected, then surveys using this technique in the past would need to be reevaluated. The work is being conducted in shallow water with video cameras that are designed to rotate, thus simulating diver behavior while performing the Bohnsack-Bannerot method. Comparisons with ROV transects will be conducted in the Florida Keys.

FSU also have one graduate student and two undergraduate students conducting behavioral studies of red grouper in Florida Keys within and outside of marine protected areas in anticipation of offshore work on Pulley Ridge.

Community Structure (CS)

PIs: M. Dennis Hanisak, John Reed, Joshua Voss, and Sara Edge (HBOI-FAU)

Note: The Year 1 Sub-Award from the University of Miami was in place at HBOI-FAU in February 2012. Per the proposal timeline, our work is to begin in Q3 (July) of 2012.

Objective 1 (Data Compilation/Assimilation): To compile and assimilate existing data on community structure of MCEs from the entire study area into a comprehensive database

Initial data compilation efforts are associated with our team's recent CIOERT cruises to Pulley Ridge (PR) in 2010 and 2011 so that current key data are made available to all team members. These field surveys are the most recent ones at PR and will be very helpful for the UM-REPP cruises beginning in August 2012. Specifically, Leg 1 of the CIOERT Florida Shelf-Edge Exploration II cruise was conducted with the NOAA Ship *Nancy Foster* and the University of

Connecticut's *Kraken 2* ROV and included 12 ROV dives, MOCNESS trawls, CTD casts, and AUV Glider deployment on PR. The Preliminary Cruise Report, submitted to UM on March 8, 2012, included SEADESC Level I data analysis which describes in detail each ROV dive including: cruise metadata, figures showing each dive track overlaid on the new multibeam sonar maps, dive track data, objectives, general description of the habitat and biota, and images of the biota and habitat that characterize the dive site. On May 23, we submitted the results of our benthic analyses of the ROV photo transects performed by Stephanie Farrington and John Reed. These data included the percent cover of higher taxa (Phylum), and breakdown of coral taxa, as well as density (# individuals/m^2) for invertebrates >3 cm that could be distinguished as individuals. The fish data analyzed by Stacey Harter (NMFS) were reported separately.

<u>Objective 2 (Characterize MCEs)</u>: To locate, characterize, and determine the distribution of MCEs in the study area

Planning for the first cruise on this project scheduled in August 2012 is underway.

<u>Bio-Economic (BE)</u>

No work was planned for the BE subgroup during year 1 or year 2 of this project.

<u>Decision Support Toolkit (DST)</u>

The Decision Support Toolkit (DST) team has relatively modest goals for the first 2 years of the project. This is in line with the amount of funding allocated to the DST team during this time period. The DST team contribution to the project will be more significant during the last several years of the project after more data has been acquired. That said, the DST team has not been idle and has focused on establishing the basic information management infrastructure that will be need until the construction of the Decision Support Toolkit can begin (in year 4).

During the first year of the project we have acquired a machine and the necessary storage infrastructure to serve as the project data repository for the next several years. This machine has been installed in University of Miami's colocation facility, the NAP of the Americas. The system has been configured for sftp and bbcp data transfer programs. The automated file rules are currently being built and the processes being documented. Administration of the system is being handled by the University of Miami Center for Computational Science (CCS). CCS has started work on a survey to be distributed to all data transfer partners. This survey will be distributed during June 2012. This survey will enable us to define the metadata data requirements for all existing and anticipated future datasets.

<u>Management Application (MA)</u>

MA finalized the membership of the Stakeholders Advisory Board (SAB) and held the first (phone) conference for initiating input by the SAB into the DST sub-project.

Full SAB membership and affiliations:

Mr. Gregory Boland	BOEM/Environ. Sciences Div.
Dr. Steve Bortone, Exec. Dir.	GMFMC
Dr. James Byrne, Mar. Sci. Prog. Mgr.	The Nature Conservancy

Mr. Billy Causey, SE Regional Dir.	NOAA/NOS/Natl Marine Sanctuaryies
Dr. Roy E. Crabtree, Regional Administr.	NOAA/NMFS/SE Region
Dr. Alyssa Dausman, SCT co-lead	GCERTF
Dr. Todd Gedamke, Div. Chief	NOAA/NMFS/SEFSC – Demersal Fisheries
Mr Dan Kimball, Supt. ENP/DTNP	DOI/NPS
Dr. John McDonough	NOAA/OAR/OE
Mr. Gil McRae, Director	FWC/FWRI
Dr. Roger Puglise, Sr. Fish Biol.	SAFMC
Ms. Cathy Tortorici	NOAA/NMFS/SE Region

Meeting discussion, following a general overview of the program, centered on the database set-up for the DST. Several recommendations were made, especially with respect to communication with other groups doing similar large data syntheses, notably: Russ Beard (NCDC) at Stennis and his colleagues as they have experience with building regional DST and data repositories. We did reach out in a subsequent phone call to Russ and his colleagues, and exchanged updates to proposed tasks, approaches and shared recommendations for maintaining communication as new developments arise.

b. Provide a brief summary of work to be performed during the next year of support, if changed from the original proposal; and indication of any current problems or unusual developments that may lead to deviation of research directions or delay of progress toward achieving project objectives.

Project management (PM)

Planning and execution of first field season cruise (August 14-28, 2012) as well as one of the two originally planned cruises in 2013 (May). From the planning perspective:

i) Establish a full set of protocols for specimen collections and preservation; sample labeling and tracking; metadata requirements for all samples and field/laboratory data.

ii) Complete the development and field preparation of all sampling equipment (notably: bottom mounted ADCP moorings, deep and midwater light-traps and moorings, calibration of ISIIS and MOCNESS sensors and systems).

iii) Coordinate with Ship's crew, ROV crew, Technical Divers, and science party as to shipboard activities and sampling/activity priorities. Provide Chief Scientist with modified prioritized cruise Objectives list.

Physical Oceanography (PO)

The work will be performed according to the Y2 planning.

Education and training of a student at UM/RSMAS will be eliminated (or deferred to Y3), as per Y2 budget cuts. High resolution modeling archives will be limited by reduction of computer storage funds; however, modeling tasks will be minimally affected by performing additional simulations in Y3 (anticipating recovery of Y2 cuts).

Cuts to the initial NOAA/AOML Y2 disbursement (received in May 2012) were absorbed out of travel, overtime (other), and costs associated (personnel, fringe benefits, indirect charges) with 1 man-month of M. LeHenaff (CIMAS postdoc associated with the PO modeling component). These costs will be deferred to the next disbursement (second Y2, or Y3) expected in May of 2013.

Bio-Physical (BP)

Fieldwork as scheduled for the remaining first year. Activities scheduled for Year 2 may be curtailed due to major funding cuts. This will most likely result in a significant delay in sample processing, which will also impact initial bio-physical model outcomes depending on parameterizations based on these data.

Community Structure (CS)

Plans for compilation/assimilation of previous data and collection of new data on the benthic communities of Pulley Ridge are projected to occur as proposed. We have also proposed that the database currently used by HBOI-FAU on cruises might be utilized/adapted for this project.

Due to the recent budget cuts by NOAA for our Year 2 work, we unfortunately will suspend the plans for the sub-task on settlement/recruitment potential of corals as we had proposed, with that work to have been done by Drs. Joshua Voss and Dr. Sara Edge. If NOAA restores funding for this work, then we will incorporate it in revised form into the work plan.

Population Dynamics (PD)

The Ault group's work in Year 2 will focus on the objective of linking the population abundance and size structure data developed in project Year 1 to spatially-explicit reproductive output of selected reef fish species in PR MCE. Part of this effort will be a meta-analysis of relevant population dynamic and demographic literature and databases. Effort will be applied to estimating distribution, abundance and size-structure from other investigator field data collected from the Pulley Ridge MCE. During year 2, Drs. Walters and Miller will work closely with us, including an on-site visit by Dr. Walters for one to two weeks this Fall, to advance refinements of the spatial population estimation methods and to develop models that link size-structured population abundance to spatially-explicit reproductive outputs.

Coleman/Koenig- The DWH oil spill and the availability of research vessels delayed our research for one year. We will follow through to completion, based on availability of funds. Thus, we will pursue a no-cost time extension on this year's funds.

- We anticipate complete assimilation of the historical databases by the end of Yr 2.
- We anticipate completion of the preliminary test evaluating the diver-presence in the Bohnsack Bannerot method by September 2012.
- We will need funds for boat time for Pulley Ridge. Will coordinate with community folks and others to see what we can do to coordinate.

<u>Decision Support Toolkit (DST)</u>

During the next year we plan to complete the identification of dataset metadata requirements and use these to establish a common catalog for the description of all relevant project datasets, and continue our efforts to facilitate transfer of these existing datasets from the project partners to the project dataset repository. We will also complete the design and deployment the project website, which will be used for public engagement, as well as communication of project goals and accomplishments.

2. Applications:

a. Outputs – There are few outputs to be reported as we are only in the first 9 months of a five-year project. Products produced thus far are primarily those outputs generated from projects funded through other sources, but of direct relevance to this program.

i. New fundamental or applied knowledge

<u>Community Structure (CS)</u>

Reed, J., S. Farrington, S. Pomponi, D. Hanisak, and J. Voss. 2012. HBOI-FAUNOAA CIOERT Cruise Report, Survey of the Pulley Ridge Mesophotic Reef Ecosystem, NOAA Ship Nancy Foster, Florida Shelf-Edge Exploration II (FLoSEE) Cruise, Leg 1- September 12-19, 2011, NOAA Project Number: NF-11-09-CIOERT, 41 pp. & appendixes.

This cruise resulted in a rich set of new data discovering and characterizing mesophotic reef sites on Pulley Ridge and within the Pulley Ridge HAPC. New *Nancy Foster* sonar maps enabled us to discover and map several reef sites that had never been documented before. The new sonar maps and groundtruthing by ROV dives, MOCNESS trawls, and CTD casts have provided data characterizing these sites. These data will be useful for site selection, habitat characterization, and coral health assessment by the UM-REPP Connectivity Pulley Ridge.

Data from the above cruise will also be important for managers and scientists within NOAA Fisheries, the Gulf of Mexico Fishery Management Council, The Florida Keys National Marine Sanctuary, NOAA Deep Sea Coral Research and Technology Program, and NOAA Mesophotic Reef Ecosystem Program. The new maps and ROV dives documented extensive essential fish habitat (EFH) and coral/sponge habitat existing outside the protected HAPC boundaries. In particular, we documented extensive rugged rock habitat along the southern dropoff of Pulley Ridge which provides EFH for numerous large grouper species but is yet outside the borders of the HAPC. Also an extensive rocky escarpment was discovered and mapped south of the HAPC at depths of 500-800 m. Those sites outside the current HAPC boundaries that appear to be EFH should be of priority for future research cruises.

ii. Scientific publications

<u>Population Genetics (PG)</u>

Bernard, A.M., K.A. Feldheim, V.P. Richards, R.S. Nemeth and M.S. Shivji. 2012. Development and characterization of fifteen novel microsatellite loci for the Nassau grouper (*Epinephelus* *striatus*) and their utility for cross-amplification on a suite of closely related species. **Conservation Genetics Resources.** In Press.

iii. Patents

iv. New methods and technology –

Bio-physical (BP)

We have made design changes to our standard light traps that will allow both deep water deployment, as well as surface based deployment/retrieval activities.

v. New or advanced tools (e.g. models, biomarkers)

vi. Workshops

vii. Presentations

viii. Outreach activities/products (e.g. website, newsletter articles)

b. Management outcomes - I. Management application or adoption of:

i. New fundamental or applied knowledge

ii. New or improved skills

iii. Information from publications, workshops, presentations, outreach products

iv. New or improved methods or technology

v. New or advanced tools

c. Management outcomes - II. Societal condition improved due to management action resulting from output:

Nothing to report yet.

d. Partnerships established with other federal, state, or local agencies, or other research institutions (other than those already described in the original proposal).

3. Expenditures:

Program Management (PM)

Upon receiving notice of a 43% reduction in Year 2 funds, Project Management slowed spending in certain areas that could either be delayed (assuming that reduced funds are injected back into the overall project in later years), or cut entirely, with potential for reduction in final products and outputs. As the final state of the funding for all years is not clear, it is not possible to state at this time what is potentially lost vs. just delayed.

One key ‘delay’ is the hiring of a Project Assistant; this delay will delay/hamper various Program Management tasks, especially those associated with reporting, communication and organization of all sub-groups, as well as external interactions

As plans for the first field season are still underway (and not directly affected by year 2 budget reductions), most of the remaining Yr 1 sub-project spending will likely proceed as originally planned.

Bio-Physics (BP)

Funds have been spent on molecular processing of ichthyoplankton samples and in the construction of light traps and moorings for light trap deployment at Pulley Ridge. A portion of the salaries of two technicians are encumbered to prepare light traps and moorings, participate in the August cruise, and assist with obtaining permits for all activities.

Population Dynamics (PD)

PD reports that funds have been expended exactly as planned for this period, and that there were no differences or issues between expenditures and what was spent.

UM/Overall Budget

Cost Category	Planned Expenditures	Actual Expenditures (8 mo.)
a. Personnel	121,643.00	49,198.89
b. Fringe Benefits	37,703.00	16,155.40
c. Travel	34,750.00	21,054.48
d. Equipment	33,000.00	3,296.67
e. Supplies	40,611.00	9,813.24
f. Contractual	205,236.00	9,548.00
g. Construction	0.00	
h. Other	322,896.00	2,178.90
i. Total Direct charges	795,839.00	111,245.58
j. Indirect Charges	134,536.00	36,959.03
k. Total	930,375.00	148,204.61

<u>NOAA/AOML Y1 Disbursement:</u> $68,328

Cost Category	Planned Expenditures	Actual Expenditures (8 mo.)
a. Personnel	18,531	18,531
b. Fringe Benefits	6,856	6856
c. Travel	500	
d. Equipment	22,341	22,765
e. Supplies	7,500	7,076
f. Contractual	0	0
g. Construction	0	0
h. Other	6,000	
i. Total Direct charges	61,728	55,228
j. Indirect Charges	6,600	6,600
k. Total	68,328	61,828

<u>Subcontract Budgets</u>

UM-REPP Connectivity Pulley Ridge Project
Community Structure Sub-Group
M. Dennis Hanisak, John Reed, Joshua Voss, and Sara Edge (HBOI-FAU)
Expenditure Report (June 19, 2012)

Cost Category	Planned Expenditures	Actual Expenditures (8 mo.)
a. Personnel	$58,971	$0
b. Fringe Benefits	$19,778	$0
c. Travel		
d. Equipment		
e. Supplies	$8,760	$0
f. Contractual		
g. Construction		
h. Other		
i. Total Direct charges	$87,509	$0
j. Indirect Charges	$38,942	$0
k. Total	$126,451	$0

Per the proposed timeline, our work is to begin in Q3 (July) of 2012. Most of our Year 1 expenses are associated with the upcoming August 2012 cruise.

No expenditures were made against this sub-award; our analyses above were completed as part of our CIOERT work.

FSU (Coleman/Koenig)

Total planned expenditures to date: $39,871

Total expenditures to date: $0

The DWH oil spill caused us to re-evaluate priorities this past year. Our grad student received funding for this year elsewhere, but will need funds in year 2. Other funds are needed for the field work so we opted not to spend this year until we actually go in the field.

CAS (Note – PI L. Rocha has moved from University of Texas to the California Academy of Science [CAS])

Cost Category	Planned Expenditures	Actual Expenditures (8 mo.)
a. Personnel	15,153	7,000
b. Fringe Benefits	4,546	2,000
c. Travel	7,000	0
d. Equipment		
e. Supplies	16,000	2,000
f. Contractual		
g. Construction		
h. Other	6,150	4,000
i. Total Direct charges	41,849	15,000
j. Indirect Charges	8,560	4,000
k. Total	50,409	19,000

UF

No Year 1 Funds

FIU

NO Year 1 Funds

NOVA Southwestern

No Year 1 funds

Prepared By:________________________ June 27, 2012

Signature of Principal Investigator Date

Appendix A: Agenda

Pulley Ridge – All-PI meeting

November 29-30, 2011

RSMAS – Map and Chart Room, Library

Day 1 (Tuesday)

A.	Welcome (R. Cowen)	0845
B.	Introductions	0900
C.	Overview of project – Science proposal (R. Cowen)	0915
D.	Overview of Project – NOAA CSCOR Perspective (K. Puglise)	0945
E.	Overview Stakeholder Advisory Board (Ortner)	1000
F.	CIOERT connection (S. Pomponi)	1010
	Coffee Break	1015
G.	Background information – Pulley Ridge	1030
	a. ROV survey (past and recent – John Reed/S. Pomponi)	1030
	b. Fish surveys (F. Coleman/C. Koenig)	1045
	c. Existing Databases (D. Die)	1100
H.	Discussion --	1115
	Lunch Provided (1.5 hrs)	1200
I.	Fieldwork Planning (R. Cowen)	1330
	a. Subproject data needs	
	b. Timelines	
	c. Cruise dates	
	d. Technology available	1400
	i. ROVs	
	1. UNCW – (J. Reed?)	1410
	2. CUNY – (D. Gruber)	1420
	ii. Technical Diving – (R. Riera-Gomez)	1430
	iii. Moorings	
	iv. Light traps	
	v. Towed equipment	
	vi. Other options (require addl funding)	
	Coffee Break	1530
	e. Fieldwork Discussion – prioritization, timing, staffing, etc.	1600
J.	Adjourn	1700
	Ice Breaker (RSMAS Patio)	1701

Tentative Agenda

Pulley Ridge – All-PI meeting

November 29-30, 2011

Day 2 (Wednesday)

K.	Data Sharing	0900
L.	Data format for benthic data (ROV) (J. Reed)	0910
M.	Database format (F. Gayanilo)	0915
N.	Annual reports	0945
O.	Budgets	1000
	Coffee Break	1015
P.	Permits	1045
Q.	Future Meetings	1100
R.	General Discussion/New Business	1115
S.	Adjourn	1200
	Lunch (catered)	

Shipboard Autonomous Real-Time Environmental Observation Program Status, OceanScope Implementation and Next Steps

Project Personnel: P. Ortner (UM/CIMAS); P. Minnett (UM/RSMAS)
NOAA Collaborators: R. Wanninkhof, G. Goni and S. Cummings (NOAA/AOML)
Other Collaborators: A. Solokiev (NOVA) and R. Rossby (URI/GSO)

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

Link to NOAA Strategic Goals:
Goal 1**:** Climate Adaptation and Mitigation - *An informed society anticipating and responding to climate and its impacts* (*Primary*)

Funding Sources: Scientific Committee for Oceanographic Research; Royal Caribbean Cruiselines Ltd. Ocean Fund

Project Summary:
Provided herein are an "Operational Status Report" summarizing the current situation aboard the two ships already equipped (the *Explorer of the Seas* and the *Allure of the Seas*), a "OceanScope Status Report" describing the last six months of progress of the SCOR/IAPSO Working Group developing a plan for global implementation of the concepts pioneered aboard the *Explorer*, and a final section "Next Steps: Year Three and Beyond" discussing our plans for the current year (2012 - Year Three) of our Ocean Fund project and beyond that in 2013. Two appendices are provided: a handout prepared for a meeting at the Office of Science and Technology of the President (OSTP) and a summary of services to be provided OceanScope by a consultant firm we propose to hire this coming Fall. The $150K required to advance OceanScope and hire this consultant this would come from three sources: a $50K supplement we are requesting to our present Ocean Fund Year Three award (a total of $150K rather than the previously approved $100K to be transferred to UM/RSMAS in 2012), a matching $50K to be contributed by another major potential industry partner to be approached in collaboration with RCCL and $50K of government funding leveraged upon the private industry contributions.

Operational Status Report:

1. The *Explorer* monitoring system is operating well. During the summer of 2011, the seawater system operations on *Explorer* were halted several times due to the pump failure from substantial clogs in the pump intake. During this time period, there was a documented unusually high level of *Sargassum* weed floating at the surface in the Caribbean. We had never experienced this problem in all the previous years running the manned operations on the ship from 2000 through 2007. The seawater system on *Explorer* has been modified to include an inline strainer that will prevent this occurrence in the future. Members of our team from the University of the Virgin Islands in St. Thomas monitor the status of the equipment and laboratory spaces on *Explorer* and perform maintenance regularly, including cleaning these strainers, when the ship visits St. Thomas. Due to this recent experience, the latest system design for *Allure* was modified to include an inline strainer prior to installation.

Figure 1: *Explorer of the Seas* environmental monitoring system seawater pump clogged with *Sargassum* weed.

2. The physical components for the environmental seawater monitoring system on *Allure* were installed between February 19, 2012 and April 22, 2012. The crew secured the mounting hardware prior to this period and connected the seawater intake, discharge and fresh water connection once the system was in place. Mr. Richard Findley and Mr. Jim Lovin sailed on *Allure* from April 22 – 29, 2012 to finalize the installation and start up the system. The microTSG, which measures seawater temperature and salinity, was not operating during this initial cruise and the instrument was returned to the manufacturer for repair. During the initial evaluation period, adjustments were made to the system and since May 20, 2012 the seawater system has been operating as designed during each cruise. The repaired microTSG was reinstalled on May 20, 2012 and Ms. Elizabeth Williams sailed on *Allure* for the week in order to initiate the necessary calibration protocol for the instrument.

Figure 2: Modular Installation aboard *Allure of the Seas*

3. The *Allure* was a challenging vessel for the placement of meteorological instruments due to its extensive, intricate superstructure. At this time we have not deployed our own meteorological equipment on the ship. As a temporary measure, we have worked with the Electronics Engineer/Navigation on *Allure* to obtain the meteorological data from the ship's instruments. We have initiated discussions with NOAA's VOS (Voluntary Observing Ship) leadership to integrate our system into a test bed for their updated AMVER/SEAS software that is presently installed on *Allure* and utilized by the bridge officers to submit weather reports to the NOAA's National Weather Service system. The goal is to further automate the weather reports, while retaining the valuable information such as wave state, cloud cover and visibility, that only human input can provide at this time. Automating much of the required VOS data submission would represent a major contribution to the international IMO VOS program as emphasized to all of us at the WOC Paris meeting (see OceanScope section below) by the VOS representatives attending. As we have repeatedly been told, it would also be much appreciated by the ship's officers.

4. Between July 16- 21, 2012 the team from the University of Miami sailed on *Explorer* to perform scheduled calibration, maintenance and software upgrades for the system. Servers onboard were upgraded; the data acquisition software was upgraded and field-tested in preparation for the installation on *Allure.*

5. Most data for both the *Explorer* and the *Allure* are now being delivered hourly, through the established connection between the Royal Caribbean's Miami offices and RSMAS. Larger data sets generated on *Explorer* alone at present 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 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, and 4) data collected for two ancillary separately funded collaborating projects. This last group includes marine carbon dioxide (pCO2 - NOAA/AOML) and the ocean surface temperature skin (M-AERI - UM/RSMAS).

6. All data are made freely available and have been widely requested and used by investigators and students at Scripps Institution 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.

7. The data transfer mechanisms developed with cooperation and help from the RCI IT department has been successfully applied to the system on the *Allure*. The instruments and computers on both ships are now managed and controlled through the same connection. The connection can be adapted to add the third ship's installed monitoring system when it becomes active. 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 unachievable by the unmanned instruments installed on any other vessel.

8. The new modular core system already aboard the *Allure* is completely "open", and will allow the integration of any scientific instrumentation which can deliver and accept data via a computer network. With respect to the *Explorer* the scientists operating the carbon dioxide (pCO2) system have committed to continuing their operation for the foreseeable future but depending upon route changes would consider moving to the *Allure* or adding a similar system to *Allure* which has been built to accommodate this addition in the same instrument space. The project scientists for the satellite skin temperature (M-AERI) have received the next generation instrument and they are in the process of calibrating it. They have met with the officers on *Allure* and developed an initial design plan for installation. They are anticipating a late 2012 initial deployment on *Allure* and deployment of another new M-AERI instrument on *Explorer* in Spring 2013.

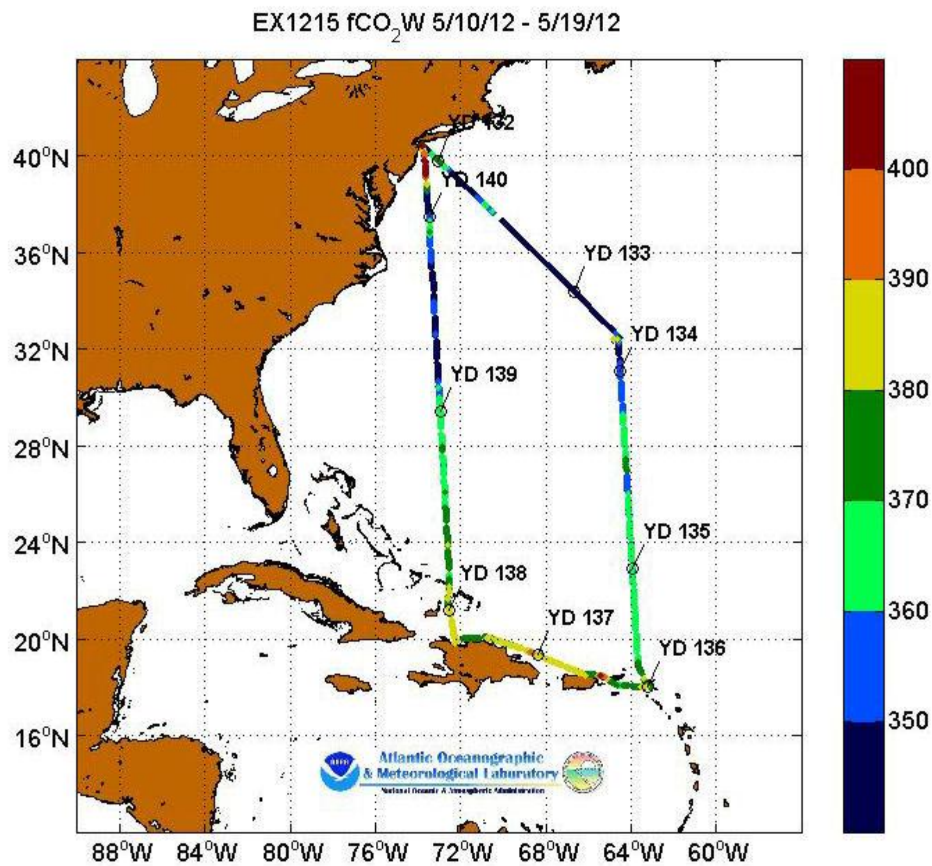


Figure 3: pCO2 measurements collected from the *Explorer of the Seas* from May 10 through May 19, 2012

9. In researching the options for guest displays on *Allure*, it was discovered that the Entertainment division has an interest in updating the Wayfinder displays to include a display screen with the ship position and environmental measurements. This is very similar to the display touch-screens that had been installed in the Eco-Learning area on *Explorer*. We have scheduled an initial meeting with Ronnie Farzad and Paul Power from Entertainment on Tuesday, July 24, 2012. Previous experience indicates the level of passenger interest in such information justifies installing sch displays on all three instrumented vessels.

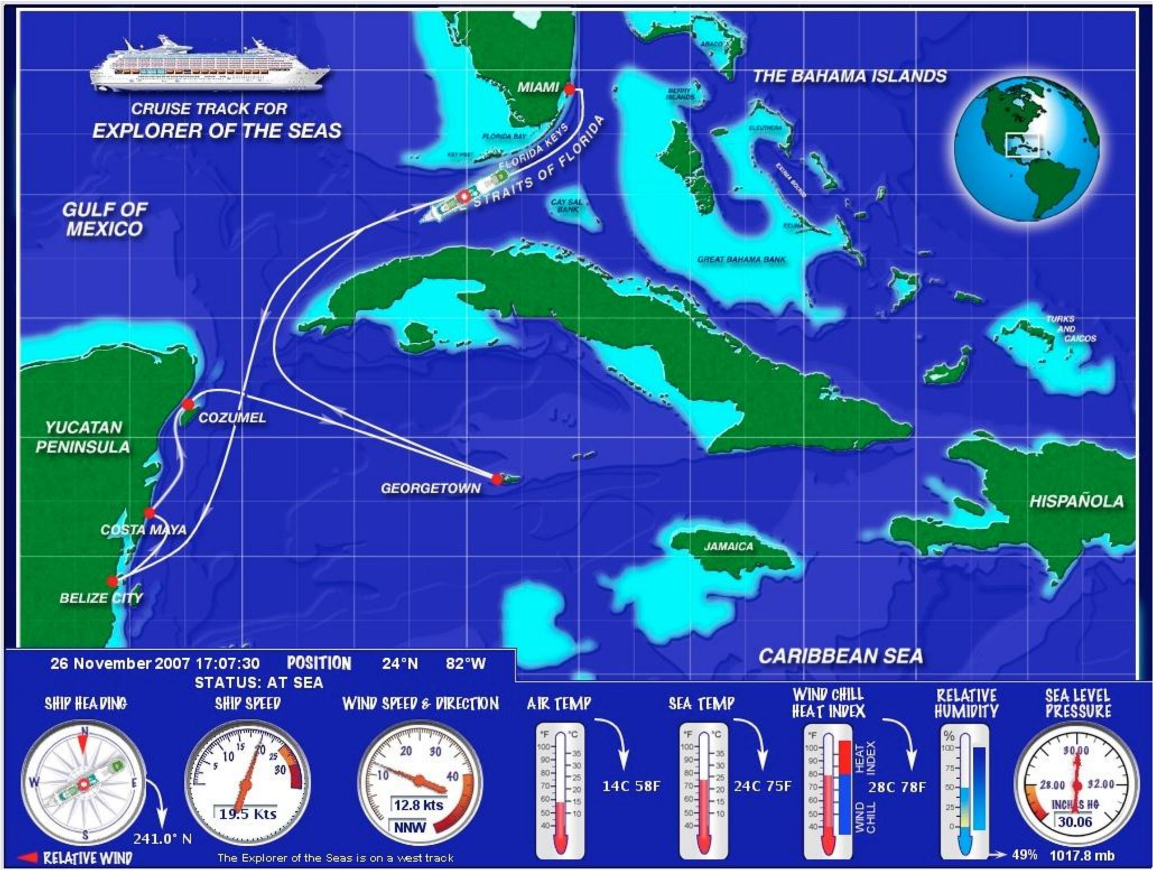


Figure 4: One screen from the guest display kiosk on the *Explorer of the Seas (2001-2007).* The measurements and ship position on this image were updated every hour.

OceanScope Status Report:

In the last six months the SCOR/IAPSO OceanScope Working Group has significantly advanced its agenda prior to and in advance of the final release of its report by the sponsoring international agencies (http://www.scor-int.org/Publications/OceanScope_Final_report.pdf) in February 2012.

1. At a meeting to establish a partnership between science and industry convened by the World Ocean Council in Paris in December 2011 a number of OceanScope Working Group members participated and there was a joint UM – RCCL presentation that was well received. (http://www.oceancouncil.org/site/pdfs/Smart%20Ocean%20-%20Smart%20Industries%20Workshop%20Report%20FINAL.pdf)

   Moreover contacts were established with MAERSK who expressed interest in contributing to the continued development of OceanScope (see **Next Steps** and below).
2. At almost the same time Rossby, Ortner *et al*. released a major publication based on the analysis of Explorer data highlighting the core premise of OceanScope: the utility of repeat transects probing the water column (*Journal of Geophysical Research*, Vol. 116, C12017, December 14, 2012)

3. In April 2012, MAERSK nominated the OceanScope Working Group for the Thor Heyerdahl award. While the likelihood of receiving the award is minimal, that they went to the effort of nominating we take as an indication of their sincere interest in the program.

4. In May 2012, Tom Rossby (co-editor with Ortner of the report and co-author with Ortner of the funded SCOR proposal establishing the Working Group), briefed senior representatives of the major U.S. federal ocean funding agencies (NOAA, NASA and ONR) at a meeting convened by the Office of Science and Technology of the President. Attached as Appendix One is the one page document distributed in advance of the meeting.

5. July 2012, OceanScope (Rossby and Ortner) were asked to attend the IOOS (Integrated Ocean Observing System) Summit to be held next November in DC and prepared a White Paper on OceanScope for advance distribution to the invited participants.

Next Steps: Year Three and Beyond

In Year Three (2012) we will complete our original plan to instrument two additional RCCL vessels and continue to advance OceanScope from vision to project implementation. Moving just beyond that into 2013, we plan to operate the systems aboard the RCCL vessels and participate in the initial efforts to initiate OceanScope implementation as described below.

1. With respect to our original three year proposal to the Ocean Fund we plan to complete a second modular system and install it upon a ship (either RCI or Celebrity) as yet to be determined. Components for this have already been ordered (those with a longer lead time) and with the experience of *Allure* we expect assembly in the lab and installation aboard to be a lot quicker.

2. The selection of the next ship installation will depend upon a number of selection criteria: 1) scientific value of its geographic coverage in its contributions to long-term climate monitoring and filling in gaps coverage 2) the ease of installation 3) ease of access for annual maintenance and the potential for additional technical support from sister institutions, which will promote OceanScope networking 4) importance of choosing a ship with two annual transatlantic crossings, and, finally, 5) the next projected dry dock year for the ships under consideration which would provide an opportunity to test the next phase of installations in a bulbous bow location.

   TransAtlantic passaging ships currently being considered include:
   <u>Royal Caribbean International ships:</u>
   Jewel of the Seas - Europe/Canada/Caribbean
   Brilliance of the Seas – Europe/Canada/Caribbean
   Navigator of the Seas – Europe /Caribbean
   Liberty of the Seas – Europe/Caribbean
   Independence of the Seas - Europe/Caribbean
   Vision of the Seas – Europe/Panama Canal/Caribbean

   <u>Celebrity ships</u>:
   Constellation – Russia/Scandinavia/Greece/Turkey/Caribbean

Solstice - Australia/Caribbean/Mediterranean/Greek Isles/Suez Canal
Equinox - Caribbean/Mediterranean/Greece/Turkey
Silhouette - Caribbean/Italy/Eastern Mediterranean/Adriatic
Reflection - Caribbean/Mediterranean
Eclipse - Caribbean/Mediterranean

On the other hand, our OceanScope partners at the National Oceanographic Centre in Southhampton, U.K., would like to cooperate with us in instrumenting (and maintaining) the *Sovereign of the Seas* which regularly visits Southampton. They have already been aboard to inspect the ship's spaces.

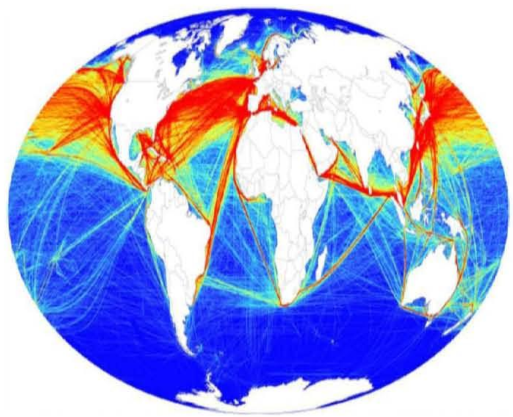
3. Advancing OceanScope in accordance with the implementation plan and schedule provided in the report will require over the coming months:

a) Establishing an OceanScope subgroup to work with the ICS and WOC to obtain an IMO circular endorsing OceanScope and promoting industry cooperation (akin to that provided for the VOS vessels);
b) Forming an Ad Hoc OceanScope Advisory Committee with Industry, Government and Science membership;
c) Forming an OceanScope Technology subgroup to address some of the key issues that have already been identified (optimal instrument location and minimization of bubble interference) as well as to work with with the instrument development industry to advance some of the most promising technologies discussed in the report; and,
d) Hiring a consultant to work with OceanScope leadership in developing a business plan and a funding strategy. Given the current governmental funding situation, it is our expectation that major private philanthropic foundation support will be required to implement the North Atlantic Test Bed (Phase One of OceanScope) and to leverage the international intergovernmental support needed to achieve the global vision of OceanScope. A consultant experienced in this area is essential to advance this agenda. Initial discussions have been held with Blue Earth Consultants who recently facilitated the Google charette on ocean observations and have worked successfully in this arena. Attached as Appendix Two are some preliminary materials provided to us describing the services they can offer us.

4. Advancing OceanScope will require funding now that we have exhausted the funds provided the Working Group by SCOR and IAPSO. This would come from three sources: <u>a $50K supplement we are requesting to our present Ocean Fund Year Three award (a total of $150K rather than the previously approved $100K to be transferred to UM/RSMAS in 2012)</u>, a matching $50K to be contributed by MAERSK whom we approach in collaboration with RCCL and $50K of government funding leveraged upon the private industry contributions once those commitments have been obtained.

OceanScope

OceanScope proposes a formal partnership between the ocean-observing community and the global shipping industry for the systematic long-term study of the ocean water column from the surface to depth. According to the report released by Scientific Committee on Oceanic Research/International Association for the Physical Sciences of the Oceans (SCOR/IAPSO) Working Group 133, the rationale is that commercial ships on the high seas offer a cost-effective opportunity to contribute to directly addressing a significant observational gap in the present and planned global ocean observing system. Through science-industry partnership, the implementation of standardized methods and technologies and a fleet sufficient to achieve economies of scale, OceanScope's systematic long-term observation of the water column would serve four distinct and critical needs: forecast/ nowcast applications; studies of ocean processes and dynamics; effects on climatology; and informed knowledge of the state of the global ocean from the surface down



The Opportunity: Global Commercial Traffic in 2009

What is unique about the OceanScope concept is its proposal to directly measure ocean currents, to create synergies by integrating circulation measurements with simultaneous present and next-generation chemical and biological measurements and to freely distribute these data to the international research and operational ocean communities.

What is also unique is that the partnership proposed is the product of a Working Group that included not only scientists, but also ship owners and operators, naval architects, government agencies and ocean technology companies. The Working Group's report has been enthusiastically received by major industry organizations including the International Chamber of Shipping and the World Ocean Council. The complete OceanScope report (Ortner and Rossby, co-editors) can be downloaded from the SCOR website: http://www.scor-int.org/Working_Groups/wg133.htm.

What is proposed therein is to establish OceanScope as a non-governmental entity and begin in the North Atlantic Ocean basin with the initial assistance of substantial private foundation funding. A 5-year ramp-up is envisioned, which would serve to fully test, evaluate, and refine the program before sustained national and international funding is required for global implementation.

International Council for Science SCOR Scientific Committee on Oceanic Research

IAPSO

BLUE EARTH
CONSULTANTS

Creating sustainable solutions

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Overview of Blue Earth Consultants and Potential Services for OceanScope

Blue Earth Consultants is an environmental consulting firm founded in 2005 with a portfolio of over 65 projects completed for a multitude of clients in the United States and internationally. The firm work across sectors and specializes in developing sustainable solutions to complex, multi-faceted marine and terrestrial issues, providing the best ideas and consulting services that help improve resource management and sustainable practices around the world. Blue Earth Consultants has expertise and engages in funding and financing framework design, partner and funder engagement and development, strategic planning and institutional design, science integration, research and analysis, and the implementation of sustainable management measures. Blue Earth Consultants recommends innovative and practical tools and strategies to enhance resource management, sustainable practices, and environmental and social resiliency. It assists in the creation of institutions, programs, and projects that realize significant returns for the environment and social welfare. More information about Blue Earth Consultants is available at www.BlueEarthConsultants.com.

Blue Earth Consultants is well-positioned to assist OceanScope with assessment and rollout of a fundraising strategy, as well as provide advice and recommendations for development of the most effective institutional design to support OceanScope in effectively achieving its goals over the next 5 years. Blue Earth Consultants proposes providing consulting services in four key areas, described below:

- Situational Analysis and Feasibility Assessment: Blue Earth Consultants will conduct interviews with donors and other experts and perform additional research to better understand and assess the donor landscape and feasibility of securing funding for OceanScope. This work will help offer insights into where efforts are best spent as well as the most appropriate methods for framing donor engagement and cultivation approaches. It will also assist in raising awareness and gaining buy-in for the project.
  - Deliverable: PowerPoint of findings and recommendations
- Fundraising Strategy: Building off of results of the situational analysis and feasibility assessment, Blue Earth Consultants will perform research to identify potential donors within the foundation and company-sponsored foundation sectors whose goals and priorities overlap with OceanScope and will store all relevant data into a *funder database*. The consultants will then identify and prioritize top prospects using a criteria ranking methodology. Based in findings, Blue Earth Consultants will then craft a fundraising strategy that will include cultivation approaches, target ask amounts, and timeline.
  - Deliverable: Fundraising strategy and funder database
- Donor Cultivation Support: Blue Earth Consultants will assist OceanScope in approaching and developing relationships with potential donors. The firm will assist with the development of an "elevator pitch" and prepare talking points and other materials tailored to best engage each donor. This service could also include development of professionally designed marketing collateral, such as a brochure or webpage, for example.
  - Deliverables: Elevator pitch and customized donor talking points; marketing collateral (optional)
- Institution Building Support and Guidance: Blue Earth Consultants will assist OceanScope in evaluating and identifying the most effective institutional design to achieve the project goals. These services may range from high-level, with presentation of options and recommendations for OceanScope to consider to more in-depth, including creation of the institutional design framework and implementation assistance.
  - Deliverables: TBD

Development of an Autonomous Ammonium Fluorescence Sensor (AAFS) with a View Towards *In-situ* Application

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Award Number: *N000141010210*

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

Link to NOAA Strategic Goals:
***Goal 3*:** Healthy Oceans - *Marine fisheries, habitats, and biodiversity sustained within healthy and productive ecosystems*
***Goal 4*:** Resilient Coastal Communities and Economies - *Coastal and Great Lakes communities that are environmentally and economically sustainable*

Funding source: National Ocean Partnership Program (ONR and NSF)

LONG-TERM GOALS

Our goal is to develop a portable autonomous ammonium sensor. Such a sensor could be deployed for periods of up to a month aboard ships, moorings or drifting buoys or used as a component in lowered or towed oceanographic instrument packages for vertical profiling.

OBJECTIVES

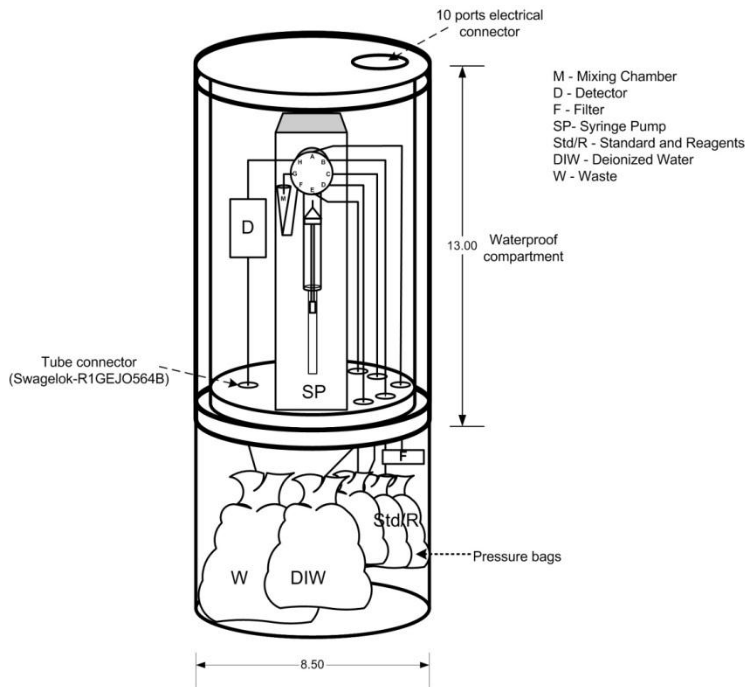
Our technical objective is to develop a robust, relatively simple, inexpensive, low power and compact instrument with a detection limit in the nM range and a sampling frequency of at least 6 samples per hour. Robustness, simplicity, low construction cost, lower power and small size are the practical desiderata for commercial application. Commercialization and the lowered instrument costs that will result are essential to permit wider application throughout the oceanographic community.

APPROACH AND WORK PLAN

Our approach has been to first design, assemble and demonstrate engineering prototypes suitable for bench-top laboratory use, take these aboard ship and once we have achieved the key design objectives test these first in an ongoing sampling program at coastal sewage outfalls along the east coast of Florida and second underwater by taking advantage of a "permanent" large mooring associated with the NOAA underwater habitat in the Florida Keys. Once we have achieved (and verified in the field) all our basic design objectives we will then concentrate upon further miniaturizing, reducing power consumption as much as possible and re-packaging for the possible alternative applications. These last efforts will be facilitated by the large and diverse South Florida user community and the related instrument development activities occurring both at UM/CIMAS and AOML. Key personnel in the initial steps are Drs. Amornthammarong and Dr. Zhang. Dr. Ortner, his graduate student and Mr. Shailer Cummings, while assisting in these initial steps, will take a much larger role with regard to underwater deployment and field testing.

WORK COMPLETED

Since the project started, progress has been rapid and specific advances made with regard to the basic mechanics of instrumentation. First an effective, simple mixing chamber was designed that could be used in conjunction with a syringe pump for flow analysis. Second a new design of fluidic system was developed incorporating this mixing chamber, the Autonomous Batch Analyzer (ABA) system, and the ABA was repeatedly tested in the field (on a ship, at a coastal inlet, etc.). Both have been described in the peer-reviewed literature (Amornthammarong et al, 2010 and 2011). Highlights of the results obtained are presented below. Building upon these advances a submersible, battery-powered system has been designed (see figure below) and is now under construction. The electrical port provides access to data logger, communication and battery modules. These will either be self-contained and submersible or will be incorporated into larger integrated buoy or moored systems in order to facilitate longer deployment periods and take advantage of pre-existing data communication channels.



RESULTS

A simple, effective mixing chamber used in conjunction with a syringe pump for flow analysis was developed and thoroughly evaluated in the laboratory. It was constructed using a conventional 5 ml pipette tip and its performance compared with a widely-used mixing coil. The results obtained demonstrated that the standard mixing coil does not rapidly and completely mix solutions. Utilizing a configuration that reversed solution positions in the chamber with each mixing cycle, the proposed mixing chamber was able to achieve complete mixing in a significantly shorter time than the mixing coil. The influence of injected sample volume on absorbance signals was then evaluated by calculating an $S_{1/2}$ value for the system. As tested with a minimal rinse, the system has no discernable carryover. Testing this new approach in our previously described silicate measurement system resulted in a more than two fold improvement in sensitivity (see Amornthammarong et al, 2010).

An autonomous batch analyzer (ABA) was then developed for the measurement of ammonium in natural waters. The system combined previously described batch analysis and continuous flow analysis methods and our new mixing chamber (see Amornthammarong et al, 2011). With its simpler design, the ABA system is robust, flexible, inexpensive, and requires minimal maintenance. The sampling frequency is ca. 8/hr and the potential limit of detection ca 1 nM which is comparable to the most sensitive flow through or batch analysis methods previously described and within the design specifications we had set for our project. In addition, the system produces a calibration curve by auto-dilution from a single ammonium stock standard solution with the same accuracy as traditional manual calibration methods. This last aspect is particularly important for extended (one month or longer) *in- situ* deployments.

Representative results obtained during the field tests are given below. Figure 1 plots underway measurements of ammonium in the surface seawater in South Florida coastal waters, including Florida Bay, Florida Key and Southwest Florida shelf waters taken aboard a cruise of the UNOLS vessel, RV/F.G. Walton Smith. Concentrations were elevated at several near shore locations near freshwater outflows from the Big Cypress/Southern Everglades. The shipboard system was remotely controlled and monitored from Miami over the Internet without any operating technician on board. It was then deployed at shore-locations. Figure 2 shows the ammonium concentrations in Lake Mabel (Port Everglades, Fort Lauderdale, FL) during May 17-20, 2011. The results clearly show a cycle with ca. 24-25 hr periodicity. Figure 3 shows the ammonium concentrations in the Port Everglades inlet from June 30 – July 6, 2011. There were two ammonium maxima around 4 am and 4 pm every day from 1-3 July. The ammonium cycles closely match the tidal cycles in the inlet with outflow water carrying high ammonium concentration. The ammonium concentrations were low during holidays (3-4 July) and a heavy rainfall day (5 July). The data were much more variable than those from Lake Mabel. In both cases the tested systems were self-contained and operated autonomously.

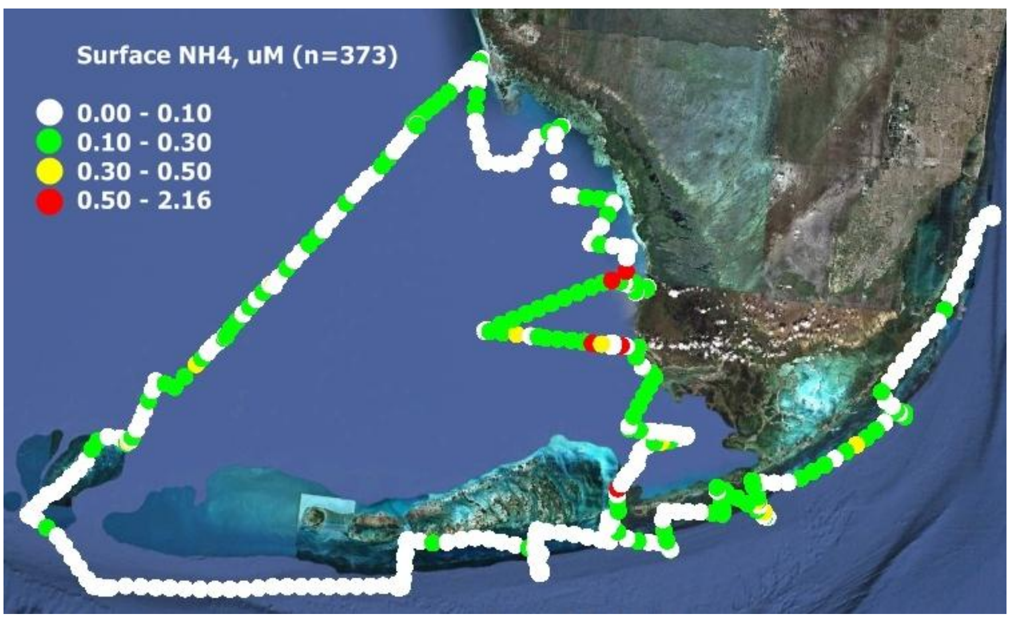


Figure 1. Surface ammonium concentrations in Florida Bay and vicinity during June 7-11, 2011.

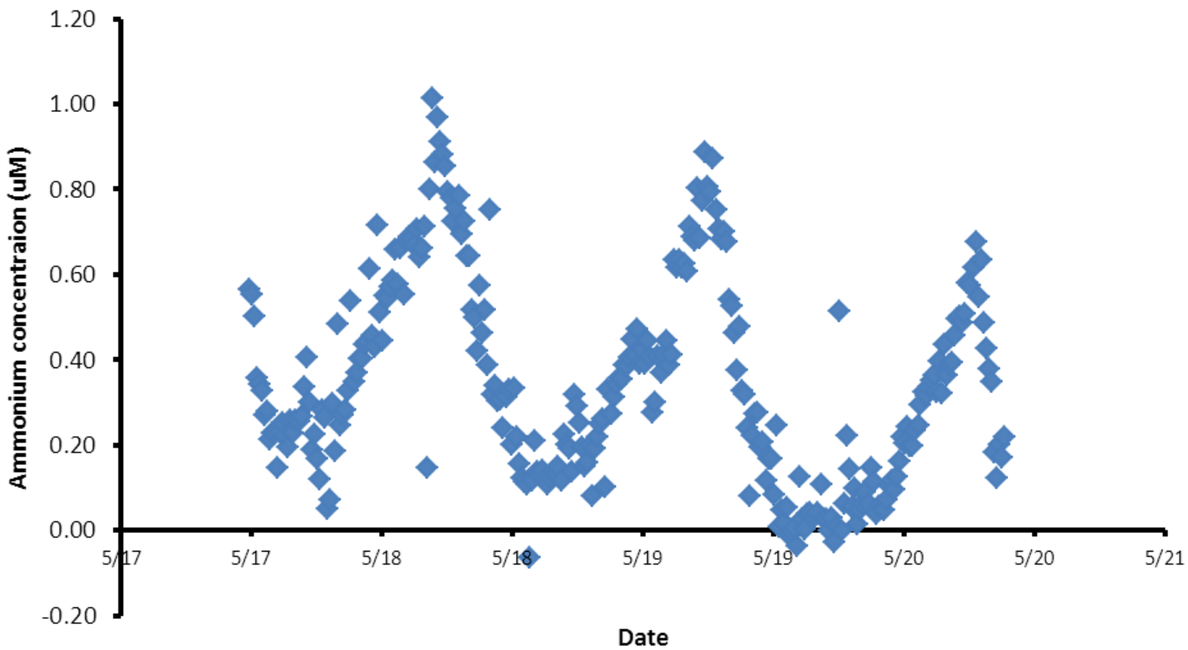


Figure 2: Ammonium concentrations in Lake Mabel (near Florida Atlantic University at Port Everglades, Fort Lauderdale, FL) during May 17-20, 2011.

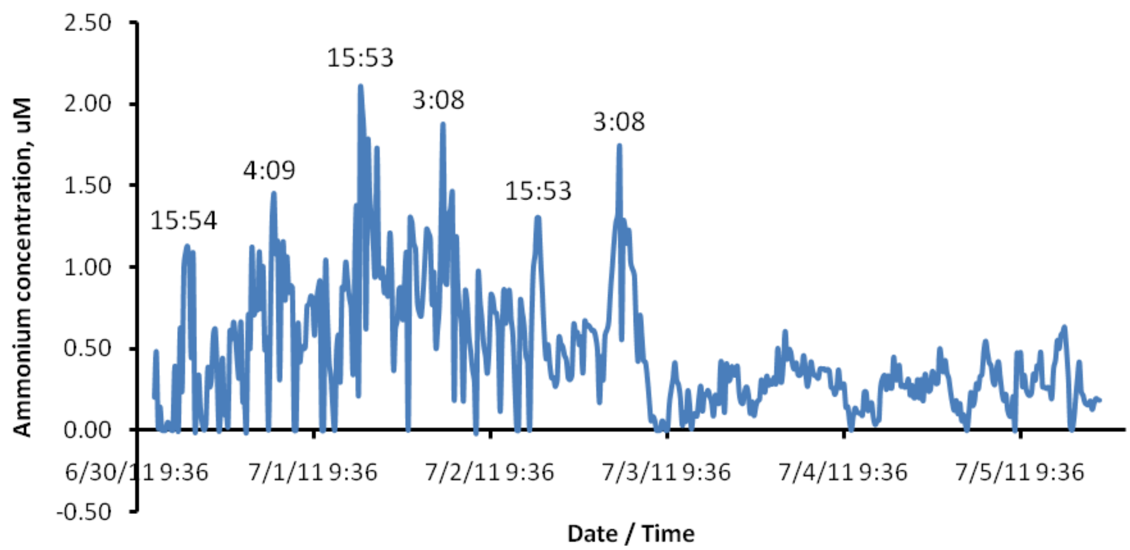


Figure 3. Ammonium concentrations at Port Everglades inlet, Fort Lauderdale, FL from 6/30/11 to 7/6/11.

IMPACT AND APPLICATIONS

Economic Development

The sensor system being developed will have broad applicability as a research tool in biological oceanography but more significant with respect to economic development is its wider market potential for regulatory-required monitoring of ammonium. Moreover, the basic design we have pioneered through the ABA system can be adapted to automating other wet chemical reactions such as nitrate, nitrite and phosphate, etc. extending its commercialization potential.

Quality of Life

Given the central ecological significance of ammonium in coastal and oceanic ecosystems a sensor system permitting long-term and near real-time cost effective measurements will be of significant assistance with regard to ecosystem based management of coastal living marine resources.

Science Education and Communication

With respect to science education the primary relevance will be incorporation of the system (and the measurements it permits) in graduate theses and dissertations within the marine science community. Moreover data streams from contexts of local political significance (e.g. documenting the extent of pollution associated with individual point sources like sewage outflows or groundwater springs could be useful for public outreach and education.

When the development and testing is complete we will be able to deploy such an instrument to monitor in situ ammonium in the coastal and ocean water column to study the variable influx of this rapidly assimilated nutrient that is associated with migration of zooplankton populations in benthic communities (including coral reefs), zooplankton and mesopelagic fish vertical migration, grazing by schooling herbivorous fishes and intermittent physical processes such as breaking internal waves, wind-mixing etc.

TRANSITIONS

Economic Development

Contacts have already been established (and interest expressed) by commercial instrument manufacturers.

Quality of Life

The instrument has already been used in the Florida Area Coastal Environment (a federal/state/private industry partnership) to monitor surface concentrations of ammonium in the coastal waters of the Florida Keys and south-eastern coastal waters with respect to point sources like inlets adjacent to population centers and sewage outfalls.

RELATED PROJECTS

NONE

REFERENCES

Amornthammarong, N. and Zhang, J.-Z. (2008). Shipboard Fluorometric Flow Analyzer for High-Resolution Underway Measurement of Ammonium in Seawater. *Anal. Chem.* 80, 1019-1026.

PUBLICATIONS

Amornthammarong, N.; Ortner, P.B. and J.-Z. Zhang (2010). A Simple, Effective Mixing Chamber Used in Conjunction with a Syringe Pump for Flow Analysis. *Talanta.* 81, 1472-1476.

Amornthammarong, N.; Zhang, J.-Z. and P.B. Ortner (2011). An Autonomous Batch Analyzer for the Determination of Trace Ammonium in Natural Waters Using Fluorometric Detection. *Anal. Methods.* 3, 1501-1506.

PATENTS

The University of Miami Patent and Copyright Committee has accepted the AAFS (Case Number UMJ-178) and is proceeding with test marketing to determine commercial interest.

Should the submersible system is successfully tested; another patent application will be filed by the University of Miami Patent and Copyright Committee.

OUTREACH MATERIALS

This work was highlighted in an internal newsletter of Atlantic Oceanographic and Meteorological Laboratory: AOML Keynotes, May-June 2011, Vol. 15, No. 3, Page 6 as in the following link.
www.aoml.noaa.gov/keynotes/PDF-Files/May-June11.pdf

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Public Hurricane Loss Projection Model

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

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

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

Link to NOAA Strategic Goals:
***Goal 2*:** Weather-Ready Nation - *Society is prepared for and responds to weather-related events*

Funding Source: FIU

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

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

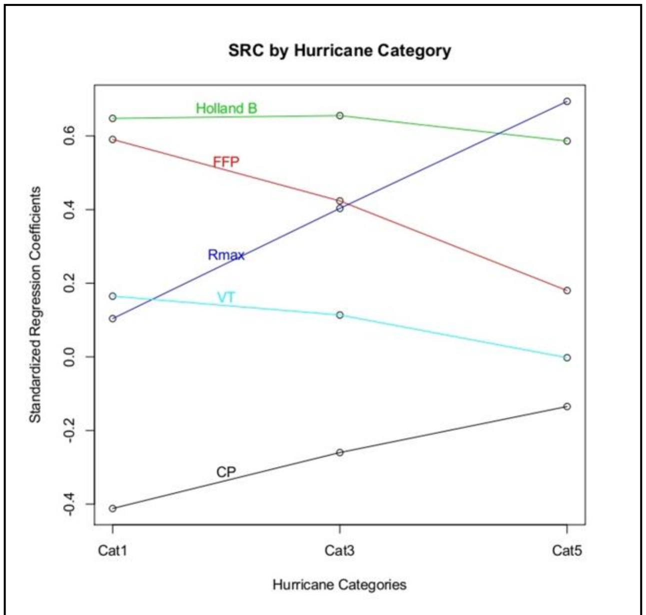

Figure 1: Standardized regression coefficients of the expected loss cost as a function of the model input variables for Category 1, 3 and 5 hurricanes.

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

The activities of the past year have focused on updating the residential model to make use of the latest climatic data and to provide wind risk information at 1 km resolution. Also our focus was to meet the standards of the 2011 Report of Activities of the Commission on Hurricane Loss Projection Methodology. The Florida Commission on Hurricane Loss Projection Methodology employs a professional team of experts to review hurricane loss models according to a book of standards. The meteorology part of the FPHLM passed the "pro team" review in August and received a unanimous acceptance vote from the Commission on Wednesday, August 17, 2011.

Research Performance Measure: All objectives were met on schedule.

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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 EDW volume, (2) to characterize its dependence on ocean processes and atmospheric forcing (with guidance from other CLIMODE analyses), (3) to parameterize these proceses 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*:** Combine data analyses and numerical model outputs.

CIMAS Research Theme:

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

Link to NOAA Strategic Goals:

***Goal 1*:** Climate Adaptation and Mitigation - *An informed society anticipating and responding to climate and its impacts*

Funding Source: NSF

Research Summary:

Observations and outputs from coupled climate models were used to estimate and analyze the volume of Eighteen Degree Water (EDW) and to investigate its relationship with other climate properties. Results from observational analyses were used to assess the models' performance. Three coupled models (GFDL coupled data assimilation (CDA), GFDL CM2.1, and NCAR CCSM3.0) are analyzed to evaluate how well EDW processes are simulated in those models, and to examine whether data assimilation improves or degrades the model's response to forcing.

In comparison with estimates from observations, the data-assimilating model gives a better representation of the formation rate, the spatial distribution of EDW, and its thickness, with the largest EDW variability along the Gulf Stream path (Figure 1). The thickness EDW layer is found within 5 degrees latitude of the Gulf Stream from observations and GFDL CDA, but not for the GFDL CM2.1 and NCAR CCSM3.0. However, GFDL CDA does not capture well the observed relationship between EDW volume and the seasonal destruction of EDW. Model-data differences are also seen in seasonal evolution of the EDW volume and formation. Observations show that the EDW volume peaks in April and the formation rate peaks in February, but both EDW volume and formation rate from models peak earlier by one or two months. The EDW formation rate in GFDL

CM2.1 is quite low compared with observations, which is related to the weak air-sea heat loss in the model (Figure 2). Unlike the observed dominant southward movement of the EDW, the EDW in models moves eastward after formation in the excessively wide Gulf Stream in the models.

Observations show a robust anti-correlation between the upper ocean heat content and air-sea heat flux, with upper ocean heat content leading air-sea heat flux by a few months. This anti-correlation is well captured by GFDL CM2.1 and CCSM3.0, but not by GFDL CDA (Figure 3). Only GFDL CM2.1 captures the observed anti-correlation between the upper ocean heat content and EDW volume (Figure 4). This suggests that, although data-assimilation process corrects the temperature field to better represent the observed EDW variability and spatial distribution, it degrades the model's thermodynamic response to forcing.

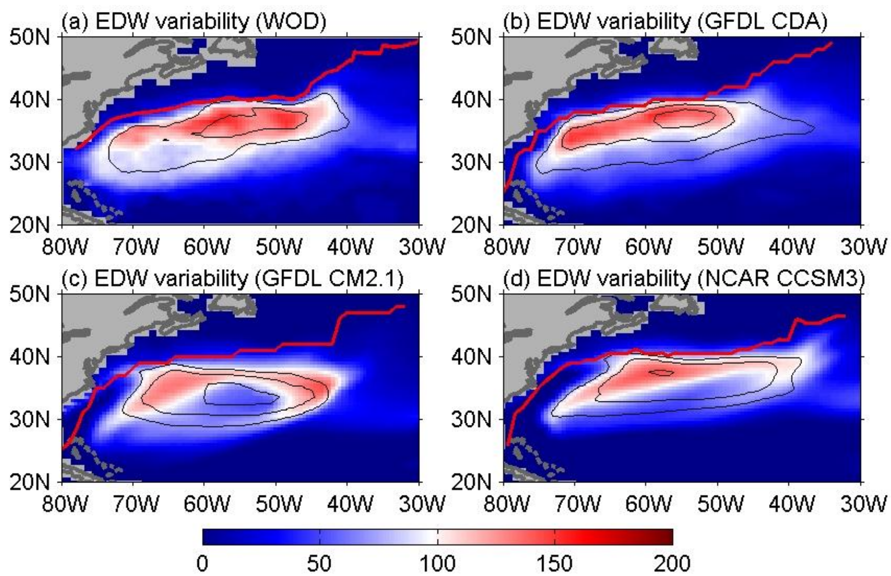

Figure 1: Spatial distribution of the variability of EDW volume from (a) WOD (observation), (b) data-assimilation model GFDL CDA, (c) GFDL CM2.1, and (d) NCAR CCSM3.0. Black contours are the EDW layer thickness. Units are in meters.

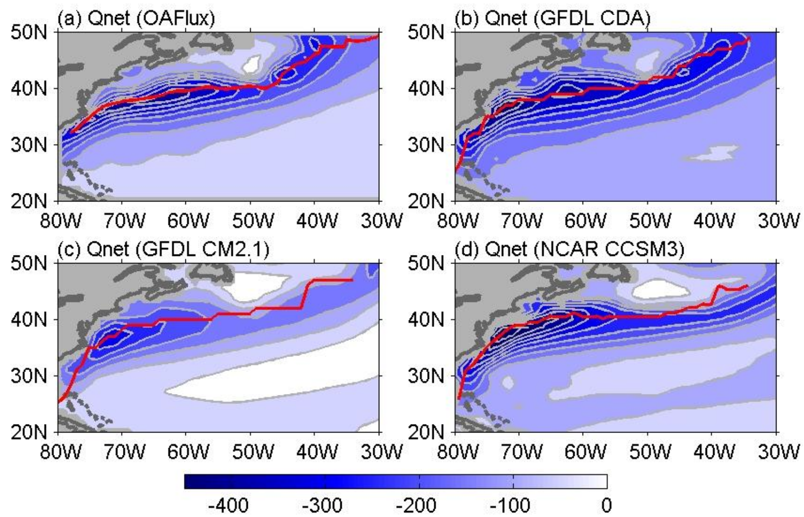

Figure 2: Wintertime (JFM) air-sea heat fluxes from (a) OAFlux, (b) data assimilation model GFDL CDA, (c) GFDL CM2.1, and (d) NCAR CCSM3.0.

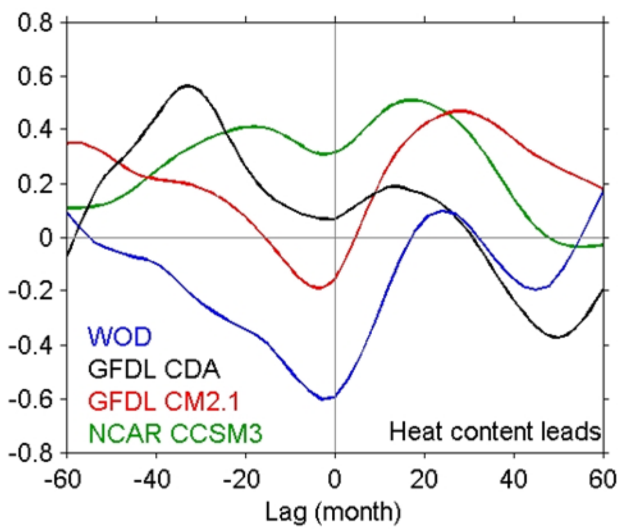

Figure 3: Lagged correlation between upper ocean heat content and EDW volume from observation (blue line) and models (CDA: black, CM2.1: red, CCSM3.0: green).

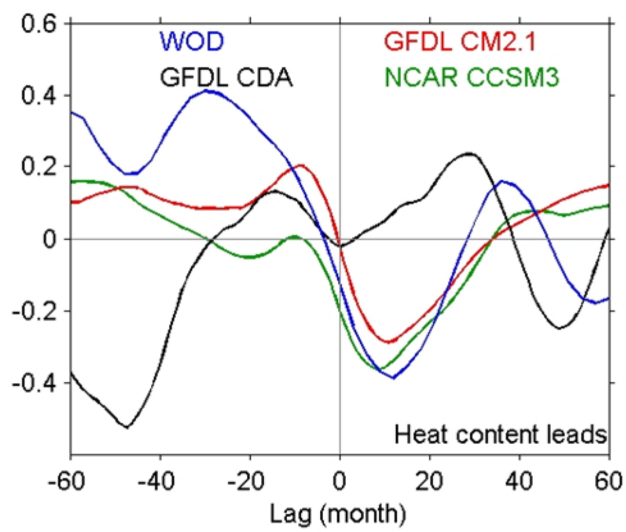

Figure 4: Lagged correlation between upper ocean heat content and air-sea heat flux from observation (blue line) and models (CDA: black, CM2.1: red, CCSM3.0: green).

Research Performance Measure: The main object is 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.

Global Impact of Eddies on Inertial Oscillations of the Mixed Layer

Project Personnel: R.C. Perez (UM/CIMAS)
NOAA Collaborator: R. Lumpkin (NOAA/AOML)
Other Collaborators: J.M. Lilly and 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 1**:** Climate Adaptation and Mitigation - *An informed society anticipating and responding to climate and its impacts*

Funding Source: NSF

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. 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.

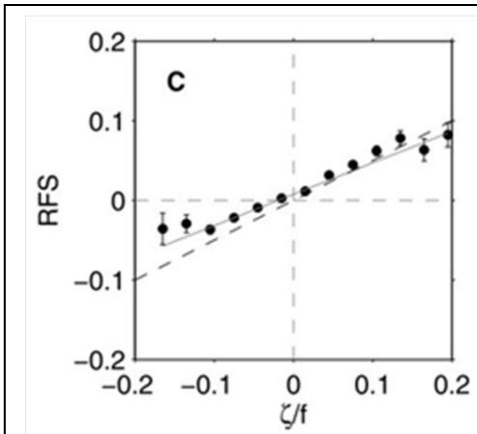

Figure 1: Mean relative frequency shift of near-inertial oscillations seen by drifters (vertical) vs. mesoscale background vorticity (ζ/f) determined from altimetry (horizontal). Error bars correspond to the standard error of the mean in each bin. Figure reproduced from Elipot et al. (2011).

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.

Research Performance Measure: The drifter data assembly center at NOAA/AOML generated a high-resolution drifter dataset. PI Rick Lumpkin has improved the drifter data set such that undrogued drifters that were previously categorized as drogued at 15 m are removed from the data set. A meeting with PIs Jonathan Lilly, Renellys Perez, and Rick Lumpkin will be held in June 2012 to plan upgrades for the next version of the data set.

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Early Warning 4-D Remote Sensing System to Assess Synoptic Threats to Coastal Ecosystems of Florida and of Adjacent States and Nations

Peter B.Ortner
Principal Investigator

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

Link to NOAA Strategic Goals:
***Goal 3*:** Healthy Oceans - *Marine fisheries, habitats, and biodiversity sustained within healthy and productive ecosystems*

Funding Source: USF/FIO

This subcontract with the University of Miami/CIMAS supports Mr. Nelson Melo, a CIMAS Task II research employee, to provide technical expertise at sea to collect optical data and other specific parameters that would be most useful for comparison with satellite and airborne remote sensing products, and to participate in post-cruise data processing and analysis.

Under the subcontract mentioned above, Nelson Melo participated from November 2011 to now (March 2012) in 2 bimonthly 5-day interdisciplinary cruises of the south Florida coastal waters south of the Caloosahatchee River mouth, including the southwest Florida shelf and the Florida Keys, aboard the University of Miami's R/V F. G. Walton Smith. During the cruises Melo collected and preprocessed 26 optical profiles with the PRR-2600 Profiling Reflectance Radiometer, 13 profiles with the PUV2500 ultraviolet radiometer, 15 hyper-spectral profiles with the Satlantic Hyper-Pro Radiometer and 26 surface hyper-spectral spectrums with the GER1500 hyper-spectral spectrometer. The data have been shared with the University of South Florida Institute for Marine Remote Sensing (IMaRS) and with the Optical Oceanography Laboratory Colleague of Marine Science. Melo is collaborating in processing the cruise data and preparing a paper entitled: “Optical Characterization of the Coastal Waters in South Florida”

VII. EDUCATION AND OUTREACH

With respect to Education and Outreach CIMAS activities have just begun to reach 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.

Enhancing minority participation in NOAA relevant science

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 in this program under the leadership of Dr. D.Die, who is the UM P.I. of the Living Marine Resources Cooperative Science Center (LMRCSC). This center is aligned with NMFS and therefore has as objectives:

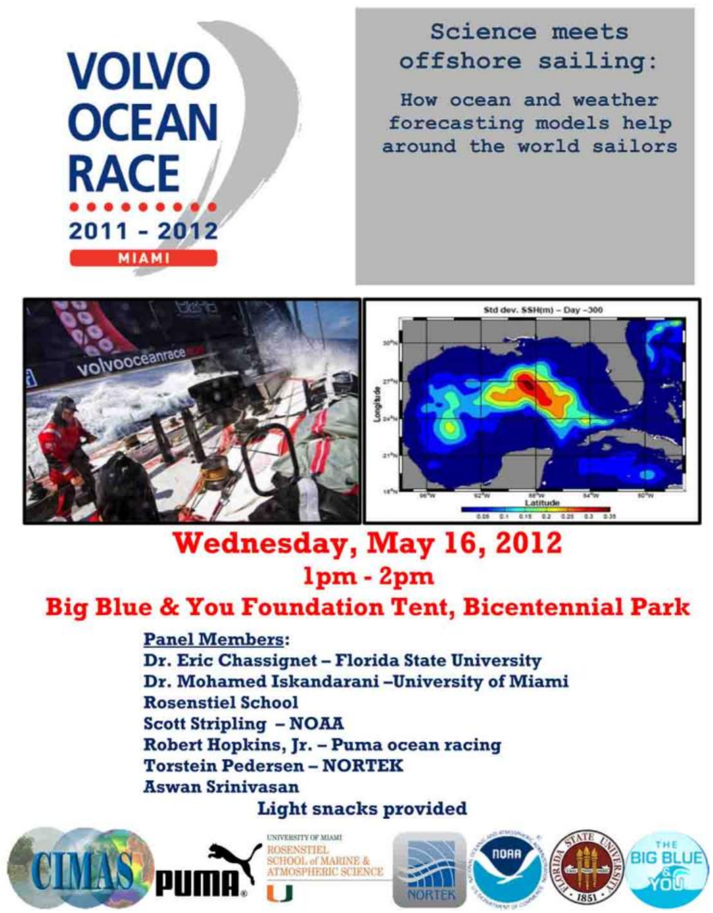
(1) prepare the future workforce in marine and fisheries sciences,
(2) strengthen collaborations across universities to enhance academic programs in marine and fisheries sciences,
(3) develop an exemplary capacity for scientific collaborations among partner institutions in the fields of marine and fisheries sciences.

As one of the three research-based University partners in the LMRCSC, UM involvement in the Center is focused on increasing diversity among participants in the UM PhD programs in the following areas: Quantitative Fisheries Science, Fisheries socio-economics, Fisheries Habitat and Aquaculture. Although the program is not funded through CIMAS, Dr. Die's educational role within CIMAS supports the activities of the LMRCSC and CIMAS often funds part of the research and studies of some LMRCSC students. The participation of US Caribbean Universities in the CIMAS partnership benefits the LMRCSC by enhancing the recruitment of a diverse student body to RSMAS. During the current reporting period four PhD students were supported by the LMRCSC, two of whom completed undergraduate degrees at the University of Puerto Rico before joining the RSMAS PhD program.

Science meets offshore sailing:

How ocean and weather forecasting models help around the world sailors

CIMAS organized and funded an outreach activity to bring together users (Volvo Ocean Race teams) of ocean (Wind, Wave, Current) forecasting products with scientists that develop models and commercial products (from CIMAS, NOAA and industry) to discuss the future of Ocean forecasting. This activity was open to the public and took place at the Volvo Ocean Race village in Miami on May 15 2012. The panel of experts consisted of Dr. Eric Chassignet (FSU), expert in Ocean current predictions, Mr. Robert Hopkins (Puma racing team), assistant navigator to the racing team, Dr. Mohamed Ishkandary (UM), expert in oceanic flow simulations, Mr. Torstein Pedersen (Nortek) expert in ocean engineering and Dr. Scott Stripling (NOAA) an expert in meteorology. The event was moderated by Dr. David Die, associate Director of CIMAS and hosted in the tent of "The Big Blue and You Foundation" our outreach and education partner for this event. This foundation was funded by a CIMAS supported graduate of the University of



Miami and aims to "..*inspire, educate and empower today's youth to become stewards of the Earth and guardians of the Ocean"* (http://www.thebigblueandyou.com/about-us/mission/). The event was held at the Volvo Ocean Race Miami village during the days when the race teams had a stopover in Miami to maximize the chance of getting people that were visiting the village to attend it. With the help of video footage from the Volvo Ocean Race and questions directed to panel members the public was able to see how research produced by CIMAS and NOAA scientists has been taken up by private industry to develop commercial products used by ocean racers. Panel members agreed that advances in observation technologies and predictions models are essential for the advancement of sailing technology. Panel members discussed some of the technical bottlenecks that make the development of more accurate predictions of wave, currents and winds.

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

Assessing the Sensitivity of Northward Heat Transport/Atlantic Meridional Overturning Circulation to Forcing in Existing Numerical Model Simulations
Shenfu Dong (UM/CIMAS)

- Dong, S., and co-authors, 2011: "Observations and Climate: The Contribution of the XBT Network to Climate Studies". WCRP meeting, Boulder CO.
- Dong, S., 2012: "How well do climate models reproduce the MOC/MHT in the South Atlantic". NOAA/AOML/PHOD Retreat, Miami FL.

NOAA Climate Test Bed (CTB) National Mult-model Ensemble (NMME) Prediction System Phase 1 NMME Implementation Plan
Ben Kirtman (UM/RSMAS)
The results of the NMME project being served in graphical form only by CPC (http://www.cpc.ncep.noaa.gov/products/NMME/), and the digital data are being served at the IRI (http://iridl.ldeo.columbia.edu/SOURCES/.Models/.NMME/). The CPC site primarily serves the real-time needs of the project, and the IRI site, along with the analysis tools that are being developed at the IRI (http://iridl.ldeo.columbia.edu/home/.tippett/.NMME/.Verification/), primarily serves research needs in terms of assessing the prediction skill and predictability limits associated with phase-I and in terms of designing the phase-II experimental protocol. While the phase-I data is limited to monthly mean data, it is a research tool (or test-bed) that is proving extremely useful in supporting the basic prediction and predictability research needs of the project participants. This database also serves as "quick look" easy access data that is the external face of the NMME experiment to the research community.

Global Carbon Data Management and Synthesis Project
Frank J. Millero, Fen Huang and Gay Ingram (UM/RSMAS); Kevin Sullivan, Denis Pierrot, F. Bringas, G.-H. Park and T.-H. Peng (UM/CIMAS)

- Andres Chamorro and Blaire Umhau, University of Miami, Summer Fellowship 2011
- Member, SCOR Working Group 127 on the Thermodynamics and Equation of State of Seawater 2008-2011.
- Invited Speaker, F.J. Millero, Ocean Acidification, Presentation at ACS Florida Award Ocean Chemistry Symposium in Honor of Frank J. Millero, Tampa, FL, 12-14 May 2011.
- Invited Speaker, F.J. Millero, Effect of ocean acidification on the speciation of metals, 2011 Goldschmidt Conference, Prague, Czech Republic, 14-19 August 2011.
- Plenary Lecture, F.J. Millero, Speciation of metals. ISMEC 2011, International Symposium on Thermodynamics of Metal Complexes, Giardini Naxos (Messina), 13-16 June 2011.

Design and testing of a monitoring array for the MOC and MHT in the South Atlantic
Renellys C. Perez (UM/CIMAS)
Created a 2012 NOAA-MPOWIR Internship opportunity.

Surface Water pCO_2 Measurements from Ships
Kevin Sullivan, Denis Pierrot, Francis Bringas, Geun-Ha Park and Leticia Barbero (RSMAS/CIMAS); F. J. Millero (UM/RSMAS)
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.

Pierrot, Barbero and Park contributed to the international activity SOCAT (Surface Ocean CO_2 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.

***Investigating Tropical Cyclone Diurnal Pulsing* and**
Development of an Objective Scheme for Predicting Tropical Cyclone Genesis
Jason P. Dunion (UM/CIMAS)
- Guest Speaker (remote), Savanna Oaks Middle School, Fitchburg, WI (Nov 2011)
- Guest Speaker, Marlborough Elementary School, Marlborough, CT (January 2012)
- University of Wisconsin-Madison Department of Atmospheric & Oceanic Sciences, Guest Lecturer (March 2012): *Diurnal Pulsing of Tropical Cyclones: An Overlooked Yet Fundamental TC Process?*

Real-Time Hurricane Wind Analysis
Bachir Annane, Sonia Otero, Russell St. Fleur (UM/CIMAS)
At NOAA/Aircraft Operations Center (AOC): Michael Shook, Hollings intern from University of Kansas Dept. of Geography, Atmospheric Science program.

Improved SFMR Surface Wind Measurements in Intense Rain Conditions
Brad. Klotz (UM/CIMAS)
Brad Klotz gave a presentation on hurricanes and hurricane research to airplane and helicopter pilots of the United States Coast Guard in May 2012. He also presented some basic information about the SFMR during this presentation as well.

Ocean Conditions in the Gulf of Mexico
Paula G. Coble Rhodes and Frank Muller-Karger (USF College of Marine Science)
Abercrombie MI, Coble PG, Conmy RN, Ayoub LM, Abercrombie MI, Coble PG, Kepkay P, Conmy RN, Bugden J, Li Z, Wood AM, Lee K. Tracking Oil Dispersion in the Gulf of Mexico by Fluorescence Spectroscopy. Invited talk presented at the Deepwater Horizon Oil Spill Principal Investigator (PI) Conference sponsored by the National Science and Technology Council Subcommittee on Ocean Science and Technology, St. Pete Beach, FL, 25-26 October 2011.

Abercrombie MI, Coble PG, Kepkay P, Conmy RN, Bugden J, Li Z, Lee K, Wood AM. Fluorescence-Based Detection of Oil and Oil-Dispersant Mixtures in Seawater. Poster presented at the Deepwater Horizon Oil Spill Principal Investigator (PI) Conference sponsored by the

National Science and Technology Council Subcommittee on Ocean Science and Technology, St. Pete Beach, FL, 25-26 October 2011.

Abercrombie MI, Coble PG, Conmy RN, Ayoub LM, Abercrombie MI, Coble PG, Kepkay P, Conmy RN, Bugden J, Li Z, Wood AM, Lee K. Tracking Oil Dispersion in the Gulf of Mexico by Fluorescence Spectroscopy. Poster presented at the Deepwater Horizon Oil Spill Principal Investigator (PI) Conference sponsored by the National Science and Technology Council Subcommittee on Ocean Science and Technology, St. Pete Beach, FL, 25-26 October 2011.

Abercrombie MI, Coble PG, Wood AM, Ayoub LM. Using Fluorescence Spectroscopy to Investigate the Temporal Persistence of Hydrocarbons in the Water Column Following the Deepwater Horizon Oil Spill. Poster presented at Ocean Sciences 2012, Salt Lake City, UT, 20-24 February 2012.

Abercrombie MI, Coble PG, Wood AM, Ayoub LM. Detecting Petroleum in the Marine Environment. Talk presented at 30th Annual Graduate Student Symposium, University of South Florida College of Marine Science, St. Petersburg, Florida, 12 March 2012.

Global Drifter Program

Sean Dolk and Erik Valdes (UM/CIMAS)

In an effort to better assess drogue presence, E. Valdes is reanalyzing data from 14,000 drifters, utilizing a program created by R. Lumpkin. This program incorporates wind presence and drifter battery voltage to more accurately determine drogue loss and discern surface current data.

In conjunction with the Adopt A Drifter Program, S. Dolk has developed a drifter information packet to distribute to schools, both domestically and internationally. Along with information about drifting buoys, their benefits, and what they are used for, S. Dolk worked with manufacturers to develop model drifters for teachers to incorporate into their lesson plans.

PIRATA Northeast Extension (PNE)

Verena Hormann, Renellys. C. Perez, Marlos. Goes, Grant. Rawson (UM/CIMAS)

NOAA collaborator Rick Lumpkin gave presentations on the PIRATA project, science aboard the NOAA ship Ronald H. Brown, and on climate science in general to several groups of students from South African schools and universities after the end of the PNE cruise in July – August 2011. Two articles related to the UCTD test during that cruise have been published in NOAA/AOML’s bimonthly newsletter *Keynotes* (Vol. 15/No. 5 & No. 6).

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

Nelson Melo, Derek Manzello, Grant Rawson, Lindsey Visser, Shaun Dolk, Kyle Seaton, and Peter Ortner (UM/CIMAS)

The SFP routinely includes undergraduate and graduate student volunteers in the research cruises, and participates in NOAA's Teacher-at-Sea program annually. The SFP collaborates in the field work with other institutions in the Gulf of Mexico and Caribbean region.

Caribbean Sea and Gulf of Mexico Bluefin Tuna Research Cruise
Barbara Muhling, Estrella Malca, Akihiro Shiroza and Sarah Privoznik (UM/CIMAS)

- Plankton meeting in Chetumal. During our port stop in April, 2012 in Mahahual Mexico, Dr. Lamkin and Estrella Malca participated in the National Plankton Meeting being held in Chetumal, Quintana Roo and hosted by EL Colegio de la Frontera Sur. Dr. Lamkin was the keynote speaker of the conference and he presented our research collaborations with our Mexican partners since 2004-2012 to a national audience.
- International participation and exchange between government agencies to include Spain's IEO (Instituto Español Oceanográfico), Mexico's Instituto Nacional de Pesca, with UM/CIMAS and NOAA scientists.
- Undergraduate university student participation includes the following students from our Mexican partner institution: Giezi Yam Poot and Ashanti Canto from ITCH (Instituto Tecnológico de Chetumal); Yareli Cota and Cyntia Sandoval from UQROO (Universidad de Quintana Roo).

Applying Bio-physical Monitoring and Capacity Assessments to Mesoamerican Reef Marine Protected Areas
Estrella Malca and Barbara Muhling (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.marfund.org/en/new_projects/second_connectivity_regional_workshop.html
- http://meteorologica.ecosur-qroo.mx/ofe/ocean/mpa/workshop2.html

US Virgin Islands Larval Distribution and Supply Research
Estrella Malca, Nelson Melo, Barbara Muhling, Sarah Privoznik, Grant Rawson and Akihiro Shiroza (UM/CIMAS)
This research project and preliminary results have been shared with local managers including the Caribbean Fisheries Management Council, University of the Virgin Islands, Virgin Islands Department of Planning and Natural Resources Department of Fish and Wildlife and the British Virgin Islands Conservation and Fisheries Department. This project has had participation (both at sea and in the laboratory) of undergraduate students from the University of Miami and from the University of the Virgin Islands since 2007.

In 2011, graduate students from the University of Virgin Islands, University of Puerto Rico and the University of South Florida also participated in the sampling effort, as well as managers from the National Authority for Maritime Affairs (ANAMAR) in the Dominican Republic. In addition, scientific presentations were given to Dominican Republic diplomats and government officials regarding future research opportunities. Also, an open house was carried out aboard the Nancy Foster on April 28th, 2011 to demonstrate laboratory and research capabilities while in port in Santo Domingo.

In 2012, to foster capacity building within the Caribbean, we hosted graduate student Sheika Guyah from the University of West Indies in Kingston, Jamaica to participate in a Larval Fish Taxonomy workshop at the Southeast Fisheries Science Center in the Early Life History Laboratory in the fall of 2012.

Integrated Coral Observing Network (ICON) Project

Ian C. Enochs, Lewis J. Gramer, Kevin P. Helmle, Michael Jankulak, Derek P. Manzello and Renee Carlton (UM/CIMAS)

Kevin Helmle engaged in outreach activities at the Miami Science Museum by delivering lectures on “Corals, Climate Change, and Sclerochronology” along with content for a science blog to the Digital Wave Program: Warming Winds and Water, Aug 3, 2011.

Kevin Helmle provide coral cores, x-radiographs, and educational materials to an interactive exhibit entitled “Earth Lab: degrees of change” which opened Sept15, 2011 at the Marian Koshland Science Museum of the National Academy of Sciences in Washington D.C.

Global Drifter Program

Shaun Dolk and Erik Valdes (UM/CIMAS)

In an effort to better assess drogue presence, E. Valdes is reanalyzing data from 14,000 drifters, utilizing a program created by R. Lumpkin. This program incorporates wind presence and drifter battery voltage to more accurately determine drogue loss and discern surface current data.

In conjunction with the Adopt A Drifter Program, S. Dolk has developed a drifter information packet to distribute to schools, both domestically and internationally. Along with information about drifting buoys, their benefits, and what they are used for, S. Dolk worked with manufacturers to develop model drifters for teachers to incorporate into their lesson plans.

Evaluation of ESA listed Acropora spp. Status and Actions for Management and Recovery

Dana E. Williams, Allan J. Bright and Caitlin Cameron (UM/CIMAS)

“The Future of Elkhorn Coral in the Florida Keys” as part of the "Delicate Balance of Nature" Community Lecture Series, Dagny Johnson State Park.

Assessing the Locations and Status of Reef Fish Spawning Aggregations in the Florida Keys

Art Gleason (UM/CIMAS)

- Results from the acoustic mapping and the aerial surveys were presented at the Gulf Caribbean Fisheries Institute. November, 2011.
- A poster presentation showing the results from the aerial surveys was presented at the Florida American Fisheries Society annual meeting. November, 2011.
- Results from the acoustic mapping and the aerial surveys were presented at Florida Keys National Marine Sanctuary. Scientific Advisory Council. December, 2012.
- Results from the acoustic mapping and the aerial surveys were presented at the southeast Acoustic Consortium workshop and Forum. March, 2012.

Dispersal, Habitat Use and Behavior of Neonate Sea Turtles in the Gulf of Mexico and Waters Impacted by the Deep Water Horizon MSC 252 Oil Spill

Kate L. Mansfield (FIU)

- Florida International University: *FOUND: the sea turtle lost years*. FIU Ocean Life Lecture, Key Largo, FL (April 2012).
- Mansfield, K.L., J.A. Wyneken and J. Luo. *New insights to the in-water behavior and movements of oceanic stage sea turtles*. Oral presentation. 32nd Annual International Symposium on Sea Turtle Biology and Conservation in Huatulco, Oaxaca, Mexico (March 2012).

- Mansfield, K.L., J.A. Wyneken and J. Luo. *Satellite telemetry provides insight to the sea turtle "lost years"*. Ocean Sciences Meeting, Salt Lake City, UT (February 2012).
- Florida International University: *Satellite telemetry and sea turtle life history: tracking the "lost years"*. Departmental seminar. Miami, FL (January 2012).

Collaborative Research: Dynamics of Eighteen Degree Water from CLIMODE Observations and its Climate Implications
Shenu Dong (UM/CIMAS)

- Kelly, K. A., and S. Dong, 2012: Contributions to Eighteen Degree Water Interannual Volume Anomalies. Poster at Ocean Sciences, Salt Lake City, February 2012.
- Kelly, K. A., and S. Dong, 2011: Modeling EDW Volume Anomalies and Climate Implications. CLIMODE workshop presentation at Woods Hole Oceanographic Institution. July 2011.

Agreement between the University of South Florida College of Marine Science and NOAA Fisheries to Provide Support for the USF Marine Resource Assessment Program
Ernst Peebles and Cameron Ainsworth (USF-CMS)
http://www.marine.usf.edu/research/mra-about.shtml

The USF Marine Assessment graduate Program

Because this is the first submission of a CIMAS Annual Report by the USF-CMS MRA program (prior funding was through the CESU National Network), an update of the entire program period is provided below to create a complete record of the its curriculum and graduate student activities. The following courses were developed for the MRA program as part of the present award's Statement of Work. Additional courses are currently under development. "Florida FWC" refers to employees of the Florida Fish and Wildlife Conservation Commission. Courses are listed by their course designations within the USF system.

OCE6934.635F09: ***Fish Biology***, taught Spring 2009* by Ernst Peebles, David Mann and Joseph Torres of USF-CMS (19 students, including 4 agency employees - 21% agency)

USF students: Heather Broadbent, Aaron Brown, Christine Cass, Lindsey Flynn, Danielle Greenhow, Sennai Habtes, Mark Hartman, Lara Henry, Sheri Huelster, Eloy Martinez, Monica Mion, Erica Ombres, Kara Radabaugh, Holly Rolls, Carrie Wall

Florida FWC students: Kelley Kowal, Christy Stephenson, Laura Wiggins

NOAA students: Catherine Bruger (NMFS SERO, St. Petersburg)

This course was taught for the second time during Spring 2012 by Christopher Stallings, Ernst Peebles, and Joseph Torres of USF-CMS. (14 students, including 6 agency employees – 43% agency)

USF students: Dinorah Chacin, Michael Drexler **(formerly FWC), Alisha Gray, Joshua Kilborn**, Orian Tzadik (formerly FWC)**, Amy Wallace**, Sky Williams (part-time FWC), Maria Vega-Rodriguez

Florida FWC students: Christopher Bradshaw, Michael Murphy, Beverly Sauls, Dustin Addis (audited)

US Coast Guard students: Aron Kaloostian (Marine Science Technician, USCG)

NOAA students: Mary Janine Vara (NMFS SERO, St. Petersburg)

OCE6934.635X10: ***Fish Population Dynamics***, taught August 2010 by Dr. Jim Berkson (USF Courtesy Associate Professor) with Co-Instructors Dr. Katie Andrews (NMFS, SEFSC, Panama City Lab), Dr. Brian Linton (NMFS, SEFSC, Miami Lab), Dr. Shannon Cass-Calay (NMFS, SEFSC, Miami Lab), Dr. Steve Cadrin (University of Massachusetts at Dartmouth), and Dr. Rick Hart (NMFS, SEFSC, Galveston Lab)(13 students, including 8 agency employees – 62% agency)

USF students: Claudia Baron-Aguilar, Sennai Habtes, Sheri Huelster, Elon Malkin, Kara Radabaugh

Florida FWC students: Christopher Bradshaw, Angela Collins, Claire Crowley, Anne Dowling, Michael Drexler, Michael Murphy, Holly Rolls, Beverly Sauls

NOAA students: none

OCE6934.629S10: ***Applied Multivariate Statistics***, taught Spring 2010 by David Mann and David Jones of USF-CMS (13 students, including 4 agency employees - 31% agency)

USF students: Brian Barnes, Regina Easley, Lindsey Flynn, Adrienne George, Sennai Habtes, Mark Hartman, Sheri Heulster, Elon Malkin, Leslie Wade

Florida FWC students: David Chagaris, Claire Crowley, Holly Rolls

NOAA students: Catherine Bruger (NMFS SERO, St. Petersburg)

This course was taught for the second time during Fall 2011 by David Jones and David Mann of USF-CMS (18 students, including 4 agency employees - 22% agency)

USF students: Dinorah Chacin, Michael Drexler (formerly FWC)**, Alisha Gray, Joshua Kilborn**, Natasha Mendez-Ferrer, Juan Millan, Kara Radabaugh, Benjamin Ross, Paul Suprenand, Orian Tzadik (formerly FWC)**, Maria Vega-Rodriguez, Amy Wallace**, Sky Williams, Bo Yang

Florida FWC students: Richard Knudsen, Michael Murphy, Beverly Sauls

NOAA students: Mary Janine Vara (NMFS SERO, St. Petersburg)

OCE6934.628S11: ***Dynamics of Marine Ecosystems***, taught Spring 2011 by Kendra Daly and Mark Luther of USF-CMS (9 students, including 4 agency employees - 44% agency)

USF students: Natasha Mendez-Ferrer, Benjamin Ross, Mark Squitieri, Tonu Toomepuu (audited), Sky Williams

Florida FWC students: Claire Crowley, Matthew Garrett, Richard Knudsen

NOAA students: Catherine Bruger (NMFS SERO, St. Petersburg)

OCE6934.640F11: ***Fishery Ecology Reading Group***, taught Fall 2011 by Chris Stallings, Cam Ainsworth, Ernst Peebles and Steve Murawski of USF (9 students, including 3 agency employees - 33% agency).

USF students: Dinorah Chacin, Michael Drexler (formerly FWC)**, Alisha Gray, Joshua Kilborn**, Orian Tzadik (formerly FWC)**, Amy Wallace**

Florida FWC students: Christopher Bradshaw, Beverly Sauls, Julie Vecchio

NOAA students: none

*Course was taught prior to present award as part of the MRA program.
** USF graduate students supported by fellowships under the present award (fellowships first became effective Fall 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 nominally meet on a quarterly basis although scheduling has been difficult. Many Fellows-related matters are now addressed and implemented by means of email exchanges and all meetings other than, possibly, an Annual one will continue to 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. Richard Knabb	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

Relationship of the Atlantic Warm Pool with the Atlantic Meridional Overturning Circulation
S.-K. Lee, L. Zhang, D. B. Enfield (UM/CIMAS)

- The paper "Multidecadal co-variability of North Atlantic sea surface temperature, African dust, Sahel rainfall and Atlantic hurricanes" was highlighted by *Nature Geoscience* in the issue of April 2012.

Global Carbon Data Management and Synthesis Project
F.J. Millero, F. Huang and G. Ingram (UM/RSMAS); K. Sullivan, D. Pierrot, F. Bringas, G.-H. Park and T.-H. Peng (UM/CIMAS)

- Florida Award (Florida section of the American Chemical Society (FLACS), 2011) to Frank J. Millero.

Investigation of the Mean and Turbulence Structure of the Hurricane Boundary Layer
J. A. Zhang, and S. Lorsolo (UM/CIMAS)

- The peer-reviewed publication entitled *Estimation and mapping of hurricane turbulent energy using airborne Doppler measurements*, Zhang et al., Mon. Wea. Rev. 139, 1447-1462, has received the "2011 AOML Outstanding Paper Award"

A Sixteen-Year Tropical Cyclone Global Positioning System Dropwindsonde Dataset
K.. Sellwood (UM/CIMAS)

- National Aeronautics and Space Administration, Group Achievement Award for outstanding performance during the Genesis and Rapid Intensification Processes (GRIP) airborne Earth science Mission in 2010. (Members of the Global Hawk Instruments Dropsondes sub-group:
- Jeff Halverson (NASA/GSFC, Principal Investigator); Joseph Cione and Gary Wick (NOAA); Kathryn Sellwood (UM/CIMAS).

Ocean Conditions in the Gulf of Mexico
P.G. Coble Rhodes and F. Muller-Karger (USF College of Marine Science)

- M.I. Abercrombie – Outstanding Student Presentation, Ocean Sciences 2012, Salt Lake City, Utah.

Studies in Support of NOAA's Operational Ocean Heat Content Analysis Using Deep Water Horizon Measurements
L.K. (Nick) Shay (UM/RSMAS)

- In 2012, L. K. Shay was elected Fellow of the American Meteorological Society.

AOML's South Florida Program (SFP): Long-Term Measurement of Physical, Chemical, and Biological Water Column Properties in the South Florida Coastal Ecosystem
N. Melo, D. Manzello, G. Rawson, L. Visser, S. Dolk, K. Seaton and P. Ortner (UM/CIMAS)

- Michelle Wood was appointed the NOAA Representative to the RECOVER Leadership Group for the Comprehensive Everglades Restoration Plan. Chris Kelble is one of two

NOAA representatives on the Science Coordination Group for the South Florida Restoration Task Force.

Agreement between the University of South Florida College of Marine Science and NOAA Fisheries Support for the Marine Resource Assessment Program
Ernst Peebles and Cameron Ainsworth (USF-CMS)

- Julie Vecchio (FWC, incoming MRA student) – 2nd place, best poster, annual meeting of the Florida Chapter of the American Fisheries Society, Ocala, Feb 2012.
- Orian Tzadik (MRA student) –2nd place, best presentation, USF-CMS 2012 Graduate Student Symposium.
- Kara Radabaugh (MRA student) –4th place, best presentation, USF-CMS 2012 Graduate Student Symposium.
- Dinorah Chacin (MRA student) was notified in March 2012 that she has won an NSF Graduate Research Fellowship.
- Holly Rolls (MRA student) won the 2011 ICES Early Career Scientist Award for Best Presentation, Gdansk, Poland. http://ices-usa.noaa.gov/index.html
- Kara Radabaugh (MRA student) –1st place, best presentation, USF-CMS 2011 Graduate Student Symposium.

Rosenstiel School Professor Receives Distinguished Geochemistry Award

Frank Millero honored for outstanding contributions to the field of marine geochemistry

Frank Millero receives Goldschmidt award from Sam Mukasa, Past President of Geochemical Society

PRAGUE — August 29, 2011 — University of Miami (UM) Rosenstiel School of Marine and Atmospheric Science chemist Frank Millero received the prestigious V. M. Goldschmidt Award from the Geochemical Society honor for his major achievements to the field of geochemistry. The medal was presented by Sam Mukasa, past president of the Geochemical Society. during a ceremony at the V. M. Goldschmidt Conference, which this year took place in Prague, August 14-19.

In his acceptance speech, Millero thanked all those who have influenced his early development in the field. He also recognized the undergraduate and graduate students, postdoctoral fellows, technicians, and colleagues who co-authored papers with him over the years. His last acknowledgement was to his wife Judy who has put up with his crazy life style over 46 years of marriage. “She has been my moral strength over the years,” he said.

Millero is a leader in the application of physical chemistry to natural waters, and his work has defined the field for the last forty years. As director of the UM Rosenstiel School Marine Physical Chemistry Lab, he uses thermodynamic and kinetic principles to better understand the biogeochemical processes occurring in the marine environment.

His research group is involved in scientific studies to identify the global carbon dioxide cycle in the world’s oceans in order to better understand how much atmospheric CO2, from the burning of fossil fuels, is reaching the deep oceans. Laboratory and field studies are also being made on the effect of organic matter on the solubility of iron in natural waters.

During the last four decades, Millero has made enormous contributions to the literature of marine geochemistry and chemical oceanography. He has published more than 413 publications in refereed journals, 32 book chapters, five books and numerous reports and abstracts. Noteworthy books are his three editions of Chemical Oceanography and his book Physical Chemistry of Natural Waters.

Millero has been recognized with numerous awards that include Sigma Xi Professor of the year (1989), ONR Ocean Educator Award (1990), Chairman of Geochemical Section of American Chemical Society, Gold Medal from Florida Academy of Science for Contributions to Science (1994), Distinguished Alumni Hall of Fame, Warren High Schools (1995), UM Distinguished Faculty Scholar Award (1996), UM Provost Scholarly Activity Award (1998-1999), Fellow of the American Geophysical Union (1999), Fellow of the Geochemical Society and the European Association for Geochemistry (2000), American Chemistry Society Geochemistry Division Medal (2001), Carnegie Mellon 2003 Alumni Distinguished Achievement Award and Fellow of the American Association for the Advancement of Science (AAAS) (2010).

Millero received his B.S. (1961) from The Ohio State University and his M.S. (1964) and Ph.D. (1965) from Carnegie-Mellon University in physical chemistry. After a brief interval in industry, he joined the faculty of the University of Miami in 1966. From 1986 to 2006 he was associate dean of Academic Studies at the Rosenstiel School of Marine & Atmospheric Science. He currently serves as associate editor for a number of journals, and since 1993 has been editor-in-chief of M*arine Chemistry*.

The Geochemical Society and the European Association of Geochemistry jointly sponsor the Goldschmidt Conference, the premiere international conference on geochemistry.

NOAA Rewards Two Rosenstiel Students With National Fellowships

MIAMI — August 19, 2011 — Elizabeth Councill and Holly Perryman, two Marine Biology and Fisheries graduate students at the University of Miami (UM) Rosenstiel School of Marine & Atmospheric Science, have been awarded three year Ph.D. fellowships in Population Dynamics by the National Oceanic and Atmospheric Administration (NOAA). Councill and Perryman are two of only eight students recognized nationally with these prestigious scholarships this year.

Both students work in conjunction with NOAA's Cooperative Institute for Marine and Atmospheric Studies (CIMAS) based at the UM's Rosensteil School, which provides a Center of Excellence relevant to understanding the Earth's oceans and atmosphere. Councill's research focuses on mathematical modeling of the dynamics of highly migratory fish, such as Atlantic Tarpon, Bluefin Tuna and Swordfish.

"My research will help us to understand the impact our harvesting strategies have on these fish populations, so that we can maintain these food resources worldwide. Many of these exploited species are a primary or secondary food source for millions of people, and it's imperative that we maintain responsible management strategies so that those resources are available for this and the next generation," said Councill.

Perryman is focused on developing an ecosystem model of the Gulf of Mexico that will include near-shore and off-shore habitats and how they are connected - a feature that many marine ecosystem models lack.

This research impacts the economic livelihood of the United States, Mexico and Cuba, which are greatly dependent on the Gulf of Mexico. Coastal development, coastal recreation and tourism, merchant shipping, offshore oil and gas production, hard mineral mining, recreational boating, and commercial fisheries, all have a presence in the Gulf, and they are all interconnected." Said Perryman. "We need to make sure measures are in place to protect threatened and endangered species like the West Indian Manatee, Right Whale, Blue Whale, Sperm Whale, and five species of sea turtles that are also are part of this ecosystem," says Perryman.

"As a result of these awards, there will be four UM fishery students that will soon be supported by national NOAA fellowships," said Dr. David Die, associate professor and assistant director of CIMAS. "This is a direct result of the competitiveness of our quantitative fisheries academic program and the caliber of the CIMAS-supported research collaborations between the Rosenstiel School and NOAA."

2012 NOAA/Ernest F. Hollings Scholars

NOAA Office of Education
Ernest F. Hollings Undergraduate Scholarship Program

A total of 12 CIMAS affiliated students (including 6 from the University of Miami and 6 from our Partner Universities), were selected as 2012 NOAA/Ernest F. Hollings Scholars.

Chesley, Christine – Geophysics - University of Miami, FL

Iwane, Mia - Marine and Aquatic Sciences - University of Miami, FL

Kuba, Alyson - Marine and Aquatic Sciences - University of Miami, FL

Ofarrell, Halie - Marine and Aquatic Sciences - University of Miami, FL

O'Reilly, Katherine - Marine and Aquatic Sciences - University of Miami, FL

Pausch, Rachel - Marine Science, Biology, and Geology - University of Miami, FL

Lopez, Nicolas - Meteorology - Florida State University, FL

Keenan, Chandler - Environmental Science - Florida State University, FL

Smith, Jessica – Meteorology - Florida State University, FL

Stewartm Kristen – Meteorology - Florida State University, FL

Esteban, Michael - Environmental Engineering - University of South Florida, FL

Seabrook, Sarah - Marine/Biological Conservation - University of South Florida, FL

Wald, Ileana - Environmental Engineering - University of South Florida, FL

X. POSTDOCTORAL FELLOWS AND GRADUATE STUDENTS

CIMAS-Supported Postdoctoral Fellows and Graduate Students

Postdoctoral Fellows

Enochs, Ian
Hormann, Verena
Liu, Hailong
Liu, Yanyun
Yang, Haoping
Wang, Xin
Zabalo, Joaquin

Graduate Students

Task I

Birghenthal, Kaitlin
Council, Elizabeth
Johnston, Lyza
Kiel, Courtney
Shiroza, Akihiro
Vaughan, Nathan
Wylie, Jennifer

Task III

Bhatia, Kieran
Dolan, Tara
Harford, William
Huntington, Brittany
Larson, Sarah
Lohr, Kathryn
McCaskill, Claire E.
Meyers, Patrick C.
Nadon, Marc
Rodriguez, Carmen
Santos, Rolando
Waters, Jason
Woosley, Ryan

Employees

DiNezio, Pedro
Dolk, Shaun
Gramer, Lewis J.

Employees cont'd

Jankulak, Michael
Lindo, David
Malca, Estrella

Other Participants in CIMAS Projects

Postdoctoral Fellows

Adam, Thomas
Jaimes, Benjamin
Min, Dughong
Putman, Nathan F.
Simon, Anu
Toro-Farmer, Gerardo

Graduate Students

Abercrombie, Mary I.
Barnes, Brian
Cossuth, Joshua
Danger, Nick
Drexler, Michael
Drury, Crawford
El-Toury, Sharein
Ender, Alexandra
Fisch, Jay
Fischer, M.
Habtes, Sennai
Kilborn, Joshua
Lerner, Justin
Maggied, Aaron
Nutall, Matt
Smith, Matthew
Tzadik, Orian
Vasquez-Yeomans, Lourdes
Vega-Rodriguea, Maria
Wallace, Amy
Waterhouse, Lynn
West, Lorin
Yurek, Simeon
Zelinsky, David

XI. RESEARCH STAFF

Aksoy, Altug	Assistant Scientist
Amornthammarong, Natchanon	Assistant Scientist
Annane, Bachir	Senior Research Associate III
Barbero Munoz, Leticia	Postdoctoral Associate
Barton, Zachary	Research Associate I
Berberian, George	Research Associate II (PT)
Blondeau, Jeremiah	Senior Research Associate I
Bright, Allan	Research Associate II
Bringas Gutierrez, Francis	Research Associate III
Brown, Cheryl	Research Associate II
Bucci, Lisa	Senior Research Associate I
Cameron, Caitlin	Research Associate I
Carlton, Renee	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
Domingues, Ricardo	Research Associate i
Dong, Shenfu	Associate 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
Hooper, James	Research Associate III
Hormann, Verena	Postdoctoral Associate
Jankulak, Michael L.	Research Associate III
Johnson, Darlene R.	Scientist
Klotz, Bradley	Research Associate III
Le Henaff, Matthieu	Assistant Scientist
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
Muhling, Barbara	Assistant Scientist
Otero, Sonia	Senior Research Associate II
Park, Geun-Ha	Assistant Scientist
Peng, Tsung-Hung	Scientist (PT)
Perez, Renellys	Associate Scientist
Pierrot, Denis P.	Associate Scientist
Privoznik, Sarah	Research Associate I
Rawson, Grant T.	Research Associate III
Roddy, Robert	Research Associate III (PT)
Sabina, Reyna	Research Associate III (PT)
Seaton, Kyle	Research Associate II
Sellwood, Kathryn J	Research Associate III
Shiroza, Akihiro	Research Associate II
Soto, Jaime	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
Wang, Xin	Postdoctoral Associate
Wanless, David R.	Research Associate II
Wicker, Jesse A.	Research Associate III
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, Liping	Research Associate I
Zhang, Xuejin	Assistant Scientist

XII. VISITING SCIENTISTS PROGRAM

Dr. Rodrigo H. Bustamante
CSIRO Marine and Atmospheric Research
Ecosciences Precint
Brisbane, Australia
24 October, 2011

October 24, 2011 "*A Spatially-Explicit Management Strategy Evaluation Framework for the Northern Prawn Fishery"*

Dr. Hans Thomas Rossby
Professor Emeritus of Oceanography
Graduate School of Oceanography
University of Rhode Island
215 South Ferry Road
Narragensett, RI 02882
17 January, 2012 – 27 January, 2012

Prof. Kitack Lee
School of Enviromental Science and Engineering
Pohang University of Science and Technology
San-21, Hyoja-dong, Nam-gu
Pohang, 790-784
Republic of Korea
25 January, 2012 – 1 February, 2012

January 30, 2012 "*Production of Organic Carbon and DMS in High CO_2 Ocean: A Mesocosm Study"*

XIII. PUBLICATIONS

Table 1: Publication Record 2011-2012

	Institute Lead Author	NOAA Lead Author	Other Lead Author
	2011-2012	**2011-2012**	**2011-2012**
Peer Reviewed	47	21	26
Non-Peer Reviewed	13	8	4

Refereed Journal Articles

Aksoy, A., S. Lorsolo, T. Vukicevic, K. Sellwood, S. Aberson, and F. Zhang (2012), The HWRF Hurricane Ensemble Data Assimilation System (HEDAS) for high-resolution data: The impact of airborne Doppler radar observations in an OSSE. *Monthly Weather Review*, doi:10.1175/MWR-D-11-00212.1, in press.

Alexanderian, A., J. Winokur, I. Sraj, A. Srinivasan, M. Iskandarani, W.C. Thacker, and O.M. Knio (2012), Global sensitivity analysis in an ocean general circulation model: a sparse spectral projection approach. *Computational Geosciences* 16, 757–778.

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.* 3, 1501-1506.

Baker-Austin, C., J.A. Trinanes, N.G.H. Taylor, R. Hartnell, A. Siitonen, and J. Martinez-Urtaza (2012), Emerging Vibrio risk at high latitudes in response to ocean warming, *Nature*, doi:10.1038/nclimate1628, in press.

Collado-Vides, L., V. Mazzei, T. Thyberg, D. Lirman (2011), Spatio-temporal patterns and nutrient status of macroalgae in heavily managed region of Biscayne Bay, Florida, USA. *Botanica Marina* 54:377-390.

Criales, M.M., I.C. Zink, J.A. Browder, and T. L. Jackson (2011), The effect of acclimation salinity and age on the salinity tolerance of pink shrimp postlarvae. *J. Exp. Mar. Biol. Ecol*. 409: 283-289.

Dinapoli, S., M. Bourassa, and M. D. Powell (2012), Uncertainty and Intercalibration Analysis of H*Wind. *J. Atmos. Oceanic Technol.*, 29, 822-833.

Di Nezio, P.N., and G. Goni (2011), Direct Evidence of Changes in the XBT Fall-rate Bias During 1986-2008. *Geophys. Res. Lett.*, in press.

Dong, S., S.L. Garzoli, and M.O. Baringer (2011), The role of inter-ocean exchanges on decadal variations of the northward heat transport in the South Atlantic. *J. Phys. Oceanogr.*, 41(8), 1498-1511.

Dong, S., M. Baringer, G. Goni, and S. Garzoli (2011), Importance of the assimilation of Argo Float Measurements on the Meridional Overturning Circulation in the South Atlantic. *Geophys. Res. Lett.*, 38, L18603, doi:10.1029/2011GL048982.

Enochs, I.C., and D.P. Manzello (2012), Species richness of motile cryptofauna across a gradient of reef framework erosion. *Coral Reefs*, doi 10.1007/s00338-012-0886-z, in press.

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